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 (2016)

Final

Document Control Sheet

Client		Department of Communications, Energy and Natural Resources		
Project		Environmental Monitoring of Former Mining Areas of Silvermines and Avoca		
Project No		95735		
Report		Monitoring Report for the Former Mining Area of Silvermines – February 2016		
Document Reference:		95735/40/DG/27		
Version	**Author**	**Checked**	**Reviewed**	**Date**
1	P Barrett	R O'Carroll	R L Olsen	June 2016

Distribution	Copy No.

Table of Contents

Appendices

List of Tables

List of Figures

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, commencing in 2013.

The scope of the field investigation activities for the first three years was defined in the *Environmental Monitoring of Former Mining Areas of Silvermines and Avoca Monitoring Plan,* (Document Ref: 95735/40/DG/01, dated 26 February 2013) and sampling activities were performed in accordance with the programme and procedures set out therein.

Based on the findings of the monitoring program for the first three years, adjustments were made to the monitoring programme in 2016 which are detailed in the *Environmental Monitoring of Former Mining Areas of Silvermines and Avoca Summary Report*, (Document Ref: 95735/40/DG/25, dated 20 January 2016).

The Monitoring Report for the Silvermines Mining Area presents an evaluation of the results of the field investigations carried out in February 2016. This report should be read alongside the Silvermines Data Report (Document Ref: 95735/40/DG/26, dated March 2016) 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 24 ha, 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 Mountain, Co. Tipperary as shown on Map 1 in Appendix A. The Kilmastulla River is the main river which rises in the Silvermine Mountain just south of Silvermines Village (called the Silvermines Stream) 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 of Silvermines.

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 water 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 approximately 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 approximately 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 east-northeast but includes west-northwest-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

No groundwater sampling was undertaken in February 2016. Water levels were measured at two monitoring wells located upgradient and downgradient of the TMF and seven additional wells located within the TMF near its perimeter from the tailings surface, using a portable electronic water level recorder. The groundwater monitoring points are listed in Table 1 and shown on Map 2 in Appendix A. Furthermore, groundwater level data are contained in Appendix C of the Data Report and discussed in Section 6.

Four of the monitoring wells which were in addition to the nine wells have been removed from the monitoring programme because in the first round of sampling they were either found buried, or believed to be destroyed.

Table 1 Location of Silvermines Groundwater Monitoring Points in February 2016

Borehole Identifier	Easting	Northing	Water Level	Field Parameters & Chemical Analysis	Depth (m bgl)	Screen Interval (m bgl)
TMF1(D)/SRK/01 (TMF1)	179826	173165	Yes	No	23	22-23
TMF2(D)/SRK/01 (TMF2)	179445	172307	Yes	No	18	none
BH1A-GORT-06	180181	172490	Yes	No	8.8	5.5 - 8.8
BH2A-GORT-06	180216	172855	Yes	No	10	7 - 10
BH3A-GORT-06	179835	173126	Yes	No	10	7 - 10
BH4A-GORT-06	179570	172826	Yes	No	10	7 - 10
BH5A-GORT-06	179537	172312	Yes	No	10	7 - 10
BH6A-GORT-06	179868	172212	Yes	No	10	7 - 10
BH6B-GORT-06	179867	172225	Yes	No	5	3 - 5

2.1.2 Surface Water Sampling

Thirty surface water locations were sampled between 9 and 12 February 2016, as listed in Table 2 and shown on Maps 2 to 5 in Appendix A. Three sampling locations were added to the programme to provide greater detail on the calculated loadings of dissolved metals in the main rivers and streams.

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 each surface water sampling location (Appendix D of the Data Report). Samples were grab samples collected from a well-mixed portion of the 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	Sample Site Notes	Sample collected	Flow
SW10-GORT-US	GM	180206	172396	Immediately upstream of the outfall on the Kilmastulla River	Yes	NR
SW10-GORT-Discharge	GM	180205	172393	Wetland discharge prior to outfall	Yes	Bucket and Stopwatch
SW10-GORT-DS	GM	180189	172365	20m downstream of the outfall, on the Kilmastulla River	Yes	NR
SW12-GORT-Discharge	GM	179562	172165	Sample of wetland discharge prior to outfall	Yes	Bucket and Stopwatch
SW12-GORT-DS	GM	179532	172137	20m downstream of the outfall, on the Kilmastulla River	Yes	NR
SW14-GORT	GM	179336	172164	Site located on Kilmastulla River, downstream of TMF	Yes	NR
SW17-GORT	GM	180538	173038	Site located on Kilmastulla River, upstream of TMF	Yes	NR
SW18-GORT	GM	179772	172666	Site of discharge from the main pond on the TMF	Yes	NR
SW19-GORT	GM	180097	172982	Discharge at the bottom of the decant	Yes	Flow Meter
DS-GORT*	GM	178501	171870	Site located on Kilmastulla River, downstream of TMF	Yes	Float Method
SW1-SM	BG	184083	170732	Site on Silvermines Stream (upstream of Ballygown mine workings)	Yes	Flow Meter
SW2-SM-South	BG	184244	171584	Discharge from ‘Southern’ adit.	Yes	Bucket and Stopwatch
SW3-SM	BG	184258	171412	Site on Silvermines Stream (downstream of main Ballygown workings, but upstream of North adit)	Yes	Flow Meter
SW5-SM*	BG	184303	171691	Site on Silvermines Stream (downstream of main Ballygown workings and of North adit)	Yes	Flow Meter
SW4-SM-GA	BG	183961	172483	Site on Silvermines Stream (downstream of all mine workings)	Yes	Flow Meter
SW6-MAG	MG	182776	171399	Foilborrig Stream diverted around Magcobar Pit. Sampling site is just south of R499 road.	Yes	NR
SW1-GAR	GA	182116	171322	Stream sampled south of R499 road (south of old Mogul Yard)	Yes	NR
SW3-GAR	GA	181300	171648	Stream site containing drainage flows from both the tailings lagoon and western part of Mogul Yard.	Yes	Float Method
SW5-GAR	GA	181950	171418	Discharge from Knight Shaft	Yes	No Overflow
SW7-GAR	GA	181523	171493	Discharge from smaller settlement pond	Yes	Bucket and Stopwatch
SW10-GAR	GA	181640	171730	Discharge from Garryard tailings lagoon	Yes	Flow Meter
SW12-GAR	GA	181791	171569	Combined run-off from Knight Shaft and eastern part of Mogul Yard sampled north of railway and up-gradient of tailings lagoon.	Yes	Flow Meter
US-SHAL*	ShS	180749	171783	Yellow River upstream of ShS	Yes	Flow Meter

Site Name	Area	Easting	Northing	Sample Site Notes	Sample collected	Flow
SW1-SHAL	ShS	180703	171776	Water-course that runs parallel to R500. Sampling site occurs close to northern-most corner of Shallee tailings impoundment.	Yes	Flow Meter
SW4-SHAL	ShS	180324	171089	Water-course occurring west of 'Drum Dump' and Shallee South workings.	Yes	Bucket and Stopwatch
SW5-SHAL	ShS	180574	171301	Water course west of fenced off area enclosing King's House and core sheds. Further west, this same feature runs along the toe of the drum dump.	Yes	Flume
SW6-SHAL	ShS	180591	171331	Stream emanating from flooded Field Shaft	Yes	Bucket and Stopwatch
SW9-SHAL	ShS	180571	171470	Stream occurring immediately east of the southernmost Shallee tailings impoundment. Sample site is south of R499 road.	Yes	Flow Meter
SW12-SHAL	ShS	180670	171165	Stone lined drainage channel SSW of reservoir	Yes	Bucket and Stopwatch
DS-SHAL	ShS	180609	171845	Yellow River downstream of ShS and BG	Yes	Flow Meter

Notes:
Abbreviations: GM- Gortmore; BG- Ballygown; MG- Magcobar; GA- Garryard; ShS- Shallee South, NR-Not Required
* New sampling location

Samples were placed into new laboratory provided bottles with the correct preservatives. The sample bottles that required no filtering (and contained no preservatives) 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 21 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). Flow was unable to be measured at SW5-Gar due to the grating covering it.

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 some locations with greater flow, a Marsh McBirney meter was used to measure flow velocities and depths at regular intervals across the stream by wading.

The Float Method was used when the location of the river was unsafe to wade. It is the least accurate method but provides a reasonable estimate. This method requires the measurement and calculation of the cross-sectional area of the channel as well as the time it takes an object to "float" a designated distance. The water depth was measured (approximately 8 locations) and the float was released into the channel upstream from the beginning of the section and measured the amount of time it takes the "float" to travel the marked section. This was repeated at least three times and the average time calculated.

2.1.3 Vegetation and Soil Sampling

No vegetation and soil sampling was undertaken in February 2016.

2.1.4 Field QA/QC Samples

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

- Surface Water:
  - Three duplicate surface water samples; and
  - One decontamination blank was collected by pouring DI water over the surface water grab sampler 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. An additional filtration blank was collected in order to try to quantify any contamination caused by the filtration procedure.

Sample IDs for the field QA/QC samples are listed in Table 3. The duplicate samples are an independent check on sampling and laboratory precision. The standard reference materials are 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 3 Field QA/ QC Sample IDs and Descriptions

Sample ID	QA/QC Sample Type	Description
SMSD01.7	SW Duplicate	Duplicate of DS-GORT
SMSD02.7	SW Duplicate	Duplicate of SW1-GAR
SMSD03.7	SW Duplicate	Duplicate of SW1-SM
SMDB01.7	SW Decontamination blank	DI water (Lennox Lab Supplies. Batch No: TE150727W) poured over SW sampling beaker after final decon at site SW1-SM.
SMSR01.7	Standard Reference Material	Water ERA Lot #P246-740A
SMSR02.7	Standard Reference Material	Water ERA Lot #P246-740A
WB01.7	Filtration blank	Deionised water (Lennox Lab Suppliers. Batch No: TE150727W)
WB02.7	Water blank	Deionised water (Lennox Lab Suppliers. Batch No: TE150727W)

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 packs were added to cool the samples.

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

Analysis of water samples was undertaken by ALcontrol. Water 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 surface water, analyses were performed for the following parameters: pH, ammoniacal nitrogen as N, sulphate and dissolved metals including Al, Sb, As, Ba, Cd, Cr, Co, Cu, Fe, Pb, Mn, Mo, Ni, V and Zn.

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.

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 considered 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, DI water blanks and DI filtration blanks were generated in the field. Decontamination blanks were also generated 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 surface water samples were created in the field and submitted blind to the laboratory (see Table 3 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 (surface water) was cleaned, DI water was poured over the sampling equipment and collected for laboratory analysis. Analyses of these samples were used to evaluate the adequacy of the sampling equipment cleaning or decontamination procedure.

- Two certified water SRMs were sent blind to ALcontrol (Sample IDs SMSR01.7 and SMSR02.7) to evaluate laboratory accuracy. The certified SRM was supplied by ERA Certified Reference Materials and was Lot #P246-740A (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.

- One water blank was collected of the DI water during the sampling event. An additional filtration blank using DI water was collected in order to try to quantify any contamination caused by the filtration procedure.

3.2 Results of Field QA/QC Samples

3.2.1 Duplicates

Three duplicate samples (surface water) were generated in the field and sent to ALcontrol for analysis. Table 4 provides the results of the 15 dissolved metals for the three duplicate samples and the calculated RPD between each pair of samples. Note if both the original and duplicate results were less than the limit of detection (LOD), then the RPD was zero. In addition, if one of the values was less than the LOD, the LOD value is used to calculate the RPD.

The majority of RPD values shown in Table 4 are below 50 %. The RPDs for the following parameters are good: aluminium (0 to 5.2%), arsenic (0 to 26.1%), barium (0.5 to 4.7%), cadmium (0 to 2.8%), chromium (6.6 to 7.3%), cobalt (0 to 2.7%), iron (0 to 15.7%), lead (0 to 3.2%), manganese (0.5 to 11.4%), nickel (3.7 to 10.7%), vanadium (0 to 0.5%) and zinc (0.8 to 32.5%).

The RPDs that were above 50% included; antimony (59.6 %) in duplicate pair SW1-SM and SMSD03.7, copper (84 %) in duplicate pair SW1-SM and SMSD03.7 and molybdenum (63.4 %) in duplicate pair DS-Gort and SMSD01.7. These results were checked and confirmed with ALcontrol. The highest reported value of the duplicate pair is selected for interpretive use in Section 4 therefore providing a conservative evaluation.

Table 4 Water Duplicate Pairs Reported Values (µg/l) and Calculated % RPD

Dissolved Metal	LOD (µg/l)	DS-GORT	SMSDO1.7	% RPD	SW1-GAR	SMSDO2.7	% RPD	SW1-SM	SMSDO3.7	% RPD
Aluminium	<2.9	15.1	15.9	-5.2	8.48	8.57	-1.1	<2.9	<2.9	0
Antimony	<0.16	0.504	<0.16	0	0.194	0.291	-40.0	<0.16	0.296	**-59.6**
Arsenic	<0.12	0.442	0.34	26.1	0.12	0.154	-24.8	<0.12	<0.12	0
Barium	<0.03	108	110	-1.8	37.4	39.2	-4.7	40.4	40.6	-0.5
Cadmium	<0.1	0.509	0.502	1.4	8.59	8.35	2.8	<0.1	<0.1	0
Chromium	<0.22	1.58	1.7	-7.3	0.81	0.756	6.9	0.886	0.946	-6.6
Cobalt	<0.06	0.225	0.219	2.7	1.12	1.12	0	<0.06	<0.06	0
Copper	<0.85	1.92	1.86	3.2	5.74	5.62	2.1	<0.85	2.08	**-84.0**
Iron	<19	65.8	56.2	15.7	<19	<19	0	<19	<19	0
Lead	<0.02	2.37	2.41	-1.7	5.89	6.08	-3.2	<0.02	0.02	0
Manganese	<0.04	25.1	22.4	11.4	82.1	82.5	-0.5	4.3	4.11	4.5
Molybdenum	<0.24	0.463	<0.24	**63.4**	0.824	0.808	2.0	0.24	0.343	-35.3
Nickel	<0.15	2.01	2.23	-10.4	38.1	36.7	3.7	0.453	0.407	10.7
Vanadium	<0.24	0.439	0.437	0.5	<0.24	<0.24	0	<0.24	<0.24	0
Zinc	<0.41	175	173	1.1	5,310	5,270	0.8	0.821	1.14	-32.5

Notes:
Bold indicates an exceedance in the Duplicate RPD acceptance criteria

3.2.2 Decontamination Blanks

One decontamination blank (SMDB01.7) was created by pouring DI water over the surface water sampling equipment (sampling beaker) after decontamination and sent to ALcontrol for analysis. Table 5 provides the results of the 15 metals for the decontamination blank sample, the DI water blank and filtration blank samples and the associated laboratory method blank samples. 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 0.02 to 2.9 µg/l except for iron with a detection limit of 19 µg/l.

Detections were observed for two dissolved metals ranging from 0.042 µg/l (barium) to 0.223 µg/l (chromium). Both of these metals were also detected in the DI water blank. Furthermore, the levels of detections in the decontamination blank were similar to those found in the DI water blank. Relatively low concentrations of dissolved antimony (0.161 µg/l), lead (0.031 µg/l), manganese (0.144 µg/l) and zinc (0.84 µg/l) were also found in the DI water blank but not the decontamination blank.

None of the parameters which were detected in the decontamination blank were greater than ten times the detection limit. All of the detections were significantly less than the assessment criteria outlined in Section 4; therefore, these low concentrations in the blanks do not affect the interpretation of results. To assess the level of cross contamination between samples in the field, the concentrations in the decontamination blank were compared with the concentration in the preceding environmental sample. As a percentage of the preceding sample, barium was 0.1% and chromium was 25.2%. Chromium was detected in the DI Water Blank and therefore these findings are not considered to affect the integrity of the overall results.

The results from the laboratory instrumentation (method) blank were obtained from ALcontrol to determine if any contamination occurred within the laboratory (Table 5). Each method blank is specific to the associated sample batch. None of the parameters detected (2) in the method blank for sample batch 160213-69 were similar to those in the field decontamination blank sample.

Overall, the decontamination blank sample does not indicate any cross-contamination in the field and the detections were significantly less than the assessment criteria outlined in Section 4 and therefore the results are considered acceptable for their intended use.

Table 5 Water Blank and Decontamination Blank Reported Values and Laboratory Method Blanks (µg/l)

Sample Description	LOD (µg/l)	Filtration Blank WB01.7 (µg/l)	Water Blank WB02.7 (µg/l)	Laboratory Method Blank (µg/l)	Decon Blank SMDB01.7 (µg/l)	Laboratory Method Blank (µg/l)
Dissolved Metal	***Sample batch:***	**160213-77**			***160213-69***	
Aluminium	<2.9	<2.9	<2.9	<2.9	<2.9	<2.9
Antimony	<0.16	**0.189**	**0.161**	*0.66*	<0.16	0.75
Arsenic	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12
Barium	<0.03	<0.03	**0.05**	<0.03	**0.042**	<0.03
Cadmium	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Chromium	<0.22	<0.22	**0.435**	<0.22	**0.223**	<0.22
Cobalt	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06

Sample Description	LOD (µg/l)	Filtration Blank WB01.7 (µg/l)	Water Blank WB02.7 (µg/l)	Laboratory Method Blank (µg/l)	Decon Blank SMDB01.7 (µg/l)	Laboratory Method Blank (µg/l)
Dissolved Metal	***Sample batch:***	**160213-77**			***160213-69***	
Copper	<0.85	<0.85	<0.85	<0.85	<0.85	<0.85
Iron	<19	<19	<19	<19	<19	<19
Lead	<0.02	<0.02	**0.031**	<0.02	<0.02	<0.02
Manganese	<0.04	**0.056**	**0.144**	<0.04	<0.04	<0.04
Molybdenum	<0.24	<0.24	<0.24	0.96	<0.24	0.84
Nickel	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15
Vanadium	<0.24	<0.24	<0.24	<0.24	<0.24	<0.24
Zinc	<0.41	**1.21**	**0.84**	<0.41	<0.41	<0.41

Notes:
Bold indicates a detection.
Bold and italics indications a detection of a parameter also detected in the laboratory method blank.
Italics indicates a detection in the lab method blank also detected in a field water or decontamination blank in the same batch.

3.2.3 Standard Reference Material

As previously discussed two certified water SRMs were sent blind to the laboratory (Sample IDs SMSR01.7 and SMSR02.7) to evaluate laboratory accuracy. The ALcontrol laboratory reports are provided in Appendix F of the Data Report. Table 6 summarises the SRM results and provides the calculated %R values for the 15 requested metals.

Reported values for dissolved aluminium, arsenic, barium, cadmium, chromium, cobalt, copper, manganese, molybdenum, nickel, vanadium and zinc are in good agreement with the certified value (%R ranged from 89 to 107%).

One of the reported values for dissolved antimony (85%) and lead (112%) were outside the acceptable range, however the corresponding reported values for the second SRM were within acceptable ranges and therefore the interpretation of the results are not affected. Both of the reported values for dissolved iron were low at 87% and 89% which fall outside of the acceptable range. This indicates that values for iron may be biased low and any use of these values should be noted with this observation.

Table 6 Water SRM Reported Values (µg/l) and Calculated % R

Dissolved Metal	Certified Value (µg/l)	Acceptance Limits Lower (%)	Acceptance Limits Upper (%)	SMSR01.7 (µg/l)	% R	SMSR02.7 (µg/l)	% R
Aluminium	1290	88	114	1290	100	1260	98
Antimony	484	87	111	412	**85**	432	89
Arsenic	814	87	111	776	95	784	96
Barium	1690	91	109	1800	107	1750	104
Cadmium	519	89	106	502	97	516	99
Chromium	548	91	109	549	100	540	99
Cobalt	422	93	111	434	103	432	102
Copper	371	91	109	370	100	376	101
Iron	1870	90	111	1620	**87**	1660	**89**

Dissolved Metal	Certified Value (µg/l)	Acceptance Limits Lower (%)	Acceptance Limits Upper (%)	SMSR01.7 (µg/l)	% R	SMSR02.7 (µg/l)	% R
Lead	1180	90	110	1320	**112**	1260	107
Manganese	806	92	109	820	102	809	100
Molybdenum	306	90	109	286	93	293	96
Nickel	1680	91	109	1540	92	1530	91
Vanadium	500	91	107	494	99	488	98
Zinc	1430	91	110	1350	94	1320	92

Notes:
Bold indicates an exceedance in acceptance limits

3.3 Laboratory QA/QC Samples

3.3.1 ALcontrol

ALcontrol conducts 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 were 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 different standard than 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. None of the sample holding times was exceeded. ALcontrol provided the associated analytical quality control samples (AQC) data. The percentage recovery results for the AQC samples that were analysed with the regular environmental samples were checked against the individual lower control and upper control limits. All AQC samples analysed with the environmental samples were within these upper and lower control limits. In addition, several environmental samples were re-analysed to verify the results. The results of method blanks were also assessed as described in Section 3.2.2 above.

3.4 Summary of Data Checks

3.4.1 Field Physico-chemical Versus Laboratory Data

Table 7 summarises the field and laboratory results for pH and provides the calculated %RPD values between the two results. Note that 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).

The RPDs between laboratory and field pH were good at less than 26.5%. For SW12-Shal, the %RPD was higher at 36.3%. The result was confirmed with ALcontrol and the difference is believed to be due to the unstable reading obtained in the field. Recordings of pH in the field are typically lower than the laboratory due to some carbon dioxide degassing during transport or within the laboratory itself. With the exception of SW12-SHAL, the field pH and conductivity are more representative of actual conditions and are used for interpretive purposes. Overall the RPDs between the field and laboratory data are considered satisfactory.

Table 7 Field physico-chemical data and Laboratory Reported Values and Calculated % RPD

Sample Description	pH Lab (pH Units)	pH Field (pH Units)	% RPD
DS-GORT	7.64	7.43	2.8
SW10-GORT U/S	7.84	7.42	5.5
SW10-GORT-D/S	7.85	7.44	5.4
SW10-GORT-DISCHARGE	7.67	7.51	2.1
SW12-GORT-D/S	7.64	7.37	3.6
SW12-GORT-DISCHARGE	7.46	6.97	6.8
SW14-GORT	7.63	7.42	2.8
SW17-GORT	7.51	7.28	3.1
SW18-GORT	8	6.13	26.5
SW19-GORT	8.07	7.15	12.1
SM5-SM	7.87	8.11	-3.0
SW1-SM	7.65	7.56	1.2
SW2-SM-SOUTH	7.87	7.67	2.6
SW3-SM	7.53	7.84	-4.0
SW4-SM-GA	7.94	8.19	-3.1
DS-SHAL	7.52	7.24	3.8
SW12-SHAL*	6.02	4.17	36.3
SW1-SHAL	7.46	6.95	7.1
SW4-SHAL	7.52	6.13	20.4
SW5-SHAL	6.38	5.91	7.6
SW6-MAG	7.48	7.2	3.8
SW6-SHAL	6.96	6.43	7.9
SW9-SHAL	7.38	6.84	7.6
U/S-SHAL	7.03	6.72	4.5
SW10-GAR	7.61	7.6	0.1
SW12-GAR	7.53	7.32	2.8
SW1-GAR	7.17	6.69	6.9

Sample Description	pH Lab (pH Units)	pH Field (pH Units)	% RPD
SW3-GAR	7.65	7.73	-1.0
SW5-GAR	7.43	6.7	10.3
SW7-GAR	7.6	7.47	1.7

Notes:
Bold indicates an exceedance in acceptance limits
* pH value had trouble stabilising in the field

Section 4

Results and Evaluations

This section provides a statistical summary of the analytical results for surface water 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 Surface Water Sample Results

Surface water samples were collected for two major categories: the first includes mine adit discharges and discharges from wetlands as well as some drainage ditches and the second includes the rivers and streams. Table 8 provides a summary of the reported results of the 11 discharge/ drainage samples and Table 9 provides a summary of the reported results of the 19 river and stream samples. Included in the tables are the minimum, maximum, mean and standard deviation (SDEV) for dissolved metals 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 8 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	11	4	1.45	61.8	14.3	24.0
Antimony	<0.16	11	9	0.08	2.50	0.98	0.90
Arsenic	<0.12	11	9	0.06	0.66	0.34	0.24
Barium	<0.03	11	11	14.7	290	88.7	95.3
Cadmium	<0.1	11	10	0.05	32.6	9.04	12.3
Chromium	<0.22	11	11	0.46	3.93	1.71	0.97
Cobalt	<0.06	11	11	0.10	4.52	1.52	1.70
Copper	<0.85	11	11	0.98	16.8	3.97	4.45
Iron	<19	11	3	0.01	0.14	0.03	0.04
Lead	<0.02	11	11	0.11	591	60.2	177
Manganese	<0.04	11	11	0.77	356	144	138
Molybdenum	<0.24	11	5	0.12	1.42	0.34	0.39
Nickel	<0.15	11	11	1.45	58.0	19.6	22.1
Vanadium	<0.24	11	8	0.12	0.91	0.42	0.26
Zinc	<0.41	11	11	21.8	13,500	4,390	5,650

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

SW5-Gar had the highest concentrations of dissolved nickel (58 µg/l), manganese (356 µg/l) and zinc (13,500 µg/l). The highest dissolved lead was recorded at SW6-Shal (Field Shaft) with a value of 591 µg/l.

Rivers and Streams

Table 9 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	19	16	1.45	49.9	17.0	14.7
Antimony	<0.16	19	11	0.08	3.81	0.62	0.93
Arsenic	<0.12	19	16	0.06	2.28	0.40	0.51
Barium	<0.03	19	19	39.2	352	141	90.3
Cadmium	<0.1	19	17	0.05	22.7	3.85	6.70
Chromium	<0.22	19	19	0.39	1.92	1.25	0.50
Cobalt	<0.06	19	17	0.03	6.39	0.94	1.50
Copper	<0.85	19	16	0.43	66.1	8.21	15.1
Iron	<19	19	15	0.01	0.07	0.04	0.02
Lead	<0.02	19	18	0.02	333	43.0	85.7
Manganese	<0.04	19	19	3.30	770	90.3	175
Molybdenum	<0.24	19	8	0.12	2.94	0.46	0.66
Nickel	<0.15	19	19	0.45	44.1	9.30	13.2
Vanadium	<0.24	19	11	0.12	0.57	0.31	0.18
Zinc	<0.41	19	19	1.14	8,460	1,560	2,710

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 than the rest of the rivers and streams sampled in the Silvermines area (1.14 and 2.01 µg/l, respectively). SW17-Gort has background concentrations of manganese (23.3 µg/l) and barium (109 µg/l).

SW5-Shal (downstream of the drum dump) had the highest concentrations of cadmium (22.7 µg/l), manganese (770 µg/l) and nickel (44.1 µg/l). SW3-Gar (downstream of Garryard) had the highest concentration of zinc (8,460 µg/l) and SW9-Shal (downstream of field shaft) had the highest concentrations of lead (333 µg/l).

4.2 Assessment Criteria

4.2.1 Groundwater and Surface Water Assessment Criteria

No groundwater sampling was undertaken in February 2016. However, for completeness the assessment criteria discussed in section 4.2.1 relates to both surface water and groundwater.

To assess the analytical results of 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 10. These include standards for physico-chemical conditions supporting the biological elements general conditions and standards for specific pollutants. In the case of metals the EQS refers to the dissolved concentration. 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 10).

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 $CaCO_3$ (CDM Smith, 2013) and therefore the EQSs for hardness greater than 100 mg/l were selected as shown in Table 10. The appropriate ecological assessment criteria are highlighted in bold in Table 10.

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 11. These values are the maximum permissible values for a drinking water source. In the case of metals, the standards are for total metals, however they apply post treatment (including filtration) and therefore the dissolved portion is used in the assessment in Section 4.

The current Drinking Water Regulations set limit values for iron and manganese but they are categorised as Indicator Parameters. Indicator Parameters are not considered to be important health criteria but rather exceedances can affect the aesthetic quality of drinking water supplies. Iron and manganese are commonly found above the drinking water limit in groundwaters in Ireland and are intermittently above the standard in some surface waters.

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 can be utilised for screening purposes (Table 10 and Table 11).

Table 10 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
pH	pH units		**> 4.5** and < 9.0	S.I. No. 272 of 2009	Within range
Dissolved Oxygen	% Sat		**80** to **120**	S.I. No. 272 of 2009	Within range
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; 30 µg/l applies where the water hardness > 100 mg/l CaCO3.
Lead	µg/l	**7.2**	-	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

Notes:

Bold indicates the selected assessment criteria for ecological health

Table 11 Surface Water and Groundwater Assessment Criteria for Drinking Water

Parameter	Unit	Parametric value
pH	pH units	>6.5 to <9.5
Conductivity	mS/cm	2.5
Ammonium	mg/l	0.3
Sulphate	mg/l	250
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
Nickel	µg/l	20

4.2.2 Livestock Drinking Water Assessment Criteria

There are currently no Irish or European guidelines for the quality of drinking water for livestock. Recommendations for levels of toxic substances in drinking water for livestock are available from the US National Academy of Sciences (1972). Table 12 summarises the recommended levels for metals where limits have been established, and for total dissolved solids, sulphate and fluoride.

Table 12 Assessment Criteria for Livestock Drinking Water Quality

Parameter	Unit	Parametric Value	Source	Comment
Aluminium	µg/l	5,000	NAS 1972	
Arsenic	µg/l	200	NAS 1972	
Cadmium	µg/l	50	NAS 1972	
Chromium	µg/l	1,000	NAS 1972	
Cobalt	µg/l	1,000	NAS 1972	
Copper	µg/l	500	NAS 1972	
Lead	µg/l	100	NAS 1972	Lead is accumulative and problems may begin at threshold value of 0.05 mg/l. (Soltanpour and Raley, 2007)
Vanadium	µg/l	100	NAS 1972	
Zinc	µg/l	24,000	NAS 1972	
Sulphate	mg/l	500	Higgins *et. al.* 2008	<500 mg/l for calves <1,000 mg/l for adults

4.3 Comparison to Assessment Criteria

A comparison of the surface water analytical results was performed against the relevant assessment criteria for ecological and human health as described in Section 4.2. The results and exceedances are discussed in this section.

Table B-1 in Appendix B highlights the exceedances of the assessment criteria. Where exceedances of the ecological assessment criteria exist, the result is highlighted in purple, for an exceedance of the human health criteria the result is highlighted 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 surface water analytical results was made against the relevant assessment criteria for livestock drinking water 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 livestock assessment criteria, the result is highlighted in green.

4.3.1 Surface Water Assessment

The pH in surface waters in the Silvermines mining area ranged from 5.91 to 8.19, with an average of 7.2. There were five exceedances of the assessment criteria for pH at SW18-Gort (6.13 pH), SW12-Shal (6.02 pH), SW4-Shal (6.13 pH), SW5-Shal (5.91 pH) and SW6-Shal (6.43 pH) which were below the acceptable range for human health of 6.5 to 9.5 pH. The conductivity ranged from 0.059 to 1.43 mS/cm with an average of 0.46 mS/cm, with no exceedances of the human health criteria (2.5 mS/cm). Dissolved oxygen levels exceeded the ecological assessment criteria (80-120 %) at all river and stream locations at Gortmore with values ranging from 69.8 to 72.7 % saturation, with an average of 71.3 % saturation.

Ammonia concentrations were below the limit of detection (0.2 mg/l) at all sampling locations except SW3-SM (0.212 mg/l) which exceeded the ecological assessment criteria (0.14 mg/l). Sulphate exceeded the criteria for human health (250 mg/l) at both wetland discharges in the Gortmore area and four of the discharge and drainage locations in the Garryard area. As well, the human health criteria was exceeded at SW3-Gar (295 mg/l). The sulphate results that exceeded the criteria ranged from 277 to 810 mg/l, with an average of 384 mg/l.

Dissolved Metals Assessment

Concentrations of dissolved barium, cadmium, lead, manganese, nickel and zinc were elevated and exceeded the assessment criteria in many locations as discussed below, see the Table B-1 in **Appendix B** for the full listing. Table 13 provides a summary of the reported values for rivers and streams at the upstream and downstream locations at the different mining areas that exceeded the relevant ecological and human health assessment criteria for dissolved metals. For the locations refer to the maps in **Appendix A**.

The ecological assessment criterion 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 (109 µg/l), and is not discussed further. Dissolved arsenic was detected at the majority of surface water locations but was significantly below both the ecological (25 µg/l) and human health (10 µg/l) assessment criteria, with the highest concentration of 2.28 µg/l at SW5-Shal.

In the Ballygown area (Map 5 of **Appendix A**) where the Silvermines stream is located, in addition to dissolved barium, dissolved cadmium, chromium and zinc exceeded the assessment criteria at certain locations. Upstream at SW1-SM there were no exceedances of the ecological or human health criteria (except barium). The southern adit (SW2-SM-South) discharges to the Silvermines stream and had cadmium (5.07 µg/l), chromium (3.93 µg/l) and zinc (2,070 µg/l) above the ecological (0.9 µg/l) and human assessment criteria (5 µg/l) for cadmium, and the ecological assessment criteria for chromium (3.4 µg/l) and zinc (100 µg/l). It was observed that SW2-SM-North had a very small flow and is not included in the monitoring programme. Downstream on the

Silvermines stream at SW5-SM and SW4-SM-GA, dissolved zinc was also above the ecological assessment criteria with a concentrations of 191 and 176 µg/l respectively.

SW6-Mag downstream of the Magcobar area also had dissolved cadmium (1.49 µg/l) and zinc (713 µg/l) above the ecological assessment criteria.

Table 13 Summary of Reported Values for Rivers and Streams and the Surface Water Assessment Criteria

	Sample Description	Sample Location	Date Sampled	Ammoniacal Nitrogen as N	pH (field)	Sulphate	Cadmium (diss.filt)	Lead (diss.filt)	Manganese (diss.filt)	Nickel (diss.filt)	Zinc (diss.filt)
			Units	mg/l		mg/l	µg/l	µg/l	µg/l	µg/l	µg/l
			Ecological Criteria	0.14	4.5 to 9		0.9	7.2	1100	20	100
			Human Health Criteria	0.3	6.5 to 9.5		5	10	50	20	-
Ballygown	SW1-SM	Upstream	12/02/2016	<0.2	7.56	3.4	<1	0.02	4.3	0.453	1.14
	SW3-SM	DS (underground workings)	12/02/2016	<0.2	7.84	7.6	0.444	1.55	3.3	0.957	157
	SW5-SM	DS (underground workings & Adits)	12/02/2016	<0.2	8.11	10	0.451	1.16	4.14	1.29	191
	SW4-SM-Ga	Downstream (all)	12/02/2016	<0.2	8.19	34.4	0.484	1.31	3.55	1.32	176
Magcobar	SW6-Mag	Downstream	10/02/2016	<0.2	7.2	190	1.49	0.448	44.5	8.6	713
Garryard	SW1-GAR	Upstream	11/02/2016	<0.2	6.69	810	8.59	6.08	82.5	38.1	5310
	SW3-GAR	Downstream (all)	11/02/2016	<0.2	7.73	295	20.1	2.42	226	29	8460
Shallee	SW4-SHAL	Upstream	10/02/2016	<0.2	6.13	<2	0.438	96.6	60.1	3.75	48.9
	SW5-SHAL	DS (drum dump)	10/02/2016	<0.2	5.91	74.9	22.7	78.9	770	44.1	8040
	SW9-SHAL	Downstream	10/02/2016	<0.2	6.84	27.7	5.02	333	168	14	1590
	SW1-SHAL	Downstream (all)	10/02/2016	<0.2	6.95	20.5	3.27	190	119	9.39	997
Garryard/ Shallee	US SHAL	Downstream of SW3-GAR	10/02/2016	<0.2	6.72	7.1	0.791	39.8	19.4	2.07	111
	DS SHAL	Downstream of SW3-GAR and SW1-SHAL	10/02/2016	<0.2	7.24	110	7.54	56.3	82	12.5	3070
Gortmore	SW17-GORT	Upstream	09/02/2016	<0.2	7.28	7.5	<0.1	0.202	23.3	1.13	2.01
	SW12-GORT-DS	Downstream (TMF)	09/02/2016	<0.2	7.37	37	0.521	2.74	27.5	2.45	204
	SW14-GORT	Downstream (TMF and Yellow River)	09/02/2016	<0.2	7.42	27.6	0.441	2.58	19.6	1.96	163
	DS-Gort	Downstream (TMF and Yellow River)	09/02/2016	<0.2	7.43	28.7	0.509	2.41	25.1	2.23	175

Notes:

xx Exceeds Ecological Assessment Criteria

xx Exceeds Human Health Assessment Criteria

xx Exceeds both Ecological and Human Health Criteria

Metals are dissolved

At Gortmore TMF (Map 2 of **Appendix A**), dissolved zinc and lead exceeded the ecological assessment criteria and dissolved manganese exceeded the human health assessment criteria. Concentrations of dissolved lead and nickel were detected at all sampling locations but were significantly lower than the assessment criteria with the exception of dissolved lead at SW18-Gort (8.73 µg/l). Dissolved manganese exceeded the human health assessment criteria of 50 µg/l but was below the ecological assessment criterion of 1100 µg/l at the wetland discharge SW12-Gort-Disc (285 µg/l).

Dissolved zinc exceeded the ecological assessment criteria of 100 µg/l at seven locations at Gortmore TMF. The highest concentrations were recorded at the two wetland discharges with concentrations ranging from 607 µg/l at SW10-Gort-Disc to 849 µg/l at SW12-Gort-Disc. The concentration of zinc increased on the Kilmastulla River from 2.01 µg/l at the upstream location SW17-Gort, to 204 µg/l at the downstream location SW12-Gort-DS, which exceeds the ecological assessment criteria of 100 µg/l. Further downstream, at DS-Gort the concentration of dissolved zinc was 175 µg/l. SW12-Gort-DS and DS-Gort are located downstream of the wetland discharges and the Yellow Bridge Tributary which drains Garryard and Shallee. The loading from these areas are discussed in Section 5.

At Shallee (Map 3 of **Appendix A**), dissolved lead exceeded both the ecological (7.2 µg/l) and human health (10 µg/l) assessment criteria at all locations with concentrations ranging from 39.8 to 591 µg/l. The highest concentration was from the Field Shaft discharge (SW6-Shal-591 µg/l). At SW4-Shal which is upstream of the mining area, the dissolved lead concentration was 96.6 µg/l. This result was checked and confirmed by ALcontrol. With the exception of SW12-Shal (stone lined drainage channel) and SW4-Shal, dissolved zinc exceeded the ecological assessment criteria of 100 µg/l with values ranging from 111 to 8,040 µg/l.

Manganese was above the criteria for human health (50 µg/l) but below the ecological assessment criteria (1,100 µg/l) at seven Shallee locations with values ranging from 60.1 µg/l (SW4-Shal) to 770 µg/l (SW5-Shal). SW5-Shal exceeded the ecological assessment criteria for cobalt (6.39 µg/l) and copper (66.1 µg/l) and both the ecological and human health criteria for dissolved nickel (44.1 µg/l). With the exception of SW12-Shal, SW4-Shal and US-Shal, dissolved cadmium exceeded the ecological criteria (0.9 µg/l) at all locations. SW5-Shal (22.7 µg/l), DS-Shal (7.54 µg/l) and SW9-Shal (5.02 µg/l) exceeded both the ecological and human health criteria (5 µg/l).

DS-Shal is located on the Yellow River downstream of all the discharges from the Shallee and Garryard areas and located upstream of the confluence with the Kilmastulla River in the Gortmore area. US-Shal is a new sampling location on the Yellow River and is located directly upstream of the Shallee area. Increases in dissolved metal concentrations from US-Shal to DS-Shal were recorded as follows:

- Dissolved lead increased from 39.8 µg/l to 56.3 µg/l which exceeded both the ecological (7.2 µg/l) and human health (10 µg/l) assessment criteria at both locations;
- Dissolved zinc increased from 111 µg/l to 3,070 µg/l which exceeded the ecological assessment criteria (100 µg/l) at both locations;
- Dissolved cadmium increased from 0.791 µg/l to 7.54 µg/l which exceeded both the ecological (0.9 µg/l) and human health (5 µg/l) assessment criteria at DS-Shal; and

- Dissolved manganese increased from 19.4 µg/l to 82 µg/l which exceeded the human health (50 µg/l) assessment criteria at DS-Shal.

In the Garryard area (Map 4 of Appendix A), some of the highest concentrations of dissolved metals were observed. Each location in Garryard exceeded the dissolved zinc ecological assessment criteria of 100 µg/l, ranging from 5,270 (SW7-Gar) to 13,500 µg/l (SW5-Gar). All locations exceeded both the ecological (0.9 µg/l) and human health (5 µg/l) assessment criteria for cadmium (ranging from 7.84 to 32.6 µg/l). Dissolved lead was detected at all six locations but concentrations were below the assessment criteria. Nickel was above both the ecological and human health assessment criteria of 20 µg/l at all sampling locations in the Garryard area except SW7-Gar with values ranging from 29 (SW3-Gar) to 58 µg/l (SW5-Gar – Knights shaft). Dissolved 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 values ranging from 71.8 to 356 µg/l.

4.3.2 Livestock Water Quality Assessment

Recommendations for levels of toxic substances in drinking water for livestock are provided in Table 12. A limit of 100 µg/l is recommended for lead in drinking water for livestock by the National Academy of Sciences (1972). However lead is accumulative and problems may begin at threshold value of 50 µg/l. The concentration of lead recorded downstream of the Shallee mining area (DS-Shal) on the Yellow River was 56.3 µg/l. The Field Shaft (SW6-Shal) had a concentration of dissolved lead of 591 µg/l and the sampling locations on the stream SW9-Shal and SW1-Shal which are downstream of the Field Shaft had concentrations of 333 and 190 µg/l respectively. Therefore it is recommended that livestock should be prevented from drinking water in the stream in the Shallee mining area.

The water quality results for all of the ponds and streams sampled at Gortmore TMF were also assessed against the recommendations for levels of toxic substances in drinking water for livestock from the National Academy of Sciences (1972).

- No exceedances of the livestock threshold values for any metals were found; and
- The maximum recommended sulphate level for calves is 500 mg/l and for adults is 1,000 mg/l. The sulphate concentrations recorded at Gortmore were well below the recommended limits with values ranging from 7.5 to 304 mg/l. The guidelines for sulphates in water are not well defined but high concentrations cause diarrhoea; however, at the levels found in the waterbodies at Gortmore TMF it is likely that livestock are accustomed to them also. Therefore it is considered that the streams and ponds on top of the Gortmore TMF are safe for livestock but they should be continued to be monitored.

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 1 September 2015 to 27 February 2016 from Station 25044 is reproduced in Figure 1. The figure shows the measured flows ranging from >10 m^3/s following rainfall events to less than 1 m^3/s during low-flow, with a median flow of approximately 4.3 m^3/s. The recorded flow at the Coole gauging station showed that for December high flows existed and were at or above the calculated 5%-ile (high flow) of 12.9 m^3/s on several occasions after rainfall. The flow in the period November to February shows a flashy response to rainfall. The highest recorded flow in the monitoring period was on 5 December 2016 with a mean daily flow of 22.7 m^3/s. In September and October the flows were low with a baseline of 0.33 m^3/s which is below the 95%-ile (low flow) of 0.35 m^3/s. Overall flows were low in September and October and relatively high during the remainder of the monitoring period.

The flows in the Kilmastulla River in the Silvermines mining area are expected to be lower than that recorded at the EPA Station 10 km downstream, as many small tributaries drain from the surrounding mountains between the mining area and the gauging station. The EPA tool for ungauged catchments was utilised to estimate the 95%-ile flow (low flow) of the Kilmastulla River at the location just downstream of the Gortmore TMF which was 0.16 m^3/s. It is estimated that the flows would have been close to the 95%-ile low flow in the Silvermines mining area in September and October 2015. The EPA tool for ungauged catchments was also used to calculate the 5%-ile flow (high flow) which was 4.36 m^3/s as the flows were likely significantly greater than this for the majority of days in December, January and February.

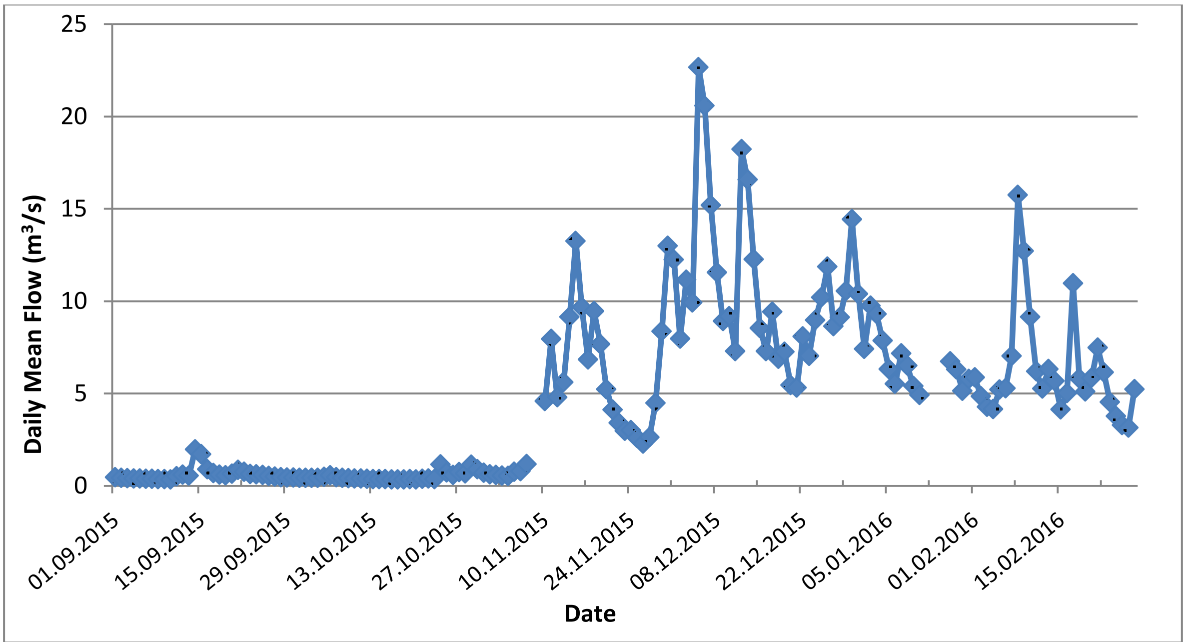


Figure 1 Mean Daily Flow (m^3/s) at Coole, Kilmastulla (Station 25044) from 1 Sept 2015 to 27 Feb 2016

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 14 presents a summary of the results from the flow measured in February 2016 at the time of sampling. Appendix B of the Data Report contains details of methodologies used per site and associated calculations.

Table 14 Surface Water Flow Value Measured in February 2016

Site Name	Flow l/s	Date
SW10-GORT Discharge	33	09/02/2016
SW12-GORT Discharge	22	09/02/2016
SW19-GORT	66.5	09/02/2016
DS-GORT	11,360	09/02/2016
SW10-GAR	27.3	11/02/2015
SW12-GAR	41.4	11/02/2015
SW3-GAR	135	11/02/2015
SW5-GAR	Flow immeasurable (grating)	11/02/2015
SW7-GAR	9.80	11/02/2015
US-SHAL	138	10/02/2016
DS-SHAL	310	10/02/2016
SW12-SHAL	11.9	10/02/2016
SW1-SHAL	70.7	10/02/2016
SW4-SHAL	0.7	10/02/2016
SW5-SHAL	4.05	10/02/2016
SW6-SHAL	9.2	10/02/2016
SW9-SHAL	37.7	10/02/2016
SW1-SM	44.2	12/02/2016
SW3-SM	91.4	12/02/2016
SW2-SM-South	1.55	12/02/2016
SW5-SM	112	12/02/2016
SW4-SM-GA	135	12/02/2016

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 15 aid with the interpretation of the loading of sulphate and dissolved cadmium, lead, manganese, nickel and zinc to rivers.

Table 15 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
DS-GORT	09/02/2016	11360	7.43	28700	28200000	0.509	500	2.41	2370	25.1	24600	2.23	2190	175	172000
SW10-GORT-DISCHARGE	09/02/2016	33	7.51	277000	790000	0.379	1.08	0.471	1.34	46.3	132	5.15	14.7	607	1730
SW12-GORT-DISCHARGE	09/02/2016	22	6.97	304000	578000	0.781	1.48	0.109	0.21	285	542	9.01	17.1	849	1610
SW19-GORT	09/02/2016	66.5	7.15	148000	850000	0.688	3.95	3.87	22.2	10.9	62.6	3.42	19.6	374	2150
SW10-GAR	11/02/2016	27.3	7.6	343000	808000	32.6	76.8	0.982	2.31	273	643	45.5	107	12100	28500
SW12-GAR	11/02/2016	41.4	7.32	375000	1340000	25.1	89.7	0.398	1.42	328	1170	55.6	199	13000	46500
SW3-GAR	11/02/2016	135	7.73	295000	3440000	20.1	234	2.42	28.2	226	2640	29	338	8460	98700
SW7-GAR	11/02/2016	9.8	7.47	343000	290000	7.84	6.64	0.393	0.33	71.8	60.8	19	16.1	5270	4460
DS-SHAL	10/02/2016	310	7.24	110000	2950000	7.54	202	56.3	1510	82	2200	12.5	335	3070	82300
SW12-SHAL	10/02/2016	11.9	6.02	1000	1030	0.05	0.05	54.4	56.1	106	109	1.45	1.5	21.8	22.5
SW1-SHAL	10/02/2016	70.7	6.95	20500	125000	3.27	20	190	1160	119	726	9.39	57.3	997	6090
SW4-SHAL	10/02/2016	0.7	6.13	1000	58.1	0.438	0.03	96.6	5.62	60.1	3.49	3.75	0.22	48.9	2.84
SW5-SHAL	10/02/2016	4.0	5.91	74900	26200	22.7	7.94	78.9	27.6	770	269	44.1	15.4	8040	2810
SW6-SHAL	10/02/2016	9.2	6.43	12600	10000	1.2	0.95	591	470	89.8	71.4	8.71	6.92	237	188
SW9-SHAL	10/02/2016	37.7	6.84	27700	90300	5.02	16.4	333	1090	168	548	14	45.6	1590	5180
U/S-SHAL	10/02/2016	138	6.72	7100	84400	0.791	9.4	39.8	473	19.4	231	2.07	24.6	111	1320
SM5-SM	12/02/2016	112	8.11	10000	96900	0.451	4.37	1.16	11.2	4.14	40.1	1.29	12.5	191	1850
SW1-SM	12/02/2016	44.2	7.56	3400	13000	0.05	0.19	0.02	0.08	4.3	16.4	0.453	1.73	1.14	4.35
SW2-SM-SOUTH	12/02/2016	1.6	7.67	33200	4450	5.07	0.68	1.12	0.15	0.765	0.1	7.23	0.97	2070	277
SW3-SM	12/02/2016	91.4	7.84	7600	60000	0.444	3.51	1.55	12.2	3.3	26.1	0.957	7.56	157	1240
SW4-SM-GA	12/02/2016	135	8.19	34400	402000	0.484	5.66	1.31	15.3	3.55	41.5	1.32	15.4	176	2060

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

The dissolved metal with the highest mass loading was zinc ranging from 2.84 to 172,000 g/day with an average of 21,900 g/day overall. The largest mass load of zinc (172,000 g/day) was found at DS-Gort (new location) which is located on the Kilmastulla River, downstream of Gortmore TMF. The DS-Gort sampling location captures the total dissolved metal load from all of the primary mining areas (Gortmore, Shallee, Garryard, Magcobar and Ballygown). Of the two wetland discharges at Gortmore TMF, SW10-Gort-Discharge had the highest loading of dissolved zinc at 1,730 g/day. SW10-Gort-Discharge had 1,610 g/day of zinc.

SW10-Gar (the discharge from the tailings lagoon) had a zinc load of 28,500 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, there was a significant increase in zinc loading to 98,700 g/day. It was observed at the time of sampling that significant flow was present in the surface water channels which drain the western part of the Mogul Yard. The stream discharges to the Yellow Bridge River which flows to the Kilmastulla River.

The dissolved zinc load upstream of Ballygown (SW1-SM) was calculated to be 4.35 g/day, which increases to 1,240 g/day downstream of the mine workings (SW3-SM). Downstream of the southern (277 g/day zinc) and northern adit at SW5-SM (new location) the zinc load increased to 1,850 g/day. Further downstream the calculated mass load at SW4-SM-GA was 2,060 g/day, which indicates that there may be another source of zinc load contributing to the stretch of river between SW5-SM to SW4-SM-GA. However, further data which will be obtained in the next monitoring round are required to confirm this. The Silvermines stream contributes this load to the Kilmastulla River.

The highest load of dissolved lead was found at DS-Gort (2,370 g/day). The mass load at DS-Shal which is located downstream of both the Shallee and Garryard mining areas was 1,510 g/day. The dissolved lead load increased from 1,160 g/day at SW1-Shal to 1,510 g/day at DS-Shal. This increase can be attributed to the lead load at US-Shal (473 g/day) located on the steam draining the Garryard mining area. The calculated lead load at SW3-Gar located directly downstream of the Garryard area was 28.2 g/day which indicates an increase in dissolved lead load of approximately 440 g/day between SW3-Gar and US-Shal. This apparent increase indicates that a diffuse contribution of dissolved lead is likely along this stretch of river. The dissolved zinc load at DS-Shal is 82,300 g/day which is an increase from the Shallee area (SW1-Shal – 6,090 g/day). The stream emerging from the Garryard area contributed 1,300 g/day (US-Shal) which indicates that there may be another source of zinc contributing to the loading result at DS-Shal. It was observed that a significant flow was draining the eastern section of the tailings impoundment and joining the Shallee stream downstream of SW1-Shal. It is recommended that this stream is sampled in the next monitoring round (if flow exists) to establish the source of the high levels of zinc recorded at DS-Shal. All results were checked and confirmed by ALcontrol and further monitoring is required to quantify impact of the Shallee mining area on the Yellow River.

Upstream of SW1-Shal the dissolved lead load was 1,090 g/day at SW9-Shal which is located immediately east of the southernmost Shallee tailings impoundment and downstream of Field Shaft. The dissolved lead loading from Field Shaft (SW6-Shal) was 470 g/day. This indicates that the discharge from the Field Shaft is not the only contributor of lead load to the stream. The majority of the stream has been surveyed between the main road and Field Shaft (where accessible) and no other inputs of surface water were observed. However, in February 2016, the stream at SW5-Shal (downstream of the drum dump) was discharging onto the road and subsequently flowing into the ditch east of the field shaft. This flow is likely joining the main stream downstream of the field shaft. Further investigation is required to confirm this and it is recommended that this temporary stream is sampled directly before entering the main stream to assess the dissolved metal load contribution.

Discharges from the Garryard and Shallee area (DS-Shal – 82,300 g/day) therefore provided the greatest mass loads of dissolved zinc to the Kilmastulla River.

5.3 Trend Analysis

5.3.1 Historical Trends

This section discusses concentration time trends for select locations including the main discharges (SW2-SM South, SW6-SHAL, SW10-Gar, SW10-Gort-Disc and SW12-Gort-Disc) and SW14-Gort which is the most downstream sampling location on the Kilmastulla River. The Mann-Kendall test was performed on the surface water data. The Mann-Kendall test is a non-parametric test that is well suited to use in water quality data analysis. The Mann-Kendall test was performed for dissolved cadmium, lead, manganese, nickel and zinc.

The Mann-Kendall test results in the identification of a trend (if one exists) and the probability of that trend being real. Table 16 shows the possible outcomes of the Mann-Kendall trend analysis as applied to the water quality data.

Table 16 Reporting the Mann-Kendall Results

Trend	P value	Trend reported as
Decreasing	0 <= p < 0.05	Decreasing
	0.05 <= p < 0.1	Likely Decreasing
	p >= 0.1	No Trend
Increasing	0 <= p < 0.05	Increasing
	0.05 <= p < 0.1	Likely Increasing
	p >= 0.1	No Trend
No Trend	p = 1	No Trend
Not Calculated	n/a	Not Calculated

Notes:
Null Hypothesis: The null hypothesis is that there is no trend.
The p-value is the probability that the null hypothesis is true.
The confidence coefficient is 0.95
The Mann-Kendall test requires the following information for a trend to be calculated: A sample size of at least three value and a maximum of 50% of the sample set is reported as non-detect.

Trend analysis was conducted for all the available data since November 2006. The Mann-Kendall test results are presented in Table 17 and facilitate general observations about trends in the water quality of the main discharges and the downstream location on the Kilmastulla River.

Table 17 Mann-Kendall Trend Analysis of data from November 2006 to February 2016

Sample Location	Parameter	Reported values (n)	p value	s value	Trend
SW10-Gar	Diss. cadmium	12	0.5	-1	No Trend
	Diss. lead	11	0.1530	-14	No Trend
	Diss. manganese	12	0.0271	-29	Decreasing
	Diss. nickel	12	0.5270	0	No Trend
	Diss. zinc	11	0.1507	16	No Trend
SW10-Gort-discharge	Diss. cadmium	8	0.1473	-11	No Trend
	Diss. lead	7	0.1838	7	No Trend

Sample Location	Parameter	Reported values (n)	p value	s value	Trend
	Diss. manganese	9	0.3772	4	No Trend
	Diss. nickel	9	0.0238	-20	Decreasing
	Diss. zinc	9	0.0589	-16	Likely Decreasing
SW12-Gort-discharge	Diss. cadmium	7	0.0666	11	Likely Increasing
	Diss. lead	7	0.3819	3	No Trend
	Diss. manganese	8	n/a	n/a	Not Calculated
	Diss. nickel	8	0.3553	-4	No Trend
	Diss. zinc	8	0.1932	8	No Trend
SW6-Shal	Diss. cadmium	10	0.5	1	No Trend
	Diss. lead	10	0.3603	5	No Trend
	Diss. manganese	10	0.1416	-13	Likely Decreasing
	Diss. nickel	10	0.2958	-7	No Trend
	Diss. zinc	10	0.2371	-9	No Trend
SW14-Gort (Kilmastulla River)	Diss. cadmium	8	0.4508	2	No Trend
	Diss. lead	9	0.3772	4	No Trend
	Diss. manganese	9	0.3011	-6	No Trend
	Diss. nickel	9	0.3060	-6	No Trend
	Diss. zinc	9	0.4585	-2	No Trend

Not Calculated: insufficient statistical evidence of a significant trend
The confidence coefficient is 0.95

The results of the Mann-Kendall analysis show that dissolved manganese concentrations are decreasing at SW10-Gar. At the SW10-Gort-discharge dissolved nickel is decreasing and dissolved zinc is likely decreasing. At the SW12-Gort-discharge dissolved cadmium is likely increasing. In the Shallee mining area dissolved manganese is likely decreasing at the field shaft (SW6-Shal). Note that additional samples are required to confirm these trends. No other statistically significant trends were observed in the data that were analysed.

5.3.2 Seasonal Trends

Table 18 shows the seasonal variation between the concentrations of dissolved metals and the calculated loads observed between the high flow sampling events in April 2013 (R1), March 2014 (R3), February 2015 (R5) and February 2016 (R7) and the low flow sampling event in August 2013 (R2), September 2014 (R4) and August 2015 (R6).

Table 18 Seasonal Variation of Concentrations and Calculated Loads of Dissolved Metals in the Main Discharges and on the most downstream location on the Kilmastulla River for the period 2013-2016

Site Description	Round & Date Sampled	Flow	Cadmium		Lead		Manganese		Zinc	
		l/s	µg/l	g/day	µg/l	g/day	µg/l	g/day	µg/l	g/day
SW2-SM South	R1 04/04/2013	2.35	4.72	0.958	1.03	0.209	1.55	0.315	1970	400
	R2 29/08/2013	1.5	4.57	0.59	0.838	0.11	0.534	0.07	1840	238
	R3 11/03/2014	3	5.18	1.34	1.1	0.29	1.86	0.48	1940	503
	R4 25/09/2014	1.1	4.65	0.44	0.912	0.09	0.563	0.05	1750	166
	R5 06/02/2015	1.93	5.45	0.907	1.11	0.185	1.02	0.17	2140	356
	R6 28/08/2015	1	4.32	0.39	0.856	0.08	0.547	0.05	1560	139
	R7 12/02/2016	1.6	5.07	0.68	1.12	0.15	0.765	0.1	2070	277
SW6-SHAL	R1 02/04/2013	5.51	0.905	0.431	236	112	60.7	28.9	179	85.2
	R2 02/09/2013	3.4	0.809	0.24	183	53.7	61	17.9	154	45.2
	R3 05/03/2014	2.208	1.29	0.25	477	91	97.9	18.7	252	48.1
	R4 22/09/2014	4.3	0.799	0.3	320	119	85.5	31.8	221	82.1

Site Description	Round & Date Sampled	Flow	Cadmium		Lead		Manganese		Zinc	
		l/s	µg/l	g/day	µg/l	g/day	µg/l	g/day	µg/l	g/day
	R5 05/02/2015	5.08	1.16	0.508	363	159.2	65.3	28.6	223	97.8
	R6 27/08/2015	3.76	0.903	0.29	211	68.6	46.4	15.1	153	49.8
	R7 10/02/2016	9.2	1.2	0.95	591	470	89.8	71.4	237	188
SW10-GAR	R1 03/04/2013	5.46	18.8	8.87	1.56	0.736	74.1	35	5390	2540
	R2 28/08/2013	2.12	10.6	1.95	1.04	0.19	321	58.9	2360	433
	R3 06/03/2014	50.7	24.8	109	2.06	9.03	226	990	9320	40800
	R4 23/09/2014	3.1	21.7	5.81	8.51	2.28	255	68.3	7150	1920
	R5 04/02/2015	16.8	30.1	43.7	1.21	1.76	148	215.1	13000	18893
	R6 26/08/2015	4.4	12	4.52	3.98	1.5	141	53.1	2590	976
	R7 11/02/2016	27.3	32.6	76.8	0.982	2.31	273	643	12100	28500
SW10-Gort-Disc	R1 27/03/2013	5.13	0.142	0.063	0.209	0.093	64.4	28.5	656	291
	R2 27/08/2013	0.22	0.05	0.001	0.05	0.001	191	3.58	175	3.28
	R3 13/03/2014	6	0.328	0.17	0.276	0.14	91.5	47.4	1040	539
	R4 25/09/2014	1.7	0.5	0.07	0.137	0.02	308	45.2	301	44.2
	R5 03/02/2015	7.22	0.199	0.12	0.095	0.059	47.1	29.4	895	558.5
	R6 25/08/2015	0.13	0.05	0	0.21	0	349	3.79	252	2.73
	R7 09/02/2016	33.0	0.379	1.08	0.471	1.34	46.3	132	607	1730
SW12-Gort-Disc	R1 26/03/2013	7.14	0.102	0.063	0.069	0.043	165	102	332	205
	R2 27/08/2013	2.05	0.05	0.01	0.04	0.01	1070	190	99.9	17.7
	R3 13/03/2014	7.826	0.462	0.31	0.061	0.04	269	182	585	396
	R4 25/09/2014	2.6	0.5	0.11	0.022	0.0	453	102	124	27.9
	R5 03/02/2015	9.63	0.5	0.41	0.01	0.008	217	181	597	497
	R6 25/08/2015	1.86	0.106	0.02	0.073	0.01	910	146	169	27.1
	R7 09/02/2016	22.0	0.781	1.48	0.109	0.21	285	542	849	1610
SW14-Gort	R1 26/03/2013	-	0.271	-	1.71	-	68.6	-	108	-
	R2 27/08/2013	-	0.104	-	1.17	-	70.4	-	42.1	-
	R3 13/03/2014	-	0.542	-	2.21	-	50.7	-	245	-
	R4 25/09/2014	-	0.145	-	2.9	-	105	-	102	-
	R5 03/02/2015	-	0.563	-	1.74	-	36.8	-	233	-
	R6 25/08/2015	-	0.106	-	1.19	-	38.6	-	51.1	-
	R7 09/02/2016	-	0.441	-	2.58	-	19.6	-	163	-
DS-Gort	R7 09/02/2016	11360	0.509	500	2.37	2330	25.1	24600	175	17200

Notes
- is not measured / calculated

As can be observed from Table 18 the concentrations of dissolved cadmium, lead, manganese and zinc are generally at similar concentrations in both low flow and high flow conditions. However, in some cases the concentrations were significantly lower during low flow conditions, particularly in August 2013. An example includes dissolved zinc in the SW10-Gort-Disc and SW12-Gort-Disc discharges, where values of dissolved zinc in these discharges ranged from 99.9-301 µg/l in low flow to 597-1,040 µg/l in high flow. This difference in the concentrations and loadings of dissolved zinc was reflected in the Kilmastulla River at SW14-Gort where the ecological assessment criterion of 100 µg/l was exceeded during high flows with reported values of 108 µg/l in April 2013, 245 µg/l in March 2014, 233 µg/l in February 2015 and 163 µg/l in February 2016. Concentrations were significantly lower than the assessment criterion in August 2013 (42.1 µg/l) and August 2015 (51.1 µg/l). This was not the case in September 2014 during low flow as dissolved zinc was detected at 102 µg/l, which is likely due to the high concentration of dissolved zinc in SW10-Gar (7,150 µg/l).

Table 18 shows that the calculated loads of dissolved cadmium, lead, manganese and zinc were all significantly lower in August 2013, September 2014 and August 2015 due to the low flow conditions. Due to the high flow conditions in February 2016, calculated loads were high. This is particularly reflected in the wetland discharges at Gortmore where the loads of cadmium, manganese, lead and zinc were the highest calculated to date.

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 19 displays the measured depth to groundwater and calculated groundwater elevations.

The groundwater elevations outside the TMF decreased from 48.73 m Ordnance Datum (OD) at the upgradient location TMF1 to 46.41 m OD at the downgradient location TMF2. 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. The groundwater elevations at TMF1 and TMF2 are similar to the elevations measured on 02/02/2015 and between 0.44 and 0.56 metres greater than the elevations measured in summer 2015 (24/8/2015).

Within the tailings area, measured water levels were in the range of 1.5 to 3.48 m below the top of the tailings surface. The exceptions were in BH3A-GORT-06 and BH6A-GORT-06 where deeper water levels were recorded. The groundwater elevations within the TMF varied between 49.19 to 54.45 m OD. These groundwater elevations are similar to the elevations measured during high flow (02/02/2015) which ranged from 48.69 to 54.23 m OD and between 0.65 to 1.4 metres higher than the elevations measured during low flow (24/08/2015).

Table 19 Measured Groundwater Levels February 2016

Borehole Identifier	Location Description	Date	Time	Depth to Groundwater (m bgl)	Depth to Groundwater (m bTOC)	Groundwater Elevation (m OD)
TMF1	Outside the perimeter of the TMF	11/2/2016	14:30	0.27	0.86	48.73
TMF2		11/2/2016	14:10	1.59	2.05	46.41
BH1A-GORT-06	Located within the TMF, near the perimeter of the tailings surface	11/2/2016	15:30	1.66	2.31	54.10
BH2A-GORT-06		11/2/2016	15:15	2.60	3.13	53.16
BH3A-GORT-06		11/2/2016	14:40	7.41	7.74	49.19
BH4A-GORT-06		11/2/2016	14:50	3.48	4.00	52.68
BH5A-GORT-06		11/2/2016	15:05	3.05	3.48	53.16
BH6A-GORT-06		11/2/2016	15:45	3.90	4.59	52.18
BH6B-GORT-06		11/2/2016	15:50	1.50	2.22	54.45

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

Section 7

Summary and Recommendations

7.1 Summary of Findings

Thirty surface water locations were sampled and analysed in February 2016 with flows measured at 21 of the locations. Groundwater levels were measured at nine wells. The field QA/QC sample results were reviewed for accuracy and precision. The laboratory QA/QC samples and laboratory reports were also reviewed. Overall the data quality is considered acceptable and the data can be used to compare to the assessment criteria and for evaluation of loads.

Statistical summaries of the analytical results for surface water 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:

- Surface water locations SW1-SM and SW17-Gort are located upstream of the mining areas of Silvermines and Gortmore respectively and have significantly lower concentrations of zinc, than the rest of the rivers and streams sampled in the Silvermines area with values of 1.14 and 2.01 µg/l, respectively which are both well below the ecological assessment criteria of 100 µg/l.

- In the Garryard area some of the highest concentrations of dissolved metals were observed. For example, SW5-Gar (Knights Shaft) had the highest concentrations of dissolved manganese (356 µg/l), nickel (58 µg/l) and zinc (13,500 µg/l). Each location in Garryard exceeded the dissolved zinc ecological assessment criteria of 100 µg/l with values ranging from 5,270 to 13,500 µg/l. All locations exceeded both the ecological (0.9 µg/l) and human health (5 µg/l) assessment criteria for cadmium (ranging from 7.84 to 32.6 µg/l). Dissolved 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 values ranging from 71.8 to 356 µg/l.

- At Shallee dissolved lead exceeded both the ecological (7.2 µg/l) and human health (10 µg/l) assessment criteria at all locations. The highest concentration was from the Field Shaft discharge (SW6-Shal) at 591 µg/l. Significant increases in lead, zinc, cadmium and manganese were recorded on the Yellow River downstream of the Shallee mining area (DS-Shal) compared to upstream (US-Shal).

- Dissolved zinc exceeded the ecological assessment criteria of 100 µg/l at the majority of the drainage and discharge locations ranging from 21.8 to 13,500 µg/l at SW5-Gar. The concentration of zinc increased on the Kilmastulla River from 2.01 µg/l at the upstream location SW17-Gort to 204 µg/l at SW12-Gort-DS. This location is downstream of the wetland discharges and the Yellow Bridge Tributary which drains Garryard and Shallee. The concentration at DS-Shal on the Yellow River tributary was significantly higher at 3,070 µg/l.

- The dissolved metal with the highest mass loading was zinc, ranging from 2.84 to 172,000 g/day with an average of 21,900 g/day overall. The largest mass load of zinc

(172,000 g/day) was found at DS-Gort which is located on the Kilmastulla River, downstream of Gortmore TMF. The highest load of dissolved lead was also found at DS-Gort (2,370 g/day). Measured flows ranged from 0.7 l/s at SW4-Shal to 11,360 l/s at DS-Gort with an average of 602.9 l/s overall.

- Livestock should be prevented from drinking water in the stream in the Shallee mining area due to the elevated lead levels (>50 µg/l).

7.2 Recommendations for the Monitoring Programme

Overall, the reduced monitoring programme was adequate in meeting the requirements of the February 2016 sampling event. Following the analysis and interpretation of the Round 7 results, the recommendations outlined below are proposed:

1. An additional sampling location on the stream draining the eastern section of the tailings impoundment in the Shallee mining area to establish the source of the high levels of zinc recorded downstream on the Yellow River.
2. An additional sampling location on the stream downgradient of the drum dump in the Shallee mining area prior to re-entering the main channel to assess the dissolved metal load contribution.

As outlined in the Summary Report (Document Ref: 95735/40/DG/25, dated 20 January 2016), a full sampling schedule will be completed in Round 8.

Section 8

References

CDM Smith (2013). Monitoring Report for the Silvermines Mining Area Round 1 2013. June 2013. Document Ref: 95735/40/DG/06.

Efroymson, R.A., Will, M.E., Suter II, G.W. and Wooten, A.C. (1997). Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Terrestrial Plants: 1997 Revision. Oak Ridge National Laboratory, Oak Ridge, TN.

European Communities (Undesirable Substances in Feedingstuffs) Regulations, 2003. (S.I. 317 of 2003)

European Communities Drinking Water Regulations, 2007 (S.I. No. 106 of 2007).

European Communities Environmental Objectives (Surface Water) Regulations, 2009 (S.I. 272 of 2009).

Ford, K.L. (2004). Risk Management Criteria for Metals at BLM Mining Sites, National Science and Technology Center, Denver, CO.

Hedberg, Y., Herting, G. and Odnevall Wallinder, I. (2011). Risks of using membrane filtration for trace metal analysis and assessing the dissolved metal fraction of aqueous media – a study on zinc, copper and nickel. *Environmental Pollution,* 159, 1144-1150.

Higgins, S.F., Agouridis, C.T. and Gumbert A.A. (2008). Drinking Water Quality Guidelines for Cattle. University of Kentucky – College of Agriculture.

National Academy of Science (1972). Water Quality Criteria. US Environmental Protection Agency. EPA R3–73–033.

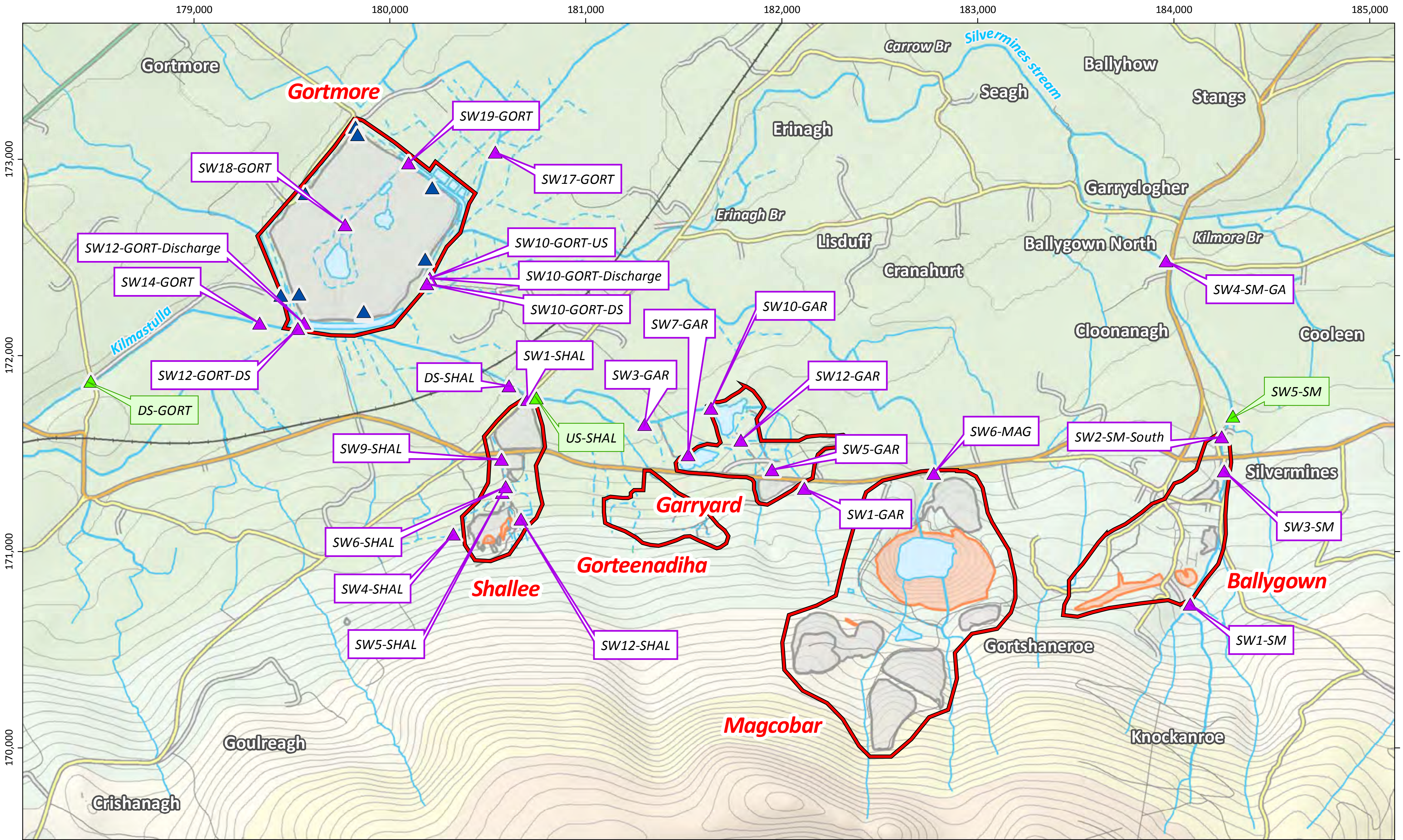
Sample, B.E., Opresko D.M., and Suter G.W. II. (1996). Toxicological Benchmarks for Wildlife. 1996 Revision. Oak Ridge National Laboratory. Oak Ridge, TN.

Soltanpour, P.N. and Raley, W.L. (2007). Livestock Drinking Water Quality. Livestock Series no. 4.908. Colorado State University.

Suter, G.W. II and Tsao. C.L. (1996). Toxicological Benchmarks for Screening Potential Contaminants of Concern for Effects on Aquatic Biota: 1996 Revision. Oak Ridge, Tennessee: Oak Ridge National Laboratory.

Appendix A

Figures



Map 1 - Silvermines - Overview

Drawn by: OC Date: 14/04/2016

Internal Project Reference: Q:\95500-95999\95735\40 Documents Generated\GIS\02_GIS_Tasks\16_MonRptR7\MXD\01_SilverMon1.mxd

CDM Smith

Legend

Sampling Locations

- Surface water
- Surface water (New point)
- Groundwater*

- Rivers
- Streams
- Pond / Wetland / Pit Lake

*Note: Only groundwater levels monitored in February 2016

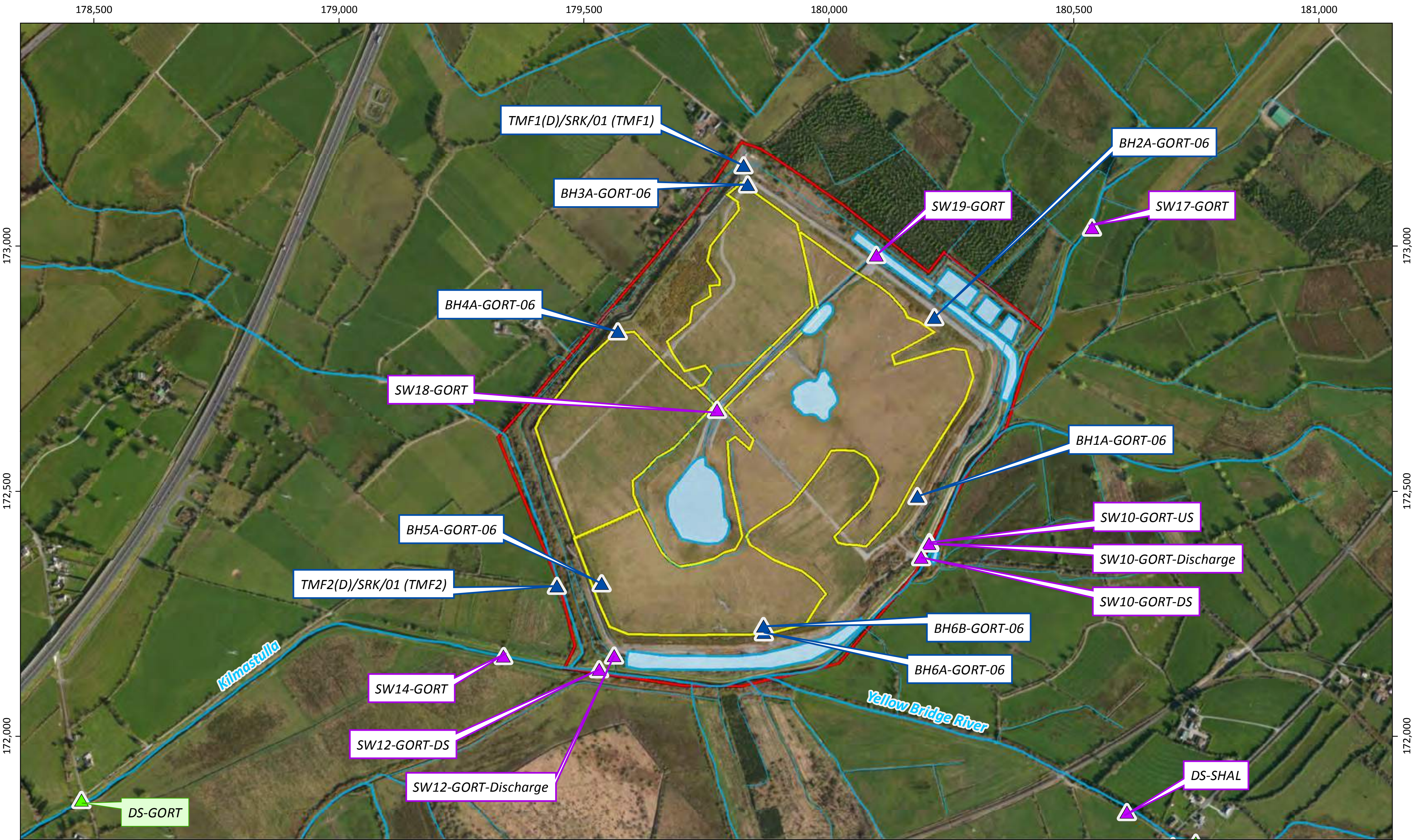
Mines

- Mining Areas
- Spoil Heap / Stockpile Dump / Waste Drum Dump / Tailings / Tailings Pond
- Open Pit

N W E S

Scale is 1:25,000

0 125 250 500 m



Map 2 - Silvermines - Gortmore TMF

Drawn by: OC *Date: 14/04/2016*

Internal Project Reference: Q:\95500-95999\95735\40 Documents Generated\GIS\02_GIS_Tasks\16_MonRptR7\MXD\02_SilverMonGM.mxd

Source: ESRI World Imagery ©ESRI (UC-G image courtesy of Microsoft, acquired on 11/6/2011)

CDM Smith

Legend

Sampling Locations
- Surface water
- Surface water *(New point)*
- Groundwater *(Levels only)*

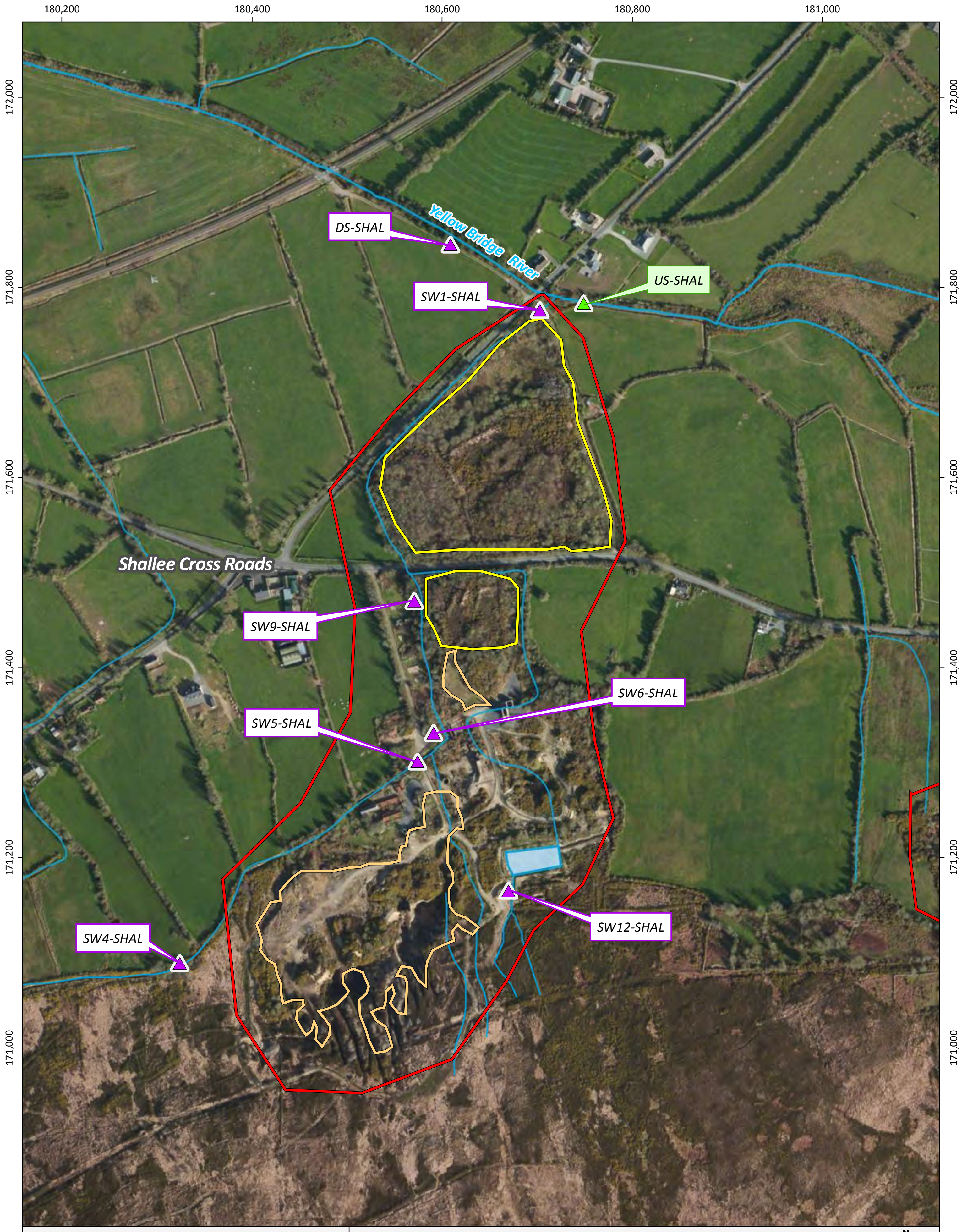
- Rivers
- Streams
- Pond / Wetland / Pit Lake

Mines
- Mining Areas

Scale is 1:10,000

0 100 200 m

N E S W



Map 3 - Silvermines - Shallee South

Drawn by: OC *Date: 14/04/2016*

Internal Project Reference: Q:\95500-95999\95735\40 Documents Generated\GIS\02_GIS_Tasks\\16_MonRptR7\MXD\03_SilverMonSh.mxd

Source: ESRI World Imagery ©ESRI (UC-G image courtesy of Microsoft, acquired on 11/6/2011)

CDM Smith

Legend

Sampling Locations
- Surface water
- Surface water *(New point)*

- Rivers
- Streams
- Pond / Wetland

Mines
- Mining Areas
- Tailings / Tailings Pond
- Spoil Heap / Waste Drum Dump

N W E S

Scale is 1:5,000

0 50 100 m

Map 4 - Silvermines - Garryard

Drawn by: OC Date: 14/04/2016

Internal Project Reference: Q:\95500-95999\95735\40 Documents Generated\GIS\02_GIS_Tasks\16_MonRptR7\MXD\04_SilverMonGAR.mxd

Source: ESRI World Imagery ©ESRI (UC-G image courtesy of Microsoft, acquired on 11/6/2011)

CDM Smith

Legend

Sampling Locations
- Surface water

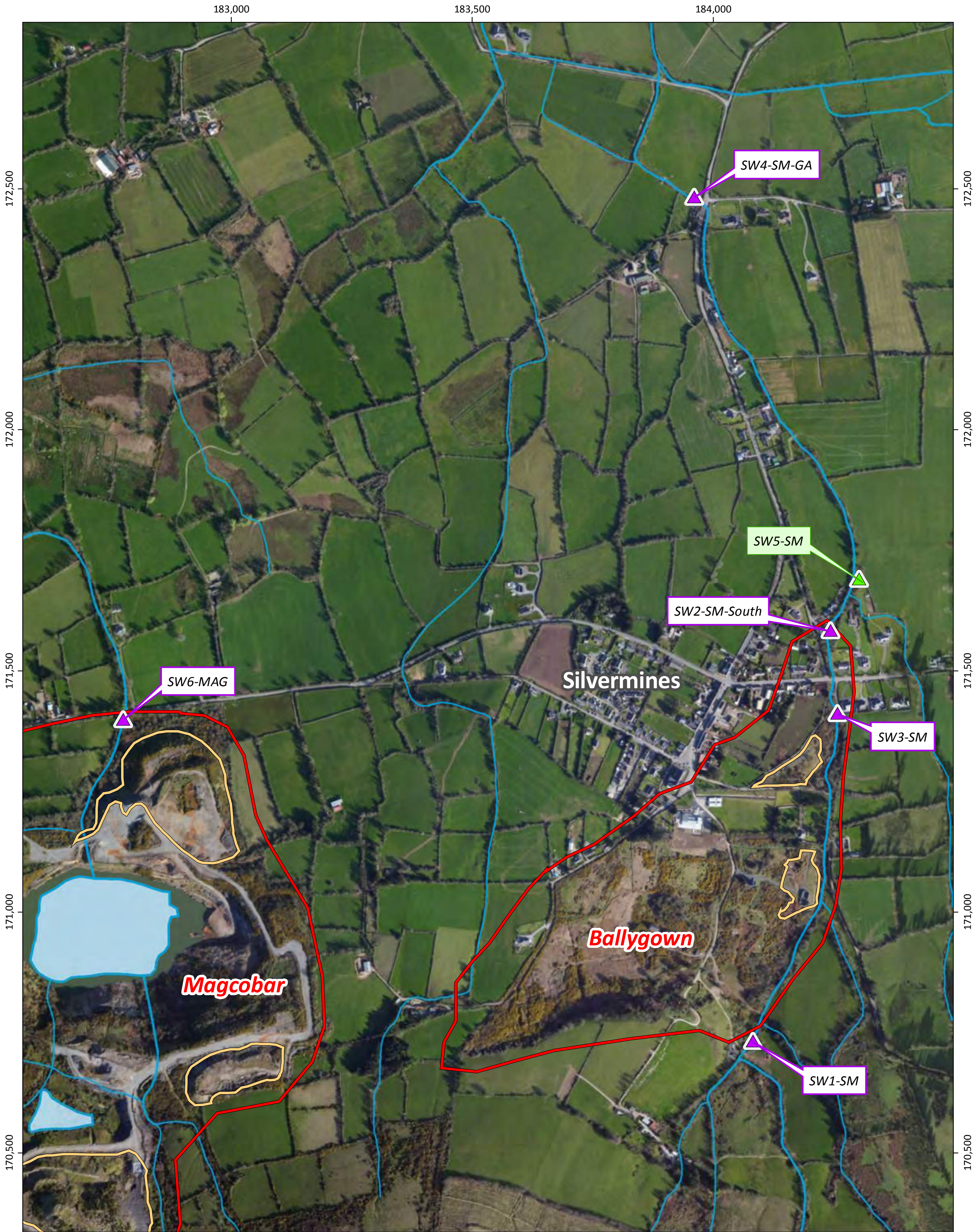
- Rivers
- Streams
- Pond / Wetland

Mines
- Mining Areas
- Stockpile Dump

Scale is 1:5,000

0 50 100 m

N W E S



Map 5 - Silvermines - Magcobar and Ballygown

Drawn by: OC   Date: 14/04/2016

Internal Project Reference: Q:\95500-95999\95735\40 Documents Generated\GIS\02_GIS_Tasks\16_MonRptR7\MXD\05_SilverMonMaBG.mxd

Source: ESRI World Imagery ©ESRI (UC-G image courtesy of Microsoft, acquired on 11/6/2011)

CDM Smith

Legend

Sampling Locations
- Surface water
- Surface water (New point)

- Rivers
- Streams
- Pond / Wetland

Mines
- Mining Areas
- Spoil Heap / Waste Drum Dump

N W E S

Scale is 1:10,000

0 100 200 m

Appendix B

Analytical Data Tables and Assessment Criteria

Table B-1 Comparison of Groundwater and Surface Water Results to Assessment Criteria R7

Sample Description	Type	Area	Date Sampled	Ammoniacal Nitrogen as N	Oxygen, dissolved (field)	pH (field)	Specific Conductance @ deg.C (field)	Sulphate	Aluminium (diss.filt)	Antimony (diss.filt)	Arsenic (diss.filt)	Barium (diss.filt)	Cadmium (diss.filt)	Chromium (diss.filt)	Cobalt (diss.filt)	Copper (diss.filt)
			Units	mg/l	mg/l	pH Units	mS/cm	mg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l
Ecological Criteria				0.14	80 to 120*	4.5 to 9	-	-	1,900	-	25	4	0.9	3.4	5.1	30
Human Health Criteria				0.3	-	6.5 to 9.5	2.5	250	200	5	10	-	5	50	-	2000
DS-GORT	River/Stream	GM	09/02/2016	*0.1*	72.2	7.43	0.346	28.7	15.9	0.504	0.442	110	0.509	1.7	0.225	1.92
SW10-GORT U/S	River/Stream	GM	09/02/2016	*0.1*	72.7	7.42	0.358	20.7	13.3	*0.08*	0.293	105	0.165	1.87	0.162	1.26
SW10-GORT-D/S	River/Stream	GM	09/02/2016	*0.1*	70.9	7.44	0.405	44.7	11.7	*0.08*	0.266	97.3	0.102	1.74	0.179	1.31
SW10-GORT-DISCHARGE	Discharge	GM	09/02/2016	*0.1*	76.1	7.51	0.738	277	*1.45*	0.414	0.21	14.7	0.379	1.41	0.229	1.83
SW12-GORT-D/S	River/Stream	GM	09/02/2016	*0.1*	70.4	7.37	0.386	37	13	*0.08*	0.382	110	0.521	1.88	0.255	1.91
SW12-GORT-DISCHARGE	Discharge	GM	09/02/2016	*0.1*	55.5	6.97	0.847	304	20.7	*0.08*	0.385	155	0.781	1.99	0.825	2.16
SW14-GORT	River/Stream	GM	09/02/2016	*0.1*	69.8	7.42	0.328	27.6	17.2	*0.08*	0.287	112	0.441	1.6	0.213	1.91
SW17-GORT	River/Stream	GM	09/02/2016	*0.1*	71.5	7.28	0.274	7.5	19.7	*0.08*	0.325	109	*0.05*	1.41	0.165	1.62
SW18-GORT	Drainage	GM	09/02/2016	*0.1*	83.4	6.13	0.500	131	*1.45*	0.526	0.251	16.2	0.571	1.24	0.173	2.94
SW19-GORT	Drainage	GM	09/02/2016	*0.1*	92.1	7.15	0.523	148	*1.45*	1.74	0.559	18.7	0.688	1.28	0.177	2.32
SW6-MAG	River/Stream	Mag	10/02/2016	*0.1*	93.2	7.2	0.484	190	2.95	0.169	0.12	42.2	1.49	0.651	0.578	6
SW10-GAR	Discharge	GAR	11/02/2016	*0.1*	92.2	7.6	0.90	343	3.33	1.38	*0.06*	28.4	32.6	2.04	3.36	4.91
SW12-GAR	Drainage	GAR	11/02/2016	*0.1*	87.6	7.32	0.956	375	*1.45*	2.35	0.568	20.6	25.1	2.39	4.05	4.13
SW1-GAR	River/Stream	GAR	11/02/2016	*0.1*	89.9	6.69	1.433	810	8.57	0.291	0.154	39.2	8.59	0.81	1.12	5.74
SW3-GAR	River/Stream	GAR	11/02/2016	*0.1*	94.8	7.73	0.884	295	*1.45*	1.02	0.324	76.3	20.1	1.92	2.08	3.82
SW5-GAR	Discharge	GAR	11/02/2016	*0.1*	59.3	6.7	0.878	323	*1.45*	2.5	0.664	19.4	25.2	2.26	4.52	4.46
SW7-GAR	Drainage	GAR	11/02/2016	*0.1*	90.2	7.47	0.782	343	*1.45*	0.423	0.164	61.9	7.84	1.1	0.536	1.92
DS-SHAL	River/Stream	Shs	10/02/2016	*0.1*	87.8	7.24	0.409	110	21.8	2.03	1.11	181	7.54	1	0.976	9.99
SW12-SHAL	Drainage	Shs	10/02/2016	*0.1*	87.6	6.02	0.059	*1*	61.1	0.177	0.147	290	*0.05*	0.459	0.562	0.984
SW1-SHAL	River/Stream	Shs	10/02/2016	*0.1*	90.4	6.95	0.139	20.5	40.1	1.06	0.309	240	3.27	0.797	1.54	11.6
SW4-SHAL	River/Stream	Shs	10/02/2016	*0.1*	83.7	6.13	0.072	*1*	25.3	*0.08*	*0.06*	352	0.438	0.394	1.06	2.37
SW5-SHAL	River/Stream	Shs	10/02/2016	*0.1*	85.9	5.91	0.234	74.9	40.9	3.81	2.28	307	22.7	1.21	6.39	66.1
SW6-SHAL	Discharge	Shs	10/02/2016	*0.1*	70.9	6.43	0.120	12.6	61.8	1.09	0.651	202	1.2	0.671	2.16	16.8
SW9-SHAL	River/Stream	Shs	10/02/2016	*0.1*	89.6	6.84	0.160	27.7	49.9	1.22	0.356	202	5.02	0.665	2.38	18.6
U/S-SHAL	River/Stream	Shs	10/02/2016	*0.1*	87.1	6.72	0.131	7.1	30.7	0.378	0.293	246	0.791	0.675	0.307	17.8
SM5-SM	River/Stream	BG	12/02/2016	*0.1*	80.8	8.11	0.229	10	4.02	*0.08*	0.198	111	0.451	1.41	0.096	*0.425*
SW1-SM	River/Stream	BG	12/02/2016	*0.1*	82.5	7.56	0.124	3.4	*1.45*	0.296	*0.06*	40.6	*0.05*	0.946	*0.03*	2.08
SW2-SM-SOUTH	Discharge	BG	12/02/2016	*0.1*	52.5	7.67	0.517	33.2	*1.45*	*0.08*	*0.06*	149	5.07	3.93	0.104	1.18
SW3-SM	River/Stream	BG	12/02/2016	0.212	83.3	7.84	0.170	7.6	*1.45*	0.257	*0.06*	63.5	0.444	1.23	*0.03*	1.12
SW4-SM-GA	River/Stream	BG	12/02/2016	*0.1*	84.9	8.19	0.262	34.4	2.95	0.209	0.229	128	0.484	1.8	0.114	*0.425*

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

* Only applies to rivers or streams (i.e. not discharges)

Table B-1 Comparison of Groundwater and Surface Water Results to Assessment Criteria R7

Sample Description	Type	Area	Date Sampled	Iron (diss.filt)	Lead (diss.filt)	Manganese (diss.filt)	Molybdenum (diss.filt)	Nickel (diss.filt)	Vanadium (diss.filt)	Zinc (diss.filt)
			Units	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l
Ecological Criteria				-	7.2	1100	-	20	-	100
Human Health Criteria				200	10	50	-	20	-	-
DS-GORT	River/Stream	GM	09/02/2016	0.0658	2.41	25.1	0.463	2.23	0.439	175
SW10-GORT U/S	River/Stream	GM	09/02/2016	0.05	0.702	15.1	*0.12*	1.55	0.571	40.5
SW10-GORT-D/S	River/Stream	GM	09/02/2016	0.0499	0.688	17.9	*0.12*	1.91	0.502	93.5
SW10-GORT-DISCHARGE	Discharge	GM	09/02/2016	*9.5*	0.471	46.3	*0.12*	5.15	0.316	607
SW12-GORT-D/S	River/Stream	GM	09/02/2016	0.0583	2.74	27.5	*0.12*	2.45	0.543	204
SW12-GORT-DISCHARGE	Discharge	GM	09/02/2016	137	0.109	285	*0.12*	9.01	0.489	849
SW14-GORT	River/Stream	GM	09/02/2016	0.0489	2.58	19.6	*0.12*	1.96	0.494	163
SW17-GORT	River/Stream	GM	09/02/2016	0.0715	0.202	23.3	*0.12*	1.13	0.497	2.01
SW18-GORT	Drainage	GM	09/02/2016	*9.5*	8.73	10.9	*0.12*	2.99	0.301	242
SW19-GORT	Drainage	GM	09/02/2016	*9.5*	3.87	10.9	1.42	3.42	0.361	374
SW6-MAG	River/Stream	Mag	10/02/2016	0.0276	0.448	44.5	0.901	8.6	*0.12*	713
SW10-GAR	Discharge	GAR	11/02/2016	*9.5*	0.982	273	0.254	45.5	0.575	12100
SW12-GAR	Drainage	GAR	11/02/2016	*9.5*	0.398	328	0.553	55.6	0.635	13000
SW1-GAR	River/Stream	GAR	11/02/2016	*0.0095*	6.08	82.5	0.824	38.1	*0.12*	5310
SW3-GAR	River/Stream	GAR	11/02/2016	0.0246	2.42	226	0.272	29	0.481	8460
SW5-GAR	Discharge	GAR	11/02/2016	*9.5*	0.231	356	0.4	58	0.649	13500
SW7-GAR	Drainage	GAR	11/02/2016	*9.5*	0.393	71.8	0.343	19	*0.12*	5270
DS-SHAL	River/Stream	Shs	10/02/2016	0.0222	56.3	82	0.968	12.5	0.275	3070
SW12-SHAL	Drainage	Shs	10/02/2016	52.6	54.4	106	*0.12*	1.45	*0.12*	21.8
SW1-SHAL	River/Stream	Shs	10/02/2016	0.0484	190	119	0.329	9.39	*0.12*	997
SW4-SHAL	River/Stream	Shs	10/02/2016	*0.0095*	96.6	60.1	*0.12*	3.75	*0.12*	48.9
SW5-SHAL	River/Stream	Shs	10/02/2016	0.0403	78.9	770	2.94	44.1	*0.12*	8040
SW6-SHAL	Discharge	Shs	10/02/2016	88.2	591	89.8	*0.12*	8.71	*0.12*	237
SW9-SHAL	River/Stream	Shs	10/02/2016	0.0669	333	168	*0.12*	14	*0.12*	1590
U/S-SHAL	River/Stream	Shs	10/02/2016	0.0365	39.8	19.4	*0.12*	2.07	*0.12*	111
SM5-SM	River/Stream	BG	12/02/2016	*0.0095*	1.16	4.14	*0.12*	1.29	0.344	191
SW1-SM	River/Stream	BG	12/02/2016	*0.0095*	0.02	4.3	0.343	0.453	*0.12*	1.14
SW2-SM-SOUTH	Discharge	BG	12/02/2016	*9.5*	1.12	0.765	*0.12*	7.23	0.914	2070
SW3-SM	River/Stream	BG	12/02/2016	*0.0095*	1.55	3.3	0.435	0.957	0.264	157
SW4-SM-GA	River/Stream	BG	12/02/2016	*0.0095*	1.31	3.55	*0.12*	1.32	0.467	176

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

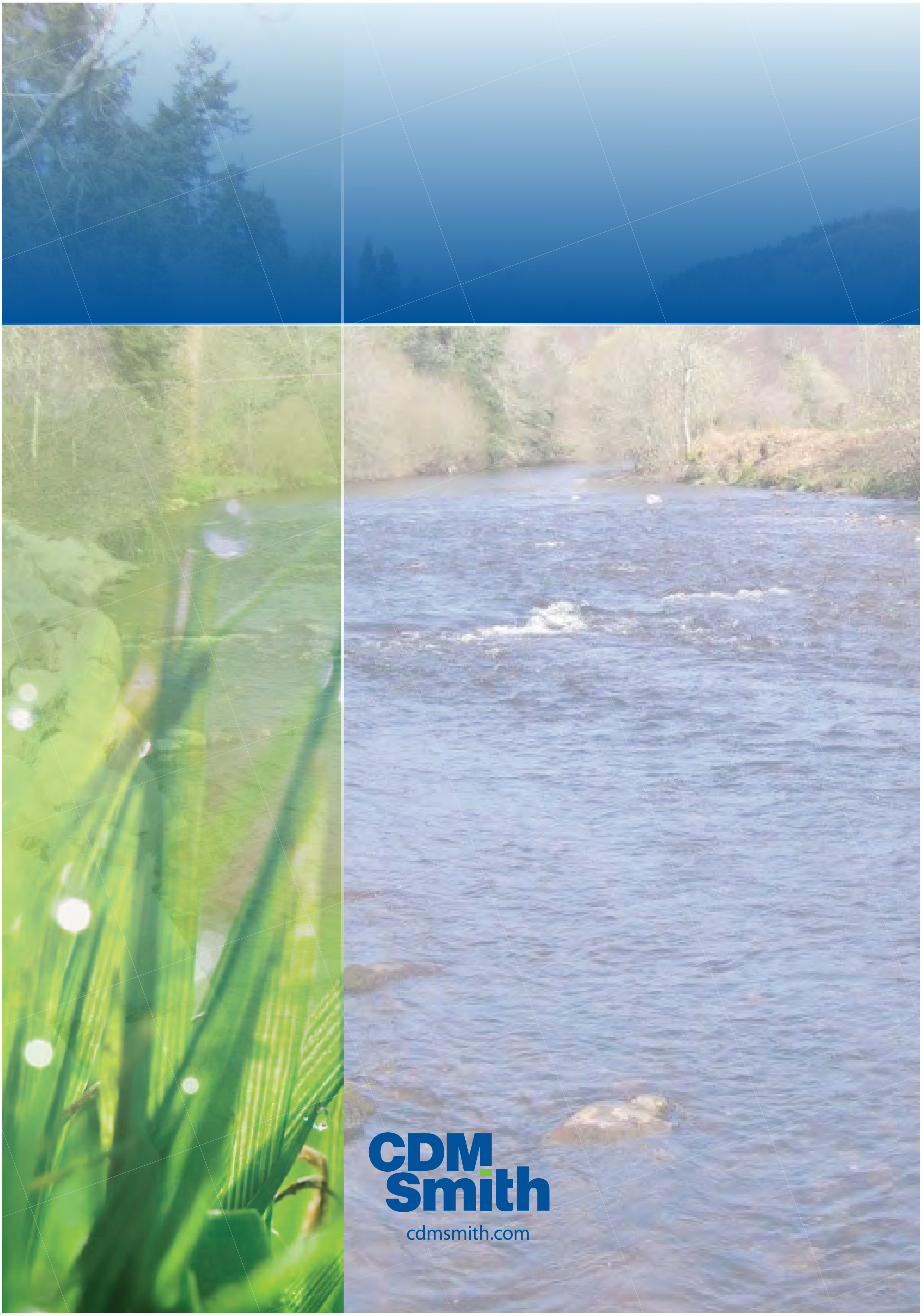
* Only applies to rivers or streams (i.e. not discharges)

Table B-2 Comparison of Surface Water Results to Assessment Criteria for Livestock Drinking Water R7

Sample Description	Area	Type	Date Sampled	Sulphate	Aluminium (diss.filt)	Arsenic (diss.filt)	Cadmium (diss.filt)	Chromium (diss.filt)	Cobalt (diss.filt)	Copper (diss.filt)	Lead (diss.filt)	Vanadium (diss.filt)	Zinc (diss.filt)
			Units	mg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l
Livestock Criteria				500	5000	200	50	1000	1000	500	100	100	24000
DS-GORT	River/Stream	GM	09/02/2016	28.7	15.1	0.442	0.509	1.58	0.225	1.92	2.37	0.439	175
SW10-GORT U/S	River/Stream	GM	09/02/2016	20.7	13.3	0.293	0.165	1.87	0.162	1.26	0.702	0.571	40.5
SW10-GORT-D/S	River/Stream	GM	09/02/2016	44.7	11.7	0.266	0.102	1.74	0.179	1.31	0.688	0.502	93.5
SW10-GORT-DISCHA	Discharge	GM	09/02/2016	277	*1.45*	0.21	0.379	1.41	0.229	1.83	0.471	0.316	607
SW12-GORT-D/S	River/Stream	GM	09/02/2016	37	13	0.382	0.521	1.88	0.255	1.91	2.74	0.543	204
SW12-GORT-DISCHA	Discharge	GM	09/02/2016	304	20.7	0.385	0.781	1.99	0.825	2.16	0.109	0.489	849
SW14-GORT	River/Stream	GM	09/02/2016	27.6	17.2	0.287	0.441	1.6	0.213	1.91	2.58	0.494	163
SW17-GORT	River/Stream	GM	09/02/2016	7.5	19.7	0.325	*0.05*	1.41	0.165	1.62	0.202	0.497	2.01
SW18-GORT	Drainage	GM	09/02/2016	131	*1.45*	0.251	0.571	1.24	0.173	2.94	8.73	0.301	242
SW19-GORT	Drainage	GM	09/02/2016	148	*1.45*	0.559	0.688	1.28	0.177	2.32	3.87	0.361	374
SW6-MAG	River/Stream	Mag	10/02/2016	190	2.95	0.12	1.49	0.651	0.578	6	0.448	*0.12*	713
SW10-GAR	Discharge	GAR	11/02/2016	343	3.33	*0.06*	32.6	2.04	3.36	4.91	0.982	0.575	12100
SW12-GAR	Drainage	GAR	11/02/2016	375	*1.45*	0.568	25.1	2.39	4.05	4.13	0.398	0.635	13000
SW1-GAR	River/Stream	GAR	11/02/2016	810	8.48	0.12	8.59	0.81	1.12	5.74	5.89	*0.12*	5310
SW3-GAR	River/Stream	GAR	11/02/2016	295	*1.45*	0.324	20.1	1.92	2.08	3.82	2.42	0.481	8460
SW5-GAR	Discharge	GAR	11/02/2016	323	*1.45*	0.664	25.2	2.26	4.52	4.46	0.231	0.649	13500
SW7-GAR	Drainage	GAR	11/02/2016	343	*1.45*	0.164	7.84	1.1	0.536	1.92	0.393	*0.12*	5270
DS-SHAL	River/Stream	Shs	10/02/2016	110	21.8	1.11	7.54	1	0.976	9.99	56.3	0.275	3070
SW12-SHAL	Drainage	Shs	10/02/2016	*1*	61.1	0.147	*0.05*	0.459	0.562	0.984	54.4	*0.12*	21.8
SW1-SHAL	River/Stream	Shs	10/02/2016	20.5	40.1	0.309	3.27	0.797	1.54	11.6	190	*0.12*	997
SW4-SHAL	River/Stream	Shs	10/02/2016	*1*	25.3	*0.06*	0.438	0.394	1.06	2.37	96.6	*0.12*	48.9
SW5-SHAL	River/Stream	Shs	10/02/2016	74.9	40.9	2.28	22.7	1.21	6.39	66.1	78.9	*0.12*	8040
SW6-SHAL	Discharge	Shs	10/02/2016	12.6	61.8	0.651	1.2	0.671	2.16	16.8	591	*0.12*	237
SW9-SHAL	River/Stream	Shs	10/02/2016	27.7	49.9	0.356	5.02	0.665	2.38	18.6	333	*0.12*	1590
U/S-SHAL	River/Stream	Shs	10/02/2016	7.1	30.7	0.293	0.791	0.675	0.307	17.8	39.8	*0.12*	111
SM5-SM	River/Stream	BG	12/02/2016	10	4.02	0.198	0.451	1.41	0.096	*0.425*	1.16	0.344	191
SW1-SM	River/Stream	BG	12/02/2016	3.4	*1.45*	*0.06*	*0.05*	0.886	*0.03*	*0.425*	*0.01*	*0.12*	0.821
SW2-SM-SOUTH	Discharge	BG	12/02/2016	33.2	*1.45*	*0.06*	5.07	3.93	0.104	1.18	1.12	0.914	2070
SW3-SM	River/Stream	BG	12/02/2016	7.6	*1.45*	*0.06*	0.444	1.23	*0.03*	1.12	1.55	0.264	157
SW4-SM-GA	River/Stream	BG	12/02/2016	34.4	2.95	0.229	0.484	1.8	0.114	*0.425*	1.31	0.467	176

xx Exceeds Livestock Assessment Criteria

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


CDM
Smith
cdmsmith.com