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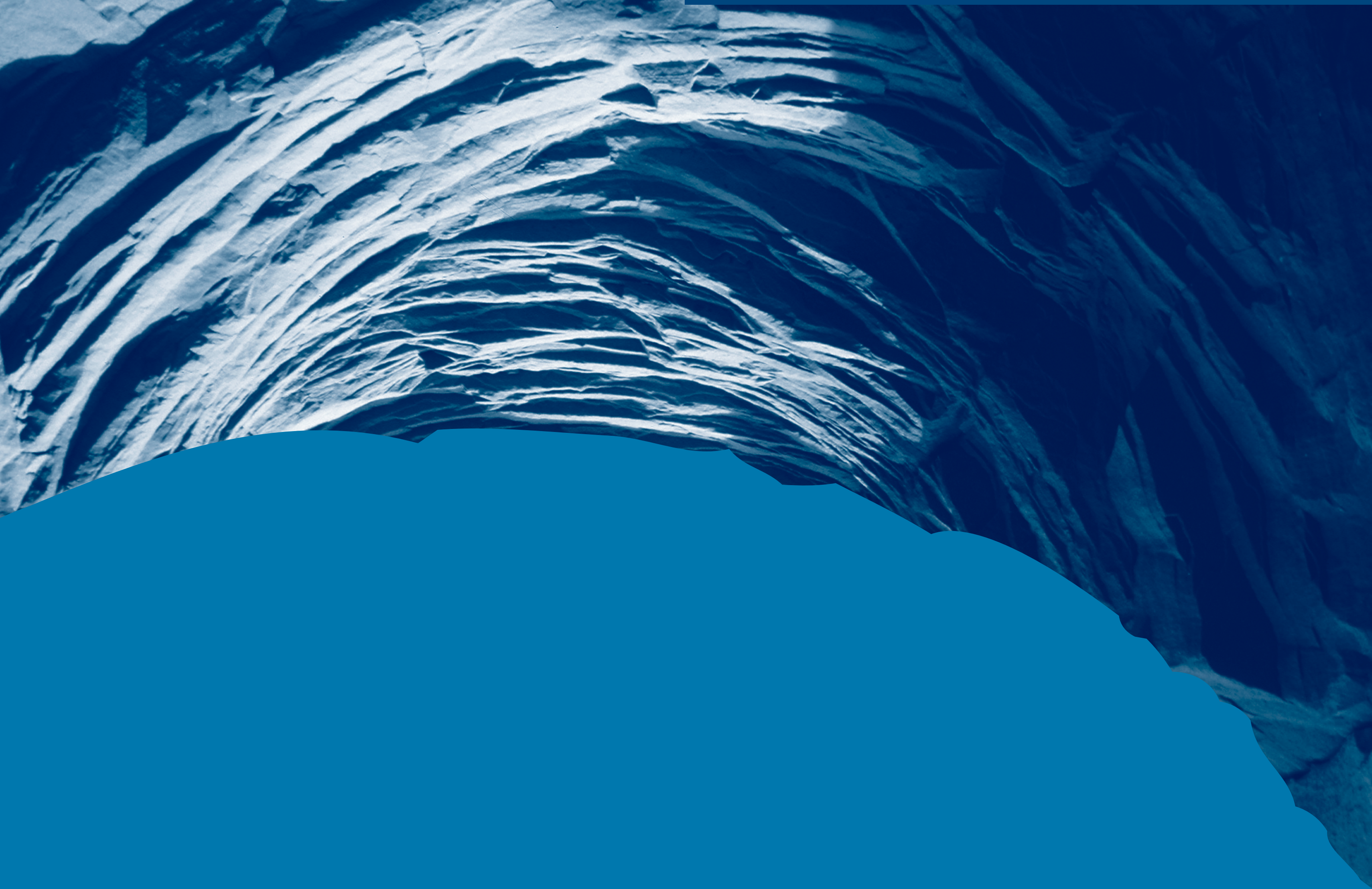

Report of the Investigation into the Presence of Lead & other Heavy Metals in the Tynagh Mines Area, Co. Galway

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Office of Environmental Enforcement

Report of the investigation into the presence of lead and other heavy metals in the Tynagh Mines Area, County Galway

Office of Environmental Enforcement, Environmental Protection Agency
PO Box 3000, Johnstown Castle Estate, County Wexford, Ireland.
Telephone : +353-53-60600 Fax : +353-53-60699

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Author: Jane Brogan

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1 Introduction

The Tynagh mines site is located 1.5 km north of the village of Tynagh, Co. Galway. The former mine site covers an area of approximately 115 hectares which is broken up into different sections with the tailings management facility (TMF) covering an area of approximately 48.5 ha. A mining lease was issued on 30th July 1963 effective for 21 years from 1st December 1962. Production commenced in 1965 from the open pit and continued from this source until 1972. The production of ore from underground sources commenced from the bottom of the open pit in the early 1970's. The mine ceased operation in 1982 and the mining lease expired in November 1983.

The host geology of the mine site is waulsortian reef limestone. The mine is located along a fault line and as a result the bedrock geology varies over short distances. The principal ore minerals present on the site were galena (PbS- lead sulphide), sphalerite ((Zn, Fe) S – zinc iron sulphide), chalcopyrite ($CuFeS_2$ – copper iron sulphide), pyrite (FeS), arsenopyrite (FeAsS – iron arsenide sulphide), tetrahedrite ($Cu_{14}Sb_4S_{13}$) and bornite (Cu_5FeS_4 – Copper Iron Sulphide). The main gangue or host minerals were barite and calcite. Minor quantities of silver occurred in association with galena and copper sulphides and some mercury was also associated with copper sulphosalts. Sphalerite contained minor association with cadmium in a Cd:Zn ratio of approximately 1:200 (Clifford *et al.,* 1986). The major minerals, which were extracted, were lead, zinc, copper, silver and barium sulphide.

1.1 Establishment of the Tynagh Mines Liaison Group

In response to local health and environmental concerns and recent site development works, Galway County Council established the Tynagh Mines Liaison Group in October 2002 to deal with environmental concerns in relation to the entire 115 ha site. The purpose of the group is to facilitate the exchange of information and the promotion of best practice in the Tynagh area, which has high levels of naturally occurring metals and a previous mining history and to apply this information and best practice to protect human health, animal health and the environment. Galway County Council chair the group and is responsible for enforcing environmental legislation within its functional area.

The Liaison Group for Tynagh Mines comprises of representatives from:

- Local Residents Group
- Galway County Council
- Environmental Protection Agency
- Western Health Board – Public Health Section
- District Veterinary Office, Department of Agriculture and Food
- Teagasc
- Office of Public Works Divisional Office, Limerick
- Department of Communications Marine and Natural Resources
- Shannon Regional Fisheries Board
- IFA

The EPA's role is to participate in the Liaison Group and to provide technical assistance to the local authority. Guidance and best practice in relation to the protection of human health, animal health and the environment was disseminated to local community representatives at the Tynagh Mines Liaison Group meetings. The available guidance was produced in relation to the Silvermines area of Co. Tipperary where lead and zinc were mined in the past. This guidance and best practice can be applied to other historic mining sites such as Tynagh to ensure that these areas are safe places in which to grow-up, live and work, provided certain precautions are taken. The liaison group has met on five occasions since its establishment. In September 2003, Galway County Council submitted a report to the Department of Environment, Heritage and Local Government outlining the concerns of the liaison group. The Council requested that funding be made available to undertake a detailed risk assessment of the site and to prepare a management and rehabilitation plan for the site.

2 Investigation of mine site and surrounding area

In response to local concerns regarding the potential impact of the site on human and animal health and the environment, and in light of the need to obtain additional baseline environmental information on the site, the EPA and Galway County Council gave a commitment to undertake an investigation of the site and surrounding area. It should be noted that surface waters in and adjacent to the site have been monitored regularly since the 1980's during and after mine closure.

The EPA organised the site investigation and prepared this investigation report. Galway County Council and the EPA funded the laboratory analysis. This report does not deal with ultimate remediation and rehabilitation of the site.

The purpose of the investigation was to delineate the extent of the area where elevated heavy metal concentrations exist and to make recommendations, where relevant, in relation to the analytical results obtained.

The sample site locations were chosen as follows:

1. Control sites – these sites were chosen to represent locations believed to be unimpacted by mining activity, either because the sites are located upstream of the mine site or are located on a separate river catchment. It is possible that these control sites will be influenced by the natural geological occurrence of the ore body;
2. Mine sample sites – located within the mine site and at the boundary; and
3. Sites downstream of the mine site.

Following discussions with local representatives the EPA arranged the investigation, which was carried out from the 24th to 27th June 2003. During the investigation the following samples were taken in accordance with the attached protocol (Appendix A) from the site and surrounding area:

- 20 surface water samples taken from various locations outside and within the site boundary both upstream and downstream of the mine site;
- 18 stream sediment samples taken in tandem with surface water samples;

- 12 mine waste/tailings samples taken from within the Tynagh mine site (samples were taken from uncovered and covered tailings, waste dump areas and residual sludge from alleged recent water pumping and disposal activities on site).

The samples were collected from the mine site and surrounding area. Sample locations are illustrated on Maps 1, 2 and 3 in Appendix B.

The surface water samples were analysed for a range of parameters including pH, alkalinity, electrical conductivity, BOD, COD, major ions, total cyanide and total and dissolved metals. The stream sediments were analysed for total metals, which include arsenic, barium, cadmium, chromium, copper, lead, mercury, nickel, selenium and zinc. The mine wastes and tailings were analysed for total metals, cyanide and a leaching test was also conducted on the mine waste to determine the potential for leaching of heavy metals from these wastes.

In relation to soil sampling and analysis, Teagasc undertook a soil sampling programme of the area on the 12th June 2003. A total of 22 soil samples were taken on a N/S E/W grid at 300 metre intervals. The centre of the grid was located at the centre of the mine. Seven soil samples were taken from within the mine site boundary and fifteen were taken from adjacent farmland.

In addition to the above, the EPA evaluated the site in relation to the establishment of a dust deposition monitoring programme. The primary objective of a dust deposition monitoring programme would be to quantify and assess the concentration of heavy metals in deposited dust. This would be done in accordance with internationally accepted methods and standards (i.e. German VDI method 2119 part 2:1972 Bergerhoff gauges and reference German TA Luft Limits for metals in deposited dust).

3 Summary of results

3.1 Surface water

A total of 20 surface water samples were taken during the investigation. Map 1 shows the surface water and stream sediment sample locations. The sample locations chosen were control sites, sites within the mine site and sites downstream of the site to try to establish background concentrations of heavy metals in surface waters and to attempt to delineate the extent of the impact of mining activities on the environment whilst recognising the occurrence of the high natural geological presence of heavy metals in the Tynagh deposit. At each sample location a surface water and stream sediment sample was taken, apart from location 03SW02 (pipe discharge) and 03SW21 (discharge from rock waste dump).

At the time of sampling, surface water temperature and dissolved oxygen were also recorded. Samples were sent for laboratory analysis for the following parameters:

- Major ions;
- pH, electrical conductivity, BOD, COD;
- Total metals and cyanide;
- Dissolved metals.

Five surface water samples were taken from control sites [03SW01; 03SW07; 03SW15; 03SW16; 03SW17]. Seven surface water samples were taken from within the mine site and at the boundary [03SW02; 03SW03; 03SW04; 03SW05; 03SW18; 03SW20; 03SW21]. Eight surface water samples were taken downstream of the mine site [03SW06; 03SW08; 03SW09; 03SW11; 03SW12; 03SW13; 03SW14; 03SW19].

The results obtained were compared to the EC (Quality of surface water intended for the abstraction of drinking water for humans) Regulations (SI No 294 of 1989) and data from other sources i.e. US EPA, Canadian Council of Resource and Environment Ministers (CCREM), the Canadian Council of Ministers for the Environment (CCME) and National Academy of Sciences, USA which cite limit concentrations of some metals and ions in drinking water for livestock. Table 3.1 provides a summary of surface water quality standards for abstraction of drinking water for human consumption and limit concentrations of heavy metal in drinking water for livestock.

Table 3.1 Water quality standards and limit concentrations for humans and livestock

Heavy metal	SI No. 294 of 1989 – European Communities (Quality of surface water intended for the abstraction of drinking water) Regulations mg/l	[1]Some cited Limit concentration in drinking water for livestock mg/l
Arsenic	0.05 – 0.1	0.5
Cadmium	0.005	0.08
Copper	0.05 – 1.0	0.5 (sheep) 1.0 (cattle)
Lead	0.05	0.1
Nickel	-	1.0
Zinc	3.0 – 5.0	25

[1] Extracted from American and Canadian sources – see text

The streams and the rivers in the area are not used for the abstraction of drinking water for human consumption. Animals in the area are allowed direct access to streams and rivers outside the mine site for drinking water. There was also evidence that animals have access to a section of the Barnacullia stream within the boundary of the mine site.

3.1.1 Surface water results from control and downstream site locations

In relation to the heavy metal concentration in the surface water, the concentrations are generally low and many are below the level of detection i.e. 0.05 mg/l. In general surface water quality in the area, particularly at the control sites and downstream of the site is satisfactory and does not represent a risk to livestock in the area.

The analysis also indicates that the higher concentrations are generally in the total - unfiltered sample i.e. total heavy metal concentration. This indicates that the majority of metals are found in the greater than 0.45µm fraction (coarse particulate fraction) where most suspended solids in natural systems are found. This fraction has generally lower toxicity properties than the dissolved fraction. Of the metals analysed zinc would appear to be the most soluble which is expected. An electrical conductivity measurement of less than 1 mS/cm indicates that the mineralisation load is generally low (SRK, 2002). Tables 1 to 3 in Appendix B provide the detailed analysis of the surface water samples taken during the investigation.

3.1.2 Surface water results from within mine site and at site boundary

The surface water inside the site and close to the boundary of the site reflects the geology of the area and the anthropogenic disturbance of minerals and host rock during mining activities. The elevated sulphate concentrations in the surface water are not unusual given the high sulphide (i.e. galena, sphalerite, chalcopyrite and pyrite) content of the ore body. The pH of the surface water at all sample locations was well above pH of 7 indicating alkaline conditions, which reflects the limestone host geology. The alkalinity of the surface waters is beneficial in that this reduces the availability of many of the heavy metals, which occur in the environment of the mine site and also buffers against the formation of acid rock drainage. The elevated BOD levels recorded in sample 03SW11 indicates the possibility of pollution arising from the addition of organic matter in the form of animal wastes or sewage effluent. The surface water samples that had an electrical conductivity measurement of greater than 1 mS/cm were all located within the mine site, which is expected since the mine wastes and waters arising from the wastes, contain elevated concentrations of heavy metals.

Results from surface water samples taken from within the Tynagh mine site indicate elevated concentrations of lead and cadmium in excess of surface water abstraction standards. Sample number 03SW21, which was taken from a discharge from the base of a waste rock dump at the south boundary of the site, had a total concentration of cadmium of 0.26 mg/l. The discharge from this waste rock dump appears to flow onto adjoining grassland where livestock are grazed. The concentration of cadmium in this discharge could potentially cause problems for livestock and access to this discharge should be prevented.

A review of surface water samples taken by Galway County Council in 2002 taken from within the mine site also indicates elevated concentrations of cadmium, lead and zinc in surface waters within the mine site and in the Barnacullia stream.

It is important to note that the concentration of heavy metals in surface waters adjacent to the site could potentially increase during periods of prolonged heavy rainfall thereby increasing the risk of exposing animals to high concentrations of these metals. In general, livestock should be prevented from ingesting and/or drinking turbid water in the area of the Barnacullia stream and on land adjacent to the rock waste dump on the south boundary of the site.

3.2 Stream sediment

A total of 18 stream sediment samples were taken during the investigation (see Map 1 for locations). Surface water sample were taken at each location prior to taking the stream sediment sample from the same location.

3.2.1 Stream sediment results from control sites

Five sediment samples were taken from control sites at locations 03/SS/01; 03/SS/07; 03/SS/15, 03/SS/16 and 03/SS17. In general the concentrations of heavy metals from these locations were very low and the sediment would not pose a risk to livestock gaining access to the stream for drinking water purposes. However, the results do indicate that the concentration of heavy metals increase closer to the site i.e. 03/SS/17. These control sample locations provide good information on the background concentrations of heavy metals in stream sediments. Table 3.2 provides a summary of the results for these locations.

Table 3.2 Stream sediment results from control sites

Sample ID	Other ID	Arsenic	Cadmium	Copper	Lead	Zinc
		mg/kg$_{DW}$				
03/SS/01	Derryfrench	10	2	30	145	446
03/SS/07	Up-stream of confluence with Barnacullia stream	<1	<1	11	46	137
03/SS/15	Grangemore upstream of SS/07	<1	<1	11	18	90
03/SS/16	Coolagh – NE of mine site	<1	<1	3	3	70
03/SS/17	Farm drain north of site close to forested area upstream of confluence with Barnacullia stream	<1	16	17	101	1496

3.2.2 Stream sediment results from within the mine and adjacent to boundary of mine site

Five stream sediment samples were taken from within the mine site and adjacent to the boundary of the site [03/SS/03; 03/SS/04; 03SS05; 03/SS/18; 03/SS/20]. Three stream sediment samples were taken from drains within the Tynagh mines site [03/SS/03; 03/SS/04; 03/SS/20] and as expected the heavy metal concentrations in the sediment were the highest recorded in the investigation. The concentrations of heavy metals in the on-site drains are very high. These substances are dangerous i.e. toxic and should not be disturbed and access by humans or livestock to these drains should be prevented. If disturbance occurs, the dangerous substances present in the waste may require the waste to be classified as hazardous waste. Table 3.3 provides a summary of stream sediment concentrations for samples taken from within and at the boundary of the mine site.

The Barnacullia stream runs from west to east at the north boundary of the mine site. There are direct discharges from the mine site to this stream and this is reflected in the high concentrations of heavy metals in the stream sediments adjacent to the mine site. One sediment sample was taken from the stream at location 03/SS/18 within the mine site boundary and a further sample was taken from the Barnacullia stream at location 03/SS/06 upstream of the confluence with Castletown River. The concentration of lead in the stream sediments at location 03/SS/18 could potentially cause toxicity problems for livestock where access is allowed for drinking purposes and where animals can disturb stream sediments. The Expert Group Report for lead in Silvermines (EPA, 2002) recommends that animals should not be allowed direct access to watercourses where the lead concentration in the sediments is greater than 1000 mg/kg_{DW}.

Most animals have a high tolerance for zinc and therefore the zinc in the stream sediments is unlikely to pose a risk to livestock. Problems may occur for livestock where they have access to streams where the concentration of zinc in the sediment is greater than 5000 mg/kg_{DW} and where the sediment becomes disturbed by the activity of the animal or during periods of heavy rainfall. Excessive zinc in the diet can depress food consumption and performance and may induce copper deficiency. The concentration of zinc in sample 03/SS/18 could potentially cause problems in livestock particularly younger animals. Livestock should be prevented from gaining access to the Barnacullia stream for drinking water between sample location 03/SS/18 to 03/SS/06 (see Map 1).

One stream sediment sample was taken from the south-east corner of the mine site at location 03/SS/05, which merges with the Lisduff River. The concentration of heavy metals in the sediment at this location is considerably lower than from other samples taken from within the mine site. This is possibly due to the fact that the stream was deep and difficult to sample.

Table 3.3 Stream sediment results from within mine site

Sample ID	Other ID	Arsenic	Cadmium	Copper	Lead	Zinc
		mg/kg_{DW}				
03/SS/03	West area mine site, drain at base of tailings dam	816	146	1285	18060	>32000
03/SS/04	Mine discharge from underground pipe to drain at base of tailings	4435	142	3606	>32000	16320
03/SS/05	Stream discharging to Lisduff river from SE site from open pit	139	46	201	427	4901
03/SS/18	Barnacullia stream adjacent to western tailings	332	41	255	2869	5162
03/SS/20	On-site drain receiving discharge from low grade lead deposit	1167	207	1377	7399	>32000

3.2.3 Stream sediment samples taken downstream of the mine site

Eight stream sediment samples were taken downstream of the mine site to establish the concentration of heavy metals in the stream sediment and to attempt to delineate the extent of the influence of the Tynagh ore and past mining activities on stream sediment heavy metal concentrations [03/SS/06; 03/SS/08; 03/SS/09; 03/SS/11; 03/SS/12; 03/SS/13; 03/SS/14; 03/SS/19]. Table 3.4 provides a summary of stream sediment concentrations from downstream of the mine site.

A stream sediment sample was taken at location 03/SS/06 on the Barnacullia stream downstream of sample 03/SS/18 before the confluence with the Castletown River. This sample has the highest concentration of heavy metals from all the samples taken from downstream locations. This is not unexpected as the Barnacullia stream receives direct discharges from the tailing ponds located within the mine site. The concentration of lead in the stream sediments along the stretch of stream from sample location 03/SS/18 to the vicinity of 03/SS/06 could potentially cause toxicity problems for livestock where access is allowed for drinking purposes and where animals can disturb stream sediments and ingest lead at concentrations greater than 1000 mg/kg_{DW}. Animals should not be allowed access to this section of the Barnacullia stream.

To the south of the mine site, the stream that emerges from the south east corner of the site was sampled at two locations i.e. at the site boundary 03/SS/05 and further downstream at location 03/SS/12. The concentrations of heavy metals in the stream sediment are elevated, particularly for zinc. However the concentration decreases with increasing distance from the site. Stream sediment sample 03/SS/19 was taken from a farm drain located downstream of the mine site to establish the concentration of heavy metals in the stream sediment. The lead concentration is low however the zinc concentration is elevated but below 5000 mg/kg_{DW}. While the concentration of lead and in particular zinc is elevated, it is unlikely that these sediments pose a risk to livestock.

The remaining stream sediment samples were taken from locations downstream of the main influence of the Tynagh mine site i.e. sample locations 03/SS/08; 03/SS09; 03/SS/11; 03/SS/13; 03/SS/14. The reduction in the concentration of heavy metals in stream sediment sample 03/SS/08 in comparison to the stream sediment taken upstream of the confluence of the Barnacullia stream (03/SS/06) reflects the dilution effect of the stream, which runs north of the Barnacullia stream.

The concentration of heavy metals from samples 03/SS/09; 03/SS/11; 03/SS/13; and 03/SS/14 are significantly less than the samples taken from within the site and from the samples taken downstream but adjacent to the mine site. It would appear that a dilution effect is occurring further downstream from the site although zinc remains elevated. Sediments from these streams do not pose a risk to livestock who may have access to the streams and rivers for drinking water.

Table 3.4 Stream sediment results from downstream of the mine site

Sample ID	Other ID	Arsenic	Cadmium	Copper	Lead	Zinc
		mg/kg$_{DW}$				
03/SS/06	Barnacullia stream downstream of 03/SS/18	61	43	182	1143	3413
03/SS/08	Castletown river downstream of 03/SS/06	14	19	42	277	1376
03/SS/09	Upstream of bridge at Coolbaun mill on Mill stream downstream of 03/SS/08	<1	11	18	110	657
03/SS/11	Downstream of confluence of Mill stream (03/SS/09) and Lisduff (03/SS/12)	10	8	30	241	631
03/SS/12	Lisduff stream downstream of 03/SS/05	21	19	171	99	2023
03/SS/13	Hearnesbrook bridge, Killcrow River	9	2	14	123	639
03/SS/14	Ballycahill Mill, Killcrow River	<1	3	11	62	358
03/SS/19	Open farm drain adjacent to Barnacullia	36	11	64	331	3387

3.3 Mine wastes and tailings

A total of 12 mine waste samples were taken from within the Tynagh mines site. Map 2 indicates the location of the mine wastes and tailings sample locations. Table 3.5 presents a summary of the results of analysis on mine waste, tailings and sludge, which were sampled from within the mine site. The concentrations are expressed as mg/kg dry weight (mg/kg$_{DW}$). Various types of mine waste were sampled across the site and at different depths. The mine wastes were analysed for total heavy metal concentration (reagent – Aqua Regia). The mine wastes were also subjected to a leaching test (National Rivers Authority (UK) leaching test) to determine the leachability of the metals within the wastes (NRA, 1994) i.e. when solid material such as mine wastes come into contact with a liquid, some constituents will dissolve to a greater or lesser extent. The degree of dissolution of individual constituents such as metals is of interest as it provides an understanding of metal behaviour in various environments. Factors which enhance metal leaching include rapidly weathering metal containing minerals, drainage conditions that increase solubility and high flow rates through contaminated material e.g. prolonged heavy rainfall.

Beached tailings samples taken from the west tailings dam (i.e. 03/MW-T/01 to 03/MW-T/05), which are mostly unvegetated, have very high concentrations of lead and zinc. The tailings also contain elevated concentrations of other metals including arsenic and copper. Two tailings samples were taken from the vegetated east tailings dam at 15 cm and 60 cm depth. The concentration of heavy metals in the vegetated tailings is much lower than in the west tailings dam.

The mine waste dump located at the western boundary of the Sperrin Galvanisers Limited development site where samples were taken at 15 cm and 1 metre depth also has very high concentrations of lead and zinc (i.e. 03/MW-T/06 and 03/MW-T/07). Local concerns were raised in relation to the potential for disturbance to this area during the construction of the galvanising plant by Sperrin Galvanisers Limited as the area has been identified as being close to where the concentrator plant was operating during the mining operation. The area is only partially vegetated. A sample was also taken at 1 metre depth from construction waste, which has been deposited at the west end of the construction site i.e. 03/MW-T/08. The construction waste deposited on the site has a lead concentration of 2457 mg/kg_{DW} and a zinc concentration of 1849 mg/kg_{DW}. While the concentration of heavy metals within this recently excavated construction waste is relatively low in comparison to the other mine wastes and tailings, which have been sampled, the handling and disposal of this waste should be carefully and actively managed to reduce risk to human and animal health and the environment.

Table 3.5 Summary of results for minewaste and tailings

Sample ID	Other ID	Arsenic	Cadmium	Copper	Lead	Zinc	Total Cyanide
		mg/kg_{DW}					
03/MW-T/01	West tailings-north	1791	57	915	20560	6344	< 2.5
03/MW-T/02	West tailings-east -15 cm	1754	131	2535	>32000	21850	< 2.5
03/MW-T/03	West tailings-east -60 cm	1630	195	1780	26520	29610	< 2.5
03/MW-T/04	West tailings-south -15cm	4380	59	1221	20300	2534	5.7
03/MW-T/05	West tailings-south -80cm	4008	55	1163	19080	3075	3.6
03/MW-T/06	Mine waste – west of Sperrin site – 15cm	1697	797	672	23640	>32000	< 2.5
03/MW-T/07	Mine waste – west of Sperrin site – 1 metre	3860	114	1299	26790	20630	12.3
03/MW-T/08	Construction waste – Sperrin site – 1 metre	113	11	162	2457	1849	< 2.5
03/MW-T/09	East tailings – 15cm	153	11	178	828	1472	< 2.5
03/MW-T/10	East tailings - 60 cm	256	22	212	2098	3936	< 2.5
03/MW-T/11	Low grade lead deposit – 15cm	644	75	952	10760	4121	< 2.5
03/MW-T/12	Waste sludge – 10cm	7504	657	19440	>32000	>32000	66.3

Sample 03/MW-T/12 was taken from a trench adjacent to the development site where it is alleged that the sludge type waste was deposited during dewatering activities during the preparation and construction of the site. This waste material has very high concentrations of lead, zinc, copper, arsenic and cadmium. Cyanide was also present at a concentration of 66.3 mg/kg_{DW}. Due to the high concentration of heavy metals in this material, and the fact that it is alleged that this has recently been deposited, Galway County Council should take the necessary steps requiring the holder of the waste to arrange for an alternative, safe waste management disposal option, which complies with all relevant waste legislation.

Table 3.6 presents a summary of the results of the leaching tests, which were carried out on the mine waste samples in accordance with the NRA leaching test methodology (NRA, 1994). The purpose of the leaching test is to ascertain the potential availability and mobility of heavy metals in the mine wastes and tailings.

Table 3.6 Summary of leaching test results carried out on minewastes and tailings

Sample ID	Other ID	Arsenic	Cadmium	Copper	Lead	Zinc
		Dissolved metals in NRA leachate mg/l				
03/MW-T/01	West tailings-north	<0.05	<0.05	<0.05	<0.05	0.34
03/MW-T/02	West tailings-east -15 cm	<0.05	0.53	0.07	0.18	28.25
03/MW-T/03	West tailings-east -60 cm	<0.05	0.20	<0.05	<0.05	5.75
03/MW-T/04	West tailings-south -15cm	<0.05	<0.05	<0.05	0.05	0.08
03/MW-T/05	West tailings-south -80cm	<0.05	<0.05	<0.05	<0.05	0.23
03/MW-T/06	Mine waste – west of Sperrin site – 15cm	<0.05	<0.05	<0.05	0.07	0.15
03/MW-T/07	Mine waste – west of Sperrin site – 1 metre	<0.05	<0.05	<0.05	<0.05	0.25
03/MW-T/08	Construction waste – Sperrin site – 1 metre	<0.05	<0.05	<0.05	<0.05	<0.05
03/MW-T/09	East tailings – 15cm	<0.05	<0.05	0.06	0.07	0.07
03/MW-T/10	East tailings - 60 cm	<0.05	<0.05	<0.05	0.05	0.08
03/MW-T/11	Low grade lead deposit – 15cm	<0.05	<0.05	0.06	0.21	0.51
03/MW-T/12	Waste sludge – 10cm	<0.05	<0.05	<0.05	0.05	0.83

The results from the leaching test indicate that zinc is relatively mobile and will leach out from the mine wastes and tailings over time. Leachate results from tailings samples taken from the west tailings east i.e. 03/MW-T/02 and 03/MW-T/03 had elevated levels of cadmium and zinc. The results for the waste sludge i.e. 03/MW-T/12 indicates low potential leachability for heavy metals apart from zinc. The potential for leaching and the subsequent release of heavy metals into the environment and associated risks must be considered prior to the undertaking of any activity on site which will lead to the disturbance of these mine wastes. However, these results indicate that, overall, the potential for heavy metals to leach from these waste materials is low.

3.4 Soil samples

Teagasc took twenty-two soil samples on a north-south, east-west axis centred on the mine site at 300 metre intervals across the mine site and surrounding farmland. Map 3 indicates the location of the soil samples. The samples were taken to a depth of 10 cm and sent for laboratory analyses for heavy metals, cyanide and NRA leaching test. The samples were sieved to 2mm prior to analyses. A summary of the results for the concentration of total metals in soils is given in Table 3.7. The grid-sampling programme resulted in eight samples being taken within the mine site with the remaining fourteen samples taken from adjoining farmland up to one kilometre away from the mine site boundary.

The soil sample results clearly indicate the limited extent of the Tynagh mines ore-body. The eight soil samples taken from within the mine site boundary [T4, T5, T6, T7, T8, T16, T17, and T18] show high concentration of heavy metals in particular lead, zinc, cadmium and arsenic. The majority of these samples are tailings and mine wastes located within the mine site. Similar concentrations of heavy metals were found in the 13 mine waste and tailing samples.

The fourteen samples taken from outside the mine site have relatively low concentrations of heavy metals in the soil however, the concentrations are greater than normal background levels for soils in Ireland (McGrath, 1998). This is not unexpected due to high natural geological occurrence of ore minerals containing lead, zinc, cadmium, copper and arsenic located in the area. The concentrations of lead in the soil samples taken from these areas are all below 1000mg/kg_{DW}, which is the soil guideline value, recommended by the Expert Group for lead in Silvermines (EPA, 2002) above which active management is recommended.

Table 3.7 Summary of results for soils samples

Sample ID		Arsenic	Cadmium	Copper	Lead	Zinc	Total Cyanide
		mg/kg_{DW}					
Tynagh 1	T1	15	2	38	121	349	<2.5
Tynagh 2	T2	12	2	59	197	340	<2.5
Tynagh 3	T3	16	4	62	494	772	<2.5
Tynagh 9	T9	67	8	77	332	756	<2.5
Tynagh 10	T10	49	5	52	362	529	<2.5
Tynagh 11	T11	19	4	24	140	419	<2.5
Tynagh 12	T12	<1	7	17	117	594	<2.5
Tynagh 13	T13	<1	2	22	40	128	<2.5
Tynagh 14	T14	4	2	21	38	125	<2.5
Tynagh 15	T15	<1	2	38	56	85	<2.5
Tynagh 19	T19	4	<1	30	86	88	<2.5
Tynagh 20	T20	39	1	51	337	177	<2.5
Tynagh 21	T21	22	1	27	201	264	<2.5
Tynagh 22	T22	14	2	30	248	451	<2.5
Tynagh 4	T4	32	3	56	509	588	<2.5
Tynagh 5	T5	1218	116	576	17980	20850	<2.5
Tynagh 6	T6	280	289	425	10250	14890	<2.5
Tynagh 7	T7	187	54	566	19790	8206	<2.5
Tynagh 8	T8	142	17	275	1602	2820	<2.5
Tynagh 16	T16	19	3	48	313	350	<2.5
Tynagh 17	T17	356	27	1042	6900	3581	<2.5
Tynagh 18	T18	1366	80	2191	26490	11870	<2.5

A comparison of the mean heavy metal concentration for soil samples from agricultural land surrounding the Tynagh mines site, agricultural soils in the Silvermines area of County Tipperary (DAFRD, 2000) and agricultural soils sampled to date as part of a National Soil Geochemical Survey of Ireland conducted by Teagasc (McGrath, 1998) is presented in Table 3.8.

Table 3.8 Heavy metals concentrations in soils in Ireland

Survey	No of samples	Arsenic	Cadmium	Copper	Lead	Zinc
		mg/kg_{DW}				
National Soil Geochemical Survey	231	-	0.53	18	30	73.1
Agricultural land - Tynagh	14	19	3	39	198	363
Agricultural land - Silvermines	213	21.9	1.11	24.5	780	365
Tynagh mine site – 10cm	8	450	74	647	10479	7894
Gortmore Tailings, Silvermines – 10cm	5	465	20	396	11694	7046

Agricultural land in the Tynagh mines area has heavy metal concentrations greater than normal background concentrations in Ireland (McGrath, 1998). The mean lead concentration of 198 mg/kg_{DW} does not, however, pose a significant risk to grazing animals. The soils from the Tynagh area have lower concentrations of lead and higher concentration of cadmium and copper than soils from similar agricultural areas, which were sampled in the Silvermines area of Co. Tipperary where sporadic incidents of lead poisoning have occurred. The incidents of lead poisoning that have occurred in the Silvermines area of County Tipperary have always been associated with animals coming in contact with either exposed soils or sediments with very high concentrations of lead i.e. soil with average mean lead soil of 3000 to 5000 mg/kg_{DW} to over 14,000 mg/kg_{DW} in some samples. Stream sediment mean lead concentrations also ranged from 3000 mg/kg_{DW} to 5,000 mg/kg_{DW} in these areas.

The results from the leaching tests carried out on the soil samples indicates that zinc, barium and copper are relatively mobile. The higher values were recorded from the samples taken from within the Tynagh mines site. This is not unexpected as the concentrations of total heavy metals in the samples taken from within the site are much higher than from the samples taken from agricultural lands adjacent to the site. Table 8 in Appendix 2 provides a summary of the NRA leaching test on the soil samples.

4 Conclusions

The investigation carried out by the EPA and Galway County Council has provided baseline information on the status of the Tynagh mines site and surrounding agricultural land.

1) In general the Tynagh mines site is heavily contaminated with heavy metals and in particular lead and zinc. It would appear that the most heavily contaminated mine waste is located in the west tailings pond, the mine waste deposit west of the Sperrin site and from the waste sludge which was allegedly deposited on the mine site during construction activities at the Sperrin site. There are large areas of the western tailings bare of vegetation, which increases the risk of dust blow from the site onto adjoining property. The lead concentration in these wastes ranged from 19080 mg/kg_{DW} to greater than 32000 mg/kg_{DW}. The low-grade lead deposit located adjacent to the open-cast pit had a relatively high concentration of lead. The surface water discharging from this waste dump also had elevated concentrations of lead and zinc.

2) The results from the leaching tests carried out on the mine wastes indicate that zinc, cadmium and to a lesser extent lead can potentially leach from some of these wastes. This has implications in relation to future disturbance and movement of wastes around the site or for the potential movement of mine-wastes off site. However, the potential for heavy metals to leach from these wastes is low, based on the tests conducted.

3) Wastes arising from mining activities are heterogeneous in nature, which makes an assessment of their properties and a classification of waste types extremely difficult. The type of wastes and their properties (e.g. mineralogical or leachability) within any specific waste deposit vary both vertically and horizontally within a very small volume of material making it very difficult to predict what reactions will occur where this waste is disturbed.

4) Proposals for future development of the site should take account of the history of mining activity on the site, the presence of mine wastes and dangerous substances and the potential negative impacts that disturbance to these wastes could have on human and animal health and the environment.

5) In general surface water quality in the area, as determined during this investigation, particularly at the control sites and downstream of the site is satisfactory and is unlikely to represent a risk to livestock in the area.

6) The discharge from the rock dump to the south west of the site that runs onto adjacent agricultural land (i.e. 03/SW/21) had high electrical conductivity indicating high mineralisation load. Given the high cadmium concentration in this run-off and that animals grazing may have access to this discharge, there is a possibility that offal from these animals may exceed the limit set for cadmium in foodstuffs.

7) The concentration of lead and other relevant metals in the stream sediment samples taken from the control sites and from downstream of the mine site, other than the Barnacullia stream, are unlikely to pose a risk to livestock who gain access to these watercourses for drinking water purposes.

8) The concentration of lead and zinc in stream sediments taken from the Barnacullia stream are elevated. The concentration of lead is greater than 1000 mg/kg_{DW}, which is considered the upper acceptable limit to which livestock can be exposed. They should not be allowed access to the stream for drinking purposes since they would disturb the stream sediments.

9) The soil sampling conducted on agricultural soils indicate that while the concentration of heavy metals are above normal national background levels, the lead concentrations are relatively low particularly in comparison to other mining areas such as the Silvermines area. It is therefore unlikely that toxicity problems from lead or other metals will occur as the lead concentrations in the soils sampled are well below 1000 mg/kg_{DW}.

5 Recommendations

1) The EPA recommends that unplanned and unauthorised disturbance of mine waste should not take place on the site due to the risk of releasing pollutants into the environment.

2) Planning conditions must be strictly enforced by Galway County Council and provide for the potential for proposed developments to cause serious pollution, particularly through the mobilisation of heavy metals held within the site. Relevant environmental protection legislation must also be strictly enforced by Galway County Council to ensure that any existing or future development taking place on or around the site does not result in environmental pollution.

3) Unauthorised access to the site by the public, and in particular children should be prevented. This site contains dangerous substances, which are potentially toxic to humans and in particular children. In addition, as this is a derelict mine site there are numerous health and safety issues on this site e.g. mine shafts, deep lagoons and open-cast pits etc. Warning notices should be erected to inform the public of the potential risks of entering this site.

4) Animal access should be prevented to the site as the concentration of heavy metals in mine wastes, tailings and stream sediments on site could potentially cause toxicity problems. Cattle are inquisitive by nature and frequently consume exposed soil and other unusual materials. Landowners should ensure that fences surrounding the perimeter of the mine site are stock proof and regularly maintained.

5) Animals, including sheep and horses, should not be allowed access to the Barnacullia stream from sample location 03/SS/18 to sample location 03/SS/06 as the concentration of lead in sediments from these locations is greater than 1000 mg/kg_{DW}. This section of the stream should be fenced off to prevent animal access for drinking purposes.

6) Animals should not be allowed to gain access to the discharge from the rock waste dump along the south boundary of the site (03/SW/21) and the area affected by this discharge should be fenced off from livestock. Additional investigations are required to delineate the area affected by the discharge.

7) It is important to note that the concentration of heavy metals in surface waters adjacent to the site could potentially increase during periods of prolonged heavy rainfall thereby increasing the risk of exposing animals to high concentrations of these metals. In general, livestock should be prevented from ingesting and/or drinking turbid water in the area of the Barnacullia stream and on land adjacent to the rock waste dump on the south boundary of the site.

8) Where dredging of the Barnacullia stream is required for drainage purposes, sediments which have a lead concentration of greater than 1000 mg/kg_{DW} should not be disposed to agricultural land, either along the stream bank or spread on adjacent fields. An alternative safe waste management disposal

option will have to be found for sediments where the concentration of lead is greater than 1000 mg/kg_{DW}.

9) The requirement for, and the benefit of carrying out a dust deposition monitoring programme on the site needs to be evaluated further. If it is deemed worthwhile, the cost incurred for establishing and maintaining the monitoring programme should be recouped from the owner(s) of the site.

10) Where local residents express concerns in relation to potential exposure to lead in their environment, the Western Health Board should consider the provision of voluntary screening of blood for lead in children and adults along the lines of the service provided to the Silvermines community by the Mid-Western Health Board. This is the most effective way of establishing whether or not there is any significant impact on human health in the area arising from potential exposure to lead.

11) Where herdowners express concern in relation to animal health, the relevant authorities should offer appropriate testing of animal health in the area.

12) A biological examination of the aquatic environment should be undertaken in the area to assess the impact of mining activities on the aquatic environment.

13) An assessment of groundwater quality in the area should be undertaken to assess the impact of mining activities on groundwater resources in the area.

14) The recommendations resulting from the Investigation into the Presence and Influence of Lead in the Silvermines area of County Tipperary and the Expert Group on lead in Silvermines, County Tipperary interim report should be adopted where relevant.

References

Bagley, C.V., Amacher, J.K., and Farrell-Poe, K. 1997. Analysis of water quality for livestock. Utah State University, Logan, UT. USA.

Canadian Council of resource and Environment Ministers. 1987. Canadian Water Quality Guidelines – Livestock Watering. CCREM, Winnipeg, Canada.

Clifford, J.A., Ryan, P., and Kucha, H. 1986. A review of the geological setting of the Tynagh orebody, Co. Galway. In: Andrews, C.J., Crowe, R.W.A., Pennell, W.M. and Pyne, J.F. *Geology and genesis of mineral deposits in Ireland*. Irish Association of Economic Geology, Dublin.

Department of Agriculture, Food and Rural Development. 2000. Report of the Investigation into the presence and influence of lead in the Silvermines area of County Tipperary. DAFRD, Dublin.

Environmental Protection Agency. 2002. *Expert Group on Lead in Silvermines County Tipperary – Interim Report*. EPA, Johnstown Castle Estate, Wexford.

McGrath, D. 1998. Use of microwave digestion for estimation of heavy metal content of soils in a geochemical survey. *Talanta 46 (1998) 439-448*. Elservier Science, Oxford, UK.

National Rivers Authority. 1994. Leaching tests for Assessment of Contaminated Land: Interim NRA Guidance – R&D Note 301. NRA, Bristol, UK.

SRK Consulting. 2002. *Management and Rehabilitation of the Silvermines Area*. Prepared for the Department of Marine and Natural Resources. SRK Consulting, Cardiff, Wales.

Appendix A
Sampling protocol

Surface water samples

Surface water samples will be taken in accordance with guidance in FOREGS and SRK report on Management and Rehabilitation of the Silvermines area. Water samples should be taken from the first, lowermost stream sediment sample point. Take GPS and record national grid reference number.

A 1 litre water sample will be taken from each sample location for the analysis listed below. A 1x 250 ml bottle preserved with sulphuric acid will be filled for ammoniacal – N and a 1x 250 ml bottle preserved with NaOH for total cyanide.

Field water sample ID numbers will be marked clearly on each water sample and will be prefixed with year/sample type/sample number e.g. Townland 03-SW-01. Water should be collected by placing the relevant container upside down and approximately 10 cm below the water surface, then turning it to fill. Rinse 1 litre containers twice downstream of sample location before taking sample.

A surface water sample from each sample location will be analysed for the following parameters:

In the field: temperature, dissolved oxygen

In the laboratory:
pH
alkalinity
Electrical conductivity
BOD
COD
Sodium
Potassium
Ammoniacal -nitrogen
Chloride
Fluoride
Total oxidised nitrogen – measured from nitrate, nitrite
Nitrate
Nitrite
Phosphate
Soluble sulphate
Total cyanide
Dissolved metals (filtered – 0.45µm) – (As, Cd, Cr, Pb, Hg, Se, Cu, Ni, Zn, B, Ca, Mg)
Total metals (unfiltered) –(As, Cd, Pb, Hg, Se, Cu, Ni, Zn, B)

In the laboratory
Procedure for dissolved metals (filtered) – sample filtered through 0.45µm, the samples are then acidified with hydrochloric acid and run on the ICP-OES.

Procedure for total metals – sample digested prior to filtering with 40% Aqua Regia, filtered through ashless filter paper and run on the ICP-OES.

Stream sediment samples
Stream sediment samples will be taken in accordance with FOREGS as far as possible. Material is taken from 5 to 10 points over a stream stretch of 250 to 500 metres. Stream sediment sampling should start from the surface water sample location and work up-stream. All samples should be located up-stream of roads and settlements.

Stream sediment samples will be taken wet and dry sieving will be undertaken in the laboratory. Ideally the wet samples should be passed through a 5-mm nylon sieve to remove stones and coarse grained material. Approximately 2-kg sample is required. Transfer the sediment sample to an appropriate polyethylene container and seal tightly. Stream sediment ID numbers will be clearly marked on each sediment sample and will be prefixed with location, year, sample type and sample number e.g. Townland 03-SS-01.

In the laboratory the sediment samples are dried, disaggregated and sieved through a < 0.150 mm nylon sieve (fine sand, silt and clay fraction). Approximately 0.3 g of each dried and sieved sample (accurately weighed) is digested (in EPA laboratory - nitric acid and hydrogen peroxide, Alcontrol – 40% Aqua Regia (nitric acid/hydrochloric acid). Total metal analysis is undertaken by ICP/OES or ICP/MS.

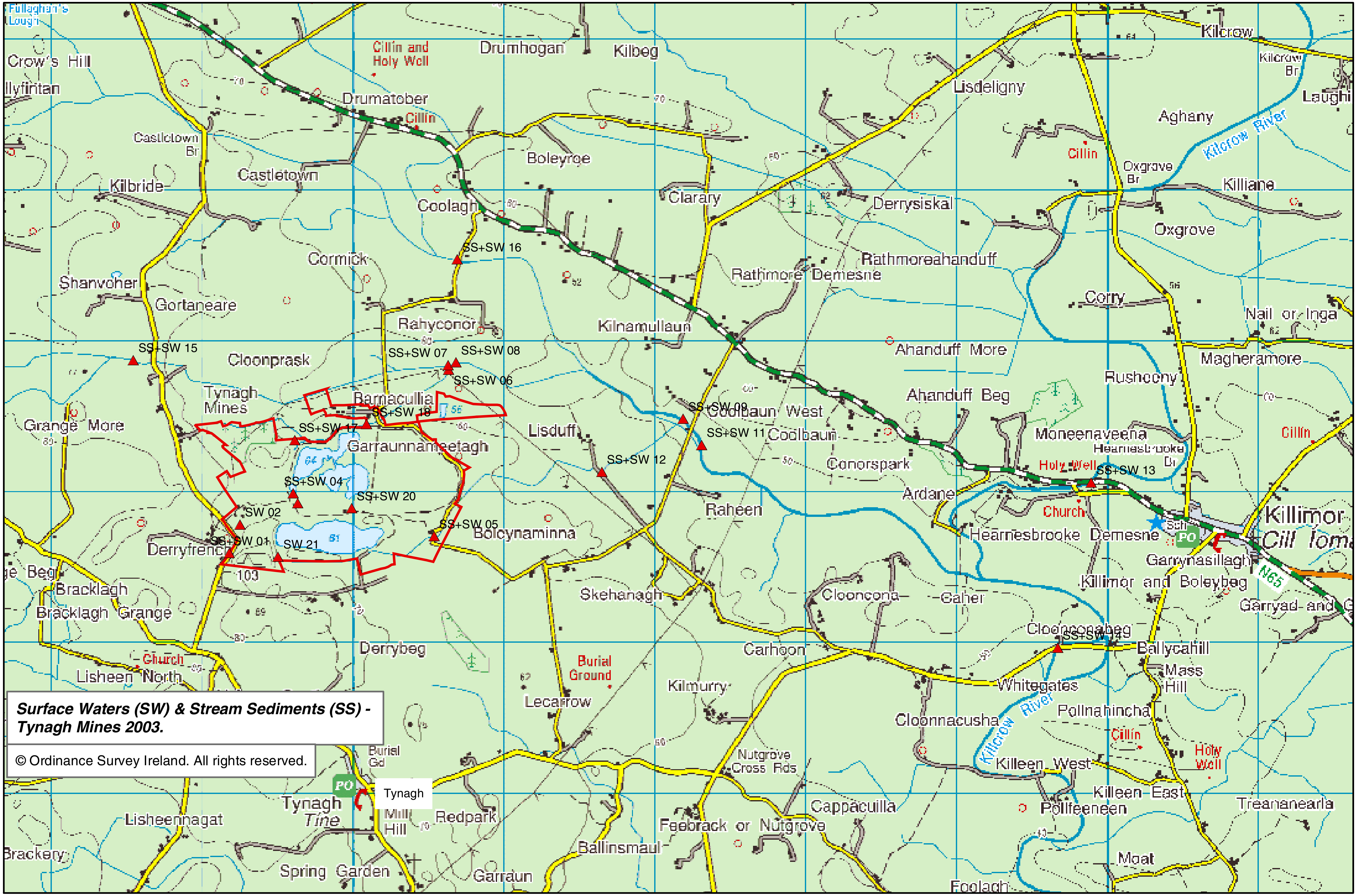
Mine wastes and tailings
Mine waste and tailings samples are not sieved. If practicable measure out an area of 10 m square in the area to be sampled. At the corners of the square collect approximately 250 g of material with trowel or auger to a depth of 10 cm. A description of the type of mine waste should be recorded on the field sheet. If practicable, some sub-surface sampling should be undertaken to a depth of 1 metre below surface. Sub-samples should be taken of 250g from the corner of the pit at the same depth. Mine waste ID numbers should be clearly marked on each mine waste sample and be prefixed with location, year, sample type and sample number e.g. Tynagh Mines 03-MW-01. National grid reference numbers will be recorded at each sample location. The mine waste/tailing samples (approx. 1- 2 kg) will be place in strong plastic bags and sealed.

In the laboratory, the mine waste/tailings samples will be dried disaggregated and digested with appropriate reagent e.g. Aqua Regia (nitric/hydrochloric acid), nitric acid and hydrogen peroxide. The mine waste/tailings is not sieved (as per recommendation from SRK). The sample is analysed for heavy metals and the results are calculated as mg/kg on a dry weight basis.

Soil samples
A standard Teagasc agricultural soil corer is used to collect the soil samples. 20 to 25 cores are taken to make up a composite soil sample. Samples are taken to 10 cm depth.

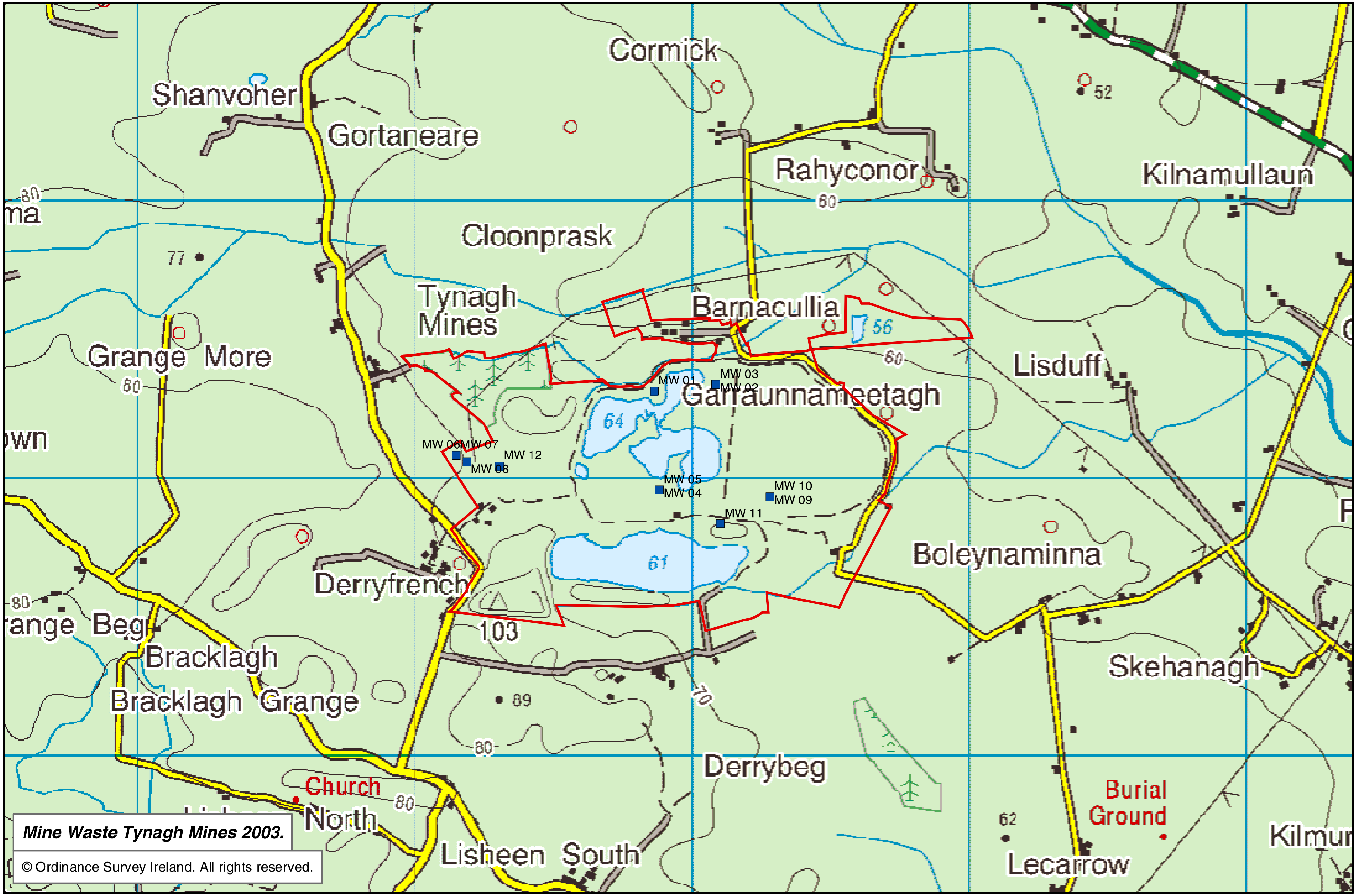
In the laboratory, samples are air dried to 40 ^{o} C and sieved through a 2mm sieve. The need to grind the sample is dependant upon the size of sub-sample to be taken for analysis. If sub-sample is 0.2 to 0.3 g, the sample should be ground prior to the sub-sample being taken. If sub-sample is 2 to 3 g in weight, no grinding of the sample is required. Aqua Regia reagent is used to extract heavy metals in soils.

Appendix B
Maps



Surface Waters (SW) & Stream Sediments (SS) - Tynagh Mines 2003.

Map 1


Cormick
Shanvoher
Gortaneare
Rahyconor
Kilnamullaun
Cloonprask
Tynagh Mines
Barnacullia
Grange More
Lisduff
Garraunnameetagh
MW 01
MW 02
MW 03
MW 04
MW 05
MW 06
MW 07
MW 08
MW 09
MW 10
MW 11
MW 12
64
61
56
Boleynaminna
Derryfrench
103
Grange Beg
Bracklagh
Bracklagh Grange
Derrybeg
Skehanagh
Burial Ground
Church
North
Lisheen South
Lecarrow
52
77
89
62
60
70
80
Mine Waste Tynagh Mines 2003.
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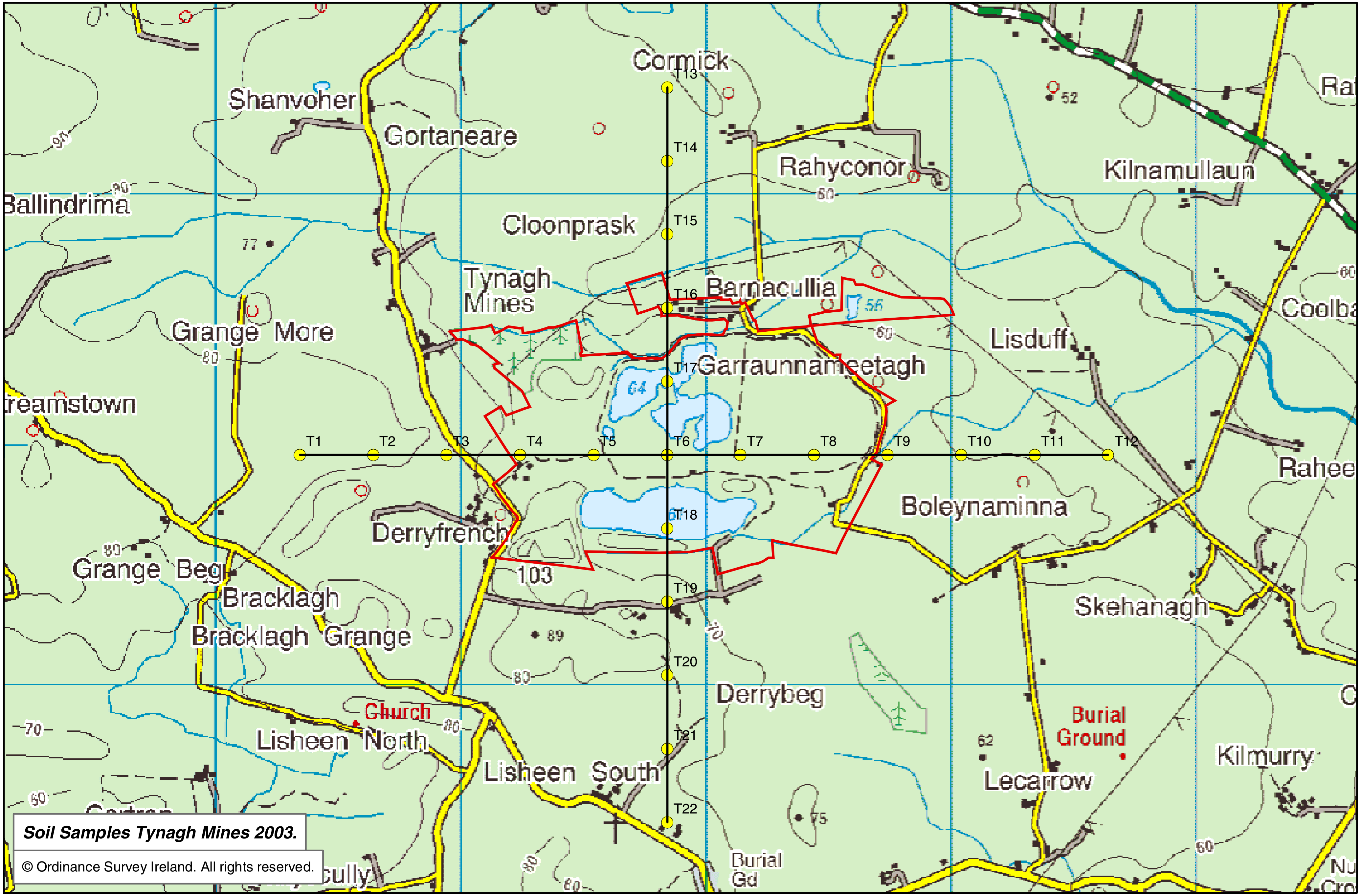
Map 2


Soil Samples Tynagh Mines 2003.
Cormick
Shanvoher
Gortaneare
Rahyconor
Kilnamullaun
Ballindrima
Cloonprask
Tynagh Mines
Barnacullia
Grange More
Lisduff
Coolba
Garraunnameetagh
Rahee
Boleynaminna
Derryfrench
Grange Beg
Bracklagh
Bracklagh Grange
Skehanagh
Derrybeg
Church
Lisheen North
Lisheen South
Burial Ground
Lecarrow
Kilmurry
Burial Gd
T1
T2
T3
T4
T5
T6
T7
T8
T9
T10
T11
T12
T13
T14
T15
T16
T17
T18
T19
T20
T21
T22
103

Map 3

Appendix C
Detailed tables of analytical results

Table 1: Summary of results for major ions in surface waters from upstream, within and downstream of Tynagh mines site

Sample Identity	Other ID	Conduct-ivity	pH	Total Alkalin-ity	Dissol-ved Calcium	Dissolved Magnesium	ortho Phosphate as PO4	Potassium	Sodium	Sulphate	Chloride	Fluoride	Total Oxidised Nitrogen	Ammoniacal Nitrogen as N	Nitrate as NO3	Nitrite as NO2	BOD Unfiltered	COD Settled
		mS/cm	pH Units	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
	Surface water abstraction (SI 294 of 1989)	1.0	5.5-9.0				0.67-0.92			200	250	1	-	0.15-3.12	50		5-7	40 (A3)
03 SW 01	up/stream mine site - Derryfrench	0.676	7.96	350	139.00	4.89	<0.03	2.2	9.8	16	17	0.2	1.6	1.0	6.6	0.12	<2	20
03 SW 02	Pipe discharge inside entrance on left side	0.688	8.19	360	146.00	5.42	<0.03	2.4	10.0	30	18	0.3	1.3	0.8	5.5	0.08	2	<15
03 SW 03	west area of mine site - pipes discharging to site drain	1.154	7.78	150	225.50	12.16	<0.03	3.2	31.5	464	26	1.3	<0.3	1.0	0.5	0.07	<2	<15
03 SW 04	mine-site discharge from underground pipe	0.746	8.15	290	150.10	9.24	<0.03	2.8	9.8	83	18	0.2	1.4	0.7	5.8	0.07	<2	<15
03 SW 05	stream discharging from SE site –Lisduff stream	0.846	7.57	240	162.90	7.53	<0.03	2.6	15.0	258	22	0.3	<0.3	1.2	1.2	<0.05	<2	30
03 SW 06	Barnacullia stream north boundary site - downstream of site SW18	0.980	8.15	260	191.20	10.50	<0.03	3.0	23.0	279	18	0.5	0.9	0.9	3.8	<0.05	<2	<15
03 SW 07	upstream of confluence with Barnacullia stream SW06	0.634	7.70	280	146.30	7.76	<0.03	1.8	9.6	17	18	0.1	0.5	0.7	2.1	<0.05	<2	<15
03 SW 08	Castletown river downstream of confluence SW06 and SW 07	0.776	8.00	300	148.00	8.69	<0.03	2.2	12.6	124	19	0.3	0.7	0.9	2.8	<0.05	<2	<15
03 SW 09	Coolbaun mill upstream of bridge	0.734	8.07	370	142.60	9.29	<0.03	2.6	9.4	30	20	0.2	0.7	0.8	2.9	<0.05	<2	17
03 SW 11	downstream of Coolbaun mill	0.744	8.03	290	141.10	9.25	<0.03	2.6	9.2	29	20	0.2	0.6	1.1	2.7	<0.05	6	19
03 SW 12	Lisduff stream- downstream ofSW05	0.856	7.83	280	163.30	8.22	<0.03	3.0	14.2	208	20	0.2	0.3	1.0	1.4	<0.05	<2	16

		Conduct-ivity	pH	Total Alkalin-ity	Dissol-ved Calcium	Dissolved Magnesium	ortho Phosphate as PO4	Potassium	Sodium	Sulphate	Chloride	Fluoride	Total Oxidised Nitrogen	Ammoniacal Nitrogen as N	Nitrate as NO3	Nitrite as NO2	BOD Unfiltered	COD Settled
03 SW 13	Hearnesbrook bridge, Killcrow river	0.708	8.23	340	142.20	7.65	<0.03	2.8	9.6	22	20	0.2	0.5	1.2	2.0	0.06	<2	25
03 SW 14	Ballycahill Mill, Killcrow	0.667	8.21	310	132.10	7.87	0.03	2.6	9.6	25	21	0.2	0.6	1.1	2.7	0.05	3	25
03 SW 15	Upstream of Tynagh mines site - Grangemore	0.748	7.95	360	152.50	7.43	<0.03	1.4	9.1	19	19	0.1	<0.3	0.9	0.9	0.05	<2	16
03 SW 16	North east of mine site - Coolagh	0.702	8.06	320	140.20	9.25	<0.03	2.6	9.3	19	19	0.2	0.9	0.9	4.0	<0.05	<2	16
03 SW 17	Open farm drain on north of site close to forested area	0.932	7.70	250	190.10	11.15	<0.03	<0.2	9.2	263	14	0.3	<0.3	0.8	<0.3	<0.05	<2	31
03 SW 18	Barnacullia stream adjacent to western tailings	0.982	8.03	270	189.50	10.59	<0.03	2.8	23.5	278	26	0.7	0.9	1.0	3.7	0.22	<2	<15
03 SW 19	Open farm drain on north east of site	1.584	7.97	270	326.00	15.25	<0.03	4.2	79.0	680	27	0.5	0.3	1.0	1.4	0.07	<2	<15
03 SW 20	On-site drain receiving discharge from low grade lead deposit (MW 11)	2.302	7.81	150	615.10	21.00	<0.03	5.0	11.2	1420	20	1.8	<0.3	0.7	0.7	<0.05	<2	<15
03 SW 21	Discharge from waste rock dump at south west boundary	2.433	7.46	140	634.30	29.22	<0.03	3.6	8.9	1580	16	2.0	<0.3	1.3	<0.3	<0.05	<2	<15

Table 2: Summary of results for total heavy metal concentration in surface waters

Sample Identity	Other ID	Total Arsenic	Total Boron	Total Cadmium	Total Chromium	Total Copper	Total Lead	Total Mercury	Total Nickel	Total Selenium	Total Zinc	Total Cyanide
		mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
	Surface water abstraction (SI 294 of 1989)	**0.05 – 0.1**	**2**	**0.005**	**0.05**	**0.05-1.0**	**0.05**	**0.001**	**-**	**0.01**	**3.0-5.0**	
	Livestock recommended limit concentration	**0.5**		**0.08**		**0.5 (s) 1.0 (c)**	**0.1**		**1.0**		**25**	
03 SW 01	up/stream mine site - Derryfrench	<0.05	<0.05	<0.05	<0.05	0.06	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
03 SW 02	Pipe discharge inside entrance on left side	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.37	<0.05
03 SW 03	west area of mine site - pipes discharging to site drain	<0.05	0.05	<0.05	<0.05	0.23	<0.05	<0.05	0.09	<0.05	5.13	<0.05
03 SW 04	mine-site discharge from underground pipe	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.86	<0.05
03 SW 05	stream discharging from SE site –Lisduff stream	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	1.15	<0.05
03 SW 06	Barnacullia stream north boundary site - downstream of site SW18	<0.05	<0.05	<0.05	<0.05	0.05	<0.05	<0.05	<0.05	<0.05	2.38	<0.05
03 SW 07	upstream of confluence with Barnacullia stream SW06	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
03 SW 08	Castletown river downstream of confluence SW06 and SW 07	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.86	<0.05
03 SW 09	Coolbaun mill upstream of bridge	<0.05	<0.05	<0.05	<0.05	0.09	<0.05	<0.05	<0.05	<0.05	0.09	<0.05
03 SW 11	downstream of Coolbaun mill	<0.05	<0.05	<0.05	<0.05	0.08	<0.05	<0.05	<0.05	<0.05	0.12	<0.05
03 SW 12	Lisduff stream- downstream ofSW05	<0.05	<0.05	<0.05	<0.05	0.12	<0.05	<0.05	<0.05	<0.05	0.43	<0.05
03 SW 13	Hearnesbrook bridge, Killcrow river	<0.05	<0.05	<0.05	<0.05	0.10	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
03 SW 14	Ballycahill Mill, Killcrow	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
03 SW 15	Upstream of Tynagh mines site - Grangemore	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
03 SW 16	North east of mine site - Coolagh	<0.05	<0.05	<0.05	<0.05	0.12	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
03 SW 17	Open farm drain on north of site close to forested area	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.16	<0.05
03 SW 18	Barnacullia stream adjacent to western tailings	<0.05	<0.05	<0.05	<0.05	0.11	<0.05	<0.05	<0.05	<0.05	2.72	<0.05
03 SW 19	Open farm drain on north east of site	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.06	<0.05	1.50	<0.05
03 SW 20	On-site drain receiving discharge from low grade lead deposit (MW 11)	<0.05	<0.05	<0.05	<0.05	<0.05	0.06	<0.05	0.82	<0.05	9.43	<0.05
03 SW 21	Discharge from waste rock dump at south west boundary	<0.05	<0.05	0.26	<0.05	0.12	<0.05	<0.05	0.59	<0.05	47.70	<0.05

Table 3: Summary of results for dissolved metals in surface waters

Sample Identity	Other ID	Dissolved Arsenic mg/l	Dissolved Boron mg/l	Dissolved Cadmium mg/l	Dissolved Chromium mg/l	Dissolved Copper mg/l	Dissolved Lead mg/l	Dissolved Mercury mg/l	Dissolved Nickel mg/l	Dissolved Selenium mg/l	Dissolved Zinc mg/l
03 SW 01	up/stream mine site - Derryfrench	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
03 SW 02	Pipe discharge inside entrance on left side	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.36
03 SW 03	west area of mine site - pipes discharging to site drain	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.10	<0.05	5.32
03 SW 04	mine-site discharge from underground pipe	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	1.00
03 SW 05	stream discharging from SE site –Lisduff stream	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	1.18
03 SW 06	Barnacullia stream north boundary site - downstream of site SW18	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	2.42
03 SW 07	upstream of confluence with Barnacullia stream SW06	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
03 SW 08	Castletown river downstream of confluence SW06 and SW 07	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.83
03 SW 09	Coolbaun mill upstream of bridge	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.10
03 SW 11	downstream of Coolbaun mill	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.10
03 SW 12	Lisduff stream- downstream ofSW05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.43
03 SW 13	Hearnesbrook bridge, Killcrow river	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
03 SW 14	Ballycahill Mill, Killcrow	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
03 SW 15	Upstream of Tynagh mines site - Grangemore	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
03 SW 16	North east of mine site - Coolagh	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
03 SW 17	Open farm drain on north of site close to forested area	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.13
03 SW 18	Barnacullia stream adjacent to western tailings	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	2.81
03 SW 19	Open farm drain on north east of site	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.05	<0.05	1.22
03 SW 20	On-site drain receiving discharge from low grade lead deposit (MW 11)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.76	<0.05	6.89
03 SW 21	Discharge from waste rock dump at south west boundary	<0.05	<0.05	0.25	<0.05	0.05	<0.05	<0.05	0.56	<0.05	41.64

Table 4: Summary of results for stream sediments

Sample Identity	Other ID	Natural Moisture Content	Arsenic	Cadmium	Chromium	Copper	Lead	Mercury	Nickel	Selenium	Zinc	Total Cyanide
		%	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
03 SS 01	up/stream mine site - Derryfrench	82.1	10	2	10	30	145	<1	30	<1	446	<2.5
03 SS 03	west area of mine site - pipes discharging to site drain	659.5	816	146	31	1285	18060	<1	517	<1	>32000	<2.5
03 SS 04	mine-site discharge from underground pipe	26.2	4435	142	30	3606	>32000	66	32	<1	16320	<2.5
03 SS 05	stream discharging from SE site –Lisduff stream	246.9	139	46	4	201	427	<1	125	<1	4901	<2.5
03 SS 06	Barnacullia stream north boundary site - downstream of site SW18	37.0	61	43	29	182	1143	<1	31	<1	3413	<2.5
03 SS 07	upstream of confluence with Barnacullia stream SW06	38.1	<1	<1	6	11	46	<1	31	<1	137	<2.5
03 SS 08	Castletown river downstream of confluence SW06 and SW 07	19.9	14	19	8	42	277	<1	23	<1	1376	<2.5
03 SS 09	Coolbaun mill upstream of bridge	26.3	<1	11	6	18	110	<1	21	<1	657	<2.5
03 SS 11	downstream of Coolbaun mill	30.5	10	8	5	30	241	<1	18	<1	631	<2.5
03 SS 12	Lisduff stream- downstream ofSW05	41.0	21	19	10	171	99	<1	64	<1	2023	<2.5
03 SS 13	Hearnesbrook bridge, Killcrow river	23.9	9	2	5	14	123	<1	15	<1	639	<2.5
03 SS 14	Ballycahill Mill, Killcrow	27.5	<1	3	4	11	62	<1	14	<1	358	<2.5
03 SS 15	Upstream of Tynagh mines site - Grangemore	166.6	<1	<1	9	11	18	<1	69	<1	90	<2.5
03 SS 16	North east of mine site - Coolagh	45.2	<1	<1	3	3	3	<1	12	<1	70	<2.5
03 SS 17	Open farm drain on north of site close to forested area	378.8	<1	16	7	17	101	<1	33	<1	1496	<2.5
03 SS 18	Barnacullia stream adjacent to western tailings	32.6	332	41	15	255	2869	<1	21	<1	5162	<2.5
03 SS 19	Open farm drain on north east of site	141.1	36	11	13	64	331	<1	73	<1	3387	<2.5
03 SS 20	On-site drain receiving discharge from low grade lead deposit (MW 11)	128.4	1167	207	13	1377	7399	<1	857	<1	>32000	<2.5

Table 5: Summary of results for mine wastes, tailings and sludges taken from within the Tynagh mine site

Sample Identity	Depth	Sample description	Natural Moisture Content	Arsenic	Barium	Cadmium	Chromium	Copper	Lead	Mercury	Nickel	Selenium	Zinc	Total cyanide
			%	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
03/MW-T/01	15 cm	Tailings from north section of west tailings dam	9.4	1791	421	57	4	915	20560	<1	11	<1	6344	<2.5
03/MW-T/02	15cm	Tailings from east section of west tailing dam	19.9	1754	70	131	9	2535	>32000	<1	82	<1	21850	<2.5
03/MW-T/03	60 cm	Tailings from east section of west tailing dam	15.7	1630	67	195	7	1780	26520	<1	102	<1	29610	<2.5
03/MW-T/04	15cm	Tailings from south section of west tailings dam	8.6	4380	1434	59	10	1221	20300	24	<1	<1	2534	5.7
03/MW-T/05	80 cm	Tailings from south section of west tailings dam	14.4	4008	304	55	10	1163	19080	20	8	<1	3075	3.6
03/MW-T/06	15cm	Mine waste dump north Sperrin site	10.4	1694	347	797	4	672	23640	8	188	<1	>32000	<2.5
03/MW-T/07	1 m	Mine waste dump north Sperrin site	8.6	3860	254	114	11	1299	26790	29	18	<1	20630	12.3
03/MW-T/08	1m	Construction waste on Sperrin site	8.1	113	1232	11	12	162	2457	<1	54	<1	1849	<2.5
03/MW-T/09	15cm	Seeded east tailings	16.9	153	3180	11	5	178	828	<1	66	<1	1472	<2.5
03/MW-T/10	60 cm	Seeded east tailings	17.4	256	600	22	6	212	2098	<1	73	<1	3936	<2.5
03/MW-T/11	15cm	Low grade lead deposit NW of open pit	11.4	644	763	75	12	952	10760	3	72	<1	4121	<2.5
03/MW-T/12	10cm	Sludge from alleged pumping activities	30.5	7504	18	657	93	19440	>32000	74	186	<1	>32000	66.3

Table 6: Summary of NRA leaching test on mine wastes

Sample Identity	Depth	Sample description	Natural Moisture Content	Dissolved Arsenic in NRA Leachate	Dissolved Barium in NRA Leachate	Dissolved Cadmium in NRA Leachate	Dissolved Chromium in NRA Leachate	Dissolved Copper in NRA Leachate	Dissolved Lead in NRA Leachate	Dissolved Mercury in NRA Leachate	Dissolved Nickel in NRA Leachate	Dissolved Selenium in NRA Leachate	Dissolved Zinc in NRA Leachate
			%	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
03/MW-T/01	15 cm	Tailings from north section of west tailings dam	9.4	<0.05	0.54	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.34
03/MW-T/02	15cm	Tailings from east section of west tailing dam	19.9	<0.05	0.84	0.53	<0.05	0.07	0.18	<0.05	0.12	<0.05	28.25
03/MW-T/03	60 cm	Tailings from east section of west tailing dam	15.7	<0.05	0.47	0.20	<0.05	<0.05	<0.05	<0.05	0.15	<0.05	5.75
03/MW-T/04	15cm	Tailings from south section of west tailings dam	8.6	<0.05	0.79	<0.05	<0.05	<0.05	0.05	<0.05	<0.05	<0.05	0.08
03/MW-T/05	80 cm	Tailings from south section of west tailings dam	14.4	<0.05	0.35	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.23
03/MW-T/06	15cm	Mine waste dump north Sperrin site	10.4	<0.05	0.46	<0.05	<0.05	<0.05	0.07	<0.05	<0.05	<0.05	0.15
03/MW-T/07	1 m	Mine waste dump north Sperrin site	8.6	<0.05	0.63	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.25
03/MW-T/08	1m	Construction waste on Sperrin site	8.1	<0.05	0.38	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
03/MW-T/09	15cm	Seeded east tailings	16.9	<0.05	0.70	<0.05	<0.05	0.06	0.07	<0.05	<0.05	<0.05	0.07
03/MW-T/10	60 cm	Seeded east tailings	17.4	<0.05	0.45	<0.05	<0.05	<0.05	0.05	<0.05	<0.05	<0.05	0.08
03/MW-T/11	15cm	Low grade lead deposit NW of open pit	11.4	<0.05	0.56	<0.05	<0.05	0.06	0.21	<0.05	<0.05	<0.05	0.51
03/MW-T/12	10cm	Sludge from alleged pumping activities	30.5	<0.05	1.20	<0.05	<0.05	<0.05	0.05	<0.05	<0.05	<0.05	0.83

Table 7:Summary of soil sample results

Sample Identity	Natural Moisture Content	Arsenic	Barium	Cadmium	Chromium	Copper	Lead	Mercury	Nickel	Selenium	Zinc	Total Cyanide
	%	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
TYNAGH 1 0.1m	3.1	15	245	2	28	38	121	<1	81	<1	349	<2.5
TYNAGH 2 0.1m	7.2	12	286	2	23	59	197	<1	73	<1	340	<2.5
TYNAGH 3 0.1m	6.9	16	457	4	22	62	494	<1	73	<1	772	<2.5
TYNAGH 9 0.1m	6.4	67	750	8	18	77	332	<1	74	<1	756	<2.5
TYNAGH 10 0.1m	6.6	49	688	5	24	52	362	<1	76	<1	529	<2.5
TYNAGH 11 0.1m	16.8	19	458	4	38	24	140	<1	70	<1	419	<2.5
TYNAGH 12 0.1m	5.3	<1	316	7	15	17	117	<1	34	<1	594	<2.5
TYNAGH 13 0.1m	3.0	<1	118	2	28	22	40	<1	82	<1	128	<2.5
TYNAGH 14 0.1m	21.6	4	115	2	20	21	38	<1	78	<1	125	<2.5
TYNAGH 15 0.1m	6.1	<1	171	2	915	38	56	<1	433	<1	85	<2.5
TYNAGH 19 0.1m	1.9	4	717	<1	12	30	86	<1	3	<1	88	<2.5
TYNAGH 20 0.1m	2.2	39	1549	1	16	51	337	<1	30	<1	177	<2.5
TYNAGH 21 0.1m	3.3	22	407	1	22	27	201	<1	35	<1	264	<2.5
TYNAGH 22 0.1m	3.1	14	278	2	28	30	248	<1	44	<1	451	<2.5
TYNAGH 4 0.1m	1.4	32	1365	3	17	56	509	<1	28	<1	588	<2.5
TYNAGH 5 0.1m	0.2	1218	24	116	6	576	17980	4	71	<1	20850	<2.5
TYNAGH 6 0.1m	8.1	280	2306	289	11	425	10250	4	114	<1	14890	<2.5
TYNAGH 7 0.1m	10.8	187	136	54	4	566	19790	3	64	<1	8206	<2.5
TYNAGH 8 0.1m	0.4	142	4840	17	6	275	1602	<1	52	<1	2820	<2.5
TYNAGH 16 0.1m	7.7	19	988	3	28	48	313	<1	60	<1	350	<2.5
TYNAGH 17 0.1m	0.3	356	1589	27	7	1042	6900	5	66	<1	3581	<2.5
TYNAGH 18 0.1m	2.3	1366	151	80	17	2191	26490	8	105	<1	11870	<2.5

Table 8: Summary of NRA leaching test on soil samples

Sample Identity	Dissolved Arsenic in NRA Leachate	Dissolved Barium in NRA Leachate	Dissolved Cadmium in NRA Leachate	Dissolved Chromium in NRA Leachate	Dissolved Copper in NRA Leachate	Dissolved Lead in NRA Leachate	Dissolved Mercury in NRA Leachate	Dissolved Nickel in NRA Leachate	Dissolved Selenium in NRA Leachate	Dissolved Zinc in NRA Leachate
	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
TYNAGH 1 0.1m	<0.05	0.37	<0.05	<0.05	0.05	<0.05	<0.05	<0.05	<0.05	0.10
TYNAGH 2 0.1m	<0.05	0.39	<0.05	<0.05	0.06	<0.05	<0.05	<0.05	<0.05	0.07
TYNAGH 3 0.1m	<0.05	0.40	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.07
TYNAGH 9 0.1m	<0.05	0.50	<0.05	<0.05	0.09	<0.05	<0.05	<0.05	<0.05	0.10
TYNAGH 10 0.1m	<0.05	0.31	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.07
TYNAGH 11 0.1m	<0.05	0.25	<0.05	<0.05	0.09	<0.05	<0.05	<0.05	<0.05	0.06
TYNAGH 12 0.1m	<0.05	0.31	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.11
TYNAGH 13 0.1m	<0.05	0.42	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.06
TYNAGH 14 0.1m	<0.05	0.55	<0.05	<0.05	0.06	<0.05	<0.05	<0.05	<0.05	0.21
TYNAGH 15 0.1m	<0.05	0.31	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.07
TYNAGH 19 0.1m	<0.05	0.36	<0.05	<0.05	<0.05	0.05	<0.05	<0.05	<0.05	0.09
TYNAGH 20 0.1m	<0.05	0.40	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
TYNAGH 21 0.1m	<0.05	0.37	<0.05	<0.05	<0.05	0.06	<0.05	<0.05	<0.05	0.06
TYNAGH 22 0.1m	<0.05	0.36	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.05
TYNAGH 4 0.1m	<0.05	0.15	<0.05	<0.05	0.11	<0.05	<0.05	<0.05	<0.05	<0.05
TYNAGH 5 0.1m	<0.05	0.48	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
TYNAGH 6 0.1m	<0.05	0.39	<0.05	<0.05	0.09	<0.05	<0.05	<0.05	<0.05	0.13
TYNAGH 7 0.1m	<0.05	1.85	<0.05	<0.05	0.12	0.39	<0.05	<0.05	<0.05	0.58
TYNAGH 8 0.1m	<0.05	8.20	<0.05	<0.05	0.17	0.39	<0.05	<0.05	<0.05	1.27
TYNAGH 16 0.1m	<0.05	0.45	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.09
TYNAGH 17 0.1m	<0.05	2.58	<0.05	<0.05	0.24	0.33	<0.05	<0.05	<0.05	0.40
TYNAGH 18 0.1m	<0.05	0.39	<0.05	<0.05	0.30	0.06	<0.05	<0.05	<0.05	<0.05