Inventory of closed mine waste facilities in Northern Ireland - Phase 2 Assessment

Minerals and Waste

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BRITISH GEOLOGICAL SURVEY

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Inventory of closed mine waste facilities in Northern Ireland - Phase 2 Assessment

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Foreword

This report has been produced by the British Geological Survey under a contract with the Northern Ireland Department of the Environment (DoENI) in support of the implementation of the EU Mine Waste Directive (MWD) with regard to Article 20 - Inventory of closed waste facility.

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Summary

- The European Mine Waste Directive (MWD) seeks to mitigate the environmental effects of mine waste facilities, to prevent the occurrence of major accidents associated with tailings ponds and other waste containment structures, and encourage the reuse and minimisation of mine waste.

- This project is concerned with Article 20 of the Directive – Inventory of closed waste facilities. Each Member State must produce an inventory of closed mining waste facilities that are causing serious environmental impacts.

- The British Geological Survey in collaboration with the Geological Survey of Northern Ireland was commissioned by the Northern Ireland Department of the Environment (DoE) to collate the information required to create such an inventory for Northern Ireland.

- The GSNI Abandoned Mines database of Northern Ireland and the BGS BRITPITS database of Mines and Quarries contain over 3500 records of abandoned mine workings. The records refer to a generic location of mining or quarrying activity; consequently, a record does not necessarily constitute proof of the existence of a mine waste facility. Many of the deposits that are described as mines were often trials, excavations of limited extent into the ground exploring for minerals. The majority of these sites are unlikely to pose a serious threat to human health or the environment; therefore, in order to draw up the risk-based inventory, a screening methodology was necessary to select sites for possible inclusion in the inventory.

- The methodology used in this project to develop the inventory considers both the European Commission guidance protocol (EC, 2011), and the criteria devised by the Environment Agency in England and Wales (EA, 2012) in the preparation of their inventory, to which the British Geological Survey contributed (Palumbo-Roe and Colman, 2010). It also takes cognisance of similar work undertaken by the Geological Survey of Ireland when creating an inventory of, and undertaking an associated risk classification for, historic mine sites in the Republic of Ireland (EPA, 2009).

- A phased approach was followed, consisting of an initial qualitative study (Phase 1), aimed at data collection and categorisation, followed by a more quantitative data assessment phase (Phase 2), which appraises potential environmental impacts on water receptors of the closed mine waste facilities. Both phases are desk-based studies.

- Of the 3686 entries in the collated GSNI Abandoned Mines and BGS BRITPITS databases, 1971 are surface, 1705 underground and 10 are described as both surface and underground workings; 1248 are construction mineral sites, 633 industrial mineral sites, 871 are energy mineral sites, and 934 are metallic mineral sites. The information has been presented in tables and maps showing the distribution of closed mineral commodities in Northern Ireland by commodity type.

- The outcome of Phase 1 highlights that the majority of waste, if present, associated with the closed mine waste facilities in Northern Ireland is likely to be non-hazardous waste and substantially inert. Providing there is no evidence of physical instability, these facilities should not be included in the inventory on the basis of their non-hazardous nature.

- Exceptions comprise coal/lignite, metal base, iron and bauxite extraction, which may have associated hazardous waste with the potential to pose a particular risk to human health and the environment.

- The Phase 2 has drawn a list of potential MWD inventory sites belonging to the bauxite, copper, iron ore, lead, coal, lignite and barytes commodity types, for their potential to cause pollution to rivers and streams. The assessment is based on evidence of water and sediment quality degradation (expressed as hazard quotients), through interrogation of the Tellus geochemical survey database for Northern Ireland.

- The potential MWD inventory sites are grouped in hazard classes and ranked based on the respective hazard quotients. Map of the mine site distribution by counties and by commodity types are presented.

- This approach fulfils the source, pathway and receptor linkage of the risk-based assessment when considering aquatic ecological receptors, as it proves that a measurable impact (high concentration of contaminants) exists in the surface water receptors - downstream of the mine sites. This approach, however, cannot evaluate if the location of historical mining or quarrying activity represents an underground shaft or adit, an open pit or a mine spoil or a tailings lagoon, and therefore cannot characterise the source of mining pollution (point versus diffuse sources), causing the measured impact on the water environment. This information is required to design future rehabilitation strategies. Although less likely, the presence of additional or alternative non-mining sources of pollution cannot be ruled out.

- Data analysis has primarily focused on elements for which there are water and sediment quality standards. Uncertainties are inherent in the use of a generic sediment guideline value approach for sediment quality assessment, as well as in the use of water chemistry data that represent a single sampling event, rather than annual average values. In order to increase confidence in the geochemical assessment, baseline concentrations in water and sediment in these mineralised environments should be considered.

- The sites scoring high in terms of hazard quotient should be examined further to identify whether the presence of a waste facility might be the source of the contamination.

- The most impacted sites based on this assessment should be investigated through field visits and further sampling and testing, for inclusion in the final inventory list.

- This potential MWD inventory site list excludes considerations on physical hazard risk. The project outputs should be complemented by information sourced from relevant authorities on known concerns of risks to human or animal health, ground stability, and fire or air pollution.

1 Scope of the project

This project was commissioned by the Northern Ireland Government Department of the Environment (DoE) in support of the implementation of the EU Mine Waste Directive (MWD) with regard to Article 20 - Inventory of closed waste facility.

The EU Directive requires the application of risk assessment methods in the inventory of closed waste facilities that are either known or have the potential of impacting the environment or human health. DoENI has appointed the British Geological Survey (BGS) in collaboration with the Geological Survey of Northern Ireland (GSNI) to prepare the inventory for Northern Ireland.

For the purposes of this project the term “closed mine waste facilities” should be considered to include “abandoned mine waste facilities”.

The GSNI Abandoned Mines database of Northern Ireland and the BGS BRITPITS database of Mines and Quarries contain over 3500 records of abandoned mine workings, mostly dating from the 18th to the early 20th century. The majority of these sites are unlikely to pose a serious threat to human health or the environment; therefore, in order to draw up the inventory, a screening methodology is needed to select sites from the main waste facilities for further study and possible inclusion in the inventory.

In this project a phased approach has been undertaken consisting of a pre-selection phase (Phase 1), based on data collection, categorisation and a qualitative assessment of the nature of waste (Palumbo-Roe et al., 2013), followed by a more quantitative data assessment phase (Phase 2), which appraises potential impacts to riverine ecological receptors of the closed mine waste facilities, by comparing mine site locations with geochemical data for stream water and sediment samples held by the GSNI and BGS. The project outputs should be complemented by information sourced from relevant authorities on known concerns about risks to human or animal health, stability, and fire or air pollution, which also require consideration under the Directive.

This report describes Phase 2 of the work undertaken for the preparation of the inventory and presents the final results of the assessment and recommendations. This document should be read in conjunction with the accompanying interim report by Palumbo-Roe et al. (2013).

2 Legal background: Article 20 of the Mine Waste Directive

The EU Mine Waste Directive (EC, 2006) requires that each member state *shall ensure that an inventory of closed waste facilities, including abandoned waste facilities, located on their territory which cause serious negative environmental impacts or have the potential of becoming in the medium or short term a serious threat to human health or the environment is drawn up and periodically updated.* As indicated in the “Guidance document for a risk-based pre-selection protocol for the inventory of closed waste facilities as required by Article 20 of Directive 2006/21/EC” (EC, 2011), the inventory should be risk-based, i.e. consider the probability of an event occurring and the impact of such an occurrence. It should address the Source, Pathway and Receptor components.

3 Methodology

3.1 EXISTING GUIDANCE ON THE MINE INVENTORY

The methodology used in this project to develop the inventory considers both the European Commission guidance protocol (EC, 2011), and the criteria devised by the Environment Agency in England and Wales (EA, 2012) in the preparation of their inventory, to which the British Geological Survey contributed (Palumbo-Roe and Colman, 2010). It also takes cognisance of similar work undertaken by the Geological Survey of Ireland when creating an inventory of, and undertaking an associated risk classification for, historic mine sites in the Republic of Ireland (EPA, 2009).

3.2 PHASE 2 ASSESSMENT

The outcome of Phase 1 “Data collation and categorisation” of this project has highlighted that the majority of waste, if present, associated with the closed mine waste facilities in Northern Ireland (3586 closed mine entries) is likely to be non-hazardous waste and substantially inert (Palumbo-Roe et al, 2013). Providing there is no evidence of physical instability, these facilities should not be included in the inventory. However, as a result of the waste categorisation undertaken during Phase 1, the mine entries belonging to the “bauxite”, “copper”, “iron ore”, “lead”, “coal”, “lignite” and “barytes” commodity types were selected for further assessment, based on their potential to be associated with hazardous waste, with a total of 1806 mine entries selected for Phase 2.

The Phase 2 of this project aims to assess the risk of impacts on surface water and contamination of sediments (water receptors) posed by mine sites. Our data are not sufficient to consider other risks associated to mine sites regarding human health and physical hazards. Impacts on human health, property, livestock from mining waste facility fall within the Contaminated Land Part 2A regime and local authorities have a duty to inspect their areas for such land and keep a record of these sitesThe project outputs should be complemented by information sourced from relevant authorities on known concerns of risks to human or animal health, ground stability, and fire or air pollution.

Our approach establishes spatial linkages between known mine sites and water and/or sediment geochemical data for stream water and sediment data values that exceed specified chemical quality assessment criteria and, on the basis of this approach, the main output is to identify and rank potential inventory sites based on the risk of impacts on surface water and contamination of sediments. This approach fulfils the source, pathway and receptor linkage of the risk-based assessment when considering aquatic ecological receptors, as it proves that a measurable impact (high concentration of contaminants) exists in the surface water receptors, downstream of the mine sites. Data analysis has primarily focused on elements for which there are water and sediment quality standards.

The precautionary principle has guided this assessment when using generic water and sediment guideline values for the protection of surface water quality and ecosystems. If sites fail the environmental quality standards, consideration of the natural background concentration may be undertaken to further assess compliance and prior to any expensive or time-consuming remediation (UKTAG, 2012).

The most impacted sites based on this assessment should be investigated through field visits and further sampling and testing. Both phases are desk-based studies and, therefore, no fieldwork-based activities have been carried out.

The following assessment process was undertaken during Phase 2:

1. Identification of location of closed mine workings belonging to bauxite, copper, iron ore, lead, coal, lignite and barytes commodity types and grouping of these sites defined by GSNI/BRITPITS in the source data;
2. Identification of river network associated with closed mine workings;
3. Selection of Tellus geochemical survey sampling points located within the river network and downstream from mine entries;
4. Individual assessment of the selected Tellus sampling points of their potential for risk to riverine ecological receptors through the hazard quotient method for waters and sediments;
5. Linkage of Tellus points with hazard quotients greater than 1 with upstream mine entries, to determine a list of mine locations responsible for the identified points of potential ecological risk.
6. Ranking of the mining locations according to risk of impacts on surface water and contamination of sediments.

3.3 TELLUS GEOCHEMICAL SURVEY DATA

The Tellus project, which comprised an integrated airborne geophysical survey and ground geochemical survey of Northern Ireland, was implemented to provide high resolution regional baseline datasets to underpin government and private body policy decisions concerning sustainable economic development, social infrastructure, environment and human health (Young and Donald, 2013).

Stream waters were collected during two discrete sampling campaigns. The western side of Northern Ireland was sampled in the period 1994 to 1996. The eastern side of Northern Ireland was sampled in 2005 and 2006. Samples were collected from predominantly 1^{st} and 2^{nd} order streams at a density of approximately 1 site per 2.4 km^2. Stream water samples were filtered at 0.45 µm using cellulose acetate filters, and collected in high-density polyethylene bottles. Unfiltered samples were collected for bicarbonate, conductivity and pH; analyses were undertaken in the field office within 24 hours of collection. Acidified, filtered sample ICP-AES and ICP-MS analyses were undertaken at the laboratories of the Finnish Geological Survey (GTK) and filtered sample organic carbon and anion analyses by Alcontrol, Netherlands.

Sediment were collected in 1994-96 (2,908 sites in the west) and in 2004-06 (2,966 sites in the east) as part of the Tellus Project. Sediment samples were collected from predominantly 1^{st} and 2^{nd} order streams at a density of approximately one site per 2.5 km^2. Sediments were wet sieved at site to yield a <150µm fraction for analysis. Sample preparation and analysis were undertaken at the laboratories of the British Geological Survey, Keyworth, Nottingham. Sediments were analysed by X-ray fluorescence spectroscopy (XRF). Full details of all sampling, analytical and quality control methods are given in Smyth (2007).

4 Assessment

4.1 SELECTION OF TELLUS SAMPLING POINTS

This step involves the use of spatial queries and visual inspections using a Geographical Information System (GIS), to identify only those Tellus sampling points that are located within the same catchment as a known mine entry and are downstream from it.

The river network associated with the closed mine sites was extracted from the complete Northern Ireland river network (Figure 1). All Tellus data points associated with the extracted river network were then selected. A 25m buffer was applied to the river network to ensure selection of all samples and compensate for any variations in data capture, geo-registration and recording of the Tellus data. After this initial spatial selection, the Tellus data points were further filtered to select only samples potentially impacted by mining activities. This was done by visual inspection of the spatial relationship between Tellus sampling points and mine entries. Only Tellus points which could be joined to one or more mine entries located upstream the Tellus sampling point were selected.

The selection and filtering process resulted in the identification of 302 Tellus sampling points which form the basis of the following analysis.

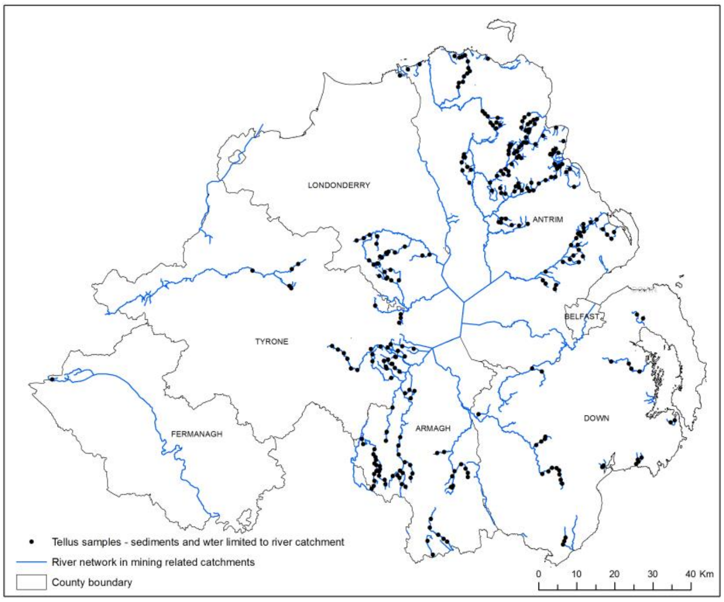

Figure 1 - River network (data supplied by Northern Ireland Environment Agency, ©Crown Copyright) showing Tellus sampling points.

4.2 APPRAISAL OF THE WATER AND SEDIMENT QUALITY IN RELATION TO ECOSYSTEM PROTECTION: HAZARD QUOTIENT APPROACH

A single line of evidence-based assessment of risk to water receptors was carried out. The ecological risks from contaminant exposure in the river catchments impacted by mining was performed by comparing the environmental concentrations of trace elements in the Tellus water and sediment samples with regulatory standards and guidelines which report threshold values with a measured adverse biological effect. This is known as the quotient approach to hazard assessment applied in Finger et al. (2004).

4.2.1 Guidelines values of contaminants in waters in relation to ecosystem protection

Specifically, hazard quotients in waters (HQ_w) were calculated using environmental quality standards (EQS) for specific pollutants set by the UK Technical Advisory Group (UKTAG) on the Water Framework Directive (WFD) to underpin the implementation of the Directive in UK. The elements considered are those for which there are water quality standards: arsenic, cadmium, copper, lead, iron, nickel and zinc. These standards are set for the protection of surface water quality and ecosystems. The criteria are dependent for some of the elements on hardness (as $CaCO_3$), which was calculated from the alkalinity measurements. These standards refer to annual means. It should be noted that the Tellus water samples represent a single sampling event, with variable stream flow conditions from site to site. Stream flow is an important factor in controlling element concentrations, typically with a decrease in concentrations as the stream flow increases because of dilution, but also with higher concentrations of certain elements at high flow due to storm runoff contributions. This adds a level of uncertainty in the assessment. Nonetheless the approach is still considered useful and appropriate in screening the potential for adverse effect in the environment of these sites and a mean to compare and rank these sites during the initial screening phase.

4.2.2 Guidelines values of contaminants in sediments in relation to ecosystem protection

Currently, in the UK there are no statutory guidelines for sediment quality. The UKTAG does not recommend setting mandatory standards in sediments (UKTAC, 2012). This is because the high uncertainty in deriving sediment ‘Predicted No-Effects Concentrations (PNECs) on riverine ecology, due to lack of sediment toxicity data for many substances and concerns on the suitability of the equilibrium partitioning approach to supplement the lack of sediment toxicity data (UKTAG, 2012). Furthermore, it is recognised there are difficulties in using measurements on sediments to provide the basis for environmental control regimes, given the high spatial variability of monitoring data. An assessment of metal mining-contaminated river sediments in England and Wales by Hudson-Edwards et al. (2008), commissioned by the Environment Agency (EA), reports on the development within the EA of interim sediment guideline values that could be used to trigger further investigation. The guidelines are based on the approach of Environment Canada, which considers a Toxic Effect Level (TEL) as the concentration below which sediment associated contaminants are not considered to represent significant hazards to aquatic organisms, and a Predicted Effect Level (PEL) as the concentration representing the lower limit of the range of concentrations associated with adverse biological effects. Hazard quotients in sediments (HQ_s) in this assessment were calculated using the PEL criteria as described above. Despite the limitation of applying generic sediment quality guidelines, there is a general consensus on the use of sediment quality guidelines as aids to identify potential problems, classify hot spots and help choose sites for more detailed studies (Wenning and Ingersoll, 2002). The elements considered in this assessment are those for which there are sediment quality standards available: arsenic, cadmium, chromium, copper, lead, nickel and zinc.

Both environmental quality standards for water and sediments used in this assessment are reported in Appendix 1.

4.2.3 Hazard Quotients for Tellus sites

The individual hazard quotients (HQ) for each element, calculated as the ratio of the environmental concentration measured in water or sediment to the adopted quality criteria, were summed up to give a total hazard estimate by each Tellus site. This approach assumes that toxicity of mixture is additive. Maps in Figure 2 and Figure 7 show the sum of hazard quotients by Tellus site, respectively, in waters (HQ_w) and sediments (HQ_s).

4.2.4 Tellus sites exceeding water quality criteria

The number of streams with HQ_w equal or greater than 1 for at least one of the considered elements (arsenic, cadmium, copper, iron, lead, and zinc) were 67, with 43 sites highlighting $HQ_w \geq 1$ for copper (Figure 4), 19 sites for iron (Figure 5), 12 for cadmium (Figure 3), and 4 sites with $HQ_w \geq 1$ for zinc (Figure 6). However, only 3 sites out of 67 had a total HQ_w greater than 5.

4.2.5 Tellus sites exceeding sediment quality criteria

The number of stream sediments exceeding the recommended Predicted Effect Levels (PEL) for at least one of the considered elements (arsenic, cadmium, chromium, nickel, lead, and zinc), therefore with calculated HQs >1, were 397. Most sites were highlighted for having HQs >1 for chromium (382 sites) (Figure 10) and nickel (363 sites) (Figure 11). 83 sites out of the 397 had HQs >1 for zinc (Figure 13), 72 sites for arsenic (Figure 8), followed by 34 sites for lead (Figure 12) and 27 sites for cadmium (Figure 9).

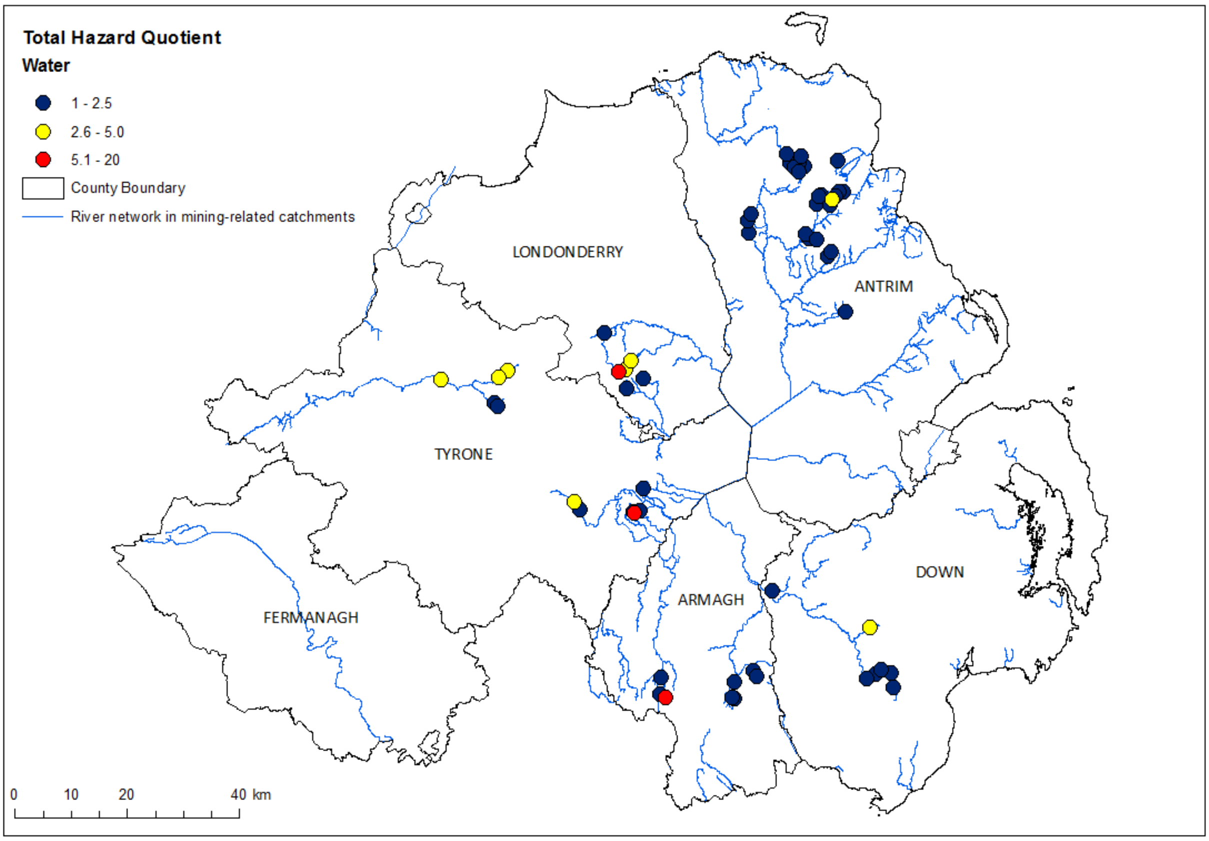

Figure 2 - Map of Tellus water sample points, downstream known mine sites, equal or exceeding environmental quality standards in water for one or more elements, in Northern Ireland counties. The sites are ranked based on the Total Hazard Quotients for waters (sum of HQ_w for arsenic, cadmium, copper, iron, lead, and zinc).

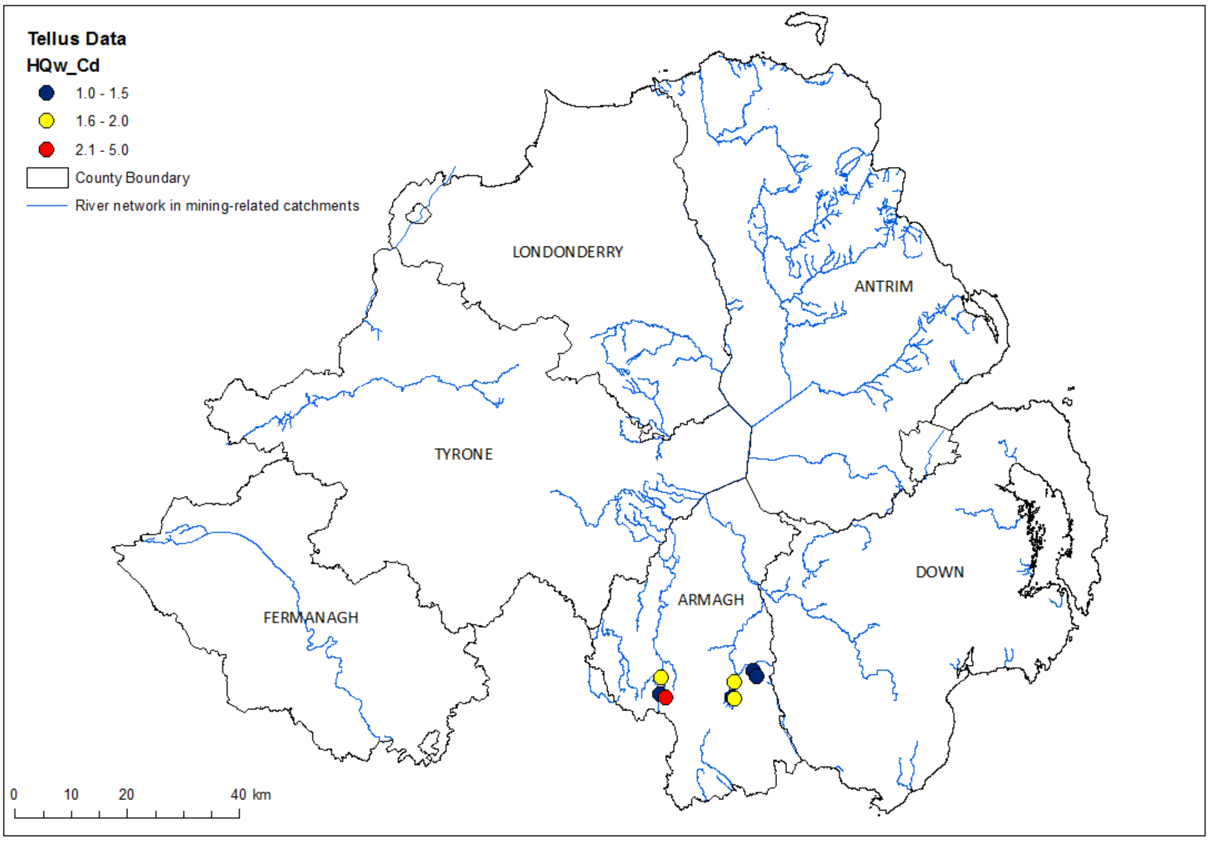

Figure 3 - Hazard quotients for cadmium (Cd) in water.

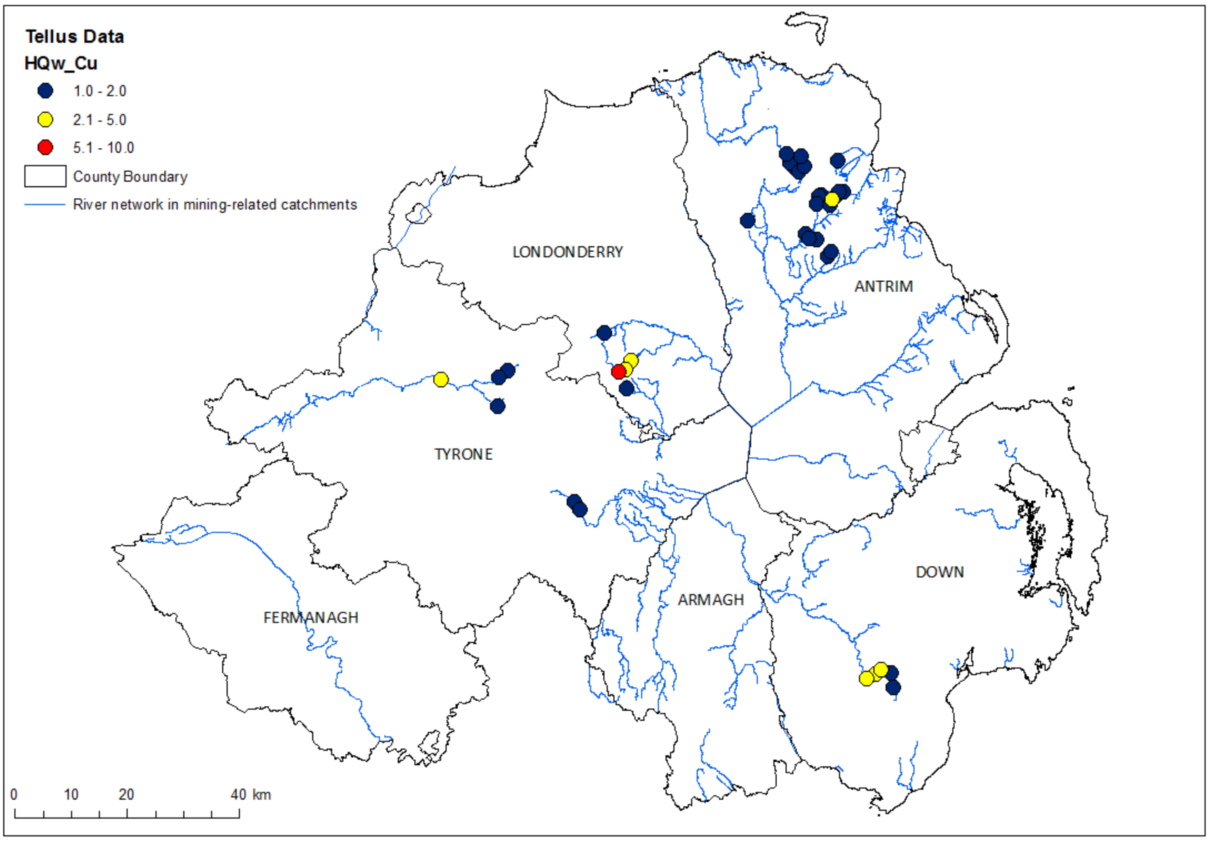

Figure 4 - Hazard quotients for copper (Cu) in water.

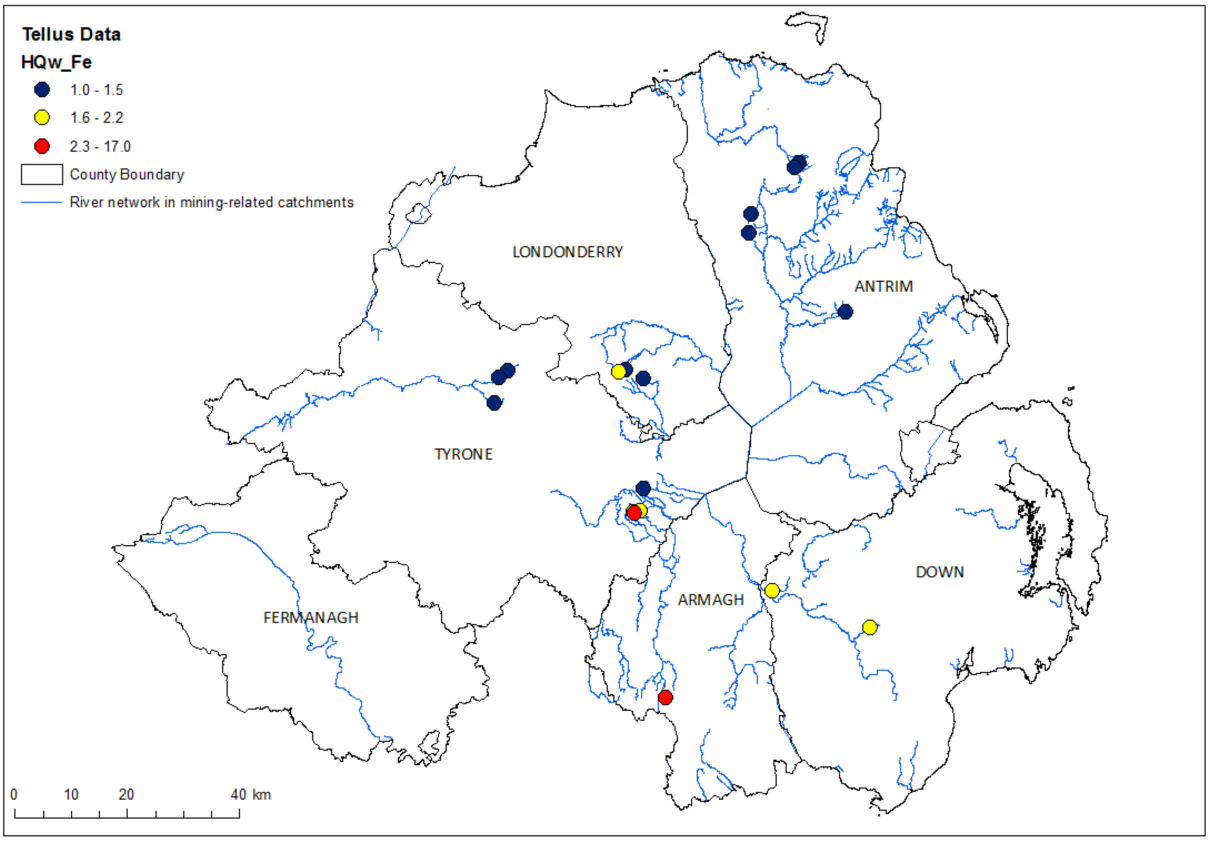

Figure 5 - Hazard quotients for iron (Fe) in water.

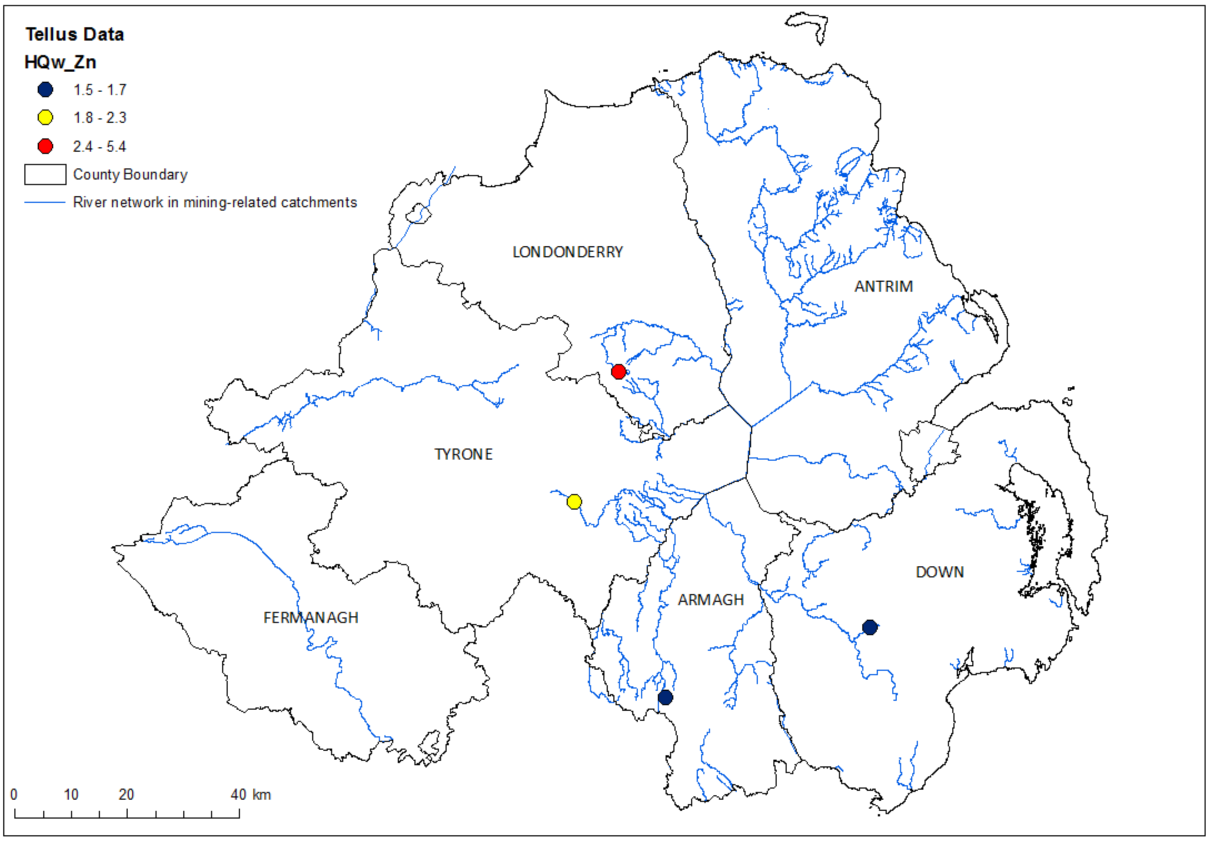

Figure 6 - Hazard quotients for zinc (Zn) in water.

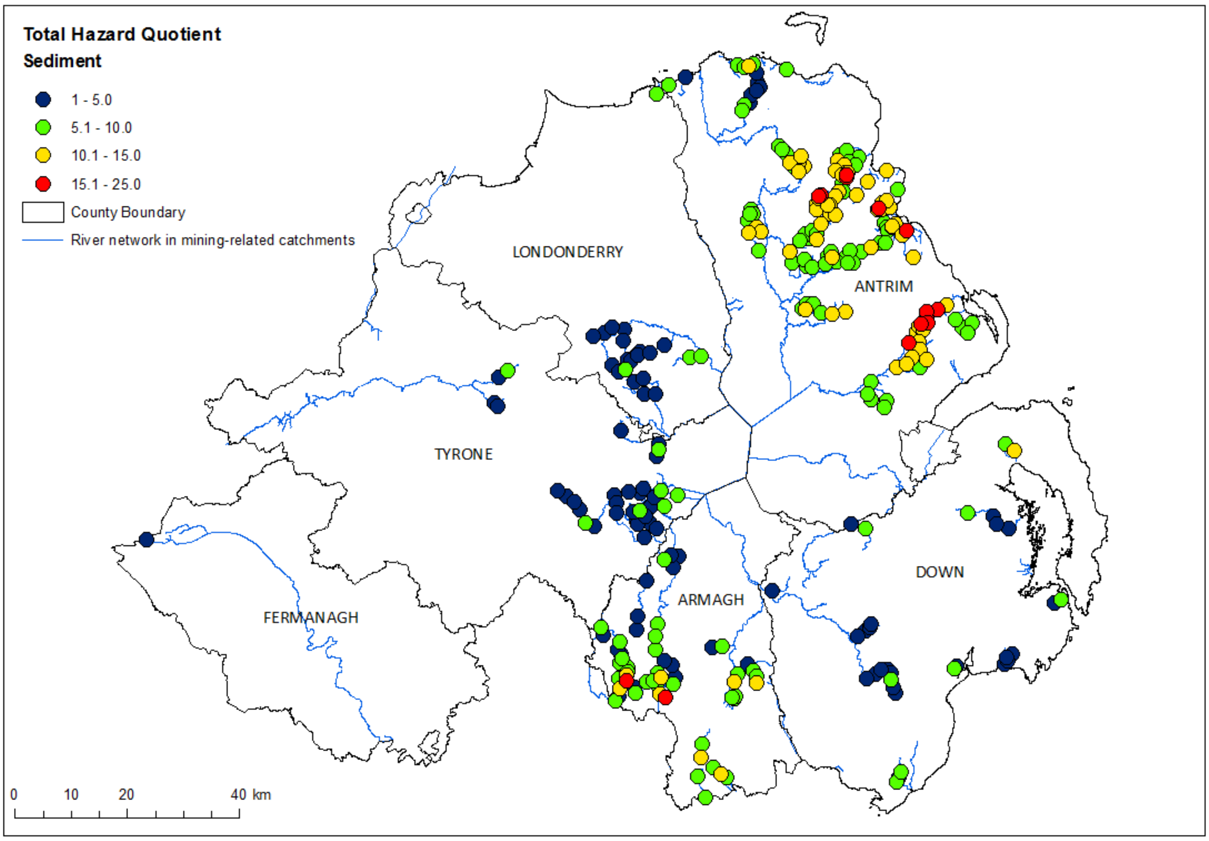

Figure 7 - Map of Tellus sediment sample points, downstream mine sites, equal or exceeding quality standards in sediments for one or more elements. Sites ranked based on the Total Hazard Quotients for sediments (sum of HQ_s for arsenic, cadmium, chromium, nickel, lead, and zinc).

4.2.6 Correlation of mining locations with known water and sediment quality failures

Each Tellus sampling location with a HQ ≥ 1 was then assessed to identify which mine entries upstream the Tellus point may have contributed to the HQ. Firstly, consideration was given to the nearest neighbour in terms of distance, then consideration of other mine entries higher up the river network.

Once Tellus data and mine entry links were identified, the distance between the mine entry and the Tellus point was measured (by the most direct route). Where mine entries were distributed over a wide area, a minimum and maximum distance between the mine entrance and the Tellus sample point was recorded. Entrances were grouped, with each named group including one or more entrances. Groups were defined by GSNI in the source data; where no group name was available, the mine name was used to link various entrances belonging to the same workings.

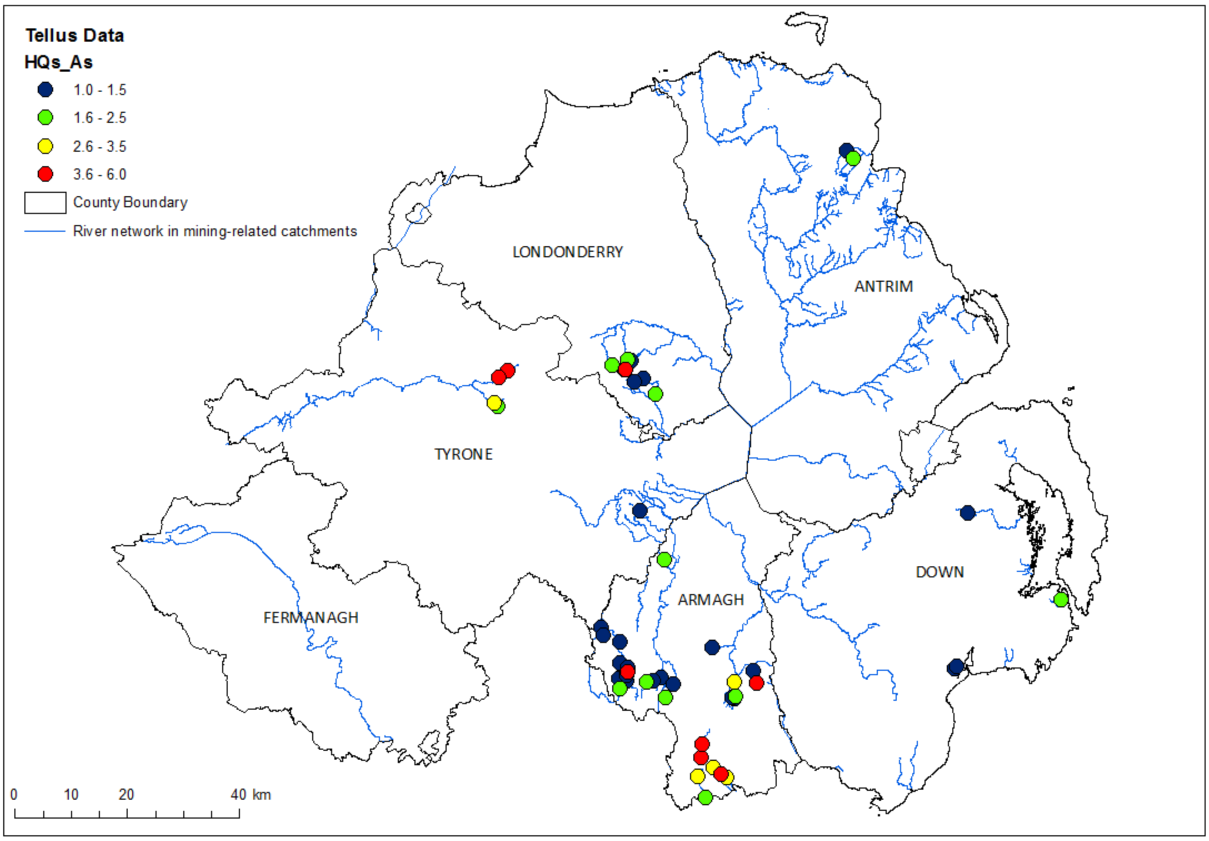

Figure 8 - Hazard quotients for arsenic (As) in sediments.

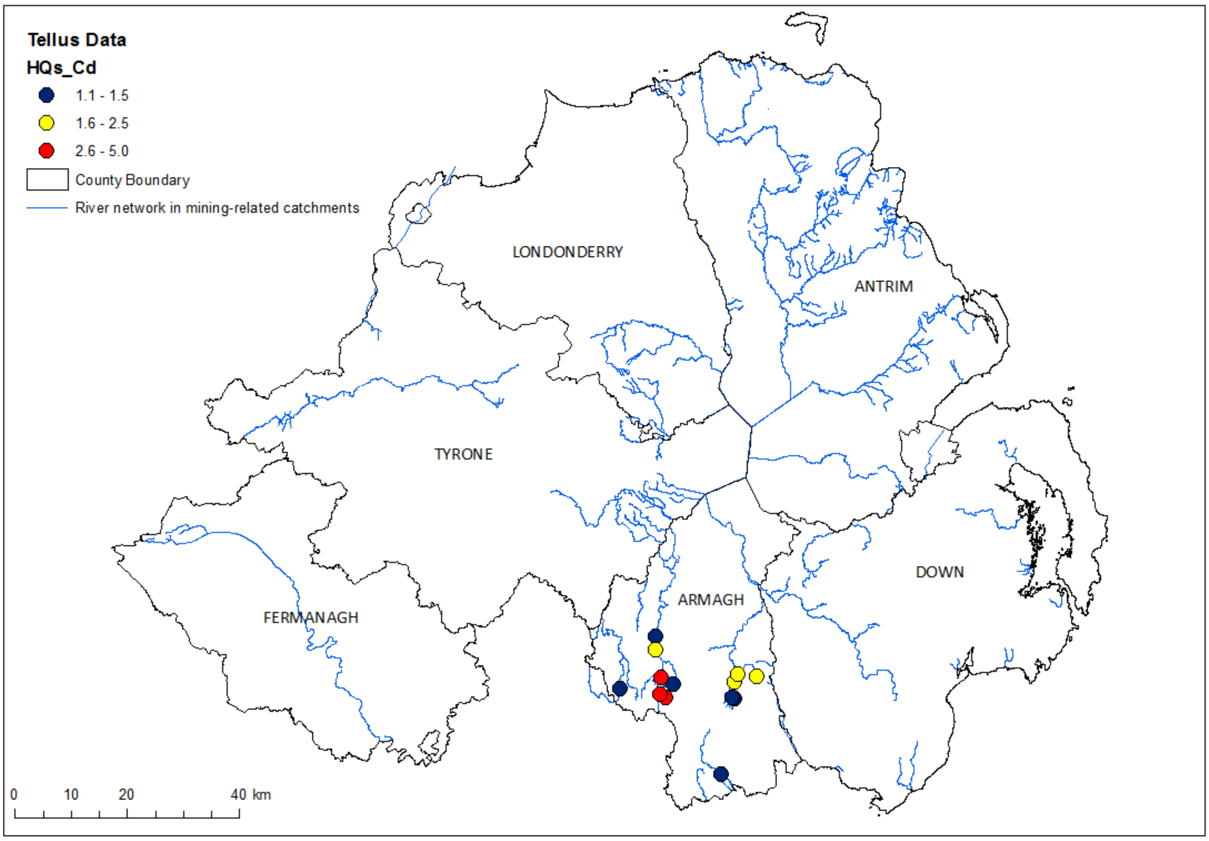

Figure 9 - Hazard quotients for cadmium (Cd) in sediments.

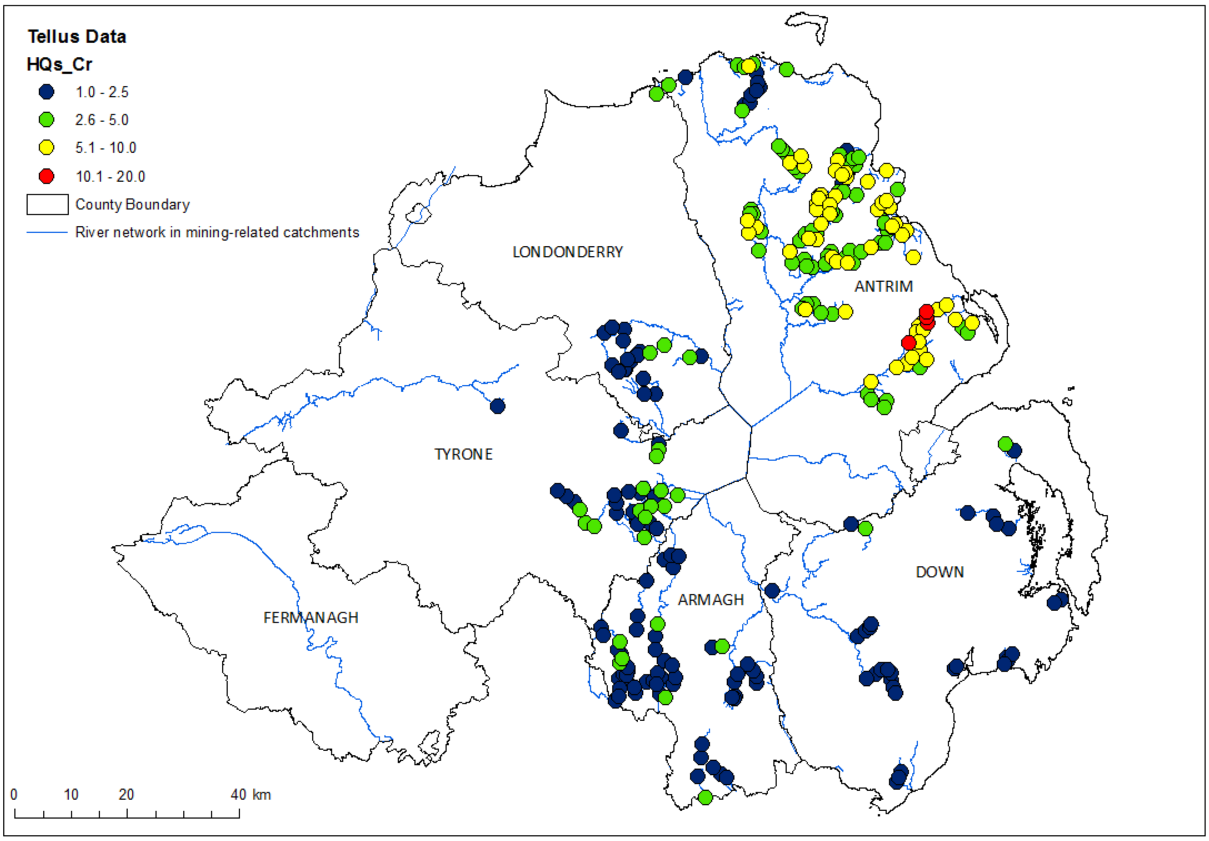

Figure 10 - Hazard quotients for chromium (Cr) in sediments.

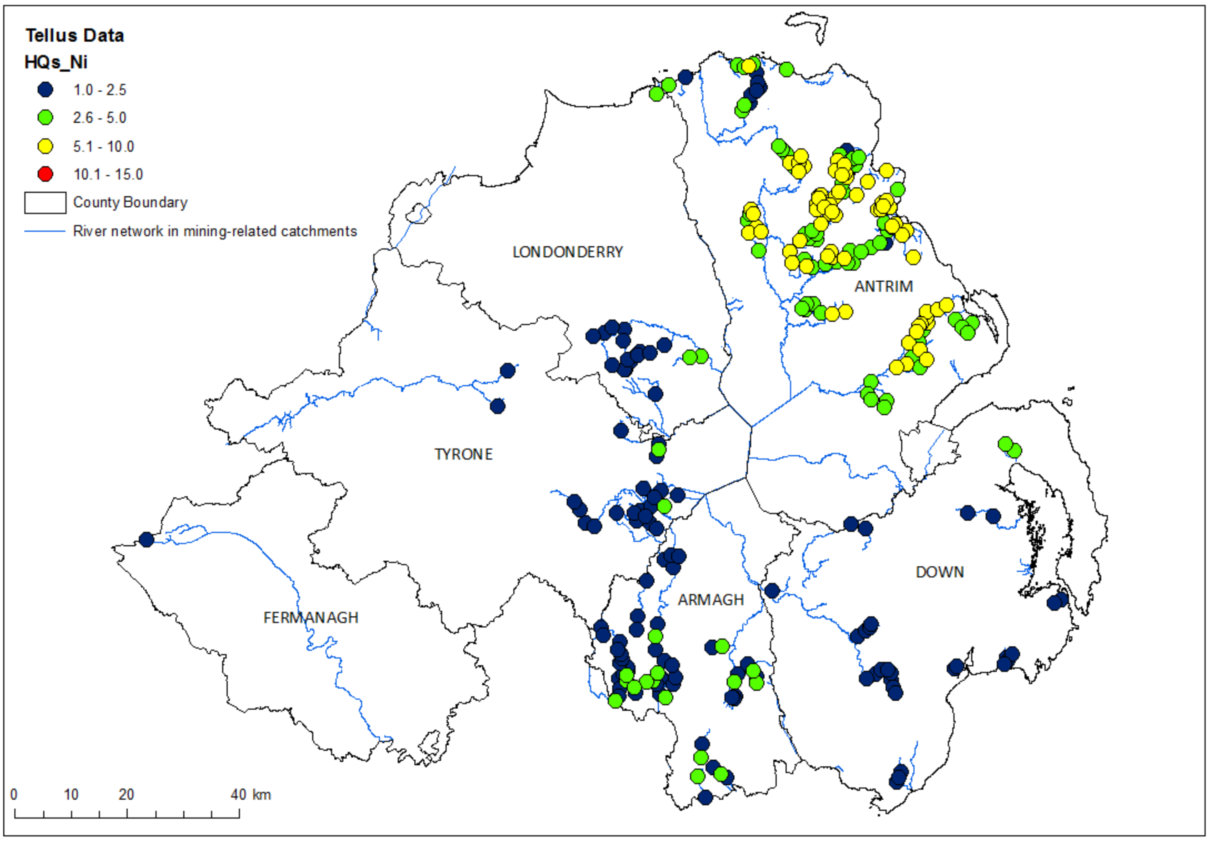

Figure 11 - Hazard quotients for nickel (Ni) in sediments.

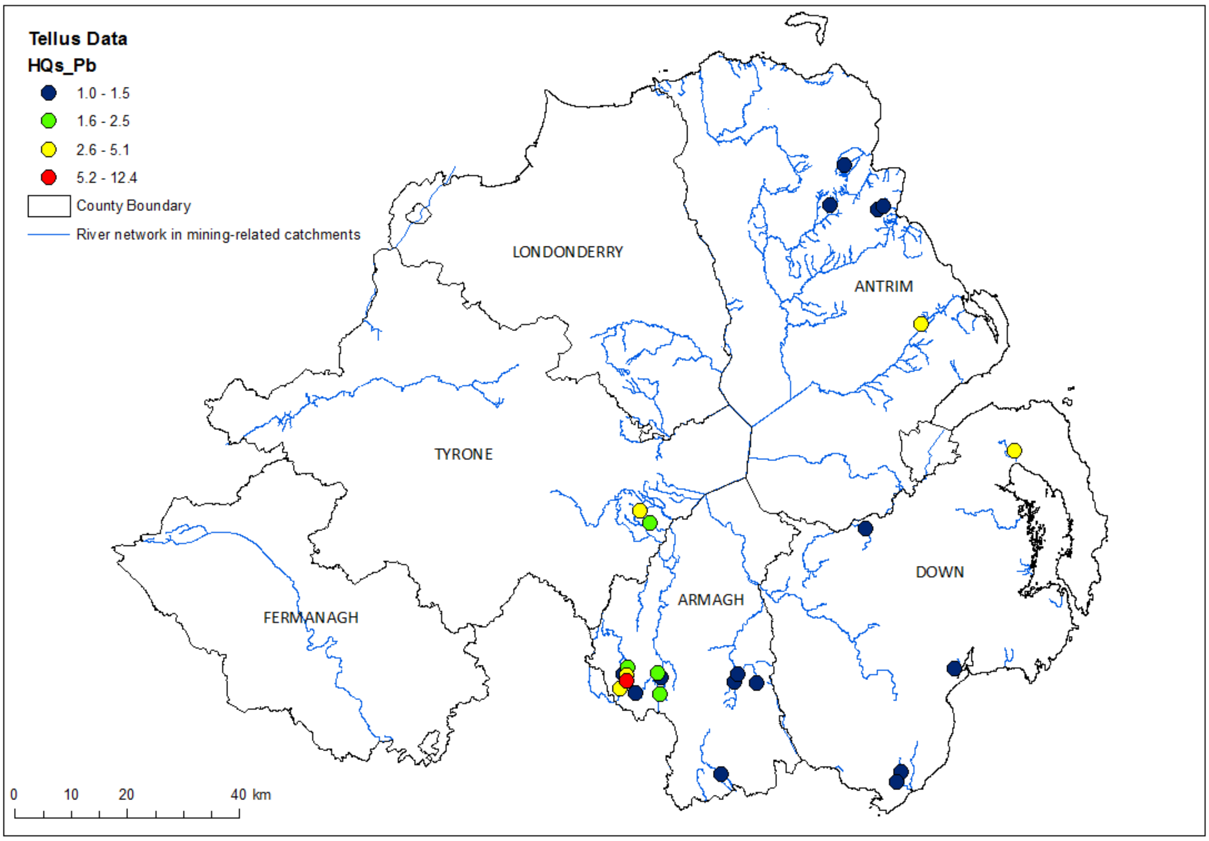

Figure 12 - Hazard quotients for lead (Pb) in sediments.

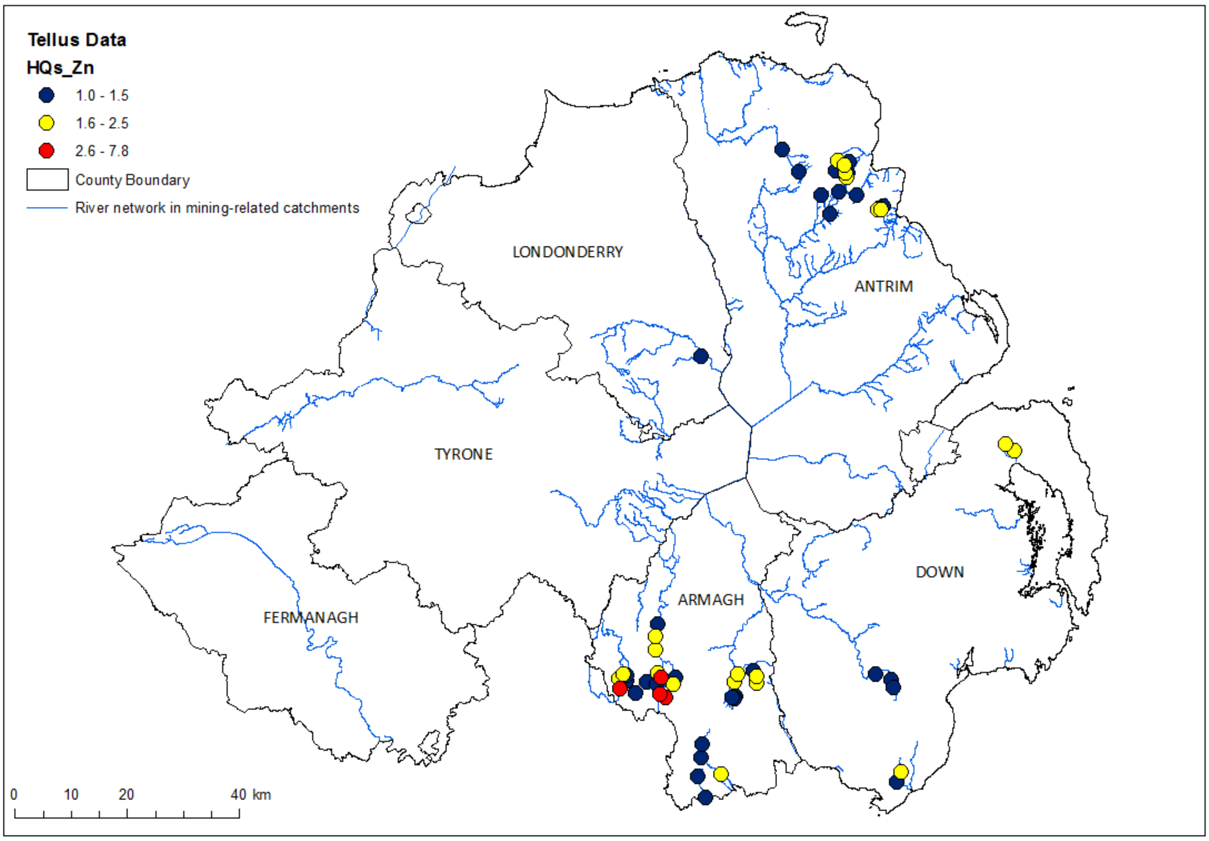

Figure 13 - Hazard quotients for zinc (Zn) in sediments.

5 Potential inventory sites

Based on the methodology described in the previous sections, a list of mine locations with evidence of impact on the aquatic ecosystem due to concentrations of potential harmful elements in water above quality reference thresholds (expressed as hazard quotients) was compiled. A parallel list was created to account for the impact on sediments. The two mine lists were ranked based on the respective hazard quotients and grouped in hazard classes.

In order to determine whether serious environmental impact has been caused, we have followed the criteria set out by the Environment Agency (EA, 2012) indicating a failure of EQS in surface water over a distance of more than 500 metres from the mine as evidence of a site causing serious environmental impacts. The data compared with the above criteria indicate that the majority of the sites in the lists cause water and sediment pollution (indicated by a HQ>1) at a distance greater than 500 m (Table 1 to Table 7).

Such an inventory is purely based on evidence of water and sediment quality degradation through interrogation of Tellus geochemical survey data, while excludes considerations on physical hazard risk, the presence of a waste facility and/or the source of contamination (e.g. mine water discharges from mine adits, mine waste spoils, tailings, etc.).

5.1 MINE SITE RANKING BY HAZARD QUOTIENTS IN WATER FOR THE PROTECTION OF WATER QUALITY UNDER THE WFD

Given the high number of sites with an associated hazard quotient exceeding a value of 1, the mine sites were assigned to three classes, depending on the HQ score, to facilitate their ranking: class I ($HQ_w > 10$), class II ($5 > HQ_w > 2.5$), class III ($2.5 > HQ_w > 1$). There were no data with $10 > HQ_w > 5$. While for a HQ between 1 and 10 some adverse effect or moderate hazard is probable, if HQ exceeds 10, high hazard is anticipated (Finger et al., 2004). There were 37 mine sites related to observed downstream water quality failures. Figure 25 to Figure 27 show the maps of the first (highest) class.

5.2 MINE SITE RANKING BY HAZARD QUOTIENTS IN SEDIMENTS FOR THE PROTECTION OF FRESHWATER ECOSYSTEMS

The mine sites were assigned to class I ($25 > HQ_s > 15$), class II ($15 > HQ_s > 10$), class III ($10 > HQ_s > 5$), class IV ($5 > HQ_s > 1$), depending on the HQ score. There were 126 mine sites associated with Tellus samples with $HQ_s \geq 1$. Figure 25 to Figure 35 show the maps of the first (highest) class.

5.3 POTENTIAL MINE INVENTORY FOR EACH COUNTY

Full list of mine sites ranked by water hazard quotients for each county is reported in Table 1. The list of ranked mine sites by sediment hazard quotients is reported by county in Table 2 to Table 7. The following maps in Figure 14 to Figure 24 show the distribution of mine sites and their risk-based ranking for each county.

5.3.1 COUNTY ANTRIM

Figure 14 and Figure 15 show mine locations included in the present inventory for Co. Antrim. The number for each site references a unique identifier for the study. The mines included in the inventory list are mainly iron and bauxite mines (Figure 38 and Figure 39) from the main iron mining districts in mid and south Co. Antrim, where sub-horizontal stratabound beds of lateritic iron ore and bauxite in the Interbasaltic Formation of the Paleogene Antrim Lava Group were historically exploited. Based on the hazard quotients, the potential for hazards to aquatic life may exist posed by copper in water (class III: 2.5 >tot HQ_w> 1) and by chromium and nickel in sediments (most sites with HQ_s> 5). Ballycastle West in north Co. Antrim, Serse and Glenbuck coal mines and Libbert lignite mine are also listed because of their HQ_s for chromium and nickel.

5.3.2 COUNTY ARMAGH

Figure 16 and Figure 17 show mine locations included in the present inventory for Co. Armagh. The mines included in the list are mainly lead mines (Figure 36 and Figure 37). Historically important veins associated with zinc, copper and barytes, are hosted within Lower Paleozoic sedimentary rocks of the Leadhills Supergroup. Tullynawood Mine has far the highest hazard scores given by iron, cadmium and zinc in water and zinc, nickel and cadmium in the sediments downstream from the mine location. Relatively lower (class III) are those HQ_w for the other mine sites. College Mine, Derrynose, Tullydonnel and Aughnurgan lead mines have the highest HQ_s (>10) from lead, zinc, cadmium, chromium and nickel in the sediments.

5.3.3 BELFAST AND COUNTY DOWN

Figure 18 and Figure 19 show mine locations included in the inventory for Co. Down. The mines included in the list for HQ_w> 1 are Gransha, Deenommed iron ore mines, Knockagore coal mine and Fofannyreagh lead mine. Based on their HQ_s, the following mines are included: lead mines at Conlig and Conlig South in north Co. Down, and Leitrim Hill, Fofannyreagh, Moleylane East and Ballydargan, iron ore mines at Gransha, Deenommed Tullyratty copper and lead mine; and Annacloy, Tullygavan, Maze, and Knockagore coal mines.

5.3.4 COUNTY TYRONE

Figure 20 and Figure 21 show the distribution of mine locations included in the inventory in the county. These are coal mines (Figure 40 and Figure 41) concentrated in the Coalisland Coalfield, historically exploiting late Carboniferous hard coal seams and the Glenlark, Cappagh Copper and Teebane West\Crockanboy lead and copper workings.

5.3.5 COUNTY LONDONDERRY

Figure 22 and Figure 23 show mine locations included in the inventory for Co. Londonderry. Located in the south-west of the county the mines are mostly for iron ore (Figure 38 and Figure 39) working the veins containing hematite, in association with barytes or quartz, hosted by the Slieve Gallion Granite and surrounding volcanic rocks. The sites are mostly associated with the lowest hazard classes both for sediment and water contamination, except for Tintagh iron working (Class I – HQ water for copper, zinc and iron).

5.3.6 COUNTY FERMANAGH

Figure 24 shows a lack of sites belonging to the inventory in the county, except for the Belleek Iron Mine (class IV – HQ sediment) in north-west Co. Fermanagh, where ironstones (hematite) were historically worked.

Table 1 – Site score for mine sites in Northern Ireland, by county, based on total hazard quotients for waters downstream of the mine sites: class I (HQ_w> 10), class II (5 >HQ_w> 2.5), class III (2.5 >HQ_w> 1)

Mine ID Number	MINE GROUP NAME*	Commodity	Easting	Northing	County	Distance (m) mine -Tellus sample	Total_HQw	HQwCd	HQwCu	HQwFe	HQwZn	Class
80	GLENRAVEL EVISHACROW	Iron Ore	317144	419634	Antrim	75	2.51	0.00	2.51	0.00	0.00	III
8	BALLYBADDIN	Iron Ore	313296	426627	Antrim	2700	2.41	0.00	1.27	1.14	0.00	III
95	LISBREEN BACK BURN RATHSHERRY	Iron Ore, Coal	314674	412640	Antrim	220-240	1.85	0.00	1.85	0.00	0.00	III
72	ELGINNY	Bauxite, Iron Ore	316636	409689	Antrim	220-370	1.55	0.00	1.55	0.00	0.00	III
33	CARNAMENAGH	Iron Ore	310677	422143	Antrim	4100	1.46	0.00	1.46	0.00	0.00	III
43	CLONETRACE	Bauxite, Iron Ore	317129	410450	Antrim	60-220	1.40	0.00	1.40	0.00	0.00	III
68	DUNEANY, GLENBUCK	Iron Ore	303084	414253	Antrim	300-800	1.23	0.00	0.00	1.23	0.00	III
51	CROMMELIN TUFTARNEY GLENRAVEL	Bauxite, Iron Ore	315596	419727	Antrim	200	1.22	0.00	1.22	0.00	0.00	III
107	PARKMORE	Iron Ore	318452	420765	Antrim	180-350	1.20	0.00	1.20	0.00	0.00	III
116	TROSTAN	Iron Ore, Bauxite	318520	388181	Antrim	500-700	1.16	0.00	1.16	0.00	0.00	III
114	SKERRY EAST	Bauxite, Iron Ore	313965	419038	Antrim	700-1700	1.11	0.00	1.11	0.00	0.00	III
78	GLENBUCK	Coal	302794	415147	Antrim	700	1.08	0.00	1.08	0.00	0.00	III
23	BANK VIEW	Iron Ore	319590	399532	Antrim	80	1.05	0.00	0.00	1.05	0.00	III
32	CARGAN	Iron Ore, Bauxite	316974	418388	Antrim	180-250	1.00	0.00	1.00	0.00	0.00	III
75	EVISHACROW	Bauxite	317255	418891	Antrim	450-600	1.00	0.00	1.00	0.00	0.00	III
Mine ID Number	MINE GROUP NAME*	Commodity	Easting	Northing	County	Distance (m) mine -Tellus sample	Total_HQw	HQwCd	HQwCu	HQwFe	HQwZn	Class
121	TULLYNAWOOD MINE	Lead	286442	329721	Armagh	1500	17.92	4.88	0.00	11.33	1.71	I
48	CORRINURE PIT	Coal, iron ore, sulphur	298698	332654	Armagh	1400	1.88	1.88	0.00	0.00	0.00	III
6	AUGHNAGURGAN	Lead, Iron Pyrites	286700	331308	Armagh	3000	1.63	1.63	0.00	0.00	0.00	III
55	DARKLEY	Lead	285850	331860	Armagh	2500	1.63	1.63	0.00	0.00	0.00	III
82	GRANEMORE	Lead	288690	332085	Armagh	2900	1.63	1.63	0.00	0.00	0.00	III
66	DRUMNAHONEY	Lead	305945	361375	Armagh	1400	1.53	1.53	0.00	0.00	0.00	III
112	SERSE	Coal	303939	333280	Armagh	2300	1.38	1.38	0.00	0.00	0.00	III

* Source: GSNI Abandoned Mines database of Northern Ireland

Table 1 (continued) – Site score for mine sites in Northern Ireland, by county, based on total hazard quotients for waters downstream of the mine sites: class I (HQ_w> 10), class II (5 >HQ_w> 2.5), class III (2.5 >HQ_w> 1)

Mine ID Number	MINE GROUP NAME*	Commodity	Easting	Northing	County	Distance (m) mine -Tellus sample	Total_HQw	HQwCd	HQwCu	HQwFe	HQwZn	Class
84	GRANSHA DEENOMMED	Iron Ore	324970	343133	Down	1400-1600	3.41	0.00	0.00	1.95	1.46	II
90	KNOCKAGORE	Coal	307998	349897	Down	1300	1.85	0.00	0.00	1.85	0.00	III
76	FOFANNYREAGH	Lead	328062	332258	Down	1700	1.83	0.00	1.83	0.00	0.00	III
Mine ID Number	MINE GROUP NAME*	Commodity	Easting	Northing	County	Distance (m) mine -Tellus sample	Total_HQw	HQwCd	HQwCu	HQwFe	HQwZn	Class
125	TINTAGH	Iron Ore	280314	387714	Londonderry	1000	16.03	0.00	9.09	1.57	5.37	I
58	DERRYNOYD	Barytes	275637	395488	Londonderry	1000	1.28	0.00	1.28	0.00	0.00	III
35	CARNDAISY TIRGAN	Iron Ore	282233	387369	Londonderry	1360	1.17	0.00	0.00	1.17	0.00	III
56	DERRYGANARD	Iron Ore	279712	386280	Londonderry	1000	1.14	0.00	1.14	0.00	0.00	III
Mine ID Number	MINE GROUP NAME*	Commodity	Easting	Northing	County	Distance (m) mine -Tellus sample	Total_HQw	HQwCd	HQwCu	HQwFe	HQwZn	Class
106	NORTH DUNGANNON	Coal	280576	364795	Tyrone	220-620	16.98	0.00	0.00	16.98	0.00	I
30	CAPPAGH COPPER	Copper	267506	367455	Tyrone	4500-5600	4.27	0.00	1.97	0.00	2.30	II
44	COALISLAND NORTH	Coal, Deep	284188	367420	Tyrone	nd	4.20	0.00	4.20	0.00	0.00	II
79	GLENLARK	Lead	259991	389451	Tyrone	300-1400	3.07	0.00	1.74	1.33	0.00	II
0	AGHAK INSALLAGH GLEBE	Coal	282766	364298	Tyrone	370	2.17	0.00	0.00	2.17	0.00	III
115	TEEBANE	Lead, Iron Pyrites	257799	383374	Tyrone	850	1.55	0.00	1.55	0.00	0.00	III
64	DRUMENAGHER	Coal	285295	361375	Tyrone	2700	1.38	1.38	0.00	0.00	0.00	III
29	CAPPAGH	Copper	267506	367455	Tyrone	4400 - 5600	1.02	0.00	1.02	0.00	0.00	III

* Source: GSNI Abandoned Mines database of Northern Ireland

Table 2 – Mine sites ranked based on sum of hazard quotients for sediments downstream of the mine sites in Co. Antrim: class I (25>HQ_s>15), class II (15 >HQ_s> 10), class III (10 >HQ_s> 5), class IV (5 >HQ_s> 1)

Mine ID Number	MINE GROUP NAME*	Commodity	Easting	Northing	County	Distance (m) mine -Tellus sample	Total_HQs	HQs_Cd	HQs_Cr	HQs_Ni	HQs_Pb	HQs_Zn	Class
113	SHANES HILL	Iron Ore	333247	398672	Antrim	900	20.3	0.0	12.4	7.9	0.0	0.0	I
86	HIGHTOWN	Iron Ore	333339	399364	Antrim	800-1000	20.2	0.0	12.7	7.5	0.0	0.0	I
7	BALLY BRACKEN	Iron Ore	333319	396286	Antrim	3600	19.2	0.0	13.8	5.4	0.0	0.0	I
51	CROMMELIN,	Bauxite, Iron Ore	315596	419727	Antrim	200	15.9	0.0	6.8	7.8	0.0	1.2	I
93	LIBBERT	Lignite	331265	413711	Antrim	500-800	15.8	0.0	8.6	7.2	0.0	0.0	I
99	LOWTOWN	Iron Ore	335549	400220	Antrim	700	15.7	0.0	8.7	7.0	0.0	0.0	I
21	BALLYVADDY	Iron Ore	328360	412985	Antrim	1500 - 1700	14.9	0.0	8.5	6.3	0.0	0.0	II
117	TUFTARNEY GLENRAVEL	Iron Ore, Bauxite	316072	419408	Antrim	900-1000	14.8	0.0	6.6	8.2	0.0	0.0	II
13	BALLYCASTLEWEST	Coal, Iron Ore, Bauxite	303714	443595	Antrim	120 - 130	14.7	0.0	6.9	7.8	0.0	0.0	II
10	BALLYBOLEY	Iron Ore	332709	397239	Antrim	250-350	14.6	0.0	8.3	6.3	0.0	0.0	II
36	CARNLOUGH	Iron Ore	325963	417911	Antrim	100-400	14.3	0.0	5.2	5.8	1.1	2.2	II
71	EAGLE CRAIG EAST	Iron Ore	326691	417700	Antrim	1000	14.2	0.0	7.9	6.3	0.0	0.0	II
124	WHITEHALL	Iron Ore	326958	417307	Antrim	1000-1300	14.2	0.0	7.9	6.3	0.0	0.0	II
80	GLENRAVEL	Iron Ore	317144	419674	Antrim	75	13.9	0.0	6.2	7.7	0.0	0.0	II
114	SKERRY EAST	Bauxite, Iron Ore	313965	419038	Antrim	700-1700	13.9	0.0	7.2	6.8	0.0	0.0	II
77	GLEBE	Iron Ore	329463	413173	Antrim	300	13.9	0.0	8.3	5.6	0.0	0.0	II
96	LONGFIELD	Iron Ore	329527	412799	Antrim	500	13.9	0.0	8.3	5.6	0.0	0.0	II
85	GREENAGHAN	Iron Ore, Bauxite	324038	422406	Antrim	615	13.7	0.0	6.6	7.1	0.0	0.0	II
32	CARGAN	Iron Ore, Bauxite	316974	418388	Antrim	180-250	13.5	0.0	6.0	6.4	1.1	0.0	II
75	EVISHACROW	Bauxite	317255	418891	Antrim	450-600	13.5	0.0	6.0	6.4	1.1	0.0	II
107	PARKMORE	Iron Ore	318452	420765	Antrim	180-350	13.0	0.0	4.6	7.1	0.0	1.3	II
81	GLENRIFF	Iron Ore	321108	419703	Antrim	350-3000	12.8	0.0	4.7	6.8	0.0	1.2	II
8	BALLYBADDIN	Iron Ore	313296	426627	Antrim	1500	12.6	0.0	5.1	7.5	0.0	0.0	II
68	DUNEANY GLENBUCK	Iron Ore	303084	414253	Antrim	300-800	12.6	0.0	6.5	6.1	0.0	0.0	II
111	RORY'S GLEN	Iron Ore	336282	400929	Antrim	1500	12.6	0.0	7.1	5.4	0.0	0.0	II
69	DUNGONNEL CARGAN	Iron Ore	318265	417161	Antrim	900-2000	12.1	0.0	5.7	5.4	0.0	1.1	II
19	BALLYLIG	Bauxite, Iron Ore	318066	409508	Antrim	660 - 880	12.1	0.0	6.8	5.3	0.0	0.0	II

* Source: GSNI Abandoned Mines database of Northern Ireland

Table 2 (continued) – Mine sites ranked based on sum of hazard quotients for sediments downstream of the mine sites in Co. Antrim: class I (25 >HQ_s> 15), class II (15 >HQ_s> 10), class III (10 >HQ_s> 5), class IV (5 >HQ_s> 1)

Mine ID Number	MINE GROUP NAME*	Commodity	Easting	Northing	County	Distance (m) mine -Tellus sample	Total_HQs	HQs_Cd	HQs_Cr	HQs_Ni	HQs_Pb	HQs_Zn	Class
116	TROSTAN	Bauxite, Iron Ore	318520	388181	Antrim	225 - 270	12.1	0.0	5.1	7.0	0.0	0.0	II
23	BANK VIEW	Iron Ore	319590	399532	Antrim	80	11.9	0.0	5.6	6.3	0.0	0.0	II
33	CARNAMENAGH	Iron Ore	310677	422143	Antrim	4100	11.7	0.0	6.4	5.3	0.0	0.0	II
112	SERSE	Coal	318452	420765	Antrim	90	11.7	0.0	1.2	2.9	1.3	2.4	II
11	BALLYBRACKEN	Iron Ore	333319	396286	Antrim	300	11.6	0.0	7.5	4.2	0.0	0.0	II
52	CULLINANE	Bauxite, Iron Ore	327114	414502	Antrim	900 - 1000	11.2	0.0	6.2	5.0	0.0	0.0	II
59	DOONAN	Bauxite, Iron Ore	327266	413728	Antrim	1300	11.2	0.0	6.2	5.0	0.0	0.0	II
26	BERK HILL	Iron Ore	310991	407727	Antrim	2900	11.1	0.0	6.0	5.1	0.0	0.0	II
17	BALLYGILBERT	Iron Ore	333429	409978	Antrim	1600-1800	10.8	0.0	5.6	5.3	0.0	0.0	III
4	ARDCLINNIS	Iron Ore	327128	424258	Antrim	500 - 800	10.7	0.0	5.3	5.4	0.0	0.0	III
74	ESLERSTONE CROSS	Iron Ore	317028	399831	Antrim	800	10.6	0.0	4.6	6.0	0.0	0.0	III
104	MOUNT CASHEL MINES	Iron Ore	316449	415128	Antrim	800-1000	10.6	0.0	5.3	5.3	0.0	0.0	III
95	LISBREEN BACK BURN, RATHSHERRY	Iron Ore, Coal	314674	412640	Antrim	220-240	10.2	0.0	5.3	4.9	0.0	0.0	III
78	GLENBUCK	Coal	302794	415147	Antrim	700	9.8	0.0	5.2	4.6	0.0	0.0	III
109	RATHKENNY	Iron Ore, Lignite	312682	411299	Antrim	1300-1600	9.8	0.0	4.5	5.3	0.0	0.0	III
43	CLONETRACE	Bauxite, Iron Ore	317129	410450	Antrim	60-220	9.8	0.0	4.5	5.3	0.0	0.0	III
34	CARNCROAGH	Iron Ore	312508	409715	Antrim	790	9.6	0.0	4.7	4.9	0.0	0.0	III
72	ELGINNY	Bauxite, Iron Ore	316636	409689	Antrim	220-370	9.5	0.0	4.3	5.1	0.0	0.0	III
97	LOUGHCONNELLY	Iron Ore	319420	410065	Antrim	1100	9.4	0.0	4.3	5.1	0.0	0.0	III
110	RIGG MOSS	Iron Ore	342407	395890	Antrim	1500-1800	9.3	0.0	5.5	3.9	0.0	0.0	III
14	BALLYCLOGHAN	Bauxite	313780	408734	Antrim	1200	9.3	0.0	4.5	4.8	0.0	0.0	III
22	BALYRICKARD BEG	Iron Ore	337868	398402	Antrim	1500	9.3	0.0	5.2	4.0	0.0	0.0	III
18	BALLYHARTFIELD, BALLYMARTIN	Iron Ore	325648	386960	Antrim	1000 - 1700	9.3	0.0	5.1	4.2	0.0	0.0	III
87	IRISH HILL STRAID	Bauxite, Iron Ore	333424	390781	Antrim	350-400	9.2	0.0	4.8	4.4	0.0	0.0	III
94	LISBREEN BACK BURN	Iron Ore	314674	412640	Antrim	400	8.9	0.0	4.5	4.4	0.0	0.0	III

* Source: GSNI Abandoned Mines database of Northern Ireland

Table 2 (continued) – Mine sites ranked based on sum of hazard quotients for sediments downstream of the mine sites in Co. Antrim: class I (25 >HQ$_s$> 15), class II (15 >HQ$_s$> 10), class III (10 >HQ$_s$> 5), class IV (5 >HQ$_s$> 1)

Mine ID Number	MINE GROUP NAME*	Commodity	Easting	Northing	County	Distance (m) mine -Tellus sample	Total_HQs	HQs_Cd	HQs_Cr	HQs_Ni	HQs_Pb	HQs_Zn	Class
12	BALLYBADDIN	Iron Ore	313296	426627	Antrim	5200	8.7	0.0	4.6	4.1	0.0	0.0	III
118	TULLY	Iron Ore	315357	399998	Antrim	760	8.6	0.0	4.2	4.4	0.0	0.0	III
28	BRECKAGH	Iron Ore	320406	411166	Antrim	800	8.5	0.0	4.1	4.4	0.0	0.0	III
9	BALLYBARNISH	Bauxite, Lateritic Iron Ore	324934	383473	Antrim	280 - 1275	8.2	0.0	3.9	4.3	0.0	0.0	III
101	LYLES HILL	Bauxite, Lateritic Iron Ore	324768	382902	Antrim	835 - 1300	8.2	0.0	3.9	4.3	0.0	0.0	III
62	DRUMASOLE, CARRIVE	Iron Ore	327846	421233	Antrim	1100	8.0	0.0	3.7	4.2	0.0	0.0	III
15	BALLYCRAIG AHULLIER	Bauxite, Lateritic Iron Ore	288456	439216	Antrim	855 - 960	7.5	0.0	3.4	4.1	0.0	0.0	III
42	CLEGNAGH	Bauxite, Iron Ore	302759	443652	Antrim	130	6.9	0.0	3.2	3.7	0.0	0.0	III
123	UNSHINAGH	Iron Ore	326619	415668	Antrim	135 - 375	5.8	0.0	2.5	3.3	0.0	0.0	III
49	CRAIGAROGAN	Iron Ore	327130	381658	Antrim	1000	5.8	0.0	3.1	2.7	0.0	0.0	III
73	ESSATHOHAN,	Bauxite	319026	421993	Antrim	50	5.1	0.0	2.3	2.8	0.0	0.0	III
70	DUNLUCE GLENTASK	Iron Ore	291165	441120	Antrim	110 - 240	4.5	0.0	2.2	2.3	0.0	0.0	IV

* Source: GSNI Abandoned Mines database of Northern Ireland

Table 3 – Mine sites ranked based on sum of hazard quotients for sediments downstream of the mine sites in Co. Armagh: (25 >HQ$_s$> 15), class II (15 >HQ$_s$> 10), class III (10 >HQ$_s$> 5), class IV (5 >HQ$_s$> 1)

Mine ID Number	MINE GROUP NAME*	Commodity	Easting	Northing	County	Distance (m) mine -Tellus sample	Total_HQs	HQs_Cd	HQs_Cr	HQs_Ni	HQs_Pb	HQs_Zn	Class
45	COLLEGE MINE	Lead	280700	333271	Armagh	250-340	20.1	0.0	2.0	3.1	12.4	1.4	I
121	TULLYNAWOOD MINE	Lead	286442	329721	Armagh	1500	17.3	4.6	2.9	4.9	0.0	7.7	I
57	DERRYNOOSE	Lead	279752	331682	Armagh	350-800	12.2	0.0	2.3	2.3	3.2	2.6	II
119	TULLYDONNELL	Copper	297698	315810	Armagh	1200	12.2	1.3	1.5	2.9	1.3	2.4	II
48	CORRINURE PIT	Coal, iron ore, sulphur	298698	332654	Armagh	1400	10.8	1.8	1.4	2.8	1.4	2.4	III
6	AUGHNURGAN	Lead, Iron Pyrites	286700	331334	Armagh	115-180	10.2	4.7	2.2	2.1	1.7	4.3	III
60	DRUMALTNAMUCK	Lead	294212	322538	Armagh	150-500	9.6	0.0	1.9	2.5	0.0	1.1	III
50	CREGGAN	Lead	293810	316986	Armagh	500-850	9.0	0.0	1.5	2.8	0.0	1.3	III

* Source: GSNI Abandoned Mines database of Northern Ireland

Table 3 (continued) – Mine sites ranked based on sum of hazard quotients for sediments downstream of the mine sites in Co. Armagh: class I (25 >HQ_s> 15), class II (15 >HQ_s> 10), class III (10 >HQ_s> 5), class IV (5 >HQ_s> 1)

Mine ID Number	MINE GROUP NAME*	Commodity	Easting	Northing	County	Distance (m) mine -Tellus sample	Total_HQs	HQs_Cd	HQs_Cr	HQs_Ni	HQs_Pb	HQs_Zn	Class
108	RACARBRY	Lead	285450	333994	Armagh	1100	8.7	0.0	2.0	2.8	2.0	1.8	III
31	CARGACLOGHER	Lead	284565	332859	Armagh	700-800	8.3	0.0	2.3	3.0	0.0	1.5	III
63	DRUMBANAGHER	Coal	305945	335398	Armagh	2700	7.0	0.0	1.5	2.7	0.0	1.3	III
89	KILCALM MINE	Lead	282167	330343	Armagh	960	7.0	0.0	2.2	2.3	1.4	1.1	III
82	GRANEMORE	Lead	288690	332085	Armagh	1000	6.5	1.2	1.8	2.2	0.0	1.5	III
38	CARRICKGALLOGLY	Lead	298390	328963	Armagh	2600	6.1	0.0	1.7	1.6	0.0	1.2	III
66	DRUMNAHONEY	Lead	305945	361375	Armagh	1900	6.1	0.0	1.7	1.6	0.0	1.2	III
41	CLAY	Lead	282838	331053	Armagh	2700-2900	6.0	0.0	0.0	3.0	0.0	1.5	III
55	DARKLEY	Lead	285850	331860	Armagh	1200-1300	5.2	0.0	1.8	2.1	0.0	1.2	III
39	CARRICKLANE	Coal	295351	338735	Armagh	1000	5.0	0.0	1.7	2.2	0.0	0.0	III
65	DRUMGAR,	Coal Trials	282236	344390	Armagh	770 - 800	3.9	0.0	2.2	1.6	0.0	0.0	IV
40	CAVANAGARVAN PIT	Coal	280701	335265	Armagh	840	3.6	0.0	2.3	0.0	0.0	0.0	IV
5	ARDRESS WEST	Iron Ore	290254	355623	Armagh	400	3.5	0.0	1.5	1.9	0.0	0.0	IV

* Source: GSNI Abandoned Mines database of Northern Ireland

Table 4 – Mine sites ranked based on sum of hazard quotients for sediments downstream of the mine sites in Co. Down: class I (25>HQ_s>15), class II (15 >HQ_s> 10), class III (10 >HQ_s> 5), class IV (5 >HQ_s> 1)

Mine ID Number	MINE GROUP NAME*	Commodity	Easting	Northing	County	Distance (m) mine -Tellus sample	Total_HQs	HQs_Cd	HQs_Cr	HQs_Ni	HQs_Pb	HQs_Zn	Class
46	CONLIG	Lead	349170	377732	Down	750	12.2	0.0	1.9	3.2	5.1	2.0	II
84	GRANSHA,	Iron Ore	324970	343133	Down	1300-1400	10.9	0.0	6.1	4.8	0.0	0.0	III
47	CONLIG SOUTH	Lead	349322	376316	Down	1000-1500	8.6	0.0	2.5	4.3	0.0	1.8	III
91	LEITRIM HILL	Lead	329744	317476	Down	250	6.7	0.0	1.6	1.9	1.3	2.0	III
1	ANNACLOY	Coal	322868	360473	Down	600	5.8	0.0	2.6	1.9	1.3	0.0	III
120	TULLYGAVAN	Coal	341349	363497	Down	160-250	5.3	0.0	2.0	2.1	0.0	0.0	III
76	FOFANNYREAGH	Lead	328062	332258	Down	300	4.8	0.0	1.7	2.1	0.0	1.0	IV

* Source: GSNI Abandoned Mines database of Northern Ireland

Table 4 (continued) – Mine sites ranked based on sum of hazard quotients for sediments downstream of the mine sites in Co. Down: class I (25>HQ_s>15), class II (15 >HQ_s> 10), class III (10 >HQ_s> 5), class IV (5 >HQ_s> 1)

Mine ID Number	MINE GROUP NAME*	Commodity	Easting	Northing	County	Distance (m) mine -Tellus sample	Total_HQs	HQs_Cd	HQs_Cr	HQs_Ni	HQs_Pb	HQs_Zn	Class
103	MONEYLANE EAST	Lead	339169	336304	Down	350	4.8	0.0	1.9	1.7	0.0	0.0	IV
102	MAZE	Coal	321956	361464	Down	1200	4.2	0.0	2.3	1.9	0.0	0.0	IV
90	KNOCKAGORE	Coal	307998	349897	Down	1300	3.8	0.0	1.9	1.9	0.0	0.0	IV
122	TULLYRATTY	Copper, Lead	356563	348520	Down	1100	3.4	0.0	1.9	1.5	0.0	0.0	IV
16	BALLYDARGAN	Iron Pyrites, Lead	349269	338753	Down	470	3.1	0.0	1.9	1.2	0.0	0.0	IV

* Source: GSNI Abandoned Mines database of Northern Ireland

Table 5 – Mine sites ranked based on sum of hazard quotients for sediments downstream of the mine sites in Co. Fermanagh: class I (25>HQ_s>15), class II (15 >HQ_s> 10), class III (10 >HQ_s> 5), class IV (5 >HQ_s> 1)

Mine ID Number	MINE GROUP NAME*	Commodity	Easting	Northing	County	Distance (m) mine -Tellus sample	Total_HQs	HQs_Cd	HQs_Cr	HQs_Ni	HQs_Pb	HQs_Zn	Class
25	BELLEEK	Iron Ore	194624	359419	Fermanagh	600	1.2	0.0	0.0	1.2	0.0	0.0	IV

* Source: GSNI Abandoned Mines database of Northern Ireland

Table 6 – Mine sites ranked based on sum of hazard quotients for sediments downstream of the mine sites in Co. Londonderry: class I (25 >HQ_s> 15), class II (15 >HQ_s> 10), class III (10 >HQ_s> 5), class IV (5 >HQ_s> 1)

Mine ID Number	MINE GROUP NAME*	Commodity	Easting	Northing	County	Distance (m) mine -Tellus sample	Total_HQs	HQs_Cd	HQs_Cr	HQs_Ni	HQs_Pb	HQs_Zn	Class
88	ISLANDMORE AREA	Iron Ore	287558	437370	Londonderry	1300 - 1400	6.2	0.0	3.2	3.0	0.0	0.0	III
67	DUNARNON	Iron Ore	288695	389938	Londonderry	3500	5.7	0.0	2.7	3.1	0.0	0.0	III
125	TINAGH	Iron Ore	280474	387714	Londonderry	640	4.4	0.0	2.3	1.0	0.0	0.0	IV
53	CULLION	Coal	281595	391330	Londonderry	1100	4.3	0.0	2.5	1.9	0.0	0.0	IV
92	LETTERAN, STRAW	Iron Ore	279135	389314	Londonderry	1300	4.3	0.0	1.5	1.1	0.0	0.0	IV
54	CULLION 2	Coal	282698	391755	Londonderry	675	4.1	0.0	2.5	1.6	0.0	0.0	IV
58	DERRYNOYD	Barytes	275637	395488	Londonderry	1000	3.5	0.0	1.7	1.8	0.0	0.0	IV
61	DRUMARD	Iron Ore	280114	393600	Londonderry	680 - 1100	2.7	0.0	1.2	1.5	0.0	0.0	IV

* Source: GSNI Abandoned Mines database of Northern Ireland

Table 6 (continued) – Mine sites ranked based on sum of hazard quotients for sediments downstream of the mine sites in Co. Londonderry: class I (25 >HQ_s> 15), class II (15 >HQ_s> 10), class III (10 >HQ_s> 5), class IV (5 >HQ_s> 1)

Mine ID Number	MINE GROUP NAME*	Commodity	Easting	Northing	County	Distance (m) mine -Tellus sample	Total_HQs	HQs_Cd	HQs_Cr	HQs_Ni	HQs_Pb	HQs_Zn	Class
27	BRACKAGH SLEIVE	Iron Ore	281411	388233	Londonderry	1400	1.4	0.0	0.0	0.0	0.0	0.0	IV
35	CARNDAISY TIRGAN	Iron Ore	282233	387369	Londonderry	180-550	1.4	0.0	0.0	0.0	0.0	0.0	IV
56	DERRYGANARD	Iron Ore	279712	386280	Londonderry	4400	1.1	0.0	1.1	0.0	0.0	0.0	IV

* Source: GSNI Abandoned Mines database of Northern Ireland

Table 7 – Mine sites ranked based on sum of hazard quotients for sediments downstream of the mine sites in Co. Tyrone: class I (25 >HQ_s> 15), class II (15 >HQ_s> 10), class III (10 >HQ_s> 5), class IV (5 >HQ_s> 1)

Mine ID Number	MINE GROUP NAME*	Commodity	Easting	Northing	County	Distance (m) mine -Tellus sample	Total_HQs	HQs_Cd	HQs_Cr	HQs_Ni	HQs_Pb	HQs_Zn	Class
0	AGHAK INSALLAGH	Coal	282766	364298	Tyrone	400-800	7.8	0.0	3.3	0.0	3.1	0.0	III
3	ANNAGHONE	Coal	285144	373466	Tyrone	1500 - 2500	7.5	0.0	3.3	4.2	0.0	0.0	III
44	COALSLAND NORTH	Coal	284188	367420	Tyrone	1100-2000	5.6	0.0	3.7	1.9	0.0	0.0	III
79	GLENLARK	Lead	259991	389451	Tyrone	300-1400	5.2	0.0	0.0	1.0	0.0	0.0	III
29	CAPPAGH	Copper	267506	367455	Tyrone	4400 - 5600	4.7	0.0	3.7	1.0	0.0	0.0	IV
64	DRUMENAGH	Coal	285295	361375	Tyrone	700	4.6	0.0	1.7	1.0	1.9	0.0	IV
115	TEEBANE	Lead, Iron Pyrites	257799	383374	Tyrone	850	3.9	0.0	1.0	1.3	0.0	0.0	IV
2	ANNAGHER	Coal	284188	367420	Tyrone	1100-2400	3.2	0.0	2.2	1.0	0.0	0.0	IV
24	BARROW	Iron Ore	279497	380526	Tyrone	2400	3.1	0.0	1.6	1.5	0.0	0.0	IV
105	MULLAGHMORE	Coal	278410	364346	Tyrone	930	3.0	0.0	1.6	1.4	0.0	0.0	IV
30	CAPPAGH COPPER	Copper	267506	367455	Tyrone	900	2.1	0.0	2.1	0.0	0.0	0.0	IV
106	NORTH DUNGANNON	Coal	280576	364795	Tyrone	150-530	1.9	0.0	1.9	0.0	0.0	0.0	IV
20	BALLYMENAGH	Coal	281387	366334	Tyrone	1170	1.5	0.0	1.5	0.0	0.0	0.0	IV
98	LOWER CULLION	Coal	281395	366305	Tyrone	1200	1.5	0.0	1.5	0.0	0.0	0.0	IV

* Source: GSNI Abandoned Mines database of Northern Ireland

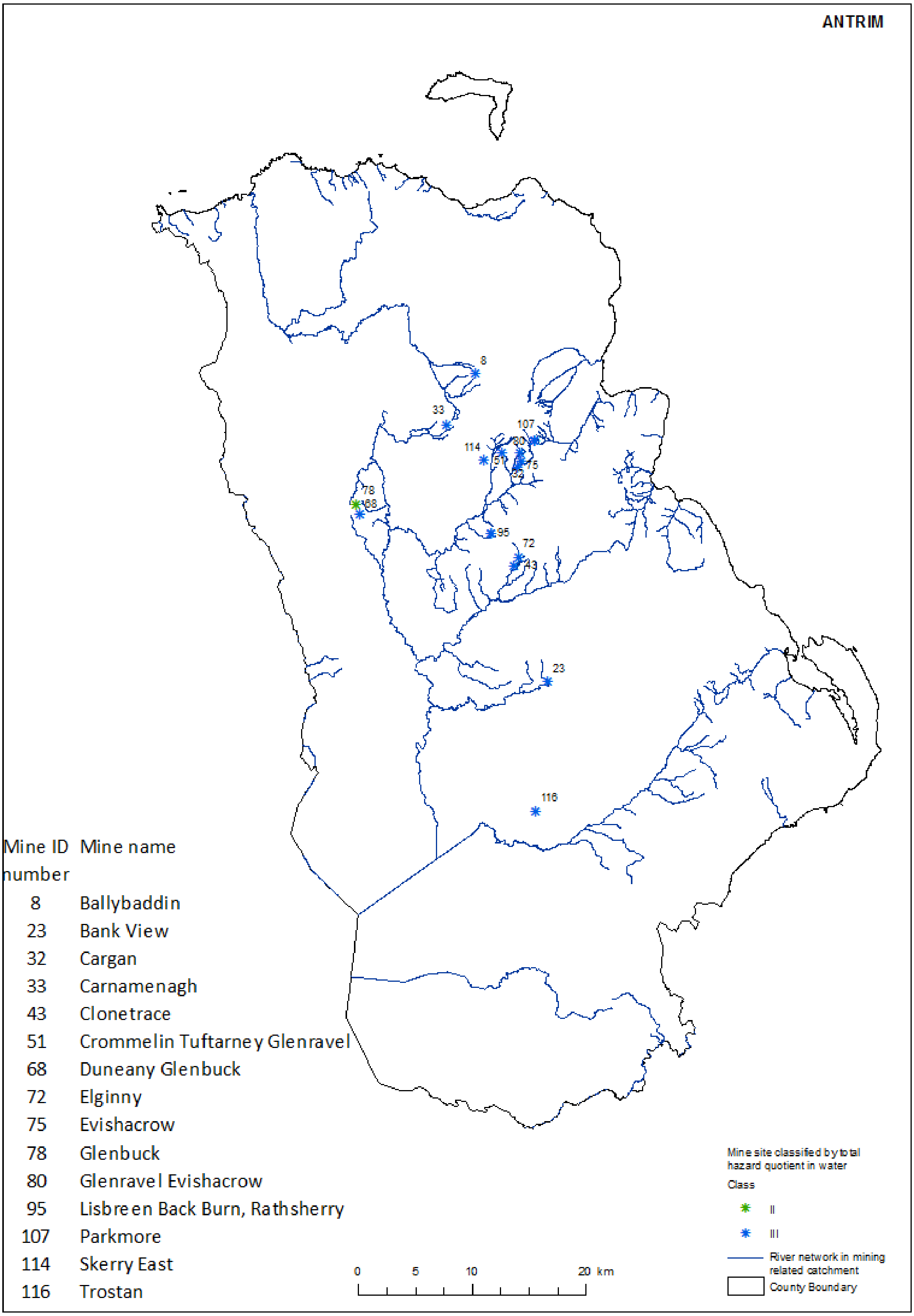

Figure 14 - Co. Antrim: map of mine sites assigned to hazard classes representing the potential for adverse effects to riverine ecology posed by contaminants <u>in water</u>; ranking based on the Total Hazard Quotient measured in Tellus water samples, class I (HQ_w>10), class II (5 >HQ_w >2.5), class III (2.5 >HQ_w >1).

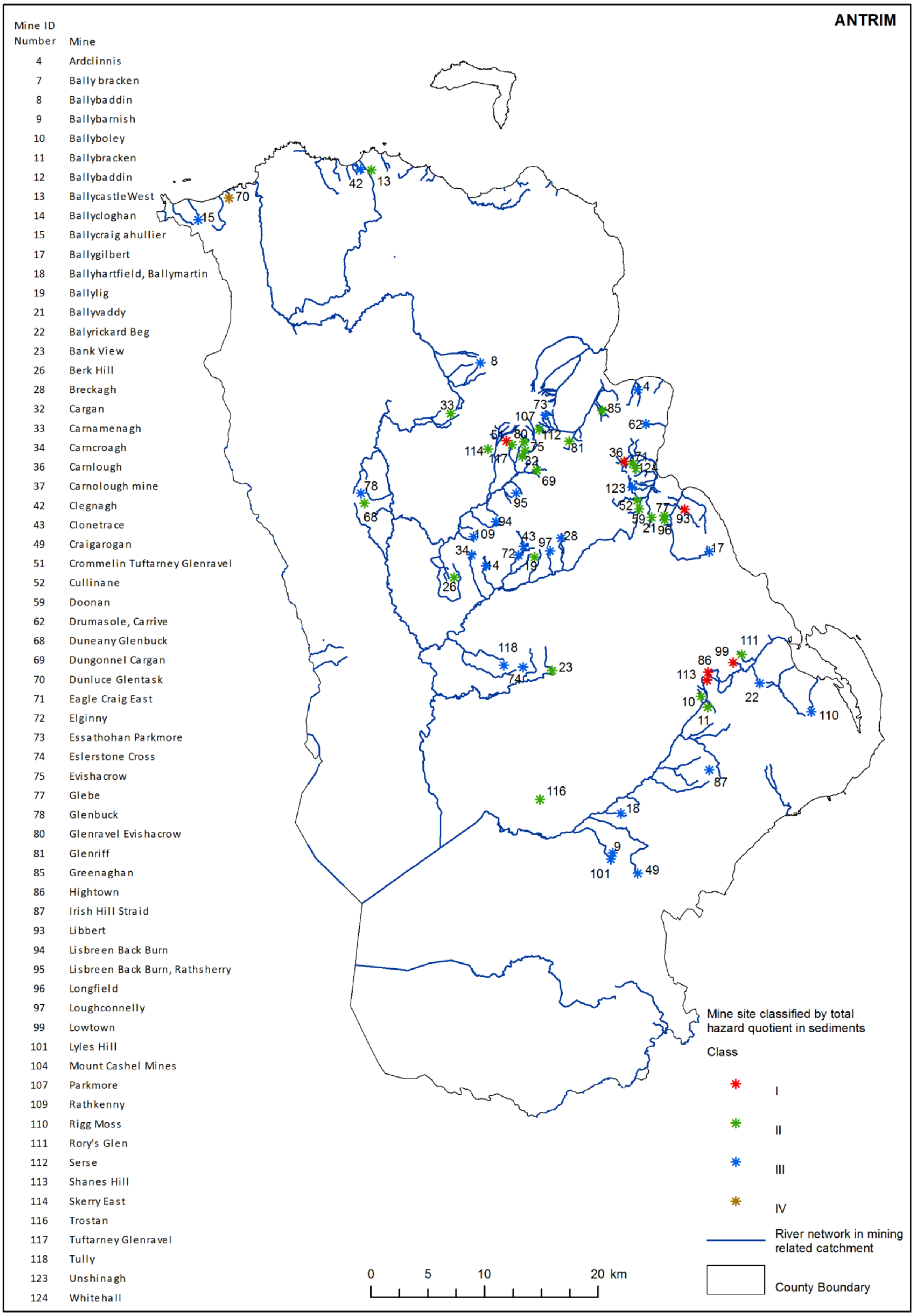

Figure 15 - Co. Antrim: map of mine sites assigned to hazard classes representing the potential for adverse effects to riverine ecology posed by contaminants in sediments; ranking based on the Total Hazard Quotient measured in Tellus sediment samples, class I (25>HQ$_s$>15), class II (15 >HQ$_s$ >10), class III (10 >HQ$_s$ >5), class IV (5 >HQ$_s$ >1).

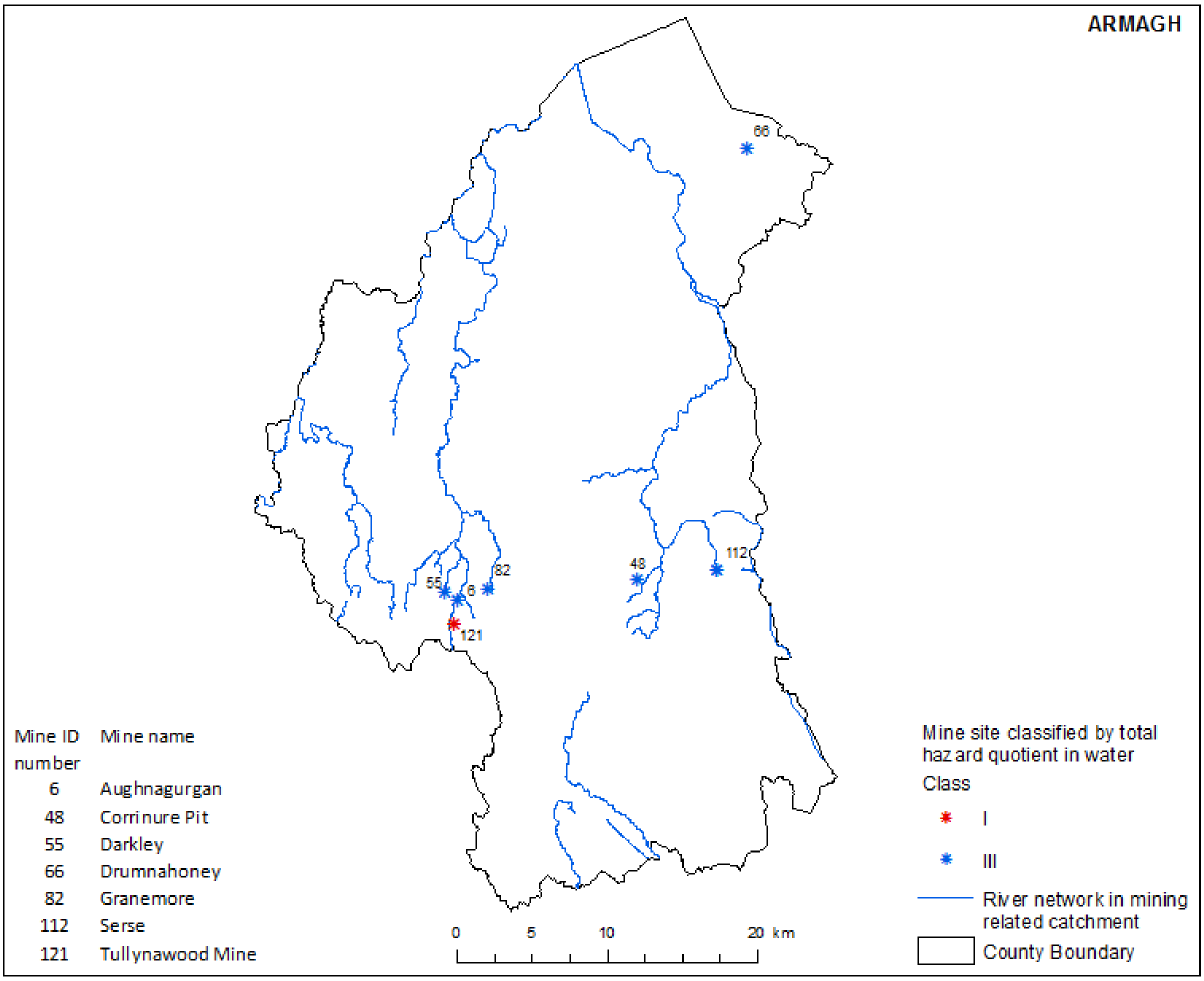

Figure 16 - Co. Armagh: map of mine sites assigned to hazard classes representing the potential for adverse effects to riverine ecology posed by contaminants in <u>water</u>; ranking based on the Total Hazard Quotient measured in Tellus water samples, class I (HQ_w>10), class II (5 >HQ_w >2.5), class III (2.5 >HQ_w >1).

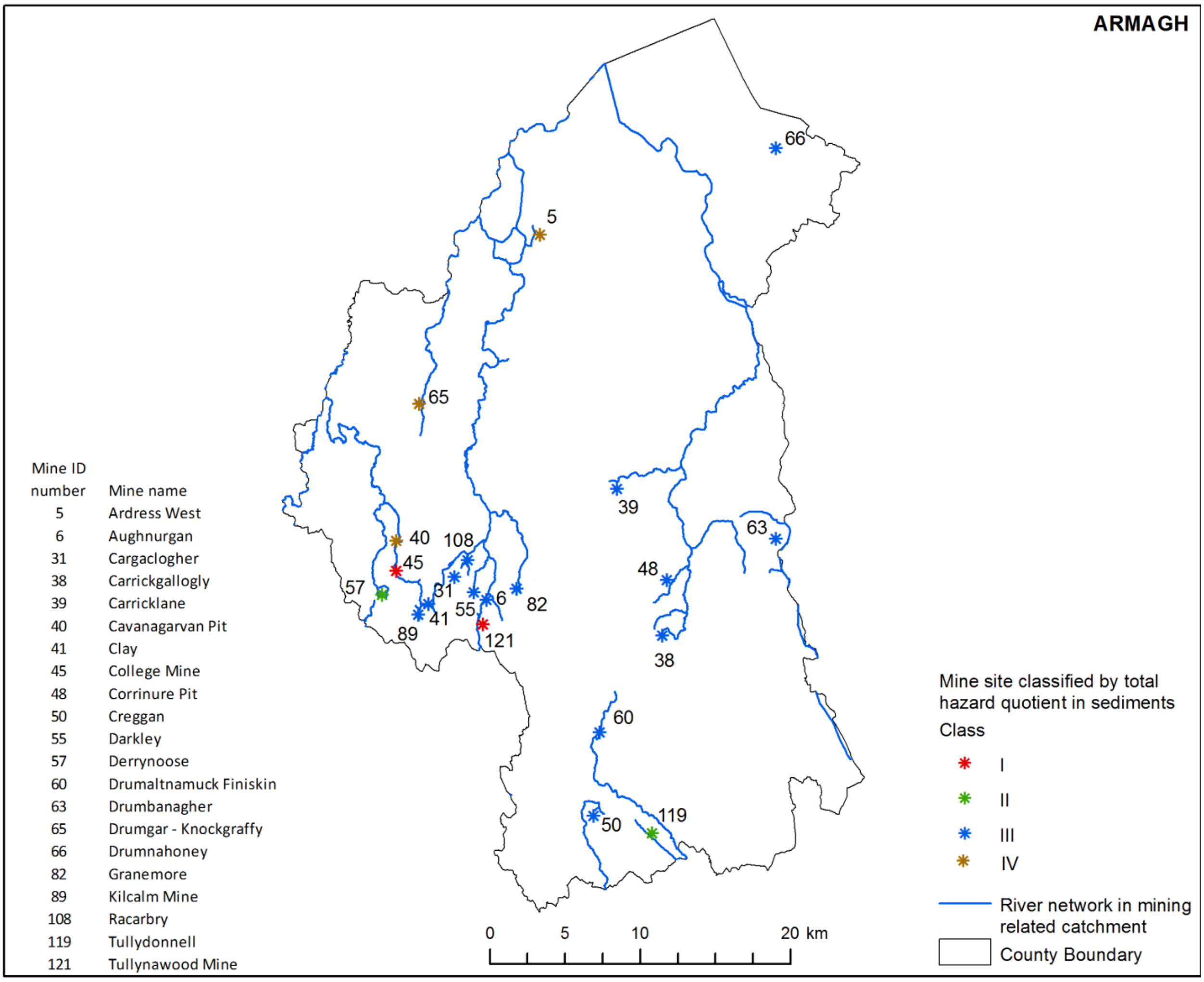

Figure 17 - Co. Armagh: map of mine sites assigned to hazard classes representing the potential for adverse effects to riverine ecology posed by contaminants in <u>sediments</u>; ranking based on the Total Hazard Quotient measured in Tellus sediment samples, class I (25>HQ>15), class II (15 >HQw >10), class III (10 >HQw >5), class IV (5 >HQw >1).

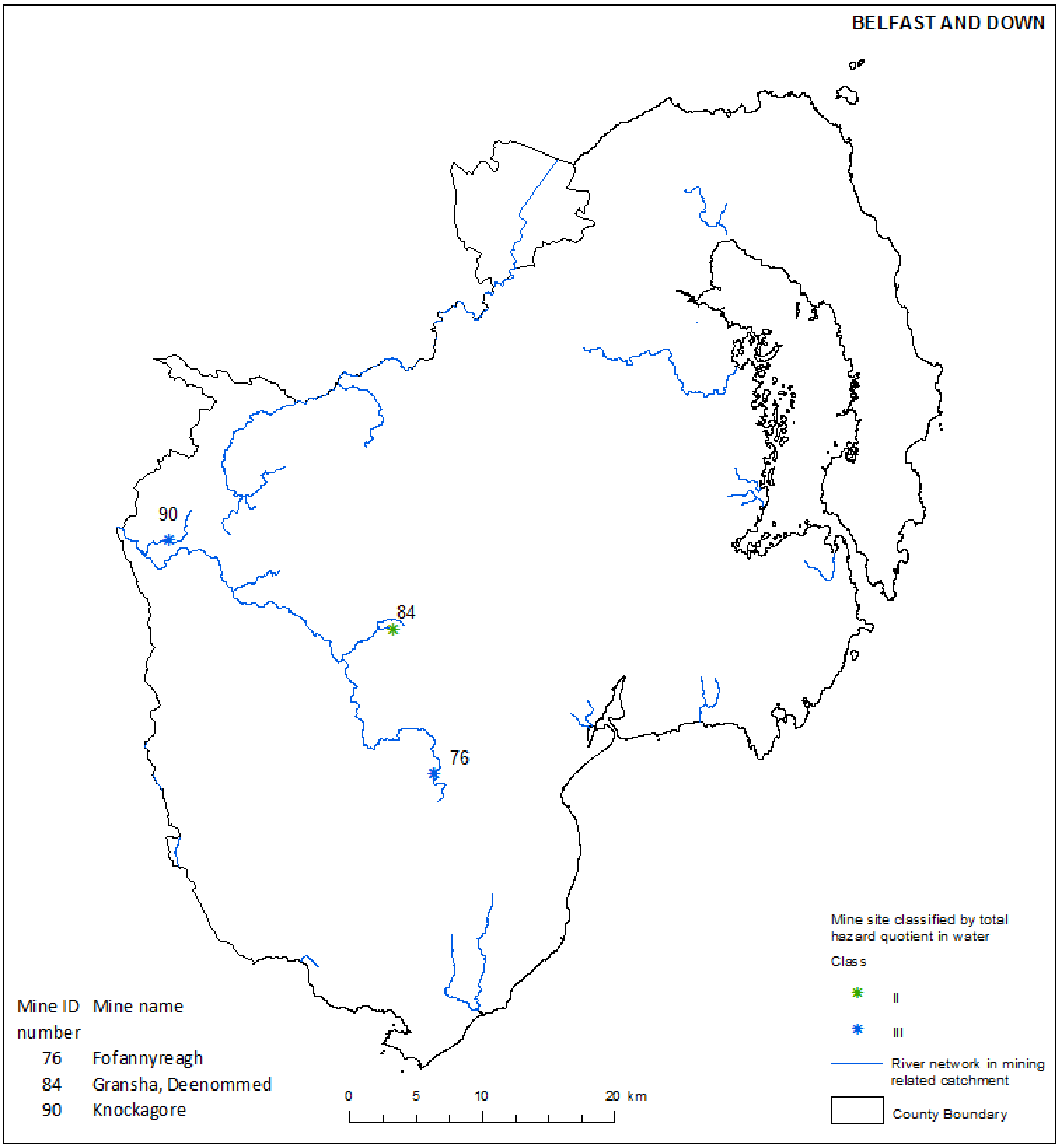

Figure 18 - Belfast and Co. Down: map of mine sites assigned to hazard classes representing the potential for adverse effects to riverine ecology posed by contaminants in <u>water</u>; ranking based on the Total Hazard Quotient measured in Tellus water samples, class I (HQ_w>10), class II (5 >HQ_w >2.5), class III (2.5 >HQ_w >1).

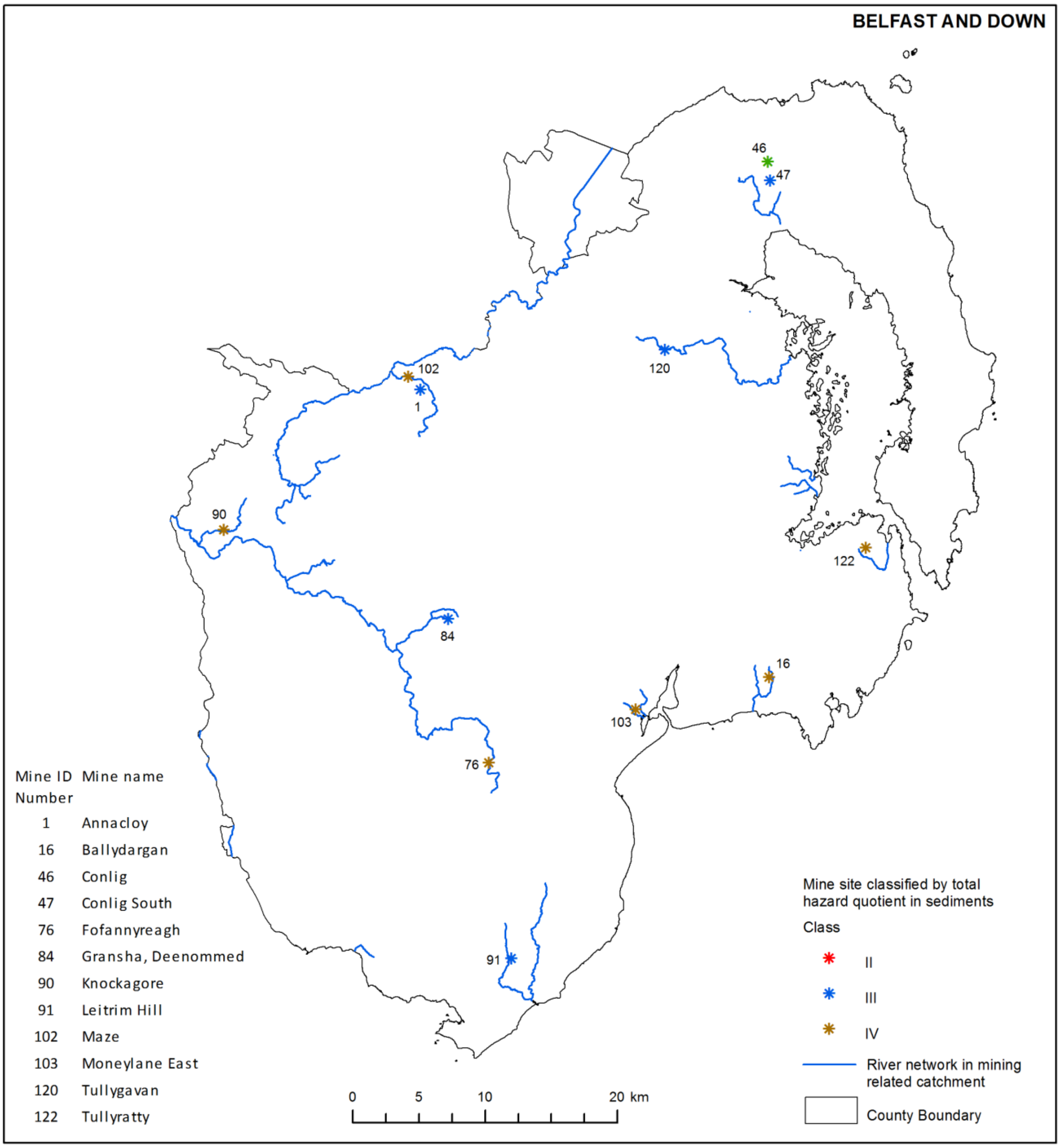

Figure 19 - Belfast and Down: map of mine sites assigned to hazard classes representing the potential for adverse effects to riverine ecology posed by contaminants in <u>sediments</u>; ranking based on the Total Hazard Quotient measured in Tellus sediment samples, class I ($25>HQ_s>15$), class II ($15 >HQ_s >10$), class III ($10 >HQ_s >5$), class IV ($5 >HQ_s >1$).

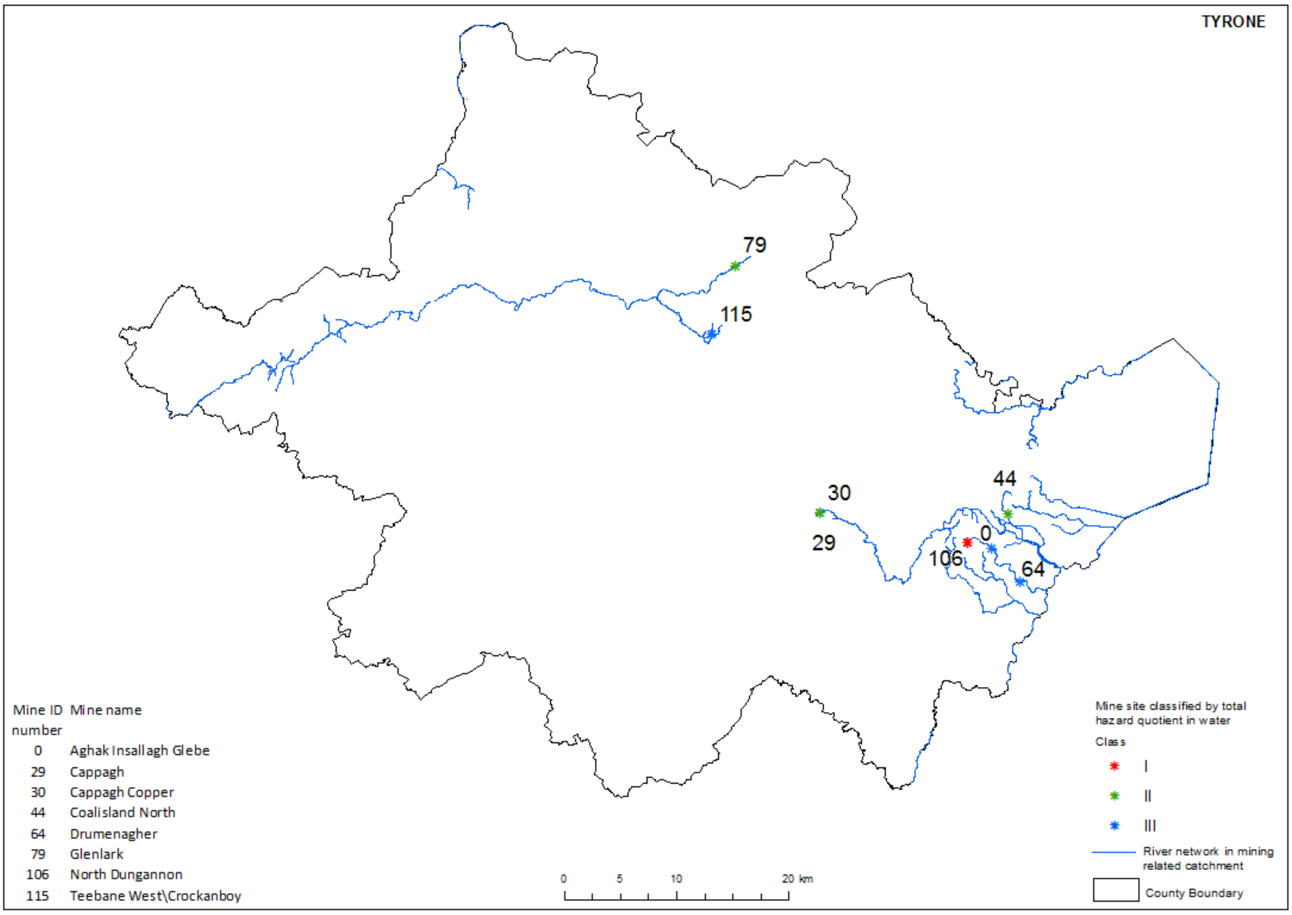

Figure 20 - Co. Tyrone: map of mine sites assigned to hazard classes representing the potential for adverse effects to riverine ecology posed by contaminants in water; ranking based on the Total Hazard Quotient measured in Tellus water samples, class I (HQ_w>10), class II (5 >HQ_w >2.5), class III (2.5 >HQ_w >1).

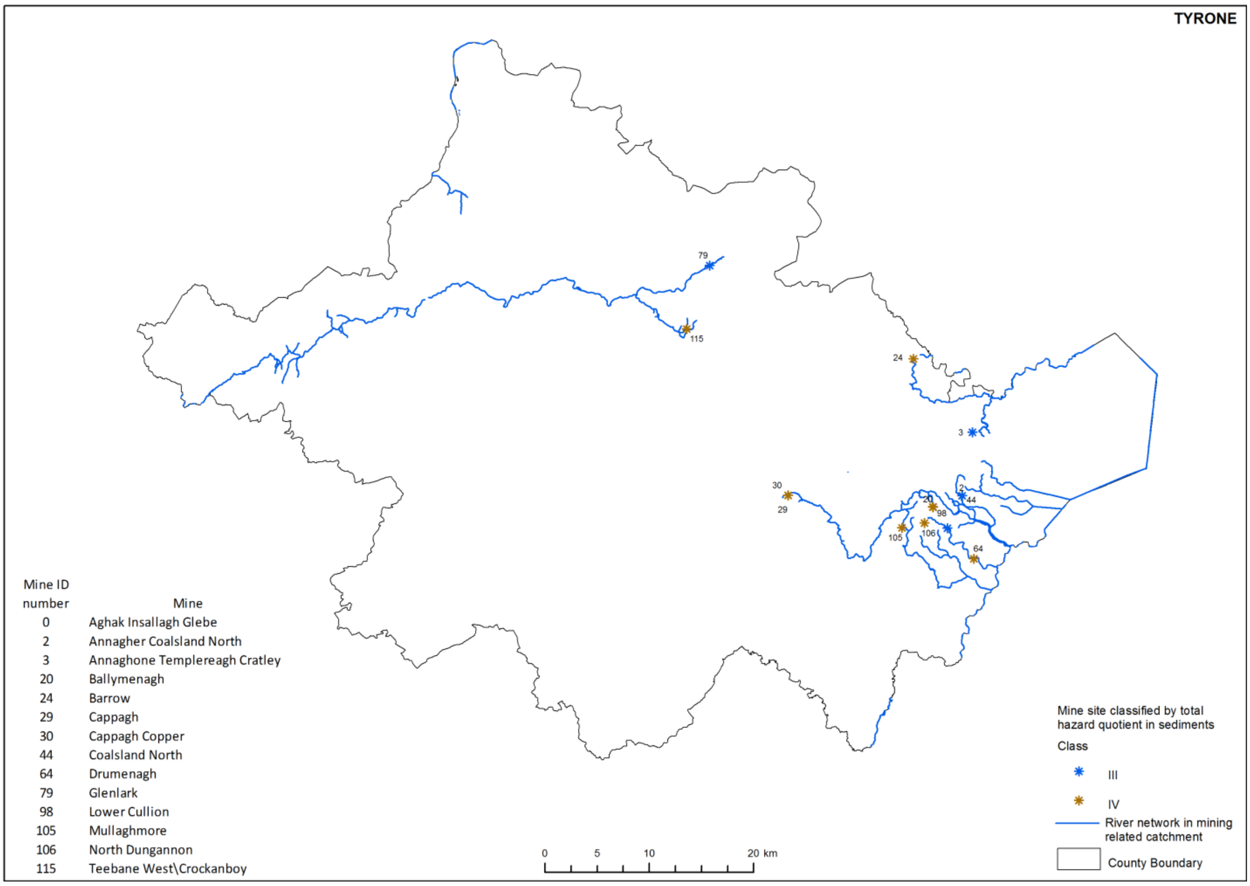

Figure 21 - Co. Tyrone: map of mine sites assigned to hazard classes representing the potential for adverse effects to riverine ecology posed by contaminants in sediments; ranking based on the Total Hazard Quotient measured in Tellus sediment samples, class I (25>HQ_s>15), class II (15 >HQ_s >10), class III (10 >HQ_s >5), class IV (5 >HQ_s >1).

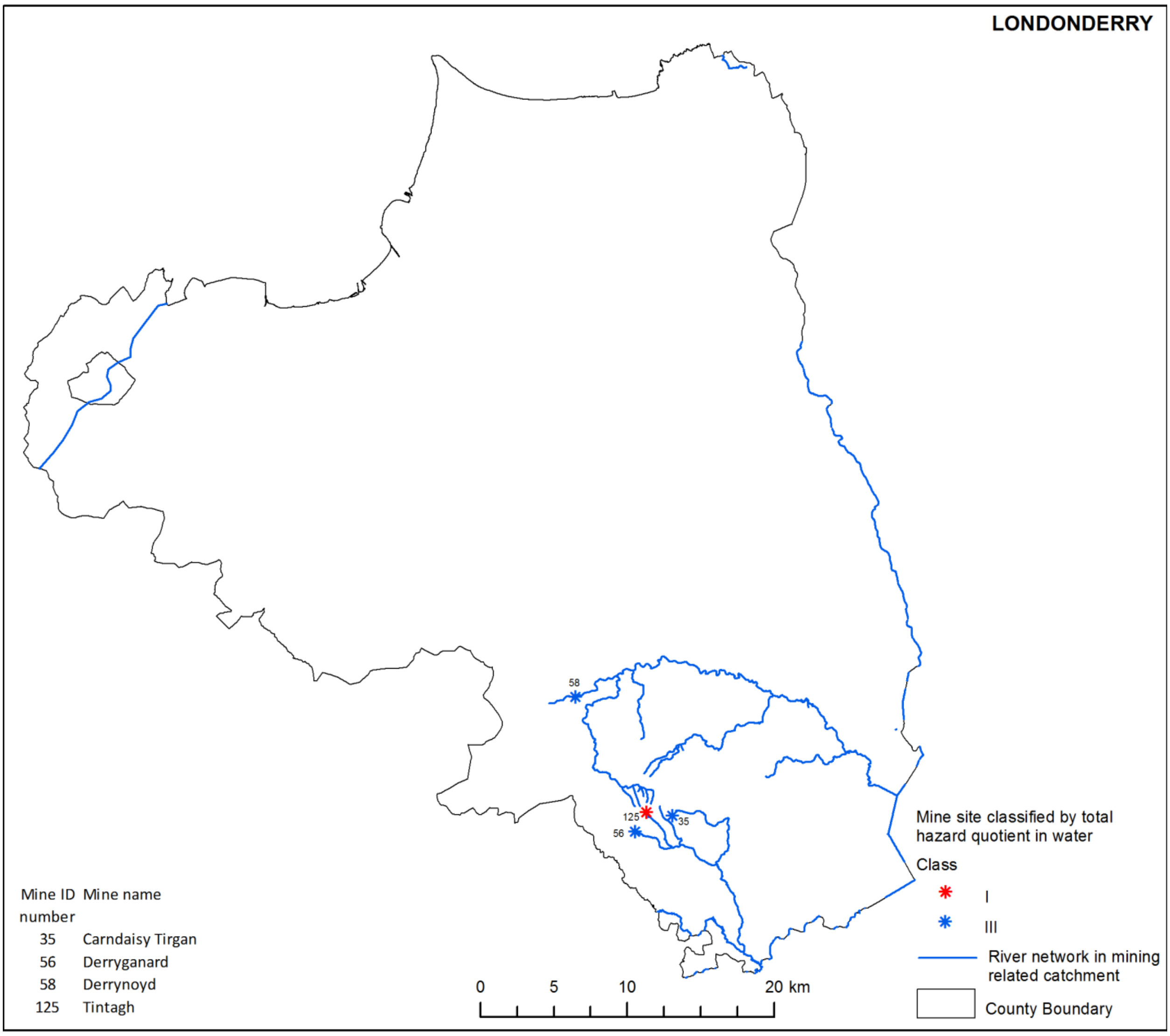

Figure 22 - Co. Londonderry: map of mine sites assigned to hazard classes representing the potential for adverse effects to riverine ecology posed by contaminants in <u>water</u>; ranking based on the Total Hazard Quotient measured in Tellus water samples, class I (HQ_w>10), class II (5 >HQ_w >2.5), class III (2.5 >HQ_w >1).

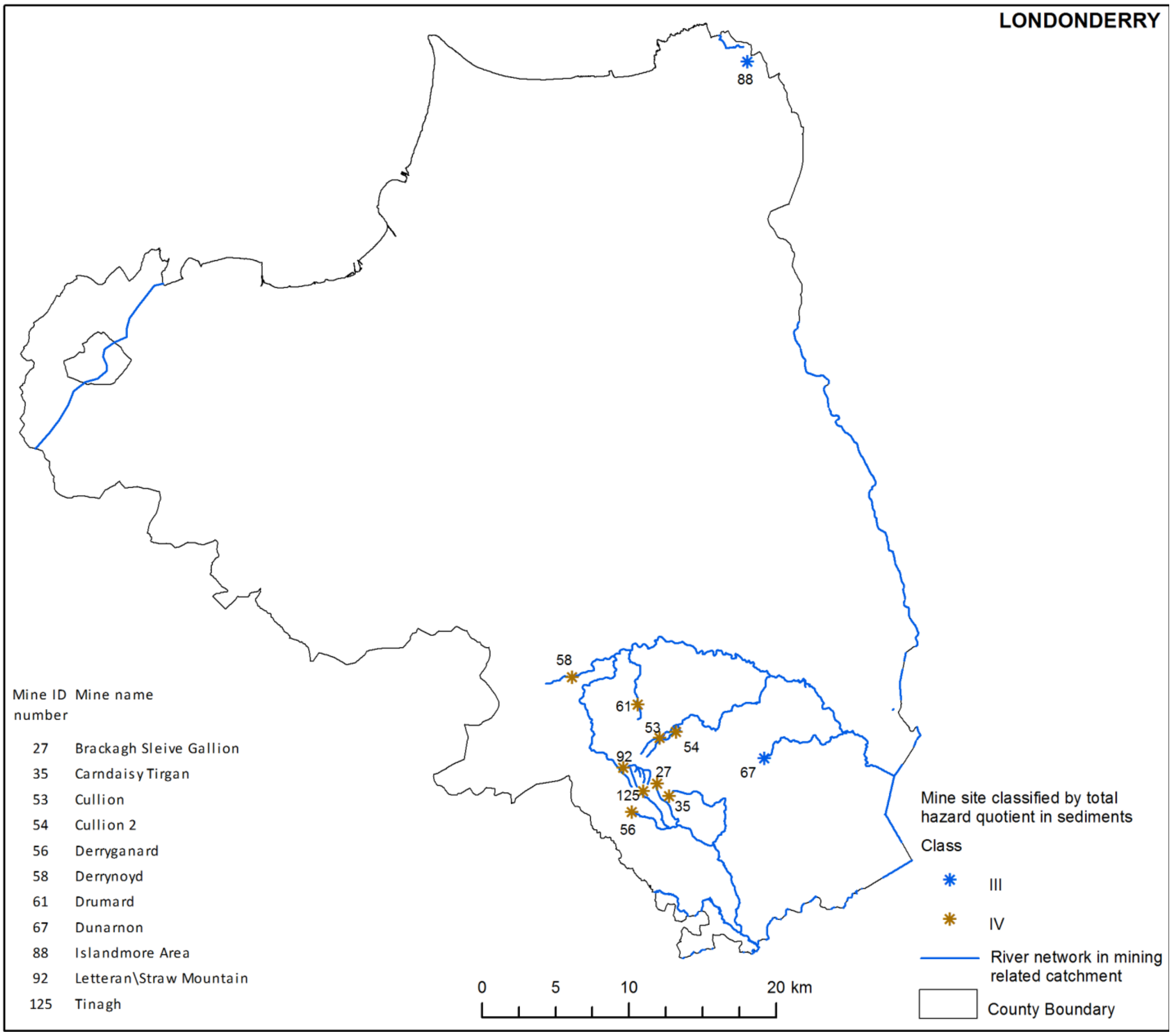

Figure 23 - Co. Londonderry: map of mine sites assigned to hazard classes representing the potential for adverse effects to riverine ecology posed by contaminants in <u>sediments</u>; ranking based on the Total Hazard Quotient measured in Tellus sediment samples, class I (25>HQ_s>15), class II (15 >HQ_s >10), class III (10 >HQ_s >5), class IV (5 >HQ_s >1).

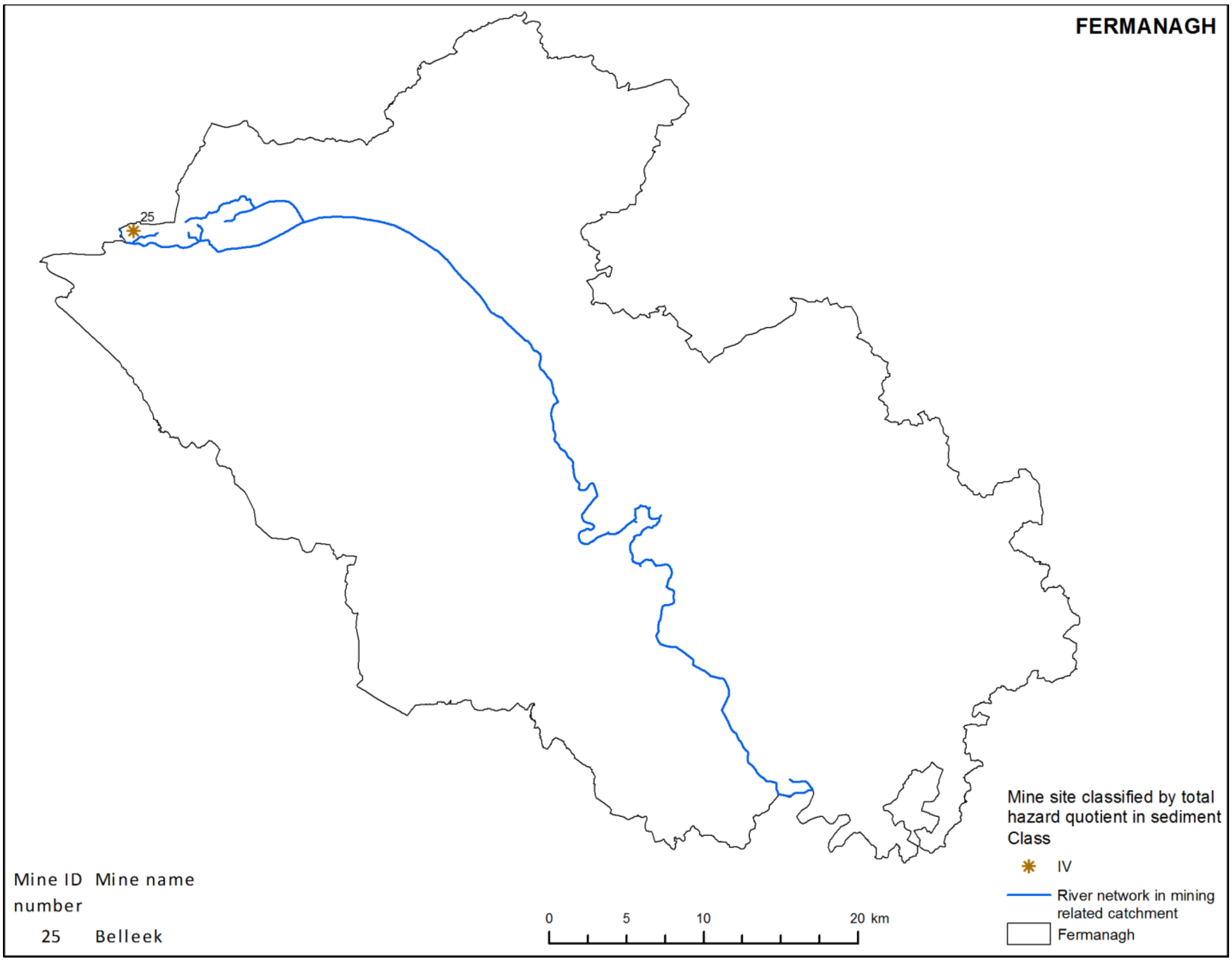

Figure 24 - Co. Fermanagh: map of mine sites assigned to hazard classes representing the potential for adverse effects to riverine ecology posed by contaminants in <u>sediments</u>; ranking based on the Total Hazard Quotient measured in Tellus sediment samples, class I (25>HQ_s>15), class II (15 >HQ_s >10), class III (10 >HQ_s >5), class IV (5 >HQ_s >1).

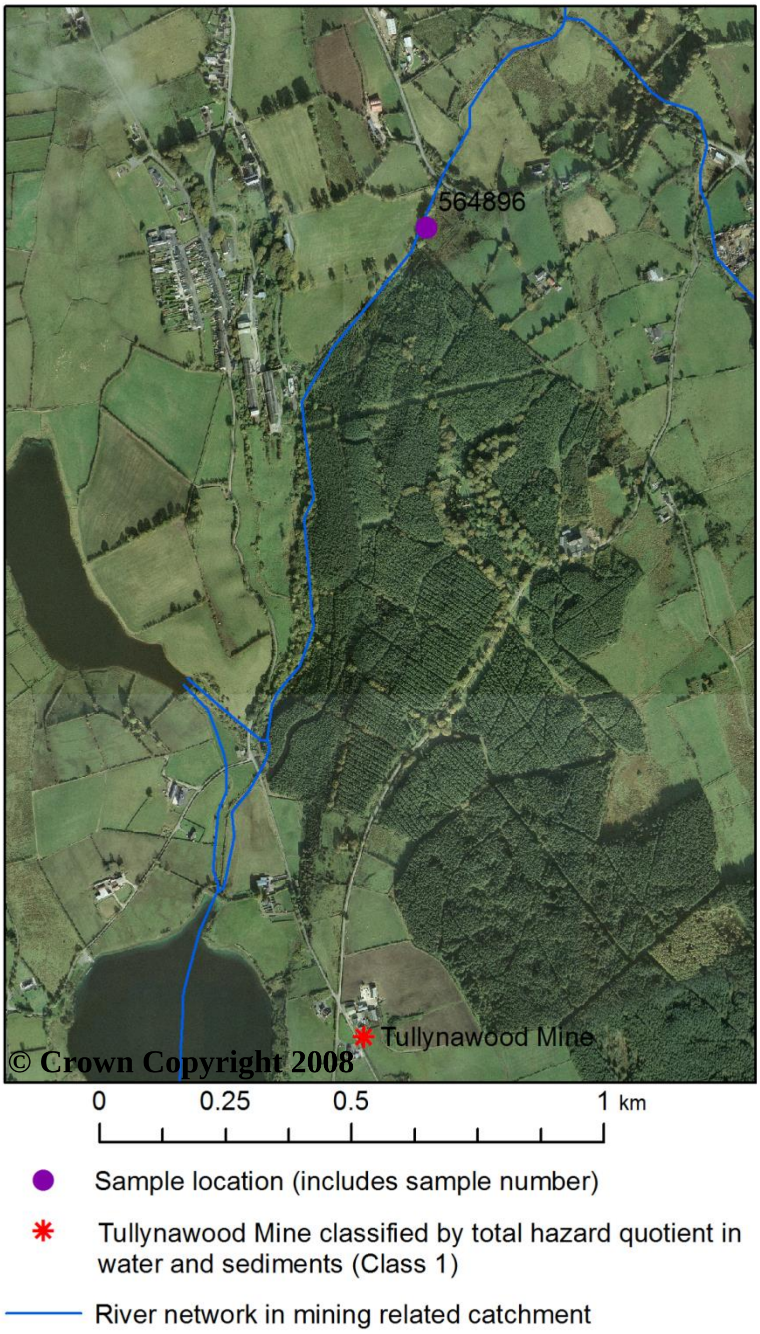

Figure 25 - Aerial photography map showing location of Tullynawood Lead Mine and downstream Tellus sampling point used in the assessment.

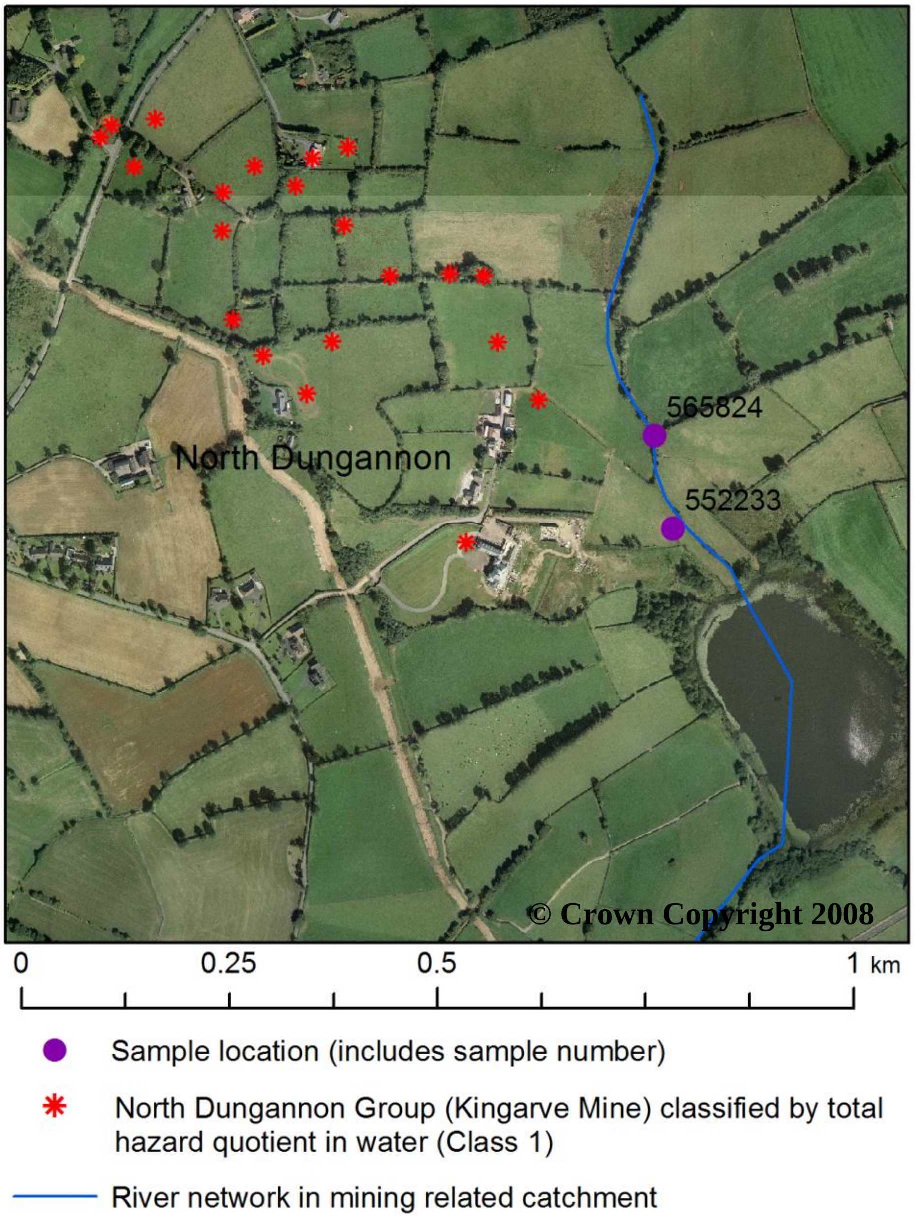

Figure 26 - Aerial photography map showing location of the North Dungannon Coal Mine Group and downstream Tellus sampling point used in the assessment.

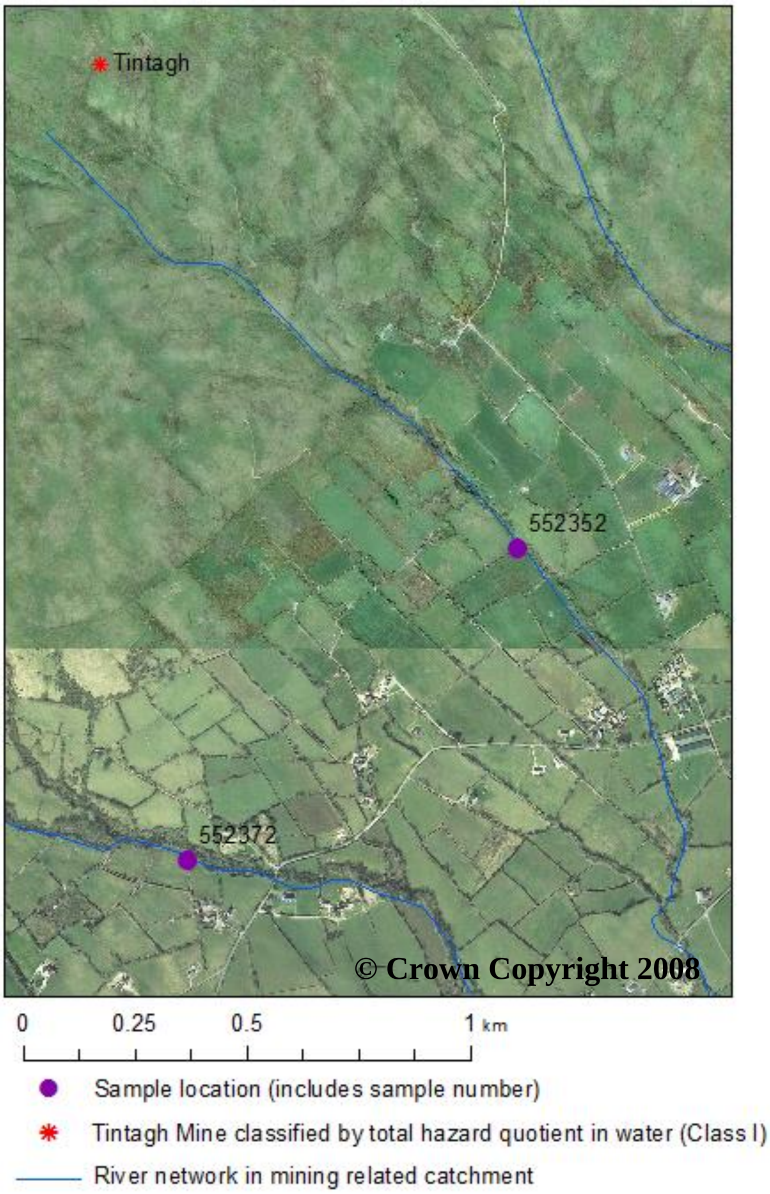

Figure 27 - Aerial photography map showing location of Tintagh Iron Mine and downstream Tellus sampling point used in the assessment.

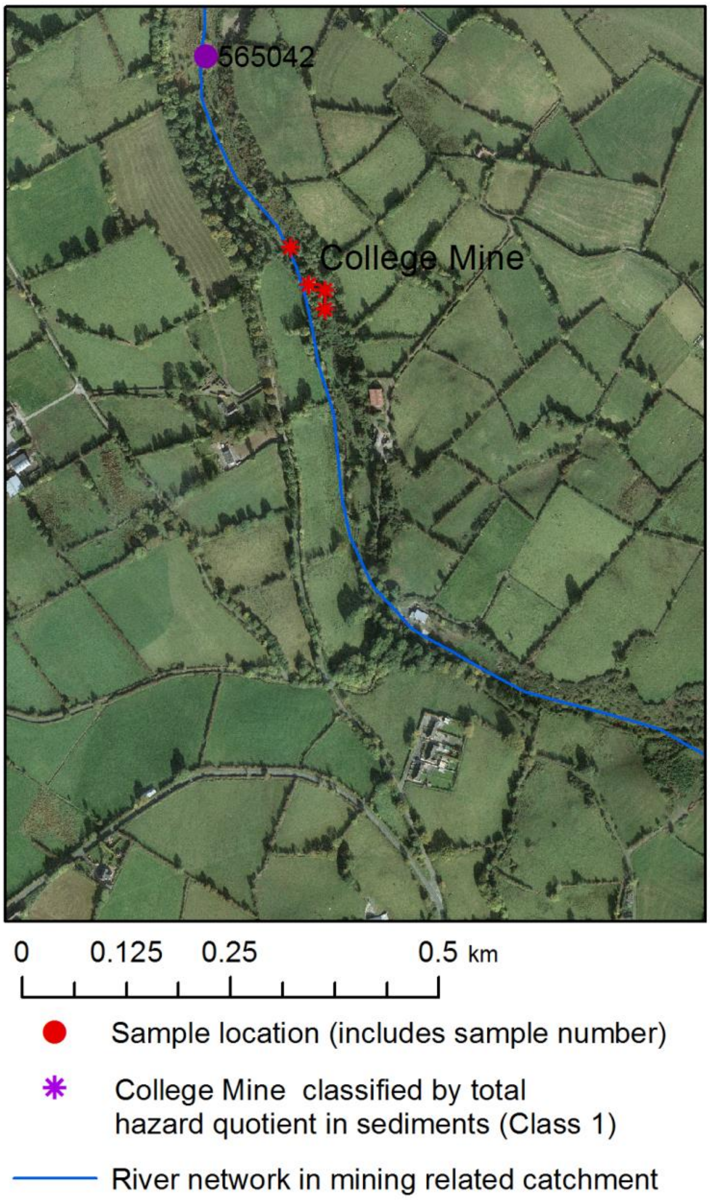

Figure 28 - Aerial photography map showing location of College Lead Mines Group and downstream Tellus sampling point used in the assessment.

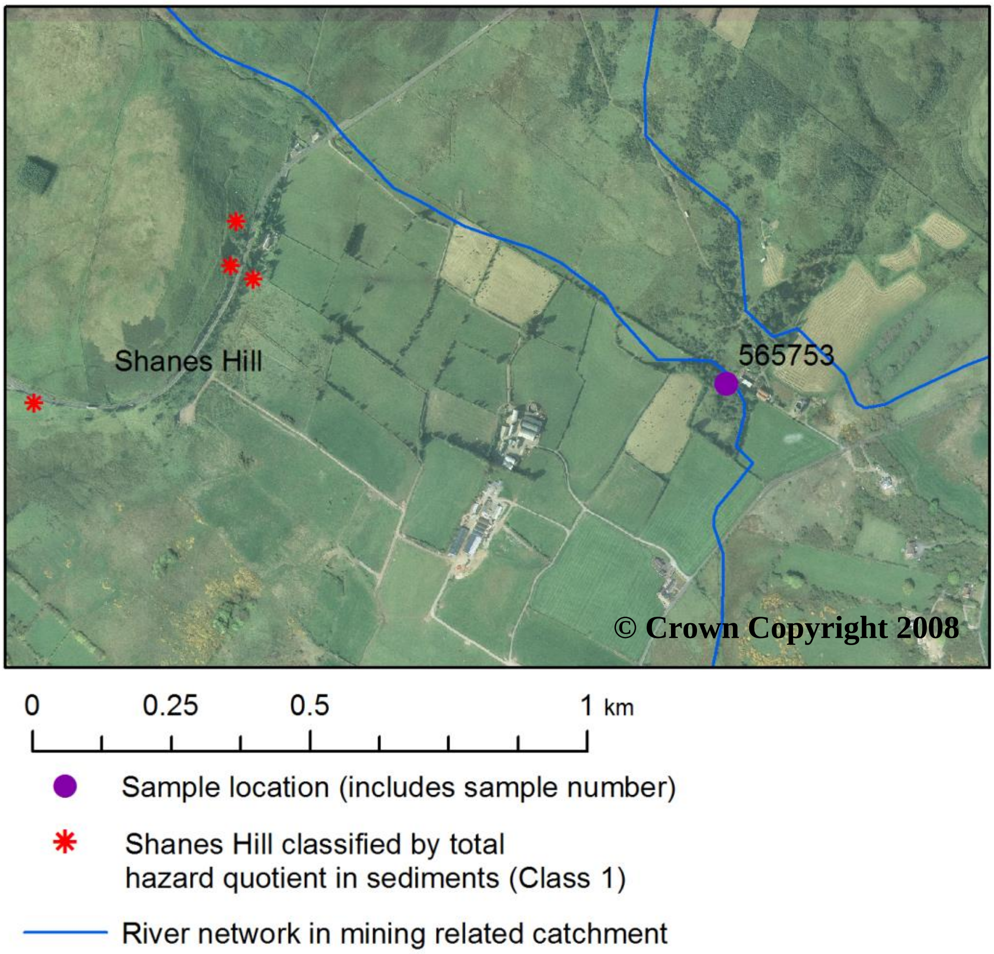

Figure 29 - Aerial photography map showing location of Shanes Hill Iron Ore Mines Group and downstream Tellus sampling point used in the assessment.

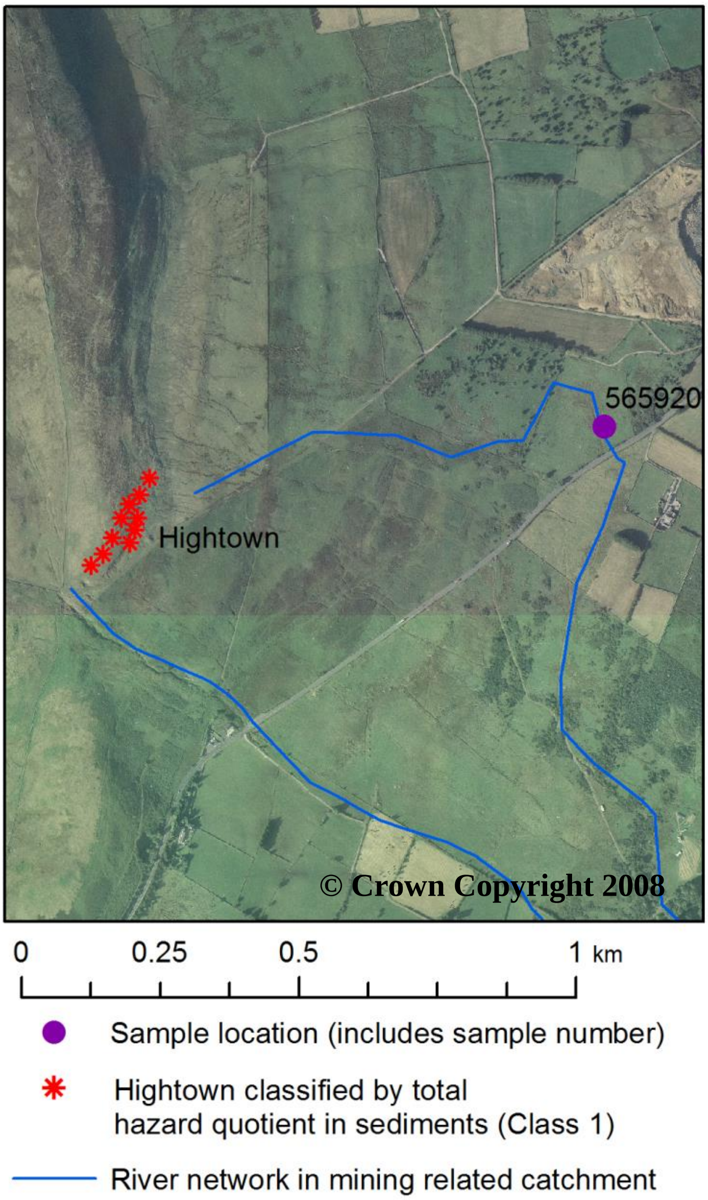

Figure 30 - Aerial photography map showing location of Hightown Iron Ore Mines Group and downstream Tellus sampling point used in the assessment.

Figure 31 - Aerial photography map showing location of Ballybracken Iron Ore Mine and downstream Tellus sampling point used in the assessment.

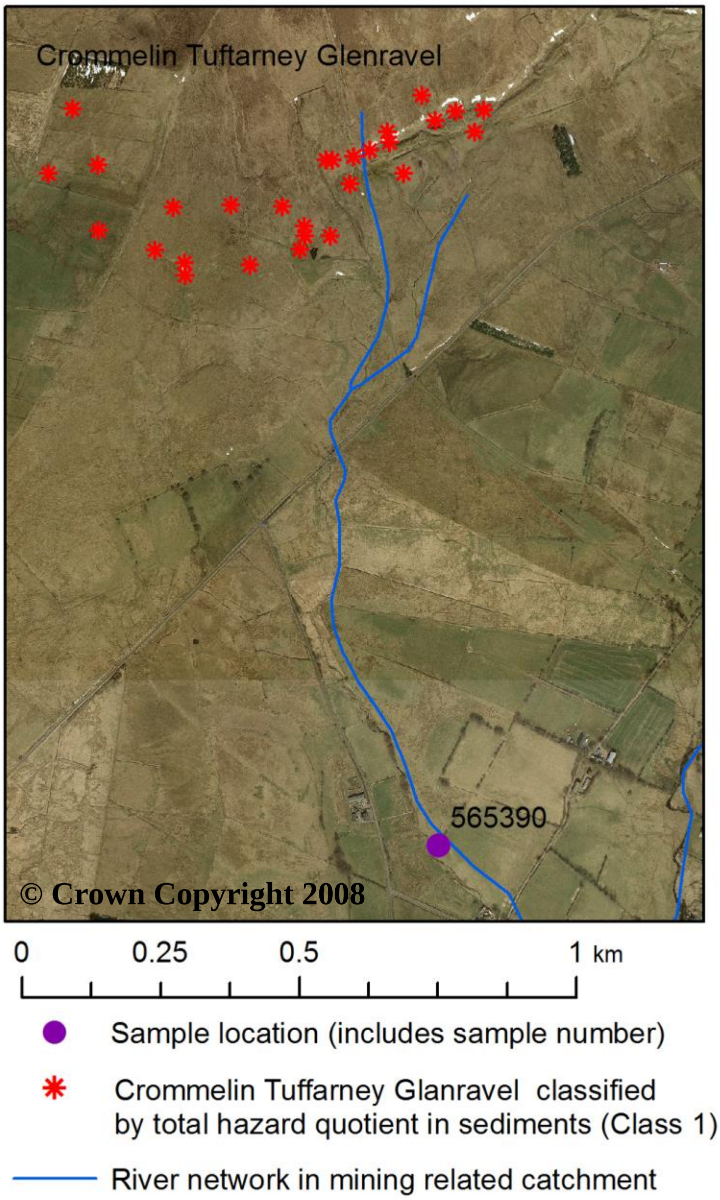

Figure 32 - Aerial photography map showing location of Crommelin /Tuftarney/ Glenravel Iron Ore mines Group and downstream Tellus sampling point used in the assessment.

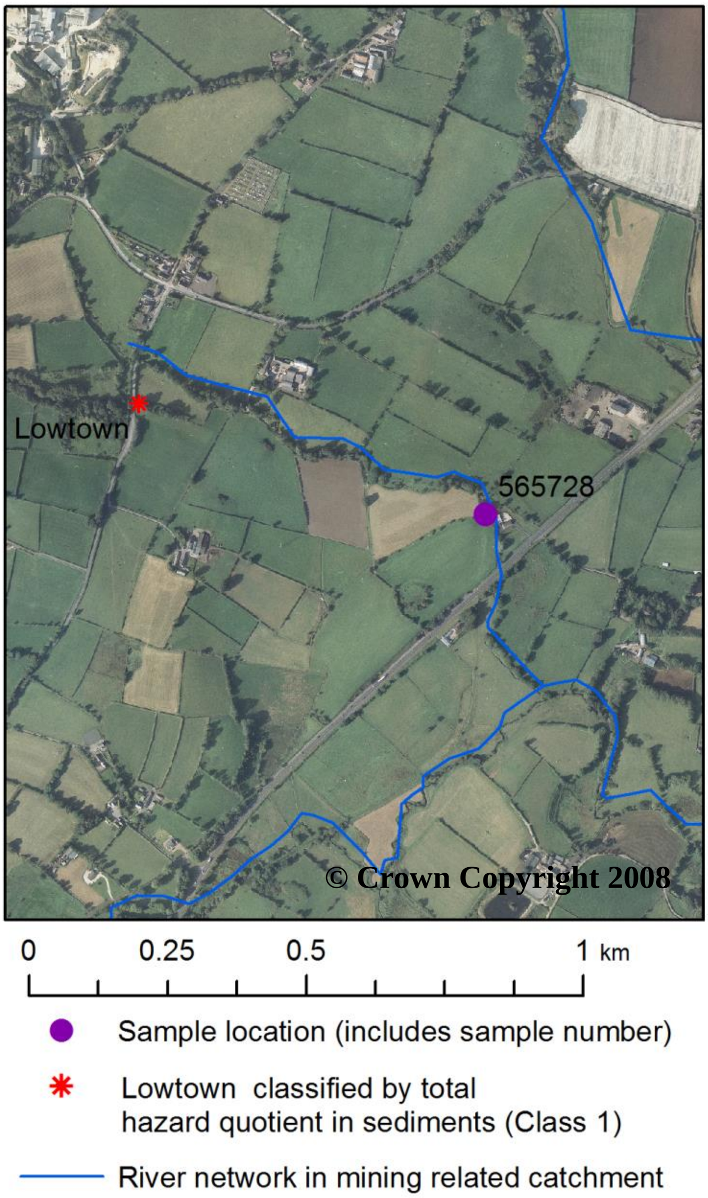

Figure 33 - Aerial photography map showing location of Lowtown Iron Ore Mine and downstream Tellus sampling point used in the assessment.

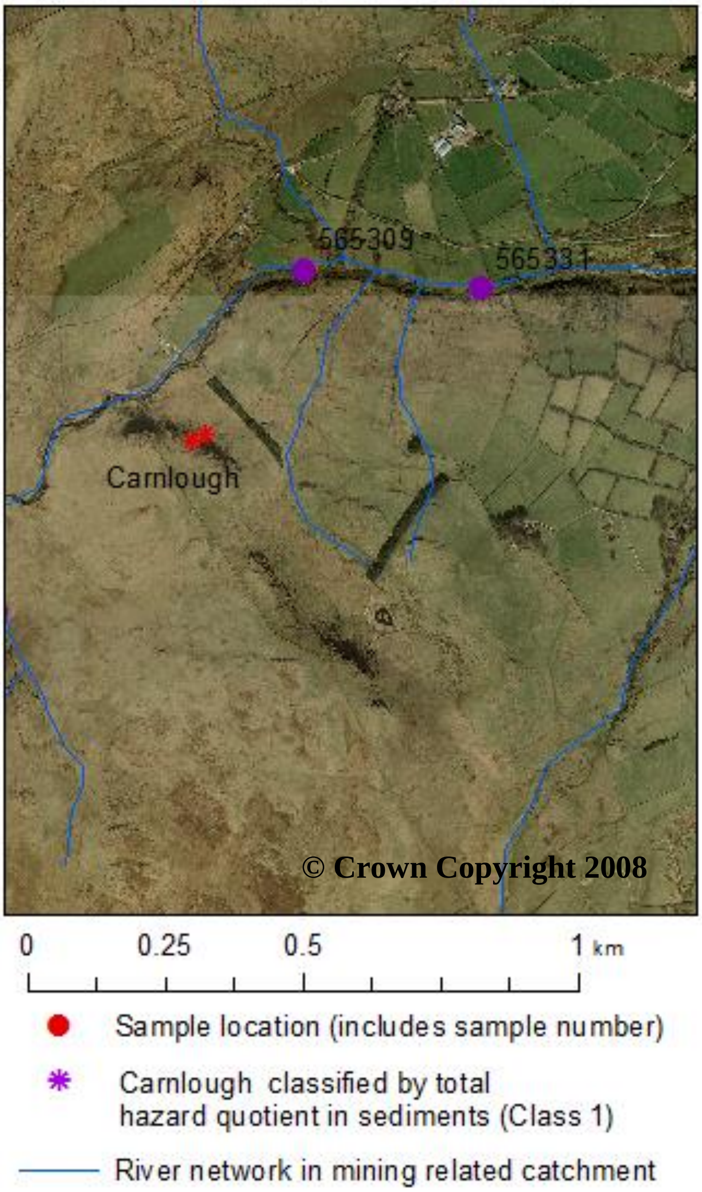

Figure 34 - Aerial photography map showing location of Carnlough Iron Ore Mines Group and downstream Tellus sampling point used in the assessment.

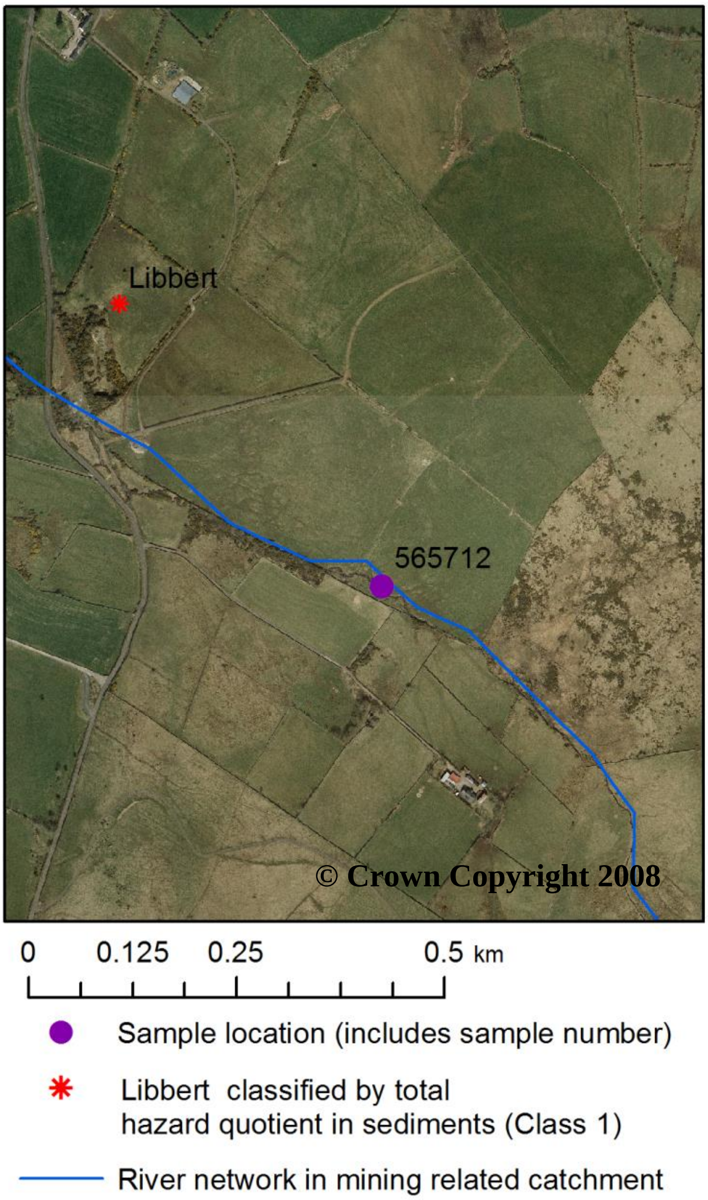

Figure 35 - Aerial photography map showing location of Libbert Iron Ore Mine and downstream Tellus sampling point used in the assessment.

5.3.7 Spatial distribution of closed mineral workings by commodity type

Maps in Figure 36 to Figure 41 show the spatial distribution of closed mineral workings and their hazard quotient score by commodity type (lead and copper; iron ore and bauxite; coal and lignite) in Northern Ireland.

Most of the listed lead mines had associated cadmium problems in the waters, while most of the iron ore and bauxite ore mines were associated with downstream waters enriched in copper and to some extent iron; the coal mines were linked to iron, cadmium, and copper water quality failures to variable extents and the copper mines to copper water quality failures.

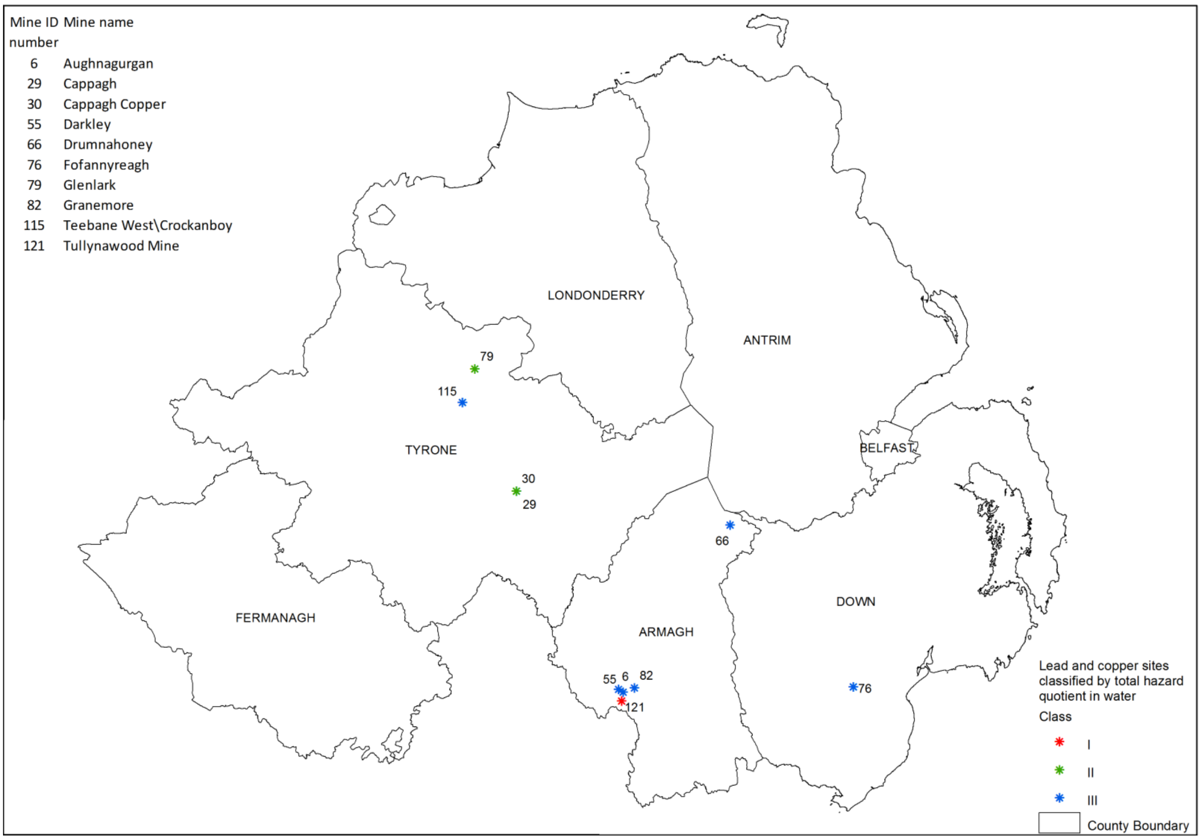

Figure 36 - Map of mine sites ranked by hazard quotients in water shown by commodity type: Lead and Copper.

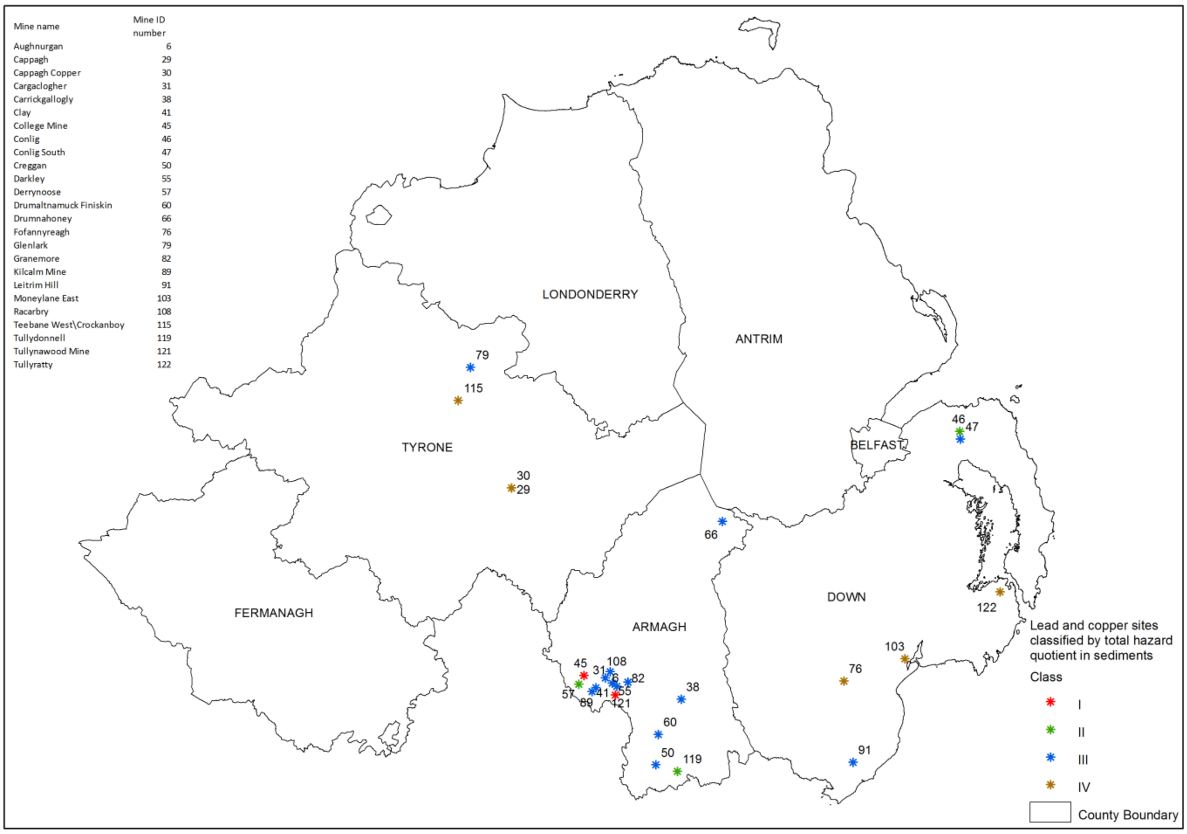

Figure 37 - Map of mine sites ranked by hazard quotients in sediments shown by commodity type: Lead and Copper.

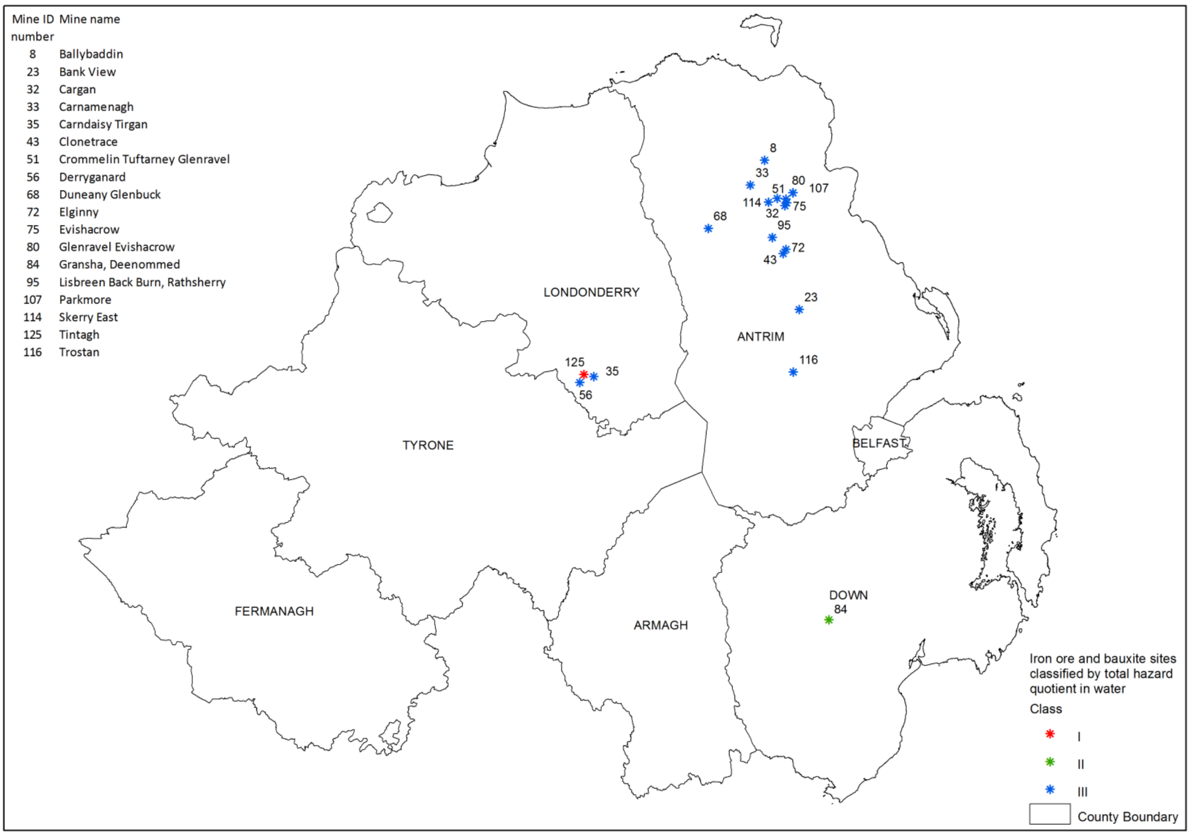

Figure 38 - Map of mine sites ranked by hazard quotients in water shown by commodity type: Iron ore and bauxite.

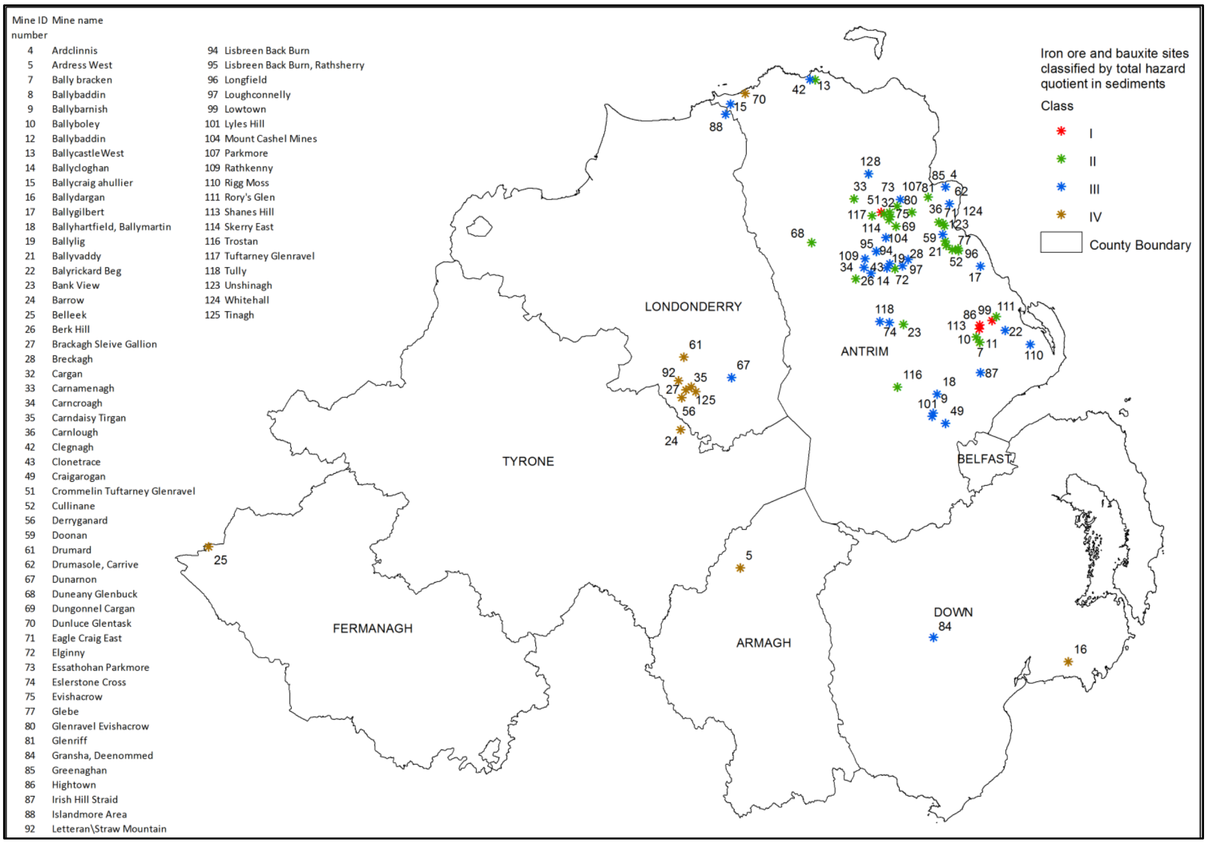

Figure 39 - Map of mine sites ranked by hazard quotients in sediments shown by commodity type: Iron ore and bauxite.

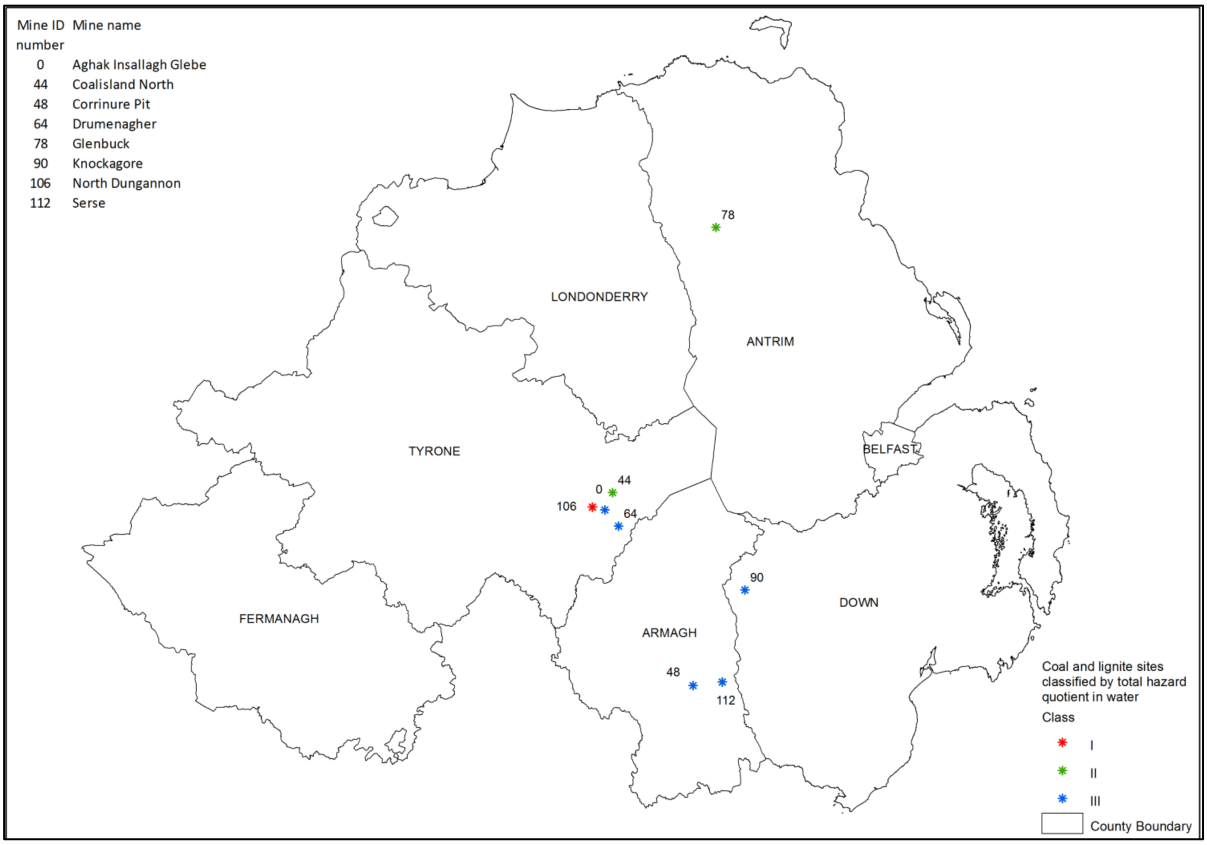

Figure 40 - Map of mine sites ranked by hazard quotients in water shown by commodity type: Coal and lignite.

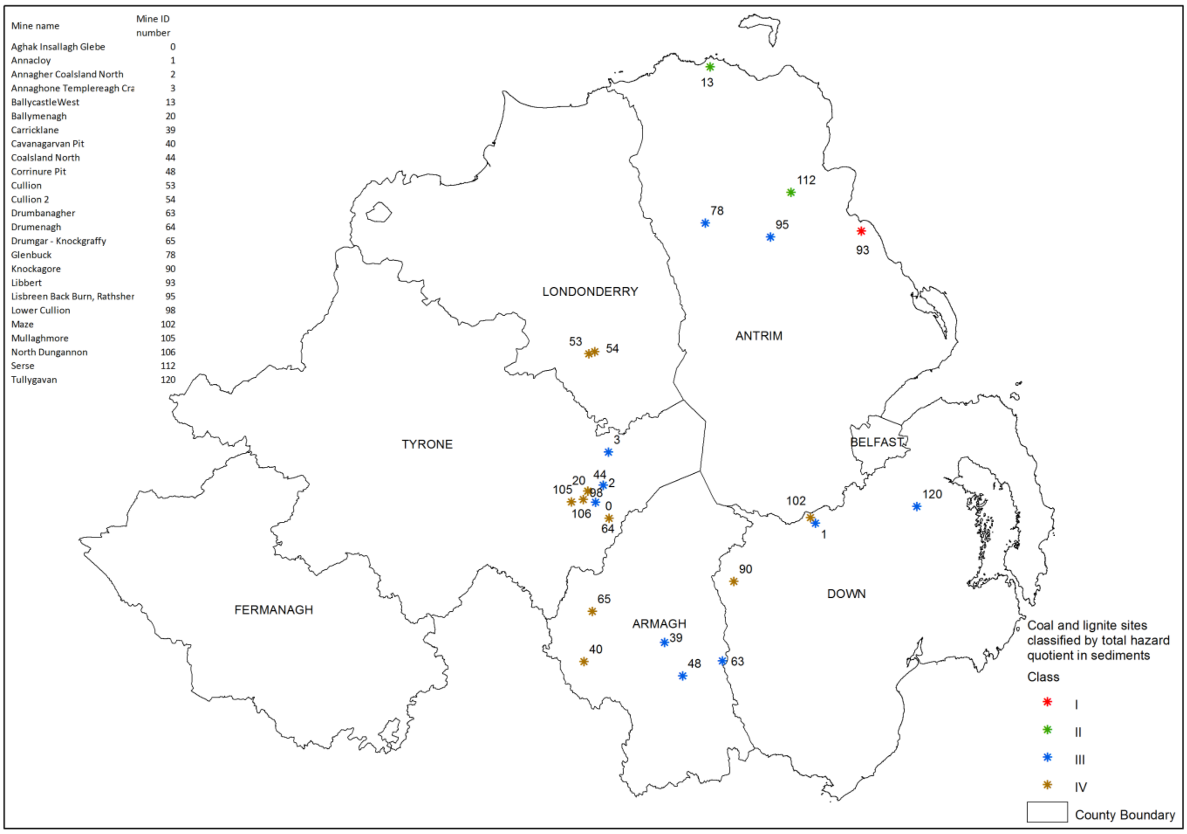

Figure 41 - Map of mine sites ranked by hazard quotients in sediments shown by commodity type: Coal and lignite.

5.4 MINE ENTRIES NOT ASSESSED

There are 403 mine entries, belonging to 40 mine groups (Table 8) that were not evaluated in the present geochemical assessment, because a Tellus sampling point did not exist downstream of the mine location.

Table 8 – List of mine groups that were not subjected to the geochemical assessment.

MINE GROUP*	COUNTY
ANTIVILLE, BALLYLORAN	ANTRIM
BALLYCASTLEEAST	ANTRIM
BALLYCASTLEEAST, CARRICKMOREIRON	ANTRIM
BALLYNABARNISH	ANTRIM
BALLYNURE CASTLETOWN	ANTRIM
BALLYVOY	ANTRIM
BAY	ANTRIM
BENBANE HEAD	ANTRIM
CARMAGRIM	ANTRIM
CROCKATEEMORE	ANTRIM
DRUMAVADDY BROUGHANORE	ANTRIM
FAIRHEAD	ANTRIM
FEIGH MOUNTAIN	ANTRIM
GALBOLY	ANTRIM
GOLDNAMUCK	ANTRIM
KNOCKBRACK	ANTRIM
MAIDENMOUNT	ANTRIM
PORTNAGREE	ANTRIM
SALT PANS	ANTRIM
TORGLASS	ANTRIM
WEST DIVISION, CLIPPERSTOWN	ANTRIM
DOOHAT OR CROSSREAGH WORKINGS	ARMAGH
KILMONAGHAN MINE	ARMAGH
TEER LEAD TRIAL	ARMAGH
BALLYGUNAGHAN	DOWN
CASTLEWARD	DOWN
CORPORATION	DOWN
GUNS ISLAND	DOWN
KILLOUGH	DOWN
ROSSTREVOR	DOWN
BALLAGHGEE	FERMANAGH
FINNER WORKINGS	FERMANAGH
MAGHERAMENAGH	FERMANAGH
ROSSBEG	FERMANAGH
CREENAGH, COALISLAND SOUTH	TYRONE
GORTNAGLOGH	TYRONE
KELLYS COALISLAND	TYRONE
MILLTOWN	TYRONE
TULLYRAW	TYRONE
WASHINGBAY	TYRONE

* Source: GSNI Abandoned Mines database of Northern Ireland

6 Conclusions and recommendations for decision on final MWD inventory sites

6.1 CONCLUSIONS

The conclusions in this section incorporate the work carried out during both Phase 1 (Palumbo-Roe et al., 2013) and Phase 2 (present report) of this project.

- We have collated the GSNI Abandoned Mines database of Northern Ireland and the BGS BRITPITS database of Mines and Quarries. They contain over 3500 records of abandoned mine workings. The records refer to a generic location of mining or quarrying activity; consequently, a record does not necessarily constitute proof of the existence of a mine waste facility. Many of the deposits that are described as mines were often trials, excavations of limited extent into the ground exploring for minerals. Of the 3686 entries, 1971 are surface workings, 1705 underground workings and 10 are described as having both surface and underground workings; 1248 are construction mineral sites, 633 are industrial mineral sites, 871 are energy mineral sites and 934 are metallic mineral sites.

- Guided by the relevant criteria set out in the MWD Directive and related documents, and informed by a similar assessment carried out in England and Wales, we consider the majority of the closed waste facilities in Northern Ireland to contain non-hazardous waste and substantially inert; providing there is no evidence of physical instability, they should not be included in the inventory. Exceptions comprise the waste associated with coal/lignite, base metal, iron and bauxite mines, which need to be further assessed in a more quantitative manner. A selection of 1806 mine locations (bauxite, copper, iron ore, lead, coal, lignite and barytes) of the 3586 entries have been subjected to the geochemical assessment in Phase 2 of the project.

- Phase 2 assessment has drawn a list of potential MWD inventory sites, selected on the basis of evidence of potential detrimental impact on the aquatic ecosystem due to concentrations of potential harmful elements in water or sediment above quality reference thresholds (expressed as hazard quotients - HQ), through interrogation of Tellus data. These sites are ranked based on the respective hazard quotients and grouped in hazard classes. The mine sites were assigned to class I (HQ_w>10), class II (5 >HQ_w> 2.5), class III (2.5 >HQ_w> 1) based on the HQ in waters, and to class I (25 >HQ_s> 15), class II (15 >HQ_s> 10), class III (10 >HQ_s> 5), and class IV (5 >HQ_s> 1) based on the HQ in sediments. The information is presented in tables and maps by county and mineral commodity type.

- The majority of the sites in the lists cause a water and/or sediment quality failure at a distance greater than 500 m and, therefore, are considered to cause serious environmental impacts to the water environment, according to the criteria set out by the Environment Agency in a similar assessment in England and Wales (EA, 2012) and the recommendations in the "Guidance document for a risk-based pre-selection protocol for the inventory of closed waste facilities as required by Article 20 of Directive 2006/21/EC" (EC, 2011).

- This approach fulfils the source, pathway and receptor linkage of the risk-based assessment when considering aquatic ecological receptors, as it proves that a measurable impact (high concentration of contaminants) exists on the surface water receptors, downstream of the mine sites. Data analysis has primarily focused on elements for which there are water and sediment quality standards.

- There were 37 mine sites related to observed downstream water quality failures and 126 mine sites associated with downstream sediment quality failures.

- 40 mine groups were not evaluated in the geochemical assessment because a spatial linkage between the mine and water/sediment geochemical data is missing, due to absence of Tellus 1st and 2nd order stream samples in proximity.

- Chromium and nickel in sediments and copper, iron and zinc in water are the major contributors to the high hazard quotient scoring associated with iron ore and bauxite mine locations. The counties most severely affected are Antrim and Londonderry. It is worthwhile to note that, during the course of this project, the research by Lass-Evans (2013) has suggested that the high Cr and Ni sediment concentrations in Co. Antrim do not result from mining activities and most likely reflect an association with their geological parent material. These results highlight the need to consider baseline conditions of catchments to better understand the impact of mining and what restoration goals are achievable in mining impacted catchments.

  Lead, zinc, cadmium, chromium and nickel are enriched in sediments downstream of some lead and copper mine sites. Also iron, zinc, cadmium and copper are variably enriched in waters. The county most severely affected is Armagh.

  Iron, copper and cadmium in water and chromium and nickel in sediments are the major contributors to the hazard quotient scoring associated with the coal mines in the inventory. The county most severely affected is Tyrone.

  Arsenic and lead concentrations measured in Tellus water samples are below the water quality standards.

6.2 UNCERTAINTIES

Uncertainties in the approach have been highlighted as follows:

- Uncertainties are inherent in the use of a generic sediment guideline value approach for sediment quality assessment.

- Uncertainty lies also in the use of water chemistry data that represent a single sampling event, rather than annual average values, against which water quality assessment has been carried out.

6.3 LIMITATIONS

- Phase 2 assessment does not consider physical hazards or human and animal health impact.

- With the available data, we cannot evaluate if the location of mining or quarrying activity from our source databases represents an underground shaft or adit, an open pit or a mine spoil or a tailings lagoon.

- There are a number of sites for which the geochemical assessment was not undertaken due to lack of sampling point downstream of these sites.

6.4 RECOMMENDATIONS

- We have drawn a list of potential MWD inventory sites belonging to the bauxite, copper, iron ore, lead, coal, lignite and barytes commodity types, for their potential to cause serious pollution to stream waters and sediments. The project outputs should be complemented by information sourced from relevant authorities on known concerns of risks to human or animal health, ground stability, and fire or air pollution.

- A further assessment should be carried out to consider the risk to animal health posed by soils and sediments (source of widespread land contamination during flooding) in lead mining areas, considering the Tellus soils and sediments against the guideline values for lead set for the protection of animal health of 1000 mg lead/ kg soil (EPA, 2004).

- The sites included in the potential MWD inventory list should be examined further, through collation of site specific data or field visit, in order to identify the presence of mine heaps, tailings pond, mine adits or fluvial tailings, responsible for the contamination. This information on the nature of mining pollution should be included in the database, as it would inform future remediation strategy for these sites. Although less likely, the presence of additional or alternative non-mining sources of pollution cannot be ruled out and should be verified through the field visit.

- For those sites for which the geochemical assessment was not undertaken due to lack of sampling point downstream of these sites, it is recommended to carry out further examination to gather information necessary to assess their impact on the environment and human health. This might imply desk work, based on compiling and assessing available site specific historical information, or field investigations, including some degree of sampling of deposited waste, water, sediment, etc.

- The sites prioritised in the potential MWD inventory for their risk to water receptors in this project and those potentially highlighted in complementary databases for risk to human and animal health should be investigated through field visits, following a tiered risk assessment approach. The risk-based site ranking made in this assessment provides a way to prioritise the sites for field visits, on the basis of the available resources. For sites falling in class I using HQ for water and in class I and II using HQ for sediments, high hazard is anticipated (Finger et al., 2004). Some guidance on performing the initial site investigation can be found in EPA-GSNI (2009). It is especially recommended that the sites scoring high in terms of hazard quotient in water should be re-sampled, due to the uncertainty in using water data from a single sampling event in the assessment. Some sites, upon further examination, may not meet the criteria for inclusion in the final inventory list.

- In our assessment, based on limited site specific information, we have followed the precautionary principle and used generic guideline values for the protection of surface water quality and ecosystems. However, due to the presence of mineralised veins in the host rocks and as a result of centuries of mining activity in these areas, it is recognised that ecosystems may have adapted or acclimatised to certain high concentrations of metals in surface waters and sediments, as a result of their natural abundance. Indeed, the Technical Guidance document (TGD) for Deriving Environmental Quality Standards (EQSs) (European Communities, 2011) considers the ‘added risk’ approach that takes these background concentrations into account, when assessing risk against water and sediment quality standards. If sites fail the environmental quality standards, consideration of the natural background concentration may be undertaken to further assess compliance and prior to any expensive or time-consuming remediation (UKTAG, 2012). Therefore, in order to increase confidence in the geochemical assessment, it is recommended that baseline concentrations in water and sediment in these mineralised environments are derived and the “added risk” approach applied in the assessment. More research is needed to develop appropriate guidelines for the protection of the ecology in mining areas, having regard to the naturally elevated concentrations of metals and the likely adaptation of ecology to these conditions.

Appendix 1

ELEMENT	SEDIMENT QUALITY THRESHOLDS**		WATER QUALITY THRESHOLDS §		
	Predicted Effect Level (PEL) mg/kg		EQS, µg/l (annual average)	Hardness mg/l as $CaCO_3$	Type of standard, legal status
Arsenic	17		50	NA	UK standard, statutory
Cadmium	3.53		≤0.08 0.08 0.09 0.15 0.25	Class 1: <40 Class 2: 40 - <50 Class 3: 50 - <100 Class 4: 100 - <200 Class 5: ≥200	EU standard, statutory
Chromium	90		chromium(III): 4.7 chromium(VI): 3.4	NA	UK standard, statutory
Copper	197		1 6 10 28	0 - 50 50 - 100 100 - 250 >250	UK standard, statutory
Iron	-		1000	NA	UK standard, statutory
Lead	91.3		7.2	NA	EU standard, statutory
Nickel	35.9		20	NA	EU standard, statutory
Zinc	315		8 50 75 125	0 - 50 50 - 100 100 - 250 >250	UK standard, statutory

** HUDSON-EDWARDS, K A, MACKLIN, M G, BREWER P A, DENNIS, I A. 2008. Assessment of Metal Mining-Contaminated River Sediments in England and Wales. *Environment Agency Science Report* SCHO1108BOZD-E-P

§ downloaded on 20/12/2013 from Environment Agency web site: http://evidence.environment-agency.gov.uk/ChemicalStandards/driver.aspx?did=24

Glossary

Hazard Quotient **-** The ratio of an exposure level by a contaminant (e.g., maximum concentration) to a screening value selected for the risk assessment for that substance (e.g. EQS or PEL). If the exposure level is higher than the toxicity value, then there is the potential for risk to the receptor.

Mine entries - location of mining or quarrying activity; the site may refer to the location of any of the following:

- surface mineral workings.
- a shaft or adit level to underground mineral workings.
- sites with both surface and underground workings.
- spoil tips or tailings lagoons resulting from mineral workings.

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British Geological Survey holds most of the references listed below, and copies may be obtained via the library service subject to copyright legislation (contact libuser@bgs.ac.uk for details). The library catalogue is available at: http://geolib.bgs.ac.uk.

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