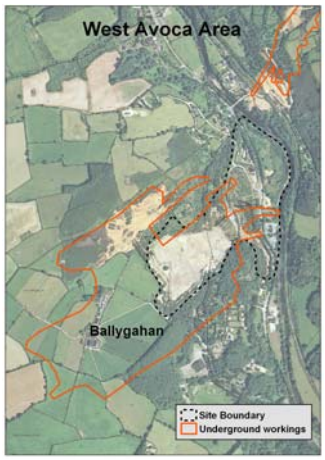
BALLYGAHAN

Background information



Mine Name: Ballygahan

Mine District: Avoca

Alternative Names:
Ballymurtagh Landfill

Elements of interest:
Pb, As, Cu, Zn, Cd, Ni

Project Prefix: AVO-

County:	**Townland:**	**Grid Reference:**
Wicklow	Ballygahan	E319719, N181573

Site Description and Environmental Setting

The Ballygahan site includes most of the area of the 20th-century West Avoca mine, including the site of the former open pit, the main decline entrance to the underground workings that underlie most of the area, the emergency tailings pond and the processing plant and workshops and offices area. Since closure in 1982, the mine site has been transformed through its use as a municipal landfill and associated rehabilitation works (photo, right). The site boundary (Fig. 1) encloses 22 ha of which the landfill site (6.5 ha) comprises almost a third.

The site lies along the main Rathdrum – Avoca road, the tailings pond to the east, bordering the Avoca River, and most of the remainder of the site occupying the side of the valley to the west. North and south of the site the steep valley sides are wooded and contain numerous houses. Some of these, notably those on the south side, were formerly mine staff accommodation (Fig. 1). The site rises to the west and is bordered on the northwest by Ballymurtagh mine site and to the west and southwest by farmland, mainly pasture. Ballygahan and Ballymurtagh were initially two separate mines but have been linked by the Margaret Adit since the mid-19th century. In the 20th century, they were part of one large site, West Avoca.

Numerous 19th-century mine features remain on the Ballygahan site. The **Ballygahan Shaft** dates from at least the first half of the 19th century and was the main shaft in the old Ballygahan mine, used for both pumping water and hoisting ore. Mianrai Teoranta rehabilitated and deepened this shaft in the 1940s to 290m below surface and it has been used since as the main discharge route for mine water

in West Avoca. The water rises via two reservoirs along the shaft before flowing along the **Road Adit** to the Avoca River (Fig. 1). The Road Adit has been rehabilitated in recent years by Wicklow County Council: it was cleaned out, the entrance reinforced and it is now securely gated (photo, right). A parshall flume with an infrared warning sensor is used to monitor water levels. West of the old open pit area and modern landfill site are the **Twin Shafts** and their associated engine houses. The Engine shaft lies southwest of the Drawing shaft. One engine house is represented by part of a wall but the other, the Drawing Shaft engine house, has an intact chimney and has recently been conserved (photo, left). The shafts were begun in the 1850s as part of the westward extension of Ballygahan mine and reached their final depth of 300m below surface in 1864. They were used for pumping water (Engine shaft) and raising ore (Drawing shaft). In the 20th century, the shafts were used solely for ventilation and as an escapeway. Both are capped with reinforced concrete slabs. About 50m northeast of the Twin Shafts is the conserved chimney of the **Tramway Engine house**, used for hauling the wagons of the small railway built in the 1840s to carry ore to the port of Arklow. The **Ballygahan Engine house**, on the north edge of the former open pit, is also included in this site. It comprises an intact chimney and three partly intact walls (photo, right). The remaining 19th century mine workings include the **Western Whim Drawing shaft** and the **Margaret adit** and its associated shaft – all are capped.

A number of buildings on site date from the 1940s and 1950s when Mianrai Teoranta undertook exploration and some rehabilitation of the mine workings. The most prominent buildings are those of the company's headquarters, now part of Wicklow County Council's yard close to the Road adit. The concrete shell of storehouses can still be discerned beside the Twin Shafts.

St. Patrick's Copper Mines Ltd. (1958-62) constructed a large number of buildings on and around the site. Many of these were later used by Avoca Mines Ltd. (1969-82). In addition, it constructed the main decline, the **Knight Tunnel**, that was used to enable vehicles to gain access to the underground workings (photo, right). This was also subsequently used by Avoca Mines Ltd.. The 5m high and 5m wide tunnel entrance was sealed with a concrete plug after closure of the mine in 1982.

The building north of the road at the site entrance was built as the main office – it is now being converted for heritage use (Fig. 1). Behind this are old staff hostels or apartments. The Director's Lodge, mine manager's house and staff hosing were located along the Red Road south of the site. Two intact buildings across the road from Whitebridge were used as a laboratory and garage by St. Patrick's Copper Mines Ltd.. This company also constructed most of the mine buildings used for processing ore on the site, including the mill and workshops (photo, left). These buildings were also used by Avoca Mines Ltd. and were dismantled after closure of the mine. The area previously occupied by the mill and workshops was backfilled with spoil and covered by a thick layer of imported topsoil before revegetation by the County Council. Several concrete pads beside the road that winds up to the open pit site are all that remain of the workshops. Of the mill there is no trace.

Apart from the open pit, now filled in and the surface grassed, several large spoil heaps are the most obvious remnant of mining on the Ballygahan site. The red-brown spoil forms a prominent, steep embankment along the side of the road (SP39a, photo, right). Above the site of the Knight Tunnel entrance is another large spoil heap (SP33), now considerably overgrown by pine, heather and gorse. The emergency tailings pond (SP41), seen when active at bottom of photo (above), is another waste pile of considerable size. The exact thickness is uncertain but is estimated to be around 2m based on the height of the embankment and retaining wall above the river. The emergency tailings pond was also rehabilitated by the council, using a similar technique of covering it with imported topsoil and seeding with grass. This part of the site was to be developed as a Miner's Park but it is now growing wild and the surface has been extensively colonized by gorse and other species. Table 1 gives estimates of the area and volume of the waste heaps on the Ballygahan site.

Table 1 Area and volume of spoil heaps at Tigroney East

Waste ID	Area (m^2)	Volume (m^3)
AVO-SP33	4,934	*4,737
AVO-SP36	808	808
AVO-SP39a/39b	16,046	*51,771
AVO-SP41	29,106	58,212

Source: HMS-IRC, modified after Gallagher and O'Connor 1997;
* LIDAR survey 2007 (CDM Report).

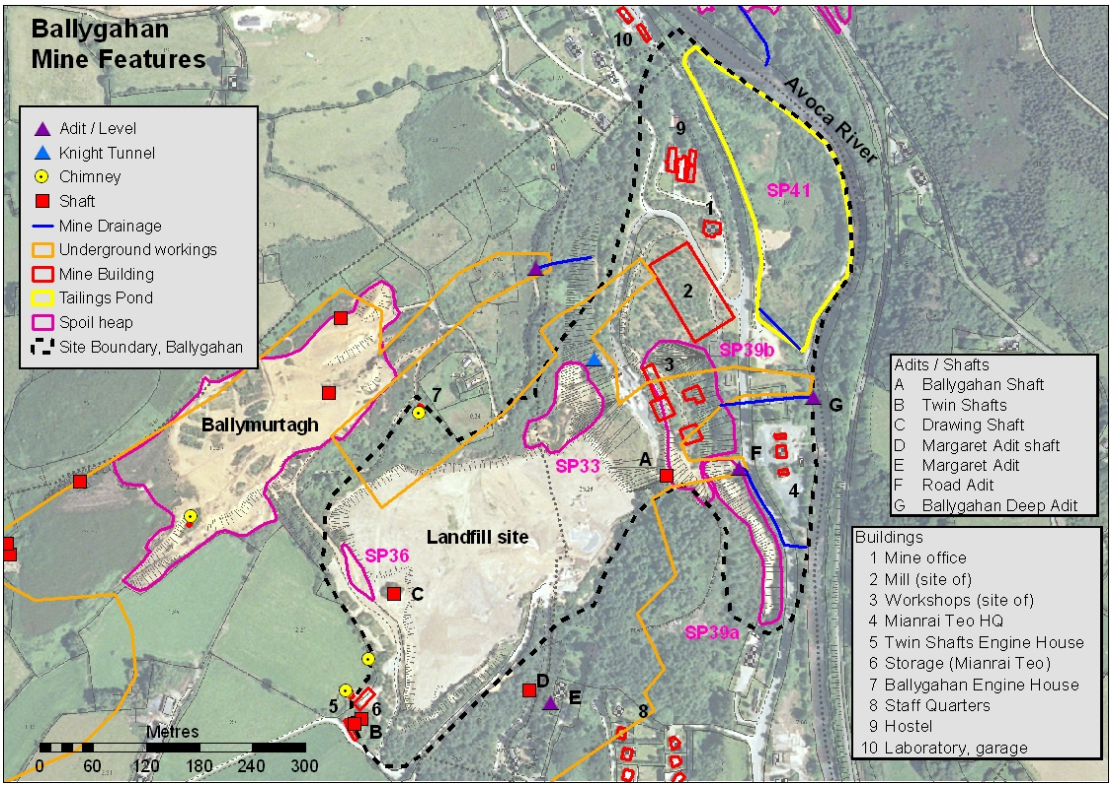


Fig. 1 Ballygahan: mine features

Geochemical assessment

1. Surface water

Surface water samples were collected from five sites at Ballygahan (Fig. 2), though only the Road Adit discharge and the mixing zone in the River immediately downstream were sampled in both summer and winter. A surface drain on the emergency tailings pond flows via a plastic pipe into the river. The small flow to the river (c. 0.03 l/s) was sampled in winter but there was no flow in summer. The river immediately downstream of the discharge was also sampled in winter. The Ballygahan Deep Adit (G on Fig. 1) discharges water through a plastic pipe on the river bank. This was not sampled as it was inaccessible in winter and had stopped flowing in summer. The remaining samples were taken from the Road Adit discharge, both near the adit entrance (February 2007) and at the weir where it enters the river (November 2006), and in the river mixing zone immediately downstream of the discharge point (November 2006). Table 2 summarizes the data for elements of interest. It includes data for the Avonmore River upstream of the mine site for comparison.

The Road Adit discharge has a low pH (3.7 – 3.9), though not as low as the Tigroney Deep Adit or surface run-off samples from East Avoca (2.2 – 3.3). Samples were unsurprisingly highly acidic and were enriched in Cu, Pb and Zn. They also had elevated Ni and Cd contents, similar to those noted for the Deep Adit in Tigroney West. In general, there is little seasonal variation in composition in the Road Adit discharge. This is similar to the Deep Adit discharge and was also noted by Gray (1995). The impact of the adit discharge can be seen in the mixing zone samples, taken within several metres downstream of the point of discharge, particularly in the winter sample for which acidity, Pb, Zn, Cu, Ni and Cr were all high by comparison

with the Avonmore River sample. The Emergency Tailings Pond drainage (pH = 4.3) also had high concentrations of Cu and Zn and elevated concentrations of Pb, Ni and Cr but, as noted, this is a volumetrically very minor discharge.

Table 2: Data for surface water, Ballygahan

	Pb (tot) µg/l	Zn (tot) µg/l	Cu (tot) µg/l	Ni (tot) µg/l	Cd (tot) µg/l	Cr (tot) µg/l	Acidity mg/l $CaCO_3$
Winter 2006/7							
TMF drainage (1)	28	1491	1578	39	4	39	63
River d/s TMF (2)	8	126	27	6	<1	14	8
Road adit (entrance)(3)	305	8716	301	62	11	2	772
Road adit (weir) (4)	372	15880	364	88	11	<1	972
River mixing zone (5)	152	6361	169	37	5	19	300
Avonmore River u/s	4	58	<1	4	<1	3	8
Summer 2007							
Road adit (entrance) (3)	278	9374	234	59	12	4	540
River mixing zone (5)	29	1053	89	9	2	5	25
Avonmore River u/s	3	139	124	2	<1	3	4

Figures in brackets refer to site numbers, Fig. 2

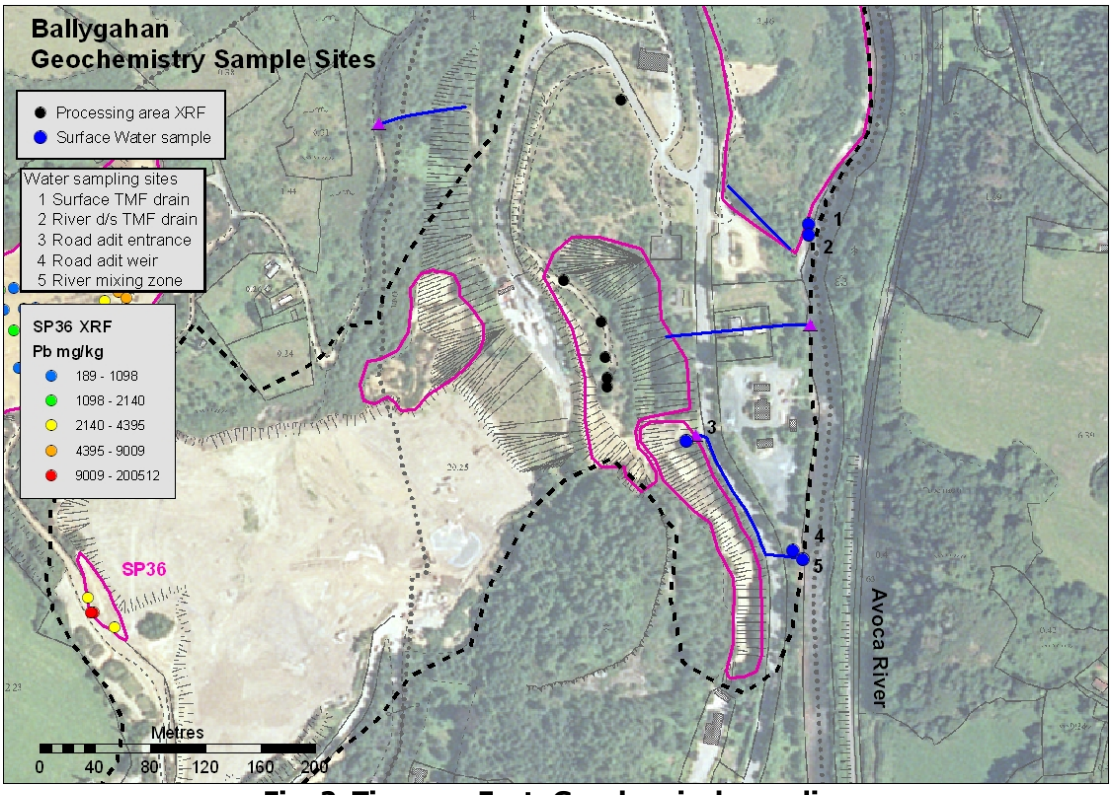


Fig. 2 Tigroney East: Geochemical sampling

Measured flow rates for the Road Adit discharge were 26.3 l/s (February 2007) and 13.4 l/s (June 2007), similar to those recorded at the Deep Adit in Tigroney West in East Avoca. Using the corresponding chemical analyses, the metal discharge rates can be computed (Table 3). Pb, Cu and Zn discharge rates are significantly lower than those computed for the Deep Adit in Tigroney West, reflecting lower concentrations of these elements in the mine water. In contrast, Fe discharge rates

are much higher. The Road Adit is responsible for most of the Fe introduced in mine water to the Avoca River whereas the Deep Adit contributes most of the Pb, Cu and Zn. Zn and Cu discharges rates are at the low end or even below the range measured by Gray (1995) over a 12-month period in 1994/95. Fe is within the range, albeit at the lower end of it. The sample taken at the river mixing zone greatly exceeds the current draft EC Environmental Objective for Surface Waters for heavy metals, including Pb, Zn, Cu, Cd and Ni.

Table 3: Metal discharge rates, Road Adit: seasonal variation

	Pb kg/day	Zn kg/day	Cu kg/day	Fe kg/day	Ni kg/day	Cd kg/day
February 2007 (26.3 l/s)	0.75	21.4	0.74	232.4	0.15	0.02
June 2007 (13.4 l/s)	0.32	10.8	0.27	111.4	0.07	0.01
Gray (1995), mean		53	2.7	285		0.08

2. Groundwater

No groundwater sources were sampled for this project nor were leachate analyses carried out on any spoil samples from Ballygahan. Two monitoring wells were sunk in the Emergency Tailings pond as part of the Avoca Feasibility Study (CDM 2008). High concentrations of Cu and Zn were measured in water in both wells, up to 8,570 µg/l Cu and 12,310 µg/l Zn. Pb was below the detection limit of 50 µg/l while 80 µg/l Ni was measured in one well. Water in two groundwater wells located immediately south of the Emergency Tailings pond had very similar metal concentrations. A further well that is monitored by Wicklow County Council, located immediately east of Ballygahan Shaft, had extremely high measured metal concentrations when analysed for the Avoca Feasibility Study (CDM 2008): 160,700 µg/l Cu, 620 µg/l Pb, 580 µg/l Ni and 137,700 µg/l Zn (all total metal contents except for Zn which is dissolved metal content). Groundwater in the area is thus severely affected by the mine site.

3. Stream sediments

One stream sediment sample was collected opposite the northern end of the Emergency Tailings Pond, down stream of the Deep Adit discharge. However, no samples were collected immediately downstream of the Road Adit discharge. Details of stream sediment sampling and analyses are contained in the Avoca District report.

4. Solid Waste

Owing to time constraints, none of the main waste heaps on the Ballygahan site were analysed *in situ* by XRF. The small heap SP36 was analysed in the course of work on the Ballymurtagh site. In addition, a number of analyses were carried out in the area around the former processing site. Sample sites are shown on Fig. 2. Further sampling was carried out for the Avoca Feasibility Study (CDM 2008).

The SP36 samples are classified as for other Avoca sites, i.e. using quantiles derived for all spoil analyses at Avoca, but excluding tailings and processing area samples (Fig. 2). Two of the analyses gave measured Pb concentrations between 1.6 and 1.9%, with other metals such as Cu, Zn and As present in a few thousand mg/kg.. The other two samples had less than 4000 mg/kg Pb. Measured Fe (8 – 36%) and S (up to 6%) contents are very high, reflecting the presence of pyrite. This spoil heap is very small – it was originally used as a source of metal-rich waste for revegetation trials carried out nearby for the Avoca Life project (Gallagher *et al.* 1998).

The samples analysed around the old processing area had 148 – 2085 mg/kg Pb, 107 – 296 mg/kg Zn, 124 – 1313 mg/kg Cu and 93 – 343 mg/kg As. These analyses indicate that rehabilitation of the site has not entirely blanketed the mine waste that previously formed the surface of the site.

5. HMS-IRC Site Scores

Table 4 Risk-ranking scores for mine waste, Ballygahan

Waste	SP33	SP36	SP39	SP41	W008	Totals
1. Hazard Score	**18**	**37**	**29**	**15**	**776**	**875**
2. Pathway Score						
Groundwater	4.41	9.24	6.74	3.11	181.29	204.79
Surface Water	1.23	2.92	2.20	2.85	178.37	187.58
Air	0.05	0.04	0.26	0.03	0.00	0.37
Direct Contact	0.51	0.33	4.43	0.99	0.00	6.25
Direct Contact (livestock)						
3. Site Score	**6**	**13**	**14**	**7**	**360**	**399**

The total HMS-IRC Site Score for Ballygahan is 399 (Table 4). The Road adit discharge accounts for 90% of this score (Fig. 3). No analysis was carried out on SP33 or SP39a but data from adjacent heaps, SP34 and SP39b, respectively, were used to instead. The emergency tailings pond was not analysed either so data from Shelton Abbey tailings pond was applied. The contribution of the solid waste to the total score is very low – this is similar to the situation in Tigroney West where the Deep adit accounts for 84% of the site score.

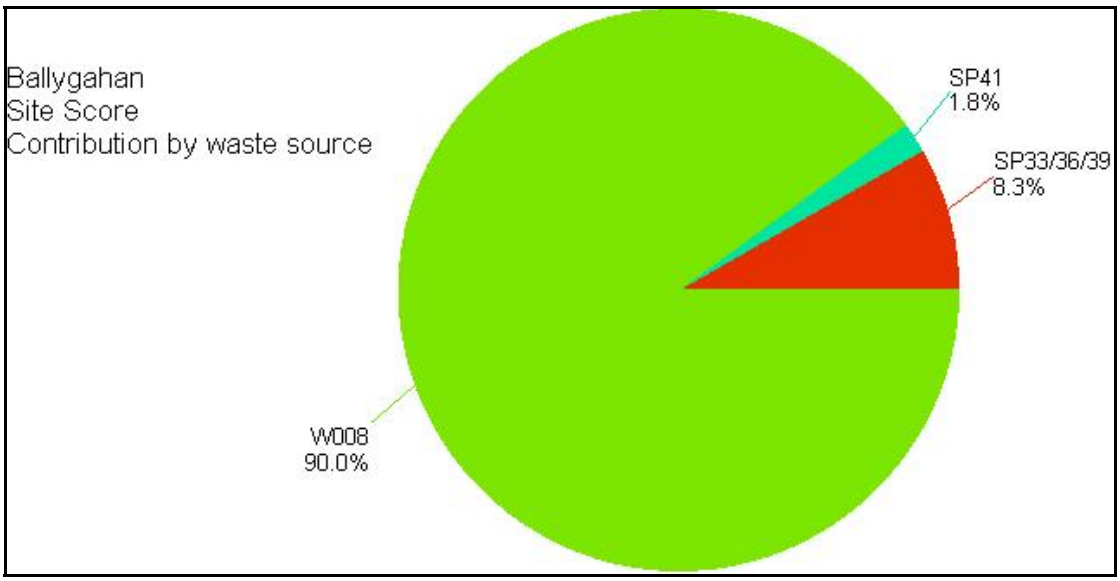


Fig. 3 Contribution of individual waste sources to Ballygahan Site Score

Fig. 4 shows the contribution of the different pathways to the total site score at Tigroney West. Pathways are the routes by which receptors are exposed to the hazard. Groundwater and surface water pathways make an almost equal contribution to the score which largely reflects the contribution of the Road adit discharge. In Tigroney West, the Deep adit surface water pathway score exceeds that for groundwater since the length of impacted river is deemed to be greater because the Deep adit is a further 1 km upstream. The direct contact and air

pathway scores are negligible, reflecting the minimal input from the solid waste heaps.

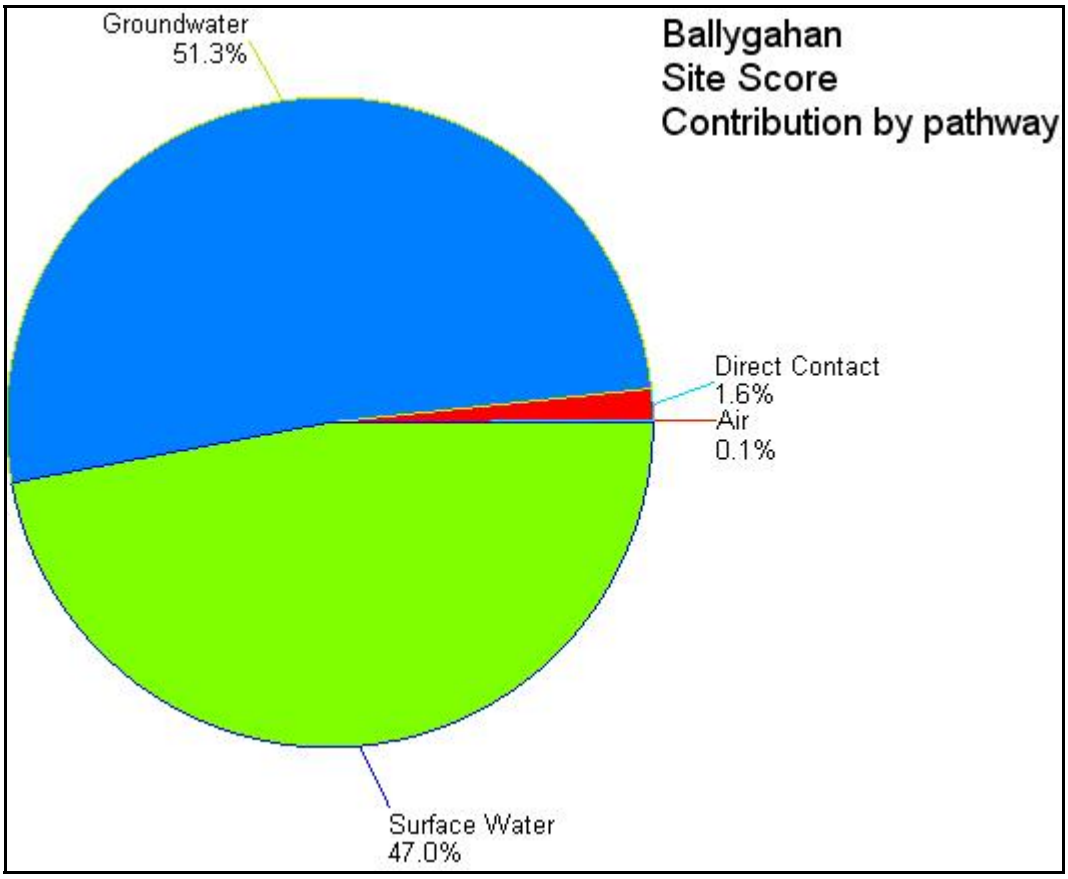


Fig. 4 Contribution of individual pathways to Ballygahan Site Score

6. Geochemical overview and conclusions

The Road Adit is the main drain for the extensive underground workings in West Avoca. The mine water discharged to the river has very high concentrations of Cu, Pb, Zn and elevated Ni, Cd and Cr, as well as low pH and high acidity. The flow rate from the Road Adit varies on a seasonal basis but metal concentrations in the discharge remain relatively constant so that periods of highest flow, generally the winter months, correspond to the maximum input of metals to the river. Metal discharge rates measured during the course of the HMS-IRC project ranged up to 0.75 kg/day Pb, 21.04 kg/day Zn, 0.74 kg/day Cu, 232 kg/day Fe and 0.02 kg/day Cd, indicating an ongoing and significant input of metals to the Avoca River ecosystem. As a consequence, the Road Adit is by far the most important contributor to the Ballygahan score in the HMS-IRC site scoring system.

Very few analyses of solid waste were carried out for the HMS-IRC project and. for the purpose of scoring the waste heaps in the HMS-IRC scoring system, median data for waste heaps on the adjacent site, Ballymurtagh, were used. In the area of the old processing plant, significant levels of metals were detected in surface material indicating that the extensive rehabilitation in this area, including spreading of imported topsoil, has not entirely blanketed the previous spoil cover.

Groundwater from several monitoring wells on the site has very high measured concentrations of Cu, Zn, Pb and Ni. In so far as the groundwater immediately below the site may be expected to be in contact with solid mine waste or mineralized bedrock, such measured concentrations are unsurprising. However they do emphasize the potential for extreme groundwater contamination in the areas around the site.

References

CDM (2008) Feasibility Study for management and remediation of the Avoca Mining site. Prepared for the Geological Survey of Ireland. CDM, USA.

Gray, N.F. (1995) Main adit flow and metal discharge rates. Water Technology Research, Technical Report 13, November 1995. Trinity College Dublin