Wales Metal Mines Programme

The impact of abandoned metal mines on water quality in the Upper Wye

Report No: 1016

Author(s) name: Ellis Krishan, Tom Williams, Dave Johnston

Author(s) affiliation: Natural Resources Wales

About Natural Resources Wales

Natural Resources Wales’ purpose is to pursue sustainable management of natural resources. This means looking after air, land, water, wildlife, plants and soil to improve Wales’ well-being, and provide a better future for everyone.

Evidence at Natural Resources Wales

Natural Resources Wales is an evidence-based organisation. We seek to ensure that our strategy, decisions, operations and advice to Welsh Government and others are underpinned by sound and quality-assured evidence. We recognise that it is critically important to have a good understanding of our changing environment.

We will realise this vision by:

- Maintaining and developing the technical specialist skills of our staff;
- Securing our data and information;
- Having a well-resourced proactive programme of evidence work;
- Continuing to review and add to our evidence to ensure it is fit for the challenges facing us; and
- Communicating our evidence in an open and transparent way.

This Evidence Report series serves as a record of work carried out or commissioned by Natural Resources Wales. It also helps us to share and promote use of our evidence by others and develop future collaborations. However, the views and recommendations presented in this report are not necessarily those of NRW and should, therefore, not be attributed to NRW.

Report series: Wales Metal Mines Programme

Report number: 1016

Publication date: 02 September 2026

Title: The Impact of Abandoned Metal Mines on Water Quality in the Upper Wye

Author(s): **E Krishan, T Williams, D Johnston**

Technical editor: D Johnston

Quality assurance: Tier 3: High level internal peer review – staff.

Sign off - Project executive or Management level, co-signed by Integrated Evidence Manager

Peer reviewer(s): P Edwards, T Hatton-Ellis, J Tanner, L Park, R Thomas, V Lane

Approved by: R Cardwell

Series editor(s): D Johnston

Restrictions: None

Distribution list

Core distribution list managed by the Library: National Library of Wales, British Library, Welsh Government, NatureScot, Natural England

Other organisations and individuals this report has been distributed to by the authors or contract manager:

Recommended citation for this volume:

Krishan E, Williams T, Johnston D. 2026. The impact of abandoned metal mines on water quality in the Upper Wye. NRW Evidence Report, Report No: 1016, 129pp, NRW, Cardiff.

Contents

List of figures

List of tables

Crynodeb gweithredol

Cyflwyniad a chefndir

Mwyngloddiau segur yw'r prif reswm pam mae cyrff dŵr yng Nghymru yn methu â bodloni’r safonau ansawdd amgylcheddol ar gyfer metelau a osodwyd ar eu cyfer gan Reoliadau’r Amgylchedd Dŵr (Y Gyfarwyddeb Fframwaith Dŵr) (Cymru a Lloegr) 2017 (Rheoliadau’r Gyfarwyddeb Fframwaith Dŵr). Mewn ymateb i'r mater hwn, sefydlwyd Rhaglen Mwyngloddiau Metel Cymru yn 2020 i leihau llygredd sy'n deillio o fwyngloddiau metel segur. Mae'n cael ei chyflwyno ar y cyd gan Cyfoeth Naturiol Cymru (CNC) a’r Awdurdod Adfer Safleoedd Mwyngloddio (a elwid yr Awdurdod Glo gynt).

Prif rôl CNC yn Rhaglen Mwyngloddiau Metel Cymru yw cynnal gwerthusiadau sy'n seiliedig ar dystiolaeth i bennu ffynonellau llygredd mewn dalgylchoedd a nodi lle byddai camau adferol o fudd i’r amgylchedd.

Mae'r astudiaeth hon yn ystyried effeithiau ansawdd dŵr o fwyngloddiau metel segur yn nalgylch ‘Gwy Uchaf’, sy'n cynnwys chwe chorff dŵr afonol o dan Reoliadau’r Gyfarwyddeb Fframwaith Dŵr sydd wedi'u lleoli yn nalgylch rheoli afon Gwy i fyny'r afon o Raeadr Gwy. Mae pump o'r chwe chorff dŵr wedi'u llygru gan ollyngiadau o sinc, plwm a chadmiwm o fwyngloddiau segur ac nid yw pedwar yn cyflawni statws cemegol nag ecolegol ‘Da’ o ganlyniad (Cylch 3 Rheoliadau’r Gyfarwyddeb Fframwaith Dŵr, 2024).

Yn 2020, daeth trosolwg o asesiadau cyrff dŵr sy’n methu (Yr Awdurdod Glo, 2020) i’r casgliad bod hi’n debygol iawn bod pum mwynglawdd yn cyfrannu at lygredd yn y dalgylch (safleoedd ‘Coch’). Y rhain yw Pumlumon, Nantiago, Nantygwrdy, Dolminers a Nanty, ac mae pedwar ohonynt mewn dwy lednant yn y dalgylch uchaf, sef blaenddyfroedd afon Gwy ac afon Tarenig. Mae Nanty wedi'i leoli ar lannau afon Gwy ychydig i lawr yr afon o gydlifiad y ddwy lednant. Ystyriwyd bod effeithiau'r 11 mwynglawdd arall yn y dalgylch yn anhysbys neu'n annhebygol (h.y. ‘Oren’ neu ‘Gwyrdd’).

Ers adroddiad 2020, mae astudiaethau nodweddu mwynglawdd penodol i’r safle wedi'u cynnal mewn pedwar o'r pum safle ‘Coch’. Comisiynwyd y rhain i ddeall ffynonellau llygredd yn well ac i ddatblygu model cysyniadol o'r safleoedd. Mae gwaith monitro ansawdd a llif dŵr mewn safleoedd mwynglawdd ‘Coch’ a chyrsiau dŵr yn y dalgylch wedi mynd rhagddo.

Canfyddiadau

Mae'r rhan fwyaf o'r llygredd metelau yn nalgylch Gwy Uchaf yn deillio o fwyngloddiau segur yn y ddau gorff dŵr i fyny'r afon. Afon Tarenig ac afon Gwy uwchben y cydlifiad ag afon Tarenig yw’r rhain. Mae llwythi cyfartalog cyfrifedig o fetelau yn dangos bod afon Tarenig yn cyfrannu 509 kg o sinc, 66 kg o blwm ac 1.9 kg o gadmiwm yn flynyddol at y dalgylch. Mae afon Gwy uwchben afon Tarenig yn cyfrannu 1,477 kg o sinc, 162 kg o blwm a 6.6 kg o gadmiwm yn flynyddol at y dalgylch.

Mae cyfraniadau llwythi metel o'r ddwy lednant yn cynrychioli 70% o'r plwm, 54% o'r cadmiwm a 54% o'r sinc a gyfrifwyd yn afon Gwy uwchlaw ei chydlifiad ag afon Bidno. Fodd bynnag, mae rhywfaint o ansicrwydd yn gysylltiedig â'r amcangyfrifon llif (h.y. mae rhywfaint o dystiolaeth bod cyfraddau llif wedi'u goramcangyfrif) a ddefnyddir yn y cyfrifiad hwn ar gyfer afon Gwy i fyny'r afon o afon Bidno. Mae'r ansicrwydd hwn yn awgrymu'n gryf nad yw'r llwyth sy'n cael ei gario gan afon Gwy yn y lleoliad hwn mor fawr ag yr adroddwyd ac felly gallai cyfanswm cyfraniadau blaenddyfroedd afon Tarenig ac afon Gwy fod yn agosach at 100%.

Mae gwaith monitro parhaus gan CNC yn awgrymu bod cyfraniadau llwythi metel o bob un o'r mwyngloddiau ‘Coch’ fel a ganlyn:

- Nantygwrdy: 676 kg y flwyddyn o sinc, 87 kg y flwyddyn o blwm a 3 kg y flwyddyn o gadmiwm.
- Pumlumon: 539 kg y flwyddyn o sinc, 190.5 kg y flwyddyn o blwm a 2.1 kg y flwyddyn o gadmiwm.
- Nantiago: 383 kg y flwyddyn o sinc, 27.2 kg y flwyddyn o blwm ac 1.8 kg y flwyddyn o gadmiwm.

Mae'r data'n dangos nad yw mwynglawdd Dolminers yn cyfrannu'n sylweddol at lygredd yn y dalgylch. Mae canlyniadau cychwynnol y gwaith monitro ansawdd dŵr ym mwynglawdd Nanty hefyd yn awgrymu nad yw'r mwynglawdd hwn yn cyfrannu'n sylweddol at lygredd yn y dalgylch, ond dylid cadarnhau hyn ar ôl cwblhau'r gwaith monitro sy'n weddill yn 2026 (gweler yr argymhellion).

Mae tair ffynhonnell arwahanol o lygredd sy'n gysylltiedig â mwyngloddiau Nantygwrdy a Phumlumon, ac mae pob un yn cyfrannu o leiaf 400 kg y flwyddyn o gyfanswm y llygredd metel (sinc, plwm a chadmiwm). Dyma'r prif ffynonellau yn y dalgylch ac fe'u rhestrir isod (yn nhrefn eu heffaith):

1) Llygredd gwasgaredig yn Nantygwrdy: Hen ardal llawr trin sydd wedi'i hailweithio'n helaeth ac a ddefnyddir bellach fel datblygiad ar gyfer chwaraeon moduro. Mae hyn yn cynnwys llif bach, crynodedig o ddŵr sy’n llawn metelau sy'n croesi'r iard ac yn gollwng i afon Gwy, a allai fod â tharddiad mwynglawdd.
2) Llygredd gwasgaredig ym Mhumlumon, i lawr yr afon o geuffordd Pumlumon: Tomenni sborion helaeth o weithgarwch mwyngloddio, yn bennaf ar hyd glan ddwyreiniol afon Tarenig.
3) Ceuffordd Nantygwrdy (sy'n llifo i Nant y Gwrdy).

Cyfanswm hyd y cwrs dŵr sy'n fwy na'r safonau ansawdd amgylcheddol ar gyfer sinc sydd ar gael yn fiolegol yw 40.6 km. Mae hyn yn cynnwys 7 km o'r corff dŵr sydd fwyaf i lawr yr afon – GB109055042280 (afon Gwy – cydlifiad afon Marteg i gydlifiad afon Elan) – sydd fel arall wedi'i ddosbarthu i fod â statws ‘da’. Yn unol â dadansoddiadau blaenorol, nid ystyrir bod afon Bidno wedi'i llygru ac felly nid yw'n cyfrannu at y cyfanswm hwnnw.

Mae'r dadansoddiad o ddata yn dangos y gallai ymyriad mewn ffynhonnell o lygredd gwasgaredig ym Mhumlumon (i lawr yr afon o geuffordd Pumlumon) leihau'r llwyth cadmiwm, plwm a sinc o’r swm gofynnol i wneud i'r pwynt i lawr yr afon o afon Tarenig (gorsaf fonitro 50002, uwchben cydlifiad afon Gwy) gydymffurfio â'r safonau ansawdd amgylcheddol ar gyfer y metelau hyn. Gallai hyn arwain at newid statws Rheoliadau’r Gyfarwyddeb Fframwaith Dŵr ar gyfer metelau yn y corff dŵr hwn.

Mae amcangyfrifon o leihau llwyth ar afon Gwy uwchben afon Tarenig yn dangos y gallai trin pob ffynhonnell sy'n gysylltiedig â Nantygwrdy a Nantiago arwain at gydymffurfedd o ran cadmiwm, plwm a sinc yn y pwynt monitro i lawr yr afon o bob mwynglawdd ar y corff dŵr hwn (53078).

Oherwydd yr ansicrwydd sy'n gysylltiedig â data hydrometreg y llif amcangyfrifedig ar gyfer y cyrff dŵr sy'n weddill, a'r dalgylch, nid yw'n bosibl pennu'r union fudd y byddai camau adferol yn ei gyflawni. Fodd bynnag, gellir tybio y bydd unrhyw fesurau adferol a weithredir ar y ddwy ‘lednant ffynhonnell’ yn cyfrannu’n anochel at welliant amgylcheddol i lawr yr afon.

Argymhellion

Dylai camau adferol ganolbwyntio ar y prif ffynonellau sy'n gysylltiedig â mwyngloddiau Nantygwrdy, Pumlumon a Nantiago. Gellid ystyried blaenoriaethu ymyriadau llygredd gwasgaredig ym mwynglawdd Pumlumon dros ffynonellau eraill o ystyried y gallai un ymyriad wella amodau afon Tarenig yn sylweddol, gan newid statws yr afon o dan Reoliadau’r Gyfarwyddeb Fframwaith Dŵr o bosibl.

Dylai Pumlumon fod yn destun ymchwiliad manwl pellach ac ymarfer astudiaeth pen desg tebyg i'r rhai a gynhaliwyd yn y mwyngloddiau ‘Coch’ eraill yn y dalgylch.

Dylid monitro effeithiau unrhyw gamau adferol arfaethedig mewn cyrff dŵr ledled y dalgylch, er mwyn pennu'r newid mewn crynodiadau metelau ledled y rhan o’r afon yr effeithir arni ar hyn o bryd.

Dosbarthwyd statws ‘Oren’ i fwyngloddiau Nant Nod, De Pumlumon, Hirgoed Ddu a Fagwr Fraith yn astudiaeth 2020. Mae'r holl fwyngloddiau segur hyn wedi'u lleoli o fewn ffin corff dŵr afon Tarenig. Yn seiliedig ar ganfyddiadau’r astudiaeth hon, argymhellir rhoi statws ‘Gwyrdd’ i’r mwyngloddiau hyn, gan nad ydynt yn ffynonellau sylweddol o lygredd sy’n effeithio ar statws y corff dŵr. Dylid ailgategoreiddio Dolminers hefyd, gan roi statws ‘Gwyrdd’ iddo.

Mae angen asesiad pellach o effeithiau llygredd o fwynglawdd Nanty cyn unrhyw ailgategoreiddio posibl i’r statws ‘Coch’. Dylid cwblhau hyn unwaith y bydd gwaith monitro 2026 wedi dod i ben.

Executive summary

Introduction and background

Abandoned mines are the principal reason why waterbodies in Wales fail to achieve their WFDR Environmental Quality Standards for metals set by the Water Environment (Water Framework Directive) (England and Wales) Regulations 2017 (WFDR). In response to this issue, the Wales Metal Mines Programme (WMMP) was established in 2020 to reduce pollution arising from abandoned metal mines. It is being jointly delivered by Natural Resources Wales (NRW) and the Mining Remediation Authority (MRA, formerly Coal Authority).

NRW's main role in the WMMP is to conduct evidence-based evaluations to determine the sources of pollution in catchments and identify where remedial action would result in environmental benefit.

This study considers the water quality impacts from abandoned metal mines in the 'Upper Wye' catchment, which comprises of six WFDR river waterbodies located in the Wye Management Catchment upstream of Rhayader. Five of the six waterbodies are polluted by discharges of zinc, lead, and cadmium from abandoned mines and four do not achieve 'Good' chemical or ecological status as a result (WFDR Cycle 3 2024).

The 2020 Failing Waterbodies (FWB) Assessment Overview (Coal Authority, 2020) determined that there were five mines which are highly likely to be contributing to pollution in the catchment ('Red' sites). These are Plynlimon, Nantiago, Nantygwrdy, Dolminers, and Nanty, four of which are in two tributaries in the upper catchment, the Wye headwaters and the Afon Tarenig. Nanty is located on the banks of the River Wye just downstream of the confluence of both tributaries. The impacts from the other 11 mines in the catchment were deemed to be unknown or unlikely (i.e. 'Amber' or 'Green').

Since the 2020 report, site-specific mine characterisation studies have been undertaken at four of the five 'Red' sites. These were commissioned to better understand the pollution sources and to develop a conceptual model of the sites. Water quality and flow monitoring at 'Red' mine sites and watercourses in the catchment has continued.

Findings

Most of the metals pollution in the Upper Wye catchment originates from abandoned mines in the two upstream waterbodies. They are the Afon Tarenig and the River Wye above the confluence with the Afon Tarenig. Calculated average loadings of metals indicate that the Afon Tarenig contributes 509 kg zinc, 66 kg lead, and 1.9 kg cadmium annually into the catchment. The River Wye above the Afon Tarenig contributes 1477 kg zinc, 162 kg lead, and 6.6 kg cadmium annually into the catchment.

The metal loading contributions from both tributaries represent 70% of the lead, 54% of the cadmium and 54% of the zinc calculated in the River Wye above its confluence with the

Afon Bidno. However, there is some uncertainty associated with the flow estimations (i.e. there is some evidence that flow rates have been overestimated) for the Wye upstream of the Afon Bidno used in this calculation. This uncertainty strongly suggests that the load carried by the River Wye at this location is not as great as reported and therefore the total contributions of the Afon Tarenig and Wye Headwaters may be closer to 100%.

Ongoing NRW monitoring suggests that metal loading contributions from each of the 'Red' mines are as follows:

- Nantygwrdy: 676 kg/yr zinc, 87 kg/yr lead, and 3 kg/yr cadmium.
- Plynlimon: 539 kg/yr zinc, 190.5 kg/yr lead, and 2.1 kg/yr cadmium.
- Nantiago: 383 kg/yr zinc, 27.2 kg/yr lead, and 1.8 kg/yr cadmium.

The data indicate that Dolminers mine is not a significant contributor to pollution in the catchment. The initial results of the water quality monitoring at Nanty mine also suggests that this mine is not a significant contributor to pollution in the catchment, but this should be confirmed upon completion of the remaining 2026 monitoring (see recommendations).

Three discrete pollution sources associated with Nantygwrdy and Plynlimon mines each contribute at least 400 kg/yr of total metal pollution (zinc, lead, and cadmium). These are the principal sources in the catchment and are listed below (in order of impact):

1) Diffuse pollution at Nantygwrdy: Old dressing floor area which has been extensively reworked and now used as a motorsports development. This includes a small, concentrated flow of water enriched in metals which traverses the yard and discharges into the River Wye, which may be of mine origin.

2) Diffuse pollution at Plynlimon, downstream of Plynlimon Adit: Extensive mining spoil tips primarily along the eastern bank of the Afon Tarenig.

3) Nantygwrdy Adit (which discharges into the Nant y Gwrdy stream).

The total length of watercourse exceeding the bioavailable zinc EQS is 40.6 km. This includes 7 km of the most downstream waterbody: GB109055042280 (Wye – conf Afon Marteg to conf Afon Elan) which is otherwise classified as being of 'Good' status. As per previous analyses, the Afon Bidno is not considered to be polluted and as such does not contribute to that total.

The data analysis indicates that a diffuse pollution source intervention at Plynlimon (downstream of Plynlimon Adit) could reduce the required cadmium, lead, and zinc load to make the downstream point of the Afon Tarenig (monitoring station 50002, above the River Wye confluence) compliant with the EQS for these metals. This could result in a WFDR status change for metals in this waterbody.

Loading reduction estimates on the River Wye above the Afon Tarenig indicate that treatment of all sources associated with Nantygwrdy and Nantiago could result in cadmium, lead, and zinc compliance at the monitoring point downstream of all mines on this waterbody (53078).

Due to uncertainty associated with the estimated flow hydrometry data for the remaining waterbodies, and catchment, it is not possible to determine the exact benefit that remedial action would achieve. It can, however, be presumed that any remedial measures implemented on the two ‘source tributaries’ will inevitably contribute to betterment and environmental improvement downstream.

Recommendations

Remedial action should focus on the principal sources associated with Nantygwrdy, Plynlimon and Nantiago mines. Prioritisation of diffuse pollution interventions at Plynlimon mine could be considered over other sources given that a single intervention could significantly improve conditions in the Afon Tarenig, potentially achieving WFDR status change.

Plynlimon should be subject to further detailed investigation and a desk study exercise comparable to those undertaken at the other ‘Red’ mines in the catchment.

The impacts of any planned remedial action should be monitored in waterbodies throughout the catchment, to determine the change in metals concentrations throughout the currently impacted length.

Nant Nod, Plynlimon South, Hirgoed Ddu, and Fagwr Fraith mines were all categorised as ‘Amber’ sites in the 2020 study. All these abandoned mines are located within the Afon Tarenig waterbody boundary. Based on the findings of this study, it is recommended that these mines are assigned ‘Green’ status, as they are not significant sources of pollution affecting the status of the waterbody. Dolminers should also be recategorised as ‘Green’.

Further assessment of pollution impacts from Nanty mine is required prior to any potential recategorisation from ‘Red’ status. This should be completed once the 2026 monitoring has concluded.

1. Introduction and background to the programme

Wales has a long history of mining for metals dating back to the Bronze Age. The industry reached a peak in the 19th century and by the 1920s most mining had ended, leaving a legacy of over 1300 abandoned mines. These abandoned mines are a source of metal pollution to rivers through discharges of water from underground mine workings and leaching and erosion from spoil heaps. Metals, including zinc, lead and cadmium, are causing around 700 km of Welsh rivers (Coal Authority, 2020) to fail to achieve ‘Good’ chemical or ecological status as required by the Water Environment (Water Framework Directive) Regulations 2017 (WFDR) (Defra, 2017). The pollution harms the river ecology, reducing fish populations and diversity of invertebrate life.

Abandoned mines are the principal cause of waterbodies in Wales failing to achieve Environmental Quality Standards (EQS) for metals under The Water Framework Directive (Standards and Classification) Directions (England and Wales) 2015 (WFD Directions) (Defra, 2015).

In response to this issue, the Wales Metal Mines Programme (WMMP) was established in 2020 and is being jointly delivered by Natural Resources Wales (NRW) and the Mining Remediation Authority (MRA, formerly Coal Authority). This programme is one of a number delivering the River Basin Management Plans (RBMPs) in Wales, which are designed to protect and improve the water environment for the benefit of people and wildlife.

The primary objective of the WMMP is to reduce pollution of land and rivers and to mitigate other identified hazards and risks from abandoned metal mines. This will help achieve cleaner rivers and directly contribute to the sustainable management of natural resources as detailed in the Environment (Wales) Act 2016 and the Well-being of Future Generations (Wales) Act 2015.

The current priorities of abandoned metal mine investigation, monitoring and remedial work delivered under the WMMP have been determined from historical evidence-based studies, including the Metal Mine Strategy for Wales (Environment Agency Wales, 2002) and more recently, the Failing Waterbodies (FWB) Assessment Overview in 2020 (Coal Authority, 2020). The FWB report identified which metal mine sources were a primary reason for waterbodies failing to achieve WFDR ‘Good’ status and whether a status change was possible following remedial interventions.

The FWB report (Coal Authority, 2020) categorised known abandoned metal mines within Welsh catchments known to be failing to meet ‘Good’ status as ‘Red’, ‘Amber’, or ‘Green’. ‘Red’ sites are known or highly likely to be impacting the water environment. ‘Amber’ sites might be impacting the water environment but are subject to a greater degree of uncertainty, and more information is needed to determine whether they should be recategorised as ‘Red’ or ‘Green’. ‘Green’ sites are unlikely to be impacting water quality. The report identified 129 ‘Red’, 140 ‘Amber’ and 278 ‘Green’ sites across affected water bodies in Wales. This has since been reviewed and there are now considered to be 115 ‘Red’ and 128 ‘Amber’ sites. The pollution risk categorisation of mines within the Wye catchment was supported by Appendix C6 of the FWB report, which was produced in December 2019 (Coal Authority, 2019).

The Severn RBMP (Natural Resources Wales, 2022) identifies pollution from mines as a challenge to achieving the objectives of the WFDR in the Welsh part of the Severn River Basin District. Eleven waterbodies, including the six identified in this report, are identified as failing to achieve ‘Good’ status due to discharges from metal mines.

The purpose of this report is to identify the priority sources of metals that are polluting the Upper Wye catchment from abandoned metal mines. This report builds on the FWB report (Coal Authority, 2020) and incorporates the findings of monitoring and other investigations undertaken since the FWB report was published. This includes water quality monitoring surveys from ‘Red’ and ‘Amber’ mines within the upper part of the Wye catchment, other monitoring and information gathered from the catchment (e.g. WFDR Cycle 3 monitoring) and mine-specific investigations and reports. This study makes recommendations on priority pollution sources to be considered for remedial interventions within the catchment, based on the available evidence at the time of writing.

2. Upper Wye catchment characteristics

2.1. Catchment description

The catchment area described in this report comprises six WFDR river waterbodies, within the ‘Wye, Source to Ithon’ Operational Catchment, located within the uppermost part of the Wye Management Catchment. Hence the study area which is the subject of this report has been termed the Upper Wye catchment, as shown on Figure 1.

The surface waterbodies within the catchment include the following:

- GB109055042360: Wye – source to conf Afon Tarenig.
- GB109055042350: Afon Tarenig – source to conf R Wye.
- GB109055042340: Afon Bidno – source to conf R Wye.
- GB109055042330: Wye – conf Afon Tarenig to conf Afon Bidno.
- GB109055042320: Wye – conf Afon Bidno to conf Afon Marteg.
- GB109055042280: Wye – conf Afon Marteg to conf Afon Elan.

The River Wye from its source to the confluence with the Afon Elan is the principal river within the study area catchment, with two tributaries: the Afon Tarenig and Afon Bidno.

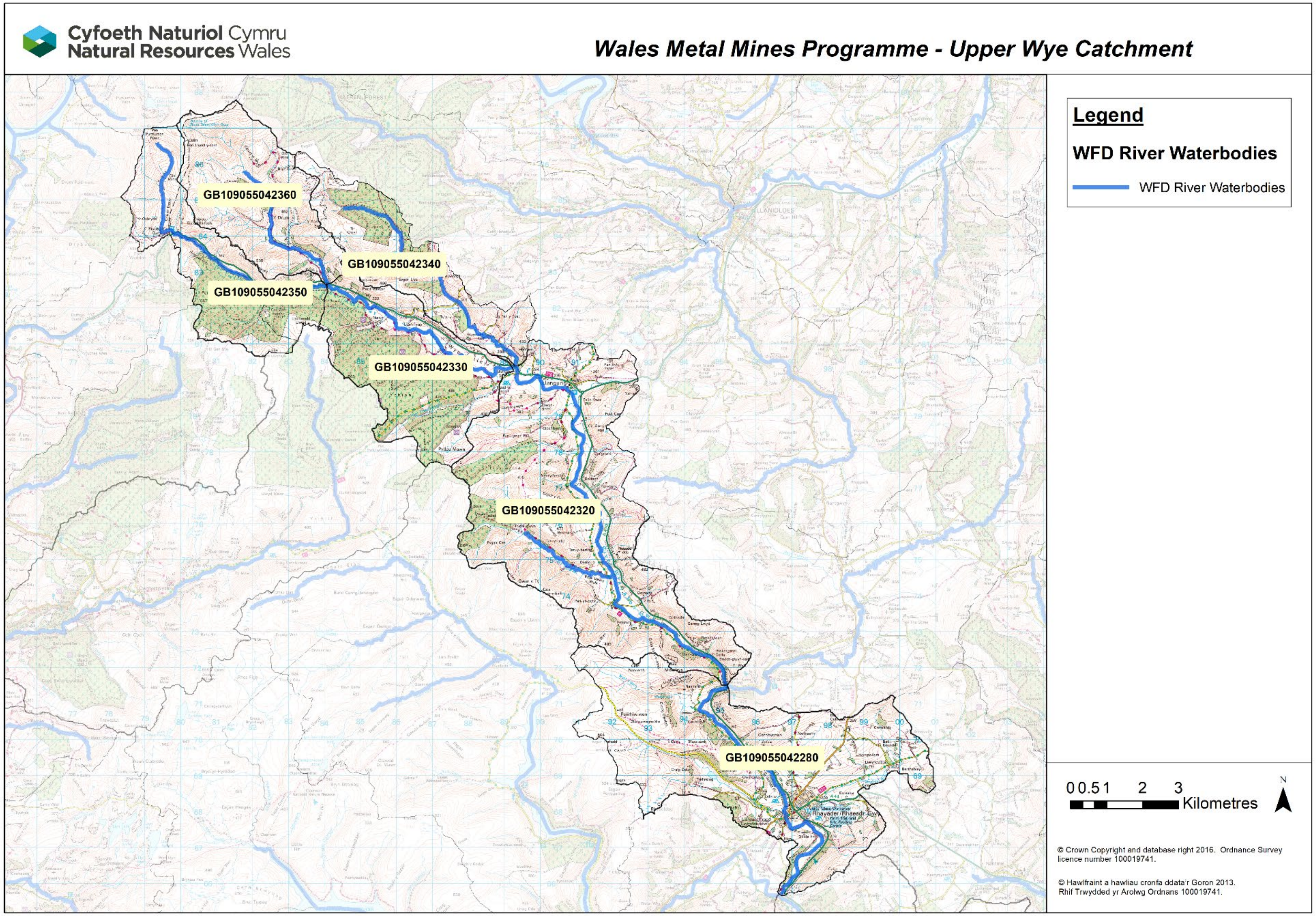

Figure 1: The Upper Wye catchment, and WFDR surface waterbodies

2.2. Mining history

There is evidence that mining within the Upper Wye catchment was prevalent from the mid-19th century, with mining operations ceasing in the late 19th century and occasionally extending into the early 20th century. The abandoned metal mines within the Upper Wye catchment are shown on Figure 2.

Most of the abandoned mines within the Upper Wye catchment comprise of a single shaft or level, with limited information relating to the history of mining operations and the mine workings. There is evidence of larger scale abandoned mine workings within the Upper Wye catchment in the form of the Nantiago, Nantygwrdy, Dolminers, Nanty and Plynlimon mines.

Plynlimon mine was one of the more productive mines in the catchment, yielding approximately 3270 tons of lead concentrates between 1867 and 1897 (Jones, 1922). Plynlimon East is located approximately 1.5 km northeast of Plynlimon, although this mining operation was minor as it was curtailed prematurely by the loss of surface facilities in the Wye Valley when the Nantiago supply dam burst (Hall, 2004). There is no evidence of any mining features at Plynlimon East based on historical maps and aerial imagery.

Nantiago, located on the Nant Iago tributary of the River Wye, was also relatively productive. This mine generated 1709 tons of lead ore and 1929 tons of zinc ore concentrates during defined periods between 1846, 1861-1866, 1869-1878, 1882-1888, and 1903-1917 (Smith, 1978).

Both Nantygwrdy mine and Dolminers produced quantities of lead, and lead and zinc ores respectively. The remains of these mines are located 320 m apart and are understood to have operated in isolation of one another. Nantygwrdy is a former lead mine which was active between 1865-1866, and from 1874-1879, during which 1595 tons of lead ore concentrates were produced (Smith, 1978). Dolminers is a former lead and zinc mine and was active between 1877 and 1884, during which period 669 tons of lead ore and 111 tons of zinc ore concentrates were produced (Smith, 1978).

Nanty mine is located further down the catchment, approximately 3.9 km southeast of Dolminers. The earliest record of Nanty is on 1836 Ordnance Survey (OS) mapping; it was not visible on 1822 records. Although some authors regard it as an ancient mine, detailed heritage investigations have not produced any evidence of this (Section 2.6). The mine was highly productive between 1856 and 1871, where it was mined for lead and silver ores (Jones, 1922).

In the FWB report (Coal Authority, 2020), 16 abandoned mines were reported within the Wye catchment. A description of each mine is provided in Table 1. Between 2020 and 2025, some of the abandoned mines have undergone additional investigation (primarily those deemed as ‘Red’), which has furthered our understanding of the mine history. This information is also summarised in Table 1.

Table 1: Abandoned metal mines in the Upper Wye catchment.

Mine[1]	NGR	Waterbody	Description	References
Cyff	SN 80501 85800	GB109055042360: Wye – source to conf Afon Tarenig	Historical maps show the presence of an old level and mining spoil. The Wye FWB report indicates that there was an unsuccessful trial level driven west in grits, and that there is no further information relating to this mine. There has been no investigation into this mine since the FWB report (Coal Authority, 2020) was published.	Coal Authority, 2020.
Plynlimon East	SN 81001 86495	GB109055042360: Wye – source to conf Afon Tarenig	The information presented above indicates that Plynlimon East was a minor working. There is no evidence of mine features on historical maps in its supposed location, and there has been no investigation into this mine since the FWB report (Coal Authority, 2020) was published.	Coal Authority, 2020.
Gerig	SN 81501 86399	GB109055042360: Wye – source to conf Afon Tarenig	Historical maps indicate that there was an old shaft, and an aqueduct system associated with this mine. There are no other signs of mining. There has been no investigation into this mine since the FWB report (Coal Authority, 2020) was published.	Coal Authority, 2020.
Nantiago	SN 82600 86320	GB109055042360: Wye – source to conf Afon Tarenig	Underground workings at Nantiago comprised an open stope and Engine Shaft (SN 82496 86389), a Trial Adit (SN 82711 86194) and the Deep Adit (SN 82641 86271). The Engine Shaft was advanced 60 Fathoms below the Deep Adit. There are well preserved earthwork and structural remains from the mine, including foundations, ironwork, wheel pits, dressing floors, and spoil tips. There has been an investigation into this mine since the FWB report (Coal Authority, 2020), with the findings summarised in Section 3.2.	Coal Authority, 2020. WSP, 2021a.

[1] The following mines were recorded on the GIS database, but upon reviewing historical maps and aerial imagery, did not correspond to any evidence of mining activity: Mine M27, Llyn Du, Dolhelfa, and Maen Serth. Therefore, they have not been included in this table.

Mine[1]	NGR	Waterbody	Description	References
Nantygwrdy	SN 82636 84985	GB109055042360: Wye – source to conf Afon Tarenig	Underground workings at Nantygwrdy comprised four shafts and two adits: • Tippett's Shaft (SN 83144 85072). • New Shaft (SN 82990 85031). • Air Shaft (SN 82883 85033). • Old Shaft (SN 82867 84990). • Shallow Adit (SN 82878 85040). • Deep Adit (SN 82783 85077). Tippett's Shaft was advanced to the 22 Fathom Level, Old Shaft to 46 Fathom Level, and New Shaft to 70 Fathom Level. There was a dressing floor adjacent to the River Wye. The dressing floor and mining spoil have subsequently been modified by recent developments and there are no longer any visible remains of both. There has been an investigation into this mine since the FWB report (Coal Authority, 2020), with the findings summarised in Section 3.2.	Coal Authority, 2020. WSP, 2021b.

Mine[1]	NGR	Waterbody	Description	References
Dolminers	SN 82387 84788	GB109055042360: Wye – source to conf Afon Tarenig	Underground workings at Dolminers comprised three shafts and two adits: • Murchison's Shaft (SN 82394 84783). • Brooke's Shaft (SN 82482 84637). • Trial Shaft (SN 82264 84698). • Shallow Adit (SN 82427 84783). • Deep Adit (SN 82342 84653). Murchison's Shaft was advanced to the 40 Fathom Level, whilst Brooke's Shaft was advanced to the 78 Fathom Level. Foster-Smith (1978) suggested that there is a connection between the Dolminers and Nantygwrdy mines via a level driven up from Brooke's Shaft. There is no evidence of this subsurface connection. There were dressing floors equipped with ore bins, a crusher, jigs, and buddles. There was a pumping waterwheel, supplied by a one-mile-long leat from the Cyff Brook on the western side of the River Wye. The mining operations were supported by a tramway. Most of the mining spoil in this area appears to be vegetated. There has been an investigation into this mine since the FWB report (Coal Authority, 2020), with the findings summarised in Section 3.2.	Coal Authority, 2020. WSP, 2021c.
Plynlimon	SN 79596 85801	GB109055042350: Afon Tarenig – source to conf R Wye	Plans showing the mine workings at Plynlimon are limited. There appear to be two shafts (Engine Shaft and New Shaft, down to 36 Fathom Level), and an adit which discharges into the Afon Tarenig. Historical maps indicate that there were two reservoirs and a tramway which serviced the mine. There are remnants of mine spoil tips along the banks of the Afon Tarenig, particularly along the eastern bank. There have been ongoing water quality monitoring investigations at this mine since the beginning of 2025.	Coal Authority, 2020.

Mine[1]	NGR	Waterbody	Description	References
Nant Nod	SN 78681 84107	GB109055042350: Afon Tarenig – source to conf R Wye	Historical maps from the 1890s show the ‘Nant Nod Mine (Lead)’, with a single shaft annotated. The mine was marked as disused by the early 1900s. There was a tramway connecting it to Plynlimon approximately 1.9 km northeast. It was recorded as disused at the same time as the mining level associated with the adjacent Plynlimon South, which indicates they may have been worked concurrently. There do not appear to be any extensive spoil tips based on historical maps or aerial imagery. There has been no investigation into this mine since the FWB report (Coal Authority, 2020) was published.	Coal Authority, 2020.
Plynlimon South	SN 79399 84099	GB109055042350: Afon Tarenig – source to conf R Wye	Historical maps show a mining level from the 1890s, which was marked as an old level by the early 1900s, like Nant Nod. It was also connected to Plynlimon via an old tramway. There do not appear to be any extensive spoil tips based on historical maps or aerial imagery. There has been no investigation into this mine since the FWB report (Coal Authority, 2020) was published.	Coal Authority, 2020.
Hirgoed Ddu	SN 80600 83698	GB109055042350: Afon Tarenig – source to conf R Wye	Historical maps show two old mining levels and a shaft on the northeast bank of the Afon Tarenig, and ‘old levels’ on the southwest bank of the Afon Tarenig. These were marked as old lead mining features in the 1890s. There do not appear to be any extensive spoil tips based on historical maps or aerial imagery. There has been no investigation into this mine since the FWB report (Coal Authority, 2020) was published.	Coal Authority, 2020.
Nant Gwernos	SN 82200 82598	GB109055042350: Afon Tarenig – source to conf R Wye	Historical maps show no mining features in this location, which corroborates the findings of the FWB report (Coal Authority, 2020). Historical maps show a level annotated to the southeast, at SN 82499 82287. This level was no longer annotated by the early 1900s. There has been no investigation into this mine since the FWB report (Coal Authority, 2020) was published.	Coal Authority, 2020.

Mine[1]	NGR	Waterbody	Description	References
Fagwr Fraith	SN 82600 81299	GB109055042350: Afon Tarenig – source to conf R Wye	Historical maps from the 1890s show one old mining level (lead) in this locality. It is located within a heavily vegetated area, so there are no spoil tips visible from aerial imagery, or historical maps. There has been no investigation into this mine since the FWB report (Coal Authority, 2020) was published.	Coal Authority, 2020.
Tor Du	SN 84000 85499	GB109055042340: Afon Bidno – source to conf R Wye	A mining level (lead) was annotated on historical maps in the 1890s and marked as old by the 1900s. Historical maps during the same period suggest that there were two spoil tips along the western bank of the Afon Bidno. There has been no investigation into this mine since the FWB report (Coal Authority, 2020) was published.	Coal Authority, 2020.
Glan Severn	SN 84500 81799	GB109055042330: Wye – conf Afon Tarenig to conf Afon Bidno	Historical maps show a mining level (lead) in use in the 1890s, which was marked as old by the early 1900s (SN 84467 81861). An additional old mining level (lead) was annotated on historical maps in the early 1900s (SN 84562 81997). The area is heavily forested and there is no evidence of any significant spoil tips based on aerial imagery. There has been no investigation into this mine since the FWB report (Coal Authority, 2020) was published.	Coal Authority, 2020.
Nanty South	SN 84902 81802	GB109055042330: Wye – conf Afon Tarenig to conf Afon Bidno	Historical maps show a mining level (lead) in use in the 1890s, which was marked as old by the early 1900s. The area is heavily forested and there is no evidence of any significant spoil tips based on aerial imagery. There has been no investigation into this mine since the FWB report (Coal Authority, 2020) was published.	Coal Authority, 2020.

Mine[1]	NGR	Waterbody	Description	References
Nanty	SN 85197 82289	GB109055042330: Wye – conf Afon Tarenig to conf Afon Bidno	Underground workings at Nanty comprised of four adits driven north into the lode at progressively higher elevations along a hillside, and were connected by a single shaft: • Fathom Adit (SN 85327 82397). • Shallow Adit (SN 85300 82328). • Roadway Adit (SN 85266 82247). • Deep Adit (SN 85271 82188). • Engine Shaft (SN 85276 82237). The remains of the mine, which included engine houses, waterwheels, and dressing floors, are poorly preserved. Mining spoil tips remain adjacent to the River Wye. There has been an investigation into this mine since the FWB report (Coal Authority, 2020), with the findings summarised in Section 3.2.	Coal Authority, 2020. WSP, 2021d.
Cwm Bach	SN 94799 70201	GB109055042280: Wye – conf Afon Marteg to conf Afon Elan	There is no evidence of historical mining features recorded on historical maps and aerial imagery. However, there were three old quarries located to the south of the mine entry coordinates, which were in use during the 1890s and no longer annotated by the early 1900s. There has been no investigation into this mine since the FWB report (Coal Authority, 2020) was published.	Coal Authority, 2020.

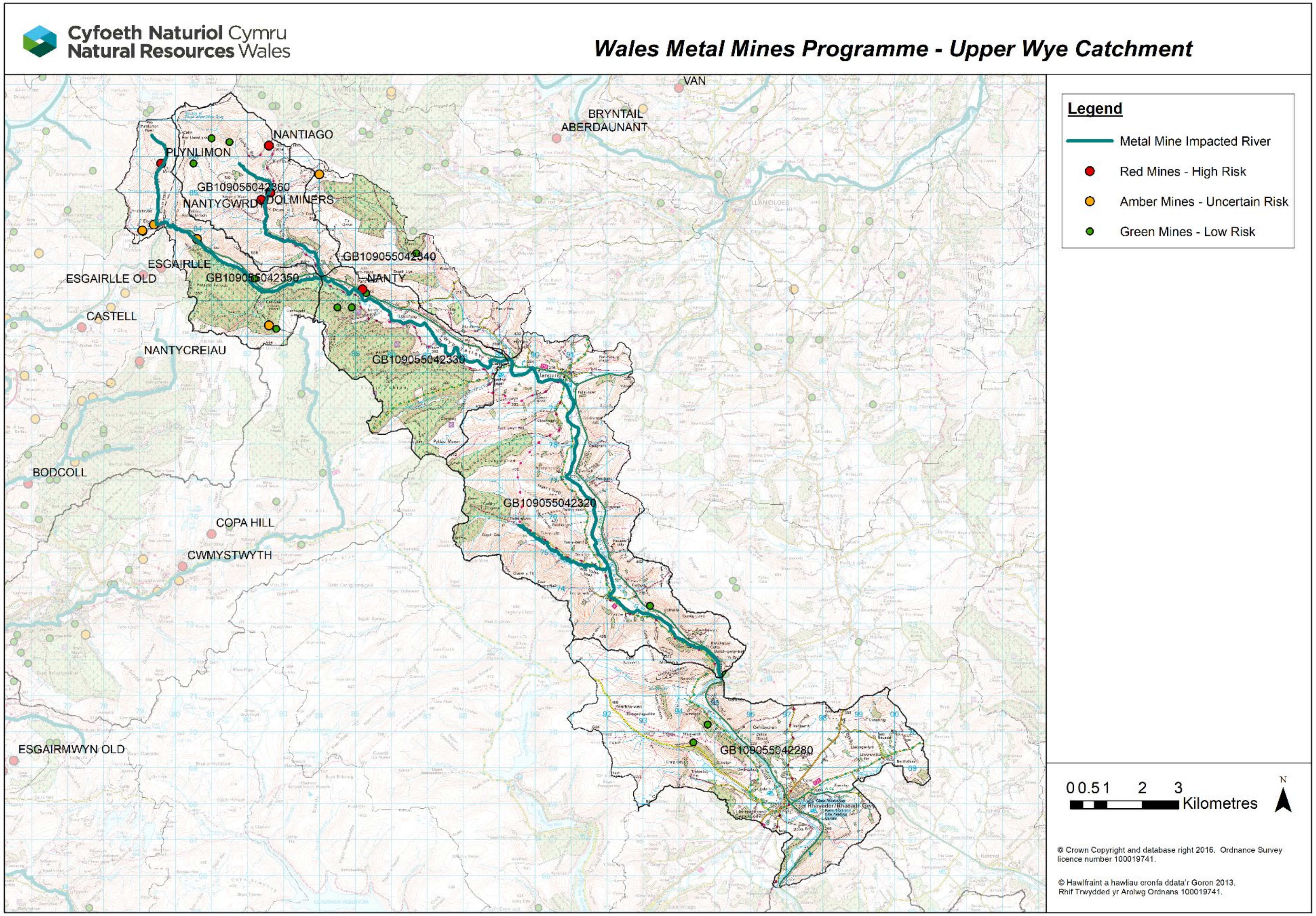

Figure 2: Abandoned metal mines located within the Upper Wye catchment

2.3. Topography

The topography of the Upper Wye catchment is characterised by a general fall in elevation from northwest towards the south and southeast.

The highest elevations are associated with the sources of the Afon Tarenig and the River Wye, on the boundary with the Severn Management Catchment. Pen Pumlumon Fawr (SN 79020 86935) is the highest point in the catchment, located at 752 m Above Ordnance Datum (mAOD), 500 m northwest of the source of the Afon Tarenig (635 mAOD). The source of the River Wye is located 1 km northeast of Pen Pumlumon Fawr at an elevation of approximately 690 mAOD.

The Afon Tarenig flows south and passes through Plynlimon mine, with the Plynlimon Adit located at an elevation of approximately 545 mAOD. The Afon Tarenig continues to follow the fall in elevation in the valley to the south, where there is a confluence between the Nant Nod and the Afon Tarenig at approximately 430 mAOD. The Afon Tarenig continues to flow east.

The River Wye flows to the southeast with a corresponding fall in elevation. The confluence between the Nant Iago and River Wye, 3 km south of the source of the River Wye, is approximately 380 mAOD. The source of the Nant Iago is located north of this confluence, at approximately 555 mAOD.

The topography of the Afon Tarenig and River Wye continues to fall to the southeast. At the confluence between these two waterbodies (SN 84085 82610), the elevation is approximately 315 mAOD. At the confluence with the Afon Bidno, the elevation is approximately 280 mAOD; the source of the Afon Bidno is approximately 360 mAOD.

At Llangurig, the River Wye flows to the south towards Rhayader with a fall in elevation from 270 mAOD to 185 mAOD over 15 km.

2.4. Geology

Two 1:50,000 scale British Geological Survey (BGS) map sheets cover the Upper Wye catchment. Sheet 164 (Llanidloes) covers the area of the catchment to the west and north of Llangurig (BGS, 2010), whilst Sheet 179 (Rhayader) covers the area of the catchment between Llangurig and Rhayader, and south (BGS, 1993).

All the recorded abandoned metal mines in the catchment (Table 1), except Cwm Bach, are located on Sheet 164 (Llanidloes). As such, this review of geological conditions will primarily relate to the geology of the Llangurig area.

The bedrock geology west of Llangurig is underlain by a succession of Late Ordovician (Ashgill) to Silurian sedimentary rocks, over 5 km thick, deposited between 450 and 420 million years ago in the Early Palaeozoic Welsh Basin. Sheet 164 indicates that the structural geology of the Llangurig region is dominated by major structures and lineaments, which in turn has governed mineralisation and historical mining in the district.

Ordovician sedimentary rocks are exposed within the ‘Plynlimon Inlier’, located in the northwest corner of the Upper Wye catchment. These include the Nant-y-Môch and Drosgol Formations. The succeeding stratigraphy comprises of Silurian rocks, predominantly mudstones and interbedded sandstone of the Llandovery Series, including the Cwmere and Devil’s Bridge Formations.

East-north-easterly trending mineralised faults are prevalent across the wider regional area of Mid Wales. These mineral lodes have been the subject of historical mining (Table 1) across the Central Wales Orefield. The geological summary of Sheet 164 indicates that the formation of these mineral lodes appears to have been initiated in the early Carboniferous. Figure 3 shows the simplified geology of the district, faulting, and mineralisation.

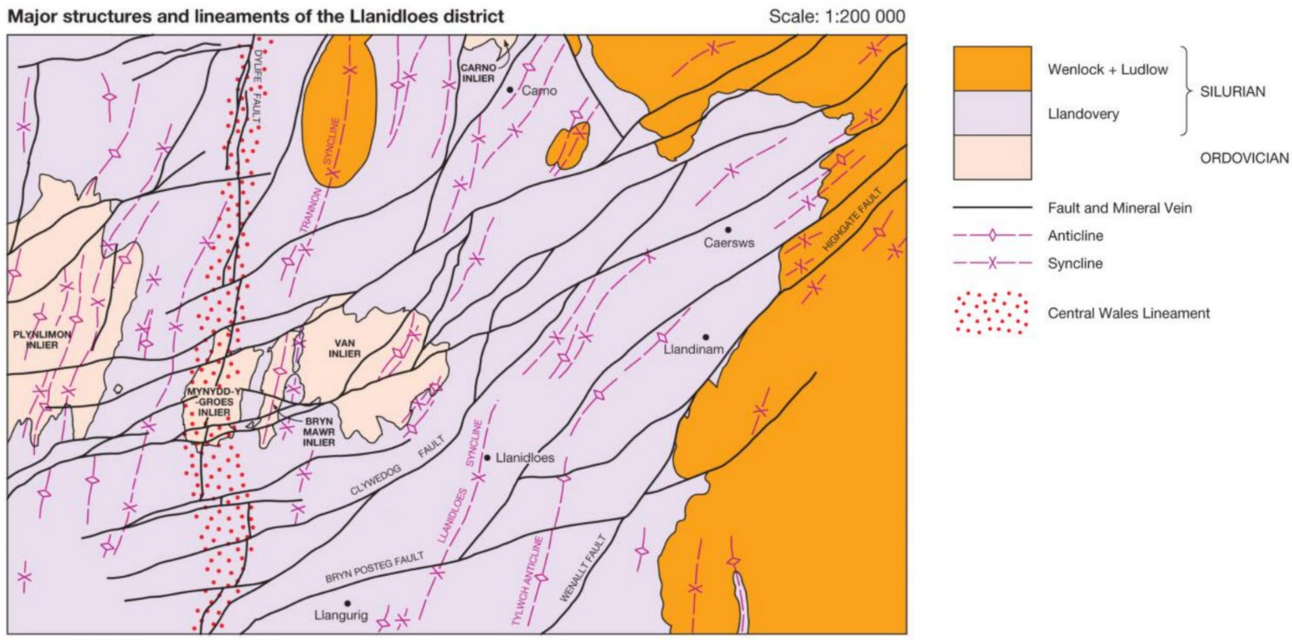

Figure 3: Simplified geology of Llanidloes district. The Upper Wye catchment to the north and west of Llangurig is shown in the bottom left of the figure – extract from Sheet 164 (BGS, 2010).

The geology of the south of the Upper Wye catchment (Sheet 179, Rhayader) is also dominated by sedimentary rocks of the Llandovery Series (Silurian). Whilst there is also a prevalent east-north-easterly structural disturbance (faulting), there is less evidence of mineralisation, which is likely to be why there are fewer abandoned metal mines recorded in this part of the catchment.

Superficial deposits are absent across much of the Upper Wye catchment. Glacial Till is mapped in topographically low areas associated with valleys, and there is evidence of Peat mapped in topographically high areas. There is also evidence of alluvial deposits associated with the footprint of existing rivers in the catchment, e.g. Alluvium in the River Wye.

2.5. Hydrogeology and hydrology

The underlying bedrock lithologies within the Upper Wye catchment (Llandovery Rocks – Undifferentiated) are described as highly indurated argillaceous sedimentary rocks with limited groundwater and are low productivity aquifers. Groundwater flow is virtually all through fractures and other discontinuities (e.g. faults) within the rock mass, with limited intergranular flow pathways. There may be some local variation in this where there are interbedded sandstones, although most of the rock units are classed as argillaceous.

The hydrology of the Upper Wye catchment is described in Section 2.1.

There are known mine water discharges from adits within the Upper Wye catchment (Table 1). These have been monitored as part of historical and ongoing investigations into abandoned metal mine pollution within the catchment. The record of the monitoring undertaken is presented in Section 3.

The hydrogeology and hydrology are significant to the conceptual site model, particularly where these factors are further complicated by historical metal mining.

2.6. Conservation and heritage designations

Conservation

Figure 4 shows conservation designations in the Upper Wye catchment. They are also summarised in Table 2.

Notably, the River Wye and the Upper Wye tributaries (including the Afon Tarenig) are designated as Sites of Special Scientific Interest (SSSI). The River Wye below the Afon Tarenig and Afon Bidno is also classified as a Special Area of Conservation (SAC). The designations are for biological features associated with the watercourse.

For the Wye SSSI and SAC to achieve favourable condition, they are required to meet objectives which might be more stringent than WFDR ‘Good’ status. In the case of chemicals, including metals, the SAC cannot achieve favourable condition without achieving ‘Good’ chemical status, i.e. appropriate standards for priority substances as per the EQS (JNCC, 2016).

Pumlumon (Plynlimon) SSSI is designated for biological features and fluvial geomorphology and incorporates the Plynlimon East and Gerig abandoned metal mines.

Nantiago (Mwyngloddfa Nantiago) SSSI is designated for mineralogical features associated with the abandoned mine.

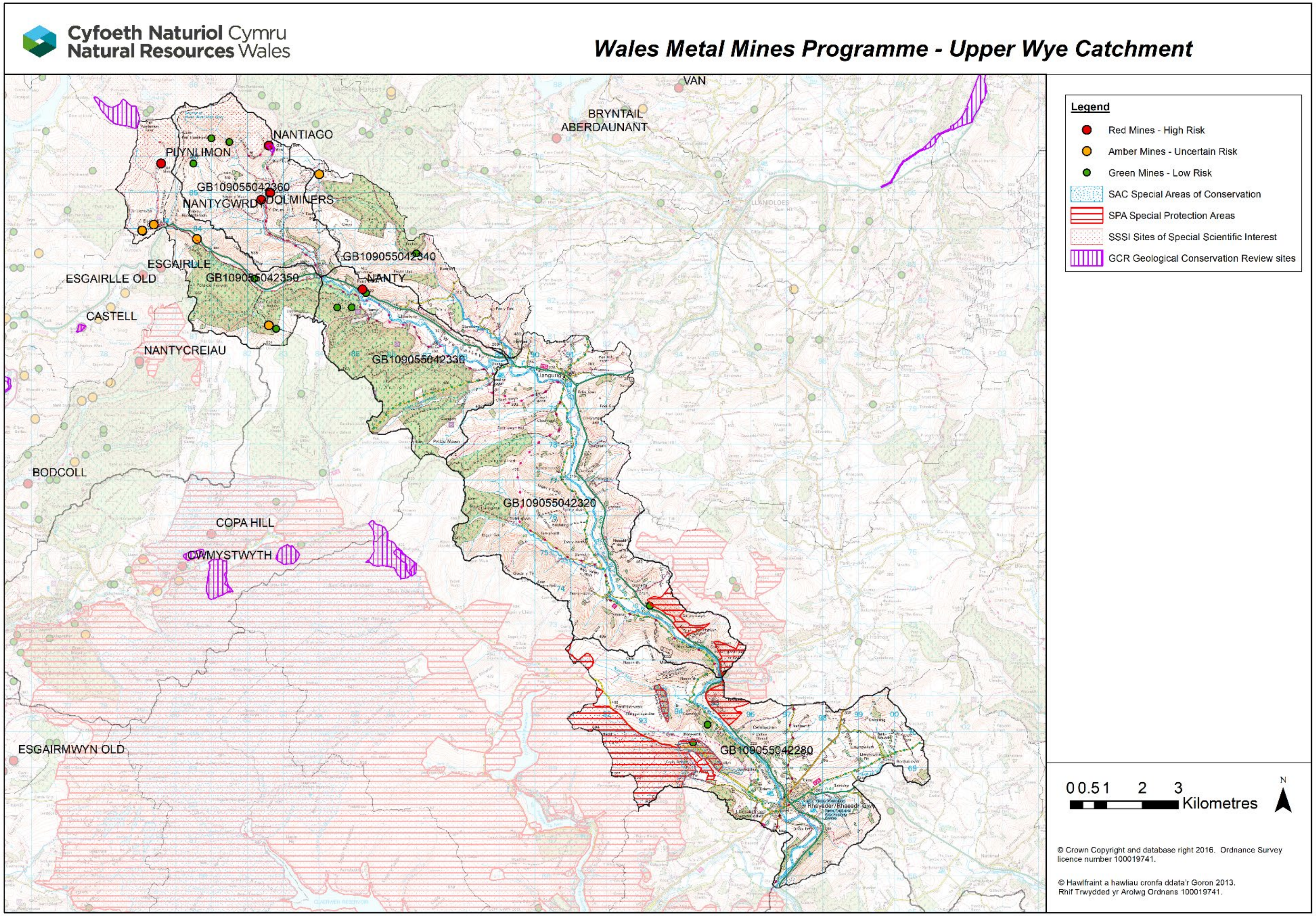

Figure 4: Conservation designations associated with the abandoned metal mines in the northern part of the Upper Wye catchment.

Table 2: Conservation designations within the Upper Wye catchment boundary

Designation	Name	Description	Protected features
SAC	River Wye / Afon Gwy	The River Wye below the Afon Tarenig including the Afon Bidno is a designated SAC. Nanty is a 'Red' mine located along the River Wye where it is designated as a SAC.	Watercourses of plain to montane levels with the *Ranunculion fluitantis* and *Callitricho-Batrachion* vegetation. Atlantic stream crayfish *Austropotamobius pallipes.* Common otter *Lutra lutra.* Atlantic salmon *Salmo salar.* Bullhead *Cottus gobio.* Twaite shad *Alosa fallax.* Allis shad *Alosa alosa.* River lamprey *Lampetra fluviatilis.* Brook lamprey *Lampetra planeri.* Sea lamprey *Petromyzon marinus.* Transition mires and quaking bogs (Countryside Council for Wales, 2008).

Designation	Name	Description	Protected features
SSSI - biological	River Wye (Upper Wye) / Afon Gwy (Gwy Uchaf)	Includes the River Wye and the Afon Tarenig and interfaces with numerous mines within the catchment.	Atlantic salmon *Salmo salar.* Aquatic invertebrate assemblage. Bullhead *Cottus gobio.* Running water. *Allium schoenoprasum* / Chives. Assemblage of RDB and/or Nationally Scarce and/or Atlantic-Western British bryophytes. Assemblage of RDB and Nationally Scarce lichens. Assemblage of RDB and/or Nationally Scarce vascular plants. *Collema dichotomum* / River Jelly-lichen. *Grimmia retracta* / a moss. *Porocyphus kenmorensis* / a lichen. *Pterygiopsis lacustris* / a lichen. Running water -Group C rivers.
SSSI - biological	Rhagnentydd Gwy Uchaf / Upper Wye Tributaries	This 18.5 ha SSSI comprises five tributaries of the River Wye, including the Afon Bidno and Nant y Dernol which are within the Upper Wye catchment study area.	Common otter *Lutra lutra.* *Features designated in the Wye SAC.*

Designation	Name	Description	Protected features
SAC	Coetiroedd Cwm Elan / Elan Valley Woodlands	The whole SAC comprises an area roughly equivalent to 440 ha. There are two areas of woodland located within the Upper Wye catchment boundary within the River Wye – Afon Marteg to Afon Elan waterbody. They are located at NGR SN 94379 69525 and SN 93617 70880.	Old sessile oak woods with Ilex and Blechnum in the British Isles. European dry heaths. Tilio-Acerion forests of slopes, screes and ravines.
Special Protection Areas (SPA)	Elenydd - Mallaen	The whole SPA comprises an area roughly equivalent to 30000 ha. A small portion of this designation is located within the Upper Wye catchment boundary, between Llangurig and Rhayader. A small portion of this SPA abuts the catchment boundary in the north but is outside of the boundary.	One of the most ornithologically important areas of hill land in Wales. *Falco columbarius* / Merlin. *Milvus milvus* / Red kite.
SAC	Elenydd	The whole SAC is equivalent to 8600 ha.	Calaminarian grasslands of the *Violetalia calaminariae.* Blanket bogs. Oligotrophic to mesotrophic standing waters with vegetation of the *Littorelletea uniflorae* and/or of the *Isoëto-Nanojuncetea.* European dry heaths. Floating water-plantain *Luronium natans.*

Designation	Name	Description	Protected features
SSSI	Elenydd	This is a 'mixed'[2] SSSI, which occupies an area of 22700 ha. Encroaches into waterbody GB109055042280: Wye – conf Afon Marteg to conf Afon Elan.	Combination of the SAC and SPA features at *Elenydd-Mallaen* and *Elenydd.* Also includes areas of geological interest including Silurian outcrops north of Caban Coch Dam, mining features at Cwmystwyth (not relevant to this catchment), and glacial landforms where the shifting course of the Elan has left abandoned channels and river terraces.

[2] SSSIs can be designated to protect biological (species and/or habitats) and/or geological (landforms and/or geology) features. Sites may be designated as just biological, just geological, or as mixed biological/geological sites.

Designation	Name	Description	Protected features
SSSI	Pumlumon (Plynlimon)	This is a 3870 ha ‘mixed’ SSSI of biological and geomorphological features. Its boundary includes a small area of the catchment around the sources of the Afon Tarenig and River Wye. The Plynlimon East and Gerig abandoned metal mines are located within the extent of this SSSI. Maesnant GCR site also borders the catchment at this location.	Acid grassland. Assemblage of RDB and/or Nationally Scarce and/or Atlantic-Western British bryophytes. Blanket bog -other ombrogenous mire. Breeding bird assemblage of upland moorland and grassland with waterbodies. *Carex bigelowii* / Stiff Sedge. *Drosera intermedia* / Oblong-leaved Sundew. Dry heath. Fluvial geomorphology of Wales. *Luronium natans* / Floating Water-plantain. *Salix herbacea* / Dwarf Willow. *Saxifraga hypnoides* / Mossy Saxifrage. *Saxifraga stellaris* / Starry Saxifrage. Standing water -Oligotrophic.

Designation	Name	Description	Protected features
SSSI	Cerrig-gwalch and Cwm Gwynllyn	Both are 'biological' SSSI. Both correspond to the similar locations of the Coetiroedd Cwm Elan / Elan Valley Woodlands SAC. Cwm Gwynllyn is located 500 m south of Cwm Bach, and Cerrig-gwalch is 1.3 km west of the mine.	*Convallaria majalis* / Lily-of-the-valley. *Melica nutans* / Mountain Melick. Semi-natural woodland. Standing water -Oligotrophic. *Luronium natans* / Floating Water-plantain.
SSSI	Cae Cwm-bach	This is a 1.5 ha 'biological' SSSI, north of Rhayader. It is located 350 m from the Cwm Bach abandoned metal mine.	Neutral grassland / Glaswelltir niwtral. *Trollius europaeus* / Globeflower / Cronnell.
SSSI	Marcheini Uplands, Gilfach Farm & Gamallt	The whole SSSI comprises an area roughly 810 ha. Part of this is located within the catchment, northwest of Rhayader at NGR SN 95274 70720. This is located 420m northeast of the Cwm Bach.	Blanket bog - other ombrogenous mire. Dry heath. Acid grassland. Breeding bird assemblage of woodland. Semi-natural woodland. Eu-Oceanic Index of Ecological Continuity: Lichens. *Protoparmelia atriseda* / a lichen. Assemblage of RDB and Nationally Scarce lichens. Grassland macrofungi assemblage.

Designation	Name	Description	Protected features
SSSI	Upper Nantserth Pasture	This is a 1.5 ha 'biological' SSSI, north of Rhayader. It is located 2.8 km away from any abandoned metal mine within the catchment (Cwm Bach).	Semi-natural woodland. Acid grassland. Flush and spring -soligenous mire. Marshy grassland.
SSSI and Geological Conservation Review (GCR) site	Mwyngloddfa Nantiago	This is a 2.5 ha 'geological' SSSI, located at the Nantiago mine.	Mineralogy of Wales / Mineralogy of Wales / Mwynoleg Cymru.
SSSI	Gwaun Llwyn-gwyn	This is a 1.9 ha 'biological' SSSI. It is located within the Upper Wye catchment, although it is not located within 5 km of any of the abandoned metal mines referenced in Table 1.	Acid grassland.
SSSI	Caeau Clochfaen-Isaf (Clochfaen-isaf Fields)	This is a 3.3 ha 'biological' SSSI. It is located within the Upper Wye catchment, although it is not located within 5 km of any of the abandoned metal mines referenced in Table 1.	Acid grassland.
SSSI	Gweunydd Nant y Dernol	This is a 3 ha 'biological' SSSI. It is located within the Upper Wye catchment, although it is not located within 5 km of any of the abandoned metal mines referenced in Table 1.	Acid grassland.

Designation	Name	Description	Protected features
SSSI	New House Meadow	This is a 2.3 ha ‘biological’ SSSI. It is located within the Upper Wye catchment, 3.4 km southeast of Cwm Bach.	Neutral Grassland.
SSSI	Coed y Cefn	This is a 27.2 ha ‘biological’ SSSI. It is located within the Upper Wye catchment, 2 km south of Cwm Bach.	*Formica lugubris* / Northern Wood Ant. Myrmecophile assemblage.

Heritage

The Clwyd-Powys Archaeological Trust (CPAT) database has been reviewed to determine whether there are any heritage features / designations within the Upper Wye catchment. Notably, the site of the Cae Gaer Roman Fortlet is located equidistant between the Nant Gwernos and Fagwr Fraith abandoned metal mines, at NGR SN 82362 81899. There is also another CPAT designated area (unknown description) close to the confluence between the Afon Tarenig and River Wye, at NGR SN 83415 82944. There are no other CPAT designated areas within the vicinity of the abandoned metal mines within the Upper Wye catchment.

CPAT also carried out a Heritage Impact Assessment under the WMMP in 2022 (Clwyd-Powys Archaeological Trust, 2022) for the Wye Valley Mine Sett, to assess the potential heritage impacts from constructing flow monitoring structures. This included Nantiago, Nantygwrdy, Dolminers, and Nanty. This was comprised of a desk-based assessment, and site inspection, to determine the heritage value of the remnant, abandoned mine assets at each locality. The desk-based assessment also included a 500m buffer from each abandoned mine locality, to determine potential impacts on heritage features.

90 heritage assets were identified across the four abandoned metal mine sites. This included 66 assets at Nantiago, 14 at Nantygwrdy and Dolminers, and 10 at Nanty. These assets included relict structures, mine features and earthworks. None of these heritage assets were designated, registered as being of national importance, or of equivalent value. Most were assessed as corresponding with ‘negligible’ and ‘low’ heritage value. 10 of the heritage assets at Nantiago were assessed as having ‘medium’ heritage value.

2.7. Failing Waterbodies Report and Water Framework Directive Regulations classification

The FWB report (Coal Authority, 2020) assigned abandoned metal mines in the Upper Wye catchment (Table 1) with the following rating, based on the likelihood of contributing to surface water pollution and WFDR failures:

- ‘Red’ (impact identified or likely): Nantiago, Nantygwrdy, Dolminers, Plynlimon, and Nanty.
- ‘Amber’ (potential impact): Nant Nod, Plynlimon South, Hirgoed Ddu, and Fagwr Fraith.
- ‘Green’ (impact unlikely): Cyff, Plynlimon East, Gerig, Nant Gwernos, Maen Serth, and Cwm Bach.

One of the main conclusions of the FWB report (Coal Authority, 2020) was that resolving the mine impacts from selected mines identified at the top of the river system (i.e. ‘Red’ mines) should provide betterment and status change relating to metals throughout the river system.

The FWB report (Coal Authority, 2020) was based on WFDR Cycle 2 Interim 2018 status. Since then, WFDR Cycle 3 2021 and 2024 Interim classifications have been completed.

Table 3 provides a summary of the classification of all cycles.

Figure 5 also shows the overall WFDR status of each waterbody in the Upper Wye catchment based on the 2024 Interim classification.

Table 3: WFDR Cycle 2 and 3 classification output

Waterbody ID	Waterbody name	Year	Overall status	Ecological status	Failing elements - ecological	Chemical status	Failing elements - chemical
GB109055042360	Wye – source to conf Afon Tarenig	2018	Moderate	Moderate	Zinc, fish, invertebrates	Moderate	Cadmium, lead
GB109055042360	Wye – source to conf Afon Tarenig	2021	Moderate	Moderate	Zinc, fish, invertebrates	Moderate	Cadmium, lead, cypermethrin
GB109055042360	Wye – source to conf Afon Tarenig	2024	Moderate	Moderate	Zinc, invertebrates	Moderate	Cadmium, lead, cypermethrin
GB109055042350	Afon Tarenig – source to conf R Wye	2018	Moderate	Moderate	Zinc, fish, AWIC, phosphate and pH.	Moderate	Cadmium, lead
GB109055042350	Afon Tarenig – source to conf R Wye	2021	Poor	Poor	Zinc, fish	Moderate	Cadmium, lead
GB109055042350	Afon Tarenig – source to conf R Wye	2024	Moderate	Moderate	Zinc, fish	Moderate	Cadmium, lead
GB109055042340	Afon Bidno – source to conf R Wye	2018	Moderate	Moderate	Fish, invertebrates	Good	-
GB109055042340	Afon Bidno – source to conf R Wye	2021	Moderate	Moderate	-	High	-
GB109055042340	Afon Bidno – source to conf R Wye	2024	Moderate	Moderate	Fish	High	-

Waterbody ID	Waterbody name	Year	Overall status	Ecological status	Failing elements - ecological	Chemical status	Failing elements - chemical
GB109055042330	Wye – conf Afon Tarenig to conf Afon Bidno	2018	Moderate	Moderate	Fish, invertebrates	Good	-
GB109055042330	Wye – conf Afon Tarenig to conf Afon Bidno	2021	Moderate	Moderate	Invertebrates	High	-
GB109055042330	Wye – conf Afon Tarenig to conf Afon Bidno	2024	Moderate	Moderate	Zinc, fish, invertebrates	Moderate	Cadmium, cypermethrin
GB109055042320	Wye – conf Afon Bidno to conf Afon Marteg	2018	Moderate	Moderate	Zinc	Good	-
GB109055042320	Wye – conf Afon Bidno to conf Afon Marteg	2021	Moderate	Moderate	Zinc	High	-
GB109055042320	Wye – conf Afon Bidno to conf Afon Marteg	2024	Moderate	Moderate	Zinc	Good	-
GB109055042280	Wye – conf to conf Afon Marteg to conf Afon Elan	2018	Moderate	Good	-	Fail	This was due to a laboratory transcription error.
GB109055042280	Wye – conf to conf Afon Marteg to conf Afon Elan	2021	Good	Good	-	Good	-
GB109055042280	Wye – conf to conf Afon Marteg to conf Afon Elan	2024	Good	Good	-	Good	-

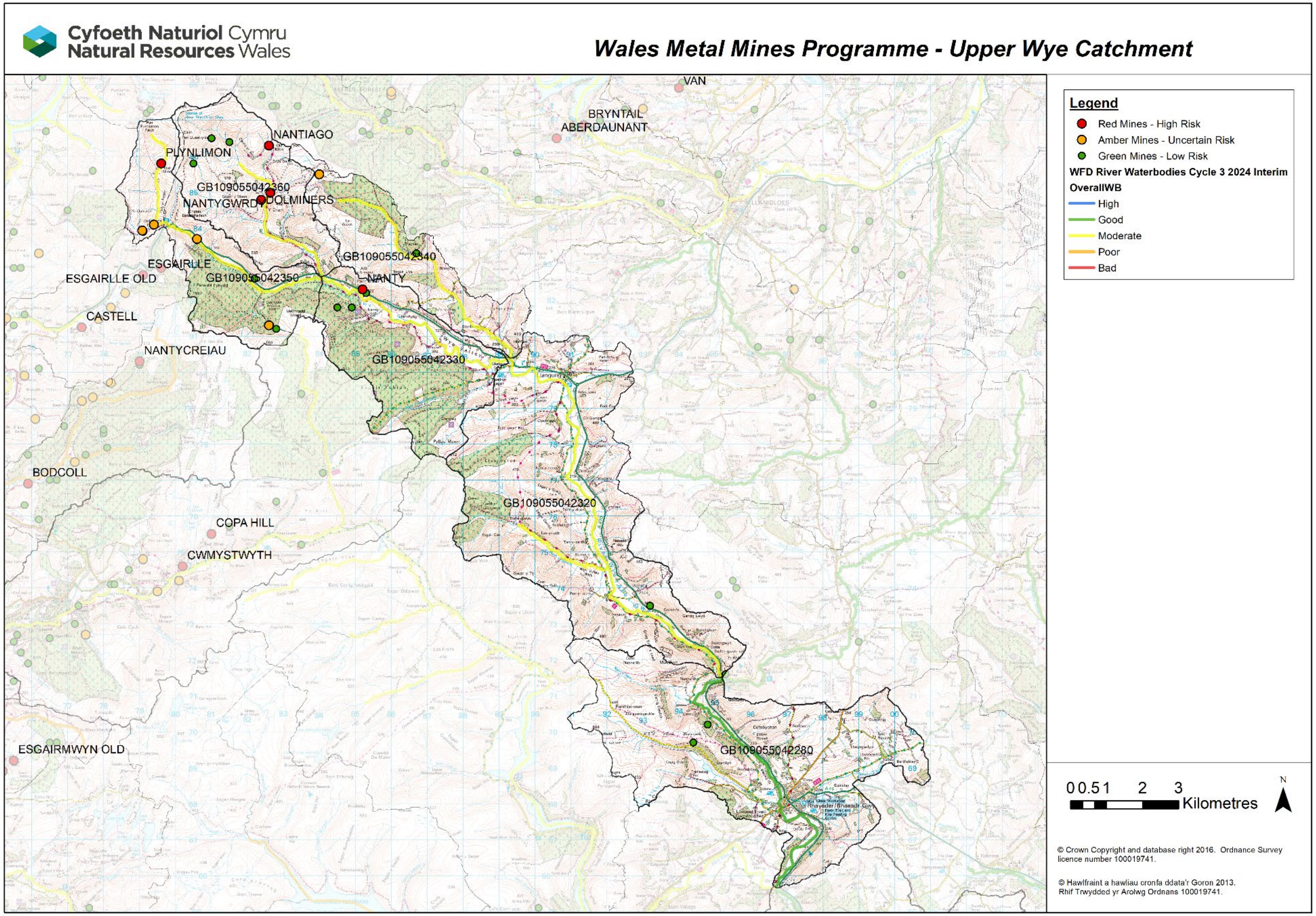

Figure 5: WFDR Cycle 3 2024 interim status of each waterbody (overall status)

3. Monitoring and investigations

3.1. Monitoring stations

As part of historical and ongoing monitoring investigations, NRW have carried out water quality monitoring of mine waters and river waterbodies in the Upper Wye catchment. This has included analysis for pollutants and other parameters discussed in Section 4.

In the northernmost part of the catchment, water quality monitoring has focused on the Nant Iago, Afon Tarenig, Nant Nod, and River Wye. Monitoring of mine waters includes those emanating from Nantiago, Plynlimon, Nantygwrdy and Dolminers. These locations are shown on Figure 6.

In the central and southern parts of the catchment, water quality monitoring has focused on the main river and tributary waterbodies (i.e. the River Wye and its tributaries), as shown on Figure 7.

The monitoring station number, coordinates, and description of each station is provided in Table 4, per WFDR waterbody. Table 4 also provides a summary of the dates of available water quality monitoring data at each station. Most of the mine waters identified within the catchment have been monitored since 2024 and 2025. This has been in response to the findings of the mine characterisation studies, summarised in Section 3.2.

Monitoring of the main river and tributary waterbodies at some stations commenced in the 1980s according to the water quality records. Monitoring of the main river and tributary waterbodies is ongoing (monitoring stations 51319, 50002, 53076, 53077, 53078, 50001, 50003, and 50004), although in some cases, monitoring of the main river and waterbodies has ceased.

Section 4 presents the water quality data used as part of this catchment characterisation report.

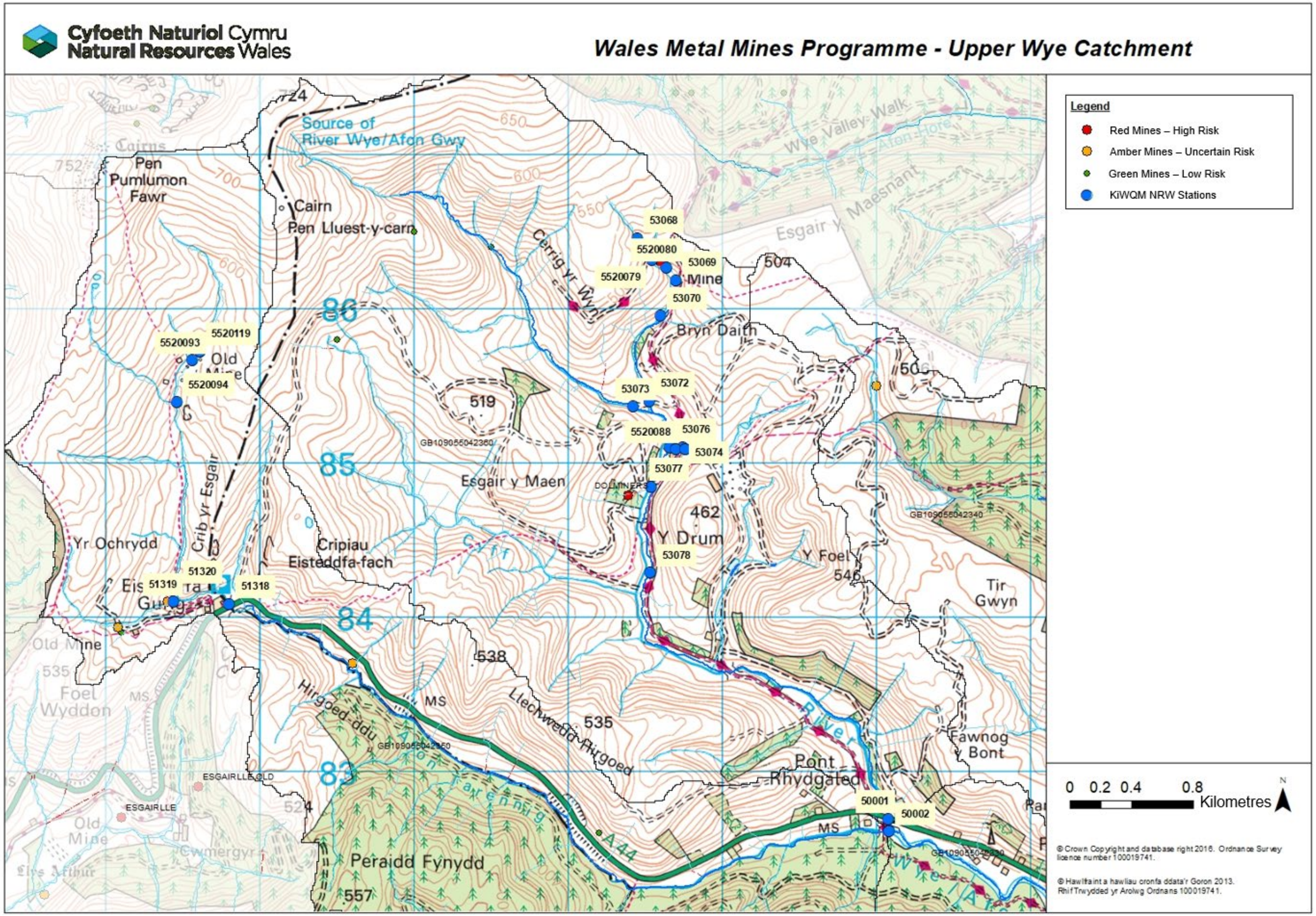

Figure 6: NRW monitoring stations in the northern part of the Upper Wye catchment

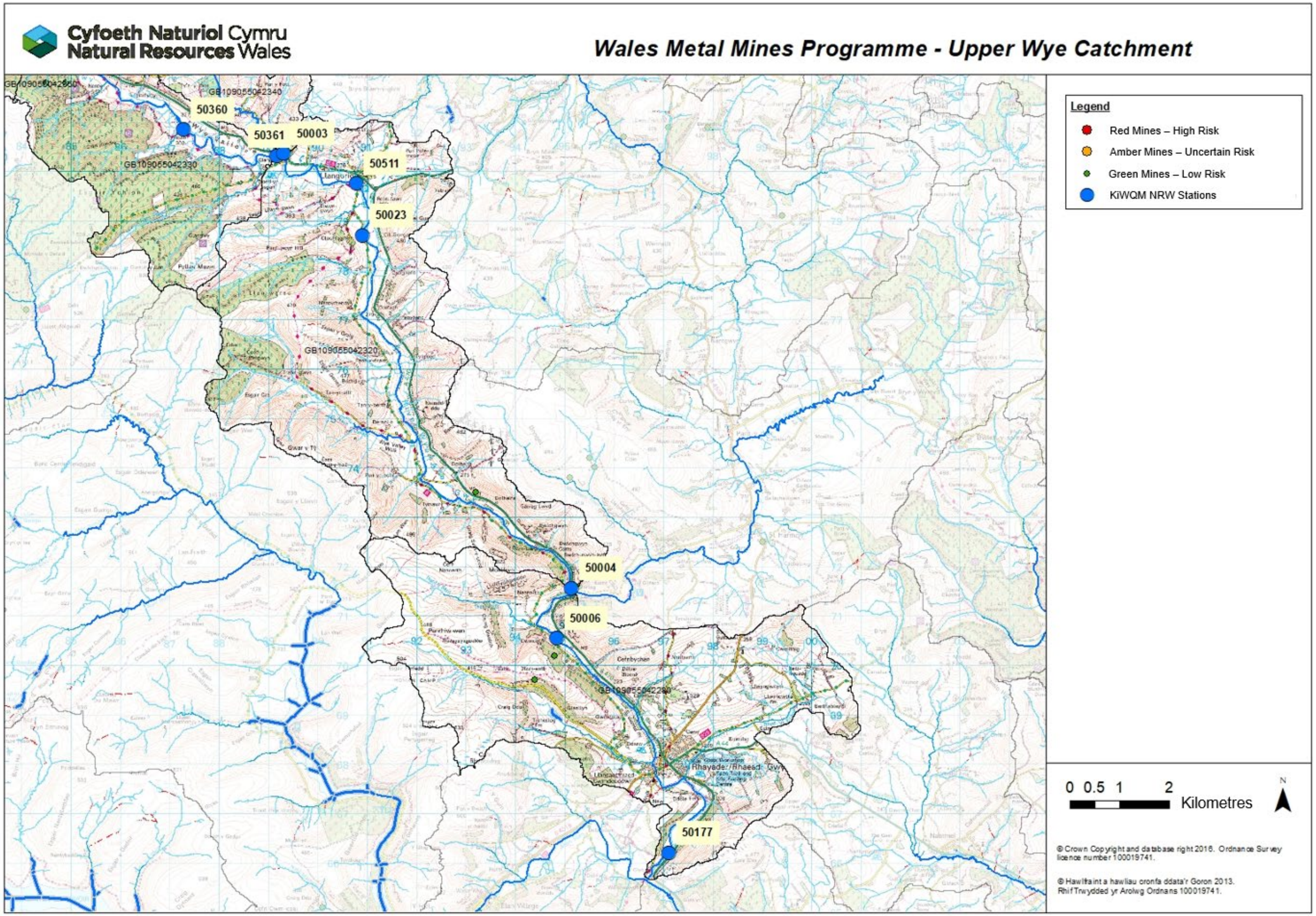

Figure 7: NRW monitoring stations in the central and southern part of the Upper Wye catchment

Table 4: Water quality monitoring stations sampled by NRW in the Upper Wye catchment

Waterbody ID and name	Monitoring station number	Description	NGR	Dates monitored
GB109055042350: Afon Tarenig – source to conf R Wye	5520092	Afon Tarenig, upstream of fines tips.	SN 79670 85810	2025 and 2026
GB109055042350: Afon Tarenig – source to conf R Wye	5520119	Plynlimon adit discharge.	SN 79611 85723	2025 and 2026
GB109055042350: Afon Tarenig – source to conf R Wye	5520093	Afon Tarenig, downstream of adit.	SN 79561 85665	2025 and 2026
GB109055042350: Afon Tarenig – source to conf R Wye	5520094	Afon Tarenig, downstream of Plynlimon.	SN 79461 85393	2025 and 2026
GB109055042350: Afon Tarenig – source to conf R Wye	51319	Nant Nod, upstream of the Afon Tarenig.	SN 79440 84098	2011 and 2012
GB109055042350: Afon Tarenig – source to conf R Wye	51320	Afon Tarenig, upstream of Nant Nod.	SN 79462 84180	2011, 2012, 2025, and 2026
GB109055042350: Afon Tarenig – source to conf R Wye	51318	Afon Tarenig at Pont Eisteddfa Gurig.	SN 79803 84085	2011 and 2012
GB109055042350: Afon Tarenig – source to conf R Wye	50002	Afon Tarenig, above the confluence with the River Wye.	SN 84085 82610	2025 and 2026
GB109055042360: Wye – source to conf Afon Tarenig	53068	Nant Iago, upstream of shaft.	SN 82450 86457	2024 – ongoing
GB109055042360: Wye – source to conf Afon Tarenig	5520079	Nant Iago at Track Culvert.	SN 82545 86318	2024 – ongoing

Waterbody ID and name	Monitoring station number	Description	NGR	Dates monitored
GB109055042360: Wye – source to conf Afon Tarenig	5520080	Nant Iago Deep Adit.	SN 82642 86267	2024 – ongoing
GB109055042360: Wye – source to conf Afon Tarenig	53069	Nant Iago, downstream of adit.	SN 82702 86182	2024 – ongoing
GB109055042360: Wye – source to conf Afon Tarenig	53070	Nant Iago, downstream of Nantiago.	SN 82602 85953	2024 – ongoing
GB109055042360: Wye – source to conf Afon Tarenig	53072	Gauging station at Nant Iago.	SN 82527 85400	2013
GB109055042360: Wye – source to conf Afon Tarenig	53073	Gauging station at River Wye.	SN 82422 85365	2013
GB109055042360: Wye – source to conf Afon Tarenig	53076	River Wye, upstream of the Nantygwrdy.	SN 82662 85102	2013, and 2024 – ongoing
GB109055042360: Wye – source to conf Afon Tarenig	53074	Nantygwrdy, downstream of adit.	SN 82747 85098	2013, and 2024 – ongoing
GB109055042360: Wye – source to conf Afon Tarenig	5520081	Nantygwrdy Deep Adit.	SN 82762 85091	2024 – ongoing
GB109055042360: Wye – source to conf Afon Tarenig	5520088	Stream flowing across the yard to the south of Nant y Gwrdy.	SN 82700 85087	2024 – ongoing
GB109055042360: Wye – source to conf Afon Tarenig	53077	River Wye, downstream of Nantygwrdy.	SN 82541 84844	2013, and 2024 – ongoing

Waterbody ID and name	Monitoring station number	Description	NGR	Dates monitored
GB109055042360: Wye – source to conf Afon Tarenig	53078	River Wye, downstream of Dolminers.	SN 82533 84287	2013, and 2024 – ongoing
GB109055042360: Wye – source to conf Afon Tarenig	57000	Blaen Cyff, upstream of the confluence with the River Wye.	SN 82430 84160	1994 and 1995
GB109055042360: Wye – source to conf Afon Tarenig	50001	River Wye, above the confluence with the Afon Tarenig.	SN 84080 82690	1993 - ongoing
GB109055042330: Wye – conf Afon Tarenig to conf Afon Bidno	50360	River Wye at Ty Mawr.	SN 87280 80850	1985 – 1988
GB109055042330: Wye – conf Afon Tarenig to conf Afon Bidno	50361	River Wye above Afon Bidno.	SN 89171 80324	2022 and 2023
GB109055042340: Afon Bidno – source to conf R Wye	50003	Afon Bidno at the Aberbidno Bridge.	SN 89310 80365	1993 - ongoing
GB109055042320: Wye – conf Afon Bidno to conf Afon Marteg	50511	River Wye at Llangurig.	SN 90780 79760	1993, 1994, 2011, and 2012
GB109055042320: Wye – conf Afon Bidno to conf Afon Marteg	50023	River Wye, confluence Afon Bidno to confluence with Afon Marteg.	SN 90903 78705	2014 and 2015
GB109055042320: Wye – conf Afon Bidno to conf Afon Marteg	50004	River Wye at the footbridge, upstream of the Afon Marteg confluence.	SN 95145 71562	1993 - ongoing
GB109055042280: Wye – conf Afon Marteg to conf Afon Elan	50006	River Wye at Nannerth Bridge	SN 94850 70550	1993, 1994, 2011, and 2012

3.2. Mine characterisation desk studies

Since the FWB report was published in 2020, the WMMP has completed site-specific investigations to characterise four of the five 'Red' mines within the Upper Wye. Desk studies were completed for Nantiago, Nantygwrdy, Dolminers and Nanty mine, but not Plynlimon (Section 2.7).

Each mine characterisation desk study involved a desk-based review of available information, supported by site walkover inspection to develop a conceptual site model of each mine.

The investigations included:

- A determination of the likely sources of pollution, point source or diffuse.
- An assessment of relative source contributions to metal loading of surface waters.
- An evaluation of the main pathways through which metals pollution enters the hydrological catchment.
- Limited monitoring of mine waters and receiving surface waters.

A summary of each desk study, and key findings, is presented in Table 5.

Table 5: Mine characterisation desk studies undertaken since the FWB report in 2020

Report title	Key findings
Catchment Mines Assessment Wales 2020 – **Nantiago** (WSP, 2021a)	A site walkover inspection was undertaken on 24 February 2021, during what has been described in the report as wet and windy weather conditions. The most notable feature identified relevant to the conceptual site model was the full flow of a surface watercourse entering subsurface mine workings via a collapsed open stope, where the Engine Shaft is located. There was also a roadside ditch capturing a significant flow from upland areas which discharged into the Nant Iago downstream. The Deep Adit and Trial Adit were identified and inspected. Images of subsurface exploration within the Trial Adit, used in the report, indicate that there was a build-up of ochreous precipitate on the mine walls. Multiple mine waste spoil tips are situated on the banks of the Nant Iago, and remnant mine infrastructure (as described in Section 2.6). Surface water samples were obtained from the Nant Iago (upstream and downstream of the mine), the Deep Adit and Shallow Adit. Conservative estimations of the water flows were presented in the report. These assumed that the water entering the open stope, and subsequently discharging from the Deep Adit, were equivalent to flows of 30 L/s. Based on the flow gauging undertaken as part of the later dye tracer study (Section 3.3), this is likely to represent an over estimation, and therefore an over estimation of metal loadings below. From the water sampling laboratory results, copper was the only determinant recorded above the EQS in the upstream sample in the Nant Iago. This indicates minimal water quality impact upgradient of the mine, as expected. The downstream sample in the Nant Iago corresponded to exceedances of the EQS, notably cadmium (12 times EQS), lead (17 times EQS), and zinc (15 times EQS). Indicative calculations presented in the report suggest that metal loading increased substantially from upstream to downstream of the mine. However, note the limitations above regarding flows. Lead loading increased from 0.5 kg/yr to 25.5 kg/yr and zinc from 4 kg/yr to 237 kg/yr (upstream to downstream). 20% of this loading increase was reported to be attributed to the Deep Adit (Trial Adit was negligible), indicating a greater impact from diffuse sources (spoil tips).

Report title	Key findings
Catchment Mines Assessment Wales 2020 – **Nantygwrdy** (WSP, 2021b)	A site walkover inspection was undertaken on 24 February 2021, during what has been described in the report as wet and windy weather conditions. The mine features identified in Table 1 were identified during the site walkover. The Old Shaft was partially collapsed at depth, but remained open, as does Tippett's Shaft and Air Shaft. New Shaft has been infilled. The Deep Adit was identified, and contained a small flow of water, estimated as 1.5 L/s. No flow was observed from the Shallow Adit. This is within the range of recorded flows from flow gauging undertaken by NRW since 2024 at the Nantygwrdy Deep Adit (flows between 1 L/s and 4.4 L/s, average 2 L/s). See Section 4.1. Much of the mine waste tip material has been reworked/removed over time from the ongoing land use changes. This includes the tip material surrounding mine features and as part of the old dressing floor. One surface water sample was obtained from each of the following features: • Upstream and downstream of Nantygwrdy in the Nant y Gwrdy. Note, only field chemistry readings were obtained for the downstream sample. • Deep Adit portal. • Upstream of the Nant y Gwrdy confluence in the River Wye (already impacted by metals upstream from Nantiago). • Midstream of the River Wye, below the confluence with Nant y Gwrdy and upstream of Dolminers, so that the impact of Nantygwrdy could be isolated. • Downstream of Dolminers in the River Wye. No exceedances of the EQS were recorded in surface water in the Nant y Gwrdy upgradient of Nantygwrdy, as expected. Cadmium, lead, and zinc all exceeded the EQS in the three samples obtained within the River Wye. In all cases, cadmium, lead, and zinc concentrations increased further downstream, indicating cumulative impacts on water quality from Nantygwrdy and Dolminers. To calculate indicative metal loadings, the sample in the River Wye upstream of the Nant y Gwrdy confluence, and the midstream River Wye sample (upstream of Dolminers) were used. This was to isolate the impact of Nantygwrdy. This suggested that lead loadings increased from 180 kg/yr to 350 kg/yr and zinc from 2040 kg/yr to 3147 kg/yr. The Deep Adit contributed 27% of the lead and 18% of the zinc, indicating a greater impact from diffuse sources (spoil tips), which have been extensively reworked on the site.

Report title	Key findings
Catchment Mines Assessment Wales 2020 – **Dolminers** (WSP, 2021c)	A site walkover inspection was undertaken on 24 February 2021, during what has been described in the report as wet and windy weather conditions. It was not possible to inspect the Shallow Adit due to forest cover. Brooke's Shaft and the Deep Adit portal were noted to be collapsed. The flow from the Deep Adit was minor, estimated to be 1.25 L/s. Tips have been mapped in the western portion of the site. Surface water samples were obtained from three points in the River Wye, and a point source location, including: • Upstream of the Nant y Gwrdy confluence in the River Wye (already impacted by metals upstream from Nantiago). • Midstream of the River Wye, below the confluence with Nant y Gwrdy and upstream of Dolminers, so that the impact of Nantygwrdy could be isolated. • Downstream of Dolminers in the River Wye, to determine the impact from Dolminers. • Deep Adit portal. Cadmium, lead, and zinc all exceeded the EQS in the three samples obtained within the River Wye. In all cases, cadmium, lead, and zinc concentrations increased further downstream, indicating cumulative impacts on water quality from Nantygwrdy and Dolminers. Indicative calculations indicate that metal loading increases downstream of Dolminers: 171 kg/yr increase in lead and 917 kg/yr of zinc. The Deep Adit contributes a minor proportion of this loading (2% zinc and 12% lead), indicating a greater impact from diffuse sources (spoil tips), which have been extensively reworked on the site. This is noticeably different compared to the more comprehensive recent NRW analysis presented in Section 5.4.2.
Catchment Mines Assessment Wales 2020 – **Nanty** (WSP, 2021d)	A site walkover inspection was undertaken on 25 February 2021, during what has been described in the report as dry weather following heavy rain in the preceding 24 hours. The Deep Adit was identified on the site and corresponded to a minor flow of water, estimated to be 1 L/s. Surface water samples were obtained from upstream and downstream of Nanty in the River Wye, and from the Deep Adit. Cadmium, lead and zinc were all recorded above the EQS in the upstream sample of the River Wye (upstream of Nanty). Concentrations did increase downstream in the River Wye, but only marginally; cadmium (1.2 times upstream), lead (1.1 times upstream) and zinc (1.2 times upstream). This outcome is different to the initial results of the NRW 2026 monitoring (Section 5.4.4). Indicative calculations indicate that metal loading increases downstream of Nanty: 19 kg/yr of lead and 833 kg/yr zinc. The contributions from the Deep Adit were deemed to be negligible. The low-lying mine waste spoil tips located along the River Wye floodplain were interpreted as a key factor for increased loadings in the River Wye.

Surface water monitoring and indicative metal loading estimates indicated that all the abandoned mines investigated in Table 5 are impacting surface water quality (to differing extents) in the Upper Wye catchment. This corroborates the findings of the FWB report (Coal Authority, 2020).

It is important to note the limitations of the one-off surface water sampling carried out as part of these investigations (Table 5), in terms of overall catchment characterisation of pollution sources. The water quality and metal loadings estimations presented in each mine characterisation study are based on a single round of spot sampling. Because a single monitoring round will not capture seasonal variations in flow, calculation of annual loadings based on that single data point should be treated with caution.

As an example of short-term variability, dye tracer testing and flow gauging undertaken at Nant Iago in 2023 (Section 3.3) determined that flow in the watercourse entering the open stope increased by 9 L/s over a 17-hour period following relatively low intensity rainfall.

In some instances, it has not been possible to record the flows of mine waters and metal loading estimates therefore rely on flow estimations based on field observations. At the Nantygwrdy Deep Adit, the flow estimate of 1.5 L/s used in the 2021 study (Table 5) is within the range recorded at this location by NRW since 2024; between 1 L/s and 4.4 L/s, average 2 L/s (see Section 4.1). At Nantiago, flow estimates for the water flowing into the open stope were 30 L/s, and this flow was used for metal loading estimations at the Deep Adit. More recent flow gauging data from the Nantiago tracer study (Section 3.3) shows that flows into the open stope were recorded between 3.3 L/s and 12.1 L/s. Discharges from the Deep Adit were between 11.3 L/s and 16.2 L/s. Using the flow estimation of 30 L/s in isolation of any other recorded data may result in an over estimation of metal loading and metals pollution contribution to the Upper Wye catchment from Nantiago.

This was also the case for main watercourses. For example, at Dolminers on the River Wye, estimated flow rates between 1500 L/s and 1800 L/s were used to calculate metal loading. These figures are significantly higher than the NRW gauging data presented in Section 4.1, which indicated that average flow rates in the River Wye at this location were between 200 L/s and 300 L/s. Consequently, the loadings presented in Table 5 are likely to be overestimated.

Monitoring data capturing a range of flow conditions may also change the relative contributions (i.e. source apportionment) from point sources and diffuse pollution. It may remain the case, as these studies indicate, that there is a greater proportion of metal loading from each mine through diffuse pollution than point source pollution. However, before these conclusions are drawn, there should be an evaluation of monitoring data over a range of different flow conditions to understand any potential changes in metal loading contributions. This evaluation is presented in Section 5 and uses additional water quality and loadings data obtained by NRW, supplemented with data obtained from the studies in Table 5, to understand the impacts of metal mine pollution in the Upper Wye catchment.

3.3. Nantiago tracer testing

In 2023 WSP were commissioned to carry out flow monitoring and tracer testing at Nantiago (WSP, 2023). The purpose of the investigation was to improve the conceptual understanding of the surface water ingress and mine flow paths originating from the open stope. The fieldwork was carried out between 30 January and 09 February 2023. There was 10.4mm of rainfall over the 11 days of fieldwork and it was relatively dry preceding the visit.

Two types of tracers were injected into the watercourse entering the open stope on three separate occasions. 13 locations were monitored for tracer using granular activated carbon (GAC) socks and Valeport monitoring. These locations are shown on Figure 8. Flow monitoring was conducted using either salt dilution gauging or the bucket and stopwatch method depending on the characteristics of the monitoring point.

The flow monitoring indicated that, during slightly higher flows, flow rates into the open stope (12.1L/s) were like the Deep Adit discharge (16.2 L/s). Differences between inputs and outputs appeared to increase under lower flow conditions; flow into the open stope was 4.7 L/s, and flow from the Deep Adit was 11.7 L/s. The spoil tips were observed to discharge seepage into the Nant Iago throughout the monitoring. ‘Tip Seepage’ (Figure 8) was the most notable point of discharge (1.6 L/s). There is likely to be additional unobserved diffuse seepage entering the Nant Iago.

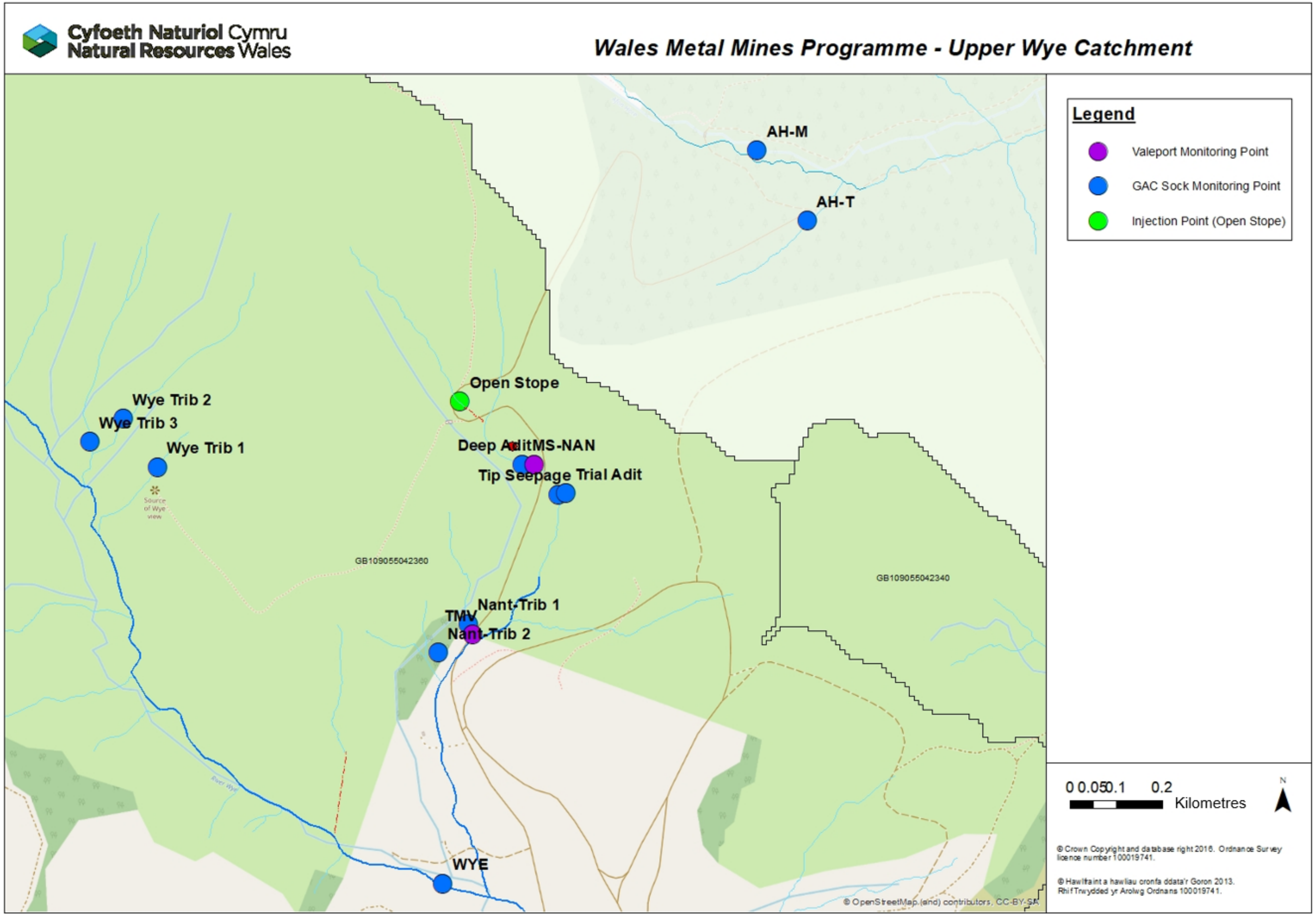

Figure 8: Injection point, GAC sock and Valeport monitoring locations at Nantiago Mine

The findings of the tracer testing indicate significant differences to the preconceived ideas of flow paths and the conceptual model of Nantiago. They suggest the following:

- Between 14% and 21% of the total tracer mass injected into the open stope was recorded at the Deep Adit. It was initially anticipated that most of the flows from the open stope would be discharged at the Deep Adit.

- MS-NAN (Figure 8), upstream of the Deep Adit, recorded the maximum possible GAC sock tracer response. This indicates that the Nant Iago is receiving water from the open stope via more than one route. The Shallow Adit is 30 m upstream of MS-NAN (SN 82589 86278). The tracer testing suggests that this may be connected to the wider sub-surface workings, including the open stope, hence the tracer response at MS-NAN. Fractures within the bedrock may also be facilitating a hydraulic pathway for tracer migration from the open stope into the surface watercourse.

- AH-T and AH-M, 850 m northeast of the open stope, recorded a strong tracer response. The tracer response time corresponds well with literature values for fracture rock fluid velocities. AH-T and AH-M are intercepted by two cross-cutting faults, which may provide a pathway from the workings of Nantiago.

- ‘Wye Trib 2’ and ‘Wye Trib 3’ (Figure 8), 750 m west of the open stope, recorded a positive tracer response. Known workings associated with Nantiago fall short of these tributaries by over 500 m. Faults are also mapped to intercept these tributaries, which may provide a flow conduit.

- The tip material is likely to be receiving water from a historical channel (infilled) pathway of the Nant Iago, located on higher ground. This may be conveying drainage from the Shallow Adit.

- Although the tracer response in the Trial Adit was not strong, it was still measured, indicating that it may be connected to subsurface workings and the open stope.

Although the results of the tracer testing differ significantly to the initial conceptual understanding, it remains clear that the main water inputs into Nantiago are from the open stope, and that increased flows into the open stope govern the extent of discharges.

4. Monitoring results

4.1. Flow results

Table 6 provides a summary of the flow data used to support the metal loading calculations for metals pollution source apportionment in the Upper Wye catchment (Section 5).

The data presented in Table 6 represents measured flow rates through salt dilution gauging, and where this has not been undertaken, flow estimates provided by NRW Hydrology are presented, along with the method used.

Flow estimates were determined for a given sampling visit date at a specific monitoring station (e.g. 04 December 2024 at monitoring station 50001). These estimates were only calculated where there was corresponding water quality data, which when combined, could be used to calculate an estimated metal loading (Section 5.1).

Table 6: Flow recorded (and estimates) at each monitoring station

Pollution source	Monitoring station	Min. flow rate (L/s)	Max. flow rate (L/s)	Mean flow rate (L/s)	Number of flow measurements
Mine water discharge	5520119: Plynlimon adit discharge.	-	-	-	Not possible to flow gauge the Plynlimon Adit discharge due to vegetation cover leading to inaccessibility.
Mine water discharge	5520080: Nant Iago Deep Adit.	-	-	-	Not possible to flow gauge the Nantiago Deep Adit.
Mine water discharge	5520081: Nantygwrdy Deep Adit.	0.9	4.4	2	16
Potential mine water discharge	5520088: Stream flowing across the yard to the south of Nant y Gwrdy.	0.1	1.95	0.95	15

Pollution source	Monitoring station	Min. flow rate (L/s)	Max. flow rate (L/s)	Mean flow rate (L/s)	Number of flow measurements
Surface watercourses	5520092: Afon Tarenig, upstream of fines tips.	12.3	81.6	39.7	7
Surface watercourses	5520093: Afon Tarenig, downstream of adit.	16.5	100.6	48.1	7
Surface watercourses	5520094: Afon Tarenig, downstream of Plynlimon.	18.6	146	67.1	7
Surface watercourses	51319: Nant Nod, upstream of the Afon Tarenig.	3.6	62.2	25.3	14
Surface watercourses	51320: Afon Tarenig, upstream of Nant Nod.	33.4	243.8	125.1	7
Surface watercourses	51318: Afon Tarenig at Pont Eisteddfa Gurig.	35.8	626	254.8	14
Surface watercourses	50002: Afon Tarenig, above the confluence with the River Wye.	109	728.8	364.2	7
Surface watercourses	53068: Nant Iago, upstream of shaft.	1.1	22.3	8.9	19
Surface watercourses	5520079: Nant Iago at Track Culvert.	0.3	5.8	2.3	16
Surface watercourses	53069: Nant Iago, downstream of adit.	2.3	39.4	16.1	19

Pollution source	Monitoring station	Min. flow rate (L/s)	Max. flow rate (L/s)	Mean flow rate (L/s)	Number of flow measurements
Surface watercourses	53070: Nant Iago, downstream of Nantiago.	2.7	45.7	18.8	19
Surface watercourses	53072: Gauging station at Nant Iago.	16.9	79	48	2
Surface watercourses	53073: Gauging station at River Wye.	46	76	61	2
Surface watercourses	53076: River Wye, upstream of the Nantygwrdy.	30.3	512.6	209.5	19
Surface watercourses	53074: Nantygwrdy, downstream of adit.	2.4	56.3	19.8	19
Surface watercourses	53077: River Wye, downstream of Nantygwrdy.	34.9	542.2	204.1	19
Surface watercourses	53078: River Wye, downstream of Dolminers.	40.7	619.4	264.2	19
Surface watercourses	57000: Blaen Cyff, upstream of the confluence with the River Wye.	-	-	-	There is no flow data available for this monitoring station. Flow estimates were not derived as there is no recent corresponding water quality data from this monitoring location (see Table 4).
Surface watercourses	50001: River Wye, above the confluence with the Afon Tarenig.	171.2	2134	726	32

Pollution source	Monitoring station	Min. flow rate (L/s)	Max. flow rate (L/s)	Mean flow rate (L/s)	Number of flow measurements
Surface watercourses	50360: River Wye at Ty Mawr.	-	-	-	There is no flow data available for this monitoring station. Flow estimates were not derived as there is no recent corresponding water quality data from this monitoring location (see Table 4).
Surface watercourses	50361: River Wye above Afon Bidno.	209	2566	1071	13
Surface watercourses	50003: Afon Bidno at the Aberbidno Bridge.	163	1657	591	17
Surface watercourses	50511: River Wye at Llangurig.	1252	6818	3411	13
Surface watercourses	50023: River Wye, confluence Afon Bidno to confluence with Afon Marteg.	-	-	-	There is no flow data available for this monitoring station. Flow estimates were not derived as there is no recent corresponding water quality data from this monitoring location (see Table 4).
Surface watercourses	50004: River Wye at the footbridge, upstream of the Afon Marteg confluence.	627	9121	4020	20
Surface watercourses	50006: River Wye at Nannerth Bridge.	975	7971	4222	11

4.2. Water quality results

Table 7 provides a summary of lead, cadmium, and zinc concentrations recorded at each monitoring station. A summary of these metal concentrations has been provided in Table 7 as they have been contributing to WFDR chemical failures, as identified during historical and more recent WFDR cycles (Section 2.7). These metals have also been recorded above respective EQS values in tributaries of the Upper Wye catchment, and the River Wye itself, resulting from legacy mining impacts; based on the findings of the mine characterisation studies (Section 3.2). Copper concentrations have been included in Table 7, as copper has been referenced in some of the mine characterisation studies (Section 3.2), though as no WFDR EQS failures for copper are recorded in the waterbodies it is not considered further in this report.

In calculating average concentrations, where the determinand concentration was reported below the laboratory limit of detection, the result has been multiplied by 0.5 as per the WFDR classification methodology. For example, where the result is reported as <2 µg/l, a figure of 1 µg/l is used in the calculation. When determining the range, the laboratory limit of detection has been used to represent the lowest value if appropriate. Table 7 presents a summary of concentrations from mine waters and main waterbodies. It is not an assessment (e.g. comparison with EQS values). The comparison with EQS values is presented in Section 4.3 (including metal bioavailability assessment, Section 4.4), which only relates to the main waterbodies in the Upper Wye catchment.

Surface watercourses

Table 7: Summary of selected metal concentrations at each monitoring station, separated into surface watercourses and mine water discharges

Monitoring station number	No. of samples	Min. lead (µg/l)	Max. lead (µg/l)	Mean lead (µg/l)	Min. cadmium (µg/l)	Max. cadmium (µg/l)	Mean cadmium (µg/l)	Min. copper (µg/l)	Max. copper (µg/l)	Mean copper (µg/l)	Min. zinc (µg/l)	Max. zinc (µg/l)	Mean zinc (µg/l)
5520092: Afon Tarenig, upstream of fines tips.	7	Below 2 µg/l.	Below 2 µg/l.	Below 2 µg/l.	<0.1	0.12	0.08	Below 1 µg/l.	Below 1 µg/l.	Below 1 µg/l.	13.5	30.2	17.4
5520093: Afon Tarenig, downstream of adit.	7	36.4	113	73	0.33	0.7	0.48	<1	1.2	1	76	220	133
5520094: Afon Tarenig, downstream of Plynlimon.	7	54.6	126	81.2	0.68	1.54	0.92	<1	1.82	1.3	179	383	241
51319: Nant Nod, upstream of the Afon Tarenig.	14	Below 2 µg/l.	Below 2 µg/l.	Below 2 µg/l.	Below 0.1 µg/l.	Below 0.1 µg/l.	Below 0.1 µg/l.	<1	1.26	0.7	6.6	13.3	9.1
51320: Afon Tarenig, upstream of Nant Nod.	22	13.6	60.5	28.7	0.38	0.82	0.49	<1	1.69	1.4	91.8	224	134
51318: Afon Tarenig at Pont Eisteddfa Gurig.	14	13.4	26.7	20.1	0.37	0.5	0.44	1.05	1.93	1.4	92.3	125	114

Monitoring station number	No. of samples	Min. lead (µg/l)	Max. lead (µg/l)	Mean lead (µg/l)	Min. cadmium (µg/l)	Max. cadmium (µg/l)	Mean cadmium (µg/l)	Min. copper (µg/l)	Max. copper (µg/l)	Mean copper (µg/l)	Min. zinc (µg/l)	Max. zinc (µg/l)	Mean zinc (µg/l)
50002: Afon Tarenig, above the confluence with the River Wye.	28	<2	18	5.6	0.1	0.37	0.16	<1	4.25	0.95	27.5	78.4	40.2
53068: Nant Iago, upstream of shaft.	19	<2	6.5	3.8	At or below 0.1 µg/l.	At or below 0.1 µg/l.	At or below 0.1 µg/l.	1.1	2.6	1.6	11.9	27.5	19.4
5520079: Nant Iago at Track Culvert.	19	19.1	125	57	0.1	0.66	0.39	1.4	2.8	2.1	39.2	117	80.9
53069: Nant Iago, downstream of adit.	21	10	48.2	18.7	0.55	1.81	1	1	2.75	1.6	144	494	259
53070: Nant Iago, downstream of Nantiago.	21	14.2	161	31	1	4.15	2	<1	2.55	1.6	211	649	381
53072: Gauging station at Nant Iago.	2	15.7	16.7	16.2	1.89	2.84	2.4	1.21	1.3	1.3	338	497	418
53073: Gauging station at River Wye.	2	Below 2 µg/l	Below 2 µg/l	Below 2 µg/l	Below 0.1 µg/l	Below 0.1 µg/l	Below 0.1 µg/l	Below 1 µg/l	Below 1 µg/l	Below 1 µg/l	Below 5 µg/l	Below 5 µg/l	Below 5 µg/l

Monitoring station number	No. of samples	Min. lead (µg/l)	Max. lead (µg/l)	Mean lead (µg/l)	Min. cadmium (µg/l)	Max. cadmium (µg/l)	Mean cadmium (µg/l)	Min. copper (µg/l)	Max. copper (µg/l)	Mean copper (µg/l)	Min. zinc (µg/l)	Max. zinc (µg/l)	Mean zinc (µg/l)
53076: River Wye, upstream of the Nantygwrdy.	19	2	7.63	3.8	0.17	0.4	0.28	<1	1.4	0.68	36.5	90.9	58.5
53074: Nantygwrdy, downstream of adit.	21	2.72	270	62	<0.1	7.1	1.5	<1	4.68	1.6	9.1	2120	445.7
53077: River Wye, downstream of Nantygwrdy.	19	10.7	116	21.1	0.57	2.62	0.86	<1	2.47	1.2	121	798	198
53078: River Wye, downstream of Dolminers.	21	8.2	16.4	11.4	0.44	0.95	0.63	<1	1.51	1	99.6	213	142
50001: River Wye, above the confluence with the Afon Tarenig.	32	<2	21.3	5	0.13	0.38	0.28	<1	9.63	1.2	38	93.9	64.9
50361: River Wye above Afon Bidno.	13	<2	4.26	1.7	0.11	0.25	0.16	<1	1.45	0.7	30	57.8	40.8

Monitoring station number	No. of samples	Min. lead (µg/l)	Max. lead (µg/l)	Mean lead (µg/l)	Min. cadmium (µg/l)	Max. cadmium (µg/l)	Mean cadmium (µg/l)	Min. copper (µg/l)	Max. copper (µg/l)	Mean copper (µg/l)	Min. zinc (µg/l)	Max. zinc (µg/l)	Mean zinc (µg/l)
50003: Afon Bidno at the Aberbidno Bridge.	17	Below 2 µg/l	Below 2 µg/l	Below 2 µg/l	Below 0.1 µg/l	Below 0.1 µg/l	Below 0.1 µg/l	Below 1 µg/l; except one sample (1.3µg/l)	Below 1 µg/l; except one sample (1.3µg/l)	Below 1 µg/l; except one sample (1.3µg/l)	<5	6.1	3.1
50511: River Wye at Llangurig.	13	<2	4.83	2.52	0.1	0.16	0.13	<1	1.31	0.85	29.2	48.6	33.8
50004: River Wye at the footbridge, upstream of the Afon Marteg confluence.	20	<2	9.4	2.2	<0.1	0.12	0.06	<1	4.44	1.3	14.8	40.1	22.2
50006: River Wye at Nannerth Bridge.	11	<2	5.3	1.6	<0.1	0.11	0.06	<1	1.35	1.1	16.9	26.8	22.1

Mine water discharges

Monitoring station number	No. of samples	Min. lead (µg/l)	Max. lead (µg/l)	Mean lead (µg/l)	Min. cadmium (µg/l)	Max. cadmium (µg/l)	Mean cadmium (µg/l)	Min. copper (µg/l)	Max. copper (µg/l)	Mean copper (µg/l)	Min. zinc (µg/l)	Max. zinc (µg/l)	Mean zinc (µg/l)
5520119: Plynlimon adit discharge.	8	622	1820	1008	2.5	4.2	3.1	3.7	11.3	6.2	851	1330	1010
5520080: Nant Iago Deep Adit.	19	8.5	90.8	24	0.4	2.5	0.9	1.1	3.1	1.9	106	617	258
5520081: Nantygwrdy Deep Adit.	19	507	1380	972	16	22.1	19.3	6.5	18.6	12.8	4400	6380	5,546
5520088: Stream flowing across the yard to the south of Nant y Gwrdy.	17	43.4	468	160.7	4	15.7	7.5	1.8	6.4	3.4	1040	4510	2031

4.3. Compliance with Environmental Quality Standards

The EQS for freshwater are presented as part of The Water Framework Directive (Standards and Classification) Directions (England and Wales) 2015 (Defra, 2015). They represent legally binding limits which establish a concentration threshold for a specific substance below which no adverse impact on the environmental medium, in this case freshwater, occurs. Table 8 presents the freshwater EQS which are relevant to the mine water-impacted surface waters of the Upper Wye catchment and explains the relevance of each substance to the WFDR.

Table 8: EQS for relevant substances of concern from abandoned mines

Substance	EQS value (µg/l)	Relation to WFDR
Cadmium	0.08	Schedule 3, Part 3 'Priority substance' under The Water Framework Directive (Standards and Classification) Directions (England and Wales) 2015 (Defra, 2015). Cadmium is also classified as one of 13 'Priority hazardous substances'. Influences the chemical status of surface waterbodies.
Lead	1.2 bioavailable	Schedule 3, Part 3 'Priority substance' under The Water Framework Directive (Standards and Classification) Directions (England and Wales) 2015 (Defra, 2015). Influences the chemical status of surface waterbodies.
Zinc	10.9 bioavailable plus consideration of the Ambient Background Concentration (µg/l); 2 µg/l for Wye catchment.	Schedule 3, Part 2 'Specific pollutant' under The Water Framework Directive (Standards and Classification) Directions (England and Wales) 2015 (Defra, 2015). Influences the ecological status of surface waterbodies.

Table 9 presents an evaluation of dissolved cadmium, lead, and zinc concentrations against the published EQS. For lead and zinc the published EQS is for the bioavailable fraction. Where this initial analysis indicates an EQS might be exceeded then further analysis for bioavailability has been undertaken in line with WFDR guidance (Section 4.4).

Table 9 also presents the scale of EQS exceedance recorded at each monitoring location. It is evident that the scale of EQS exceedance is greatest immediately downstream of the source mines and reduces further downstream as would be expected due to dilution and attenuation within waterbodies. This information has been used to support the interpretation of the total polluted length and identified pollution sources (Section 5).

Table 9: Evaluation of lead, cadmium, and zinc concentrations in the Upper Wye catchment and comparisons with Environmental Quality Standards (EQS)

Waterbody ID and name	Monitoring station	EQS: Lead (1.2 µg/l)	EQS: Cadmium (0.08 µg/l)	EQS: Zinc (12.9 µg/l)[3]	M-BAT assessment?
GB109055042350: Afon Tarenig – source to conf R Wye	5520092: Afon Tarenig, upstream of fines tips.	1/7 samples exceed EQS. Average concentration is lower than EQS.	3/7 samples exceed EQS. Average concentration is equal to EQS.	6/7 samples exceed EQS. Average concentration is 1.3x greater than EQS.	Yes, see Section 4.4.
GB109055042350: Afon Tarenig – source to conf R Wye	5520093: Afon Tarenig, downstream of adit.	7/7 samples exceed EQS. Average concentration is 61x greater than EQS.	7/7 samples exceed EQS. Average concentration is 6x greater than EQS.	7/7 samples exceed EQS. Average concentration is 10x greater than EQS.	Yes, see Section 4.4.
GB109055042350: Afon Tarenig – source to conf R Wye	5520094: Afon Tarenig, downstream of Plynlimon.	7/7 samples exceed EQS. Average concentration is 68x greater than EQS.	7/7 samples exceed EQS. Average concentration is 11.5x greater than EQS.	7/7 samples exceed EQS. Average concentration is 19x greater than EQS.	Yes, see Section 4.4.
GB109055042350: Afon Tarenig – source to conf R Wye	51319: Nant Nod, upstream of the Afon Tarenig.	No exceedances.	No exceedances.	One minor exceedance (13.3µg/l). Remaining samples do not exceed.	Yes, see Section 4.4.
GB109055042350: Afon Tarenig – source to conf R Wye	51320: Afon Tarenig, upstream of Nant Nod.	22/22 samples exceed EQS. Average concentration is 24x greater than EQS.	22/22 samples exceed EQS. Average concentration is 6x greater than EQS.	22/22 samples exceed EQS. Average concentration is 10x greater than EQS.	Yes, see Section 4.4.

[3] 10.9µg/l plus Ambient Background Concentration (ABC) of 2µg/l for the Wye Catchment (Defra 2015).

Waterbody ID and name	Monitoring station	EQS: Lead (1.2 µg/l)	EQS: Cadmium (0.08 µg/l)	EQS: Zinc (12.9 µg/l)[3]	M-BAT assessment?
GB109055042350: Afon Tarenig – source to conf R Wye	51318: Afon Tarenig at Pont Eisteddfa Gurig.	14/14 samples exceed EQS. Average concentration is 22x greater than EQS.	14/14 samples exceed EQS. Average concentration is 6x greater than EQS.	14/14 samples exceed EQS. Average concentration is 9x greater than EQS.	Yes, see Section 4.4.
GB109055042350: Afon Tarenig – source to conf R Wye	50002: River Tarenig, above the confluence with the River Wye.	27/28 samples exceed EQS. Average concentration is 5x greater than EQS.	28/28 samples exceed EQS. Average concentration is 2x greater than EQS.	28/28 samples exceed EQS. Average concentration is 3x greater than EQS.	Yes, see Section 4.4.
GB109055042360: Wye – source to conf Afon Tarenig	53068: Nant Iago, upstream of shaft.	18/19 samples exceed EQS. Average concentration is 3x greater than EQS	All samples recorded cadmium <0.1µg/l, except one which noted a minor exceedance of EQS (0.1µg/l).	16/19 samples exceed EQS. Average concentration is 1.5x greater than EQS.	Yes, see Section 4.4.
GB109055042360: Wye – source to conf Afon Tarenig	5520079: Nant Iago at Track Culvert.	19/19 samples exceed EQS. Average concentration is 47.5x greater than EQS.	19/19 samples exceed EQS. Average concentration is 5x greater than EQS.	19/19 samples exceed EQS. Average concentration is 6x greater than EQS.	Yes, see Section 4.4.
GB109055042360: Wye – source to conf Afon Tarenig	53069: Nant Iago, downstream of adit.	21/21 samples exceed EQS. Average concentration is 16x greater than EQS.	21/21 samples exceed EQS. Average concentration is 12.5x greater than EQS.	21/21 samples exceed EQS. Average concentration is 20x greater than EQS.	Yes, see Section 4.4.

Waterbody ID and name	Monitoring station	EQS: Lead (1.2 µg/l)	EQS: Cadmium (0.08 µg/l)	EQS: Zinc (12.9 µg/l)[3]	M-BAT assessment?
GB109055042360: Wye – source to conf Afon Tarenig	53070: Nant Iago, downstream of Nantiago.	21/21 samples exceed EQS. Average concentration is 26x greater than EQS.	21/21 samples exceed EQS. Average concentration is 25x greater than EQS.	21/21 samples exceed EQS. Average concentration is 30x greater than EQS.	Yes, see Section 4.4.
GB109055042360: Wye – source to conf Afon Tarenig	53072: Gauging station at Nant Iago.	2/2 samples exceed EQS. Average concentration is 13.5x greater than EQS.	2/2 samples exceed EQS. Average concentration is 30x greater than EQS.	2/2 samples exceed EQS. Average concentration is 32x greater than EQS.	Yes, see Section 4.4.
GB109055042360: Wye – source to conf Afon Tarenig	53073: Gauging station at River Wye.	2/2 samples record no exceedances of EQS.	2/2 samples record no exceedances of EQS.	2/2 samples record no exceedances of EQS.	Yes, see Section 4.4.
GB109055042360: Wye – source to conf Afon Tarenig	53076: River Wye, upstream of the Nantygwrdy.	19/19 samples exceed EQS. Average concentration is 3x greater than EQS.	19/19 samples exceed EQS. Average concentration is 3.5x greater than EQS.	19/19 samples exceed EQS. Average concentration is 4.5x greater than EQS.	Yes, see Section 4.4.
GB109055042360: Wye – source to conf Afon Tarenig	53074: Nant y Gwrdy, downstream of adit.	21/21 samples exceed EQS. Average concentration is 52x greater than EQS.	19/21 samples exceed EQS. Average concentration is 19x greater than EQS.	21/21 samples exceed EQS. Average concentration is 38x greater than EQS.	Yes, see Section 4.4.
GB109055042360: Wye – source to conf Afon Tarenig	53077: River Wye, downstream of the Nantygwrdy.	19/19 samples exceed EQS. Average concentration is 17.5x greater than EQS.	19/19 samples exceed EQS. Average concentration is 11x greater than EQS.	19/19 samples exceed EQS. Average concentration is 15x greater than EQS.	Yes, see Section 4.4.

Waterbody ID and name	Monitoring station	EQS: Lead (1.2 µg/l)	EQS: Cadmium (0.08 µg/l)	EQS: Zinc (12.9 µg/l)[3]	M-BAT assessment?
GB109055042360: Wye – source to conf Afon Tarenig	53078: River Wye, downstream of Dolminers.	21/21 samples exceed EQS. Average concentration is 9.5x greater than EQS.	21/21 samples exceed EQS. Average concentration is 8x greater than EQS.	21/21 samples exceed EQS. Average concentration is 11x greater than EQS.	Yes, see Section 4.4.
GB109055042360: Wye – source to conf Afon Tarenig	50001: River Wye, above the confluence with the Afon Tarenig.	30/32 samples exceed EQS. Average concentration is 4x greater than EQS.	32/32 samples exceed EQS. Average concentration is 3.5x greater than EQS.	32/32 samples exceed EQS. Average concentration is 5x greater than EQS.	Yes, see Section 4.4.
GB109055042330: Wye – conf Afon Tarenig to conf Afon Bidno	50361: River Wye above Afon Bidno.	5/13 samples exceed EQS. Average concentration is 1.5x greater than EQS.	13/13 samples exceed EQS. Average concentration is 2x greater than EQS.	13/13 samples exceed EQS. Average concentration is 3x greater than EQS.	Yes, see Section 4.4.
GB109055042340: Afon Bidno – source to conf R Wye	50003: Afon Bidno at the Aberbidno Bridge.	17/17 samples pass EQS.	17/17 samples pass EQS.	17/17 samples pass EQS.	Not required, as no exceedances have been recorded.
GB109055042320: Wye – conf Afon Bidno to conf Afon Marteg	50511: River Wye at Llangurig.	10/13 samples exceed EQS. Average concentration is 2x greater than EQS.	13/13 samples exceed EQS. Average concentration is 2x greater than EQS.	13/13 samples exceed EQS. Average concentration is 2.5x greater than EQS.	Yes, see Section 4.4.

Waterbody ID and name	Monitoring station	EQS: Lead (1.2 µg/l)	EQS: Cadmium (0.08 µg/l)	EQS: Zinc (12.9 µg/l)[3]	M-BAT assessment?
GB109055042320: Wye – conf Afon Bidno to conf Afon Marteg	50004: River Wye at the footbridge, upstream of the Afon Marteg confluence.	8/20 samples exceed EQS. Average concentration is 1.5x greater than EQS.	2/13 samples exceed EQS. Average concentration is below the EQS.	20/20 samples exceed EQS. Average concentration is 1.5x greater than EQS.	Yes, see Section 4.4.
GB109055042280: Wye – conf Afon Marteg to conf Afon Elan	50006: River Wye at Nannerth Bridge.	2/11 samples exceed EQS. Average concentration is 1.3x greater than EQS.	2/11 samples exceed EQS. Average concentration is below the EQS.	11/11 samples exceed EQS. Average concentration is 1.5x greater than EQS.	Yes, see Section 4.4.

4.4. Metal bioavailability assessment

Table 9 indicates that there were several exceedances of the EQS for lead and zinc associated with the surface waterbodies in the Upper Wye catchment. The potential ecological impacts on a waterbody associated with lead and zinc can be further assessed using the metal bioavailability assessment tool (M-BAT).

Using the dissolved metal concentration data along with information on the local water chemistry, the M-BAT tool calculates the bioavailable metal concentration. For zinc, this includes an assessment of pH, calcium and dissolved organic carbon (DOC) data, whilst lead only requires DOC data.

Table 10 (lead) and Table 11 (zinc) presents a summary of the annual average bioavailable lead and zinc concentrations calculated using M-BAT. This has been undertaken per monitoring station located on each of the WFDR waterbodies in the Upper Wye catchment where the relevant water quality parameters have been analysed. This is except for the Bidno as this has been screened out due to no identified exceedances in Table 9. Note, the datasets used are sometimes incomplete, for example there may have only been two sampling visits each year used to calculate the annual average. The data used to calculate each annual average is also presented in Table 10 and Table 11 so that its limitations can be clearly understood.

M-BAT also generates a site-specific Predicted No [ecological] Effect Concentration (PNEC) and Risk Characterisation Ratio (RCR). The site-specific PNEC is a concentration below which (i.e. if the bioavailable concentration is below the site-specific PNEC) adverse effects are unlikely to occur to river ecology. The RCR is a value which, if above or equal to 1, may pose a risk to river ecology. It is calculated through comparison of the bioavailable metal concentration and the EQS (zinc being 10.9 µg/l and lead being 1.2 µg/l). Average site-specific PNEC and RCR values are also presented in Table 10 and Table 11.

Prior to using the M-BAT, the zinc background concentration for the Wye (2 µg/l) was subtracted from the measured dissolved concentration, in line with Appendix A of the UKTAG M-BAT method statement (UKTAG, 2014). This allows for the consideration of the background zinc concentrations and is then compared with the EQS of 10.9 µg/l.

Table 10: Metal bioavailability assessment – lead

Monitoring station	Waterbody	Year	Number of samples (months of the year)	Bioavailable lead (µg/l) – annual average	Average site-specific PNEC	Average RCR
50002: Afon Tarenig, above the confluence with the River Wye.	GB109055042350: Afon Tarenig – source to conf R Wye.	2011	7 (June to December)	2	3.3	1.6
50002: Afon Tarenig, above the confluence with the River Wye.	GB109055042350: Afon Tarenig – source to conf R Wye.	2012	12 (January to December)	2	4	1.7
50002: Afon Tarenig, above the confluence with the River Wye.	GB109055042350: Afon Tarenig – source to conf R Wye.	2013	2 (January and May)	2.6	1.9	2.2
50002: Afon Tarenig, above the confluence with the River Wye.	GB109055042350: Afon Tarenig – source to conf R Wye.	2025	7 (February to August)	1.9	3.4	1.6
50001: River Wye, above the confluence with the Afon Tarenig.	GB109055042360: Wye – source to conf Afon Tarenig.	2012	9 (February to May, July, September to December)	2.5	3.2	2
50001: River Wye, above the confluence with the Afon Tarenig.	GB109055042360: Wye – source to conf Afon Tarenig.	2013	2 (January and May)	2.9	2	2.4
50001: River Wye, above the confluence with the Afon Tarenig.	GB109055042360: Wye – source to conf Afon Tarenig.	2024	12 (January to December)	1.1	3.4	0.9

Monitoring station	Waterbody	Year	Number of samples (months of the year)	Bioavailable lead (µg/l) – annual average	Average site-specific PNEC	Average RCR
50361: River Wye above Afon Bidno.	GB109055042330: Wye – conf Afon Tarenig to conf Afon Bidno.	2022	5 (June to August, October and December)	0.9	3	0.7
50361: River Wye above Afon Bidno.	GB109055042330: Wye – conf Afon Tarenig to conf Afon Bidno.	2023	8 (February, April to July, September and December)	0.6	3.1	0.5
50511: River Wye at Llangurig.	GB109055042320: Wye – conf Afon Bidno to conf Afon Marteg.	2011	10 (August to December)	0.9	3.3	0.8
50511: River Wye at Llangurig.	GB109055042320: Wye – conf Afon Bidno to conf Afon Marteg.	2012	3 (January and February)	1.4	2	1.2
50006: River Wye at Nannerth Bridge.	GB109055042280: Wye – conf Afon Marteg to conf Afon Elan.	2011	7 (September to November)	0.4	4	0.4
50006: River Wye at Nannerth Bridge.	GB109055042280: Wye – conf Afon Marteg to conf Afon Elan.	2012	2 (January and February)	0.6	2	0.5

Table 11: Metal bioavailability assessment – zinc

Monitoring station	Waterbody	Year	Number of samples (months of the year)	Bioavailable Zn (µg/l) – annual average	Average site-specific PNEC	Average RCR
50002: Afon Tarenig, above the confluence with the River Wye.	GB109055042350: Afon Tarenig – source to conf R Wye.	2011	7 (June to December)	36.1	13.2	3.3
50002: Afon Tarenig, above the confluence with the River Wye.	GB109055042350: Afon Tarenig – source to conf R Wye.	2012	12 (January to December)	26	16.4	2.4
50002: Afon Tarenig, above the confluence with the River Wye.	GB109055042350: Afon Tarenig – source to conf R Wye.	2013	2 (January and May)	38	10.9	3.5
50002: Afon Tarenig, above the confluence with the River Wye.	GB109055042350: Afon Tarenig – source to conf R Wye.	2025	7 (February to August)	34.3	13.3	3.2
50001: River Wye, above the confluence with the Afon Tarenig.	GB109055042360: Wye – source to conf Afon Tarenig.	2012	9 (February to May, July, September to December)	52	14.8	4.8
50001: River Wye, above the confluence with the Afon Tarenig.	GB109055042360: Wye – source to conf Afon Tarenig.	2013	2 (January and May)	74.6	10.9	6.8

Monitoring station	Waterbody	Year	Number of samples (months of the year)	Bioavailable Zn (µg/l) – annual average	Average site-specific PNEC	Average RCR
50001: River Wye, above the confluence with the Afon Tarenig.	GB109055042360: Wye – source to conf Afon Tarenig.	2024	12 (January to December)	50.2	13	4.6
50361: River Wye above Afon Bidno.	GB109055042330: Wye – conf Afon Tarenig to conf Afon Bidno.	2022	5 (June to August, October and December)	35.9	12.8	3.3
50361: River Wye above Afon Bidno.	GB109055042330: Wye – conf Afon Tarenig to conf Afon Bidno.	2023	8 (February, April to July, September and December)	33.3	12.5	3.1
50511: River Wye at Llangurig.	GB109055042320: Wye – conf Afon Bidno to conf Afon Marteg.	2011	10 (August to December)	27.2	13.3	2.5
50511: River Wye at Llangurig.	GB109055042320: Wye – conf Afon Bidno to conf Afon Marteg.	2012	3 (January and February)	30.8	10.9	2.8
50006: River Wye at Nannerth Bridge.	GB109055042280: Wye – conf Afon Marteg to conf Afon Elan.	2011	7 (September to November)	14.4	16.5	1.3

Monitoring station	Waterbody	Year	Number of samples (months of the year)	Bioavailable Zn (µg/l) – annual average	Average site-specific PNEC	Average RCR
50006: River Wye at Nannerth Bridge.	GB109055042280: Wye – conf Afon Marteg to conf Afon Elan.	2012	2 (January and February)	23.4	10.9	2.2

4.5. Assessment summary

The summary of recorded lead, cadmium and zinc concentrations (Table 7) indicates that concentrations are highest when associated with mine water from point sources (adits) in the catchment, and in watercourses immediately downstream / adjacent to diffuse pollution sources from abandoned mines.

There are no significant recorded metals EQS exceedances in the Nant Nod, the River Wye (above its confluence with the Nant Iago) and the Afon Bidno (Table 7). This corroborates the findings of previous WFDR studies associated with the Upper Wye catchment, such as the FWB report (Section 2.7).

Lead

Lead EQS exceedances have been recorded along the extent of the Afon Tarenig. At monitoring station 5520094 directly downstream of Plynlimon mine, average dissolved lead concentrations were recorded up to 68 times the EQS. The scale of these exceedances decreases progressively downstream, to five times the EQS above its confluence with the River Wye (monitoring station 50002).

Lead EQS exceedances are noted along the Nant Iago (downstream of Nantiago mine) above its confluence with the River Wye. Downstream of the Nant Iago and River Wye confluence, lead EQS exceedances are noted along the River Wye as it passes the Nantygwrdy and Dolminers mines. The extent of these exceedances, like the Afon Tarenig, also decreases downstream to four times the EQS in the River Wye above its confluence with the Afon Tarenig (monitoring station 50001).

Lead is not a failing element in the remaining downstream waterbodies.

Zinc

Zinc EQS exceedances are prevalent across all the waterbodies. The extent of zinc EQS exceedances shows a similar trend to the lead concentrations, with the extent of exceedances being much greater in watercourses adjacent to and downstream of abandoned mines in the upstream part of the catchment. Zinc exceeds the EQS between three and five times at the downstream point of four of the waterbodies, as recorded as monitoring stations 50002, 50001, 50361, and 50511.

Cadmium

Cadmium EQS exceedances follow a similar trend to zinc concentrations across the waterbodies. However, cadmium is only considered to be a failing element across three of the six waterbodies (Section 2.7).

Cadmium has not been recorded above the EQS for the two WFDR classification points associated with: GB109055042320: Wye – conf Afon Bidno to conf Afon Marteg and GB109055042280: Wye – conf Afon Marteg to conf Afon Elan.

Bioavailability

The WFDR EQS for lead and zinc applies a bioavailability test rather than comparing values with total for dissolved concentrations. In all instances on the Afon Tarenig (above the confluence with the River Wye), the average RCR for lead is above 1, indicating that lead may be having an impact on river ecology in this waterbody (Table 10). The average RCR for lead has also been recorded above 1 on the River Wye above the confluence with the Afon Tarenig. In most of the downstream locations of the River Wye, the average RCR for lead is below 1, which indicates that lead is unlikely to pose a risk to river ecology further downstream.

The average RCR for zinc is above 1 at all assessed sites in the study area (Table 11). In all instances, similar to lead, the highest average RCR values are associated with the Afon Tarenig and River Wye headwaters waterbodies, which host the most prominent abandoned metal mines in the Upper Wye catchment.

Zinc is the driving element for five of the six waterbodies failing to achieve overall ‘Good’ status, based on ecological classification. Bioavailable zinc concentrations in waterbody GB109055042280: Wye – conf Afon Marteg to conf Afon Elan are associated with average RCR values above 1 in the upstream part, i.e. monitoring station 50006 in Table 11. However, the downstream compliance point for this waterbody, as used for the WFDR classification (monitoring station 50177), does not exceed the EQS for zinc, hence the waterbody is classified as ‘Good’. This is considered further as part of the total baseline polluted length (Section 5.6).

This assessment indicates that metals pollution from Plynlimon, Nantiago, Nantygwrdy and Dolminers abandoned metal mines is contributing to EQS exceedances and WFDR failures for cadmium, lead, and zinc in the upper tributaries of the catchment. In turn, this causes exceedances of the EQS and WFDR failures in the downstream waterbodies.

4.6. Ecological impact

Of the six waterbodies assessed in this report, four fail to achieve ‘Good’ ecological status for the Benthic Invertebrates and/or Fish elements (Table 3). The ‘Reason for not Achieving Good’ ascribed to those failures is pollution from abandoned non-coal (metal) mines shared with ‘Atmospheric Deposition’ causing acidification.

Whilst invertebrate or fisheries data is not available near the mines, the data used in the WFDR classification and in other surveys is noteworthy.

The standard key applied to benthic invertebrate data is designed to assess general degradation including organic pollution. As such it cannot be directly applied to other pressures such as metals or acidification. However, where the organic enrichment pressure is low or absent, as is the case in the study catchment, then the low scores causing the element to fail must arise due to a different pressure. The WFDR invertebrate classification comprises two metrics that are assessed separately and then combined in a “worst of” approach to provide the overall invertebrate classification; WHPT ASPT (Average Score Per Taxon) WHPT NTAXA (Number of taxa contributing to the assessment). The NTAXA score may be used to indicate other pressures (UKTAG, 2023). Those NTAXA scores and the WFDR status class they represent along with a statement of confidence in that class are reproduced in Table 12 (Natural Resources Wales, 2021).

Table 12: NTAXA score per waterbody, along with UKTAG thresholds (UKTAG, 2023)

Waterbody ID	Water Body name	WHPT NTAXA Ecological Quality Ratio (EQR)	WFD Status Class
GB109055042360	Wye – source to conf Afon Tarenig.	0.664604	Moderate (uncertain)
GB109055042350	Afon Tarenig – source to conf R Wye.	0.736549	Good (uncertain)
GB109055042330	Wye – conf Afon Tarenig to conf Afon Bidno.	0.597319	Moderate (Uncertain)
GB109055042320	Wye – conf Afon Bidno to conf Afon Marteg.	0.688702	Good (uncertain)
GB109055042280	Wye – conf Afon Marteg to conf Afon Elan.	0.872026	High (uncertain)

Status boundary	WHPT NTAXA EQR	WHPT ASPT EQR
H/G	0.80	0.97
G/M	0.68	0.86
M/P	0.56	0.72
P/B	0.47	0.59

A key for specifically assessing the impact of metals on benthic invertebrate population metrics has been available since 2016 (QMUL, 2016). However, to date it has not been agreed for inclusion in the suite of elements used in the WFDR classification. That key is currently under review by researchers at Queen Mary University London (QMUL).

The MetTol 2016 report (QMUL, 2016) included monitoring of body burdens of metals in different invertebrate species. That report identified invertebrates in the Upper Wye study area to be carrying very high body burdens of lead and zinc and in some instances arsenic.

The 2016 MetTol invertebrate key was used in NRW investigations to identify Reasons for Not achieving Good status in 2021 and confirmed a metal derived impact on the invertebrate population, which resulted in abandoned metal mines being identified as driving the WFDR ecological status failure (Natural Resources Wales, 2021).

As part of their current review, QMUL were able to apply the 2016 MetTol key to the benthic invertebrate data held by NRW and produce scores for monitoring sites. Six sites in the study catchment were included in that exercise. Four sites, including the Tarenig, the Wye upstream of the Bidno confluence and the Wye upstream of the Tarenig, showed significant impact compared to the score which might be expected in the absence of anthropogenic stress (QMUL, 2016).

A recent fisheries survey by NRW (Figure 9) to inform the Upper Wye Restoration Project has indicated that fish populations upstream of the Afon Bidno are of concern. Brown Trout numbers are very low and bullheads are absent. Notably numbers of Salmon Parr are lower than expected compared to numbers of Salmon Fry, suggesting spawning is successful but growth to adulthood is compromised. The reason for this has not been determined but habitat quality is a factor. The contribution of metals, potentially due to ingestion of metals in their invertebrate food (QMUL, 2016) rather than a direct toxic effect, has not been investigated.

A report by the Wye and Usk Foundation (Wye & Usk Foundation, 2021), commissioned by NRW, reported low populations of Salmon Fry in the Afon Tarenig and absence in the Wye headwaters.

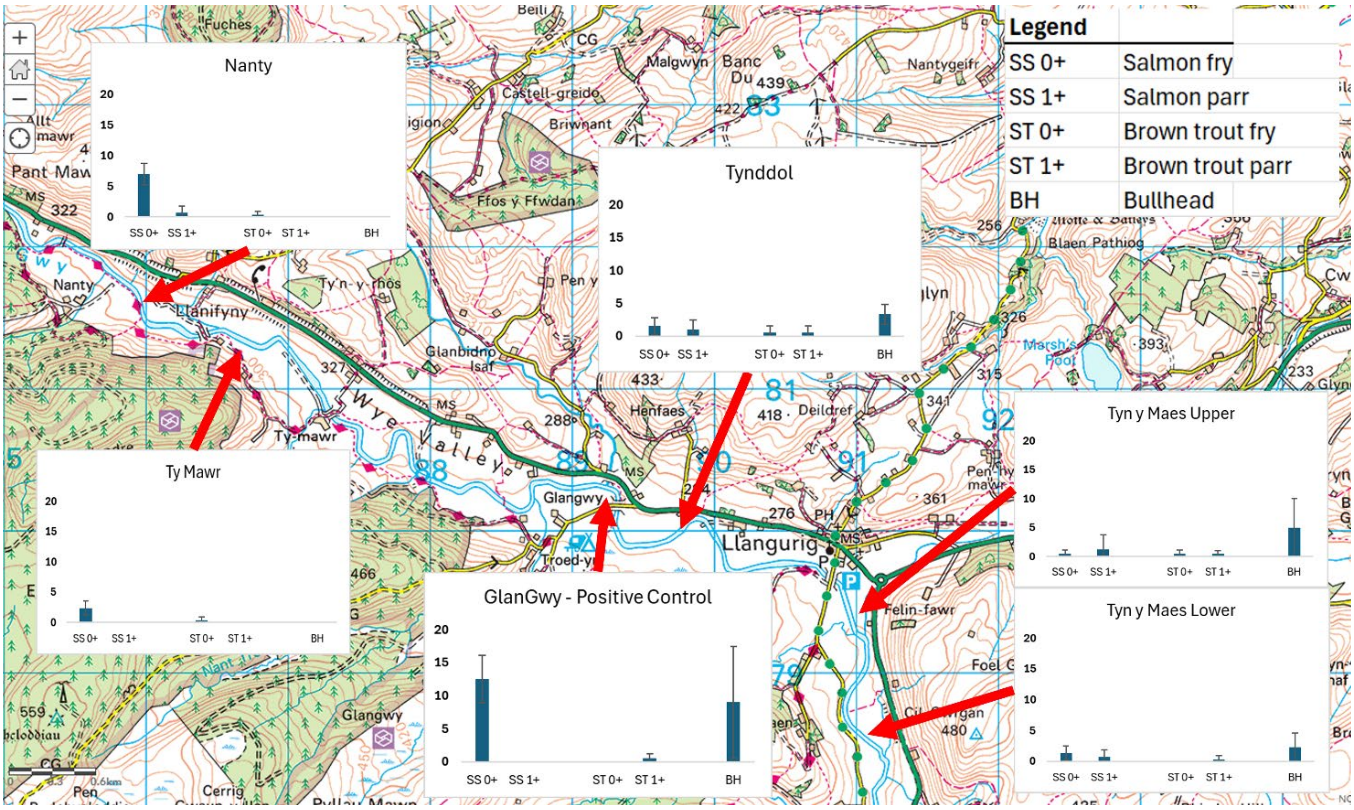

Figure 9: Upper Wye fisheries data

5. Interpretation and source apportionment

5.1. Metal loadings

Table 13 presents the zinc, lead, and cadmium loading calculations per monitoring station. Table 13 presents calculations for the two waterbodies in the catchment associated with the ‘Red’ abandoned metal mine sites: Afon Tarenig, and River Wye above the confluence with the Afon Tarenig. These calculations consider the flow and water quality data reported on in Section 4.

Metal loading estimations have also been presented for monitoring station 50561. This monitoring station is the nearest point downstream of the confluence between both the Afon Tarenig and the River Wye. This has been included to support the discussion relating to metals pollution apportionment per tributary (Section 5.3), and how this influences source apportionment in the catchment.

The average metal loadings recorded in surface water in the two upstream waterbodies and at monitoring station 50361 are shown on Figure 10.

Table 13: Minimum, maximum and average zinc, lead and cadmium loadings (kg/yr) for selected monitoring stations in the Upper Wye catchment

Monitoring station	Waterbody ID	Min. zinc (kg/yr)	Max. zinc (kg/yr)	Mean zinc (kg/yr)	Min. lead (kg/yr)	Max. lead (kg/yr)	Mean lead (kg/yr)	Min. cadmium (kg/yr)	Max. cadmium (kg/yr)	Mean cadmium (kg/yr)
5520092: Afon Tarenig, upstream of fines tips.	GB109055042350: Afon Tarenig – source to conf R Wye	4.6	46	21.4	0.4	4.4	1.6	0.02	0.31	0.13
5520119[4]: Plynlimon adit discharge.	GB109055042350: Afon Tarenig – source to conf R Wye	26.8	41.9	31.8	19.6	57.4	31.8	0.08	0.13	0.1
5520093: Afon Tarenig, downstream of adit.	GB109055042350: Afon Tarenig – source to conf R Wye	78.8	266	170	38	167.7	93.4	0.26	1.04	0.65
5520094: Afon Tarenig, downstream of Plynlimon.	GB109055042350: Afon Tarenig – source to conf R Wye	260	1,247	539	37	441	190	0.52	4.88	2.1
51318: Afon Tarenig at Pont Eisteddfa Gurig.	GB109055042350: Afon Tarenig – source to conf R Wye	141	5628	1203	20	1165	235	0.5	21.7	4.7
50002: River Tarenig, above the confluence with the River Wye.	GB109055042350: Afon Tarenig – source to conf R Wye	145	1289	509	9.3	160	66	0.44	4.85	1.9

[4] It has not been possible to flow gauge at Plynlimon Adit. The metal loading values presented here have been calculated by using an average of the determinand concentration (lead, zinc and cadmium) over the monitoring visits, and assuming a flow rate of 1 L/s. This is discussed further as part of the source apportionment.

Monitoring station	Waterbody ID	Min. zinc (kg/yr)	Max. zinc (kg/yr)	Mean zinc (kg/yr)	Min. lead (kg/yr)	Max. lead (kg/yr)	Mean lead (kg/yr)	Min. cadmium (kg/yr)	Max. cadmium (kg/yr)	Mean cadmium (kg/yr)
53068: Nant Iago, upstream of shaft.	GB109055042360: Wye – source to conf Afon Tarenig	0.9	11.4	4.9	0.1	2.2	1	0.01	0.07	0.03
5520079: Nant Iago at Track Culvert.	GB109055042360: Wye – source to conf Afon Tarenig	0.46	13.2	6.3	0.5	9.8	4.1	0.01	0.06	0.03
5520080[5]: Nant Iago Deep Adit.	GB109055042360: Wye – source to conf Afon Tarenig	10	50.5	24	0.8	5.7	2.3	0.04	0.23	0.09
53069: Nant Iago, downstream of adit.	GB109055042360: Wye – source to conf Afon Tarenig	21.4	273	113	1.4	31	9.7	0.09	1.18	0.46
53070: Nant Iago, downstream of Nantiago.	GB109055042360: Wye – source to conf Afon Tarenig	56	525	201	2.7	68	17.2	0.26	2.65	1
53072: Gauging station at Nant Iago.	GB109055042360: Wye – source to conf Afon Tarenig	180	1238	709	9	39	24	0.07	0.12	0.1

[5] It has not been possible to flow gauge at Nantiago Adit. The metal loading values presented here have been calculated by using an average of the determinand concentration (lead, zinc and cadmium) over the monitoring visits, and assuming a flow rate of 1 L/s. This is discussed further as part of the source apportionment.

Monitoring station	Waterbody ID	Min. zinc (kg/yr)	Max. zinc (kg/yr)	Mean zinc (kg/yr)	Min. lead (kg/yr)	Max. lead (kg/yr)	Mean lead (kg/yr)	Min. cadmium (kg/yr)	Max. cadmium (kg/yr)	Mean cadmium (kg/yr)
53076: River Wye, upstream of the Nantygwrdy.	GB109055042360: Wye – source to conf Afon Tarenig	52	819	383	2.1	93	27	0.27	4	1.85
53074: Nantygwrdy, downstream of adit.	GB109055042360: Wye – source to conf Afon Tarenig	5.4	630	226	1.9	141	39	0.02	1.84	0.8
5520081: Nantygwrdy Deep Adit.	GB109055042360: Wye – source to conf Afon Tarenig	170	629	335	14.3	168	65	0.61	2.42	1.19
53077: River Wye, downstream of the Nantygwrdy.	GB109055042360: Wye – source to conf Afon Tarenig	356	2359	1059	15	310	114	1	11.1	4.83
53078: River Wye, downstream of Dolminers.	GB109055042360: Wye – source to conf Afon Tarenig	411	2010	1043	12	207	94	1.1	8.8	4.6
50001: River Wye, above the confluence with the Afon Tarenig.	GB109055042360: Wye – source to conf Afon Tarenig	427	5945	1477	8.5	1600	162	1.4	31.4	6.6
50361: River Wye above Afon Bidno.	GB109055042330: Wye – conf Afon Tarenig to conf Afon Bidno	259	13295	3655	7	2007	325	1	60	15.5

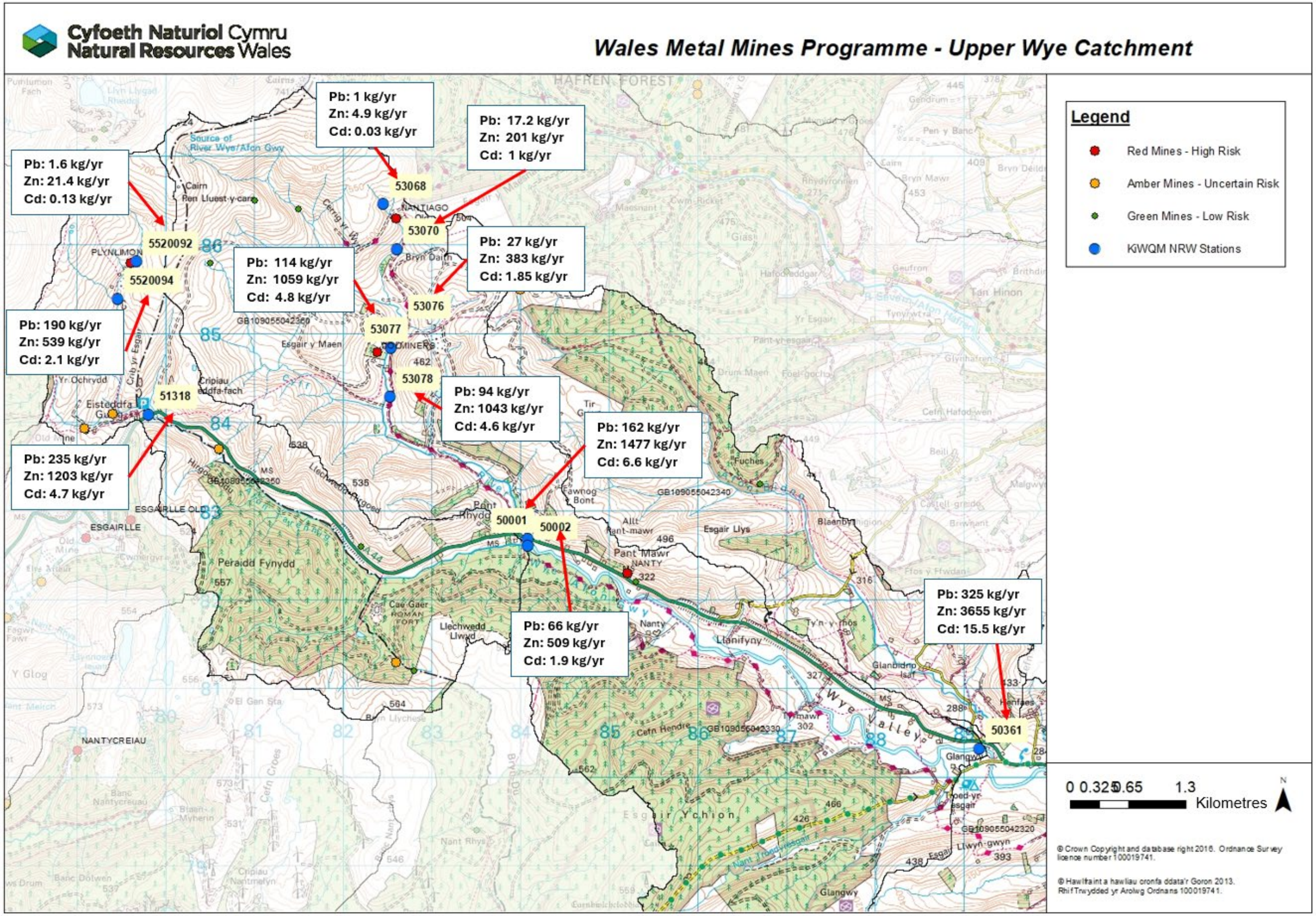

Figure 10: Average metal loadings within watercourses in the two upstream waterbodies, and at monitoring station 50361

5.2. Catchment source apportionment

Based on comparisons between the average metal loading data, the Afon Tarenig (monitoring station 50002) is contributing 20% of the lead (66 kg/yr), 12% cadmium (1.9 kg/yr), and 14% of the zinc (509 kg/yr) recorded at monitoring location 50361 on the River Wye. This is the closest monitoring station downstream of the two waterbodies in the catchment associated with 'Red' abandoned mines.

The River Wye above the confluence with the Afon Tarenig (monitoring station 50001) is contributing 50% of the lead (162 kg/yr), 42% of the cadmium (6.6 kg/yr), and 40% of the zinc (1477 kg/yr) recorded at monitoring location 50361.

The cumulative impact of both tributaries on metal loadings at monitoring station 50361 is therefore equivalent to 70% of the recorded lead (228 kg/yr), 54% cadmium (8.4 kg/yr), and 54% zinc (1986 kg/yr).

The loading estimates presented represent appropriate calculations for use in interpretations as they consider monitoring events which capture some changes in flows due to seasonality, although they will never be without limitations.

The loading estimates indicate that 30% of the lead, and 46% of the respective cadmium and zinc recorded at monitoring station 50361 originates from another pollution source downstream of both tributaries. This is unlikely to be the case based on the following evidence:

- There is no substantial source of metals pollution located between both tributaries and monitoring station 50361. Whilst Nanty mine is in this area, three rounds of water quality sampling (undertaken in quarter 1 of 2026) upstream and downstream of Nanty in the River Wye show decreasing concentrations of cadmium, lead, and zinc. This indicates Nanty may not contribute much in terms of metals pollution to the catchment, but this will be confirmed with additional monthly monitoring throughout 2026 (Section 5.4.4). There are no other known sources of metals pollution in this area.

- Average metal concentrations are lower at monitoring station 50361 compared with the two upstream locations (i.e. 39 µg/l zinc at station 50361, compared to 42µg/l at 50002 and 64.4 µg/l at 50001). This suggests that dilution of metal concentrations is occurring in the River Wye as opposed to pollution impacts from an additional source.

Instead, it is most likely that there are uncertainties relating to the flow data used in the loadings calculations, leading to high loadings at monitoring station 50361. Based on the available evidence, it is likely that the modelled flow estimates at monitoring station 50361 overestimate flow conditions (and therefore loading) in the River Wye. There is greater uncertainty with flow conditions in this part of the River Wye as there is no gauged data nearby to compliment the modelled data. Whilst the flow data from monitoring station 50001 were also based on modelled data, this flow data correlated well with monitoring locations which were flow gauged upstream along the same waterbody. Flow data from monitoring station 50002 were based on gauged information which correlated well with other monitoring locations in the same waterbody. This evidence suggests that the modelled flow rates at monitoring station 50361 are associated with the highest degree of uncertainty and as such are likely to be overestimated. In turn, this underrepresents the relative metal load contributions from both upstream tributaries by overestimating the metal loading at monitoring station 50361.

As a result, it is likely that the total flux of metals in the Wye below the Tarenig confluence (i.e. 50361) are lower than the face value calculations presented. And therefore, relative contributions of lead, cadmium and zinc from both tributaries are higher. However, it remains clear that most of the metals flux in the catchment arises from the combined discharge of the Afon Tarenig and the Wye headwaters waterbody, a finding which corresponds to the results presented in Section 4.

5.3. Waterbody source apportionment

5.3.1. Afon Tarenig

Figure 11 shows the configuration of monitoring stations and abandoned mines within the Tarenig waterbody. This waterbody hosts Plynlimon mine, as well as Nant Nod, Plynlimon South, Hirgoed Ddu, Nant Gwernos, and Fagwr Fraith.

To determine source apportionment on the Afon Tarenig, it is assumed that monitoring station 50002 represents 100% of the mass of cadmium, lead, and zinc associated with the waterbody. This is because it is located at the most downstream point, before the confluence with the River Wye. The following additional monitoring stations have been considered for apportionment:

- 5520094: Afon Tarenig, downstream of Plynlimon.
- 51319: Nant Nod, upstream of the Afon Tarenig.
- 51318: Afon Tarenig at Pont Eisteddfa Gurig.
- 50002: River Tarenig, above the confluence with the River Wye.

As presented in Table 13, average metal loadings recorded at monitoring station 50002 are equivalent to 509 kg/yr zinc, 66 kg/yr lead, and 1.9 kg/yr cadmium.

Downstream of Plynlimon mine (monitoring station 5520094), average metal loadings are equivalent to 538.8 kg/yr zinc, 190.4 kg/yr lead, and 2.1 kg/yr cadmium. This is equivalent to 288% of the lead, 113% cadmium, and 106% zinc recorded at monitoring station 50002.

As presented in Section 4.3, all metal concentrations recorded at the downstream point of Nant Nod (monitoring station 51319) are compliant with EQS. On this basis, it can be assumed that the loadings from Nant Nod mine and Plynlimon South mine are negligible and the two sites are not significant sources of pollution.

The calculated loadings suggest there is a substantial increase in metal loading in the Afon Tarenig between monitoring stations 5520094 and 51318; 664 kg/yr zinc, 45 kg/yr lead, and 2.6 kg/yr cadmium. The only mines located between these two monitoring stations are Nant Nod and Plynlimon South. The analysis above indicates that these are not significant sources of pollution, and therefore this loading increase does not make sense based on the environmental setting. The flow rate and metal concentration data used to determine metal loadings at both monitoring stations has been reviewed, with relevant findings presented below:

- The average flow rate at monitoring station 5520094 is 67 L/s based on measured flow gauging data. The average flow rate at monitoring station 51318 is 343 L/s, based on flow estimates.

- Average metal concentrations decrease between monitoring station 5520094 and 51318. Lead concentrations decrease from 81.2 µg/l to 20.4 µg/l, cadmium from 0.9 µg/l to 0.4 µg/l and zinc from 241 µg/l to 114 µg/l.

- Whilst an increase in flow rate is expected between monitoring station 5520094 and 51318, the flow rate is unlikely to increase by this magnitude (5x) across approximately 1.7km of river length, with some minor tributary inputs (e.g. Nant Nod).

- The average flow rate estimated at 51318 is only 21 L/s less than the average flow rate recorded at monitoring station 50002 (364 L/s) 5km downstream. The average flow rate at monitoring station 50002 is based on flow gauging data. OS maps show several tributaries flowing into the Afon Tarenig over the 5km distance between both monitoring stations. This is likely to contribute to an average flow rate increase significantly greater than 21 L/s between monitoring stations.

The evidence presented above suggests that the flow rate estimates at monitoring station 51318 are overestimates. This in turn is contributing to exaggerated calculated loadings at this location. The significant decreases in average metal concentrations between 5520094 and 51318 suggest that dilution of metals is occurring in this part of the Afon Tarenig, as opposed to contributions from another source. This is supported by the analysis above which also suggests that there is not a significant source of pollution between both monitoring stations.

Based on the evidence, the analysis indicates that the recorded metal load at 50002 can mainly be attributed to Plynlimon mine, and that the other mines located in this waterbody are not contributing significantly to pollution.

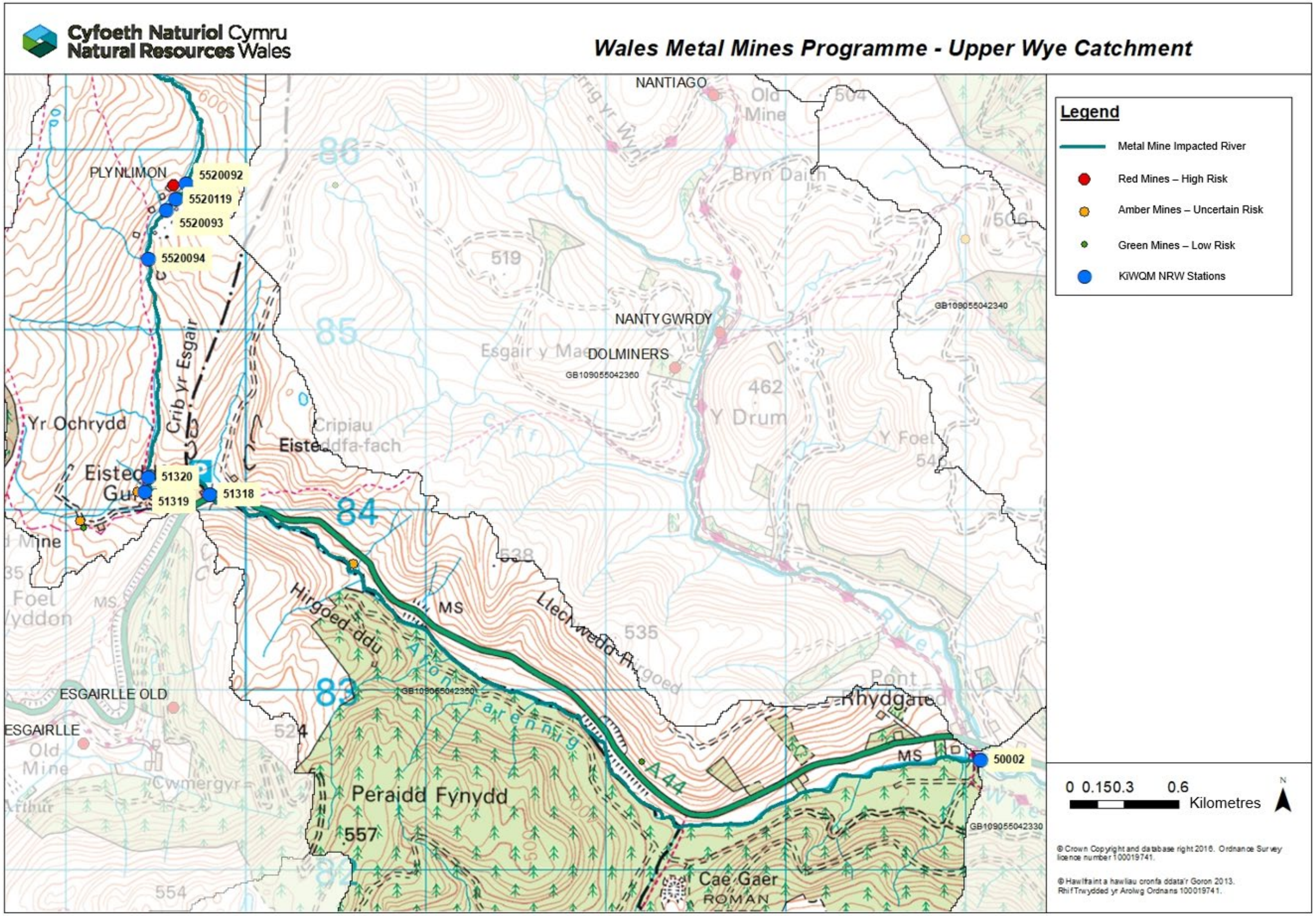

Figure 11: Configuration of monitoring stations and abandoned mines within the Tarenig waterbody

5.3.2. River Wye above confluence with Afon Tarenig

Nantiago, Nantygwrdy and Dolminers abandoned metal mines are located on the River Wye above the confluence with Afon Tarenig. To apportion pollution sources associated with these mines, water quality and metal loadings data have been interpreted from the following monitoring stations: Nant Iago downstream of Nantiago (53070), River Wye upstream and downstream of Nantygwrdy (53076 and 53077 respectively), and the River Wye downstream of Dolminers (53078).

The average metal loading calculations indicate:

- 29% of the lead loading (27.2 kg/yr), 40% cadmium (1.8 kg/yr), and 37% zinc (383 kg/yr) recorded at 53078 may be attributable to Nantiago. This is through metal loading comparisons at 53076, which is upstream of Nantygwrdy and Dolminers in the River Wye, and 53078 (the downstream location). Source apportionment at Nantiago is discussed in Section 5.4.1.

- Monitoring station 53077 (River Wye downstream of Nantygwrdy but upstream of Dolminers), accounts for 122% (114.4 kg/yr), 104% (4.8 kg/yr) and 102% (1,059 kg/yr) of the lead, cadmium and zinc load at monitoring station 53078 (downstream location). Monitoring station 53077 considers the cumulative impacts of Nantiago and Nantygwrdy. Removing the metal load contributions from Nantiago, 93% of the lead loading (87.2 kg/yr), 64% cadmium (3 kg/yr), and 65% zinc (676 kg/yr) recorded at monitoring station 53078 may be attributable to Nantygwrdy mine. Source apportionment at Nantygwrdy is discussed in Section 5.4.2.

- The average recorded metal load (lead, cadmium, and zinc) is lower at monitoring station 53078 when compared to 53077. The former is downstream of Dolminers in the River Wye, whilst the latter is upstream of Dolminers and downstream of Nantygwrdy in the River Wye. Further discussion is provided in Section 5.4.2.

It is important to note that there have been issues with flow gauging at monitoring station 53076. This is demonstrated by the average flow rate (210 L/s) being slightly higher than the downstream location at 53077 (204 L/s). This in turn may exaggerate the metal loading contributions from Nantiago and underrepresent loading from Nantygwrdy. Loading from Dolminers should not be impacted by this erroneous data as there have been no issues with its upstream (53077) and downstream (53078) monitoring point.

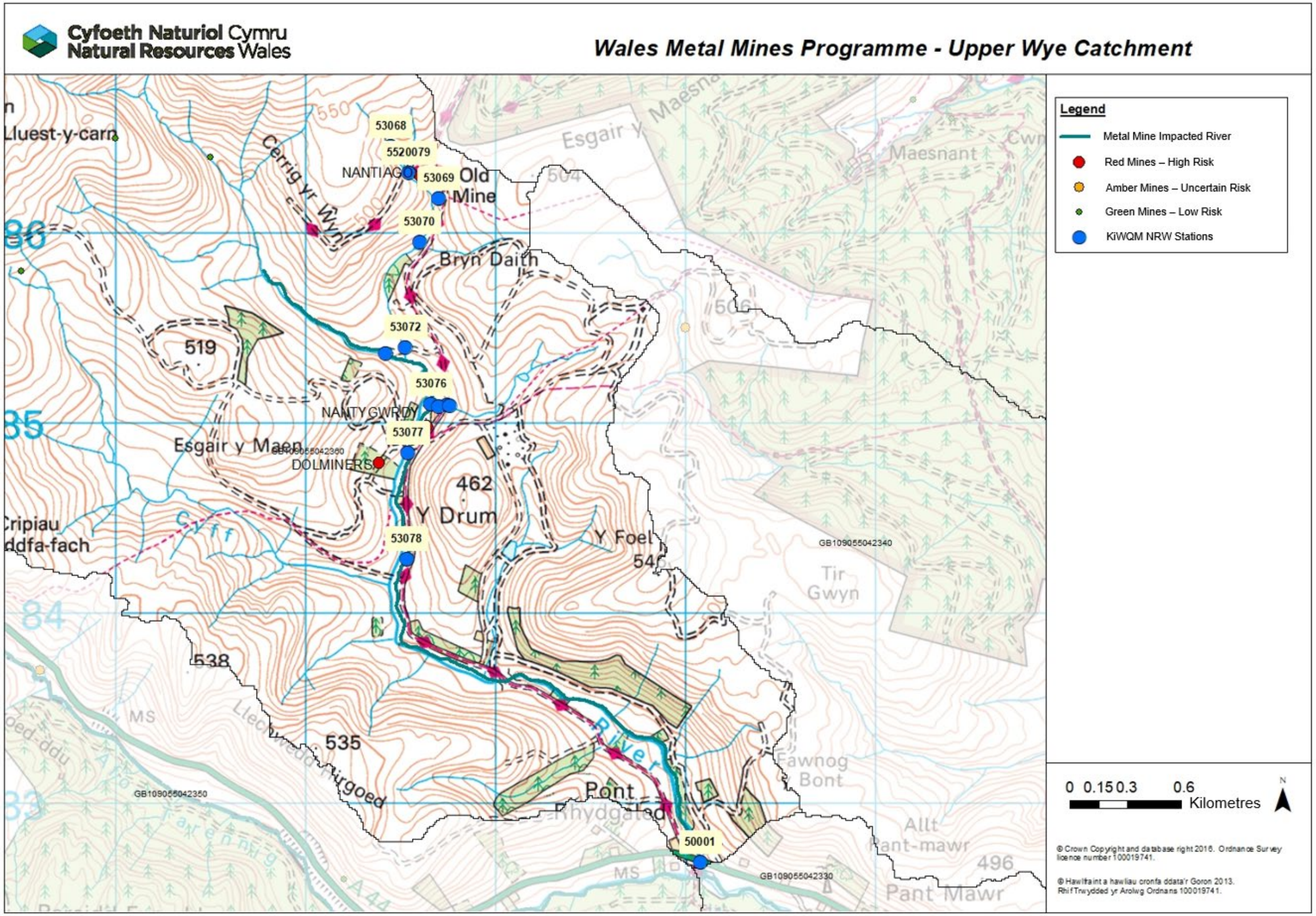

Figure 12: Configuration of monitoring stations and abandoned mines within the Wye above Tarenig waterbody

5.4. Source apportionment per mine

5.4.1. Nantiago

The Nantiago tracer test study (WSP, 2023) reported that the Deep Adit was salt gauged on three consecutive days to ascertain the discharge flow rate. Flows were recorded between 11.3 L/s and 16.2 L/s. An increase in discharge flow rate was recorded over a short period following low intensity rainfall.

Recent NRW monitoring has determined that it is not possible to accurately salt gauge the discharge from this adit as there is insufficient section length to ensure mixing and it is located within boggy terrain.

Noting the above constraints, it is important to consider the validity of the WSP data. No issues were reported and the recorded flow rates are not improbable and may likely represent adit discharge rates during a high flow event during winter months. Whilst unlikely to represent an annual average, this does indicate that an estimated annual average discharge of 1 L/s may result in an underrepresentation of metals loading. To manage the uncertainty, this evaluation reviews the contribution of metal loadings based on different flow rates to determine likely metals flux from the adit.

Water quality and metal loading data have been interpreted from the following monitoring stations: upstream of the mine in the Nant Iago (53068), track culvert (5520079), Nantiago Deep Adit (5520080), downstream of the adit in Nant Iago (53069) and downstream of the mine in the Nant Iago (53070). These stations, along with principal mine features including the collapsed open stope (Engine Shaft), adit, and remnant spoil tips along the banks of the Nant Iago, are shown on Figure 13.

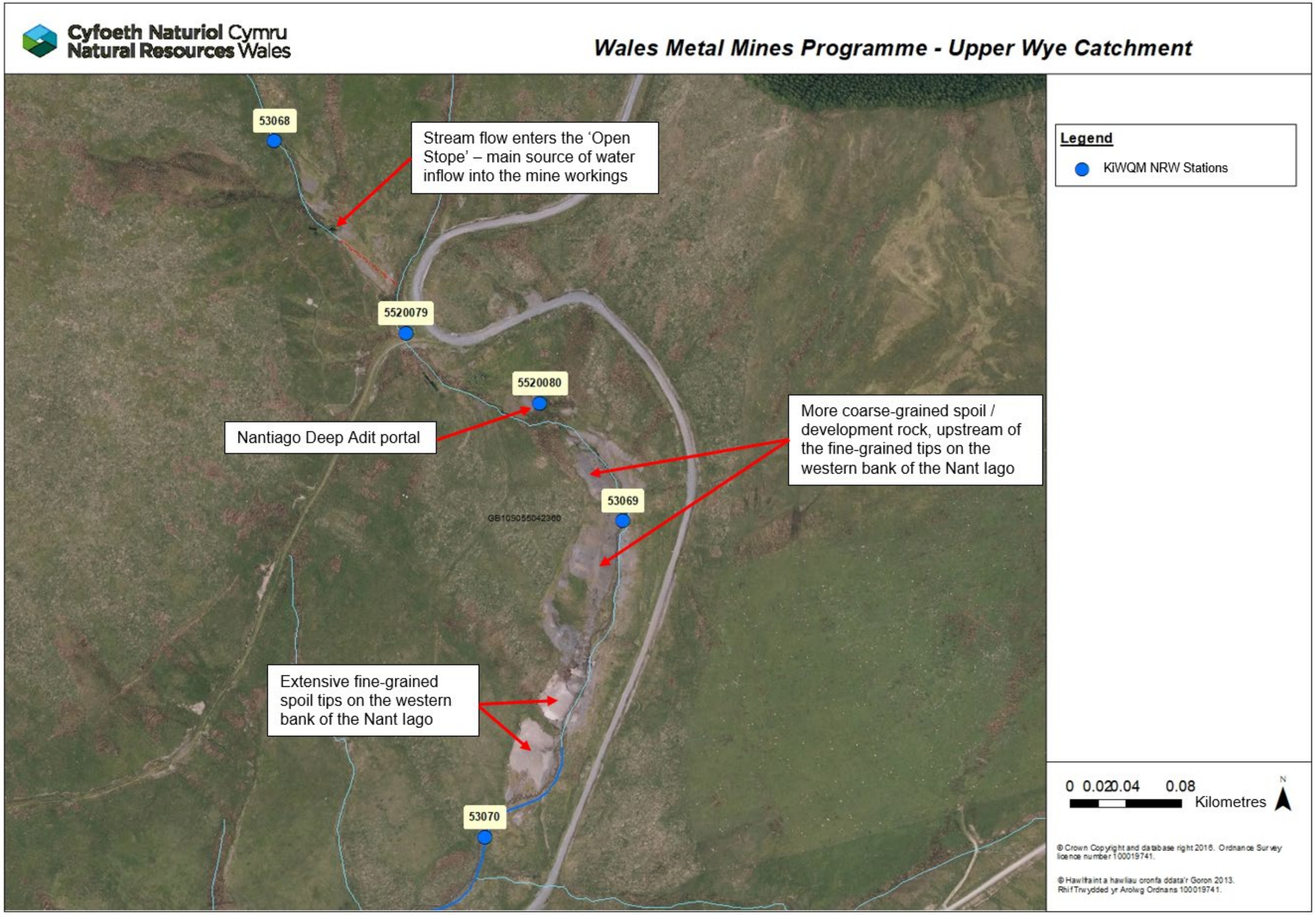

Figure 13: Key mining features associated with Nantiago Mine

For this assessment, 53070 (Nant Iago downstream of the mine) is assumed to represent the location where 100% of the total upstream metal loadings will be received. This assumption is appropriate for basic source apportionment although it is acknowledged this does not account for the complex flow pathways operating in the subsurface at Nantiago, based on the results of the tracer testing (Section 3.3).

Based on average metal loadings, 44% of the lead (7.5 kg/yr), 54% cadmium (0.55 kg/yr) and 44% zinc (88 kg/yr) recorded at monitoring station 53070 originates between sample sites 53069 and 53070. There are extensive fine grained spoil tips in this area which are likely to represent this contribution of the metal load.

The remaining load, based on average loadings, originating upstream of 53069, contributes 56% of the lead, 46% cadmium, and 44% zinc. This is likely to be from a combination of diffuse sources and the Nantiago Deep Adit.

Using an assumed average flow rate of 3 L/s for the Nantiago Deep Adit indicates that it may contribute 13% of the lead (2.3 kg/yr), 9% cadmium (0.09 kg/yr), and 12% zinc (24.4 kg/yr) recorded at 53070. The remaining metal load recorded at monitoring station 53070 may be the result of diffuse pollution sources between 53068 and 53069, which includes the dressing floors of the main mine site. This is equivalent to 43% of the lead (7.4 kg/yr), 37% cadmium (0.37 kg/yr), and 44% zinc (88.3 kg/yr) recorded at 53070. This also includes the track culvert discharge.

It is evident that the mass of metal loading significantly increases during a high flow event. For example, the recorded mass of lead was 43.7 kg/yr at 53070, cadmium 2.7 kg/yr and zinc 525 kg/yr, which is 2.5 times the average metal loading. This was recorded on 10 July 2024, where the flow rate at this location was 45.7 L/s. Conversely, during a low flow event, the recorded mass of metals is 3.5 to five times below the average metal loading mass.

Based on the understanding of the conceptual site model, it is evident that the water flowing into the open stope (Figure 13) is key to increasing discharges from the mine. Confirmed discharge points from the mine include the Deep Adit, and ephemeral issues of mine water along spoil tips which may be influenced by the flow of water discharging from the mine via the Shallow Adit and along the course of an infilled channel. During high flow events, water inflow into the stope will be at its highest, as will any subsequent discharge from the mine.

5.4.2. Nantygwrdy and Dolminers

To apportion metals source loads associated with the Nantygwrdy and Dolminers mines, water quality and metal loading data have been assessed from the following monitoring stations: upstream of Nantygwrdy in the River Wye (53076), Nantygwrdy Adit (5520081), a small flow across Nantygwrdy yard (5520088), Nant y Gwrdy downstream of the adit (53074), upstream and downstream of Dolminers in the River Wye (53077 and 53078). These stations, along with mine features, are shown on Figure 14.

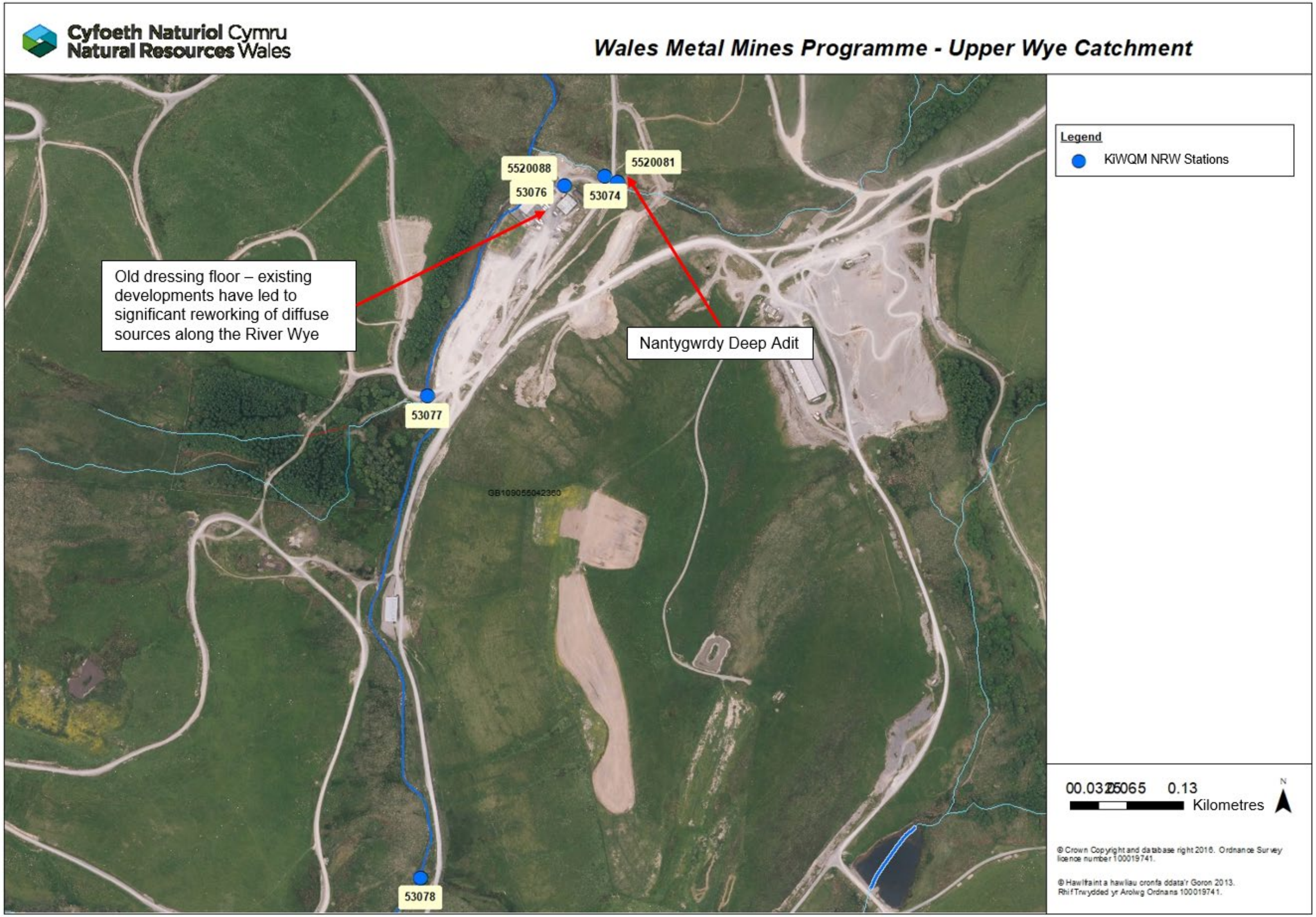

Figure 14: Key mining features associated with Nantygwrdy and Dolminers mines

To apportion source loads from Nantygwrdy mine there are some initial considerations. Monitoring station 53077 is downstream of the mine, and upstream of Dolminers, and as such is considered representative of conditions downstream of the mine. Monitoring station 53076 is already impacted by metals from Nantiago and is therefore omitted from these calculations. Monitoring station 53074 is the Nant y Gwrdy downstream of the adit, which is a potential contribution, as is the area between monitoring stations 53076 and 53077.

Based on average loadings, the recorded mass of metals at monitoring station 53077 is attributable to the following:

- Nant y Gwrdy stream, which includes Nantygwrdy Deep Adit: 34% of the lead (38.7 kg/yr), 17% cadmium (0.8 kg/yr) and 21% zinc (226 kg/yr).

- Between 53076 and 530577: 42% lead (48.5 kg/yr), 45% cadmium (2.2 kg/yr), and 42% zinc (450 kg/yr).

- The remaining mass from upstream because of Nantiago.

Loading comparisons between monitoring stations 5520081 and 53074 indicate that metals from the Nant y Gwrdy stream are most likely attributable to the Nantygwrdy Deep Adit. Based on average loadings, monitoring station 5520081 accounts for 169% of the lead, 147% cadmium, and 148% zinc recorded at 53074. This proportion changes based on low and high flow. During high flows, 5520081 accounts for 75% to 80% of the metal load at 53074 and between 2500% and 6000% during low flows.

Notably, there is a small flow over the yard at Nantygwrdy which discharges straight into the River Wye, downstream of 53076 and bypasses Nant y Gwrdy stream (53074). It has been monitored monthly since March 2024 (5520088), with its location shown on Figure 14. It is not possible to flow gauge this small flow. Visual flow estimates indicates that the flow may be up to 2 L/s during high flows. The water quality sampling indicates that it is a very concentrated solution, with average zinc concentrations being 2,031 µg/l, lead 160.7 µg/l and cadmium 7.5 µg/l. This flow may originate from Nantygwrdy and is also likely to be enriched in metals as it passes over the former dressing floor areas. Assuming an annual flow of 1 L/s, it may contribute 5 kg/yr of lead (4.4%), 0.24 kg/yr of cadmium (5%) and 64 kg/yr of zinc (6%) in the River Wye at 53077.

As presented in Section 5.3.2, calculations of average loadings indicate the mass of metals decreases between monitoring stations 53077 and 53078, River Wye upstream and downstream of Dolminers. This also coincides with a noticeable reduction in the mean and median metal concentrations between both monitoring stations. Based on the median of 26 concurrent water quality samples from both monitoring stations, zinc concentrations decrease by 19.5 µg/l, lead by 4.4 µg/l and cadmium by 0.11 µg/l. Concentrations decreased during 25 out of the 26 sampling visits. This is despite any significant surface water inputs contributing to dilution. This evidence suggests that Dolminers is not a significant source of metals pollution.

5.4.3. Plynlimon

To determine source apportionment associated with Plynlimon, water quality and metal loading data have been interpreted from the following monitoring stations: Afon Tarenig upstream of Plynlimon mine (5520092), Plynlimon Adit (5520119), Afon Tarenig downstream of the adit (5520093) and Afon Tarenig downstream of the mine (5520094). These stations, along with mine features, are shown on Figure 15. This assumes that 100% of the load recorded at 5520094 is a result of the cumulative effects of the upstream sources from Plynlimon mine.

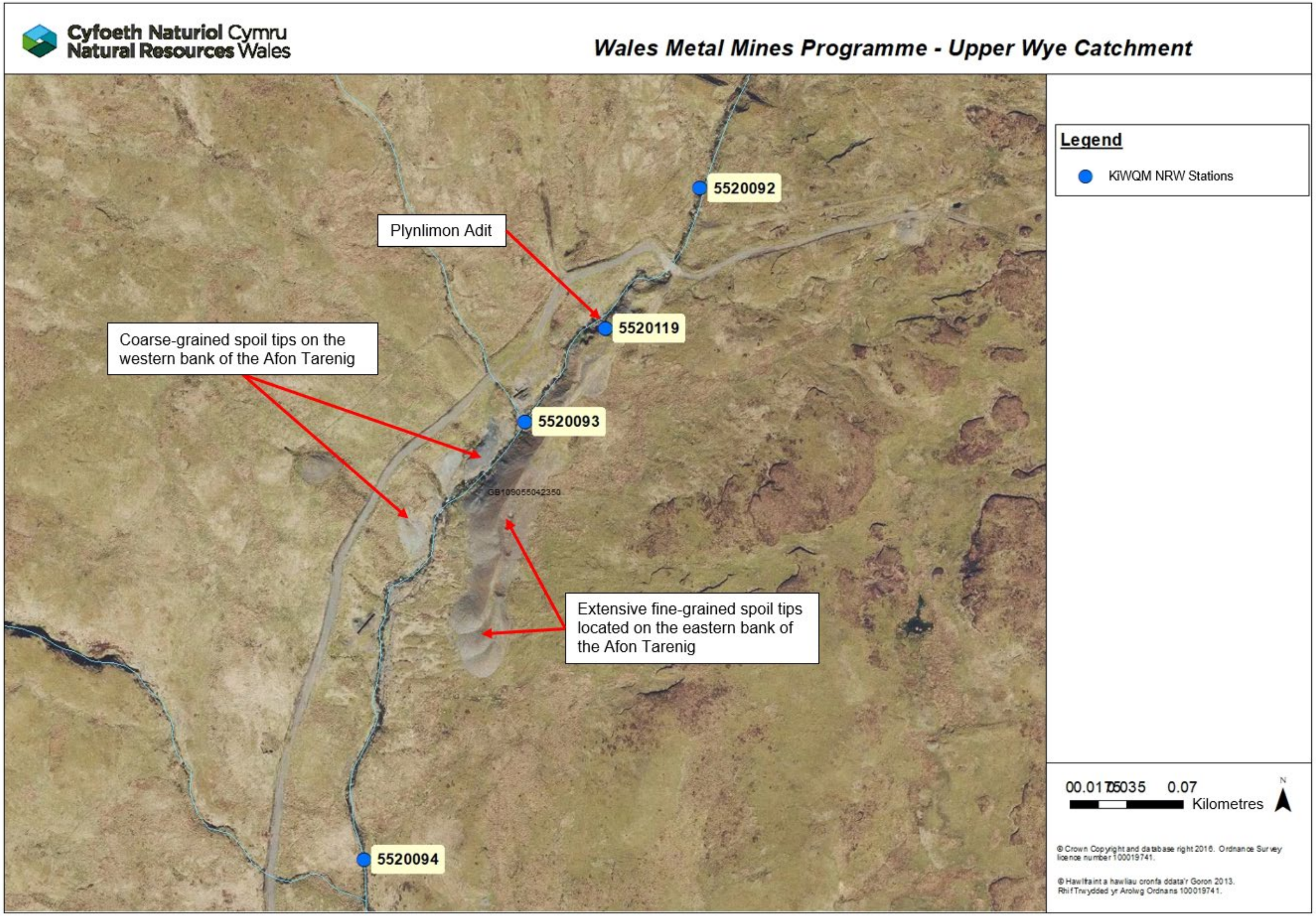

Figure 15: Plynlimon Mine

This review considers metal loadings at low, average and high flows to understand variation in source apportionment under different hydrological conditions. Loadings at monitoring stations have been calculated using data associated with the lowest and highest flow gauging results and with the average recorded flow rate.

In these calculations and in the absence of flow gauging data, metal loading arising from the Plynlimon Adit is assumed to be fixed. It is based on an estimated 1 L/s flow rate and average recorded metals concentrations across all monitoring events. However, as discussed later in the section, the data assessment also considers the impact on source apportionment when the adit flow rate is assumed to be 2.5 L/s.

Notably, the total flux of metals downstream of the mine is much greater during a high flow event, with up to 2.5 times more lead, cadmium and zinc when compared to the flux based on the average flow rate. During higher flow events, there is a lower percentage contribution from the Plynlimon Adit. This indicates a significant contribution from diffuse sources during these conditions, attributable to increased surface water run-off leading to contaminant migration from spoil tips, and evidence of tip drainage which has been observed in the field.

During lower flows, it is evident that the contribution from the Plynlimon Adit is significantly greater. This also corresponds to significant reduction in the total flux of metals recorded downstream of the mine. During these conditions there is likely to be less surface water run-off influencing diffuse pollution sources, hence the greater relative contribution of the point source.

Comparisons between monitoring stations below the Plynlimon Adit (5520093) and downstream of the mine (5520094) indicate that the greatest source of metals is downstream of the Plynlimon Adit. An average of all metal loadings suggests that 51% of the lead, and 69% of the cadmium and 68% of the zinc originates downstream of the adit. A likely source of this metals flux is the extensive spoil tips along the banks of the Afon Tarenig (Figure 15).

There are obvious limitations associated with using a fixed 1 L/s flow rate for Plynlimon Adit. Conducting a basic sensitivity analysis, assuming that the annual average flow rate of the Plynlimon Adit was 2.5 L/s, this point source may contribute 42% of the lead (79.5 kg/yr), 12% cadmium (0.2 kg/yr) and 15% zinc (80 kg/yr) recorded downstream of the mine (5520094). Using an average flow rate any higher than 2.5 L/s would increase the average flux from the adit (5520092) above that in the river downstream (5520093). This indicates that assuming a flow rate of greater than 2.5 L/s to represent the annual average flux from Plynlimon Adit would over-represent the loadings from this point source. However, it should be noted that during high flow events, it is feasible that flows from the adit could exceed 2.5 L/s, but this flow rate would not be sustained for long enough periods to be representative of an annual average.

It could be reasonable to assume that the annual average flow from the adit is between 1 L/s and 2.5 L/s, which in turn has an impact on source apportionment. An annual average flow rate of 2.5 L/s at Plynlimon Adit would mean that it is responsible for 85% of the lead load, 38% cadmium and 47% zinc recorded at 5520093. There is an approximate distance of 75m between Plynlimon Adit and the downstream sampling locality of 5520093. Between these two points there is visible evidence of mining spoil tips along the banks of the Afon Tarenig that would also contribute to the load measured at 5520093.

Therefore, the Plynlimon Adit may reasonably contribute 17% to 42% lead, 5% to 12% cadmium, and 6% to 15% zinc at 5520094; based on average loadings assuming flows of 1 L/s and 2.5 L/s.

A summary of metals pollution source apportionment from Plynlimon is provided in Figure 16. It shows the relative contribution of pollution sources based on the two different flow scenarios for the Plynlimon Adit.

Figure 16: Source apportionment at Plynlimon Mine, based on average flow rates at all monitoring locations and assuming 1 L/s flow (left) and 2.5 L/s (right) at Plynlimon Adit.

5.4.4. Nanty

Two monitoring locations were added to the NRW monitoring programme at the beginning of 2026, upstream and downstream of Nanty mine in the River Wye to understand potential pollution impacts from the mine.

It is not possible to gauge flows at these locations as the flow conditions in the River Wye are much higher than the upstream tributaries. Therefore, only water quality samples have been obtained. Table 14 provides a comparison of metal concentrations from both localities from the samples obtained to date.

Table 14: Water quality data upstream and downstream of Nanty in the River Wye, 2026

Station name	Sample date	Zinc	Zinc, dissolved	Lead	Lead, dissolved
RIVER WYE U/S NANTY MINE	26/01/2026	40.6 µg/l	43.6 µg/l	9.39 µg/l	8.63 µg/l
RIVER WYE D/S NANTY MINE	26/01/2026	38.9 µg/l	41.1 µg/l	8.78 µg/l	8.99 µg/l
RIVER WYE U/S NANTY MINE	25/02/2026	49.8 µg/l	58 µg/l	3.6 µg/l	3.85 µg/l
RIVER WYE D/S NANTY MINE	25/02/2026	37.6 µg/l	52.6 µg/l	3.52 µg/l	4.01 µg/l
RIVER WYE U/S NANTY MINE	23/03/2026	51 µg/l	52 µg/l	2.85 µg/l	2.24 µg/l
RIVER WYE D/S NANTY MINE	23/03/2026	43.4 µg/l	45.1 µg/l	2.9 µg/l	2.19 µg/l

The data in Table 14 shows that concentrations generally decrease from upstream to downstream. This may suggest that Nanty is not a significant source of metals to the River Wye, however this needs to be confirmed with the results of the additional monthly monitoring for the remainder of 2026.

5.5. Source apportionment summary

This section of the report summarises the interpretation and source apportionment discussion presented in the earlier sections. Table 15 provides a tabulated summary of the average metal fluxes to summarise the following:

- Upper Wye catchment source apportionment. This is represented by the average metal fluxes recorded at monitoring station 50361 in the River Wye. As discussed in Section 5.2, this is the closest monitoring station downstream of the two waterbodies in the catchment associated with 'Red' abandoned mines (i.e. the main sources of mine water pollution). Table 15 also presents the percentage contribution of each of the two tributaries to the average metal flux recorded at monitoring station 50361. In this case, monitoring station 50361 represents 100% of the total metal flux.

- Mine water pollution sources along the two main impacted tributaries in the catchment: Afon Tarenig and River Wye above the confluence with the Afon Tarenig. Table 15 also presents the percentage contribution of each mine to the average metal flux recorded at the downstream point of the two main mine water-impacted tributaries. In this case, for the Afon Tarenig, monitoring station 50002 represents 100% of the total metal flux, whilst monitoring station 50001 represents 100% of the total metal flux for the River Wye above the confluence with the Afon Tarenig.

- Individual metals pollution sources from each of the following 'Red' mines: Plynlimon, Nantiago, Nantygwrdy, Dolminers, and Nanty. Table 15 also presents the percentage contribution of individual mine water pollution sources at each mine. The following monitoring stations represent 100% of the metal flux contributed from each mine: 5520094 (Plynlimon), 53077 (Nantygwrdy), and 53078 (Dolminers).

At Nantiago, monitoring station 53076 has been used to represent the average flux originating from the mine site. However, monitoring station 53070 has been used to apportion pollution sources at the Nantiago mine site as it is directly downstream.

Table 15: Summary of source apportionment on a catchment, tributary and individual mine basis

Apportionment category	**Narrative**	**Average zinc flux (kg/yr)**	**% zinc contribution**	**Average lead flux (kg/yr)**	**% lead contribution**	**Average cadmium flux (kg/yr)**	**% cadmium contribution**
Upper Wye total catchment source apportionment[6]	Recorded contribution from the Afon Tarenig tributary.	509 kg/yr	14%	66 kg/yr	20%	1.9 kg/yr	12%
Upper Wye total catchment source apportionment**Error! Bookmark not defined.**	Recorded contribution from the River Wye above the Afon Tarenig confluence.	1477 kg/yr	40%	162 kg/yr	50%	6.6 kg/yr	42%
Afon Tarenig tributary source apportionment[7].	The load from Plynlimon mine (monitoring station 5520094) contributes a greater total flux than the downstream location (monitoring station 50002) on the Afon Tarenig. Plynlimon contributes 539 kg/yr zinc, 190.5 kg/yr lead, and 2.1 kg/yr cadmium. The other mines within this waterbody are not contributing significantly to pollution.	-	-	-	-	-	-

[6] Monitoring station 50361 (River Wye above Afon Bidno) represents 100% of the metal flux.
[7] Monitoring station 50002 (Afon Tarenig, above the confluence with the River Wye) represents 100% of the metal flux.

Apportionment category	Narrative	Average zinc flux (kg/yr)	% zinc contribution	Average lead flux (kg/yr)	% lead contribution	Average cadmium flux (kg/yr)	% cadmium contribution
River Wye above confluence with Afon Tarenig source apportionment[8]	Recorded contribution from Nantiago mine.	383 kg/yr	37%	27.2 kg/yr	29%	1.8 kg/yr	40%
River Wye above confluence with Afon Tarenig source apportionmentError! Bookmark not defined.	Recorded contribution from Nantygwrdy mine.	676 kg/yr	65%	87 kg/yr	93%	3 kg/yr	64%
River Wye above confluence with Afon Tarenig source apportionmentError! Bookmark not defined.	Dolminers does not contribute to the increase downstream flux.	-	-	-	-	-	-
Source apportionment at Plynlimon mine.	Recorded contribution from diffuse pollution sources, upstream of fines and downstream of Plynlimon Adit.	91.6 - 129 kg/yr	17% - 26%	13.3 - 61 kg/yr	7% - 32%	0.4 - 0.5 kg/yr	19% - 26%
Source apportionment at Plynlimon mine.	Recorded contribution from Plynlimon Adit.	32 – 80 kg/yr	6% - 15%	32 – 80 kg/yr	17% - 42%	0.1 - 0.2 kg/yr	5% - 12%

[8] Monitoring station 53078 (River Wye, downstream of Dolminers) has been used to assess relative contributions from Nantiago, Nantygwrdy and Dolminers as it is the closest monitoring station downstream of all three mines.

Apportionment category	Narrative	Average zinc flux (kg/yr)	% zinc contribution	Average lead flux (kg/yr)	% lead contribution	Average cadmium flux (kg/yr)	% cadmium contribution
Source apportionment at Plynlimon mine.	Recorded contribution from diffuse pollution sources downstream of Plynlimon Adit (including fines tip).	370 kg/yr	69%	97 kg/yr	51%	1.45 kg/yr	68%
Source apportionment at Nantiago mine.	Recorded contribution from diffuse pollution sources between monitoring stations 53068 and 53069.	88 kg/yr	44%	7.4 kg/yr	43%	0.37 kg/yr	37%
Source apportionment at Nantiago mine.	Recorded contribution from Nantiago Deep Adit.	24 kg/yr	12%	2.3 kg/yr	13%	0.09 kg/yr	9%
Source apportionment at Nantiago mine.	Recorded contribution from diffuse pollution sources between monitoring stations 53069 and 53070.	88 kg/yr	44%	7.5 kg/yr	44%	0.55 kg/yr	54%
Source apportionment at Nantygwrdy mine.	Recorded contribution from Nant y Gwrdy stream. The stream includes the Nantygwrdy Deep Adit, which contributes a greater load than the stream itself[9].	226 kg/yr	33%	39 kg/yr	45%	0.8 kg/yr	27%

[9] Average metal loads from the Nantygwrdy Adit are equal to 335 kg/yr zinc, 65.2 kg/yr lead and 1.2 kg/yr cadmium. This is greater than the average loads recorded in the receiving Nant y gwrdy stream (monitoring station 53074).

Apportionment category	Narrative	Average zinc flux (kg/yr)	% zinc contribution	Average lead flux (kg/yr)	% lead contribution	Average cadmium flux (kg/yr)	% cadmium contribution
Source apportionment at Nantygwrdy mine.	Recorded contribution from diffuse pollution sources between 53076 (River Wye, upstream of the Nantygwrdy) and 53077 (River Wye, downstream of Nantygwrdy)[10].	450 kg/yr	67%	48.5 kg/yr	55%	2.2 kg/yr	73%
Nanty mine.	Recent NRW water quality data (Section 5.4.4) show that metal concentrations generally decrease in the River Wye from upstream to downstream of this mine. As a result, it is unlikely to be a significant source, however this needs to be confirmed upon completion of the remainder of the 2026 monitoring.	-	-	-	-	-	-

[10] Note, these loadings also include those from 5520088, a small flow across the yard at Nantygwrdy. Assuming a 1 L/s flow rate, this is likely to be contributing to 4% of the lead, 6% zinc, and 5% of the cadmium as part of source "diffuse pollution sources between 53076 and 53077".

5.6. Baseline polluted length

Table 16 presents the baseline polluted length of each waterbody and therefore the catchment. The kilometres (km) of polluted length have been determined based on the concentrations of bioavailable zinc and comparison with the appropriate EQS at each sample point. The polluted length has been measured from the furthest upstream sources to the furthest downstream point exceeding the EQS using the spatial measurement tool in ArcGIS. It has required some interpolation which is discussed below. The measured lengths include watercourses which do not form part of the WFDR reporting waterbody, for example the polluted sections of the Nant Iago and Nant y Gwrdy.

The measured polluted length does not include the unpolluted reaches of the waterbodies upstream of the abandoned metal mines, for example the Afon Tarenig above Plynlimon mine.

Specific consideration has been given to assessing the polluted length associated with waterbody GB109055042280, which is classified as being of ‘Good’ status in the 2024 WFDR classification. However, the WFDR status of this waterbody is based on data from monitoring station 50177 at the downstream end of the waterbody. Monitoring station 50006, in the upper part of this waterbody exceeds the EQS for bioavailable zinc (Table 11).

An assessment of zinc bioavailability at monitoring station 50177 indicates that the average bioavailable zinc concentration is 10 µg/l; 0.9 µg/l lower than the EQS. This average is based on data collected between 2012 and 2013, and 2016 to 2018. An overall average for bioavailable zinc at monitoring station 50006 is 16.4 µg/l.

Based on the average concentration, there is a 6.4 µg/l change in bioavailable zinc concentration between monitoring stations 50006 and 50177. These stations are both located within waterbody GB109055042280 as shown on Figure 7. There is 6.5 km of river between these two monitoring stations, and assuming a constant rate of dilution, this translates to a decrease in bioavailable zinc in the waterbody by 1 µg/l roughly every kilometre. From this, it can be assumed that the bioavailable zinc EQS point of failure (10.9 µg/l) is located approximately 1 km upstream of 50177. For calculating the total polluted length, this point has been taken to be the downstream limit of the polluted length. Although this assumption has been used to calculate the polluted length, it is acknowledged that there would be step changes in zinc concentration in the river system, as opposed to a constant rate of dilution. Most of the dilution is likely to be occurring downstream of tributaries, for example, at the Nant Gwynllyn confluence with the River Wye in Rhayader.

Table 16: Baseline polluted length (based on recorded zinc concentrations)

Waterbody	Kilometres of polluted river
GB109055042360: Wye – source to conf Afon Tarenig.	5.4
GB109055042350: Afon Tarenig – source to conf R Wye.	7.2
GB109055042340: Afon Bidno – source to conf R Wye.	0[11]
GB109055042330: Wye – conf Afon Tarenig to conf Afon Bidno.	7.2
GB109055042320: Wye – conf Afon Bidno to conf Afon Marteg.	13.8
GB109055042280: Wye – conf to conf Afon Marteg to conf Afon Elan.	7
Total	40.6

5.7. Pollution source summary

Table 17 provides a ranking of the top three metals pollution sources based on relative metal loading contributions in the Upper Wye catchment. The monitoring and analysis (Section 4 and 5) presents limitations in ranking other sources in the catchment. This is discussed in further detail in this section.

Table 17: Source ranking of the top three metal pollution sources from abandoned metal mines in the Upper Wye catchment

Source ranking	Source description	Annual metals load kg/yr	Justification
1	Nantygwrdy – Diffuse pollution arising from the old dressing floor, which has been reworked and repurposed as a motorsport development. This also includes the concentrated flow of metals (5520088).	450 kg/year zinc 50 kg/year lead 2.2 kg/year cadmium	This is the single largest source of zinc and cadmium in the Upper Wye catchment. 4% to 6% of the loadings above are from the small flow of water (5520088) across the yard.

[11] There is only one monitoring station along the Bidno, at the downstream point (confluence with the River Wye). There may be EQS failures upstream that are not captured by the monitoring data presented in this report.

Source ranking	Source description	Annual metals load kg/yr	Justification
2	Plynlimon – Diffuse pollution arising from extensive fine grained mining waste tips primarily on the eastern bank of the Afon Tarenig downgradient of Plynlimon Adit.	370 kg/yr of zinc 100 kg/yr of lead 1.45 kg/yr cadmium.	The largest source of lead in the Upper Wye catchment. The only significant source in the Afon Tarenig.
3	Nantygwrdy Adit – Point source, which discharges into the Nant y Gwrdy stream, which flows into the River Wye.	335 kg/yr of zinc 65 kg/yr lead 1.2 kg/yr cadmium.	-

Nantiago may contribute 383 kg/yr of zinc, 27 kg/yr of lead, and 1.8 kg/yr of cadmium, based on loadings at monitoring station 53076 (River Wye, upstream of the Nantygwrdy). This is generally less than the individual sources identified in Table 17. In addition, these loadings from Nantiago are not necessarily reflected in the loadings calculated at the immediate downstream point from Nantiago (53070), which indicates approximately half of this amount. Note from the discussion in Section 5.3.2 that this may be due to flow gauging issues at 53076, which may be overestimating the loading at this location. Alternatively, the lower than anticipated loadings at 53070 may also be attributable to the fact that all the pollution from Nantiago does not necessarily enter the Nant Iago, as evidenced by the tracer testing study (WSP, 2023).

It is evident that most metals pollution from Nantiago is related to the large tip complex, with point source discharges noted from the tips (Section 5.4.1). This in turn is likely to be influenced by the flow of water entering the open stope, which is known to issue from the spoil tips at the downstream side of the mine on the western bank below the Deep Adit, subsequently entering Nant Iago. It is also likely that the flow of the Nant Iago is scouring the base of the spoil tips which exist along its banks, further contributing to surface water pollution. A remedial solution at Nantiago which focussed on managing the flow of water into the open stope (i.e. a diversion) could feasibly reduce the point source and diffuse loading from the sources at this mine site. However, prioritising remedial action of the three sources in Table 17 would result in a greater reduction in overall metal loadings in the catchment, assuming they were dealt in their entirety.

At Plynlimon, whilst most of the loading originates downstream of Plynlimon Adit, this point source may contribute up to 160 kg/yr of total lead, cadmium and zinc (Table 15), making it the second greatest point source contributor in the catchment. However, there are numerous diffuse pollution sources in the catchment with a greater overall loading contribution than Plynlimon Adit. Plynlimon would benefit from an additional desk study to understand the mine in greater detail, and this forms part of this report's recommendations.

Average metal loadings indicate that Dolminers is not contributing to metal loading in the catchment. Compared to the other 'Red' sites in the catchment, this study indicates that it is not one of the main contributors and is therefore a lower priority for further investigation. The same is applicable to Nanty, although this will be confirmed upon completion of the remaining 2026 water quality monitoring.

6. Benefits of remediation

6.1. Background

The abandoned lead and zinc mines of the Upper Wye catchment are known to be the source of pollution causing 40 km of river across five waterbodies to exceed the Environmental Quality Standards (EQS) for zinc, lead and cadmium. At its maximum, the EQS is exceeded by factors of 68 for lead (Afon Tarenig, downstream of Plynlimon), 30 for cadmium and 32 for zinc (gauging station at Nant Iago); see Section 4.3. Downstream of the two main mine water impacted tributaries, the EQSs are generally exceeded by factors of 1.5, 2 and 3 respectively.

The Water Environment (Water Framework Directive) Regulations 2017 identify lead as a 'Priority substance' for which there is a duty to progressively reduce discharges; and cadmium as a 'Priority hazardous substance' for which there is a duty to cease or phase out emissions.

The Wye below the Afon Tarenig is a SAC and for it to achieve its objectives it is required to meet objectives which are in some cases more stringent than WFDR 'Good' status. In the case of chemicals including metals, the SAC cannot achieve favourable condition under the Common Standards Monitoring regime (JNCC, 2016) for protected sites without achieving the appropriate standards as per the EQSs.

Estimates of annual mass flux of metals from the Plynlimon, Nantiago, Nantygwrdy and Dolminers mines are as follows:

- Zinc: 2,430 kg.
- Cadmium: 7 kg.
- Lead: 324 kg.

Three abandoned mine sites have been definitively identified as requiring intervention to improve the environmental condition and potentially comply with the metals EQSs. These include Nantygwrdy, Plynlimon and Nantiago mines. A further mine, Nanty, has been identified as requiring further investigation to determine its contribution to pollution. Remedial works at these sites could significantly reduce metal loadings into the catchment including:

- Minimising surface water interactions with mine spoil.
- Minimising clean surface water entry into mine workings.
- Reducing spoil erosion and leaching.
- Treatment of mine water.

Due to the nature of any remedial works, it is not possible to accurately quantify the reduction in metals loading. Nevertheless, it will contribute to a significant improvement in water and ecological quality in 40 km of river.

In 2020, the WMMP commissioned site-specific qualitative benefits assessment for a small number of sites not including those on the Upper Wye. The conclusions of those assessments, which can be broadly applied to any catchment including the Wye, were:

> *"Utilising the information gathered, the assessment has determined that benefits would be most significant for the following impact categories:*
>
> - *Contribution to legislative objectives including the Well-being of Future Generations (Wales) Act 2015 and the Environment (Wales) Act 2016: the proposed scheme would enhance water quality in the area with benefits for local residents and visitors; and*
>
> - *Biodiversity and non-use: the scheme would be expected to significantly improve water quality and hence suitability of the aquatic habitat for plants, invertebrates and fish.*
>
> *Moderate benefits would be experienced for angling, with minor benefits for property values, informal recreation, abstraction, heritage, landscape and archaeology, and local benefits (covering use of the area as an educational resource)".*

The report did also identify some negative aspects of remediation, largely associated with the construction phase of the works:

> *"During the construction phase, there could be negative impacts in terms of noise, HGV movements and carbon released. There would additionally be temporary negative impacts for landscape during construction (with potential negative impacts for recreation and tourism as highlighted by the ecosystem services assessment)".*

A draft multi-criteria benefits assessment which considers several facets of environmental impact which would be improved by remediation of abandoned metal mines has identified the Upper Wye catchment to be the fifth highest priority for remediation in Wales (NRW 2025 – draft).

6.2. Alignment with the aims of Sustainable Management of Natural Resources (SMNR)

The evidence strongly indicates that remediation projects support the four aims of SMNR:

- Aim 1 (Natural resources safeguarded and enhanced): Remediation safeguards water resources by preventing ongoing contamination and enhances the quality of both water and soil. For example, by capping and vegetating spoil, the soil quality is improved, and water quality is enhanced downstream.

- Aim 2 (Resilient ecosystems): There is a direct contribution to ecosystem resilience. A river free from heavy metal stress has a much greater capacity to cope with other stresses, whether extreme weather or invasive species.
- Aim 3 (Healthy places for people, free from risks): Wales has communities historically shaped by mining; making those landscapes healthy and safe addresses a long-standing environmental risk. Remediation projects reduce risks on and off site allowing safer access and use of the environment. In doing so, they protect current generations and remove a burden from future ones, fulfilling the Well-being Act's preventative approach.
- Aim 4 (Regenerative economy, sustainable use of resources): A regenerative economy means not only cleaning up but creating new opportunities from it. The evidence of job creation, tourism, and improved land productivity all point to turning an old polluting mine into an asset. Pollution from abandoned mines can impact local economies with the implication that reducing the pollution can open the way for regeneration of those local economies. The heritage tourism potential (e.g. industrial heritage trails) is a sustainable land use that can continue indefinitely if well-managed, recycling the mining legacy into cultural capital. Skill development in remediation contributes to Wales's green economy growth. Collaboration with academia and industry spurs innovation that could be exported, potentially leading to Wales being a leader in this field.

6.3. Alignment with well-being goals

Potential remediation is also aligned the well-being goals, as follows:

- ***Prosperous Wales***: Remediation aligns well with long-term prosperity by mitigating constraints on economic activity and creating new ones (jobs, tourism).
- ***Resilient Wales***: Improvement in biodiversity, ecosystem resilience and ecosystem service restoration through a reduction in environmental risk.
- ***Healthier Wales***: Reduced pollution of water and land, potential and increased recreation (active lifestyles).
- ***More Equal Wales***: Remediation can contribute to reducing inequalities by improving conditions places where environmental quality is reduced and contributing to social and economic inequality.

- ***Cohesive Communities****:* While harder to measure, we discussed how involvement in remediation and enjoying cleaner local environment can bring people together. One suggestion is for NRW to include community volunteering or citizen science in monitoring remediation outcomes, which fosters involvement.
- ***Vibrant Culture and Thriving Welsh Language****:* Remediation projects in Welsh-speaking areas can incorporate bilingual interpretation, local history and Welsh placenames of features, thus actively promoting culture and language.
- ***Globally Responsible Wales****:* By cleaning up our own legacy pollution, Wales demonstrates leadership in environmental responsibility, contributing to global goals (e.g., the UN Sustainable Development Goals). It also means Wales is not exporting harm by reducing its contribution to marine pollution.

6.4. Alignment with NRW's well-being objectives

Reducing pollution from abandoned metal mines contributes to all three of NRW's well-being objectives, as follows:

- **Well-being objective 1: Nature is recovering**
    - Preventing water pollution from impacting protected sites through identifying and evaluating the key contributors (metals) and working with key sectors to act.
    - Scaling up nature-based solutions in rural areas to build connectivity between habitats, securing multiple benefits for nature and people through working with planners and developers to embed in developments.
    - Optimising opportunities for nature's recovery by embedding it in all NRW policies, strategies, plans, programmes and projects.
- **Well-being objective 2: Communities are resilient to climate change**
    - Maintaining, improving and restoring terrestrial and freshwater habitats to build ecosystem resilience and deliver societal benefits.
    - Mitigating the impacts of floods and droughts and improving water quality through identifying opportunities for integrated management of land and water at the catchment scale.
- **Well-being objective 3: Pollution is minimised**
    - Restoring water quality in catchments affected by the legacy of abandoned metal mines, through using our evidence and working collaboratively to identify priorities for action.

- Minimising pollution of land and water through collaborative working to stimulate positive action and build effective solutions.
- Minimising pollution in highly protected and designated waters through identifying the actions required of a range of sectors.
- Maintaining, improving and restoring terrestrial and freshwater habitats to build ecosystem resilience and deliver societal benefits.
- Building the capability and capacity of the Welsh workforce to support pollution minimisation through working with others to advocate for green skills and jobs.

6.5. Financial benefits

An assessment of financial benefits using National Water Environment Benefits data but using the methodology of the Natural Capital Approach forecast for a 40-year whole life benefit (not discounted) estimates benefits within the range £21.9 m to £31.5 m.

6.6. Conclusion

Remedial action of mine water pollution sources would translate to numerous benefits and would align with several strategic policy objectives. It may never be feasible for all 40 km of currently impacted river to be compliant with EQS for relevant metals (i.e. for those waterbodies to achieve ‘Good’ status), although remediation would contribute to a much-reduced polluted length. This is explored in greater detail in Section 7.

Mobilisation and transport of contaminated sediment into the wider downstream catchment, including onto agricultural land during flood events, will be reduced post remediation. This will reduce the risk to population health although the exact benefits of these elements are not monitored or quantified in relation to remediation. The benefits of a cleaner freshwater environment will be realised in the provision of ecosystem services and decreased inequalities.

Other pressures in the Wye catchment such as physical modifications, agricultural and sewage pollution are being addressed through other initiatives such as the Upper Wye Restoration Programme. These activities will be complemented by the improvement in water quality delivered by metal mine remediation.

The importance of the River Wye for biodiversity is reflected in its designation as SSSI and SAC. One significant feature for which the Wye SAC is designated is Atlantic Salmon. The species is noted to be in significant decline across Wales and measures to reduce pollution and restore habitat in its stronghold areas, such as the higher altitude tributaries of the Wye are proposed to increase resilience to the impacts of climate change.

Overall, the benefits of remediation and the resultant reduction in the discharged metals load to the Upper Wye from abandoned metal mines are significant.

7. Remedial action

7.1. Approach

Based on the evidence presented in this report, the principal sources of metals pollution from abandoned mines within the Upper Wye catchment have been identified. This section of the report explores the potential recommended remedial actions.

As presented in Section 2.7, all waterbodies except GB109055042280 (Wye – conf Afon Marteg to conf Afon Elan) do not achieve ‘Good’ status. Further analysis in Section 5.6 indicates that a significant length (7 km) of this waterbody exceeds the bioavailable zinc EQS.

The analysis in this report demonstrates that the metals pollution driving the EQS failures throughout the catchment is associated with abandoned metal mines located on the two most upstream waterbodies within the catchment. Treatment of the principal sources of pollution (Table 17) will contribute to betterment of the catchment and reduce the polluted length (Table 16), potentially returning some of the waterbodies to ‘Good’ WFDR status for metals with a corresponding recovery in ecological quality.

This section explores the impact pollution source remedial action would have on loading reduction in the catchment overall, and specifically for the two upstream waterbodies. This has been done by considering what loading reduction would be required for achieving compliance with the EQS at the downstream point of the Afon Tarenig (Section 7.2), River Wye above the Afon Tarenig (Section 7.3) and remaining catchment (Section 7.4), using zinc as an example as failures are ubiquitous across the catchment. Lead and cadmium loadings are also referenced for the two waterbodies.

7.2. Afon Tarenig

334 kg/yr of zinc (66% reduction) would need to be removed for the Afon Tarenig at monitoring location 50002 (downstream point of the Afon Tarenig above River Wye) to be compliant with the EQS of 12.9 µg/l. Similarly, 42 kg/yr of lead (64% reduction) and 0.8 kg/yr of cadmium (43% reduction) would need to be removed to achieve respective EQS values (1.2 µg/l and 0.08 µg/l).

Plynlimon mine is the key contributor to metals pollution in this waterbody.

Based on a review of the pollution sources at this mine (Section 5.4.3), it may be feasible to achieve the total required reduction in loading from interventions on the tips to the south of Plynlimon Adit. This source is contributing 370 kg/yr zinc, 100 kg/yr lead and 1.45 kg/yr of cadmium.

Therefore, a remedial solution which focused on spoil tip interventions in the south of Plynlimon mine could result in the Afon Tarenig achieving overall ‘Good’ WFDR status for lead, cadmium and zinc. Noting that this would require a high level of efficiency relating to the remediation, which may not be feasible, other sources at Plynlimon could also be targeted for remediation, including the adit.

Notably, the FWB report (Coal Authority, 2020) categorised four mines in the waterbody (Nant Nod, Plynlimon South, Hirgoed Ddu, and Fagwr Fraith) as ‘Amber’ sites, i.e. requiring further information. Given that the Afon Tarenig could achieve ‘Good’ WFDR status for metals by interventions at Plynlimon mine alone it is unlikely that these sites are significant sources of metals in the waterbody. These mines should therefore be recategorised as ‘Green’.

7.3. River Wye above Tarenig

Treatment of all known sources at Nantiago and Nantygwrdy could result in a loading reduction of 1059 kg/yr zinc, 114 kg/yr lead, and 4.8 kg/yr of cadmium. These include diffuse pollution at Nantygwrdy and the adit (two of the three principal sources, Table 17), and interventions preventing uncontrolled discharges and scouring of tips at Nantiago. This would likely comprise of a surface water diversion to bypass the open stope and scour protection and capping of the spoil tips along the Nant Iago.

1049 kg/yr zinc, 85 kg/yr lead, and 4 kg/yr cadmium removal is needed for the downstream monitoring station (53078) to achieve compliance of the metal EQS. This essentially means that all known sources at Nantygwrdy and Nantiago would need to be treated to 100% efficiency (i.e. full pollution removal) to achieve compliance. This may never be feasible.

The key conclusion is that remediation of mine water sources along this waterbody will reduce catchment metal loading, contribute to a reduced polluted length downstream, and will bring this waterbody closer to overall compliance.

7.4. Catchment wide

At monitoring location 50361 (River Wye above Afon Bidno), which is the closest downstream of both tributaries (Section 7.2 and 7.3), there would need to be a reduction in zinc load of 2800 kg/yr upstream for this point to be compliant. Similarly, 2600 kg/yr, 2300 kg/yr, and 1350 kg/yr of zinc would need to be removed upstream of the catchment to ensure that monitoring stations 50511, 50006 and 50004 were compliant respectively. These all represent monitoring points in the River Wye downstream of the main pollution sources.

The total zinc input from both main source tributaries is equivalent to 2000 kg/yr. This indicates that treatment of all known sources on these tributaries may not result in compliance at monitoring stations 50361, 50511 and 50006. However, there is uncertainty over the calculated flows in the lower catchment below the Tarenig confluence which may overestimate loadings in those waterbodies, as discussed in Section 5.2. As the two main impacted waterbodies are mainly responsible for the metal pollution downstream, achieving EQS compliance on them would inevitably achieve compliance in the downstream waterbodies.

7.5. Recommended interventions

Based on the discussion above, it may be prudent to prioritise a diffuse pollution remedial intervention at Plynlimon. This is because remedial action may lead to positive WFDR status change of the Tarenig waterbody, whilst tackling one of the major pollution sources in the catchment. This mine however needs to be understood in greater detail through undertaking desk study before remedial action; see report recommendations.

As it is difficult to quantify any WFDR status changes for other waterbodies, other remediation should target maximising the removal of the highest total metal flux in the catchment. This means prioritising the mine sources listed in Section 5.7.

Implementation of these remedial actions will reduce the total polluted length and move the point of WFDR failure further upstream. This should be assessed and supported by ongoing monitoring.

8. Conclusions and recommendations

8.1. Conclusions

This study provides a comprehensive overview of the Upper Wye catchment relating to metals pollution from abandoned metal mines. It has collated all available and relevant water quality information and flow data to identify key pollution sources within the catchment. Through this analysis it has presented recommendations for feasible remedial action. This study can be seen as the most up to date record of understanding of metals pollution associated with the Upper Wye catchment. The main conclusions from this study have been summarised below.

All waterbodies in the Upper Wye catchment, except for GB109055042280 (Wye – conf to conf Afon Marteg to conf Afon Elan), do not achieve 'Good' overall status under the WFDR. The WFDR classifications undertaken in 2018, 2021 and 2024 identify metals (lead, zinc and cadmium) as failing elements. The Reason for Not Achieving Good (RNAG) for the Afon Tarenig, and River Wye above the Afon Tarenig identifies abandoned non-coal mines as the source of that pollution. Pollution in the headwaters tributaries is in turn causing failures to achieve 'Good' WFDR status in downstream waterbodies in the Upper Wye catchment.

Metal loading estimates have been used to evaluate the cumulative impact of the Afon Tarenig and the River Wye above the Afon Tarenig on overall catchment pollution. Metal loadings from these tributaries have been calculated at the nearest monitoring point downstream of the confluence (50361). The data shows that both tributaries contribute most of the metal load at monitoring station 50361; 70% of the recorded lead (228 kg/yr), 54% cadmium (8.4 kg/yr), and 54% zinc (2000 kg/yr). The evidence presented in Section 5.2 suggests metal percentage contributions from both tributaries are likely to be higher than the available data shows. This is because the estimated flow rates used for loadings at monitoring station 50361 are considered to overestimate flow rates. This in turn overestimates the metal loadings at monitoring station 50361.

Plynlimon mine is the only significant contributor to metals pollution on the Afon Tarenig. This is demonstrated by the fact that loadings for all metals are higher in the Afon Tarenig immediately downstream of Plynlimon mine than at the WFDR compliance point for this waterbody which is located just upstream of the confluence with the River Wye.

Source apportionment on the River Wye above the Afon Tarenig waterbody is more complex due to there being three abandoned metal mines identified as significant sources in the FWB report (Coal Authority, 2020). Metal loadings data indicates that Nantygwrdy and Nantiago mines are contributing the highest loadings to the waterbody and causing the failure. Dolminers is not considered to be a significant contributor in the waterbody.

The analysis indicates that the three most significant metals pollution sources in the catchment are associated with:

- Diffuse pollution at Nantygwrdy mine old dressing floor (currently repurposed as a motorsports development), including a discrete discharge to the River Wye which rises on the mine surface and traverses the yard.
- Diffuse pollution at Plynlimon mine (downstream of Plynlimon Adit, primarily along the eastern bank of the Afon Tarenig).
- Point source contributions from the Nantygwrdy Adit (which discharges into the Nant y Gwrdy stream).

Pollution from Nantiago is difficult to quantify due to the complex configuration of mine discharges, as evidenced by the tracer testing study (WSP, 2023). Total loadings recorded immediately downstream of the mine in the Nant Iago and upstream of the Nantygwrdy in the River Wye were both lower than total loading contributions from Nantygwrdy. Metals pollution from Nantiago is primarily from diffuse sources, although it is likely that this in part is governed by the flow entering the open stope, which is known to influence mine water discharge at multiple locations, including issues from spoil tips.

Initial water quality monitoring data from Nanty suggests it is not a significant source of metals pollution to the River Wye. This needs to be confirmed once the 2026 monitoring has concluded.

The calculated polluted watercourse length of 40.6 km has been determined based on calculations of bioavailable zinc and comparison to the EQS. Notably, despite having an overall ‘Good’ WFDR classification status, GB109055042280 (Wye –conf Afon Marteg to conf Afon Elan) is polluted for a length of 7 km. The WFDR classification only considers the downstream compliance point, but there are exceedances of the zinc EQS at an upstream sample point. The polluted length of this waterbody was determined by calculating the difference in average concentration between both points, and assuming constant dilution and a linear decrease in concentration downstream to a point where zinc concentrations are compliant with the EQS.

This study evaluated possible remedial objectives based on quantified total loading reduction from pollution source interventions, and a consideration of whether that reduction would translate to compliance with the metals EQSs. Like other calculations presented in this study, this was not without its limitations due to flow estimation data leading to excessively high loadings downstream. The initial findings indicated that a diffuse intervention at Plynlimon mine (tips downstream of Plynlimon Adit) could lead to the Afon Tarenig achieving overall ‘Good’ WFDR status for metals by reducing lead, cadmium and zinc concentrations to a compliant level. It should also be noted that the waterbody also fails to achieve ‘Good’ WFDR status due to cypermethrin, which is not related to the abandoned mines.

As discussed in Section 7.3, removal of all sources at Nantygwrdy and Nantiago (i.e. 100% reduction in load) is required for the Wye above the Tarenig to achieve ‘Good’ WFDR status, which is unlikely to be feasible.

At a catchment level, quantification of the impact of remedial interventions in the headwaters on the downstream waterbodies is complicated by uncertainty in the flow data. However, if remedial interventions are implemented on the two upstream waterbodies, this will inevitably result in a reduction in metals concentrations downstream.

8.2. Recommendations for action

Based on the findings of this study, the following actions are recommended.

Investigative and assessment actions

- Plynlimon mine: Continued routine monitoring should be undertaken and the site should be subject to further detailed investigation and a desk study exercise comparable to those undertaken at the other 'Red' mines in the catchment.
- Nantygwrdy mine: A short-term, high resolution monitoring exercise should be instigated to further define the pollution sources and inform a scoping study for remedial options.
- Nant Iago mine: A short-term, high resolution monitoring exercise should be instigated to further define the pollution sources. The study should be repeated following surface water diversion works, and for a longer-term period.
- Nanty mine: Continuation of ongoing 2026 monitoring to confirm any surface water pollution impacts.
- Continued routine monitoring of the sites, sources and the catchment waterbodies to quantify the impacts of remedial interventions in terms of reduced metals loading and concentrations, and the reduction in impacted length. This includes flow gauging further downstream in the River Wye to better understand flows for metal loading calculations.
- Undertake a detailed desk-based assessment of landscape and heritage assets in the catchment area, to determine any considerations remediation should factor in for the safeguarding of these assets.
- Conduct an environmental and human health baseline assessment for the study area which will be considered for future remediation. This is to highlight opportunities and constraints that will then feed into project screening.

Categorisation actions

- Nant Nod, Plynlimon South, Hirgoed Ddu, and Fagwr Fraith mines were all categorised as 'Amber' sites by the FWB Report (Coal Authority, 2020). This study has concluded that they are not significant contributors to pollution in the Upper Wye catchment and as such should be assigned ‘Green’ status.

- Dolminers mine, initially categorised as a ‘Red’ site in FWB has been determined not to be a significant source of pollution and should be recategorised to ‘Green’.
- It is not yet possible to recategorise Nanty mine, despite initial data showing no pollution impacts. This will be undertaken once the 2026 monitoring has concluded. Nantygwrdy, Plynlimon and Nantiago remain as ‘Red’ mines.

Remedial actions

- Once appropriate investigative and site characterisation actions are complete, diffuse pollution interventions at Plynlimon mine should be prioritised. A single intervention at this significant source could lead to change in overall WFDR status of the Afon Tarenig waterbody.
- Reduction of pollution from the two most significant sources at Nantygwrdy mine: the Deep Adit and the spoils associated with the dressing floor.
- Surface water intervention to stop the watercourse entering the open stope at Nantiago. This should be followed by a monitoring programme to determine the impact of the intervention and allow a re-characterisation to determine if further intervention is required.

References

BGS. (1993). *BGS Map Sheet 179, Rhayader: 1:50,000 scale bedrock and drift.*

BGS. (2010). *Sheet 164 Llanidloes Bedrock and Superficial Deposits. British Geological Survey 1:50 000 geology series.*

Clwyd-Powys Archaeological Trust (CPAT). (2022). *Wye Valley Mine Sett, Llangurig, Powys - Heritage Impact Assessment.*

Coal Authority. (2019). *Metal Mine Failing Waterbodies Assessment – River System Appendix (Wye MC).*

Coal Authority. (2020). *Metal Mine Failing Waterbodies Assessment – Overview Report.*

Countryside Council for Wales. (2008). *Core Management Plan (Including Conservation Objectives) for River Wye Special Area of Conservation.*

Department for Environment, Food and Rural Affairs (Defra). (2015). The Water Framework Directive (Standards and Classification) Directions (England and Wales), 2015. Statutory Instruments 2015, No. 1623.

Department for Environment, Food and Rural Affairs (Defra). (2017). The Water Environment (Water Framework Directive) (England and Wales) Regulations 2017. Statutory Instruments 2017, No. 407.

Department for Environment, Food and Rural Affairs (Defra). (2019). *14637 WT0970 Ecological Impacts Contaminated Sediments FINAL.*

Environment Agency Wales. (2002). *Metal Mine Strategy for Wales.*

Hall, J. (2004). *The Plynlimon Mines, Ceredigion, Wales, U.K; an integrated evaluation from new surface geological mapping and contemporary subsurface documentation.*

Joint Nature Conservation Committee (JNCC). (2016). *Common Standards Monitoring Guidance for Rivers, ISSN 1743-8160.*

Jones, O. (1922). *Lead and zinc. The mining district of north Cardiganshire and west Montgomeryshire. Memoirs of the Geological Survey, Special Reports on the Mineral Resources of Great Britain, Vol. 20.*

Natural Resources Wales. (2021). *NTAXA_2021 waterbody classification csv.file.*

Natural Resources Wales. (2021). *WFD Investigation Desk Based Stage 2 On Invertebrates Failure on River Wye conf Afon Tarenig to conf Afon Bidno*.

Natural Resources Wales. (2022). *Welsh Part of the Severn River Basin Management Plan (2021 – 2027) Summary.*

Queen Mary University of London. (2016). *Applying the current version of MetTol index to NRW routine monitoring data.*

Smith, J. R. (1978). *The Mines of Montgomery and Radnorshire.*

UKTAG (2014). *UKTAG River & Lake Assessment Method Specific Pollutants (Metals). Metal Bioavailability Assessment Tool (M-BAT),* Water Framework Directive – United Kingdom Technical Advisory Group.

UKTAG (2023). *UKTAG River Assessment Method Benthic Invertebrate Fauna: Invertebrates (General Degradation): Whalley, Hawkes, Paisley & Trigg (WHPT) metric.* Stirling: Water Framework Directive – United Kingdom Technical Advisory Group.

WSP. (2021a). *Catchment Mines Assessment Wales 2020 - Nantiago.*

WSP. (2021b). *Catchment Mines Assessment Wales 2020 - Nantygwrdy.*

WSP. (2021c). *Catchment Mines Assessment Wales 2020 - Dolminers.*

WSP. (2021d). *Catchment Mines Assessment Wales 2020 - Nanty.*

WSP. (2023). *Nantiago Mine Tracer Test V2.*

Wye & Usk Foundation. (2021). *Fisheries Habitat Restoration Plan: Welsh Wye Catchment.*