Dalradian Gold Limited

Review of Discharge Criteria for Licence 068/12/2 at Curraghinalt, Gortin, County Tyrone, BT79 7SF

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1 Introduction

This technical report is prepared as supplementary information to support the application for a variation to Water Licence 068/12/2 for the existing discharge at Curraghinalt, Gortin, County Tyrone, BT79 7SF (Irish Gird Co-ords E257063.7, N386658.6) ('the Site').

The report:

- Reviews the existing Water Licence discharge criteria against standard methods for the assessment of discharge criteria for watercourses;
- Proposes variations to the Water Licence; and
- Predicts the impact of discharges from the site on receiving water quality, with comment on historical data for Curraghinalt Burn and Owenkillew River.

Water Licence 068/12/2 was granted in February 2014. The discharge consent compliance and monitoring criteria are outlined in Table 1-1. Proposed variations to the discharge consent are outlined in Table 1-2. All other criteria are proposed to remain the same. The discharge consent values are the required concentrations at the end-of-pipe from the water treatment plant at the Site.

Environmental Quality Standards (EQS) and water quality guideline values used in this report are outlined in Tables 1-3 and 1-4. These standards and guidelines are relevant to the Owenkillew River, which is considered as the receiving waters for the discharge.

Table 1-3 summarises EQS values that are defined through legislation, i.e., SR 351 The Water Framework Directive (Classification, Priority Substances and Shellfish Waters) Regulations (Northern Ireland) 2015. Table 1-4 identifies guideline values for water quality parameters for which there are no statutory EQS values (TSS) or where there are values identified in the recent British Standard related to rivers with freshwater pearl mussel populations (BS EN 16859:2017, Guidance standard on monitoring freshwater pearl mussel populations and their environment).

For this assessment values in Table 1-3 are used through this report apart from:

- The BS EN 16859:2017 value for BOD is used, as this value refers to annual average concentrations (rather than the SR351 standard that refers to the 90%le concentration). The use of an annual average is more consistent with EQS values for other parameters.
- A value of 25 mg/L is used for TSS in the absence of other standards. This is based on a standard in the old Freshwater Fish Directive (which has been replaced by the Water Framework Directive, which has no standard for TSS). The calculated and observed TSS concentrations in this assessment are also compared to a guideline value of 10 mg/L, which is presented in an unpublished report on water quality guidelines for watercourses with freshwater pearl mussels. Given the unpublished nature of the 10 mg/L value, the assessment is based on 25 mg/L, as this value was considered as an EQS when the Freshwater Fish Directive was active. However, the 10 mg/L guideline is referred to in Section 3, where calculations are made of the impact of discharges on the quality of water in the Owenkillew River. This approach is consistent to that used in the Environmental Impact Assessment for the Curraghinalt Project (see Curraghinalt Project Environmental Statement – Volume 3, Appendix C4 – Annex B).

Table 1-1: Discharge Consent 068/12/2 Limits

Parameter	Symbol	Unit	Discharge consent concentration
pH	pH	s.u.	6 – 9
Total suspended solids	TSS	mg/L	50
Biological oxygen demand	BOD	mg/L	10
Hardness	Hardness	mg/L	none[1]
Zinc (Total)	Zn_T	µg/L	33.8
Mercury (Diss)	Hg_D	µg/L	1.7
Cadmium (Diss)	Cd_D	µg/L	0.7
Iron (Diss)	Fe_D	mg/L	3.9
Copper (Diss)	Cu_D	µg/L	16.2
Chromium (Diss)	Cr_D	µg/L	(8.1)[2]
Nickel (Diss)	Ni_D	µg/L	(20)[2]
Arsenic (Diss)	As_D	µg/L	(50)[2]
Lead (Diss)	Pb_D	µg/L	(7.2)[2]
Visible Oil and Grease			No Trace

[1]The discharge consent requires hardness to be monitored, but there is no consent concentration or EQS value.
[2]Discharge consent has these parameters as 'informative' only, with Action Plans to be developed only if concentrations exceed the EQS. The values in brackets are non-bioavailable EQS values as outlined in Table 1-3.

Table 1-2: Proposed Variations to Discharge Consent

Parameter	Symbol	Unit	Discharge consent concentration	Comment
Zinc (Total)	Zn_T	µg/L	remove	Criteria to be removed and replaced with dissolved zinc criteria
Zinc (Diss)	Zn_D	µg/L	490 or 111*	New criteria, to be consistent with SR351[1] standard, see Table 1-3
Copper (Diss)	Cu_D	µg/L	16.2 or 0.33*	Updated to include bioavailable equivalent concentrations

*These EQS refer to bioavailable concentrations of substances.
[1]SR 351 The Water Framework Directive (Classification, Priority Substances and Shellfish Waters) Regulations (Northern Ireland) 2015

Table 1-3: EQS Values for Parameters Considered in this Memo

Parameter	Symbol	Unit	Average Annual (AA) EQS	Annual Max EQS	Source of EQS
pH	pH	s.u.	6.6 – 9.0	-	[1]SR 351
Zinc (Diss)	Zn_D	µg/L	10.9* or 23⁺	-	SR 351
Biological oxygen demand	BOD	mg/L	-	3 (90%ile)	SR 351
Mercury (Diss)	Hg_D	µg/L	0.07	-	SR 351
Cadmium (Diss)	Cd_D	µg/L	0.08	0.45	SR 351
Iron (Diss)	Fe_D	mg/L	1	-	SR 351
Copper (Diss)	Cu_D	µg/L	1* or 15⁺	-	SR 351
Chromium (Diss)	Cr_D	µg/L	3.4 (Cr VI) or 8.1 (total of Cr III and VI)	-	SR 351
Nickel (Diss)	Ni_D	µg/L	20 or 4*	34*	SR 351
Arsenic (Diss)	As_D	µg/L	50	-	SR 351
Lead (Diss)	Pb_D	µg/L	7.2 or 1.2*	-	SR 351

*These EQS refer to bioavailable concentrations of substances.

⁺EQS for non-bioavailable Zn and Cu back-calculated using M-BAT tool for EIA assessment.

[1]SR 351 The Water Framework Directive (Classification, Priority Substances and Shellfish Waters) Regulations (Northern Ireland) 2015

Table 1-4: Non-statutory Guideline Values for Parameters Considered in this Memo

Parameter	Symbol	Unit	Average Annual (AA)	Annual Max EQS	Source of guideline / Comment
pH	pH	s.u.	6.2 – 7.3	-	[1]BS EN 16859:2017
Total suspended solids	TSS	mg/L	25	-	[2]Freshwater Fish Directive ***Used as standard in this report for TSS***
Total suspended solids	TSS	mg/L	10		[3]Un-published report on Freshwater Pearl Mussels ***Results of assessment in this report reviewed against this value***
Biological oxygen demand	BOD	mg/L	1.4	-	BS EN 16859:2017 ***Used as standard in this report for BOD***

[1]BS EN 16859:2017 Guidance standard on monitoring freshwater pearl mussel populations and their environment

[2]Freshwater Fish Directive is no longer in operation having been superseded by Water Framework Directive. However, this contains published standard for TSS which is used here to be consistent with Environmental Impact Assessment submitted for Curraghinalt Mine

[3]Based on unpublished report indicating potential guideline value for protection of freshwater pearl mussels. Value is used here in the absence of other statutory guidelines or standards.

2 Development and Assessment of Discharge Criteria

Under the Water (Northern Ireland) Order 1999, the discharge of trade or sewage waste to any waterway requires the consent of the Department of Agriculture, Environment and Rural Affairs (DAERA). Discharge consents include conditions outlining the quality and quantity of waste discharges.

As noted on the DAERA website, the conditions are drawn up to ensure that the discharge can be absorbed by the receiving water without damaging the aquatic environment or breaching national or European Commission (EC) standards. Industrial consent applications are assessed by department technical staff who assess whether permitted discharges are at acceptable levels.

Therefore, the approach for receiving a discharge consent is as follows:

- Applicant undertakes assessments and calculations to propose discharge consent conditions;
- Application reviewed by regulators who decide on final values; this work is undertaken by NIEA WMU.

DAERA uses a 'Monte Carlo' modelling approach that is consistent with methods used by the England and Wales Environment Agency (EA) and the Scottish Environment Protection Agency (SEPA).

The EA has published details of its procedures on the use of a two-stage process in the development and assessment of any discharge criteria, based on initial screening tests and detailed modelling. The methods are outlined in:

- https://www.gov.uk/guidance/surface-water-pollution-risk-assessment-for-your-environmental-permit; and
- LIT 10419 'Modelling: surface water pollution risk assessment' (Environment Agency 2014).

In overview, the EA methods look to:

1. Prevent concentrations in receiving waters from exceeding an EQS;
2. Limit increase in background concentrations in receiving waters to less than 10% of EQS, for parameters where background concentrations are less than the EQS; and
3. Limit increase in background concentrations in receiving waters to less than 3% of EQS, for parameters where background concentrations are already more than the EQS.

The methodology contains four tests within the screening process and three further tests in the modelling stage, if required. These are outlined below and illustrated in Figure 2-1.

We undertake calculations in the following sections to estimate maximum discharge concentrations for the parameters outlined in Table 1, using the screening and modelling tests, following the approach used by the EA. Calculations are not undertaken for:

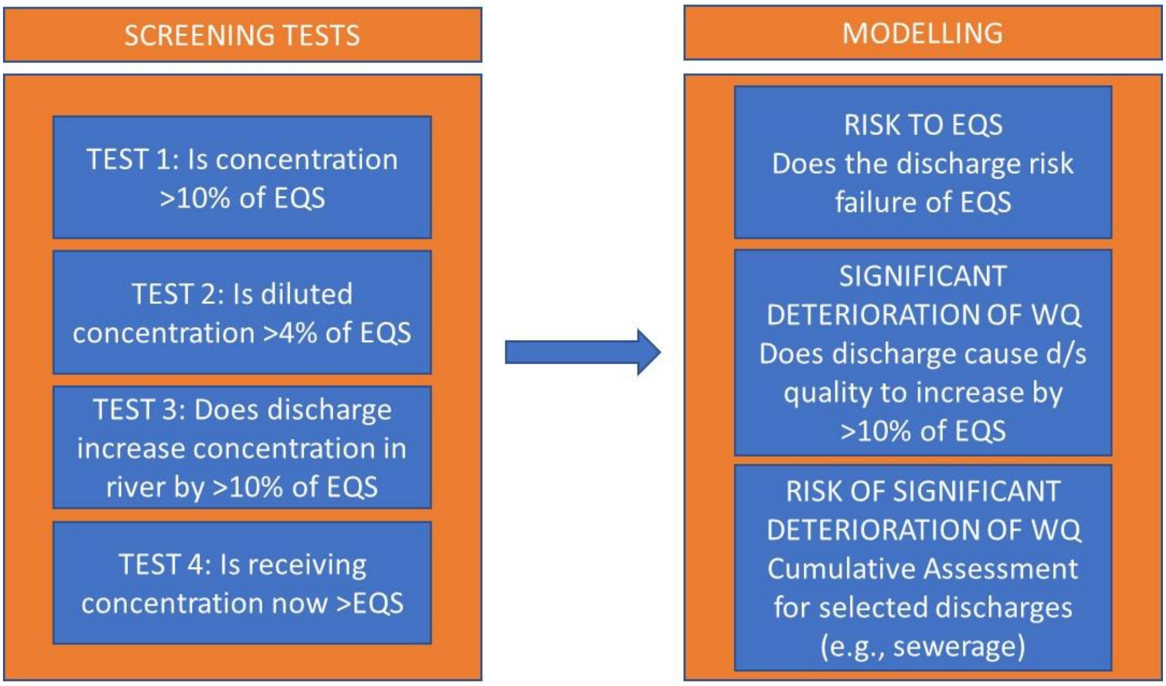
- pH, as simple dilution calculations are not appropriate for the assessment of pH
- Hardness as there is no consented discharge concentration
- Total Zinc, as it is to be replaced by a consented concentration for Dissolved Zinc
- Oil and Grease, as the consent is non-numeric, being 'No Trace'

The discharge from the Site is to the Curraghinalt Burn, which is a small tributary of the Owenkillew River. The Owenkillew River is part of the Owenkillew River Special Area of Conservation (SAC). Calculations of the impact on discharges from the Site on water quality in the Owenkillew River are the focus of this assessment, given the sensitivity of the watercourse. The Curraghinalt Burn is a minor watercourse with limited ecological value (based on ecological baseline assessment in the Environmental Impact Assessment completed for the Curraghinalt Mine Project) and which has no freshwater Pearl Mussels.

Although the Curraghinalt Burn will provide some dilution of the effluent, this is not taken into account in these calculations, which assume that the discharge from the Site is direct to the Owenkillew River. This is a more conservative assessment (no dilution in Curraghinalt Burn) and provides a transparent and robust assessment, without the introduction of another step in the calculations.

The input data used in the calculations are summarised in Appendix 1 (for flow) and Appendix 2 (for water quality).

Figure 2-1. Schematic of the Environment Agency Process for Discharge Consents



The methods outlined in Figure 2-1 are normally applied against discharge criteria proposed by an applicant. However, in this case we undertake a series of "backwards" calculations with the aim of calculating the lowest permitted concentration produced by each method. These values are then compared to the existing discharge criteria outlined in Table 1-1 and the proposed dissolved zinc concentration in Table 1-2.

2.1 Input Data

The key input data for the calculations are:

- Water quality standards or EQS;
- Flow data for discharge and receiving waters; and
- Background water quality in receiving waters.

The water quality standards used in the calculations are outlined in Table 1-1. The flow data used for the discharge and receiving waters is outlined in Appendix 1, and the water quality data used for the Owenkillew River is summarised in Appendix 2.

2.2 Screening tests

The EA Screening tests are shown in Figure 2-1. Tests 1 and 2 are initial screening tests undertaken for discharges where there is limited or no information on flows and water quality in the receiving environment. As there is detailed information on the Owenkillew flows and water quality these initial tests are unnecessary and the assessment therefore focusses on Tests 3 and 4. Under the EA guidance, discharge criteria need to pass a minimum of Tests 3 and 4 to be compliant.

2.2.1 Screening Tests 3 and 4

Test 3 involves dilution calculations in the receiving waters, considering both flow and background concentrations (BC) in the Owenkillew River. Test 3 is passed if the concentration in the receiving water is increased by less than 10% of EQS.

The maximum allowable discharge concentrations required to pass Test 3 are shown in Table 2-1. These concentrations increase the background concentrations in the receiving water by the maximum allowable 10% of the EQS.

Table 2-1: TEST 3. Does discharge increase parameter concentration in receiving water by >10% of EQS?

Parameter	Unit	Max discharge concentration	Max diluted concentration	Average BC in Owenkillew + 10% EQS = max PEC	AA-EQS
TSS[1]	mg/L	836	2.5	6.73 + 2.5 = 9.23	25
BOD	mg/L	46.8	0.14	1.12 + 0.14 = 1.26	1.4
Zn_D	µg/L	364* or 769	1.09* or 2.3	0.822* + 1.09* = 1.9* 3.55 + 2.3 = 5.85	10.9* or 23⁺
Hg_D	µg/L	2.3	0.007	0.005 + 0.007 = 0.012	0.07
Cd_D	µg/L	2.7	0.008	0.028 + 0.008 = 0.036	0.08
Fe_D	mg/L	33.4	0.10	0.87 + 0.1 = 0.97	1
Cu_D	µg/L	33.4*	0.10*	0.04* + 0.1* = 0.14*	1*
Cr_D	µg/L	114	0.34	0.64 + 0.34 = 0.98	3.4 (CrVI)
Ni_D	µg/L	134*	0.40*	0.099* + 0.4* = 0.50*	4* or 20
As_D	µg/L	1672	5.0	1.26 + 5 = 6.26	50
Pb_D	µg/L	241	0.72	0.45 + 0.72 = 1.17	1.2* or 7.2

*These EQS refer to bioavailable concentrations and percentages based on bioavailable EQS.
⁺EQS for non-bioavailable Zn back-calculated using M-BAT tool.
[1]Using an AA-EQS for TSS of only 10 mg/L results in a maximum discharge concentration of 334 mg/L.

Test 4 checks whether the predicted concentration in the receiving water in Test 3 is greater than the EQS. This checks whether the increase in background concentration from the addition of the discharge takes the resulting parameter concentration above the EQS.

The maximum allowable discharge concentrations required to pass Test 3 are used for this assessment. Test 4 therefore checks whether the maximum allowable concentrations calculated from Test 3 are greater than the EQS. As seen in Table 2-2 below, all maximum allowable discharge concentrations from Test 3 also pass Test 4.

Table 2-2: TEST 4. Is parameter concentration in receiving river now > EQS?

Parameter	Unit	Max discharge concentration from Test 3	Predicted concentration in receiving water	AA-EQS	Pass or Fail
TSS	mg/L	836	9.23	25	Pass
BOD	mg/L	46.8	1.26	1.4	Pass
Zn_D	µg/L	364* or 769	1.9* 5.85	10.9* or 23+	Pass
Hg_D	µg/L	2.3	0.0124	0.07	Pass
Cd_D	µg/L	2.7	0.036	0.08	Pass
Fe_D	mg/L	33.4	0.97	1	Pass
Cu_D	µg/L	33.4*	0.14*	1*	Pass
Cr_D	µg/L	114	0.98	3.4 (CrVI) or 8.1 (total of Cr III and VI)	Pass
Ni_D	µg/L	134*	0.50*	4* or 20	Pass
As_D	µg/L	1672	6.26	50	Pass
Pb_D	µg/L	241	1.17	1.2* or 7.2	Pass

*These EQS and discharge consent concentrations refer to bioavailable concentration.
+EQS for non-bioavailable Zn back-calculated using M-BAT tool.

The maximum discharge concentrations allowable under Tests 3 and 4 are compared to the existing and proposed discharge criteria in Table 2-3. The proposed discharge criteria would all pass the screening tests. No further modelling would normally be required. But to ensure a robust and transparent process, Monte Carlo modelling assessments have been carried out and the results are provided in the following section.

Table 2-3: Summary of Screening Tests

Parameter	Unit	Max discharge concentration	Discharge consent concentration	Pass or Fail Screening Test
TSS	mg/L	836	50	Pass
BOD	mg/L	46.8	10	Pass
Zn_D*	µg/L	364*	111*	Pass
Zn_D	µg/L	769	490	Pass
Hg_D	µg/L	2.3	1.7	Pass
Cd_D	µg/L	2.7	0.7	Pass
Fe_D	mg/L	33.4	3.9	Pass
Cu_D	µg/L	33.4*	16.2 or 0.33*	Pass
Cr_D	µg/L	114	(8.1)	Pass
Ni_D	µg/L	134*	(20)	Pass
As_D	µg/L	1672	(50)	Pass
Pb_D	µg/L	241	(7.2)	Pass

*These refer to bioavailable concentrations.

2.3 Monte Carlo Modelling Assessment

The Monte Carlo modelling methods are outlined in LIT 10419 ‘Modelling surface water pollution risk assessment’. The calculations are undertaken in “backwards” mode to calculate the maximum discharge criteria that will comply with the Monte Carlo methodology.

The first stage of the assessment involves the preparation of input data, including water quality and flow data. A summary of the input data is presented in Appendices 1 and 2.

The ‘Monte Carlo’ RQP modelling software available from UK regulators is then used to “backwards” calculate the discharge quality needed to achieve a target river water quality downstream (i.e., increasing the mean background concentration in the receiving water by <10% of the EQS).

As this approach calculates the permittable discharge concentrations, the required discharge quality input to the model is the output variable. However, an estimate of the likely standard deviation of the discharge concentrations is required. The EA recommends starting with the mean and standard deviation of the current discharge quality. Following this, the measured mean and standard deviation of the treated discharge is used, as measured at sampling location DCS2 (see Section 3.4). These values are used as a starting point for the calculation, and as such only the ratio of the mean to standard deviation is important. The exact values used in the model do not affect the results of the Monte Carlo calculations.

Outputs from the Monte Carlo software “backwards” modelling for each parameter are shown in Figures 2-2 to 2-13, with a summary in Table 2-4. These calculations provide a more accurate estimate of allowable discharges that would comply with the EQS values and these concentrations are lower than those calculated in the Screening tests above.

Table 2-4: Results of Monte Carlo “Backwards” Modelling

Parameter	Unit	EQS	Mean target downstream river quality[1]	Mean allowable discharge concentration	Consented Concentration	Consent pass or fail
TSS	mg/L	25	9.23	579.58	50	Pass
BOD	mg/L	1.4	1.26	34.83	10	Pass
Zn_D*	µg/L	10.9*	1.9*	246.26*	111*	Pass
Zn_D	µg/L	23⁺	5.85	548.32	490	Pass
Hg_D	µg/L	0.07	0.0124	1.77	1.7	Pass
Cd_D	µg/L	0.08	0.036	0.83	0.7	Pass
Fe_D	mg/L	1	0.97	23.65	3.9	Pass
Cu_D*	µg/L	1*	0.14*	23.89*	0.33*	Pass
Cr_D	µg/L	3.4 or 8.1	0.98	64.34	(8.1)	Pass
Ni_D	µg/L	4* or 20	0.50*	96.01*	(20)	Pass
As_D	µg/L	50	6.26	1189.9	(50)	Pass
Pb_D	µg/L	1.2* or 7.2	1.17	169.27	(7.2)	Pass

[1]Mean target downstream river quality calculated as in increase in the background concentration in the Owenkillew River by the maximum allowable 10% of the EQS.
*These EQS refer to bioavailable concentrations and discharges based on bioavailable EQS.
⁺EQS for non-bioavailable Zn and Cu back-calculated using M-BAT tool.

Parameter concentrations in the discharge consent are also provided in Table 2-4 for comparison. For all parameters the discharge consent concentrations are lower than the calculated maximum mean allowable concentrations. For most parameters, the discharge criteria are significantly lower than the calculated concentrations.

Figure 2-2. Monte Carlo "Backwards" Calculation: TSS (in mg/L)

Name of discharge	Curraghinalt Mine Water Treatment Plant Discharge
Name of river	Owenkillew River
Name of determinand	TSS (mg/L)

UPSTREAM RIVER DATA		DISCHARGE DATA	
Mean flow	3000	Mean flow	9
95% exceedence flow	800	Standard deviation of flow	2.97
Mean quality	6.73	Mean quality	9.75
Standard deviation of river quality	6.46	Standard deviation of quality	7.42
90-percentile	13.67	... or 95-percentile	23.59

RIVER DOWNSTREAM OF DISCHARGE		DISCHARGE QUALITY NEEDED	
Mean quality	9.23	Mean quality	579.58
Standard deviation of quality	7.30	Standard deviation of quality	417.32
90-percentile quality	16.86	95-percentile quality	1385.8
95-percentile quality	28.38	99-percentile quality	2113.8
99-percentile quality	35.46	99.5-percentile quality	2370.0
Quality target (Mean)	9.23		

Figure 2-3. Monte Carlo "Backwards" Calculation: BOD (in mg/L)

Name of discharge	Curraghinalt Mine Water Treatment Plant Discharge
Name of river	Owenkillew River
Name of determinand	BOD (mg/L)

UPSTREAM RIVER DATA		DISCHARGE DATA	
Mean flow	3000	Mean flow	9
95% exceedence flow	800	Standard deviation of flow	2.97
Mean quality	1.12	Mean quality	0.99
Standard deviation of river quality	0.92	Standard deviation of quality	0.74
90-percentile	2.17	... or 95-percentile	2.37

RIVER DOWNSTREAM OF DISCHARGE		DISCHARGE QUALITY NEEDED	
Mean quality	1.26	Mean quality	34.83
Standard deviation of quality	0.93	Standard deviation of quality	24.62
90-percentile quality	3.06	95-percentile quality	82.41
95-percentile quality	3.15	99-percentile quality	124.85
99-percentile quality	3.36	99.5-percentile quality	139.72
Quality target (Mean)	1.26		

Figure 2-4. Monte Carlo "Backwards" Calculation: Bioavailable Zn (in µg/L)

Name of discharge	Curraghinalt Mine Water Treatment Plant Discharge
Name of river	Owenkillew River
Name of determinand	Zn* (µg/L)

UPSTREAM RIVER DATA		DISCHARGE DATA	
Mean flow	3000	Mean flow	9
95% exceedence flow	800	Standard deviation of flow	2.97
Mean quality	0.87	Mean quality	0.28
Standard deviation of river quality	0.39	Standard deviation of quality	0.37
90-percentile	1.37	... or 95-percentile	0.88

RIVER DOWNSTREAM OF DISCHARGE		DISCHARGE QUALITY NEEDED	
Mean quality	1.90	Mean quality	246.26
Standard deviation of quality	1.49	Standard deviation of quality	285.73
90-percentile quality	3.38	95-percentile quality	769.01
95-percentile quality	4.31	99-percentile quality	1436.3
99-percentile quality	7.53	99.5-percentile quality	1701.2
Quality target (Mean)	1.90		

Figure 2-5. Monte Carlo "Backwards" Calculation: Non-bioavailable Zn (in µg/L)

Name of discharge	Curraghinalt Mine Water Treatment Plant Discharge
Name of river	Owenkillew River
Name of determinand	Zn (µg/L)

UPSTREAM RIVER DATA		DISCHARGE DATA	
Mean flow	3000	Mean flow	9
95% exceedence flow	800	Standard deviation of flow	2.97
Mean quality	3.55	Mean quality	12.88
Standard deviation of river quality	2.61	Standard deviation of quality	11.08
90-percentile	6.64	... or 95-percentile	33.21

RIVER DOWNSTREAM OF DISCHARGE		DISCHARGE QUALITY NEEDED	
Mean quality	5.85	Mean quality	548.32
Standard deviation of quality	3.56	Standard deviation of quality	441.42
90-percentile quality	10.19	95-percentile quality	1397.5
95-percentile quality	12.47	99-percentile quality	2224.2
99-percentile quality	17.82	99.5-percentile quality	2522.6
Quality target (Mean)	5.85		

Figure 2-6. Monte Carlo "Backwards" Calculation: Hg (note values are in ng/L)

Name of discharge	Curraghinalt Mine Water Treatment Plant Discharge
Name of river	Owenkillew River
Name of determinand	Hg (ng/L)

UPSTREAM RIVER DATA		DISCHARGE DATA	
Mean flow	3000	Mean flow	9
95% exceedence flow	800	Standard deviation of flow	2.97
Mean quality	5.00	Mean quality	230
Standard deviation of river quality	0.00	Standard deviation of quality	600
90-percentile	5.00	... or 95-percentile	870.07

RIVER DOWNSTREAM OF DISCHARGE		DISCHARGE QUALITY NEEDED	
Mean quality	12.40	Mean quality	1766.3
Standard deviation of quality	16.37	Standard deviation of quality	3388.3
90-percentile quality	22.52	95-percentile quality	6848.8
95-percentile quality	33.93	99-percentile quality	16764.0
99-percentile quality	73.83	99.5-percentile quality	21365.9
Quality target (Mean)	12.40		

Figure 2-7. Monte Carlo "Backwards" Calculation: Cd (in µg/L)

Name of discharge	Curraghinalt Mine Water Treatment Plant Discharge
Name of river	Owenkillew River
Name of determinand	Cd (µg/L)

UPSTREAM RIVER DATA		DISCHARGE DATA	
Mean flow	3000	Mean flow	9
95% exceedence flow	800	Standard deviation of flow	2.97
Mean quality	0.03	Mean quality	0.19
Standard deviation of river quality	0.02	Standard deviation of quality	0.12
90-percentile	0.06	... or 95-percentile	0.42

RIVER DOWNSTREAM OF DISCHARGE		DISCHARGE QUALITY NEEDED	
Mean quality	0.04	Mean quality	0.83
Standard deviation of quality	0.03	Standard deviation of quality	0.51
90-percentile quality	0.08	95-percentile quality	1.81
95-percentile quality	0.09	99-percentile quality	2.60
99-percentile quality	0.15	99.5-percentile quality	2.88
Quality target (Mean)	0.04		

Figure 2-8. Monte Carlo "Backwards" Calculation: Fe (in mg/L)

Name of discharge	Curraghinalt Mine Water Treatment Plant Discharge
Name of river	Owenkillew River
Name of determinand	Fe (µg/L)

UPSTREAM RIVER DATA		DISCHARGE DATA	
Mean flow	3000	Mean flow	9
95% exceedence flow	800	Standard deviation of flow	2.97
Mean quality	0.87	Mean quality	0.28
Standard deviation of river quality	0.39	Standard deviation of quality	0.37
90-percentile	1.37	... or 95-percentile	0.88

RIVER DOWNSTREAM OF DISCHARGE		DISCHARGE QUALITY NEEDED	
Mean quality	0.97	Mean quality	23.65
Standard deviation of quality	0.41	Standard deviation of quality	27.44
90-percentile quality	1.50	95-percentile quality	73.86
95-percentile quality	1.78	99-percentile quality	137.95
99-percentile quality	2.35	99.5-percentile quality	163.40
Quality target (Mean)	0.97		

Figure 2-9. Monte Carlo "Backwards" Calculation: Bioavailable Cu (in µg/L)

Name of discharge	Curraghinalt Mine Water Treatment Plant Discharge
Name of river	Owenkillew River
Name of determinand	Cu (µg/L)

UPSTREAM RIVER DATA		DISCHARGE DATA	
Mean flow	3000	Mean flow	9
95% exceedence flow	800	Standard deviation of flow	2.97
Mean quality	0.04	Mean quality	3.13
Standard deviation of river quality	0.02	Standard deviation of quality	2.52
90-percentile	0.07	... or 95-percentile	7.80

RIVER DOWNSTREAM OF DISCHARGE		DISCHARGE QUALITY NEEDED	
Mean quality	0.14	Mean quality	23.89
Standard deviation of quality	0.11	Standard deviation of quality	18.12
90-percentile quality	0.27	95-percentile quality	58.84
95-percentile quality	0.33	99-percentile quality	91.51
99-percentile quality	0.54	99.5-percentile quality	103.14
Quality target (Mean)	0.14		

Figure 2-10. Monte Carlo "Backwards" Calculation: Cr (in µg/L)

Name of discharge	Curraghinalt Mine Water Treatment Plant Discharge
Name of river	Owenkillew River
Name of determinand	Cr (µg/L)

UPSTREAM RIVER DATA		DISCHARGE DATA	
Mean flow	3000	Mean flow	9
95% exceedence flow	800	Standard deviation of flow	2.97
Mean quality	0.64	Mean quality	0.76
Standard deviation of river quality	1.22	Standard deviation of quality	1.03
90-percentile	1.45	... or 95-percentile	2.42

RIVER DOWNSTREAM OF DISCHARGE		DISCHARGE QUALITY NEEDED	
Mean quality	0.98	Mean quality	64.34
Standard deviation of quality	1.60	Standard deviation of quality	76.66
90-percentile quality	1.83	95-percentile quality	203.71
95-percentile quality	2.51	99-percentile quality	385.40
99-percentile quality	10.18	99.5-percentile quality	458.08
Quality target (Mean)	0.98		

Figure 2-11. Monte Carlo "Backwards" Calculation: Bioavailable Ni (in µg/L)

Name of discharge	Curraghinalt Mine Water Treatment Plant Discharge
Name of river	Owenkillew River
Name of determinand	Ni (µg/L)

UPSTREAM RIVER DATA		DISCHARGE DATA	
Mean flow	3000	Mean flow	9
95% exceedence flow	800	Standard deviation of flow	2.97
Mean quality	0.10	Mean quality	4.65
Standard deviation of river quality	0.09	Standard deviation of quality	2.44
90-percentile	0.20	... or 95-percentile	9.27

RIVER DOWNSTREAM OF DISCHARGE		DISCHARGE QUALITY NEEDED	
Mean quality	0.50	Mean quality	96.01
Standard deviation of quality	0.34	Standard deviation of quality	48.72
90-percentile quality	0.96	95-percentile quality	189.35
95-percentile quality	1.14	99-percentile quality	257.69
99-percentile quality	1.65	99.5-percentile quality	280.13
Quality target (Mean)	0.50		

Figure 2-12. Monte Carlo "Backwards" Calculation: As (in µg/L)

Name of discharge	Curraghinalt Mine Water Treatment Plant Discharge
Name of river	Owenkillew River
Name of determinand	As (µg/L)

UPSTREAM RIVER DATA		DISCHARGE DATA	
Mean flow	3000	Mean flow	9
95% exceedence flow	800	Standard deviation of flow	2.97
Mean quality	1.26	Mean quality	2.63
Standard deviation of river quality	1.19	Standard deviation of quality	3.14
90-percentile	2.55	... or 95-percentile	7.94

RIVER DOWNSTREAM OF DISCHARGE		DISCHARGE QUALITY NEEDED	
Mean quality	6.26	Mean quality	1189.9
Standard deviation of quality	6.75	Standard deviation of quality	1275.8
90-percentile quality	13.09	95-percentile quality	3562.7
95-percentile quality	18.15	99-percentile quality	6410.8
99-percentile quality	30.22	99.5-percentile quality	7517.1
Quality target (Mean)	6.26		

Figure 2-13. Monte Carlo "Backwards" Calculation: Pb (in µg/L)

Name of discharge	Curraghinalt Mine Water Treatment Plant Discharge
Name of river	Owenkillew River
Name of determinand	Pb (µg/L)

UPSTREAM RIVER DATA		DISCHARGE DATA	
Mean flow	3000	Mean flow	9
95% exceedence flow	800	Standard deviation of flow	2.97
Mean quality	0.45	Mean quality	1.31
Standard deviation of river quality	0.55	Standard deviation of quality	1.47
90-percentile	0.97	... or 95-percentile	3.85

RIVER DOWNSTREAM OF DISCHARGE		DISCHARGE QUALITY NEEDED	
Mean quality	1.17	Mean quality	169.27
Standard deviation of quality	1.11	Standard deviation of quality	172.47
90-percentile quality	2.60	95-percentile quality	492.88
95-percentile quality	3.43	99-percentile quality	866.54
99-percentile quality	5.44	99.5-percentile quality	1009.7
Quality target (Mean)	1.17		

2.4 Summary

Assessments are made using standard methods to calculate appropriate discharge criteria for the Site. Based on standard assessment methods all consented discharge values pass the standard tests to show no significant impact on the receiving waters. Proposed discharge criteria for dissolved zinc and bioavailable copper are also shown to pass the standard tests.

3 Impact of Discharges on Receiving Waters

The existing discharge concentrations and proposed amendments to the Water Licence were predicted (Section 2.3) to result in no significant impact on the receiving waters. In this chapter, further calculations are undertaken to model the impact of discharges from the site on the background water quality in the Owenkillew River. This information will assist DAERA in the carrying out its Habitats Regulation Assessment. The following methods are used:

- The 'Monte Carlo' RQP modelling software;
- Assessment of the risk of non-compliance calculations within the RQP software; and
- Observed water quality data from the Curraghinalt Burn and Owenkillew River from period of operation of the water treatment plant.

3.1 "Forwards" Modelling to Assess Impact on Owenkillew River

The 'Monte Carlo' RQP modelling software used to "backwards" calculate maximum discharge quality in Section 2.3 of this report can also be used to "forwards" calculate the impact that a known discharge quality will have on the receiving waters.

In this section, we calculate the effects on the receiving waters in two ways:

1. Assuming discharge concentrations are consistent with the maximum allowable concentration under the discharge consent and at the maximum flows from Appendix 1; and
2. Assuming discharge concentrations based on a review of historical data (see Section 3.3.2), assuming observed discharge flow values outlined in Appendix 1.

The inputs are outlined in Table 3-1.

Table 3-1: Inputs to "Forwards" Monte Carlo Modelling

Parameter	Unit	Conservative Calculation[1]			Calculation Based on Observed Data		
		Average	Standard Deviation	Average Flow (L/s)	Average	Standard Deviation	Average Flow (L/s)
TSS	mg/L	50	0	9	5.6	2.1	3.6
BOD	mg/L	10	0	9	1.0	0.8	3.6
Zn_D*	µg/L	111*	0	9	No data[2]	No data[2]	3.6
Zn_D	µg/L	490+	0	9	12.9	11.1	3.6
Hg_D	µg/L	1.7	0	9	0.23	0.15	3.6
Cd_D	µg/L	0.7	0	9	0.05	0.10	3.6
Fe_D	mg/L	3.9	0	9	0.33	0.41	3.6
Cu_D*	µg/L	0.33*	0	9	No data[2]	No data[2]	3.6
Cu_D	µg/L	16.2	0	9	1.53	0.42	3.6
Cr_D	µg/L	8.1	0	9	0.32	0.42	3.6
Ni_D	µg/L	20	0	9	4.1	1.4	3.6
As_D	µg/L	50	0	9	1.72	1.66	3.6
Pb_D	µg/L	7.2	0	9	0.61	1.30	3.6

[1]Conservative calculations assume a constant discharge concentration at the consent limit (i.e., the standard deviation is set to zero).
[2]Insufficient parameters in discharge monitoring data to allow explicit calculation of bioavailable concentrations. Concentrations of dissolved organic carbon, dissolved calcium and pH are required to calculate bioavailable concentrations. Dissolved organic carbon and calcium are not currently measured within the suite of parameters analysed for discharge concentrations. These parameters have not been required to date. The addition of these parameters is recommended in the conclusions of this report for future monitoring.
*These refer to bioavailable concentrations.

The "forwards" calculations determine if the discharge could cause the receiving water quality to deteriorate by more than 10% of the EQS. The observed mean upstream quality is compared to the calculated downstream quality for parameters with an Annual Average (AA) EQS value. Where the substance has only a maximum concentration EQS (or 95%ile), the predicted and observed 95%ile concentrations are compared. If the calculated downstream concentration is higher than the upstream concentration plus 10% of the EQS, the substance would be considered as a significant discharge.

As for inputs and as per guidelines:

- The discharge criteria are set in the calculation as an upper limit of the discharge (i.e., 95%ile value in the Monte Carlo software). To be conservative, it is assumed that the mean is the same as the 95%ile value (i.e., the discharge is at a constant concentration which is at the upper discharge limit).
- Water quality for the Owenkillew River is based on the analysis of baseline data summarised in Appendix 2, Table A2-2. For parameters that appear to fit to a normal or lognormal distribution, the modelling is undertaken using the mean and standard deviation values as outlined in Table A2-2. For parameters that are not normally or log-normally distributed, the raw data is input into the Monte Carlo software as per guidelines for non-parametric data.
- Flow values for the calculations are summarised in Appendix 1.

Results from the Monte Carlo modelling assessment of the discharge consent concentrations are shown in Appendix 3 and summarised in Table 3-2. For all parameters, the modelling predicts a 10% or lower increase relative to the EQS value in baseline mean.

Results from the Monte Carlo modelling assessment using observed discharge quality are shown in Appendix 4 and summarised in Table 3-3. For all parameters, the modelling predicts significantly lower than 10% increases relative to the EQS value in baseline mean.

All discharge criteria and observed concentrations are shown to be compliant in terms of the predicted increase in downstream concentrations and they are considered protective of the receiving environment.

Table 3-2: Results of Conservative Monte Carlo Modelling

Parameter	Unit	EQS	Observed Mean Quality Upstream of Discharge	Calculated Mean Quality Downstream of Discharge	Increase in Mean Concentration in Receiving River as Percent of EQS
TSS[1]	mg/L	25	6.73	7.02	1.2%
BOD	mg/L	1.4	1.12	1.16	2.9%
Zn_D	µg/L	23[+]	3.55	5.59	8.9%
Hg_D	µg/L	0.07	0.005	0.012	10%
Cd_D	µg/L	0.08	0.03	0.035	6.3%
Fe_D	mg/L	1	0.87	0.89	2%
Cu_D	µg/L	15[+]	1.08	1.15	0.5%
Cr_D	µg/L	8.1 (total of Cr III and VI)	0.64	0.74	1.2%
Ni_D	µg/L	4* or 20	0.76	0.83	0.4%
As_D	µg/L	50	1.26	1.50	0.5%
Pb_D	µg/L	1.2* or 7.2	0.45	0.49	0.6%

*These EQS refer to bioavailable concentrations.
[+]EQS for non-bioavailable Zn and Cu back-calculated using M-BAT tool.
[1]Using the guideline for TSS of 10 mg/L results in an increase in mean concentration in the receiving waters (as percent of EQS) of 2.9%.

Table 3-3: Results of Monte Carlo Modelling with Observed Data

Parameter	Unit	EQS	Observed Mean Quality Upstream of Discharge	Calculated Mean Quality Downstream of Discharge	Increase in Mean Concentration in Receiving River as Percent of EQS
TSS[1]	mg/L	25	6.73	6.84	0.4%
BOD	mg/L	1.4	1.12	1.12	0%
Zn_D	µg/L	23[+]	3.55	3.60	0.2%
Hg_D	µg/L	0.07	0.005	0.0053	0.4%
Cd_D	µg/L	0.08	0.03	0.033	3.8%
Fe_D	mg/L	1	0.87	0.87	0%
Cu_D	µg/L	15[+]	1.08	1.08	0%
Cr_D	µg/L	8.1 (total of Cr III and VI)	0.64	0.71	0.9%
Ni_D	µg/L	4* or 20	0.76	0.76	0%
As_D	µg/L	50	1.26	1.30	0.1%
Pb_D	µg/L	1.2* or 7.2	0.45	0.47	0.3%

*These EQS refer to bioavailable concentrations.
[+]EQS for non-bioavailable Zn and Cu back-calculated using M-BAT tool.
[1]Using the guideline for TSS of 10 mg/L results in an increase in mean concentration in the receiving waters (as percent of EQS) or 1.1%.

3.2 Risk of EQS Non-compliance

This section assesses the “Risk to EQS” (i.e. could the proposed load cause failure of the receiving water EQS) caused by observed discharge concentrations. This is a standard test within the EA guidance.

This assessment identifies the risk that a discharge could result in exceedance of an EQS in the receiving waters. In this test, the EA suggests that metals values are input as total metals even if the EQS is for dissolved metals, to provide a conservative input. The analysis is therefore undertaken using total metals and dissolved metals so the results can be compared to the appropriate EQS values.

Total metals values are not measured at the current discharge location (as the discharge is not licensed for total metals), but they are recorded at the surface water sampling location SW05 in the Owenkillew River. The values at SW05 are used in the assessment.

The risk of non-compliance for the EQS is assessed by using the results of the ‘Monte Carlo’ simulation to undertake a ‘compliance with mean standards test’ within the RQP software; this provides a percentage risk that the EQS could be exceeded. In order to pass the compliance test, a risk of exceedance of EQS needs to be no more than 5%. Results are presented with and without the observed discharge from the treatment plant to isolate the impact of the discharge on the test. As outlined in Appendix 2, there are samples from the Owenkillew River for selected parameters which reflect an exceedance of the EQS under baseline conditions.

Results from the compliance test for dissolved metals and other parameters are summarised in Table 3-4, based on an assumed monthly sampling programme (i.e., 12 samples every year). The same analysis for total metals is shown in Table 3-5. The majority of parameters comply with the criteria outlined above, namely a less than 5% change of exceedance of the EQS in the receiving waters.

Based on the mean and standard deviation of the baseline water quality data there is a chance that the average observed concentration in the Owenkillew (over a year) could exceed the EQS for three parameters: BOD, cadmium (total only) and iron (total and dissolved). This means that the natural variability in these parameters within natural waters is such that there is a risk (15.7% chance for BOD) that the average of 12 monthly samples could exceed the EQS values. With the addition of the site discharge, the risk of non-compliance remains for these parameters, but the results show that the Site discharge would have no (0%) impact on the risk of exceedance of the EQS value in the Owenkillew River for BOD and iron (total and dissolved).

An increase in the risk of non-compliance is calculated for total cadmium. There is no exceedance predicted for dissolved cadmium. As the EQS is based on dissolved metals, the results in Table 3-5 (although consistent with the EA method) do not indicate any change is required in the discharge criteria, nor do the results in Table 3-4 and Section 3.1, which compare cadmium discharges to the relevant EQS values.

For TSS, the discharge has no impact on compliance for the 25 mg/L standard considered in this assessment (see Table 1-4). If the lower 10 mg/L guideline standard was considered, the calculations showed a slight (1%) increase in the risk that a 10 mg/L target in the Owenkillew River is exceeded in any year. Given the standard deviation of TSS samples (equal to the mean) and the detection limit for TSS of 10 mg/L, this increase is considered negligible and within the range of uncertainty of the TSS baseline data.

Table 3-4: Results of Non-compliance calculations – dissolved metals and other parameters

Parameter	Unit	EQS	Chance of non-compliance – no discharge	Chance of non-compliance – with discharge	Difference
TSS	mg/L	[1]25	0%	0%	0%
BOD	mg/L	1.4	15.7%	15.7%	0%
Zn_D	µg/L	23⁺	0%	0%	0%
Hg_D	µg/L	0.07	0%	0%	0%
Cd_D	µg/L	0.08	0%	0%	0%
Fe_D	mg/L	1	13.6%	13.6%	0%
Cu_D	µg/L	15⁺	0%	0%	0%
Cr_D	µg/L	3.4 (CrVI) or 8.1 (total of Cr III and VI)	0%	0%	0%
Ni_D	µg/L	4* or 20	0%	0%	0%
As_D	µg/L	50	0%	0%	0%
Pb_D	µg/L	1.2* or 7.2	0%	0%	0%

*These EQS refer to bioavailable concentrations.
⁺EQS for non-bioavailable Zn and Cu back-calculated using M-BAT tool.
[1]Using the guideline for TSS of 10 mg/L results in a chance of non-compliance of 6.8%, compared to 5.4% under baseline conditions.

Table 3-5: Results of Non-compliance calculations for total metals

Parameter	Unit	EQS	Chance of non-compliance – no discharge	Chance of non-compliance – with discharge	Difference
Zn_T	µg/L	23⁺	0%	0%	0%
Hg_T	µg/L	0.07	0%	0%	0%
Cd_T	µg/L	0.08	6.56%	9.89%	3.33%
Fe_T	mg/L	1	97.42%	97.42%	0%
Cu_T	µg/L	15⁺	0%	0%	0%
Cr_T	µg/L	3.4 (CrVI) or 8.1 (total of Cr III and VI)	0%	0%	0%
Ni_T	µg/L	20	0%	0%	0%
As_T	µg/L	50	0%	0%	0%
Pb_T	µg/L	7.2	0%	0%	0%

⁺EQS for non-bioavailable Zn and Cu back-calculated using M-BAT tool.

3.3 Review of Observed Discharge

3.3.1 Introduction

Water quality data has been collected on behalf of DGL on a monthly basis from 2014 to 2019 for five locations along the Curraghinalt Burn and the Owenkillew River:

1. On the Curraghinalt Burn upstream of the water treatment plant outfall pipe (DCS1);
2. Water from the outfall pipe itself (i.e., treated water; DCS2);
3. On the Curraghinalt Burn downstream of the outfall pipe (DCS3);
4. On the Owenkillew River upstream of the confluence with the Curraghinalt Burn (DCS4); and
5. On the Owenkillew River downstream of the confluence with the Curraghinalt Burn (DCS5).

In May 2015, the current Water Treatment Plant was installed and began operating. In September 2015, the laboratory used for sample analysis changed from McQuillan to Jones Environmental Laboratories; this change in laboratory introduced lower analytical limits of detection (LOD), which allows for the detection of lower parameter concentrations.

For consistency with laboratory LODs, we analyse the water quality data from September 2015 to May 2019, which allows for an assessment of the impacts of discharges from the treatment plant over this period.

Figure 3-1 shows the locations of the water quality sampling points, and Table 3-6 provides more information regarding exact coordinates, dates of data collection and number of samples taken. Table 3-7 highlights the parameters measured, along with their LODs, EQS, and discharge thresholds from the discharge consent.

Table 3-6: Water quality sampling locations, dates of data and number of samples (n)

Location	Easting (m)	Northing (m)	Dates of Data	n
DCS1	257069	386939	Nov 2014 – July 2019	60
DCS2	257069	386891	Nov 2014 – July 2019	61
DCS3	257075	386926	Nov 2014 – July 2019	60
DCS4	257150	387077	Nov 2014 – July 2019	60
DCS5	257108	387113	Nov 2014 – July 2019	61

Figure 3-1. Location of water quality sampling along Curraghinalt Burn and Owenkillew River

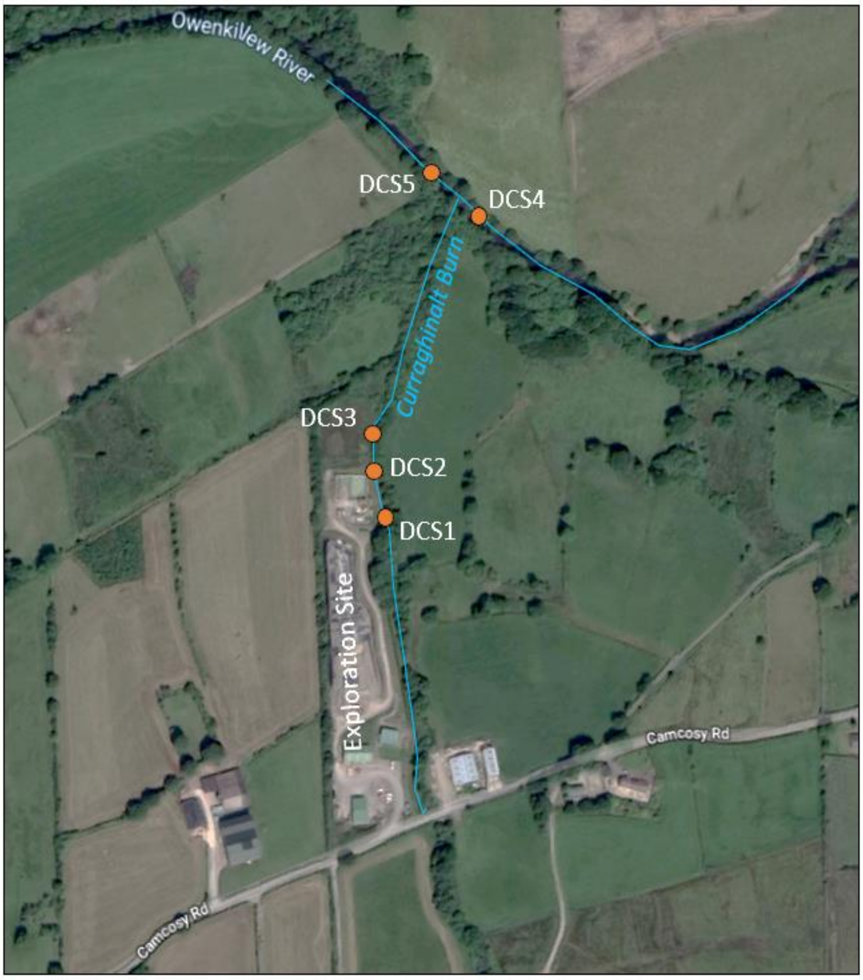


Table 3-7: Overview of analysed water quality parameters

Parameter	Unit	LOD(s)
pH	s.u.	-
TSS	mg/L	10
BOD	mg/L	1
Zn_D	µg/L	1.5
Hg_D	µg/L	0.01 or 0.5
Cd_D	µg/L	0.03
Fe_D	mg/L	0.0047
Cu_D	µg/L	3
Cr_D	µg/L	0.2
Cr III	µg/L	2
Cr VI	µg/L	2
Ni_D	µg/L	0.2
As_D	µg/L	0.9
Pb_D	µg/L	0.4

3.3.2 Treated Discharge Water Quality (DCS2)

Table 3-8 compares the observed discharge water quality with the discharge consent values. The results show that the measured values are all below the consent limits.

Bioavailable concentrations are not able to be calculated for the discharge alone, as the full suite of parameters required for bioavailable calculations are not included in the DCS2 analyses. Concentrations of dissolved organic carbon, dissolved calcium and pH are required to calculate bioavailable concentrations using the standard M-BAT tool. Dissolved organic carbon and calcium are not currently measured within the suite of parameters analysed for discharge concentrations. These parameters have not been required to date, and it is recommended that these parameters are measured in future monitoring to enable the calculation of bioavailable parameter concentrations.

Table 3-8: Estimated and measured concentrations of key parameters in treated discharge, discharge consent limits and parameter distributions (N = normal, LN = log-normal, NP = non-parametric).

Parameter	Unit	Measured Mean Concentration	Measured Max Concentration	Standard Deviation	Discharge Consent Limits from Tables 1-1 and 1-2	Distribution
pH	s.u.	7.58	8.96	0.41	6 – 9	NP
TSS	mg/L	5.6	15	2.1	50	NP
BOD	mg/L	1.0	3.0	0.8	10	NP
Zn_D	µg/L	12.9	49.0	11.1	490 or 111*	N
Zn_T	µg/L	10.9	33.0	9.3	33.8	NP
Hg_D	µg/L	0.23	0.60	0.15	1.09	NP
Cd_D	µg/L	0.05	0.43	0.10	0.7	NP
Fe_D	mg/L	0.33	1.98	0.41	3.9	N
Cu_D	µg/L	1.53	4.0	0.42	16.2 or 0.33*	NP
Cr_D	µg/L	0.32	2.2	0.42	(8.1)[1]	NP
Ni_D	µg/L	4.1	8.0	1.4	(20)[1]	NP
As_D	µg/L	1.72	6.7	1.66	(50)[1]	NP
Pb_D	µg/L	0.61	6.5	1.30	(7.2)[1]	NP

*These refer to bioavailable concentrations.

[1]Discharge consent has these parameters as 'informative' only, with Action Plans to the developed only if concentrations exceed the EQS. The values in brackets are EQS values are outlined in Table 2-3

3.3.3 Observed Impact of Discharge on Owenkillew River Water Quality

As noted above, water quality has been measured in the Owenkillew River upstream and downstream of the Curraghinalt Burn on a monthly basis. Water quality is also measured in the Curraghinalt Burn upstream and downstream of the discharge point.

The data from September 2015 to May 2019 is analysed to assess whether there have been measurable impacts on the water quality in the receiving waters and whether any changes in the Owenkillew River are consistent with what would be predicted by the discharge calculations in Section 3.1.

Each parameter on the discharge consent is considered below, and calculations are made of the difference between concentrations upstream and downstream of the discharge location on the Curraghinalt Burn and upstream and downstream of the confluence of the Curraghinalt Burn with the Owenkillew River. The calculations consider:

- Differences observed during single sampling periods, when samples are taken at all locations on the same day or within one or two days; and
- Differences between averaged concentrations to assess if there is any long-term difference in concentrations that can then be compared to EQS.

3.3.3.1 pH

Measured pH along the Curraghinalt Burn is shown in Figure 3-12. Mean laboratory pH measured upstream of the water treatment plant outfall pipe was 6.94, whereas downstream of the pipe mean pH increased to 7.43. Mean pH of the treated discharge was 7.58, with all values within the permitted discharge consent limits of 6.0 to 9.0.

On a monthly basis, recorded pH increases downstream of the treatment plant outfall for 78% of sampling rounds. The maximum increase downstream of the plant outfall is +1.73. The timeseries of recorded differences between samples for locations up- and downstream of the treatment plant outfall pipe is shown in Figure 3-3.

Figure 3-2. pH measured along Curraghinalt Burn; coloured dashed lines are sample averages by location and black dashed lines are discharge consent limits.

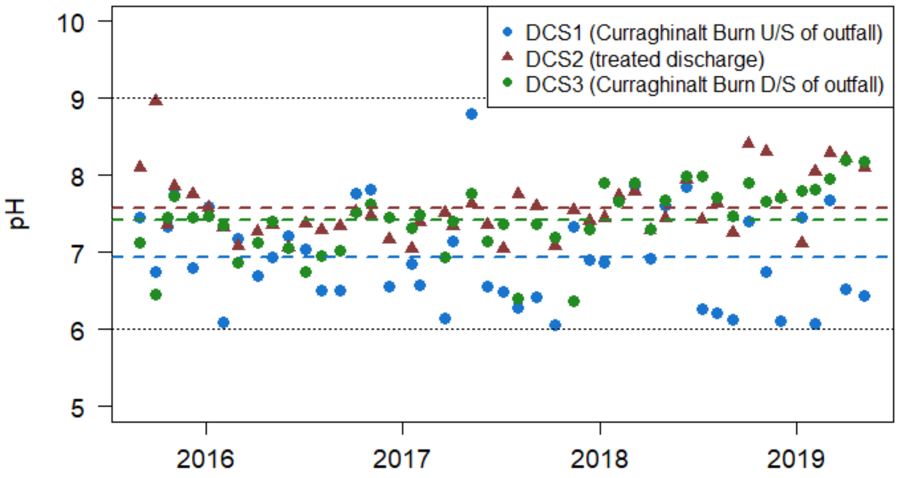
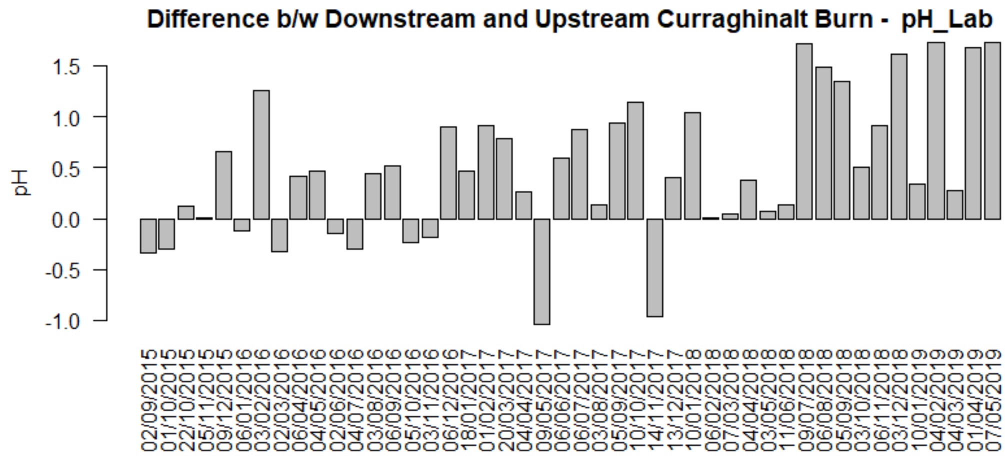


Figure 3-3. Timeseries of difference in pH between Curraghinalt Burn samples downstream and upstream of the treatment plant outfall pipe.



Concentrations of pH within the Owenkillew River are seen in Figure 3-4. Mean laboratory pH measured upstream of the confluence with Curraghinalt Burn was 7.05, whereas downstream of the pipe mean pH decreased to 6.68. All data is within the EQS range of 6 – 9. Both mean pH values are within the tighter range of concentrations (6.2 to 7.3) defined in Table 1-4 for watercourses with freshwater pearl mussels, although individual samples are outside of this range, both upstream and downstream of the Curraghinalt Burn. Mean pH of the water sample taken downstream along the Curraghinalt Burn was 7.43.

On a monthly basis, recorded pH decreases downstream of the confluence for 50% of sampling rounds, with a maximum decrease of -3.13. This is notable as the pH of the Curraghinalt Burn is higher or similar to that in the Owenkillew upstream of the burn.

Figure 3-4. pH measured along Owenkillew River; coloured dashed lines are sample averages by location and black dashed lines are discharge consent limits.

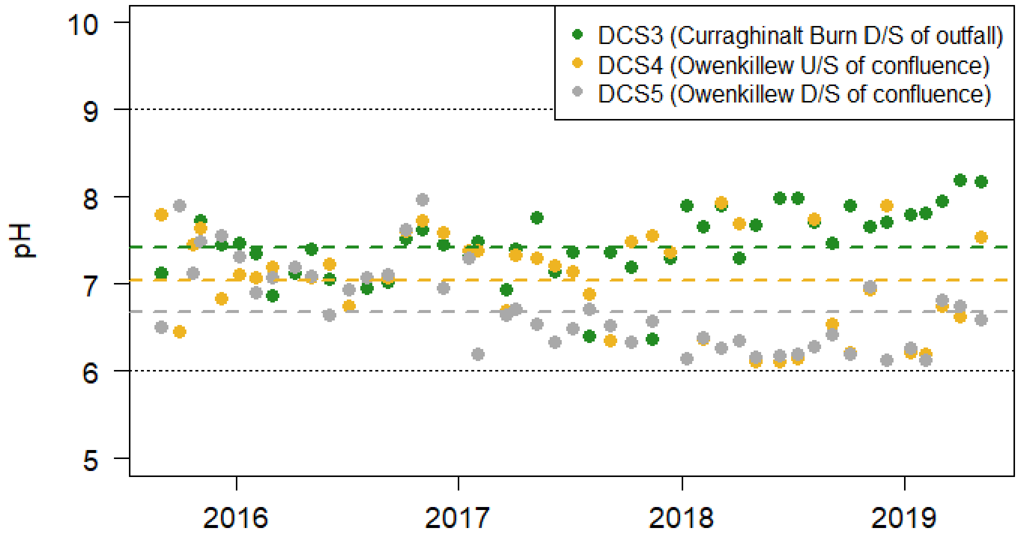
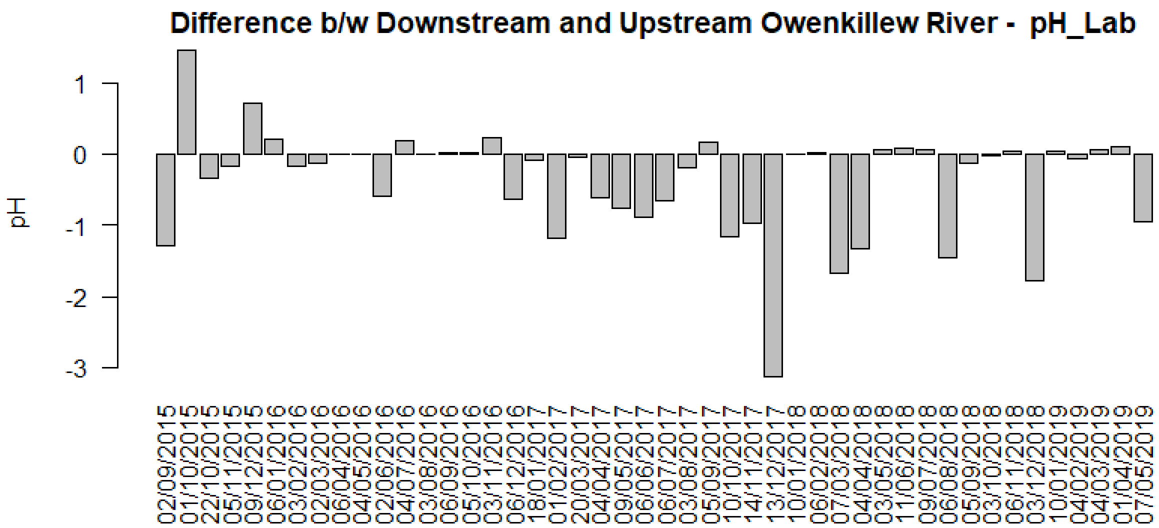


Figure 3-5. Timeseries of difference in pH between Owenkillew River samples downstream and upstream of the confluence with the Curraghinalt Burn.



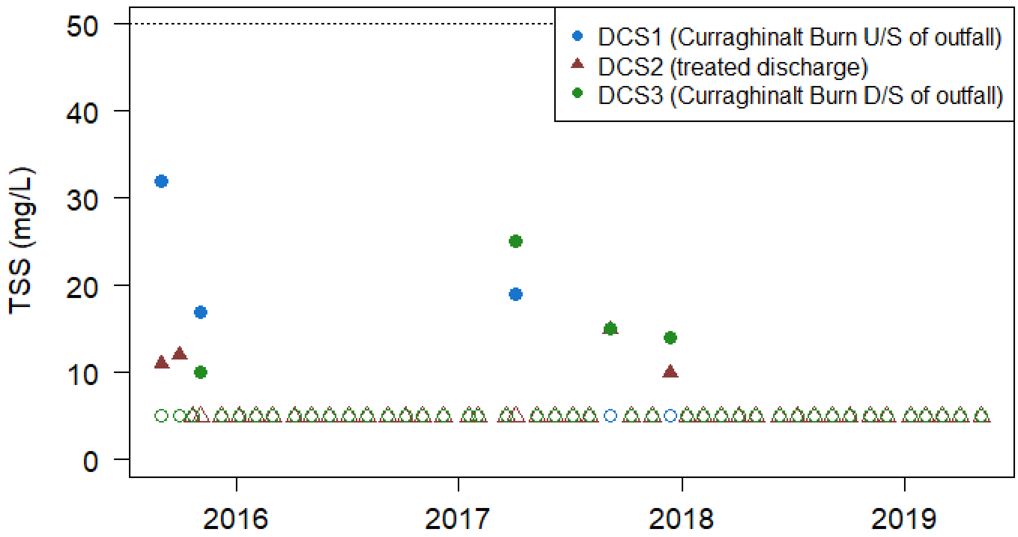
There were two notable increases in pH downstream of the confluence which raised pH above the upper EQS for pH; these were on 1st October and 9th December 2015, where pH recorded downstream of the confluence were 7.91 and 7.55, respectively. See Figure 3-5 for a timeseries of recorded differences between locations up- and downstream of the confluence.

There is no evidence of any significant change in pH within the Owenkillew River, consistent with the discharge from the mine site.

3.3.3.2 Total Suspended Solids (TSS)

TSS concentrations along the Curraghinalt Burn are shown in Figure 3-6. Most of the samples up- and downstream of the discharge point have recorded TSS concentrations below the LOD (10 mg/L). No concentrations at the discharge exceed the discharge consent limit of 50 mg/L.

Figure 3-6. TSS measured along Curraghinalt Burn; black dashed line is the discharge consent limit. Hollow data points indicate values that are below detection limit.



The TSS concentrations in the Owenkillew River up- and downstream of the Curraghinalt Burn are shown in Figure 3-7. As above, most samples record TSS concentrations below the level of detection. Mean TSS measured upstream of the confluence with Curraghinalt Burn was 6.17 mg/L, whereas downstream of the confluence mean TSS decreased to 5.59 mg/L; these concentrations are below the 25 mg/L EQS for TSS used in this assessment and below the lower 10 mg/L guideline value outlined in Table 1-4. Mean TSS of the water sample taken downstream along the Curraghinalt Burn was 5.96 mg/L.

On a monthly basis, recorded TSS decreases downstream of the confluence for 10% of sampling rounds, with a maximum decrease of -13.0 mg/L. See Figure 3-8 for a timeseries of recorded differences between locations up- and downstream of the confluence.

There is no evidence for any impact of the discharge on TSS concentrations in the Owenkillew River.

Figure 3-7. TSS measured along Owenkillew River; black dashed line is the discharge consent limit. Hollow data points indicate values that are below detection limit.

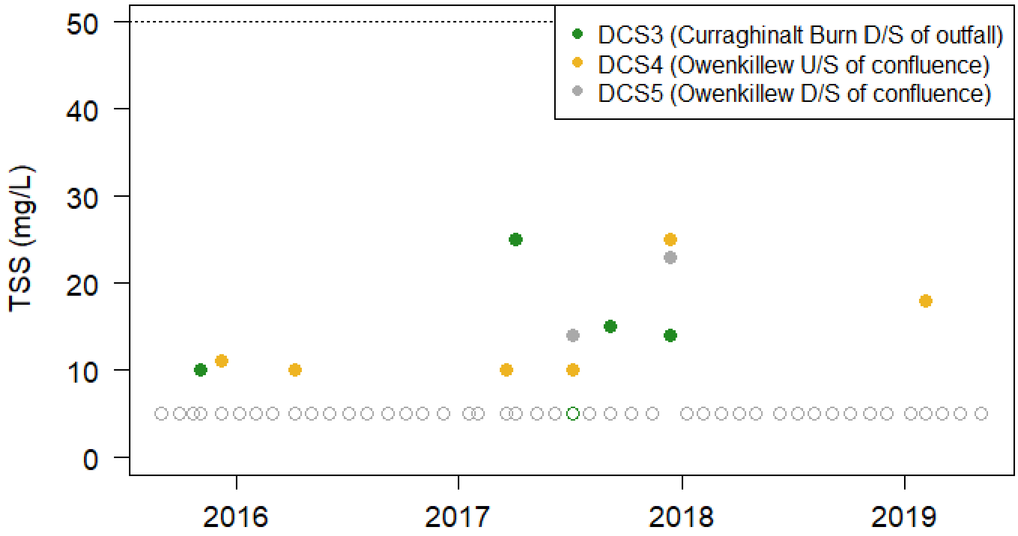
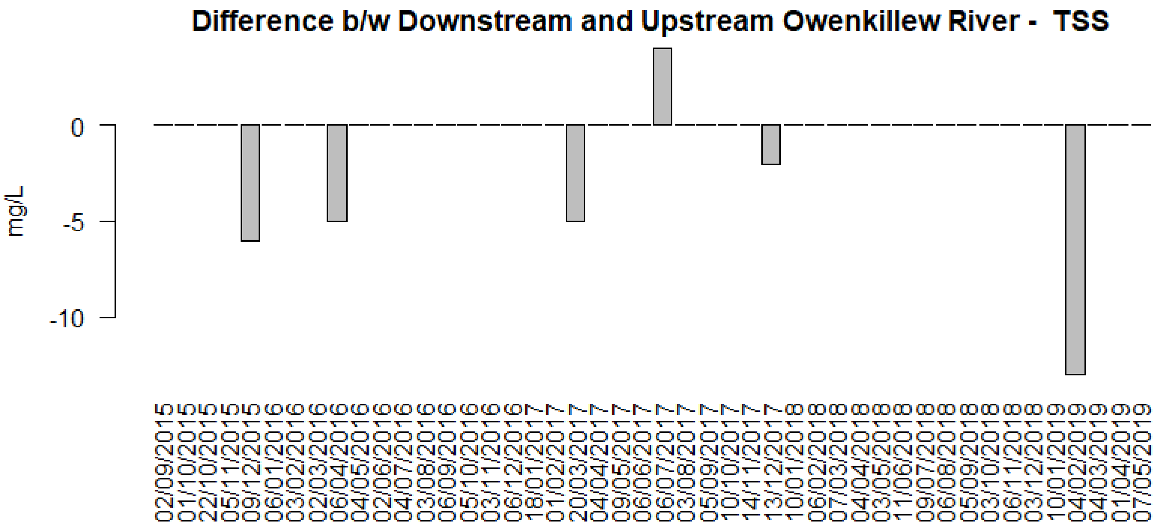


Figure 3-8. Timeseries of difference in TSS between Owenkillew River samples downstream and upstream of the confluence with the Curraghinalt Burn.



3.3.3.3 Biological Oxygen Demand (BOD)

Concentrations of BOD in the Curraghinalt Burn and at the outfall are shown in Figure 3-9. Mean BOD measured upstream of the water treatment plant outfall was 1.24 mg/L, whereas downstream of the outfall pipe mean BOD decreased slightly to 0.98 mg/L. Mean BOD measured in the treated discharge was 1.0 mg/L, with all values below the discharge consent limit of 10 mg/L.

There is no change in recorded BOD values upstream and downstream of the treatment plant outfall pipe for 72% of the sampling rounds. BOD values increase and decrease between the two locations for 9% and 19% of the sampling rounds, respectively. See Figure 3-10 for a timeseries of recorded differences between locations upstream and downstream of the treatment plant outfall pipe.

No outfall concentrations exceeded the discharge limit and there was no discernible change in water quality due to the discharge in the Curraghinalt Burn.

Figure 3-9. BOD measured along Curraghinalt Burn; black dashed line is the discharge consent limit. Hollow data points indicate values that are below detection limit.

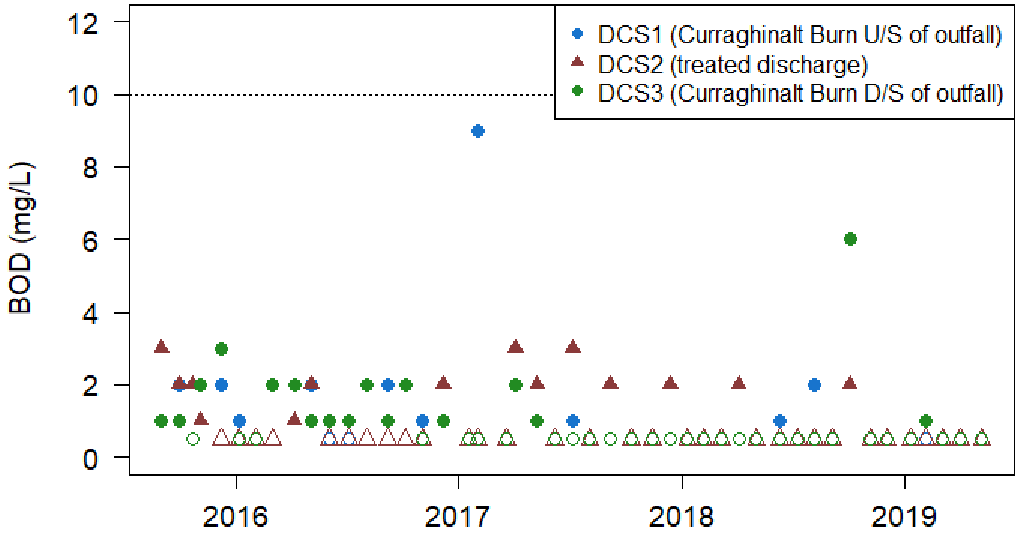
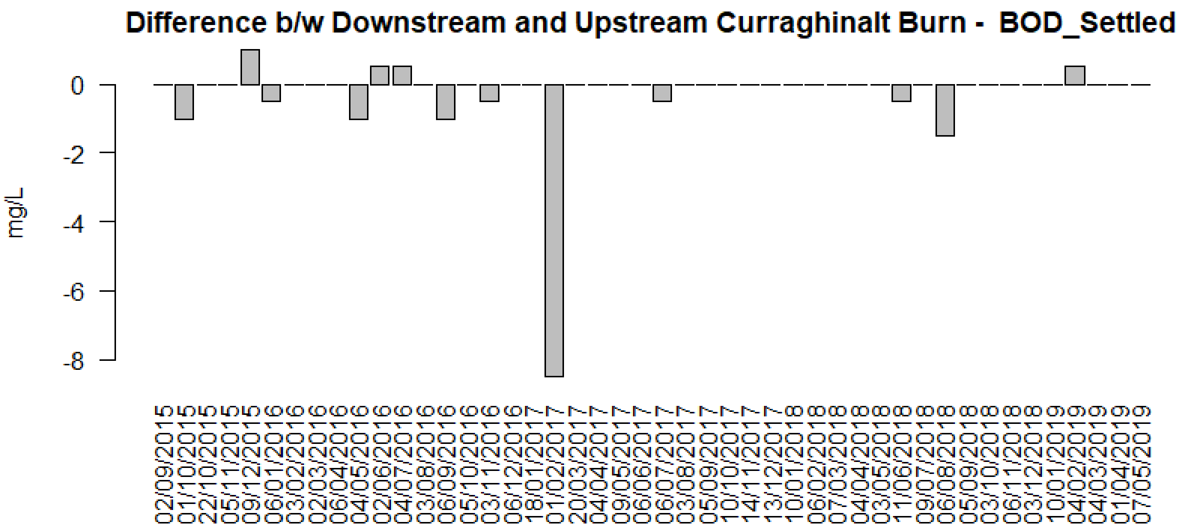


Figure 3-10. Timeseries of difference in BOD between Curraghinalt Burn samples downstream and upstream of the treatment plant outfall pipe.



BOD concentrations in the Owenkillew River are shown in Figure 3-11. Mean BOD measured upstream of the confluence with Curraghinalt Burn was 1.03 mg/L; downstream of the confluence mean BOD was also 1.03 mg/L. Both measured mean BOD concentrations are below the EQS of 1.4 mg/L. Mean BOD of the water samples taken downstream along the Curraghinalt Burn was 0.98 mg/L.

On a monthly basis, 66% of sampling rounds recorded no change in BOD downstream of the confluence. Increases and decreases were recorded downstream of the confluence for 17% of sampling rounds each. See Figure 3-12 for a timeseries of recorded differences between locations up- and downstream of the confluence.

The BOD discharge from the water treatment plant is similar to background conditions with no measurable change in water quality in the Owenkillew River.

Figure 3-11. BOD measured along Owenkillew River; black dashed line is the discharge consent limit. Hollow data points indicate values that are below detection limit.

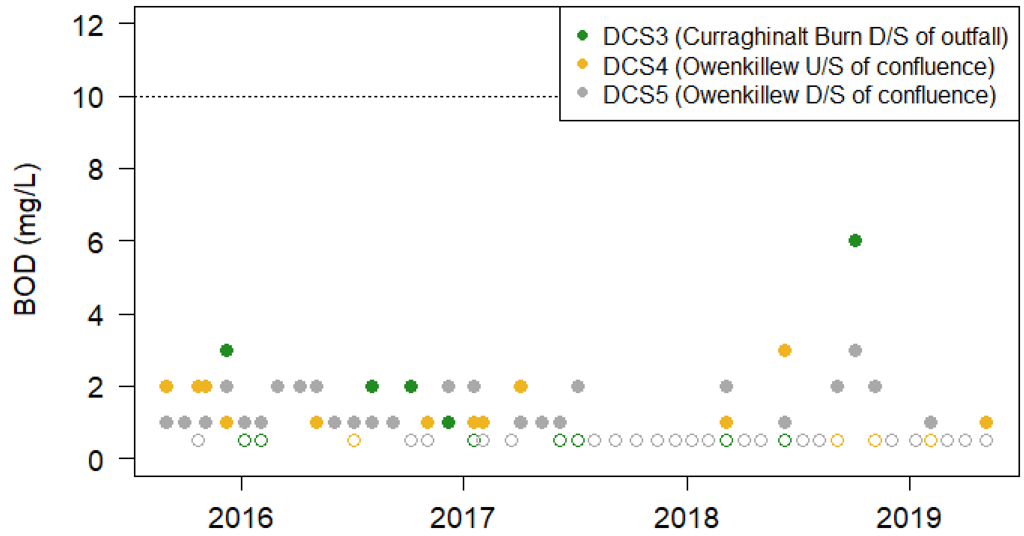
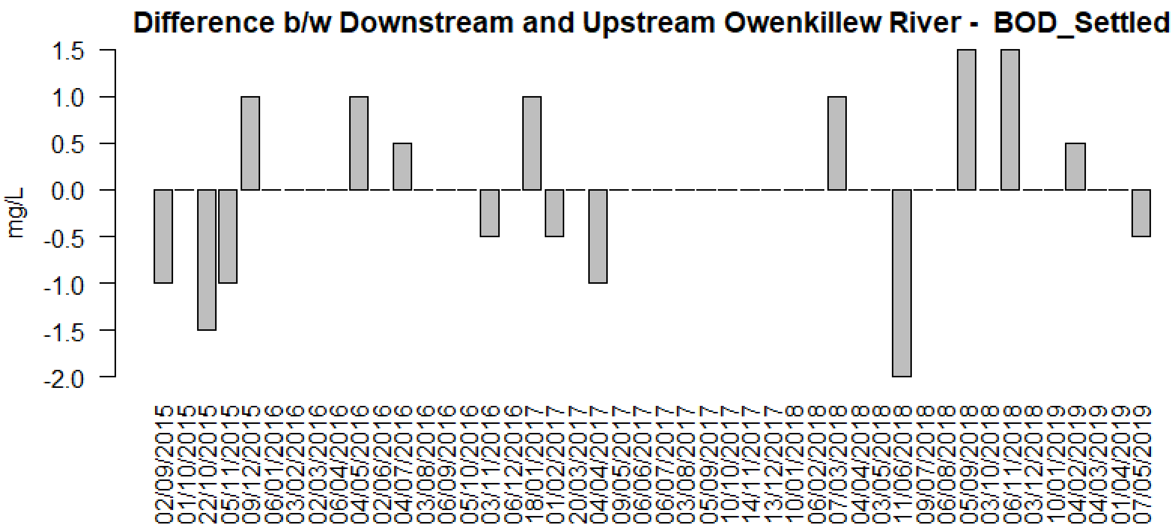


Figure 3-12. Timeseries of difference in BOD between Owenkillew River samples downstream and upstream of the confluence with the Curraghinalt Burn.



3.3.3.4 Arsenic (As)

Dissolved arsenic concentrations upstream and downstream of the discharge point on the Curraghinalt Burn are shown in Figure 3-13. Mean dissolved arsenic measured upstream of the water treatment plant outfall pipe was 1.95 µg/L; downstream of the outfall pipe mean arsenic increased slightly to 2.03 µg/L. Mean dissolved arsenic measured in the treated discharge was 1.72 µg/L, with all values below the discharge consent limit of 50 µg/L.

On a monthly basis, recorded arsenic increases and decreases downstream of the treatment plant outfall for 41% and 39% of sampling rounds, respectively. The maximum increase was recorded as +4.9 µg/L, and the maximum decrease was recorded as -5.9 µg/L. Figure 3-14 shows a timeseries of recorded differences between locations up- and downstream of the treatment plant outfall pipe. Given the discharge consent limit is 50 µg/L, these variations are considered minor.

Figure 3-13. Dissolved arsenic measured along Curraghinalt Burn; coloured dashed lines are sample averages by location. Hollow data points indicate values that are below detection limit.

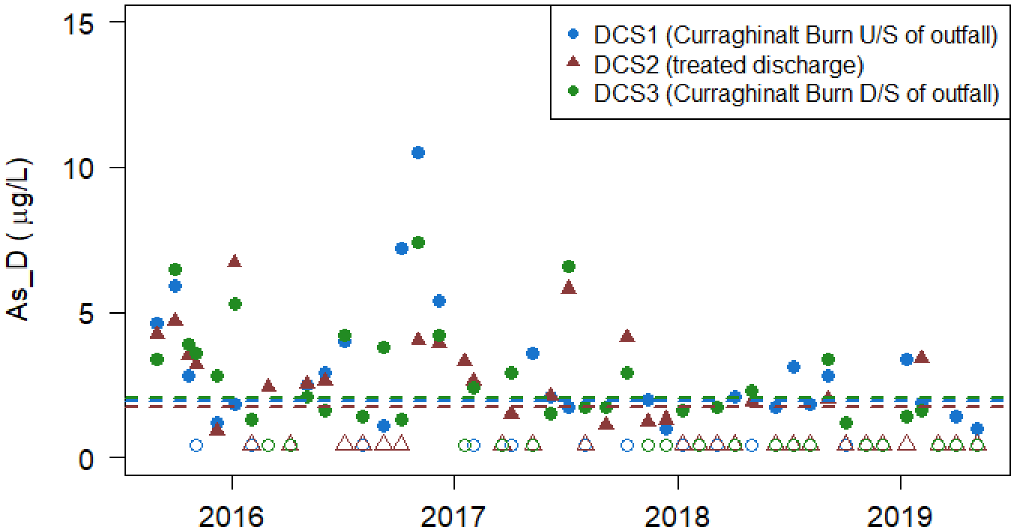
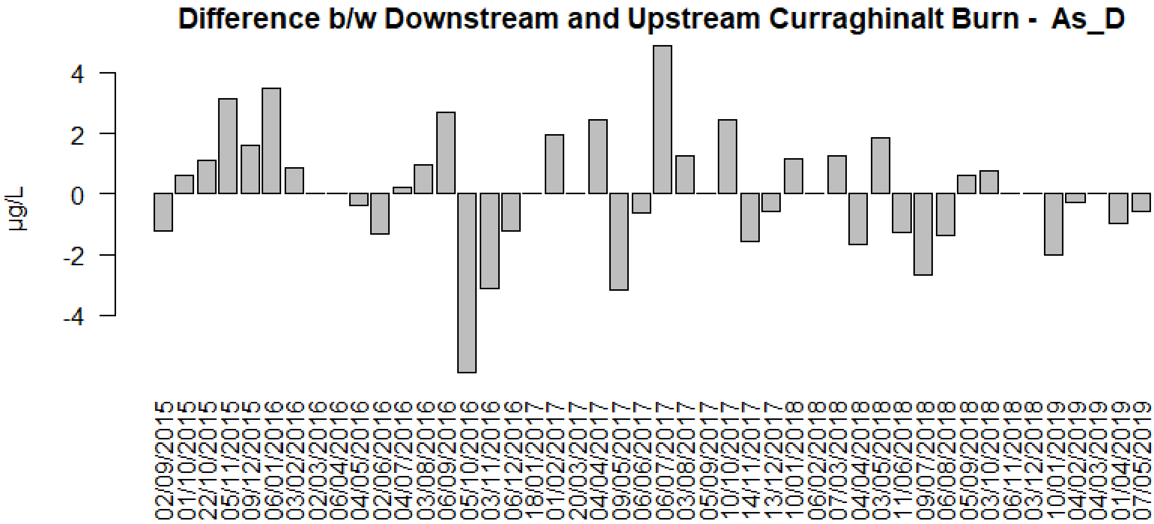


Figure 3-14. Timeseries of difference in As_D between Curraghinalt Burn samples downstream and upstream of the treatment plant outfall pipe.



Arsenic concentrations in the Owenkillew River upstream and downstream of the Curraghinalt Burn are shown in Figure 3-15. Mean dissolved arsenic measured upstream of the confluence with Curraghinalt Burn was 1.24 µg/L; downstream of the confluence mean arsenic concentration was 1.04 µg/L. The mean arsenic concentration of the water sample taken downstream along the Curraghinalt Burn was 2.03 µg/L.

On a monthly basis, 56% of sampling rounds recorded no change in dissolved arsenic downstream of the confluence. Increases and decreases were recorded downstream of the confluence for 22% sampling rounds each. See Figure 3-16 for a timeseries of recorded differences between locations upstream and downstream of the confluence.

Figure 3-15. Dissolved arsenic measured along Owenkillew River; coloured dashed lines are sample averages by location. Hollow data points indicate values that are below detection limit.

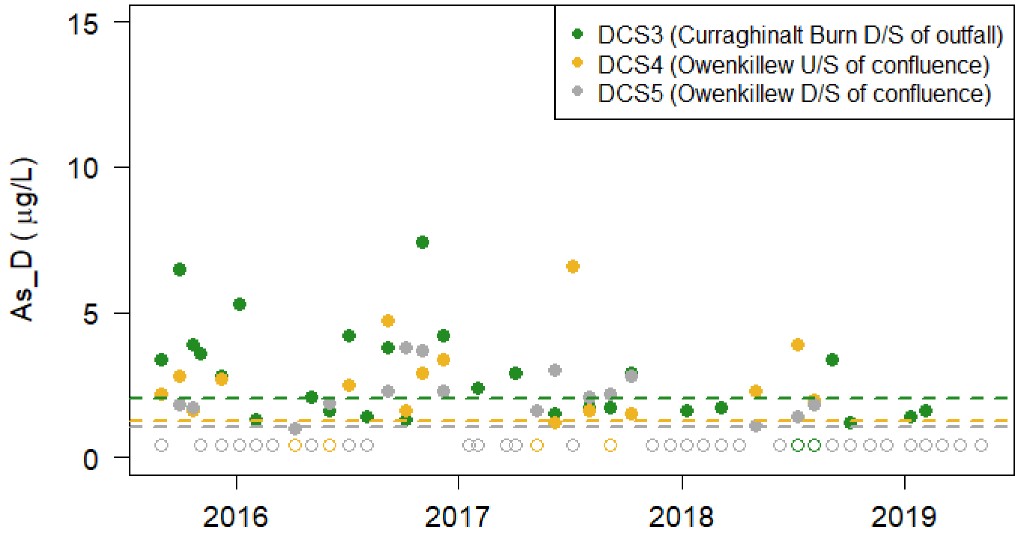
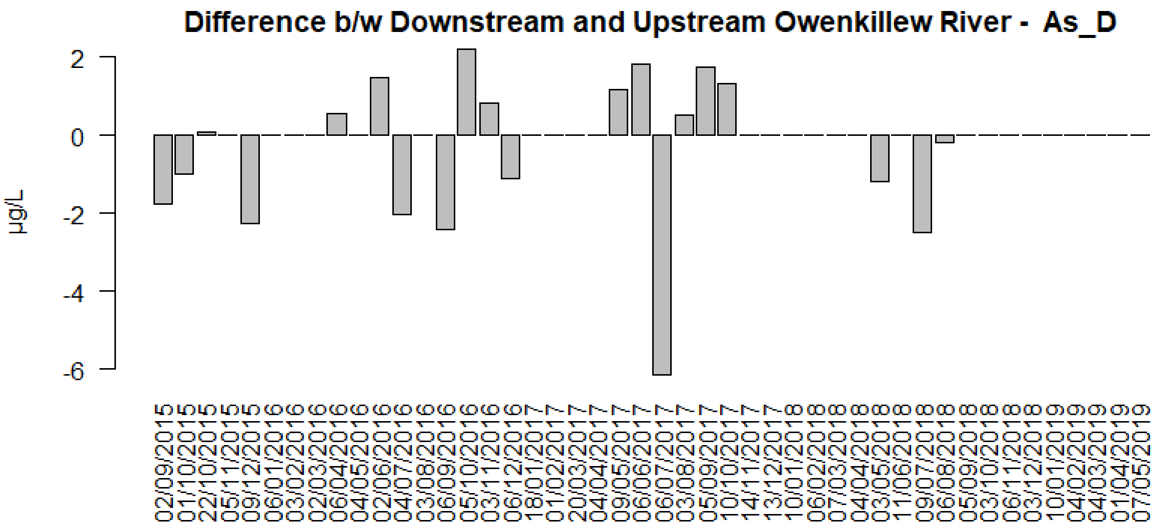


Figure 3-16. Timeseries of difference in As_D between Owenkillew River samples downstream and upstream of the confluence with the Curraghinalt Burn.



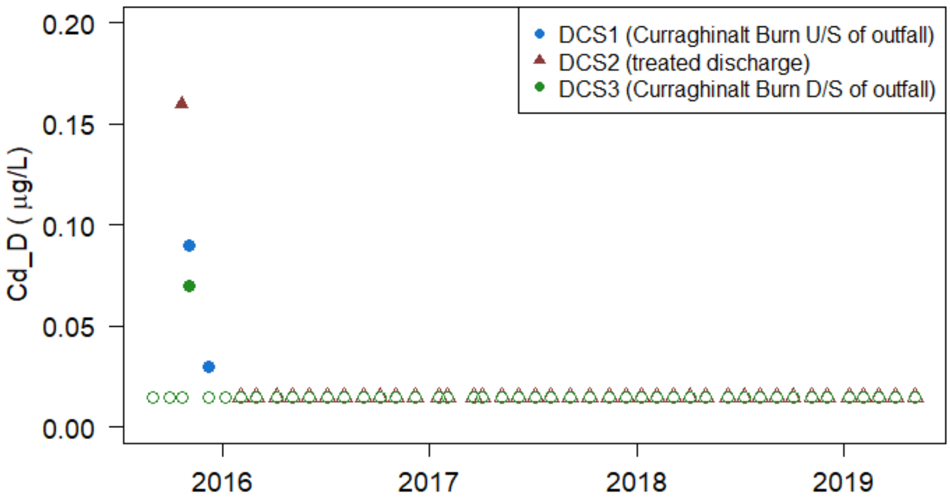
This suggests that the flow rate from the Curraghinalt Burn is such a small proportion of the flow in the Owenkillew River that there is no consistent change or noticeable impact of the treatment plant discharge on water quality in the larger watercourse.

The conclusion is therefore that the mine discharge has no measurable impact on arsenic in the Owenkillew River.

3.3.3.5 Cadmium (Cd)

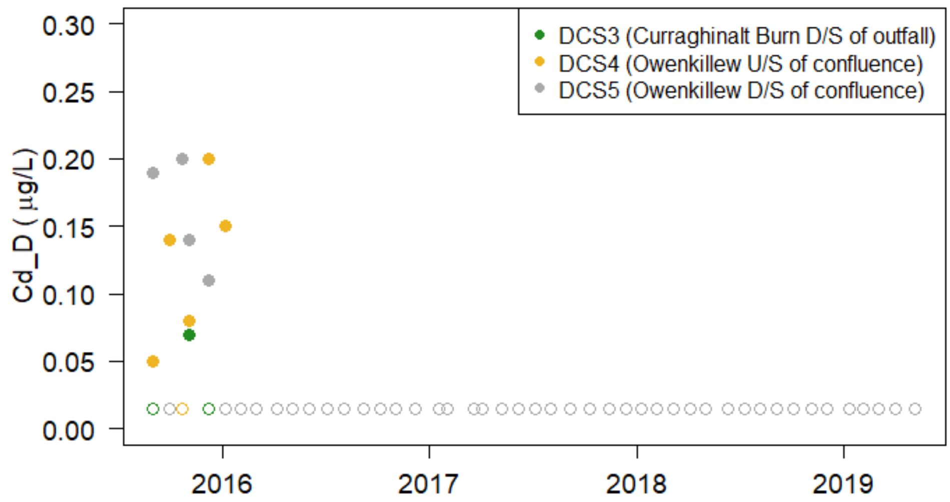
Dissolved cadmium concentrations upstream and downstream of the discharge point on the Curraghinalt Burn are shown in Figure 13-17. With the exception of a handful of samples in late-2015, there is no measurable concentration of cadmium in the discharge or in the Curraghinalt Burn.

Figure 3-17. Dissolved cadmium measured along Curraghinalt Burn; hollow data points indicate values that are below detection limit.



A similar pattern was observed in the Owenkillew River (see Figure 3-18), with a handful of elevated cadmium concentrations measured upstream and downstream of the confluence with the burn in late-2015, with no consistent trend of increasing concentrations downstream. From 2016 onwards, all measurements were below detection indicating no measurable cadmium concentrations in the watercourse and <u>no measurable effect of the mine discharge on cadmium concentrations in the Owenkillew River.</u>

Figure 3-18. Dissolved cadmium measured along Owenkillew River; black dashed line is the discharge consent limit. Hollow data points indicate values that are below detection limit.



3.3.3.6 Copper (Cu)

Dissolved copper concentrations upstream and downstream of the discharge point on the Curraghinalt Burn are shown in Figure 3-19. The majority of concentrations of copper in the discharge and in the Curraghinalt Burn are all below detection, apart from selected samples that show no evidence of an increase in cadmium concentrations as a result of the discharge from the Site.

Dissolved copper concentrations in the Owenkillew River upstream and downstream of the Curraghinalt Burn are shown in Figure 3-20. A similar pattern was observed in the Owenkillew River, with the majority of concentrations recorded below detection; this indicates no measurable copper concentrations in the watercourse and no measurable effect of the mine discharge on copper concentrations in the Owenkillew River.

Figure 3-19. Dissolved copper measured along Curraghinalt Burn; black dashed line is the discharge consent limit. Hollow data points indicate values that are below detection limit.

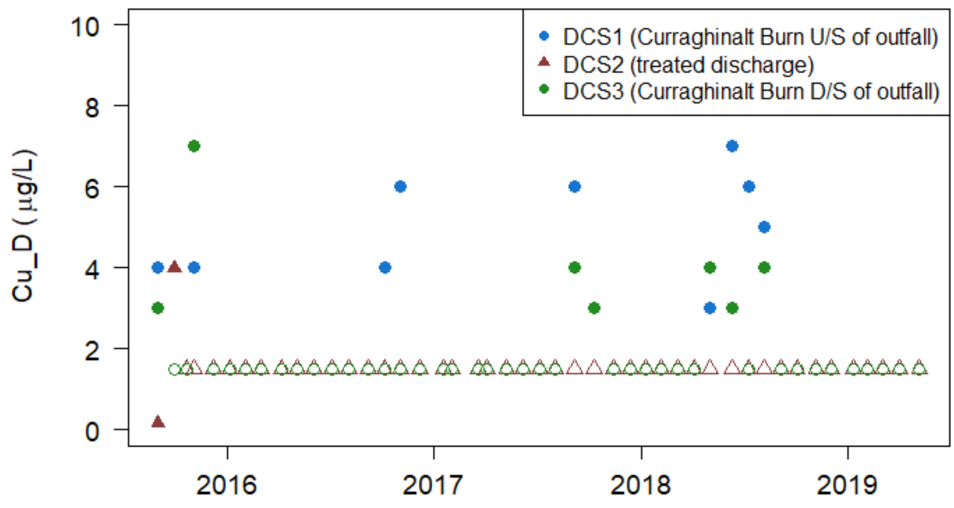
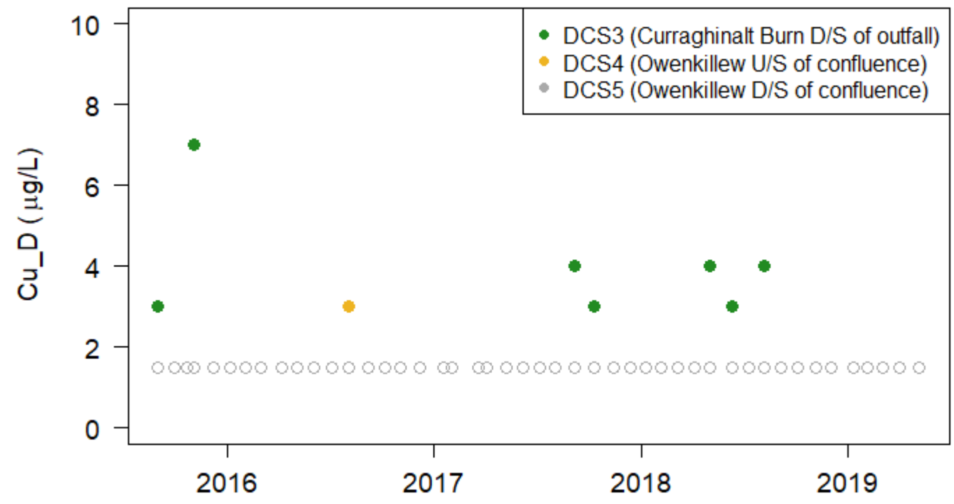


Figure 3-20. Dissolved copper measured along Owenkillew River; black dashed line is the discharge consent limit. Hollow data points indicate values that are below detection limit.



3.3.3.7 Chromium (Cr)

Dissolved chromium concentrations upstream and downstream of the discharge point on the Curraghinalt Burn are shown in Figure 3-21. Mean dissolved chromium concentration measured upstream of the water treatment plant outfall pipe was 0.20 µg/L. Downstream of the outfall pipe, mean chromium concentration was 0.21 µg/L. Mean dissolved chromium concentration measured in the treated discharge was 0.32 µg/L, with all values below the discharge consent limit of 8.1 µg/L.

As most sampling rounds measured values below detection, there is little or no difference between dissolved chromium concentrations recorded upstream and downstream of the treatment outfall pipe, with 72% of sampling rounds recording no change. Increases in chromium downstream of the outfall pipe were recorded for 15% of the sampling rounds, with a maximum recorded increase of +0.7 µg/L. However, a similar number of samples showed a decrease in concentrations. Figure 3-22 shows a timeseries of recorded differences between locations up- and downstream of the treatment plant outfall pipe.

Figure 3-21. Dissolved chromium measured along Curraghinalt Burn; hollow data points indicate values that are below detection limit.

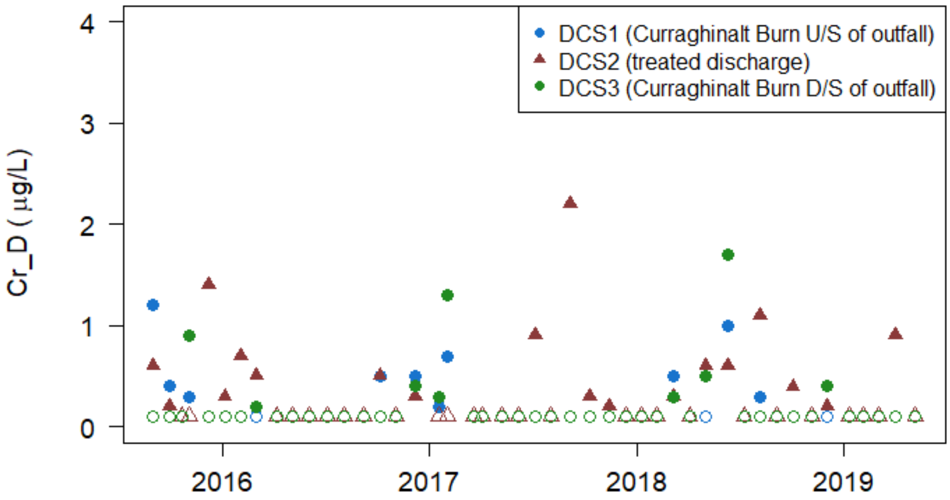
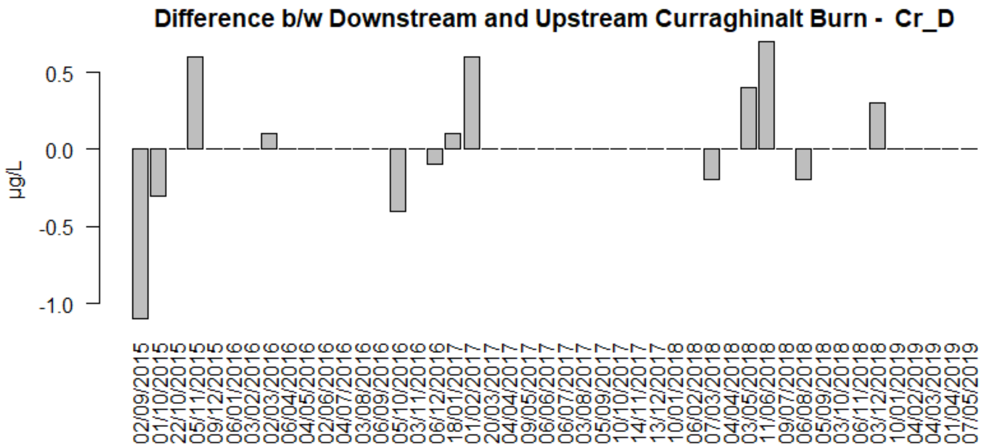


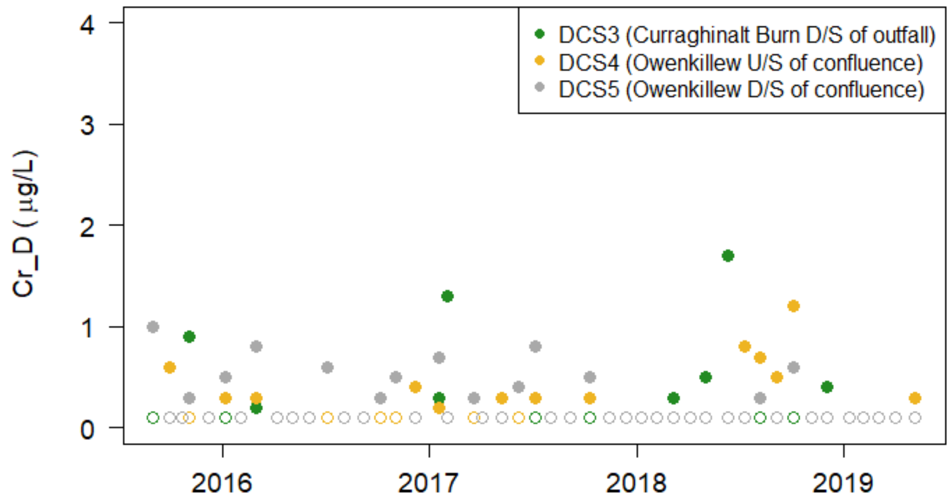
Figure 3-22. Timeseries of difference in Cr_D between Curraghinalt Burn samples downstream and upstream of the treatment plant outfall pipe.



Dissolved chromium concentrations in the Owenkillew River upstream and downstream of the Curraghinalt Burn are shown in Figure 3-23. Mean dissolved chromium measured upstream of the confluence with

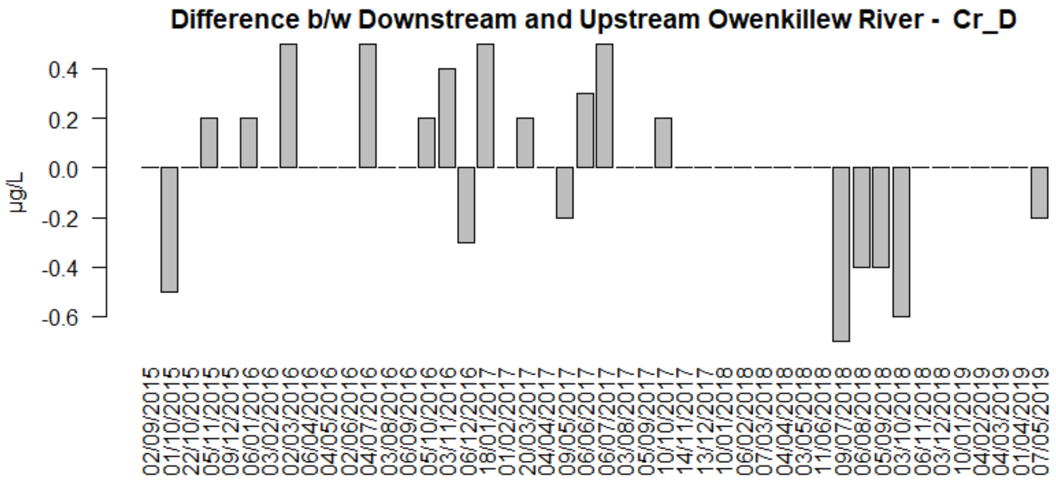
Curraghinalt Burn was 0.23 µg/L; downstream of the confluence the mean chromium concentration was also 0.23 µg/L. Mean concentrations both upstream and downstream of the confluence are below the EQS value. Mean chromium concentration taken downstream along the Curraghinalt Burn was 0.21 µg/L.

Figure 3-23. Dissolved chromium measured along Curraghinalt Burn; black dashed line is the discharge consent limit. Hollow data points indicate values that are below detection limit.



Given the number of sampling rounds with measured values below detection, there is little or no difference between dissolved chromium concentrations recorded upstream and downstream of the confluence with the Curraghinalt Burn for 59% of sampling rounds. Decreases and increases in chromium concentration were measured for 17% and 24% of sampling rounds, respectively. See Figure 3-24 for a timeseries of recorded differences between locations upstream and downstream of the confluence.

Figure 3-24. Timeseries of difference in Cr_D between Owenkillew River samples downstream and upstream of the confluence with the Curraghinalt Burn.

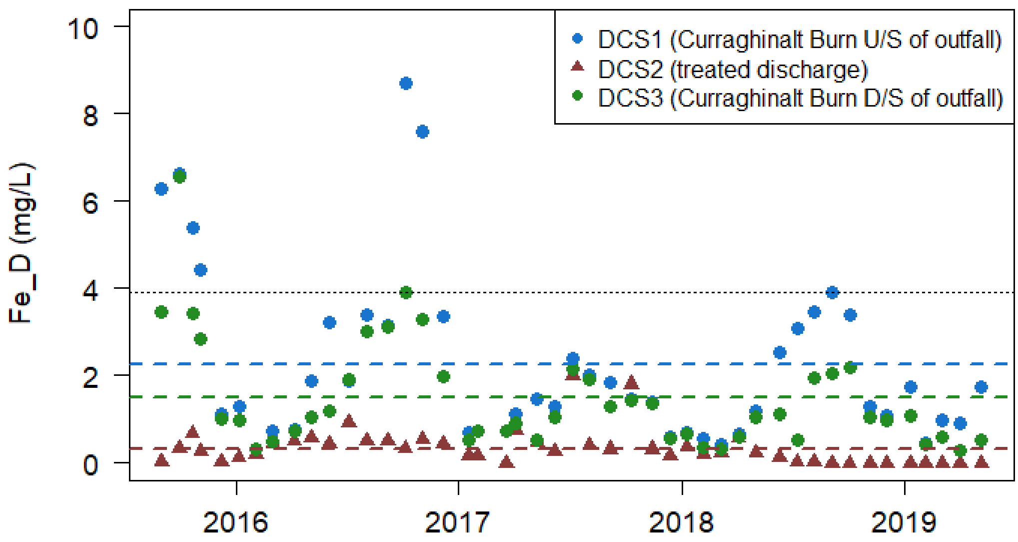


<u>There is no evidence of consistent or measurable increases in chromium concentrations in the Curraghinalt Burn due to the water treatment plant discharge</u>.

3.3.3.8 Iron (Fe)

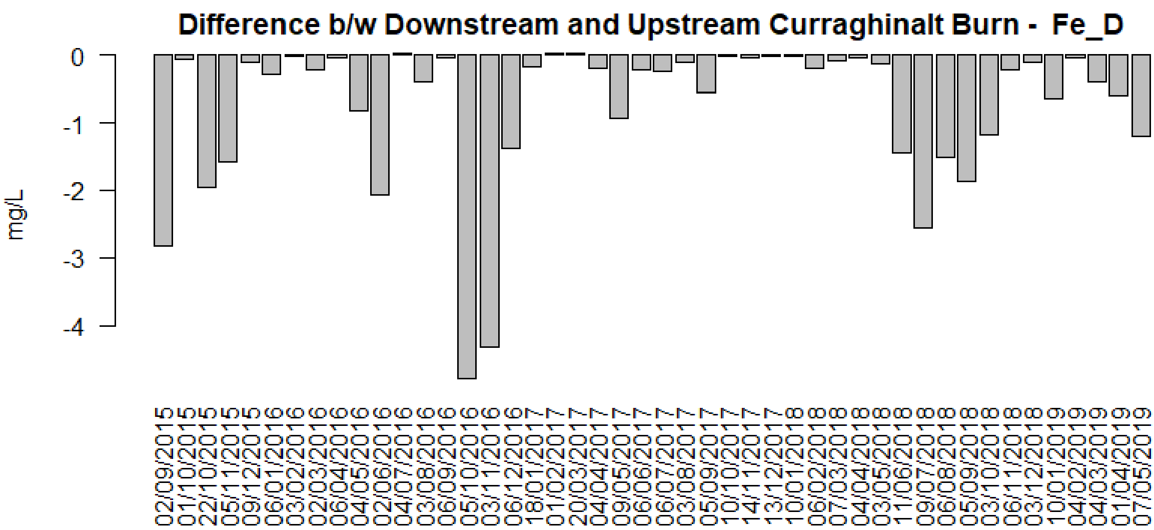
Dissolved iron concentrations upstream and downstream of the discharge point on the Curraghinalt Burn are shown in Figure 3-25. Mean dissolved iron measured upstream of the water treatment plant outfall pipe was 2.26 mg/L; downstream of the outfall pipe mean iron decreased to 1.48 mg/L. Mean dissolved iron measured in the treated discharge was 0.33 mg/L, with all values below the discharge consent limit of 3.9 mg/L.

Figure 3-25. Dissolved iron measured along Curraghinalt Burn; coloured dashed lines are sample averages by location and black dashed line is the discharge consent limit.



The concentration of iron in the discharge is less than the background concentration in the Curraghinalt Burn, so would not be expected to increase concentrations in the watercourse. This is shown clearly in Figure 3-26 below.

Figure 3-26. Timeseries of difference in Fe_D between Curraghinalt Burn samples downstream and upstream of the treatment plant outfall pipe.



Dissolved iron concentrations in the Owenkillew River upstream and downstream of the Curraghinalt Burn are shown in Figure 3-27. Mean dissolved iron measured upstream of the confluence with Curraghinalt Burn was 0.92 mg/L; downstream of the confluence mean iron concentration was 0.96 mg/L; these mean concentrations are just below the EQS of 1.0 mg/L.

Mean iron concentration downstream along the Curraghinalt Burn was 1.48 mg/L, slightly higher than the PGV. See Figure 3-28 for a timeseries of recorded differences between locations up- and downstream of the confluence.

However, as outlined above, the iron concentrations in the discharge were lower than background concentrations in the Curraghinalt Burn; therefore, any increase in iron concentrations in the Owenkillew River downstream of the confluence with the Curraghinalt Burn will result from background iron concentrations in this watercourse and not the water treatment plant outfall.

Figure 3-27. Dissolved iron measured along Owenkillew River; black dashed line is the discharge consent limit.

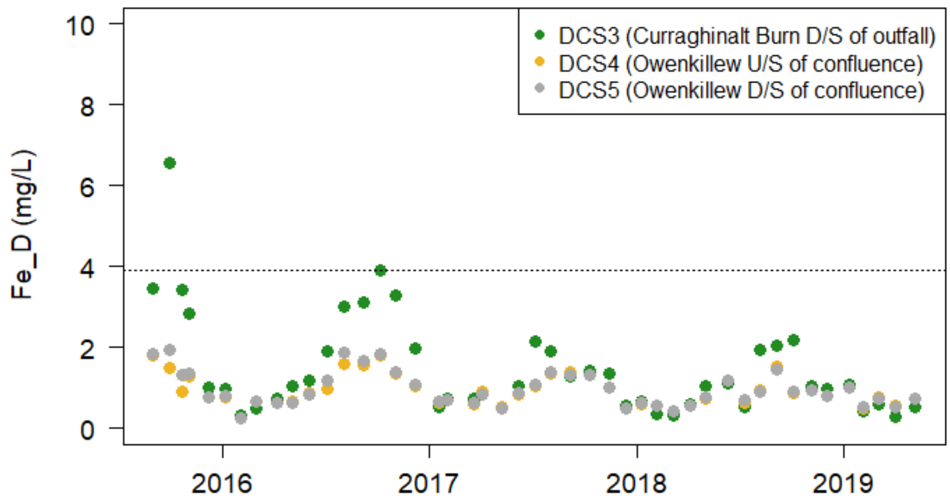
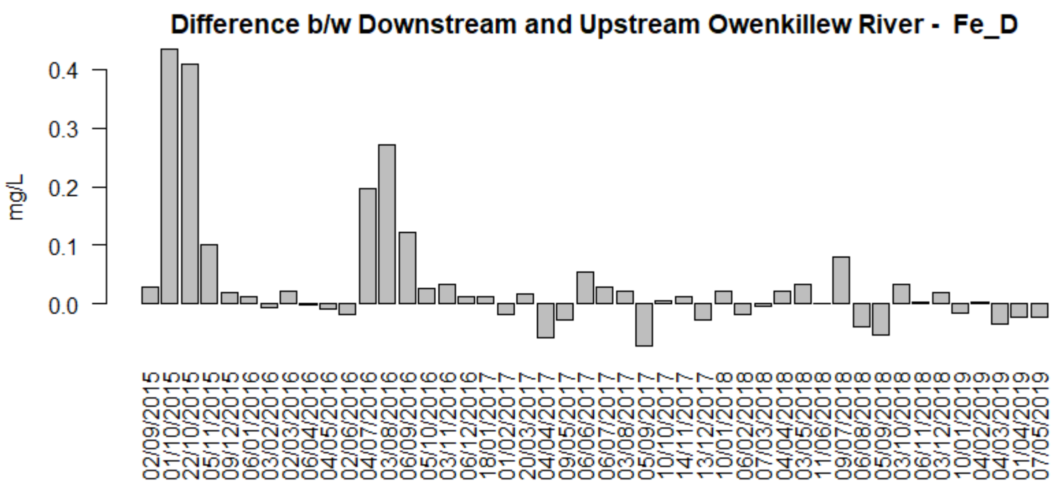


Figure 3-28. Timeseries of difference in Fe_D between Owenkillew River samples downstream and upstream of the confluence with the Curraghinalt Burn.



3.3.3.9 Mercury (Hg)

Dissolved mercury concentrations upstream and downstream of the discharge point on the Curraghinalt Burn are shown in Figure 3-29. Almost all mercury concentrations in the Curraghinalt Burn and discharge are less than detection limits, with all values below the adjusted discharge consent limit of 1.09 µg/L. There is no evidence of any change in the mercury concentrations in the Curraghinalt Burn due to the site discharge.

Dissolved mercury concentrations in the Owenkillew River upstream and downstream of the Curraghinalt Burn are shown in Figure 3-30. A similar pattern was observed in the Owenkillew River, with most samples recording below detection for mercury, with no measurable effect of the mine discharge on mercury concentrations in the Owenkillew River.

Figure 3-29. Dissolved mercury measured along Curraghinalt Burn; hollow data points indicate values that are below detection limit.

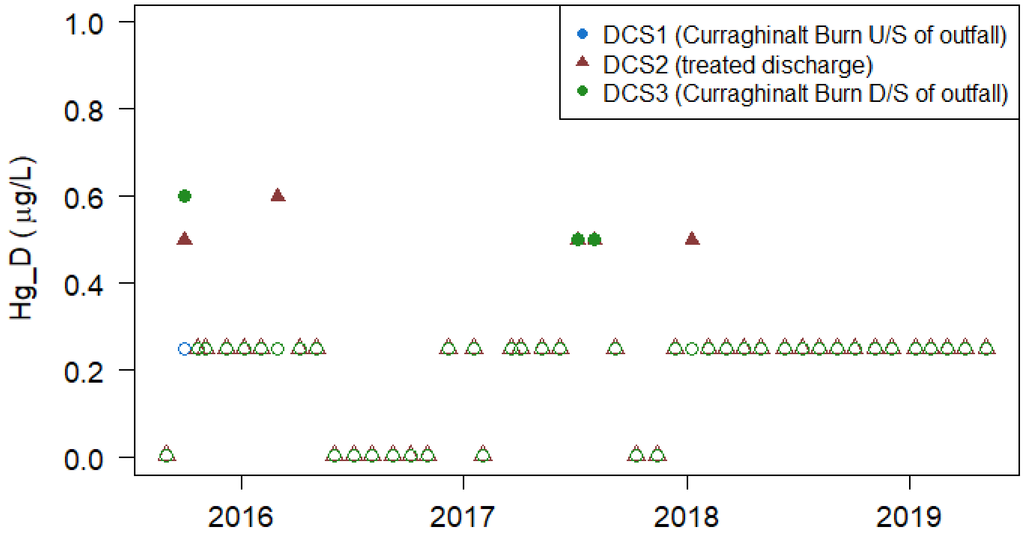
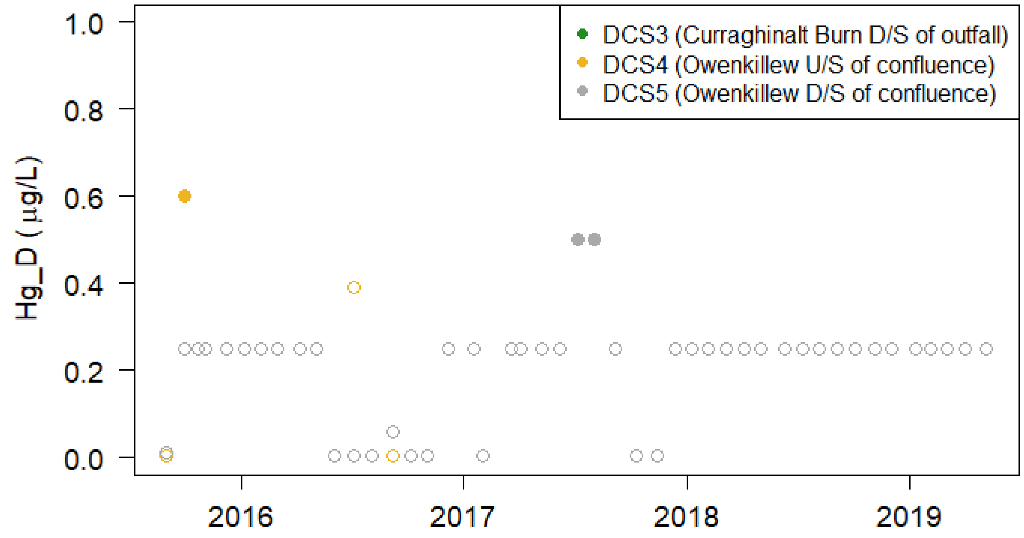


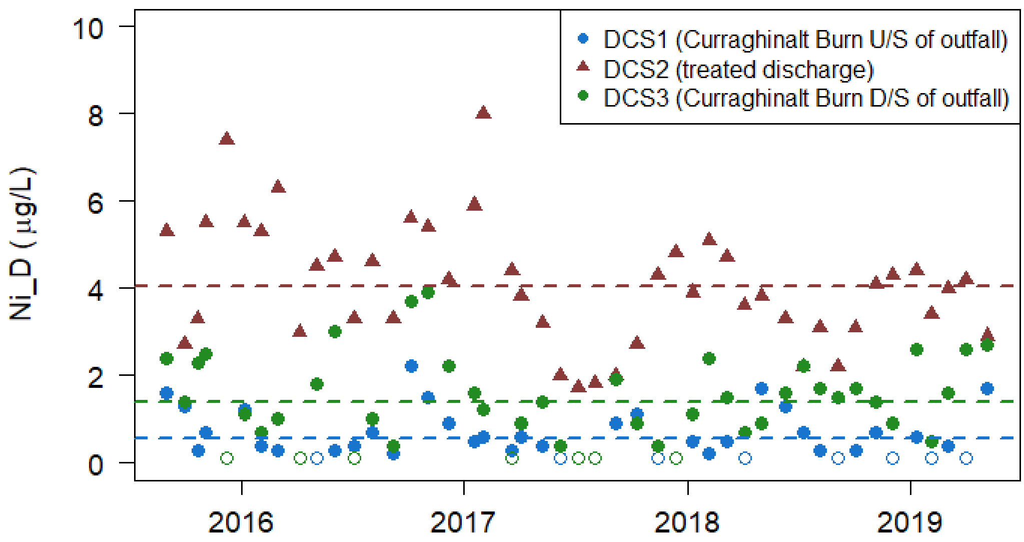
Figure 3-30. Dissolved mercury measured along Owenkillew River; hollow data points indicate values that are below detection limit.



3.3.3.10 Nickel (Ni)

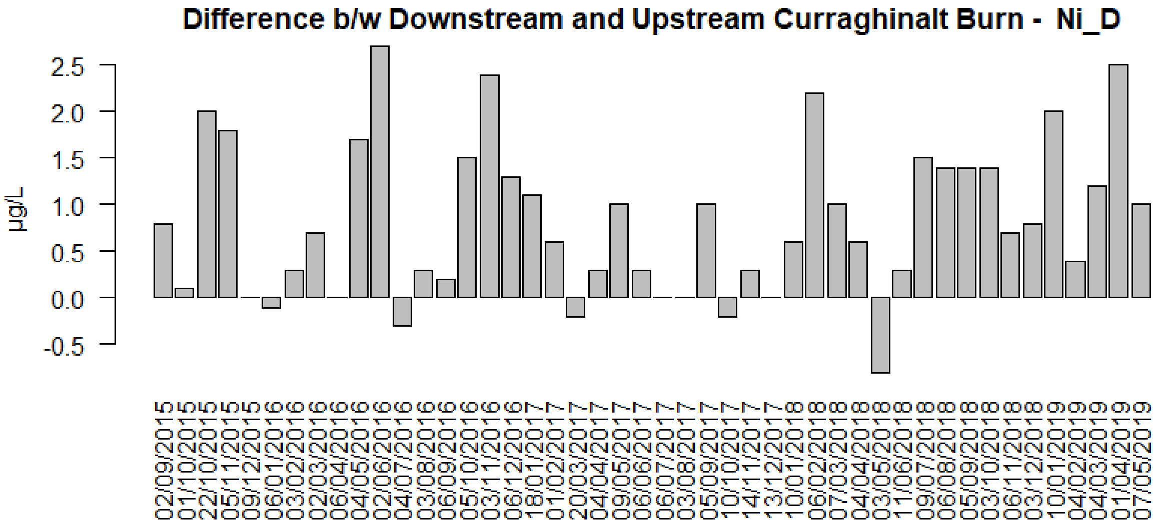
Dissolved nickel concentrations upstream and downstream of the discharge point on the Curraghinalt Burn are shown in Figure 3-31. Mean dissolved nickel measured upstream of the water treatment plant outfall pipe was 0.58 µg/L; downstream of the outfall pipe mean nickel increased to 1.40 µg/L. Mean dissolved nickel measured in the treated discharge was 4.10 µg/L, with all values below the discharge consent limit of 20 µg/L.

Figure 3-31. Dissolved nickel measured along Curraghinalt Burn; coloured dashed lines are sample averages by location. Hollow data points indicate values that are below detection limit.



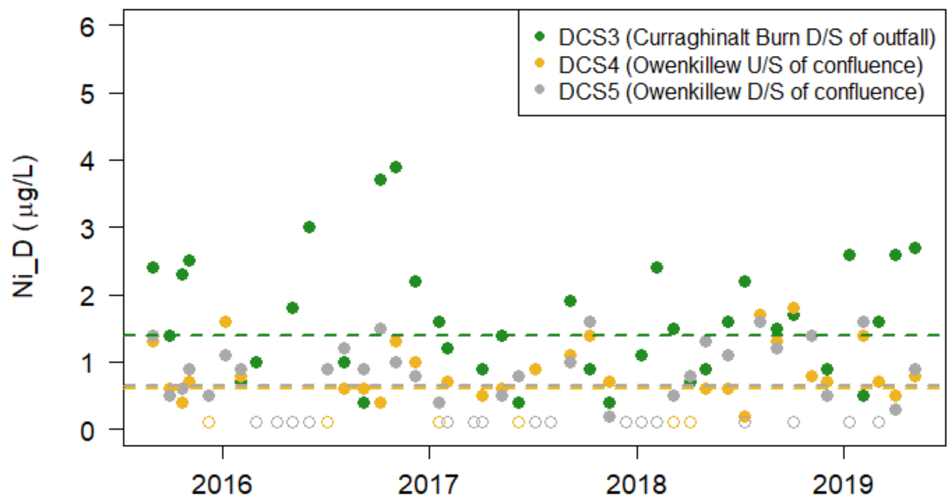
On a monthly basis, recorded nickel increases downstream of the treatment plant outfall for 78% of sampling rounds. The maximum increase was recorded as +2.7 µg/L. See Figure 3-32 for a timeseries of recorded differences between locations upstream and downstream of the treatment plant outfall pipe. There was a mean increase in dissolved nickel concentration downstream of the outfall pipe of +0.82 µg/L.

Figure 3-32. Timeseries of difference in Ni_D between Curraghinalt Burn samples downstream and upstream of the treatment plant outfall pipe.



Dissolved nickel concentrations in the Owenkillew River upstream and downstream of the Curraghinalt Burn are shown in Figure 3-33. Mean dissolved nickel concentrations measured upstream of the confluence with Curraghinalt Burn was 0.61 µg/L; downstream of the confluence mean nickel concentration was 0.64 µg/L. Mean nickel concentration of the water sample taken downstream along the Curraghinalt Burn was 1.40 µg/L.

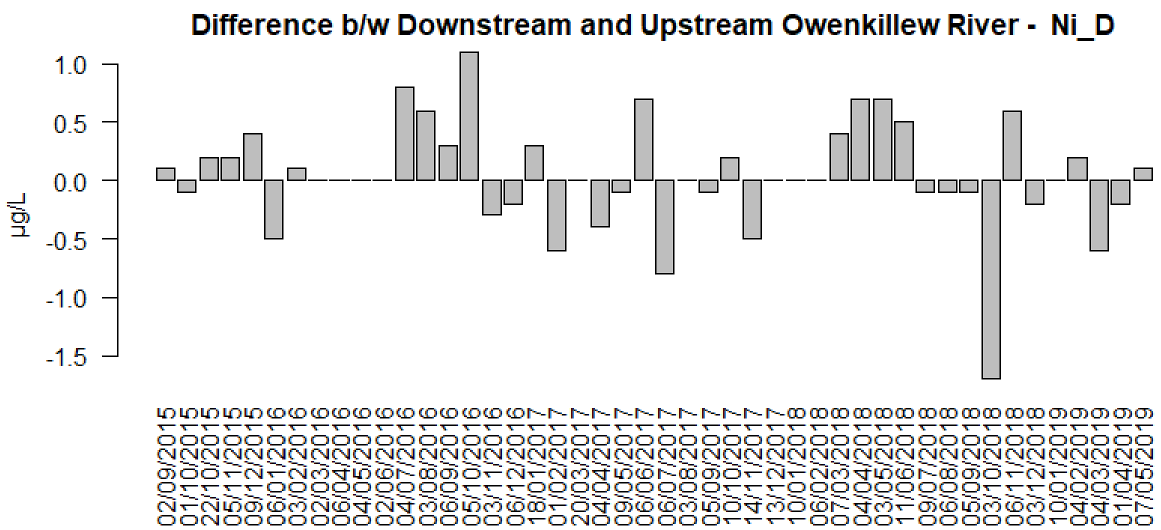
Figure 3-33. Dissolved nickel measured along Owenkillew River; coloured dashed lines are sample averages by location. Hollow data points indicate values that are below detection limit.



There is little or no difference between dissolved nickel concentrations recorded up- and downstream of the confluence with the Curraghinalt Burn for 22% of sampling rounds. Decreases (up to -1.7 µg/L) and increases (up to +1.1 µg/L) were measured downstream of the confluence for 37% and 41% of sampling rounds, respectively. See Figure 3-34 for a timeseries of recorded differences between locations upstream and downstream of the confluence.

<u>There is no evidence of consistent and measurable changes in nickel concentrations in the Owenkillew River as a result of the discharge from the water treatment plant.</u>

Figure 3-34. Timeseries of difference in Ni_D between Owenkillew River samples downstream and upstream of the confluence with the Curraghinalt Burn.



3.3.3.11 Lead (Pb)

Dissolved lead concentrations upstream and downstream of the discharge point on the Curraghinalt Burn are shown in Figure 3-35. The majority of the concentrations of lead in the discharge and in the Curraghinalt Burn are below detection. Within the data set, there is only a period in late-2015 when elevated lead concentrations were measured, although concentrations were below the discharge consent limit of 7.2 µg/L. In this period, there is no evidence that the discharge is consistently raising the Curraghinalt Burn concentration, as seen in Figure 3-36.

Figure 3-35. Dissolved lead measured along Curraghinalt Burn; black dashed line is the discharge consent limit. Hollow data points indicate values that are below detection limit.

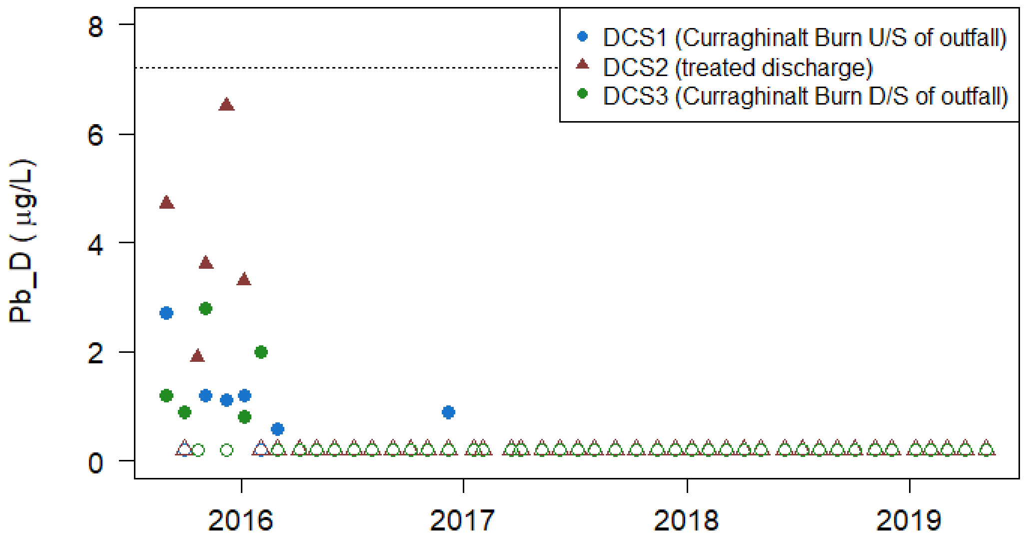
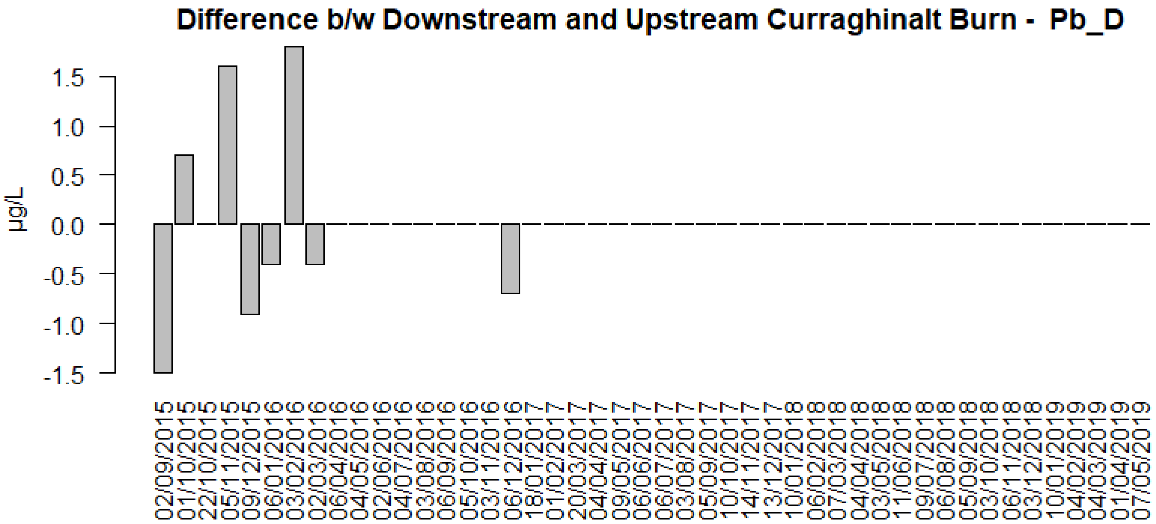
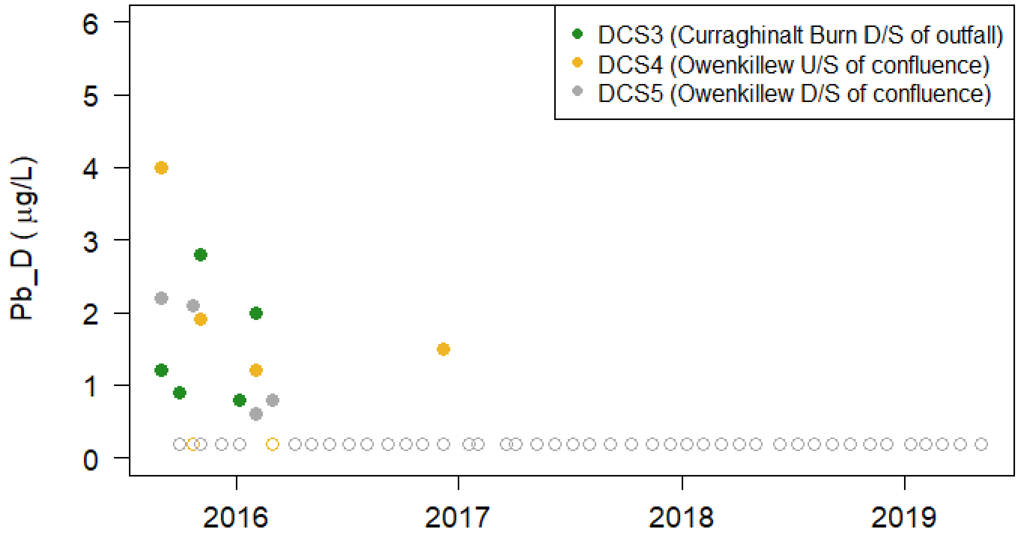


Figure 3-36. Timeseries of difference in Pb_D between Curraghinalt Burn samples downstream and upstream of the treatment plant outfall pipe.



A similar pattern was observed in the Owenkillew River (see Figure 3-37), with a period of elevated lead concentrations measured upstream and downstream of the confluence of the Curraghinalt Burn in late-2015, with no consistent trend of increasing concentrations downstream. From 2016 onwards, almost all measurements were below detection, indicating no measurable lead concentrations in the watercourse and no measurable effect of the mine discharge on lead concentrations in the Owenkillew River. All mean concentrations of dissolved lead are below the PGV of 7.2 µg/L.

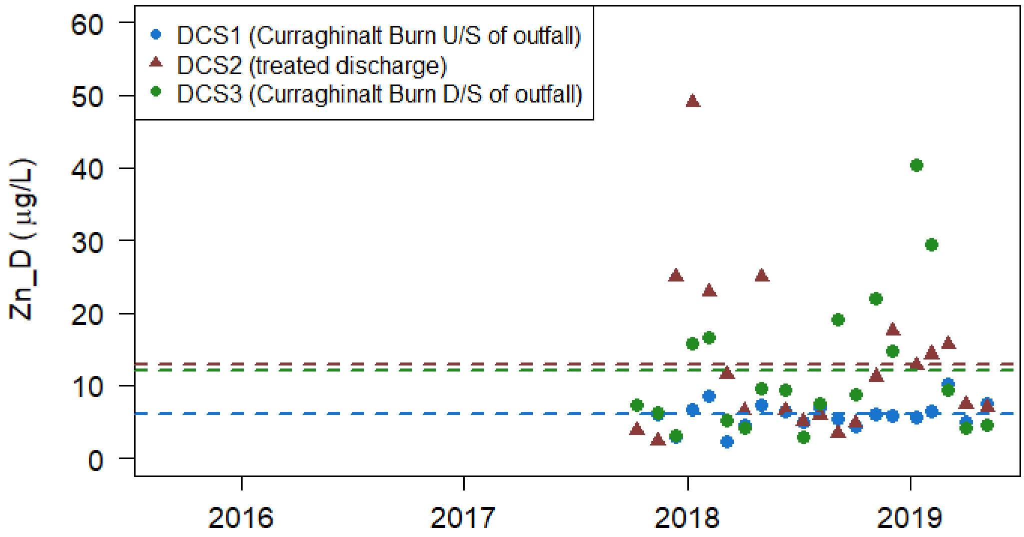
Figure 3-37. Dissolved lead measured along Owenkillew River; black dashed line is the discharge consent limit. Hollow data points indicate values that are below detection limit.



3.3.3.12 Zinc (Zn)

Dissolved zinc was only analysed in samples collected between mid-2017 and 2019. In these samples, mean dissolved zinc measured upstream of the water treatment plant outfall pipe was 6.06 µg/L; downstream of the outfall pipe mean zinc doubled, averaging 12.05 µg/L (see Figure 3-38). Mean dissolved zinc measured in the treated discharge was 12.9 µg/L.

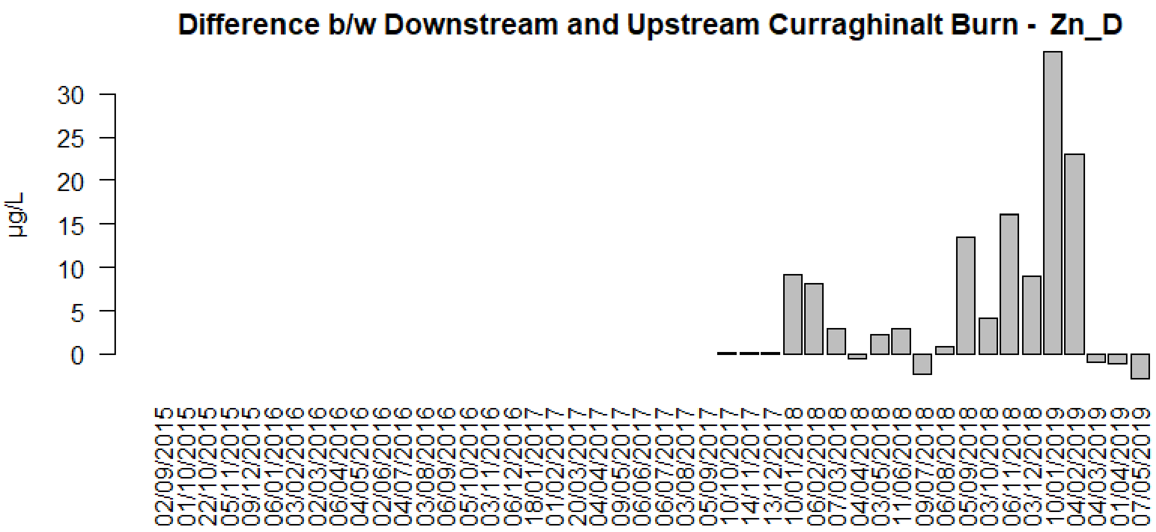
Figure 3-38. Dissolved zinc measured along Curraghinalt Burn; coloured dashed lines are sample averages by location.



Three values were recorded as exceeding the m-BAT tool back-calculated non-bioavailable zinc (i.e., dissolved zinc) EQS of 23 µg/L, with a maximum recorded concentration of 49 µg/L.

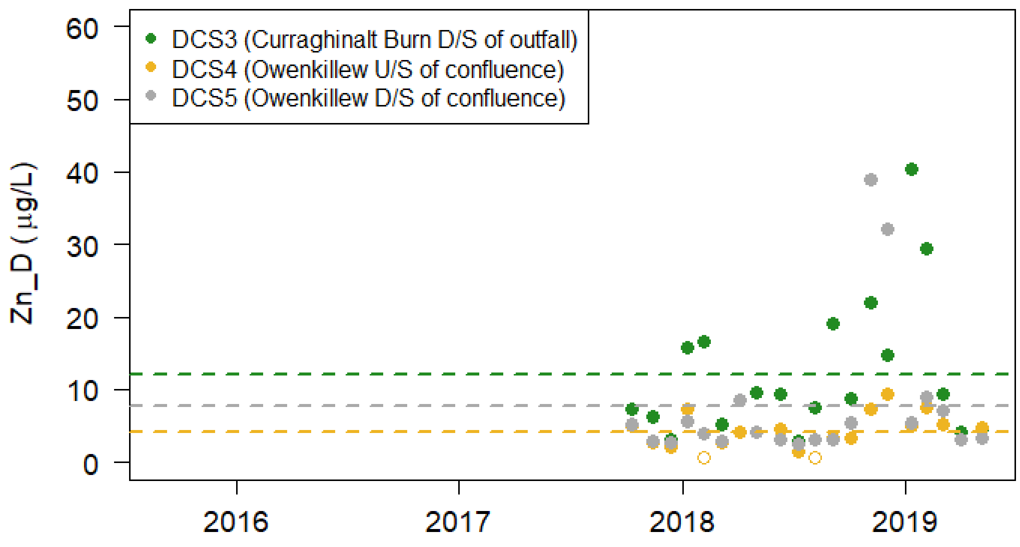
On a monthly basis, 75% of sampling rounds recorded increased dissolved zinc concentration downstream of the outfall pipe, with a maximum recorded increase of +34.8 µg/L. See Figure 3-39 for a timeseries of recorded differences between locations upstream and downstream of the outfall pipe.

Figure 3-39. Timeseries of difference in Zn_D between Curraghinalt Burn samples downstream and upstream of the treatment plant outfall pipe.



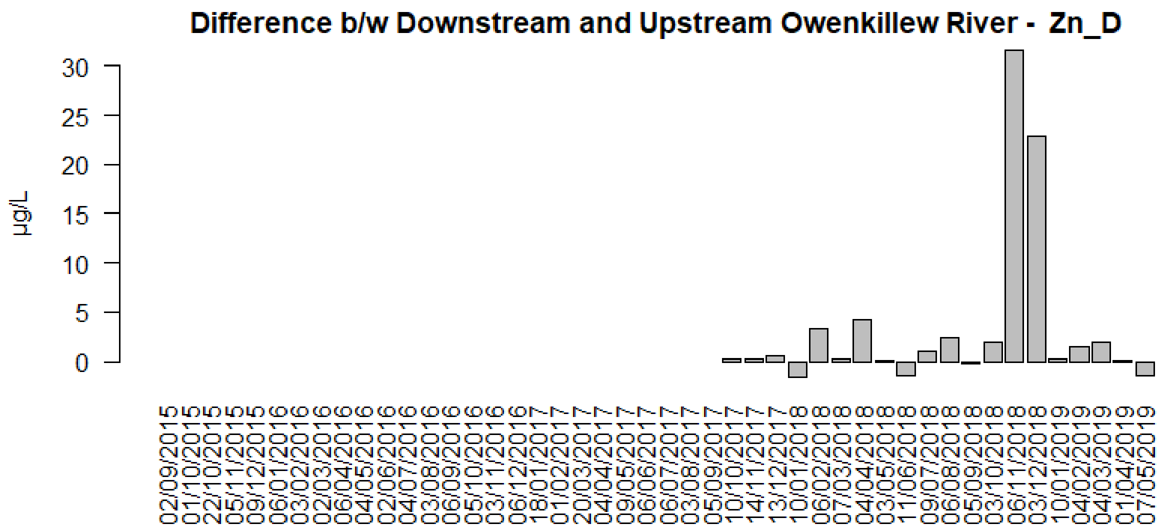
Mean dissolved zinc measured in the Owenkillew River upstream of the confluence with the Curraghinalt Burn was 4.26 µg/L; downstream of the confluence mean zinc increased to 7.64 µg/L (see Figure 3-40), below the dissolved zinc (non-bioavailable) EQS of 23 µg/L. Mean dissolved zinc measured downstream along the Curraghinalt Burn was 12.05 µg/L.

Figure 3-40. Dissolved zinc measured along Owenkillew River; coloured dashed lines are sample averages by location. Hollow data points indicate values that are below detection limit.



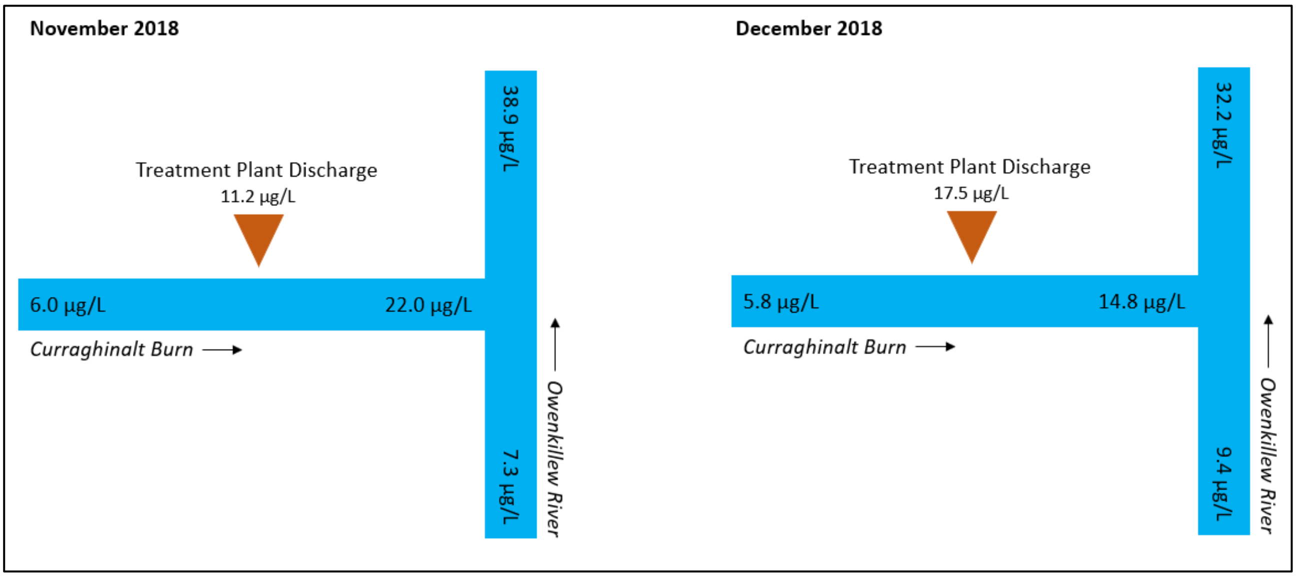
On a monthly basis, 75% of sampling rounds recorded increased dissolved zinc concentration downstream of the confluence, with a maximum recorded increase of +31.6 µg/L. See Figure 3-41 for a timeseries of recorded differences between locations up- and downstream of the confluence.

Figure 3-41. Timeseries of difference in Zn_D between Owenkillew River samples downstream and upstream of the confluence with the Curraghinalt Burn.



There are two instances of dissolved zinc exceeding the EQS of 23 µg/L downstream of the confluence with the Curraghinalt Burn. In these instances (November and December 2018), the concentration of dissolved zinc upstream of the confluence with the burn was below the EQS. However, dissolved zinc concentrations in both the discharge itself and downstream of the outfall pipe in the Curraghinalt Burn were below the EQS (see Figure 3-42). It is therefore unlikely that the concentration of dissolved zinc in the discharge caused the observed increases in zinc over the EQS downstream of the confluence.

Figure 3-42. Schematic of Zn_D concentrations recorded in the Curraghinalt Burn and Owenkillew River in November and December 2018.



The remaining 18 (of 20) sampling rounds show downstream concentrations of dissolved zinc of less than 9 µg/L, which is below the EQS of 23 µg/L. While there is an observable increase in dissolved zinc downstream of the confluence with the Curraghinalt Burn, the majority of sampling rounds show that the increased concentrations are still well below the EQS.

It is not possible to calculate bioavailable zinc for the samples taken along the Curraghinalt Burn or the Owenkillew River using the m-BAT tool, as the tool requires coincident values for dissolved organic carbon and dissolved calcium; these parameters were not analysed in the discharge consent samples (i.e., DCS1 to DCS5).

4 Summary and Conclusions

The report reviews the discharge consent values for the water treatment plant at the Site and proposes a variation to Water Licence 068/12/2. The proposed variations are shown in Table 4-1 below.

Table 4-1: Proposed Variations to Discharge Consent

Parameter	Symbol	Unit	Discharge consent concentration
Zinc (Total)	Zn_T	µg/L	Remove from consent
Zinc (Diss)	Zn_D	µg/L	Add to consent with values; 490 or 111*
Copper (Diss)	Cu_D	µg/L	Add bioavailable concentration to consent; 16.2 or 0.33*
*These refer to bioavailable concentrations of substances.			

The current and proposed discharge criteria were tested against standard calculations outlined in EA guidance for the assessment of discharge Licences. These included screening tests and Monte Carlo modelling. All discharge criteria were found to be compliant with the standard tests, indicating the criteria are protective of the receiving waters.

Forward calculations were made of the impact of discharges from the Site on water quality in the Owenkillew River, based on (i) assuming discharges were at the maximum allowed limit and (ii) based on historical data for discharges from the water treatment plant at the Site. The results of these calculations will be able to be used by DAERA for the Habitats Regulations Assessment.

A review was undertaken of the observed water quality within the Owenkillew River while the water treatment plant has been in operation. The analysis indicated that no observed samples in the discharge exceeded the discharge criteria. The analysis also concluded that there was no evidence of an increase in background concentrations in the Owenkillew River as a result of discharges from the water treatment plant.

It was not possible to calculate bioavailable zinc or copper for the discharge monitoring samples (i.e., DCS1 to DSC5) using the standard m-BAT tool, as the tool requires coincident values for dissolved organic carbon and dissolved calcium. These parameters were not analysed in the discharge monitoring samples to date as discharge concentrations were not compared to bioavailable concentrations. Going forward, it is recommended that the parameter analysis suite includes dissolved organic carbon and dissolved calcium, so that bioavailable concentrations are able to be calculated in the future.

5 Appendix 1: Summary of Flow Inputs to Calculations

The discharge compliance calculations require estimates of:

- Flow rates in the receiving water for the effluent discharge (i.e., Owenkillew River); and
- Flow rate for the discharge, which is the combination of flows from the adit and surface water runoff captured from the exploration site.

A detailed hydrological assessment of the Owenkillew River was undertaken for the Curraghinalt Mine EIA. The assessment calculated that;

- Annual average flow for the Owenkillew River upstream of Curraghinalt Burn was 3,000 L/s
- Annual 95%ile low flow at the same location was 800 L/s

These values are used in this assessment.

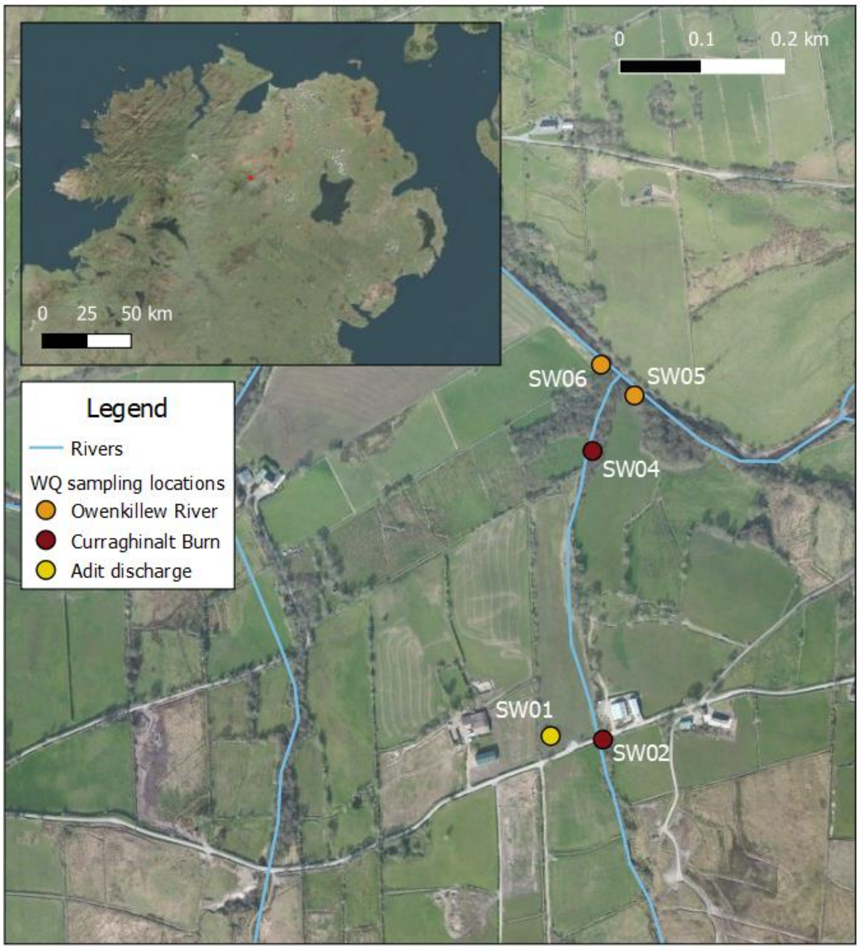
Monitoring records of discharge from the mine water treatment plant over a 7-month period (between February and August 2018) indicate a mean daily discharge rate of ~3.6 L/s, and a daily maximum rate of 9.4 L/s.

The calculations undertaken by Environ (*Environ (2013*) Revised Conceptual Design: Water Management and Treatment. Report for Dalradian Gold by Environ EC (Canada) Inc, May 2013) in support of the existing discharge permit are based on measured average flow rates from the adit ranging from 1.8 to 6.5 L/s. A conservative maximum discharge from the adit was assumed to be 9 L/s. The contribution from surface water runoff was considered to be 1.3 L/s for average flow conditions, falling to zero for dry weather conditions. This information would suggest an average treatment rate of 7.8 L/s (6.5 L/s adit flow and 1.3 L/s surface water runoff), with a maximum flow of around 10.3 L/s (9 L/s for adit flow and 1.3 L/s for surface water runoff). The average of these two flow rates (9.0 L/s) is used in the calculations in this report as the average flow rate from the water treatment plant. This value is used to provide a reasonably conservative value (above average rates), but one that is lower than the predicted and measured maximum values. However, in some cases the observed data is used to assess the impact of the discharge from the treatment plan on Owenkillew River quality.

6 Appendix 2: Summary of Background Water Quality Inputs to Calculations

Background water quality data for the discharge calculations are required for the Owenkillew River upstream of the Curraghinalt Burn. Water quality data for the Owenkillew River upstream of the confluence with the Curraghinalt Burn was taken from the DGL baseline sampling program point SW05 (E 257150, N 387077). The analysis is based on data from sampling rounds taken between June 2011 and January 2019. Figure A2-1 shows the location of SW05, as well as surrounding sampling locations along the Curraghinalt Burn and Owenkillew River. The other sampling points are discussed in more detail in the main body of the report.

Figure A2-1. Water quality sampling locations



In line with the Quality Assurance / Quality Control (QAQC) and data analysis methods performed in the 2019 'Addendum to Water Quality Baseline for Curraghinalt Mine Project', all data were subject to the following checks;

- Assessment of blank samples;
- Assessment of blind duplicates;
- Assessment of dissolved versus total metal concentrations;
- Assessment of field versus laboratory measurements;
- Identification of parameters recorded below detection and setting of below detection parameter values to ½ the analytical limit of detection; and the

- Identification and removal of recorded parameter outliers.

These are consistent with the data check requirements in the EA guidance LIT 10419 'Modelling: surface water pollution risk assessment'.

Results from the QAQC analysis are detailed in ES (2017; Appendix C3) for data collected prior to 2017; detailed QAQC results for data collected from 2017 – 2019 is can be found in the 2019 Baseline Addendum. Table A2-1 below provides a brief overview of the QAQC analysis results.

Table A2-1: Overview of QAQC analyses for water quality data

QAQC Check	Result
Blank samples	1 instance of BOD >5x LOD (2017-2019 data); 1 instance of Cr_D >5x LOD (2017-2019 data); Low levels of As, Cr, Cu, Fe, Ni and Zn in several samples (all data) – however low level 'trace concentrations' would not affect the results for other samples
Blind duplicates	All duplicates for SW05 (2017-2019) show good correlation (< ±20% relative percent difference); Pre-2017, 90.2% of duplicates (all samples, not just SW05) show good correlation
Dissolved vs Total Metals	For 2017-2019 data, 86% of sample (all samples, not just SW05) dissolved results are within 1.1x the total concentration; Pre-2017, 99.1% of the results (all samples, not just SW05) have a dissolved concentration less than the total metal concentration
Field vs Lab Measurements	For 2017-2019 data, generally poor correlation – could result from differences in instrument calibration or minor changes in sample composition between sampling and laboratory analysis; Pre-2017, generally good correlation between field and lab pH and EC
Parameters below detection	All values recorded below detection set to ½ analytical detection limit
Outliers	No outliers identified

Plots of SW05 water quality data for each parameter included in the discharge consent permit can be found below (Figures A2-2 to A2-13), along with Table A2-2, which lists each parameter and its respective limit(s) of detection. Also provided are the mean, median and 95%ile values used in the discharge calculations, as well as whether each parameter has a normal, log-normal or non-parametric distribution.

The only adjustment to the input data for the calculation of statistics is for dissolved mercury. For this parameter, 45 of the 51 total samples recorded below detection concentrations for a detection limit of 0.01 µg/L. Of the remaining 6 samples, one has a detection limit of 0.05 µg/L, one of 0.1 µg/L and four with 0.5 µg/L. If the samples with high detection limits are used when calculating average concentrations, they significantly distort the calculated statistics, suggesting a mean of 0.05 µg/L, when almost 90% of samples are below a detection limit of 0.01 µg/L. As the EQS for mercury is 0.07 µg/L, this would erroneously suggest that mean mercury concentrations in the Owenkillew River are close to the EQS. Therefore, for the statistics in Table A2-2 the five samples with the elevated detection limits (0.5 and 1 µg/L) are excluded. For all other parameters, there is a lower range of detection limits within the dataset. Where there are some elevated detection limits, they have a lower impact on the calculated statistics and/or the impact does not raise average concentrations close to an EQS, where the data would suggest this is not realistic.

Table A2-2: Parameters analysed for SW05, limits of detection (LOD), number of samples, mean, median and P95, and parameter distribution (N = normal, LN = log-normal, NP = non-parametric).

Parameter	Unit	LOD(s)	n	Mean	Median	P95	Std. Dev.	Distribution
pH	s.u.	0.01	36	7.06	7.10	8.00	0.66	NP
TSS	mg/L	10	48	6.7	5.0	19.5	6.46	NP
BOD	mg/L	1 or 2	29	1.1	0.5	3.0	0.92	NP
Zn_D*	µg/L	1.5	48	0.82	0.76	1.74	0.48	N, LN
Zn_D	µg/L	1.5	48	3.55	2.96	7.48	2.61	N, LN
Hg_D	µg/L	0.01, 0.1 or 0.5	46	0.0054	0.005	0.005	0.0029	NP
Cd_D	µg/L	0.03 or 0.6	38	0.028	0.015	0.08	0.027	NP
Fe_D	mg/L	0.002, 0.0047 or 0.02	48	0.87	0.87	1.47	0.39	N
Cu_D*	µg/L	0.3, 3 or 9	48	0.040	0.035	0.083	0.024	NP
Cu_D	µg/L	0.3, 3 or 9	48	1.08	1.0	1.69	0.51	NP
Cr_D	µg/L	0.2 or 2	48	0.64	0.21	1.62	1.22	NP
Ni_D*	µg/L	0.2	48	0.099	0.09	0.27	0.092	NP
Ni_D	µg/L	0.2	48	0.76	0.80	1.54	0.50	NP
As_D	µg/L	0.9 or 1	48	1.26	0.87	3.85	1.19	NP
Pb_D	µg/L	0.02, 0.4 or 6	48	0.45	0.20	1.50	0.55	NP

*Indicates bioavailable parameter concentration.

Figure A2-2. TSS concentration for sampling point SW05

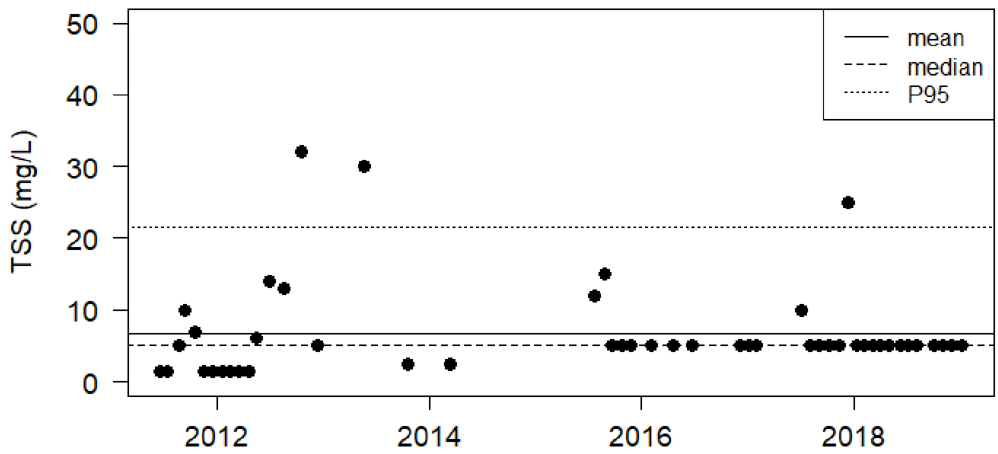


Figure A2-3. BOD concentration for sampling point SW05

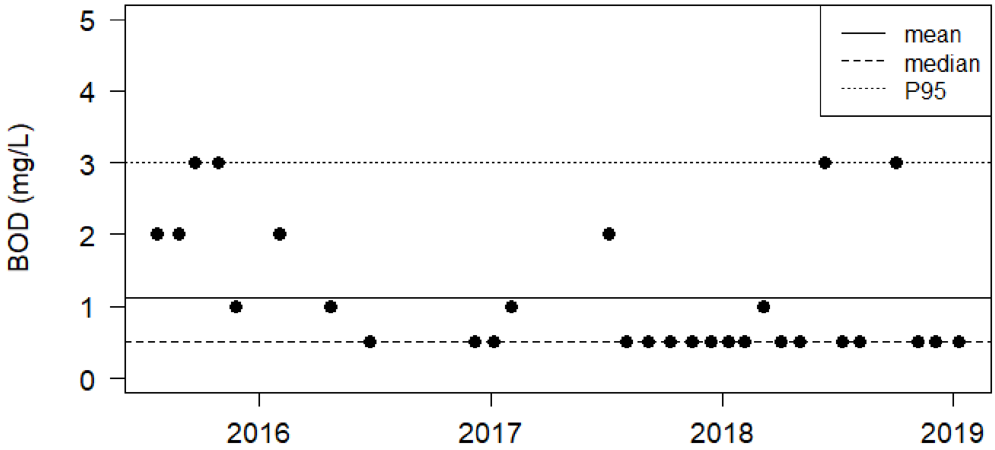


Figure A2-4. pH concentration for sampling point SW05

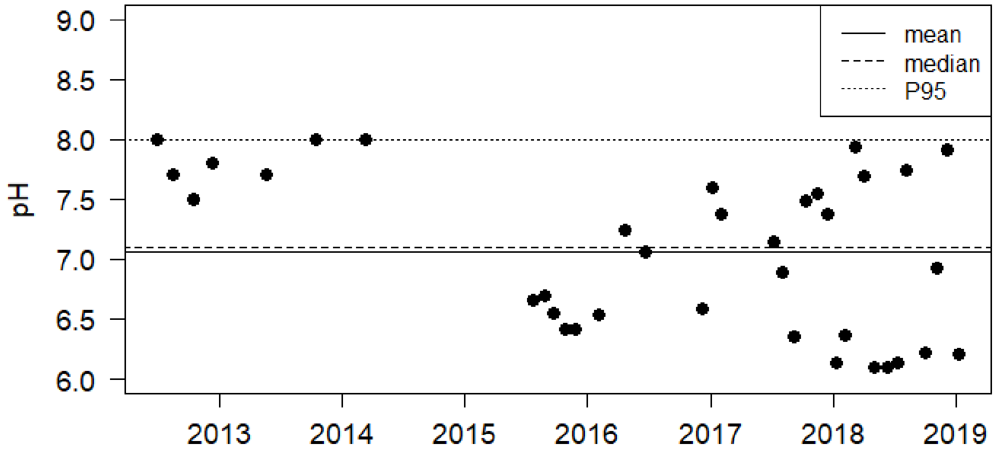


Figure A2-5. As_D concentration for sampling point SW05

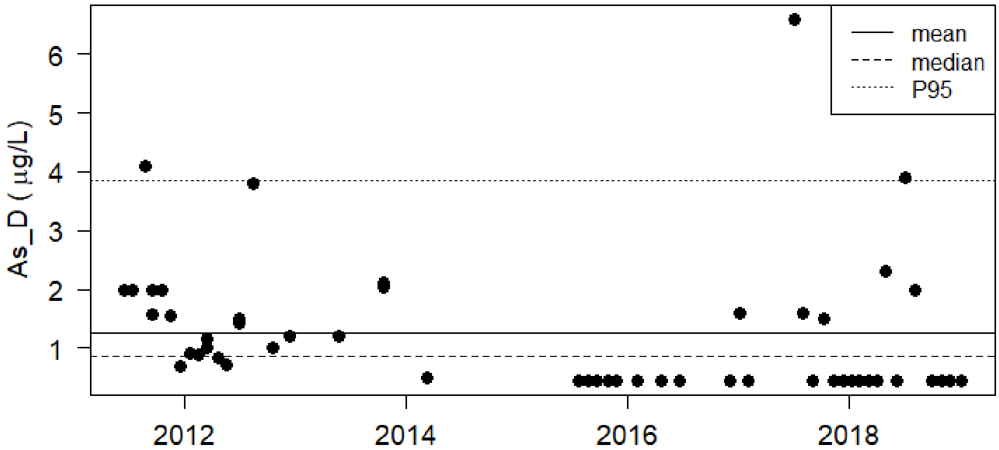


Figure A2-6. Cd_D concentration for sampling point SW05

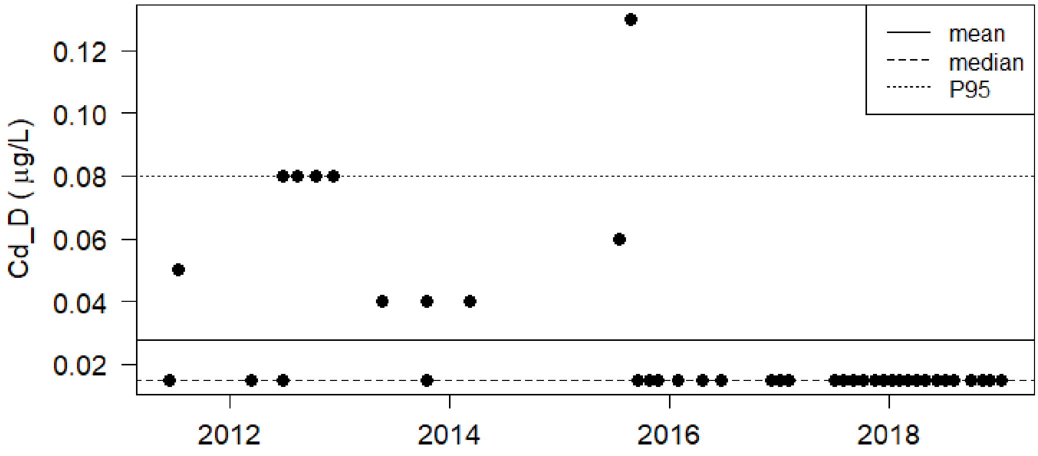


Figure A2-7. Bioavailable Cu concentration for sampling point SW05

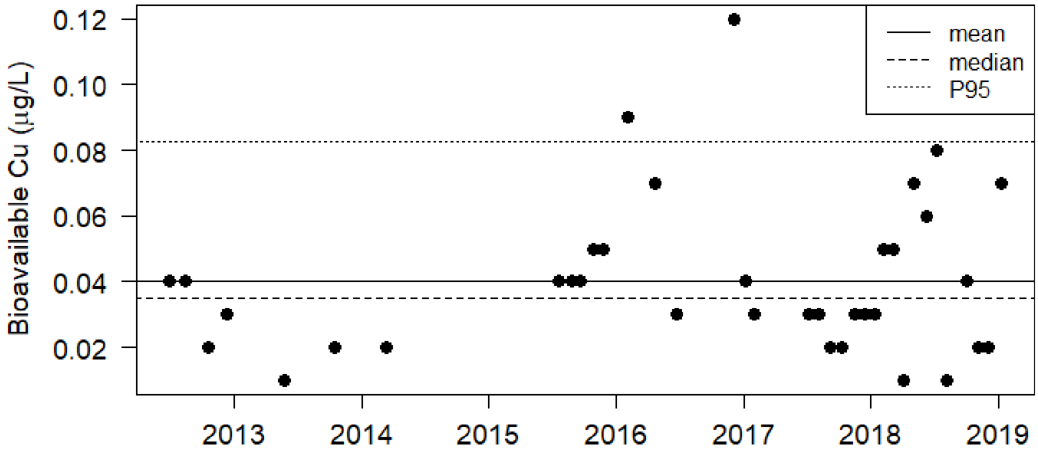


Figure A2-8. Cr_D concentration for sampling point SW05

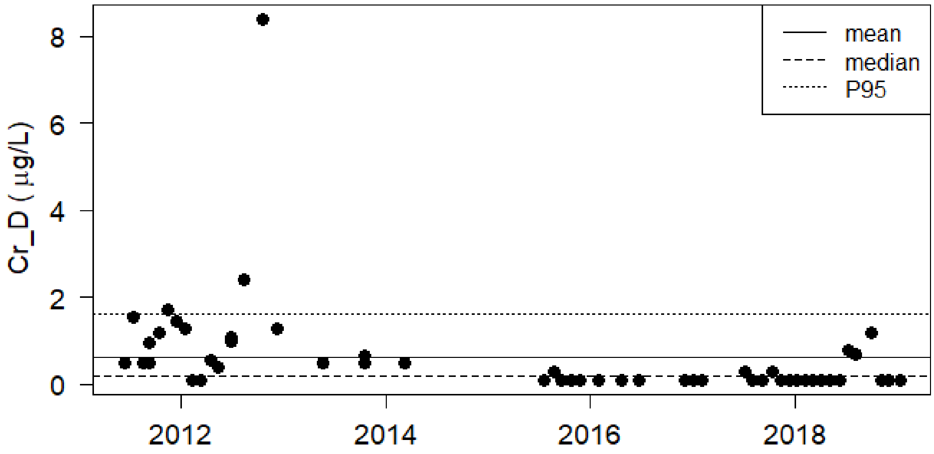


Figure A2-9. Fe_D concentration for sampling point SW05

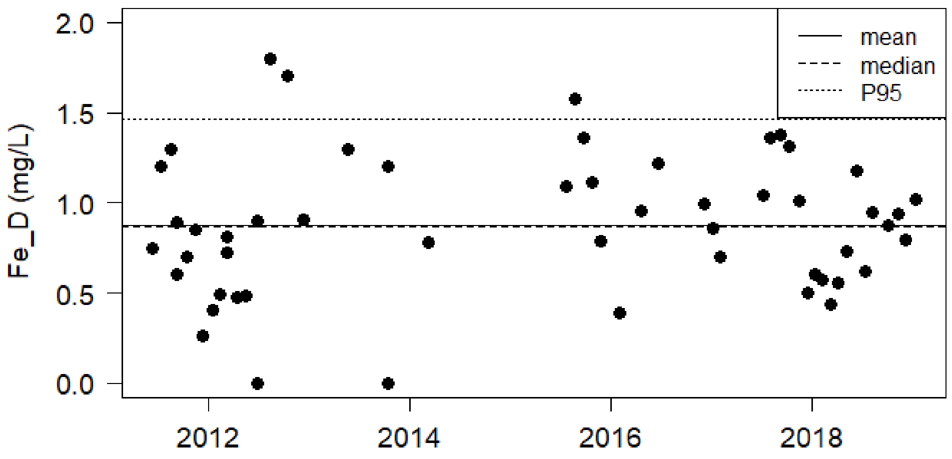


Figure A2-10. Hg_D concentration for sampling point SW05

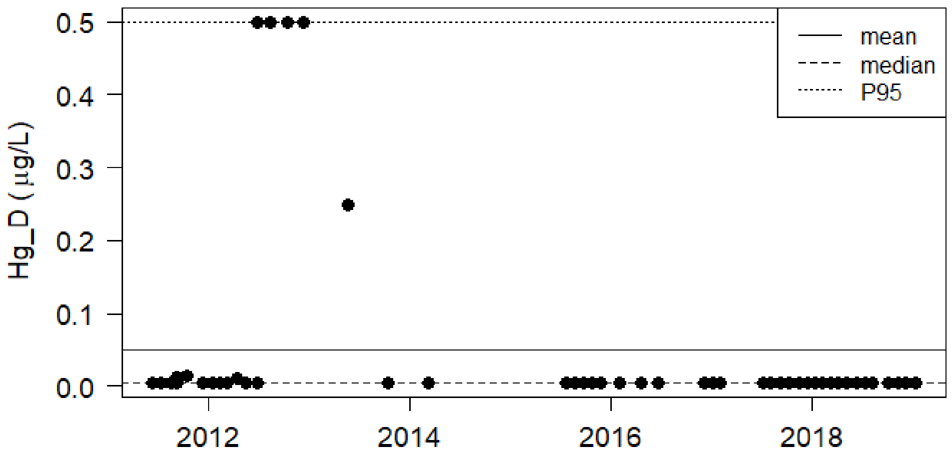


Figure A2-11. Bioavailable Ni concentration for sampling point SW05

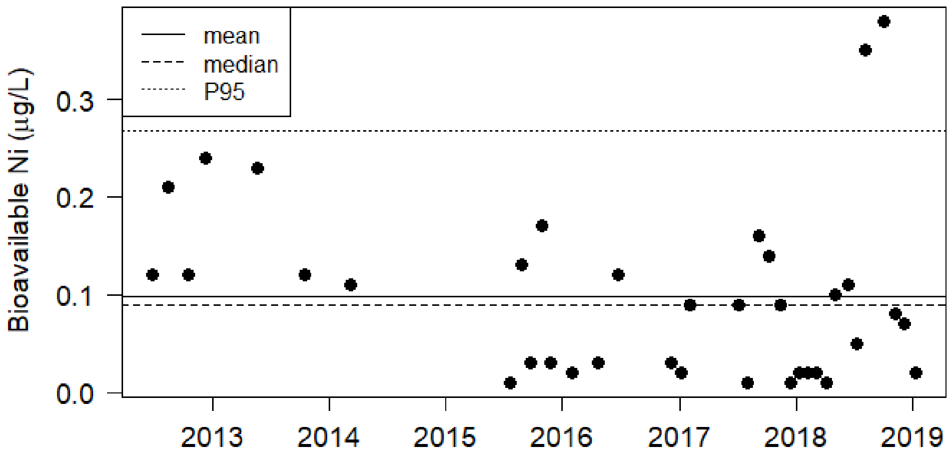


Figure A2-12. Pb_D concentration for sampling point SW05

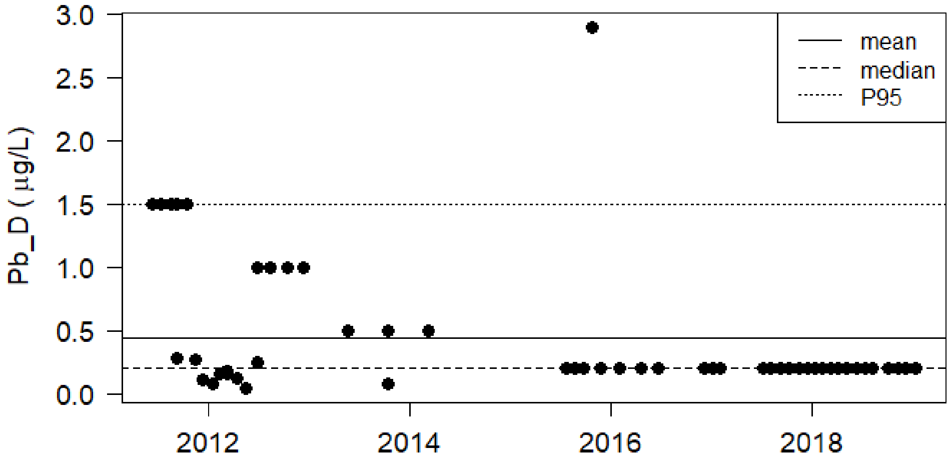
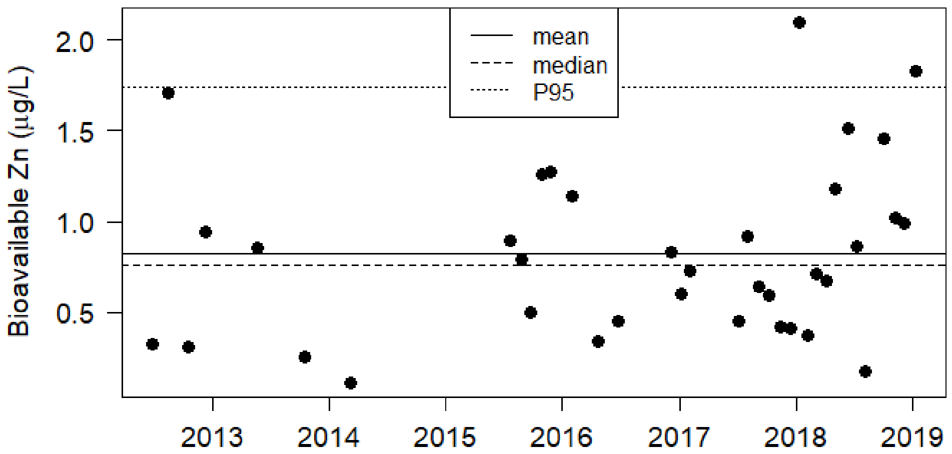


Figure A2-13. Bioavailable Zn concentration for sampling point SW05



7 Appendix 3: Conservative Forwards Calculations of Impact of Discharge on Owenkillew River Quality

Figure 7-1. Monte Carlo "Forwards" Calculation Conservative: TSS (in mg/L)

Name of discharge	Curraghinalt Mine Water Treatment Plant Discharge
Name of river	Owenkillew River
Name of determinand	TSS

UPSTREAM RIVER DATA		DISCHARGE DATA	
Mean flow	3000	Mean flow	9
95% exceedence flow	800	Standard deviation of flow	2.97
Mean quality	6.73	Mean quality	50
Standard deviation of river quality	6.46	Standard deviation of quality	0.00
90-percentile	13.67	... or 95-percentile	50.00

RIVER DOWNSTREAM OF DISCHARGE		DISCHARGE QUALITY	
Mean quality	7.02	Mean quality	50.00
Standard deviation of quality	6.77	Standard deviation of quality	0.00
90-percentile quality	13.84	95-percentile quality	50.00
95-percentile quality	26.54	99-percentile quality	50.00
99-percentile quality	32.65	99.5-percentile quality	50.00

Differences between the above values and the corresponding input data are due to the effect of the Monte Carlo sample.

Figure 7-2. Monte Carlo "Forwards" Calculation Conservative: BOD (in mg/L)

Name of discharge	Curraghinalt Mine Water Treatment Plant Discharge
Name of river	Owenkillew River
Name of determinand	BOD

UPSTREAM RIVER DATA		DISCHARGE DATA	
Mean flow	3000	Mean flow	9
95% exceedence flow	800	Standard deviation of flow	2.97
Mean quality	1.12	Mean quality	10
Standard deviation of river quality	0.92	Standard deviation of quality	0.00
90-percentile	2.17	... or 95-percentile	10.00

RIVER DOWNSTREAM OF DISCHARGE		DISCHARGE QUALITY	
Mean quality	1.16	Mean quality	10.00
Standard deviation of quality	0.92	Standard deviation of quality	0.00
90-percentile quality	3.02	95-percentile quality	10.00
95-percentile quality	3.03	99-percentile quality	10.00
99-percentile quality	3.06	99.5-percentile quality	10.00

Differences between the above values and the corresponding input data are due to the effect of the Monte Carlo sample.

Figure 7-3. Monte Carlo "Forwards" Calculation Conservative: Non-bioavailable Zn (in µg/L)

Name of discharge	Curraghinalt Mine Water Treatment Plant Discharge
Name of river	Owenkillew River
Name of determinand	Dissolved zinc (non-bioavailable)

UPSTREAM RIVER DATA		DISCHARGE DATA	
Mean flow	3000	Mean flow	9
95% exceedence flow	800	Standard deviation of flow	2.97
Mean quality	3.55	Mean quality	490
Standard deviation of river quality	2.61	Standard deviation of quality	0.00
90-percentile	6.64	... or 95-percentile	490.00

RIVER DOWNSTREAM OF DISCHARGE		DISCHARGE QUALITY	
Mean quality	5.59	Mean quality	490.00
Standard deviation of quality	2.95	Standard deviation of quality	0.00
90-percentile quality	9.09	95-percentile quality	490.00
95-percentile quality	10.67	99-percentile quality	490.00
99-percentile quality	16.12	99.5-percentile quality	490.00

Differences between the above values and the corresponding input data are due to the effect of the Monte Carlo sample.

Figure 7-4. Monte Carlo "Forwards" Calculation Conservative: Hg (in ng/L)

Name of discharge	Curraghinalt Mine Water Treatment Plant Discharge
Name of river	Owenkillew River
Name of determinand	Dissolved Mercury (ng/L)

UPSTREAM RIVER DATA		DISCHARGE DATA	
Mean flow	3000	Mean flow	9
95% exceedence flow	800	Standard deviation of flow	2.97
Mean quality	5.00	Mean quality	1700
Standard deviation of river quality	0.00	Standard deviation of quality	0
90-percentile	5.00	... or 95-percentile	1700.0

RIVER DOWNSTREAM OF DISCHARGE		DISCHARGE QUALITY	
Mean quality	12.01	Mean quality	1700.0
Standard deviation of quality	3.92	Standard deviation of quality	0.00
90-percentile quality	17.28	95-percentile quality	1700.0
95-percentile quality	19.78	99-percentile quality	1700.0
99-percentile quality	25.45	99.5-percentile quality	1700.0

Differences between the above values and the corresponding input data are due to the effect of the Monte Carlo sample.

Figure 7-5. Monte Carlo "Forwards" Calculation Conservative: Cd (note concentrations in ng/L)

Name of discharge	Curraghinalt Mine Water Treatment Plant Discharge
Name of river	Owenkillew River
Name of determinand	Dissolved Cadmium (ng/L)

UPSTREAM RIVER DATA		DISCHARGE DATA	
Mean flow	3000	Mean flow	9
95% exceedence flow	800	Standard deviation of flow	2.97
Mean quality	31.71	Mean quality	700
Standard deviation of river quality	24.79	Standard deviation of quality	0
90-percentile	60.52	... or 95-percentile	700.00

RIVER DOWNSTREAM OF DISCHARGE		DISCHARGE QUALITY	
Mean quality	35.46	Mean quality	700.00
Standard deviation of quality	27.20	Standard deviation of quality	0.00
90-percentile quality	81.66	95-percentile quality	700.00
95-percentile quality	84.23	99-percentile quality	700.00
99-percentile quality	148.66	99.5-percentile quality	700.00

Differences between the above values and the corresponding input data are due to the effect of the Monte Carlo sample.

Figure 7-6. Monte Carlo "Forwards" Calculation Conservative: Fe (in mg/L)

Name of discharge	Curraghinalt Mine Water Treatment Plant Discharge
Name of river	Owenkillew River
Name of determinand	Dissolved iron

UPSTREAM RIVER DATA		DISCHARGE DATA	
Mean flow	3000	Mean flow	9
95% exceedence flow	800	Standard deviation of flow	2.97
Mean quality	0.87	Mean quality	3.9
Standard deviation of river quality	0.39	Standard deviation of quality	0.00
90-percentile	1.37	... or 95-percentile	3.90

RIVER DOWNSTREAM OF DISCHARGE		DISCHARGE QUALITY	
Mean quality	0.89	Mean quality	3.90
Standard deviation of quality	0.39	Standard deviation of quality	0.02
90-percentile quality	1.38	95-percentile quality	3.90
95-percentile quality	1.61	99-percentile quality	3.90
99-percentile quality	2.16	99.5-percentile quality	3.90

Differences between the above values and the corresponding input data are due to the effect of the Monte Carlo sample.

Figure 7-7. Monte Carlo "Forwards" Calculation Conservative: Non-bioavailable Cu (in µg/L)

Name of discharge	Curraghinalt Mine Water Treatment Plant Discharge
Name of river	Owenkillew River
Name of determinand	Dissolved Copper (non bioavailable)

UPSTREAM RIVER DATA	
Mean flow	3000
95% exceedence flow	800
Mean quality	1.08
Standard deviation of river quality	0.51
90-percentile	1.74

DISCHARGE DATA	
Mean flow	9
Standard deviation of flow	2.97
Mean quality	16.2
Standard deviation of quality	0.00
... or 95-percentile	16.2

RIVER DOWNSTREAM OF DISCHARGE	
Mean quality	1.15
Standard deviation of quality	0.52
90-percentile quality	1.68
95-percentile quality	1.80
99-percentile quality	2.63

DISCHARGE QUALITY	
Mean quality	16.20
Standard deviation of quality	0.00
95-percentile quality	16.20
99-percentile quality	16.20
99.5-percentile quality	16.20

Differences between the above values and the corresponding input data are due to the effect of the Monte Carlo sample.

Figure 7-8. Monte Carlo "Forwards" Calculation Conservative: Cr (in µg/L)

Name of discharge	Curraghinalt Mine Water Treatment Plant Discharge
Name of river	Owenkillew River
Name of determinand	Dissolved chromium

UPSTREAM RIVER DATA	
Mean flow	3000
95% exceedence flow	800
Mean quality	0.64
Standard deviation of river quality	1.22
90-percentile	1.45

DISCHARGE DATA	
Mean flow	9
Standard deviation of flow	2.97
Mean quality	8.1
Standard deviation of quality	0.00
... or 95-percentile	8.10

RIVER DOWNSTREAM OF DISCHARGE	
Mean quality	0.74
Standard deviation of quality	1.54
90-percentile quality	1.43
95-percentile quality	1.94
99-percentile quality	10.13

DISCHARGE QUALITY	
Mean quality	8.10
Standard deviation of quality	0.00
95-percentile quality	8.10
99-percentile quality	8.10
99.5-percentile quality	8.10

Differences between the above values and the corresponding input data are due to the effect of the Monte Carlo sample.

Figure 7-9. Monte Carlo "Forwards" Calculation Conservative: Non-bioavailable Ni (in µg/L)

Name of discharge	Curraghinalt Mine Water Treatment Plant Discharge
Name of river	Owenkillew River
Name of determinand	Dissolve nickel (non-bioavailable)

UPSTREAM RIVER DATA		DISCHARGE DATA	
Mean flow	3000	Mean flow	9
95% exceedence flow	800	Standard deviation of flow	2.97
Mean quality	0.76	Mean quality	20
Standard deviation of river quality	0.50	Standard deviation of quality	0.00
90-percentile	1.36	... or 95-percentile	20.00

RIVER DOWNSTREAM OF DISCHARGE		DISCHARGE QUALITY	
Mean quality	0.83	Mean quality	20.00
Standard deviation of quality	0.51	Standard deviation of quality	0.01
90-percentile quality	1.44	95-percentile quality	20.00
95-percentile quality	1.79	99-percentile quality	20.00
99-percentile quality	2.13	99.5-percentile quality	20.00

Differences between the above values and the corresponding input data are due to the effect of the Monte Carlo sample.

Figure 7-10. Monte Carlo "Forwards" Calculation Conservative: As (in µg/L)

Name of discharge	Curraghinalt Mine Water Treatment Plant Discharge
Name of river	Owenkillew River
Name of determinand	Dissolved arsenic

UPSTREAM RIVER DATA		DISCHARGE DATA	
Mean flow	3000	Mean flow	9
95% exceedence flow	800	Standard deviation of flow	2.97
Mean quality	1.26	Mean quality	50
Standard deviation of river quality	1.19	Standard deviation of quality	0.00
90-percentile	2.55	... or 95-percentile	50.00

RIVER DOWNSTREAM OF DISCHARGE		DISCHARGE QUALITY	
Mean quality	1.50	Mean quality	50.00
Standard deviation of quality	1.32	Standard deviation of quality	0.00
90-percentile quality	2.52	95-percentile quality	50.00
95-percentile quality	4.16	99-percentile quality	50.00
99-percentile quality	7.49	99.5-percentile quality	50.00

Differences between the above values and the corresponding input data are due to the effect of the Monte Carlo sample.

Figure 7-11. Monte Carlo "Forwards" Calculation Conservative: Pb (in µg/L)

Name of discharge	Curraghinalt Mine Water Treatment Plant Discharge
Name of river	Owenkillew River
Name of determinand	Dissolved lead

UPSTREAM RIVER DATA

Mean flow	3000
95% exceedence flow	800
Mean quality	0.45
Standard deviation of river quality	0.55
90-percentile	0.97

DISCHARGE DATA

Mean flow	9
Standard deviation of flow	2.97
Mean quality	7.2
Standard deviation of quality	0.00
... or 95-percentile	7.20

RIVER DOWNSTREAM OF DISCHARGE

Mean quality	0.49
Standard deviation of quality	0.61
90-percentile quality	1.51
95-percentile quality	1.54
99-percentile quality	3.32

DISCHARGE QUALITY

Mean quality	7.20
Standard deviation of quality	0.00
95-percentile quality	7.20
99-percentile quality	7.20
99.5-percentile quality	7.20

Differences between the above values and the corresponding input data are due to the effect of the Monte Carlo sample.

8 Appendix 4: Forwards Calculations of Impact of Discharge on Owenkillew River Quality Based on Observed Water Quality

Figure 8-1. Monte Carlo "Forwards" Calculation Observed: TSS (in mg/L)

Name of discharge	Curraghinalt Mine Water Treatment Plant Discharge
Name of river	Owenkillew River
Name of determinand	TSS (mg/L)

UPSTREAM RIVER DATA		DISCHARGE DATA	
Mean flow	3000	Mean flow	3.6
95% exceedence flow	800	Standard deviation of flow	1.2
Mean quality	6.73	Mean quality	5.61
Standard deviation of river quality	6.46	Standard deviation of quality	2.07
90-percentile	13.67	... or 95-percentile	9.47

RIVER DOWNSTREAM OF DISCHARGE		DISCHARGE QUALITY	
Mean quality	6.84	Mean quality	5.61
Standard deviation of quality	6.79	Standard deviation of quality	2.10
90-percentile quality	13.59	95-percentile quality	11.22
95-percentile quality	26.35	99-percentile quality	15.81
99-percentile quality	32.56	99.5-percentile quality	16.38

Differences between the above values and the corresponding input data are due to the effect of the Monte Carlo sample.

Figure 8-2. Monte Carlo "Forwards" Calculation Observed: BOD (in mg/L)

Name of discharge	Curraghinalt Mine Water Treatment Plant Discharge
Name of river	Owenkillew River
Name of determinand	BOD (mg/L)

UPSTREAM RIVER DATA		DISCHARGE DATA	
Mean flow	3000	Mean flow	9
95% exceedence flow	800	Standard deviation of flow	2.97
Mean quality	1.12	Mean quality	0.98
Standard deviation of river quality	0.92	Standard deviation of quality	0.80
90-percentile	2.17	... or 95-percentile	2.46

RIVER DOWNSTREAM OF DISCHARGE		DISCHARGE QUALITY	
Mean quality	1.12	Mean quality	0.95
Standard deviation of quality	0.92	Standard deviation of quality	0.78
90-percentile quality	2.99	95-percentile quality	3.00
95-percentile quality	2.99	99-percentile quality	3.00
99-percentile quality	3.00	99.5-percentile quality	3.00

Differences between the above values and the corresponding input data are due to the effect of the Monte Carlo sample.

Figure 8-3. Monte Carlo "Forwards" Calculation Observed: Non-bioavailable Zn (in µg/L)

Name of discharge	Curraghinalt Mine Water Treatment Plant Discharge
Name of river	Owenkillew River
Name of determinand	Dissolved Zinc (ug/L)

UPSTREAM RIVER DATA		DISCHARGE DATA	
Mean flow	3000	Mean flow	3.6
95% exceedence flow	800	Standard deviation of flow	1.2
Mean quality	3.55	Mean quality	12.9
Standard deviation of river quality	2.61	Standard deviation of quality	11.1
90-percentile	6.64	... or 95-percentile	33.27

RIVER DOWNSTREAM OF DISCHARGE		DISCHARGE QUALITY	
Mean quality	3.60	Mean quality	13.25
Standard deviation of quality	2.70	Standard deviation of quality	10.67
90-percentile quality	6.60	95-percentile quality	33.79
95-percentile quality	8.39	99-percentile quality	53.79
99-percentile quality	13.14	99.5-percentile quality	61.01

Differences between the above values and the corresponding input data are due to the effect of the Monte Carlo sample.

Figure 8-4. Monte Carlo "Forwards" Calculation Observed: Hg (in ng/L)

Name of discharge	Curraghinalt Mine Water Treatment Plant Discharge
Name of river	Owenkillew River
Name of determinand	Dissolved Mercury (ng/L)

UPSTREAM RIVER DATA		DISCHARGE DATA	
Mean flow	3000	Mean flow	3.6
95% exceedence flow	800	Standard deviation of flow	1.2
Mean quality	5.00	Mean quality	220.76
Standard deviation of river quality	0.00	Standard deviation of quality	148.58
90-percentile	5.00	... or 95-percentile	500.55

RIVER DOWNSTREAM OF DISCHARGE		DISCHARGE QUALITY	
Mean quality	5.34	Mean quality	214.28
Standard deviation of quality	0.34	Standard deviation of quality	150.29
90-percentile quality	5.77	95-percentile quality	500.00
95-percentile quality	5.98	99-percentile quality	627.04
99-percentile quality	6.48	99.5-percentile quality	646.01

Differences between the above values and the corresponding input data are due to the effect of the Monte Carlo sample.

Figure 8-5. Monte Carlo "Forwards" Calculation Observed: Cd (note concentrations in ng/L)

Name of discharge	Curraghinalt Mine Water Treatment Plant Discharge
Name of river	Owenkillew River
Name of determinand	Dissolved Cadmium (ng/L)

UPSTREAM RIVER DATA		DISCHARGE DATA	
Mean flow	3000	Mean flow	3.6
95% exceedence flow	800	Standard deviation of flow	1.6
Mean quality	31.71	Mean quality	49.78
Standard deviation of river quality	24.79	Standard deviation of quality	96.34
90-percentile	60.52	... or 95-percentile	177.98

RIVER DOWNSTREAM OF DISCHARGE		DISCHARGE QUALITY	
Mean quality	32.72	Mean quality	49.18
Standard deviation of quality	27.19	Standard deviation of quality	95.52
90-percentile quality	79.86	95-percentile quality	273.85
95-percentile quality	80.03	99-percentile quality	448.93
99-percentile quality	146.76	99.5-percentile quality	462.20

Differences between the above values and the corresponding input data are due to the effect of the Monte Carlo sample.

Figure 8-6. Monte Carlo "Forwards" Calculation Observed: Fe (in mg/L)

Name of discharge	Curraghinalt Mine Water Treatment Plant Discharge
Name of river	Owenkillew River
Name of determinand	Dissolved Iron (mg/L)

UPSTREAM RIVER DATA		DISCHARGE DATA	
Mean flow	3000	Mean flow	3.6
95% exceedence flow	800	Standard deviation of flow	1.6
Mean quality	0.87	Mean quality	0.33
Standard deviation of river quality	0.39	Standard deviation of quality	0.41
90-percentile	1.37	... or 95-percentile	1.01

RIVER DOWNSTREAM OF DISCHARGE		DISCHARGE QUALITY	
Mean quality	0.87	Mean quality	0.34
Standard deviation of quality	0.39	Standard deviation of quality	0.38
90-percentile quality	1.37	95-percentile quality	1.03
95-percentile quality	1.60	99-percentile quality	1.89
99-percentile quality	2.14	99.5-percentile quality	2.23

Differences between the above values and the corresponding input data are due to the effect of the Monte Carlo sample.

Figure 8-7. Monte Carlo "Forwards" Calculation Observed: Non-bioavailable Cu (in ug/L)

Name of discharge	Curraghinalt Mine Water Treatment Plant Discharge
Name of river	Owenkillew River
Name of determinand	Dissolved Copper (ug/L)

UPSTREAM RIVER DATA		DISCHARGE DATA	
Mean flow	3000	Mean flow	3.6
95% exceedence flow	800	Standard deviation of flow	1.6
Mean quality	1.08	Mean quality	1.53
Standard deviation of river quality	0.51	Standard deviation of quality	0.42
90-percentile	1.74	... or 95-percentile	2.29

RIVER DOWNSTREAM OF DISCHARGE		DISCHARGE QUALITY	
Mean quality	1.08	Mean quality	1.53
Standard deviation of quality	0.52	Standard deviation of quality	0.53
90-percentile quality	1.61	95-percentile quality	1.50
95-percentile quality	1.73	99-percentile quality	4.68
99-percentile quality	2.57	99.5-percentile quality	5.15

Differences between the above values and the corresponding input data are due to the effect of the Monte Carlo sample.

Figure 8-8. Monte Carlo "Forwards" Calculation Observed: Cr (in ug/L)

Name of discharge	Curraghinalt Mine Water Treatment Plant Discharge
Name of river	Owenkillew River
Name of determinand	Dissolved Chromium (ug/L)

UPSTREAM RIVER DATA		DISCHARGE DATA	
Mean flow	3000	Mean flow	3.6
95% exceedence flow	800	Standard deviation of flow	1.6
Mean quality	0.64	Mean quality	0.32
Standard deviation of river quality	1.22	Standard deviation of quality	0.42
90-percentile	1.45	... or 95-percentile	1.01

RIVER DOWNSTREAM OF DISCHARGE		DISCHARGE QUALITY	
Mean quality	0.71	Mean quality	0.32
Standard deviation of quality	1.55	Standard deviation of quality	0.44
90-percentile quality	1.38	95-percentile quality	1.17
95-percentile quality	1.91	99-percentile quality	2.42
99-percentile quality	10.12	99.5-percentile quality	2.57

Differences between the above values and the corresponding input data are due to the effect of the Monte Carlo sample.

Figure 8-9. Monte Carlo "Forwards" Calculation Observed: Non-bioavailable Ni (in ug/L)

Name of discharge	Curraghinalt Mine Water Treatment Plant Discharge
Name of river	Owenkillew River
Name of determinand	Dissolved Nickel (ug/L)

UPSTREAM RIVER DATA		DISCHARGE DATA	
Mean flow	3000	Mean flow	3.6
95% exceedence flow	800	Standard deviation of flow	1.6
Mean quality	0.76	Mean quality	4.06
Standard deviation of river quality	0.50	Standard deviation of quality	1.40
90-percentile	1.36	... or 95-percentile	6.66

RIVER DOWNSTREAM OF DISCHARGE		DISCHARGE QUALITY	
Mean quality	0.76	Mean quality	4.00
Standard deviation of quality	0.51	Standard deviation of quality	1.41
90-percentile quality	1.36	95-percentile quality	6.54
95-percentile quality	1.73	99-percentile quality	8.16
99-percentile quality	2.06	99.5-percentile quality	8.28

Differences between the above values and the corresponding input data are due to the effect of the Monte Carlo sample.

Figure 8-10. Monte Carlo "Forwards" Calculation Observed: As (in ug/L)

Name of discharge	Curraghinalt Mine Water Treatment Plant Discharge
Name of river	Owenkillew River
Name of determinand	Dissolved Arsenic (ug/L)

UPSTREAM RIVER DATA		DISCHARGE DATA	
Mean flow	3000	Mean flow	3.6
95% exceedence flow	800	Standard deviation of flow	1.6
Mean quality	1.26	Mean quality	1.72
Standard deviation of river quality	1.19	Standard deviation of quality	1.66
90-percentile	2.55	... or 95-percentile	4.70

RIVER DOWNSTREAM OF DISCHARGE		DISCHARGE QUALITY	
Mean quality	1.30	Mean quality	1.69
Standard deviation of quality	1.31	Standard deviation of quality	1.66
90-percentile quality	2.22	95-percentile quality	4.94
95-percentile quality	3.95	99-percentile quality	6.94
99-percentile quality	7.32	99.5-percentile quality	7.11

Differences between the above values and the corresponding input data are due to the effect of the Monte Carlo sample.

Figure 8-11. Monte Carlo “Forwards” Calculation Observed: Pb (in ug/L)

Name of discharge	Curraghinalt Mine Water Treatment Plant Discharge
Name of river	Owenkillew River
Name of determinand	Dissolved lead (ug/L; observed data)

UPSTREAM RIVER DATA		DISCHARGE DATA	
Mean flow	3000	Mean flow	3.6
95% exceedence flow	800	Standard deviation of flow	1.6
Mean quality	0.45	Mean quality	0.61
Standard deviation of river quality	0.55	Standard deviation of quality	1.30
90-percentile	0.97	... or 95-percentile	2.24

RIVER DOWNSTREAM OF DISCHARGE		DISCHARGE QUALITY	
Mean quality	0.47	Mean quality	0.61
Standard deviation of quality	0.61	Standard deviation of quality	1.33
90-percentile quality	1.50	95-percentile quality	3.84
95-percentile quality	1.50	99-percentile quality	6.99
99-percentile quality	3.30	99.5-percentile quality	7.33

Differences between the above values and the corresponding input data are due to the effect of the Monte Carlo sample.