## Dalradian Gold Limited

# Proposed Discharge Criteria for Owenkillew River and Curraghinalt Burn, Gortin, County Tyrone, BT79 7SF

## Curraghinalt Mine

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# 1 Introduction

This technical report is prepared in support of the application for a Water Licence for discharge into the Curraghinalt Burn (a tributary to the Owenkillew River) at Curraghinalt, Gortin, County Tyrone, BT79 7SF (Irish Gird Co-ords E257063.7, N386658.6) ('the Site').

The report starts with a review of the standard methods for the assessment of discharge criteria for watercourses. Discharge criteria for the Water Licence are then proposed, and calculations undertaken to predict the impact of discharges from the Site on the receiving water quality in the Curraghinalt Burn and Owenkillew River.

The set of water quality parameters for which a Water Licence is applied is based on a scoping assessment that considered (i) whether there were potential sources of the parameter within the mine site and (ii) whether there are environmental standards or guidelines that can be used to assess the parameter.

A summary of the selection of parameters for the assessment is provided in Tables 1-1 and 1-2. Parameters not identified as 'included' in the assessment are scoped out of further calculations.

As part of the Environmental Impact Assessment for the Curraghinalt Mine Project, the Curraghinalt Burn was identified as being of low ecological sensitivity and the Owenkillew River identified as being of high ecological sensitivity. Based on this work environmental standards for the protection of aquatic life are applied at the Owenkillew River, with standards for human drinking water applied in the Curraghinalt Burn.

It is noted that water licence calculations were presented as an Appendix to the project Environmental Statement (ES) (Surface Water Impact Assessment – Annex B). The calculations presented in this report follow the same England and Wales Environment Agency (EA) methods, but provide a more detailed assessment, based on discussions with NIEA and the use of the EA Monte Carlo analysis methodology. In addition, the following other updates are made to the calculations:

- Baseline water quality data for the Curraghinalt Burn and Owenkillew River have been updated to be consistent with the updated baseline report provided in the 2019 ES Addendum.
- Cyanide has been removed from the list of parameters considered for the water licence application, as cyanide has been removed from the mine process and is no longer considered a parameter of concern; there is no source of cyanide at the mine site.
- A review of environmental and drinking water standards has been undertaken, with updates to bio-available Environmental Quality Standards (EQS) and Drinking Water Standards to a wider range of parameters.

As a result of the above, there are changes to the proposed discharge criteria compared to those in the Environmental Statement (ES), although the approach to the assessment of downstream effects remains the same and the downstream effects are consistent with allowed changes based on EA and NIEA guidance. A comparison between the criteria presented in the ES and proposed for this application is provided at the end of this report.

**Table 1-1: Summary of Scoping Assessment for Water Quality Parameters (excluding metals)**

| Parameters | Units | Included in Assessment |
|---|---|---|
| ***Physical Parameters*** | | |
| pH (Lab) | s.u | Included |
| EC (Lab) | µS/cm | No NI standard and not considered parameter of concern at mine |
| TDS | mg/L | No NI standard and not considered parameter of concern at mine |
| TSS | mg/L | Included |
| Temperature | ºC | Included |
| ***Anions and Nutrients*** | | |
| Alkalinity | mg/L as $CaCO_3$ | No NI standard and not considered parameter of concern at mine |
| Chloride | mg/L | Included |
| Sulphate | mg/L | Included |
| Fluoride | mg/L | Included |
| Calcium | mg/L | No NI standard and not considered parameter of concern at mine |
| Potassium | mg/L | No NI standard and not considered parameter of concern at mine |
| Magnesium | mg/L | No NI standard and not considered parameter of concern at mine |
| Sodium | mg/L | Included |
| Total Ammonia | mg/L as N | Included |
| Nitrite | mg/L as N | Included |
| Nitrate | mg/L as N | Included |
| Orthophosphate | mg/L as P | No NI standard and not considered parameter of concern at mine |
| ***Cyanide Parameters*** | | |
| Free Cyanide | mg/L | No longer required for processing / no addition of cyanide at the mine; not included |
| Total Cyanide | mg/L | No longer required for processing / no addition of cyanide at the mine; not included |
| ***Organics*** | | |
| TOC | mg/L | No standard requested by NIEA |
| BOD | mg/L | Included |
| COD | mg/L | No standard requested by NIEA |
| ***Microbiological*** | | |
| Faecal Coliforms | CFU/100ml | No standard requested by NIEA |
| Total Coliforms | CFU/100ml | No standard requested by NIEA |
| Enterococci | CFU/100ml | No standard requested by NIEA |
| E.Coli | CFU/100ml | No standard requested by NIEA |
| [a]Visible Oil and Grease | mg/L | Included as trace limit only (i.e., not included in calculations) |

*[a] Included in lieu of EPH and Mineral Oil*

**Table 1-2: Summary of Scoping Assessment for Water Quality Parameters (dissolved metals)**

| Parameters | Units | Included in Assessment |
|---|---|---|
| ***Dissolved Metals*** | | |
| Aluminium | mg/L | Included |
| Antimony | mg/L | Included |
| Arsenic | mg/L | Included |
| Barium | mg/L | No NI standard and not considered parameter of concern at mine |
| Beryllium | mg/L | No NI standard and not considered parameter of concern at mine |
| Boron | mg/L | Included |
| Cadmium | mg/L | Included |
| Calcium | mg/L | No NI standard and not considered parameter of concern at mine |
| Chromium III | mg/L | Included |
| Chromium VI | mg/L | Included |
| Total Chromium | mg/L | Included |
| Cobalt | mg/L | No NI standard and not considered parameter of concern at mine |
| Copper | mg/L | Included |
| Iron | mg/L | Included |
| Lead | mg/L | Included |
| Manganese | mg/L | Included |
| Mercury | mg/L | Included |
| Molybdenum | mg/L | Included |
| Nickel | mg/L | Included |
| Selenium | mg/L | Included |
| Silver | mg/L | Included |
| Sodium | mg/L | Included |
| Strontium | mg/L | No NI standard and not considered parameter of concern at mine |
| Tellurium | mg/L | Not present in measurable quantities |
| Thorium | mg/L | Not present in measurable quantities |
| Tin | mg/L | No NI standard and not considered parameter of concern at mine |
| Titanium | mg/L | No NI standard and not considered parameter of concern at mine |
| Uranium | mg/L | Included |
| Vanadium | mg/L | Not present in measurable quantities |
| Zinc | mg/L | Included |

# 2 Environmental Quality Standards (EQS) and Drinking Water Standards

## 2.1 Overview

EQS and water quality guideline values considered in this report are outlined in Tables 2-1, 2-2 and 2-3. Environmental standards for the protection of aquatic life are applied at the Owenkillew River, with standards for drinking water applied in the Curraghinalt Burn.

Table 2-1 summarises EQS values for parameters that are defined through legislation:

- SR 351 The Water Framework Directive (Classification, Priority Substances and Shellfish Waters) Regulations (Northern Ireland) 2015.
- The Water Supply (Water Quality) Regulations (Northern Ireland) 2007 (SR 147) as amended by SR 2009/246, SR 2010/128 and SR 2015/363.

Table 2-2 identifies guideline values for water quality parameters for which there are no statutory EQS values, but where EQS values can be determined through reference to standards from other parts of the world and other standards/guidelines relevant to the study area, but which are not legislated standards. These guidelines include:

- Freshwater Fish Directive - This legislation has been revoked (2013), but it contained a standard for total suspended solid (TSS) concentrations that was not taken forward to other primary legislation. In the light of no other standards for TSS and given the likely importance of this parameter, the standard value from the Freshwater Fish Directive was used in this study.
- European Union agri-environmental indicator for nitrate (http://ec.europa.eu/eurostat/statistics-explained/index.php/Agri-environmental_indicator_-_nitrate_pollution_of_water) - Due to the lack of a standard for nitrate, this value was taken forward for use in this study.
- British Standard BS EN 16859:2017 Guidance standard on monitoring Freshwater Pearl Mussel populations and their environment - This document does not present water quality 'standards,' but rather reviews the available literature and identifies water bodies and water quality where there are healthy populations of Freshwater Pearl Mussels. It is noted in the Standard that "*these specific levels should not be interpreted as water quality targets but are presented to provide assistance in target-setting*." The ranges presented in the Standard are considered in this assessment.
- Canadian Environmental Quality guidelines published by the CCME (Canadian Council of Ministers of the Environment) – These provide science-based goals for the quality of aquatic and terrestrial ecosystems. They are referred to here for parameters where no specific in-stream water quality standard or guidelines are available, but which were identified in Chapter 1.

We are aware that there is an unpublished draft 2013 report prepared for NIEA that outlines management measures related to Freshwater Pearl Mussels in the Owenkillew catchment. This report provides indicative water quality guidelines for the rivers with Freshwater Pearl Mussels, based on a review of available literature. As this report has not been finalised and is not a published document, it is considered superseded by the 2017 BS EN 16859:2017. The British Standard is expected to have undertaken a more thorough review of Freshwater Pearl Mussel literature than the earlier 2013 report. However, it is noted that in the absence of a guideline value for TSS related to TSS concentrations (mg/L) in BS EN 16859:2017, results of this assessment are compared to the 10 mg/L guideline value for TSS presented in the unpublished draft report.

There will be no sewage discharges into the Curraghinalt Burn during mine operations. However, for reference NIEA would typically look for compliance of 1.5 mg/L for BOD and a value of 0.1 mg/L for ammonia in watercourses for sewage effluent discharges, with an allowed deterioration of the mid class (average) of 13% for BOD and 28% for ammonia.

**Table 2-1: Legislated EQS Values and Drinking Water Standards (AA = annual average)**

| Parameter | Unit | LEGISLATED STANDARDS | | |
|---|---|---|---|---|
| | | SR 351 | | WSR |
| | | AA | Other | |
| pH | s.u. | 6.6 – 9.0 | - | |
| BOD | mg/L | | 3 (90%ile) | |
| Temperature | °C | | 20 (max) | |
| *Nutrients/Salts* | | | | |
| Total Ammonia | mg/L N | | 0.2 (90%ile) | 0.39[a] |
| Nitrate | mg/L N | | | 11.3[b] |
| Nitrite | mg/L N | | | 0.22 |
| Chloride | mg/L | | | 250 |
| Fluoride | mg/L | | | 1.5 |
| Sulphate | mg/L | | | 250 |
| *Metals (Dissolved)* | | | | |
| Aluminium | µg/L | | | 200 |
| Antimony | µg/L | | | 5 |
| Arsenic | µg/L | | | 10 |
| Boron | mg/L | | | 1 (max) |
| Cadmium | µg/L | 0.08 | 450 (max) | 5 |
| Chromium (III) | µg/L | 4.7 | 32 (max) | |
| Chromium (VI) | µg/L | 3.4 | | |
| Total chromium / Chromium (CrIII + CrVI) | µg/L | 8.1 | | |
| Copper (bioavailable equivalent[d]) | µg/L | 6.27[c] | | 2000 |
| Copper (bioavailable) | µg/L | 1 | | |
| Iron | mg/L | 1 | | 0.2 |
| Lead | µg/L | 1.2 | 14 (max) | 10 |
| Manganese (bioavailable equivalent[d]) | µg/L | 123[c] | | 50 |
| Manganese (bioavailable) | µg/L | 123 | | |
| Mercury | µg/L | | 0.07 (max) | 1 |
| Nickel (bioavailable equivalent[d]) | µg/L | 12.8[c] | 34 (max) | 20 |
| Nickel (bioavailable) | µg/L | 4 | | |
| Selenium | µg/L | | | 10 |
| Silver | µg/L | 0.5 | 1 (max) | |
| Sodium | mg/L | | | 200 |
| Zinc (bioavailable equivalent[d]) | µg/L | 18.8[c] | | |
| Zinc (bioavailable) | µg/L | 11.9 | | |

[a] *WSR reference standard is 0.5 mg/L ammonia as $NH_4$. Values of 0.39 mg/L is ammonia as N.*

[b] *Standard is 50 mg/L nitrate as $NO_3$. Value of 11.3 mg/L is nitrate as N.*

[c] *Site-specific EQS from PNEC calculation, based on lowest concentration in Table 2-4, below.*

[d] *The 'bio-available equivalent' values for copper, zinc, manganese and nickel are used as these are the back-calculated dissolved metals concentrations equivalent to the bioavailable standard under SR351.*

**Table 2-2: Non-statutory Guideline Values for Parameters Considered in this Memo**

| Parameter | Unit | Standard | Source of guideline / Comment |
|---|---|---|---|
| *Physical* | | | |
| pH | s.u. | 6.2 – 7.3 | [a] BS EN 16859:2017 |
| BOD | mg/L | 1 - 1.4 | BS EN 16859:2017; *used as standard in this report for BOD* |
| BOD | mg/L | 1.5 | NIEA requirement for treated sewage effluent. With 13% decrease in average BOD concentrations in receiving water against baseline |
| TSS | mg/L | 25 | [b] Freshwater Fish Directive |
| TSS | NTU | 10 | [a] BS EN 16859:2017. *Relationships between turbidity and TSS concentrations (mg/L) need to be developed in the field. Testing is ongoing.* |
| Heavy metals and other toxic substances | | Refer to Water Framework Directive limits (i.e., SR251 as per Table 1-1) | BS EN 16859:2017 |
| *Nutrients/Salts* | | | |
| Total ammonia | mg/L N | 0.01 – 0.005 (median) | BS EN 16859:2017 |
| Total ammonia | mg/L N | 0.1 | NIEA requirement for treated sewage effluent. With 28% decrease in average ammonia concentrations in receiving water against baseline |
| Nitrate | mg/L N | 0.125 – 0.5 (median) | BS EN 16859:2017 |
| Nitrate | mg/L N | 5.6 | EU agri-environmental indicator for nitrate |
| *Metals (Dissolved)* | | | |
| Boron | µg/L | 1500 | [c] CCME |
| Molybdenum | µg/L | 73 | CCME |
| Uranium | µg/L | 15 | CCME |

[a] *BS EN 16859:2017: Guidance standard on monitoring freshwater pearl mussel populations and their environment*
[b] *Freshwater Fish Directive*
[c] *Canadian Council of Ministers of the Environment (CCME) Water Quality Guidelines for the Protection of Aquatic Life (October 2016)*

Table 2-3 presents drinking water standards from other jurisdictions for water quality parameters that are not covered in the Water Supply (Water Quality) Regulations (Northern Ireland) 2007. The lowest values for each of the parameters in Table 2-3 are carried forward to the assessment.

**Table 2-3: Drinking Water Standards from Other Jurisdictions for Parameters not Covered in Northern Ireland Drinking Water Standards**

| Parameter | Unit | Standard | Source of guideline / Comment |
|---|---|---|---|
| Chromium (CrIII + CrVI) | µg/L | 50 | [a]WHO, [b]EU |
| Chromium (CrIII + CrVI) | µg/L | 100 | [c]US EPA |
| Molybdenum | µg/L | 200 | [c]US EPA |
| Silver | µg/L | 100 | [c]US EPA |
| Uranium | µg/L | 30 | [c]US EPA, [a]WHO |
| Zinc | µg/L | 3000 | [a]WHO |
| Zinc | µg/L | 5000 | [c]US EPA |

[a] *World Health Organisation. Guidelines for Drinking Water Quality, 4th Edition incorporating the first addendum*
[b] *EU Council Directive 98/83/EC of 3rd November 1998*
[c] *United States Environmental Protection Agency. 2018 Edition of the Drinking Water Standards and Health Advisory Tables*

## 2.2 Bioavailable Metal Standards and M-BAT Tool

Environmental Quality Standards (EQSs) for some metals are expressed in terms of bioavailable metal concentration. This criterion currently applies to copper, zinc, manganese, nickel and lead. The EQS for such metals is referenced as $EQS_{bioavailable}$. The bioavailable concentration gives an estimate of the amount of metal that is biologically active (i.e., as toxicity) and of ecological relevance.

An EQS is the concentration of a water quality parameter in the environment below which there is not expected to be an adverse effect on the specific endpoint being considered (e.g., the protection of aquatic life). However, it is recognised "that measures of total metal in waters have limited relevance to potential environmental risk" (UKTAG, 2014). This is based on the knowledge that the amount of metal that is actually bioavailable is influenced by a range of water quality parameters, most significantly pH, dissolved organic carbon (DOC) and calcium.

The Water Framework Directive - United Kingdom Technical Advisory Group (WFD-UKTAG) has developed a river and lake assessment method for specific metals (UKTAG, 2014). This document introduces and is accompanied by M-BAT (a Metal Bioavailability Assessment Tool). M-BAT currently predicts metal bioavailability for copper, zinc, manganese and nickel.

M-BAT operates in MS Excel and is a simple-to-use tool but one which produces output results similar to much more complex Biotic Ligand Models (albeit slightly precautionary). The key output from M-BAT is an estimate of the bioavailable concentration of a metal under the conditions found at a site. This can be compared with the $EQS_{bioavailable}$ to assess compliance.

M-BAT determines metal bioavailability at specific locations using local pH, DOC and calcium water chemistry data. DOC has not been determined within the parameter suite for this project and is replaced by total organic carbon (TOC), which has been measured. Organic carbon reduces metal bioavailability so the TOC measure is less conservative than DOC but is used in the absence of TOC.

M-BAT also calculates a site-specific $PNEC_{dissolved}$ based on the pH, DOC and calcium concentrations at the site. PNEC (predicted no-effects concentration) can be considered as a site-specific EQS for the dissolved metal (not the bioavailable component).

$EQS_{bioavailable}$ from current standards are presented in Table 2-4. Site-specific PNEC values for copper, manganese, nickel and zinc are presented in Table 2-5, as derived using the m-BAT tool with background water quality values in both the Curraghinalt Burn (sampling location SW02) and Owenkillew River (SW05).

**Table 2-4: $EQS_{bioavailable}$ criteria from current standards/guidelines**

| Metal | $EQS_{bioavailable}$ | | Comment |
|---|---|---|---|
| | (ug/l) | (mg/l) | |
| Cu | 1 | 0.001 | |
| Zn | 11.9 | 0.0119 | The EQS for zinc is 10.9 ug/l plus ambient background concentration; for Northern Ireland, this is 1ug/l (UKTAG, 2014) |
| Mn | 123 | 0.123 | |
| Ni | 4 | 0.004 | |
| Pb | 1.2 | 0.0012 | Not included in M-BAT and therefore not adopted as a Project Guideline Value; the EQS of 7.2 ug/l is used. |

**Table 2-5: Calculated Site-Specific EQS (Dissolved) from PNEC calculation for Curraghinalt Burn**

| Parameter | Curraghinalt Burn (SW02) | | | Owenkillew River (SW05) | | |
|---|---|---|---|---|---|---|
| | Min (µg/L) | Max (µg/L) | Mean (µg/L) | Min (µg/L) | Max (µg/L) | Mean (µg/L) |
| Cu | 6.32 | 61.8 | 25.5 | 6.27 | 61.2 | 36.2 |
| Zn | 17.4 | 107.8 | 52.5 | 18.8 | 103.3 | 54.0 |
| Mn | 123.0 | 410.4 | 154.9 | 123.0 | 568.8 | 271.1 |
| Ni | 5.74 | 44.3 | 26.1 | 12.8 | 41.8 | 25.9 |

## 2.3 Limits of Detection

Table 2-6 lists laboratory parameters for which the limit of detection (LOD) is at or below a guideline value or standard presented above.

**Table 2-6: Parameters with Limit of Detection at or above Water Quality Guideline or Standard**

| Parameter | Unit | LOD | Guideline/Standard | Value |
|---|---|---|---|---|
| Total Ammonia | mg/l as N | 0.01 and 0.03 | BS EN 16859:2017 | 0.01 |
| Silver | µg/L | 5 | SR 351 | 0.5 (AA EQS) |

## 2.4 Selection of EQS values for assessment

For the calculation of discharge criteria, the EQS values in Table 2-1 are used throughout this report apart from the following:

- 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. 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).
- Extractable Petroleum Hydrocarbons (EPH) and mineral oil were measured during baseline studies, but there are no standards for these parameters. To allow the development of a practical discharge criteria, a general parameter encompassing all hydrocarbons was considered as ‘Visible oil and grease’, with a qualitative standard of ‘no trace’ proposed. This was considered an appropriate way to monitor against any hydrocarbon releases from the mine site and is the approach taken for the discharge consent at the existing exploration works at the site. No discharge calculations for hydrocarbons were undertaken.
- CCME guideline values for Boron, Molybdenum and Uranium are considered as EQS values for calculations.
- The ‘bio-available equivalent’ values for copper, zinc, manganese and nickel are used as these are the back-calculated dissolved metals concentrations equivalent to the bioavailable standard under SR351.

Where parameters have EQS for mean and max values (e.g., cadmium in Table 2-1) the assessment is based on the mean concentration. For BOD and Total Ammonia, the EQS is related to the 90%ile concentration. For mercury, the EQS is a maximum concentration, but for this assessment this is considered as the 95%ile concentration.

Calculated discharge criteria are then compared to the drinking water standards and forwards calculations are undertaken using the discharge criteria to assess the impact of discharges on water quality in the Curraghinalt Burn and Owenkillew River. The results of these calculations are then compared to the guideline values presented in Table 2-2.

# 3 Development 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; and
- Application reviewed by regulators who decide on final values; work is undertaken by NIEA WMU.

DAERA uses a 'Monte Carlo' modelling approach that is consistent with methods used by the 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 3-1. These methods 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 highest permitted concentration produced by each method. In this way, the proposed discharge criteria will be compliant with methods used by NIEA.

Screening tests are not applied in this application as the assessment is based on the more detailed Monte Carlo methodology, as agreed with NIEA.

We undertake calculations in the following sections to estimate maximum discharge concentrations for the parameters outlined in Tables 1-1 and 1-2, using the modelling tests and following the approach used by the EA. Calculations are not undertaken for:

- pH - simple dilution calculations are not appropriate for the assessment of pH; or
- Oil and Grease - the consent is non-numeric, being 'No Trace'.

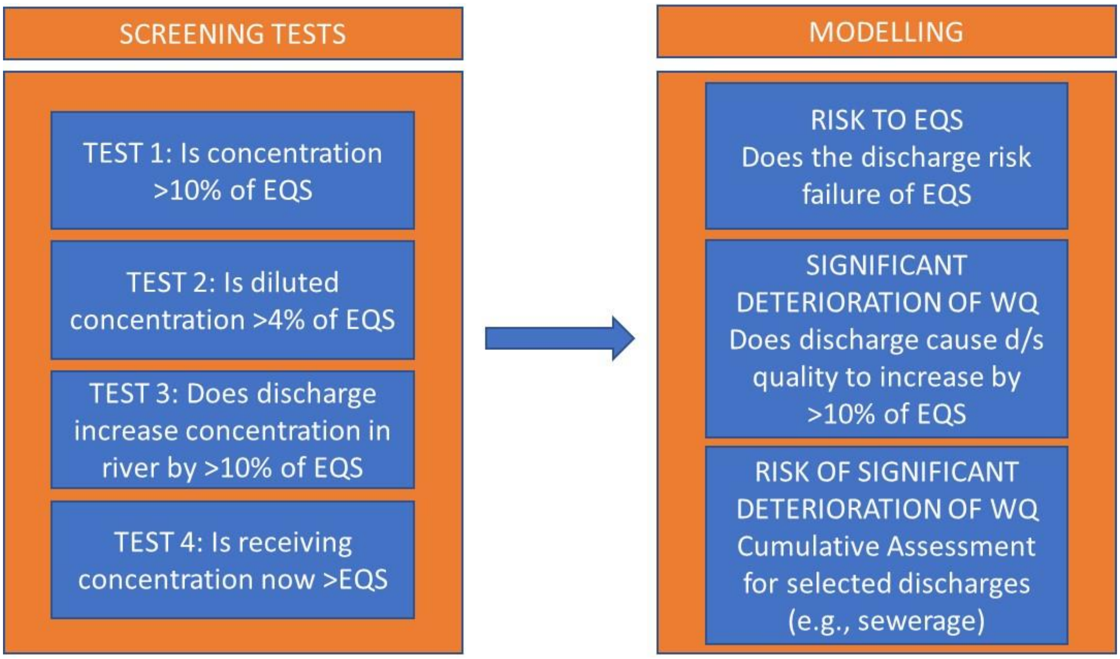
The discharge from the Site is to the Curraghinalt Burn, which is a small tributary of the Owenkillew River. The Owenkillew River is part of the Owenkillew River Special Area of Conservation (SAC). Calculations of the impact of discharges from the Site on water quality in the Owenkillew River are the 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 ES completed for the Curraghinalt Mine Project) and which has no Freshwater Pearl Mussels.

The method used in this application to calculate discharge criteria is based on:

1. Calculation of criteria based on EQS for the Owenkillew River. 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.
2. Resulting maximum allowable discharge values (end of pipe) that are protective of the Owenkillew River will be compared to drinking water standards and reduced if they would not provide compliance of these standards at the point of discharge and in the Curraghinalt Burn. Consistent with the approach in the ES, if the mean baseline concentrations in the Curraghinalt Burn are above the drinking water standards, the discharge criteria are set at the baseline mean concentration.
3. Predicted concentrations in the Owenkillew River are compared to guidelines for Fresh Water Pearl Mussels.

Once the criteria are calculated further calculations are made to present the predicted impacts of the discharge on water quality in the Owenkillew River and Curraghinalt Burn. At this stage final adjustments to the discharge criteria can be made, if required.

**Figure 3-1. Schematic of the Environment Agency Process for Discharge Consents**



## 3.1 Input Data

The key input data for the calculations are:

- Water quality standards or EQS for relevant parameters;
- Flow data for discharge and receiving waters (i.e., Curraghinalt Burn and Owenkillew River); and
- Background water quality in receiving waters.

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

## 3.2 Monte Carlo Modelling Assessment

The Monte Carlo modelling methods are outlined in LIT 10419 ‘Modelling surface water pollution risk assessment’. 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 Owenkillew River by <10% of the EQS for parameters where the mean is below the standard and 3% for parameters where baseline conditions are above the standard). Variables used in the calculation of the target downstream water quality are presented in Table 3-1.

As this approach calculates the permittable discharge concentrations, the required discharge quality input to the model is the output variable. Although there is a treatment plant at the current exploration site discharging to the Curraghinalt Burn, an enhanced Reverse Osmosis treatment plant will be constructed for the operation of the Curraghinalt Mine. This will not operate in a similar manner to the existing plant so the data is not useful for this assessment.

Outputs from the Monte Carlo software “backwards” modelling are shown in Appendix 3 and summarised in Table 3-2. These calculations predict the maximum allowable discharge that would comply with the required concentrations in Table 3-1.

Parameters with no EQS values, but with Drinking Water Standards are presented in Table 3-3. For these parameters, the drinking water standards are taken forward as proposed discharge criteria.

**Table 3-1: Calculation of Mean Target Downstream Water Quality for "Backwards" Modelling of Parameters with Environmental Standards (EQS)**

| Parameter | Unit | EQS (Annual Average unless stated) | Baseline quality (Average unless stated) | Baseline Std Dev | % change of EQS allowed | Downstream target [1] |
|---|---|---|---|---|---|---|
| *Physical* | | | | | | |
| TSS | mg/L | 25 | 6.75 | 6.56 | 10 | 9.26 |
| BOD | mg/L | 3 (90%ile) | 3 (90%ile) | 0.91 | 3 | 3.09 (90%ile) |
| *Nutrients/Salts* | | | | | | |
| Total Ammonia | mg/L N | 0.2 (90%ile) | 0.23 (90%ile) | 0.128 | 3 | 0.236 (90%ile) |
| *Dissolved metals* | | | | | | |
| Boron | mg/L | 1.5 | 0.0049 | 0.002 | 10 | 0.155 |
| Cadmium | µg/L | 0.08 | 0.029 | 0.027 | 10 | 0.0366 |
| Chromium (III) | µg/L | 4.7 | 2.47 | 0.90 | 10 | 2.94 |
| Chromium (VI) | µg/L | 3.4 | 2.47 | 0.86 | 10 | 2.81 |
| Chromium (CrIII + CrVI) | µg/L | 8.1 | 4.93 | 1.80 | 10 | 5.74 |
| Copper | µg/L | 6.27[2] | 1.08 | 0.50 | 10 | 1.71 |
| Copper (bioavailable) | µg/L | 1 | 0.041 | 0.026 | 10 | 0.14 |
| Iron | mg/L | 1 | 0.93 | 0.36 | 3[3] | 0.96 |
| Lead | µg/L | 7.2 | 0.46 | 0.56 | 10 | 1.18 |
| Manganese | µg/L | 123[2] | 81.54 | 45.5 | 10 | 93.84 |
| Manganese (bioavailable) | µg/L | 123 | 50.39 | 34.68 | 10 | 62.69 |
| Mercury | µg/L | 0.07 (95%ile) | 0.041 (95%ile) | 0.037 | 10 | 0.048 (95%ile) |
| Molybdenum | µg/L | 73 | 0.28 | 0.36 | 10 | 7.58 |
| Nickel | µg/L | 12.8[2] | 0.74 | 0.51 | 10 | 2.02 |
| Nickel (bioavailable) | µg/L | 4 | 0.10 | 0.086 | 10 | 0.50 |
| Silver | µg/L | 0.5 | 2.50 | 0 | 3 | 2.515 |
| Uranium | µg/L | 15 | 2.50 | 0 | 10 | 4.0 |
| Zinc | µg/L | 18.8[2] | 3.63 | 2.65 | 10 | 5.51 |
| Zinc (bioavailable) | µg/L | 11.9 | 0.80 | 0.43 | 10 | 1.99 |

[1]Downstream target river quality calculated as in increase in the background concentration in the Owenkillew River by the maximum allowable % of the EQS.

[2]Site-specific PNEC derived for dissolved metals using m-BAT tool.

[3] Increase for iron set at 3% although baseline is below EQS, as increase of 10% would take concentration over EQS

Following these calculations, the discharge criteria are reviewed and Table 3-4 presents the adjusted discharge criteria, with criteria values either resulting from the Monte Carlo "backwards" modelling (see Table 3-2) or set to the drinking water standard (see Table 3-3) or adjusted for the reasons outlined in the Table. For parameters where the "backwards" modelling results in a concentration higher than the associated drinking water standard, the parameter criteria are set to the drinking water standard.

The exceptions are for iron and manganese where the mean concentration in the Curraghinalt Burn is above the drinking water standard. For both these parameters, the draft discharge criteria is set to the mean of the baseline data, which is well below the concentration required for compliance in the Owenkillew River.

This provides (highlighted in orange in Table 3-4) the first set of discharge criteria which are taken forward to be assessed through "forwards" Monte Carlo calculations (i.e., predicting impact of discharge on water quality in the Owenkillew River and Curraghinalt Burn).

**Table 3-2: Results of Monte Carlo "Backwards" Modelling for Owenkillew River – Parameters with Environmental Standards (EQS)**

| Parameter | Unit | EQS (Annual Average unless stated) | Target downstream river quality[1] (Average unless stated) | Maximum allowable discharge concentration |
|---|---|---|---|---|
| *Physical* | | | | |
| TSS[1] | mg/L | 25 | 9.26 | 452 |
| BOD | mg/L | 3 (90%ile) | 3.09 (90%ile) | 31.9 |
| *Nutrients / Salts* | | | | |
| Total Ammonia | mg/L N | 0.2 (90%ile) | 0.236 (90%ile) | 2.72 |
| *Dissolved metals* | | | | |
| Boron | mg/L | 1.5 | 0.155 | 28000 |
| Cadmium | µg/L | 0.08 | 0.0366 | 1.37 |
| Chromium (III) | µg/L | 4.7 | 2.94 | 97.3 |
| Chromium (VI) | µg/L | 3.4 | 2.81 | 71.0 |
| Total Chromium | µg/L | 8.1 | 5.74 | 168 |
| Copper | µg/L | 6.27[2] | 1.71 | 120 |
| Iron | mg/L | 1 | 0.96 | 6.06 |
| Lead | µg/L | 7.2 | 1.18 | 133 |
| Manganese | µg/L | 123[2] | 93.84 | 2310 |
| Mercury | µg/L | 0.07 (95%ile) | 0.048 (95%ile) | 1.35 |
| Molybdenum | µg/L | 73 | 7.58 | 1380 |
| Nickel | µg/L | 12.8[2] | 2.02 | 243 |
| Silver | µg/L | 0.5 | 2.515 | 5.34 |
| Uranium | µg/L | 15 | 4.0 | 287 |
| Zinc | µg/L | 18.8[2] | 5.51 | 348 |

[1]Mean target downstream river quality calculated as in increase in the background concentration in the Owenkillew River by the maximum allowable % of the EQS.

[2]Site-specific PNEC derived for dissolved metals using m-BAT tool.

**Table 3-3: Parameters with no EQS, but Drinking Water Standards**

| Parameter | Unit | Drinking Water Standard |
|---|---|---|
| Nitrate | mg/L N | 11.3 |
| Nitrite | mg/L N | 0.22 |
| Chloride | mg/L | 250 |
| Fluoride | mg/L | 1.5 |
| Sulphate | mg/L | 250 |
| Aluminium | µg/L | 200 |
| Antimony | µg/L | 5 |
| Arsenic | µg/L | 10 |
| Selenium | µg/L | 10 |
| Sodium | mg/L | 200 |

**Table 3-4: Draft Discharge Criteria (highlighted in orange)**

| Parameter | Unit | EQS (Annual average unless stated) | Drinking Water Standard | Carried forward from Tables 3-2 and 3-3 | Adjusted criteria | Reason |
|---|---|---|---|---|---|---|
| *Physical* | | | | | | |
| TSS | mg/L | 25 | | 452 | 50 | Consistent with typical permit level for TSS |
| BOD | mg/L | 3 (90%ile) | | 31.9 (90%ile) | | |
| *Nutrients / Salts* | | | | | | |
| Total Ammonia | mg/L N | 0.2 (90%ile) | 0.39 | 2.72 (90%ile) | 0.39 | Set to drinking water standard |
| Nitrate | mg/L N | | 11.3 | 11.3 | | |
| Nitrite | mg/L N | | 0.22 | 0.22 | | |
| Chloride | mg/L | | 250 | 250 | | |
| Fluoride | mg/L | | 1.5 | 1.5 | | |
| Sulphate | mg/L | | 250 | 250 | | |
| *Dissolved metals* | | | | | | |
| Aluminium | µg/L | | 200 | 200 | | |
| Antimony | µg/L | | 5 | 5 | | |
| Arsenic | µg/L | | 10 | 10 | | |
| Boron | mg/L | 1.5 | 1 | 28000 | 1 | Set to drinking water standard |
| Cadmium | µg/L | 0.08 | 5 | 1.37 | | |
| Chromium (III) | µg/L | 4.7 | | 97.3 | 29 | [a] Set based on Chromium (CrIII + CrVI) drinking water standard |
| Chromium (VI) | µg/L | 3.4 | | 71.0 | 21 | [a] Set based on Chromium (CrIII + CrVI) drinking water standard |
| Chromium (CrIII + CrVI) | µg/L | 8.1 | 50 | 168 | 50 | Set to drinking water standard |
| Copper (bioavailable equivalent) | µg/L | 6.27 | 2000 | 120 | | |
| Iron | mg/L | 1 | 0.2 | 6.06 | 2.48 | Set to mean baseline in Curraghinalt as this is above drinking water standard |
| Lead | µg/L | 7.2 | 10 | 133 | 10 | Set to drinking water standard |
| Manganese (bioavailable equivalent) | µg/L | 123 | 50 | 2310 | 93.2 | Set to mean baseline in Curraghinalt as this is above drinking water standard |
| Mercury | µg/L | 0.07 (95%ile) | 1 | 1.35 (95%ile) | 1 | Set to drinking water standard |
| Molybdenum | µg/L | 73 | 200 | 1380 | 200 | Set to drinking water standard |
| Nickel (bioavailable equivalent) | µg/L | 12.8 | 20 | 243 | 20 | Set to drinking water standard |
| Selenium | µg/L | | 10 | 10 | | |
| Silver | µg/L | 0.5 | 100 | 5.34 | | |
| Sodium | mg/L | | 200 | 200 | | |
| Uranium | µg/L | 15 | 20 | 287 | 30 | Set to drinking water standard |
| Zinc (bioavailable equivalent) | µg/L | 18.8 | 3000 | 348 | | |

*[a] In absence of drinking water standards for Cr III or Cr VI, a value is calculated based on the ratio of the maximum allowable concentration from Table 3-2 applied to the drinking water standard for Total Chromium. As all baseline Cr III and Cr VI concentrations are below detection, no relationship between Total Chromium, Cr III and Cr VI can be developed for the site. Literature is clear that these relationships are site dependent, so in absence of data this approach is taken.*

## 3.2.1 Monte Carlo 'Forwards' Modelling

In this section, we calculate the effect of the discharge on the receiving waters. The "forwards" Monte Carlo calculations provide an assessment of the impact of the discharge on water quality in the Owenkillew River and Curraghinalt Burn.

### 3.2.1.1 Owenkillew River

The discharge concentrations used for the "forwards" modelling are consistent with the adjusted maximum allowable concentrations seen in Table 3-4. The calculations take the conservative assumption that all discharges are at the maximum allowed concentration. Baseline water quality for the Owenkillew River is summarised in Table A2-2 of Appendix 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. A summary of the inputs for the Owenkillew River are outlined in Table 3-5.

Results from the Monte Carlo "forwards" modelling assessment for the Owenkillew River are shown in Appendix 3 and summarised in Table 3-6. Prediction concentrations are compared to EQS values. The results show that for all parameters where the current baseline is below the EQS, the change in baseline conditions (with discharges from the mine equal to the maximum allowable concentration) is 10% or less of the EQS. Parameters where the change is <10% are those for which the discharge criteria has been adjusted in Table 3-4.

The predicted concentrations in the Owenkillew River are compared to the non-statutory water quality guideline values outlined in Table 2-2:

- TSS – the calculated mean TSS concentration in the Owenkillew River is predicted to be <10mg/L, identified as a guideline for the protection of Fresh Water Pearl Mussels. Therefore, the proposed discharge is considered protective of this guideline value.
- BOD – the calculated 90%ile BOD concentration is increased by the 3% allowed in the EA methodology applied in this assessment. In terms of the mean concentration, it is predicted to be 1.26 mg/L post-development, compared to the 1.10 mg/L pre-development. It is within the range of 1 – 1.4 mg/L identified in BS EN 16859:2017 as a guideline for Freshwater Peal Mussels. The post-development mean is also lower than the normal NIEA guidance value for sewage discharges (1.5 mg/L), although the proposed increase is slightly higher (1.6%) than the 13% increase under sewage guidance.
- Total Ammonia – the calculated 90%ile Total Ammonia concentration is increased by the 3% allowed in the EA methodology applied in this assessment. In terms of the mean concentration, it is predicted to be 0.108 mg/L, compared to the baseline mean of 0.105 mg/L. Both these values lie outside of the range for total ammonia in BS EN 16859:2017 of 0.01 to 0.005 mg/L (for median concentrations). The current and proposed mean concentrations are above the NIEA guidance for sewage discharges (0.1 mg/L) but the change in baseline is within the allowed increase of 28% used by NIEA to assess sewage discharges.
- Nitrate – the calculated mean nitrate concentration is predicted to be 0.29 mg/L which is within the range of 0.125 – 0.5 mg/L identified in BS EN 16859:2017 as a guideline for Fresh Water Pearl Mussels.

**Table 3-5: Inputs to "Forwards" Monte Carlo Modelling for Owenkillew River**

| Parameter | Unit | Conservative Calculation[1] | | | Owenkillew River Background Quality | | |
|---|---|---|---|---|---|---|---|
| | | Average | Std Dev | Flow (L/s) | Average | Std Dev | Distribution |
| *Physical* | | | | | | | |
| TSS | mg/L | 50 | 0 | 10.8 | 6.75 | 6.56 | Non-parametric |
| BOD | mg/L | 31.9 | 0 | 10.8 | 1.1 | 0.91 | Non-parametric |
| *Nutrients/Salts* | | | | | | | |
| Total Ammonia | mg/L N | 0.39 | 0 | 10.8 | 0.105 | 0.128 | Non-parametric |
| Nitrate | mg/L N | 11.3 | 0 | 10.8 | 0.22 | 0.24 | Non-parametric |
| Nitrite | mg/L N | 0.22 | 0 | 10.8 | 0.0077 | 0.0099 | Non-parametric |
| Chloride | mg/L | 250 | 0 | 10.8 | 10.9 | 5.1 | Non-parametric |
| Fluoride | mg/L | 1.5 | 0 | 10.8 | 0.15 | 0 | Non-parametric |
| Sulphate | mg/L | 250 | 0 | 10.8 | 3.30 | 7.70 | Non-parametric |
| *Metals (Dissolved)* | | | | | | | |
| Aluminium | µg/L | 200 | 0 | 10.8 | 65.8 | 37.6 | Normal |
| Antimony | µg/L | 5 | 0 | 10.8 | 1.20 | 0.66 | Non-parametric |
| Arsenic | µg/L | 10 | 0 | 10.8 | 1.22 | 1.22 | Non-parametric |
| Boron | mg/L | 1 | 0 | 10.8 | 0.0049 | 0.002 | Non-parametric |
| Cadmium | µg/L | 1.37 | 0 | 10.8 | 0.029 | 0.027 | Non-parametric |
| Chromium (III) | µg/L | 29 | 0 | 10.8 | 2.47 | 0.90 | Non-parametric |
| Chromium (VI) | µg/L | 21 | 0 | 10.8 | 2.47 | 0.86 | Non-parametric |
| Chromium (CrIII + CrVI) | µg/L | 50 | 0 | 10.8 | 4.93 | 1.80 | Non-parametric |
| Copper | µg/L | 120 | 0 | 10.8 | 1.08 | 0.50 | Non-parametric |
| Iron | mg/L | 2.48 | 0 | 10.8 | 0.93 | 0.36 | Normal |
| Lead | µg/L | 10 | 0 | 10.8 | 0.46 | 0.56 | Non-parametric |
| Manganese | µg/L | 93.2 | 0 | 10.8 | 81.5 | 45.5 | Normal |
| Mercury | µg/L | 1 | 0 | 10.8 | 0.011 | 0.037 | Non-parametric |
| Molybdenum | µg/L | 200 | 0 | 10.8 | 0.28 | 0.36 | Non-parametric |
| Nickel | µg/L | 20 | 0 | 10.8 | 0.74 | 0.51 | Non-parametric |
| Selenium | µg/L | 10 | 0 | 10.8 | 0.55 | 0.21 | Non-parametric |
| Silver | µg/L | 5.34 | 0 | 10.8 | 2.5 | 0 | Non-parametric |
| Sodium | mg/L | 200 | 0 | 10.8 | 6.49 | 1.93 | Non-parametric |
| Uranium | µg/L | 30 | 0 | 10.8 | 2.5 | 0 | Non-parametric |
| Zinc | µg/L | 348 | 0 | 10.8 | 3.63 | 2.65 | Non-parametric |

[1] Conservative calculations assume a constant discharge concentration at the consent limit (i.e., standard deviation is set to zero).

**Table 3-6: Results of "Forwards" Monte Carlo Modelling for the Owenkillew River**

| Parameter | Unit | EQS (Annual Average unless stated) | Observed Quality Upstream of Discharge (Average unless stated) | Calculated Quality Downstream of Discharge (Average unless stated) | Increase in Concentration in Receiving River as Percent of EQS (Average unless stated) |
|---|---|---|---|---|---|
| *Physical* | | | | | |
| TSS | mg/L | 25 | 6.75 | 7.14 | 2% |
| BOD | mg/L | 3 (90%ile) | 3 (90%ile) | 3.09 (90%ile) | 3% |
| *Nutrients/Salts* | | | | | |
| Total Ammonia | mg/L N | 0.2 (90%ile) | 0.23 (90%ile) | 0.23 (90%ile) | 0% |
| Nitrate | mg/L N | | 0.22 | 0.29 | |
| Nitrite | mg/L N | | 0.0077 | 0.0092 | |
| Chloride | mg/L | | 10.9 | 12.3 | |
| Fluoride | mg/L | | 0.15 | 0.16 | |
| Sulphate | mg/L | | 3.3 | 5.06 | |
| *Metals (Dissolved)* | | | | | |
| Aluminium | µg/L | | 65.8 | 66.4 | |
| Antimony | µg/L | | 1.20 | 1.27 | |
| Arsenic | µg/L | | 1.22 | 1.30 | |
| Boron | mg/L | 1.5 | 0.0049 | 0.0101 | <1% |
| Cadmium | µg/L | 0.08 | 0.0286 | 0.0366 | 10% |
| Chromium (III) | µg/L | 4.7 | 2.47 | 2.62 | 3% |
| Chromium (VI) | µg/L | 3.4 | 2.47 | 2.58 | 3% |
| Chromium (CrIII + CrVI) | µg/L | 8.1 | 4.93 | 5.19 | 3% |
| Copper | µg/L | 6.27 | 1.08 | 1.71 | 10% |
| Iron | mg/L | 1 | 0.93 | 0.94 | 1% |
| Lead | µg/L | 1.2 | 0.46 | 0.53 | 6% |
| Manganese | µg/L | 123 | 81.5 | 82.1 | <1% |
| Mercury | µg/L | 0.07 (95%ile) | 0.041 (95%ile) | 0.047 (95%ile) | 9% |
| Molybdenum | µg/L | 73 | 0.28 | 1.34 | 1% |
| Nickel | µg/L | 12.8 | 0.74 | 0.84 | <1% |
| Selenium | µg/L | | 0.55 | 0.60 | |
| Silver | µg/L | 0.5 | 2.50 | 2.51 | 2% |
| Sodium | mg/L | | 6.49 | 7.55 | |
| Uranium | µg/L | 15 | 2.50 | 2.64 | 10% |
| Zinc | µg/L | 18.8 | 3.63 | 5.5 | 10% |

### 3.2.1.2 Curraghinalt Burn

Monte Carlo "forwards" modelling was also undertaken to assess the impact of the calculated maximum discharges on the Curraghinalt Burn. Baseline water quality for the Curraghinalt Burn is summarised in Table A2-3 of Appendix 2, and flow data for the burn is summarised in Appendix 1. A summary of the inputs for the Curraghinalt Burn forwards modelling are outlined in Table 3-7.

The same approach is taken as for the Owenkillew River, but with predictions compared to drinking water standards.

Results from the Monte Carlo "forwards" modelling assessment for the Curraghinalt Burn are summarised in Table 3-8. The results show that predicted concentrations are lower than drinking water standards apart from iron and manganese, where baseline concentrations already exceed drinking water standards. The discharge criteria for iron and manganese are therefore set equal to the mean of the Curraghinalt baseline concentration. The Monte Carlo calculation predicts slight changes to baseline following discharge, due to the stochastic and conservative nature of the calculations which assume zero standard deviation for the discharge effluent, while the baseline concentrations are allowed to vary based on the observed standard deviation of the baseline data.

**Table 3-7: Inputs to "Forwards" Monte Carlo Modelling for Curraghinalt Burn**

| Parameter | Unit | Conservative Calculation[1] | | | Curraghinalt Burn Background Quality | | |
|---|---|---|---|---|---|---|---|
| | | Average | Std Dev | Flow (L/s) | Average | Std Dev | Distribution |
| *Physical* | | | | | | | |
| TSS | mg/L | 50 | 0 | 10.8 | 5.79 | 5.70 | Non-parametric |
| BOD | mg/L | 31.88 | 0 | 10.8 | 1.05 | 1.33 | Non-parametric |
| *Nutrients/Salts* | | | | | | | |
| Total Ammonia | mg/L N | 0.39 | 0 | 10.8 | 0.08 | 0.107 | Non-parametric |
| Nitrate | mg/L N | 11.3 | 0 | 10.8 | 0.18 | 0.33 | Non-parametric |
| Nitrite | mg/L N | 0.22 | 0 | 10.8 | 0.025 | 0.094 | Non-parametric |
| Chloride | mg/L | 250 | 0 | 10.8 | 9.84 | 4.67 | Non-parametric |
| Fluoride | mg/L | 1.5 | 0 | 10.8 | 0.15 | 0 | Non-parametric |
| Sulphate | mg/L | 250 | 0 | 10.8 | 1.34 | 2.41 | Non-parametric |
| *Metals (Dissolved)* | | | | | | | |
| Aluminium | µg/L | 200 | 0 | 10.8 | 80.3 | 39.4 | Non-parametric |
| Antimony | µg/L | 5 | 0 | 10.8 | 1.27 | 0.87 | Non-parametric |
| Arsenic | µg/L | 10 | 0 | 10.8 | 1.97 | 2.06 | Non-parametric |
| Boron | mg/L | 1 | 0 | 10.8 | 0.0052 | 0.0027 | Non-parametric |
| Cadmium | µg/L | 1.37 | 0 | 10.8 | 0.0358 | 0.053 | Non-parametric |
| Chromium (III) | µg/L | 29 | 0 | 10.8 | 2.47 | 0.88 | Non-parametric |
| Chromium (VI) | µg/L | 21 | 0 | 10.8 | 2.47 | 0.84 | Non-parametric |
| Chromium (CrIII + CrVI) | µg/L | 50 | 0 | 10.8 | 4.94 | 1.77 | Non-parametric |
| Copper | µg/L | 120 | 0 | 10.8 | 2.17 | 2.11 | Non-parametric |
| Iron | mg/L | 2.48 | 0 | 10.8 | 2.48 | 2.19 | Normal |
| Lead | µg/L | 10 | 0 | 10.8 | 0.50 | 0.59 | Non-parametric |
| Manganese | µg/L | 93.2 | 0 | 10.8 | 93.2 | 56.8 | Non-parametric |
| Mercury | µg/L | 1 | 0 | 10.8 | 0.012 | 0.037 | Non-parametric |
| Molybdenum | µg/L | 200 | 0 | 10.8 | 0.33 | 0.36 | Non-parametric |
| Nickel | µg/L | 20 | 0 | 10.8 | 0.74 | 0.81 | Non-parametric |
| Selenium | µg/L | 10 | 0 | 10.8 | 0.60 | 0.41 | Non-parametric |
| Silver | µg/L | 5.34 | 0 | 10.8 | 2.50 | 0 | Non-parametric |
| Sodium | mg/L | 200 | 0 | 10.8 | 6.03 | 2.04 | Normal |
| Uranium | µg/L | 30 | 0 | 10.8 | 2.50 | 0 | Non-parametric |
| Zinc | µg/L | 348 | 0 | 10.8 | 5.61 | 3.98 | Non-parametric |

[1] Conservative calculations assume a constant discharge concentration at the consent limit (i.e., standard deviation is set to zero).

**Table 3-8: Results of Monte Carlo "Forwards" Modelling for the Curraghinalt Burn**

| Parameter | Unit | Drinking Water Standards | Observed Mean Quality Upstream of Discharge | Calculated Mean Quality Downstream of Discharge | Difference in Quality |
|---|---|---|---|---|---|
| *Physical* | | | | | |
| TSS | mg/L | | 5.79 | 23.15 | 17.4 |
| BOD | mg/L | | 1.05 | 13.06 | 12.01 |
| *Nutrients/Salts* | | | | | |
| Total Ammonia | mg/L N | 0.39 | 0.08 | 0.20 | 0.12 |
| Nitrate | mg/L N | 11.3 | 0.18 | 4.50 | 4.32 |
| Nitrite | mg/L N | 0.22 | 0.025 | 0.105 | 0.08 |
| Chloride | mg/L | 250 | 9.84 | 102.9 | 93.1 |
| Fluoride | mg/L | 1.5 | 0.15 | 0.67 | 0.52 |
| Sulphate | mg/L | 250 | 1.34 | 97.75 | 96.4 |
| *Metals (Dissolved)* | | | | | |
| Aluminium | µg/L | 200 | 80.3 | 127 | 46.7 |
| Antimony | µg/L | 5 | 1.27 | 2.75 | 1.48 |
| Arsenic | µg/L | 10 | 1.97 | 5.10 | 3.3 |
| Boron | mg/L | 1 | 0.0052 | 0.39 | 0.39 |
| Cadmium | µg/L | 5 | 0.0358 | 0.554 | 0.52 |
| Chromium (III) | µg/L | [a]29 | 2.47 | 12.75 | 10.3 |
| Chromium (VI) | µg/L | [a]21 | 2.47 | 9.65 | 7.18 |
| Chromium (CrIII + CrVI) | µg/L | 50 | 4.94 | 22.4 | 17.5 |
| Copper | µg/L | 2000 | 2.17 | 47.9 | 45.7 |
| Iron | mg/L | 0.20 | 2.48 | 2.49 | 0.01 |
| Lead | µg/L | 10 | 0.50 | 4.19 | 3.69 |
| Manganese | µg/L | 50 | 93.2 | 93.5 | 0.30 |
| Mercury | µg/L | 1 | 0.012 | 0.397 | 0.38 |
| Molybdenum | µg/L | 200 | 0.33 | 77.69 | 77.36 |
| Nickel | µg/L | 20 | 0.74 | 8.21 | 7.47 |
| Selenium | µg/L | 10 | 0.60 | 4.25 | 3.65 |
| Silver | µg/L | 100 | 2.5 | 3.60 | 1.1 |
| Sodium | mg/L | 200 | 6.03 | 81.2 | 75.2 |
| Uranium | µg/L | 30 | 2.5 | 13.15 | 10.7 |
| Zinc | µg/L | 3000 | 5.61 | 138 | 133 |

*a In absence of drinking water standards for Cr III or Cr VI, a value is calculated based on the ratio of the maximum allowable concentration from Table 3-2 applied to the drinking water standard for Total Chromium. As all baseline Cr III and Cr VI concentrations are below detection, no relationship between Total Chromium, Cr III and Cr VI can be developed for the site. Literature is clear that these relationships are site dependent, so in absence of data this approach is taken.*

### 3.2.2 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. However, this is normally undertaken for an existing discharge with measured effluent concentrations. In this case, we have calculated appropriate dissolved concentrations using the Monte Carlo method, such that introducing totals metals at this time would mean that any results are not comparable to the calculations presented above. In any case, the compliance monitoring for the mine site discharges will be based on dissolved and not total metals. As a result, dissolved metals are used in these calculations.

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 3-9, based on an assumed monthly sampling programme (i.e., 12 samples every year). 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. However, exceedances are predicted for three parameters which either have their mean values above the standard (iron), high standard deviations that result in some samples exceeding the standard (Total Ammonia) or detection limits which approach or exceed the standard (silver). The impact of the mine discharge is minor for all parameters, with a 3% increase in non-compliance for iron, <1% for Total Ammonia, BOD and Chromium III, and zero for other parameters.

**Table 3-9: 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 |
|---|---|---|---|---|---|
| *Physical* | | | | | |
| TSS | mg/L | 25 | 0 | 0 | 0 |
| BOD | mg/L | 3 (90%ile) | 4 | 4.8 | 0.8 |
| *Nutrients / Salts* | | | | | |
| Total Ammonia | mg/L N | 0.2 (90%ile) | 12.5 | 13.2 | 0.8 |
| *Dissolved metals* | | | | | |
| Boron | mg/L | 1.5 | 0 | 0 | 0 |
| Cadmium | µg/L | 0.08 | 0 | 0 | 0 |
| Chromium (III) | µg/L | 4.7 | 0 | 0 | 0 |
| Chromium (VI) | µg/L | 3.4 | 0.2 | 0.4 | 0.2 |
| Chromium (CrIII + CrVI) | µg/L | 8.1 | 0 | 0 | 0 |
| Copper | µg/L | 6.27[1] | 0 | 0 | 0 |
| Iron | mg/L | 1 | 26 | 29 | 3 |
| Lead | µg/L | 7.2 | 0 | 0 | 0 |
| Manganese | µg/L | 123[1] | 0.5 | 0.5 | 0 |
| Mercury | µg/L | 0.07 (95%ile) | 0 | 0 | 0 |
| Molybdenum | µg/L | 73 | 0 | 0 | 0 |
| Nickel | µg/L | 12.8[1] | 0 | 0 | 0 |
| Silver | µg/L | 0.5 | 100 | 100 | 0 |
| Uranium | µg/L | 15 | 0 | 0 | 0 |
| Zinc | µg/L | 18.8[1] | 0 | 0 | 0 |

# 4 Summary and Conclusions

This technical report is prepared in support of the application for a Water Licence for discharge into the Curraghinalt Burn (a tributary to the Owenkillew River) at Curraghinalt, Gortin, County Tyrone, BT79 7SF (Irish Gird Co-ords E257063.7, N386658.6) ('the Site').

Discharge criteria (maximum allowable concentrations) were calculated based on standard methods outlined in LIT 10419 'Modelling: surface water pollution risk assessment' (Environment Agency 2014). The proposed discharge criteria were tested against the Monte Carlo modelling approached required by NIEA.

The discharge criteria were set based on EQS values for the Owenkillew River. They were then adjusted with comparison to drinking water standards, so that the discharge quality at the outfall into the Curraghinalt Burn met (at a minimum) Northern Ireland and other international drinking water standards. Finally, the impact of the discharge on mean water quality in the Owenkillew River was compared to non-statutory guidelines, including the British Standard relevant to monitoring Freshwater Pearl Mussel populations and their environment.

The proposed discharge water quality criteria are summarised in Table 4-1.

**Table 4-1: Proposed Discharge Criteria**

| Parameter | Unit | Proposed Discharge Criteria | Discharge Criteria from ES |
|---|---|---|---|
| *Physical* | | | |
| pH | - | 6.6-9.0 | 6.6-9.0 |
| Temperature | $^oC$ | 20 | 20 |
| TSS | mg/L | 50 | 50 |
| BOD | mg/L | 31.9 | 17.9 |
| *Nutrients / Salts* | | | |
| Total Ammonia | mg/L N | 0.39 | 0.39 |
| Nitrate | mg/L N | 11.3 | 11.3 |
| Nitrite | mg/L N | 0.22 | 0.22 |
| Chloride | mg/L | 250 | 250 |
| Fluoride | mg/L | 1.5 | 1.5 |
| Sulphate | mg/L | 250 | 250 |
| *Dissolved metals* | | | |
| Aluminium | µg/L | 200 | 200 |
| Antimony | µg/L | 5 | 5 |
| Arsenic | µg/L | 10 | 10 |
| Boron | mg/L | 1 | 9 |
| Cadmium | µg/L | 1.37 | 1.6 |
| Chromium (III) | µg/L | 29 | 96 |
| Chromium (VI) | µg/L | 21 | 69 |
| Chromium (CrIII + CrVI) | µg/L | 50 | 50 |
| Copper | µg/L | 120 | 310 |
| Iron | mg/L | 2.48 | 1.74 |
| Lead | µg/L | 10 | 10 |
| Manganese | µg/L | 93.2 | 160 |
| Mercury | µg/L | 1 | 1 |
| Molybdenum | µg/L | 200 | 440 |
| Nickel | µg/L | 20 | 20 |
| Selenium | µg/L | 10 | 10 |
| Silver | µg/L | 5.34 | 2 |
| Sodium | mg/L | 200 | 200 |
| Uranium | µg/L | 30 | 90 |
| Zinc | µg/L | 348 | 470 |

# 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). Average and 95%ile low flow conditions are required for the Monte Carlo calculations; and
- Flow rate for the discharge, which is the combination of flows from the underground workings and surface water runoff captured from the exploration site. Average and Standard Deviation values are required for the Monte Carlo calculations

A detailed hydrological assessment of the Owenkillew River was undertaken for the Curraghinalt Mine EIA. The assessment calculated an annual average flow for the Owenkillew River upstream of the Curraghinalt Burn of 3,000 L/s. The annual 95$^{th}$ %ile low flow upstream of the Curraghinalt Burn was 800 L/s. These were considered conservative in the EIA as data from the UK Low Flows dataset and ongoing flow monitoring in the Owenkillew River suggests slightly higher flow rates. However, for consistency with the EIA, these values are used in this assessment.

At the current exploration works (located at the same location as the proposed discharge consent) water retained and treated before discharge is sourced from (i) water emerging from the existing exploration adit and (ii) surface water runoff from within the exploration site area. The current discharge consent for the works considers a peak treatment flow of around 9 L/s. 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.

During operations of the Curraghinalt Mine, there will be no flow from the adit (flows currently from adit will be directed to the underground mine) and the only remaining water treated at the proposed discharge will be surface water runoff from the exploration site area. However, the treatment plant is to be designed to be able to treat water from the underground mine, as a contingency for mining operation. Therefore, the discharge consent is based on treating underground mine water.

Based on groundwater modelling outlined in the Curraghinalt Mine ES application, the annual average inflows to the underground workings in the operational mine are given in Table A1-1. Annual averages vary from 5.5 L/s to 10.9 L/s, with an average of 8.8 L/s and a Standard Deviation of 1.2 L/s. The upper 90%ile estimate varies from 6 L/s to 13.4 L/s, with an average of 9.5 L/s and a Standard Deviation of 1.8 L/s. To be conservative, the upper 90%ile values are considered.

For the current exploration works the surface water runoff from the site is estimated to be 1.3 L/s for average conditions, falling to zero for low flows. The same values for surface water are considered here as used for the exploration works as no further surface development is proposed at the site during the mine operations.

Therefore, for the treated discharge the following flow rates are considered:

- Average, 10.8 L/s (90%ile average underground flow of 9.5 L/s plus average of surface water runoff of 1.3 L/s); and
- Standard Deviation, 1.8 L/s based on underground water only

Flows in the Curraghinalt Burn were also calculated for the EIA. The average flow in the Curraghinalt Burn is calculated as 22.2 L/s, with the 95%ile low flow of 5.8 L/s.

**Table A1-1: Underground water inflow rates to operational mine (values from Environmental Statement, Appendix C4, Technical Annex A – Site Wide Water Balance, Table 11)**

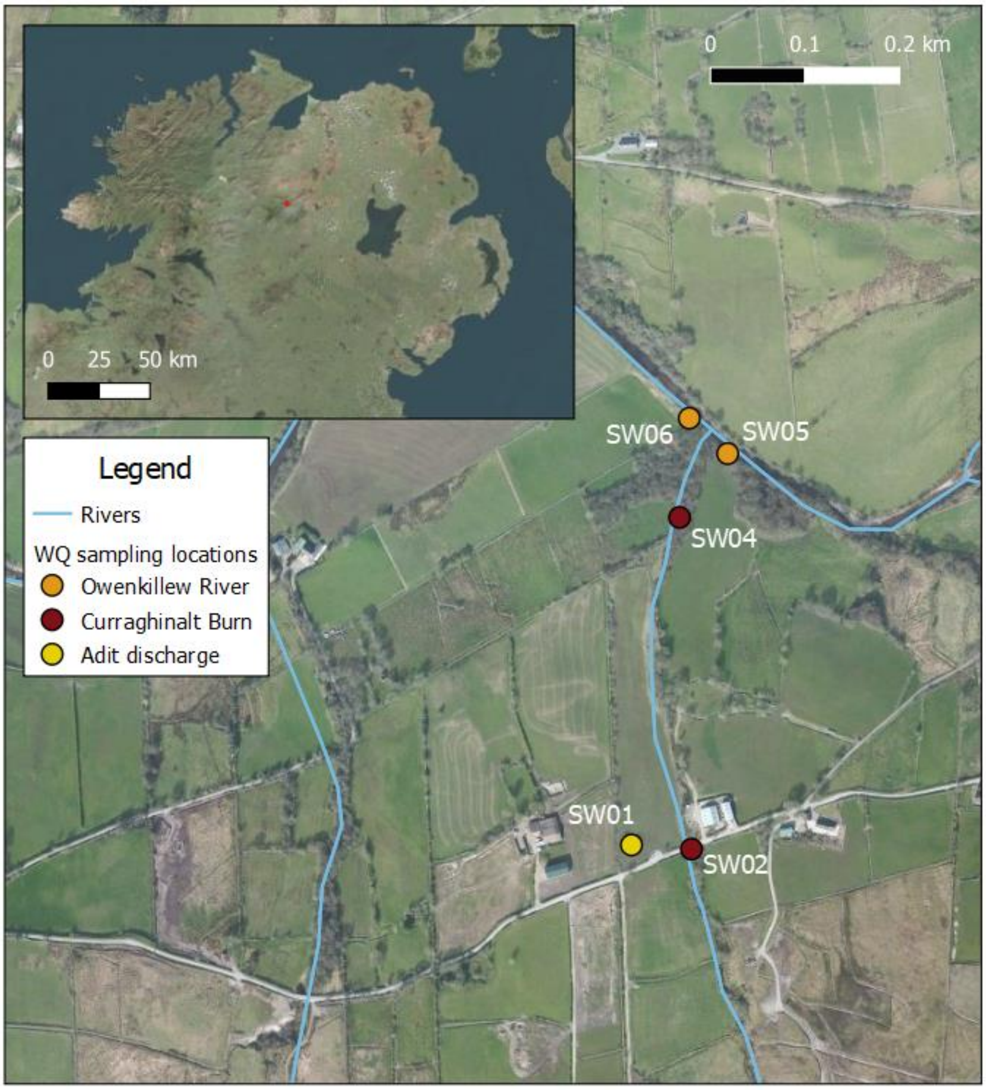
| Year | Underground Flow – Annual Average (L/s) | Underground Flow – Annual 90%ile (L/s) |
|---|---|---|
| 1 | 5.5 | 6 |
| 2 | 8.7 | 10.6 |
| 3 | 10.6 | 12.9 |
| 4 | 8.9 | 9.9 |
| 5 | 7.8 | 8 |
| 6 | 7.6 | 7.8 |
| 7 | 8.3 | 9 |
| 8 | 10.9 | 13.4 |
| 9 | 10.6 | 11.5 |
| 10 | 9.2 | 9.5 |
| 11 | 8.7 | 8.9 |
| 12 | 8.9 | 9.5 |
| 13 | 10 | 12.2 |
| 14 | 9 | 9.1 |
| 15 | 8.7 | 8.8 |
| 16 | 8.7 | 9 |
| 17 | 8.6 | 8.6 |
| 18 | 8.5 | 8.8 |
| 19 | 8.4 | 8.5 |
| 20 | 8.3 | 8.4 |
| **Mean** | **8.8** | **9.5** |
| **Standard Deviation** | **1.2** | **1.8** |

# 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 and for the Curraghinalt Burn upstream of the water treatment plant. 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). Data for the Curraghinalt Burn upstream of the water treatment plant was taken from the DGL baseline sampling program point SW02 (E 257116, N 386658).

The analysis is based on data from sampling rounds taken between June 2011 and January 2019. Figure 6-1 shows the location of SW05 and SW02, as well as surrounding sampling locations along the Curraghinalt Burn and Owenkillew River.

**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 (SW05, 2017-2019 data);<br>1 instance of Cr_D >5x LOD (SW05, 2017-2019 data);<br>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);<br>Pre-2017, 90.2% of duplicates (all samples, not just SW05 and SW02) show good correlation. |
| Dissolved vs Total Metals | For 2017-2019 data, 86% of sample (all samples, not just SW05 and SW02) dissolved results are within 1.1x the total concentration;<br>Pre-2017, 99.1% of the results (all samples, not just SW05 and SW02) 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;<br>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<br>All F values for SW05 set to ½ analytical detection limit (>95% of values below LOD) |
| Outliers | 2 x Zn outliers for SW02<br>1 x Total ammonia outlier for SW02 |

A summary of Owenkillew River (SW05) water quality data for each parameter included in the discharge consent permit can be found in 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 and an indication of the number of samples where values are recorded as below detection.

A summary of Curraghinalt Burn (SW02) water quality data for each parameter included in the discharge consent permit can be found in Table A2-3, 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 and an indication of the number of samples where values are recorded as below detection.

A number of parameters recorded a high number of samples with concentrations below the limit of detection. A large number of samples with non-detects can impact statistical analyses, especially if there are varying detection limits through a sampling programme.

Based on EA (2012), 'Pollution Inventory Reporting – General Guidance Notes, LIT7665-1200, parameters with more than 95% of samples below detection limit could be considered as not present in terms of monitoring and regulation. Within the Owenkillew River and Curraghinalt Burn datasets, silver and uranium samples are all below the detection limit, with all fluoride samples below detection in the Curraghinalt Burn and one sample in the Owenkillew River above detection. For these parameters, there has been a consistent level of detection achieved by the laboratories undertaking the analyses, so the standard deviation of the water quality is zero for these variables, apart from fluoride in the Owenkillew where the standard deviation is low. Based on the EA guidance and given that the number of non-detects is above 95%, the mean of fluoride in the Owenkillew is changed to half the detection limit and the standard deviation is set to zero for the discharge criteria calculations. The effects of the large number of non-detects will be reviewed through the development of the discharge criteria.

From further review of the baseline data, two parameters (mercury and all species of chromium) are impacted by a large number of non-detections, where the detection limit changes over time. For chromium, all samples taken between 2015 and 2019 have detection limits of 2 or 6 ug/L, with samples taken pre-2015 having detection limits of up to 20 or 30 ug/L. The samples with higher detection limits where samples were recorded as below detection (and thus set to half of the detection limit) are distorting the mean and standard deviation of the data, where no trace of chromium has actually been recorded in the samples. There are also four sampling rounds from 2012 where samples were recorded at the detection limit of 20 ug/L. For all sampling locations on the Owenkillew River (SW05, SW06, SW07, SW08, SW23 and SW24), all samples of Chromium III are measured below detection where there are detection limits of 2 or 6 ug/L, with only samples at 20 ug/L being above these values. The same pattern is seen for Chromium VI, although there are a few other points above detection throughout the Owenkillew River sampling locations. All data for chromium on the Owenkillew River are shown in Figure A2-2.

The purpose of this assessment is to develop discharge criteria that can be managed through an appropriate monitoring regime, including within the receiving waters. The inclusion of the chromium samples with the 20 or 30 ug/L detection limit would skew the baseline towards higher chromium concentrations and suggest the potential for existing exceedances of environmental standards, when this does not appear to be the case. Excluding the samples with 20 or 30 ug/L detection gives revised means and standard deviations for the Owenkillew River, as shown in Table A2-2. These updated values are used in the assessment and take the mean values for both Chromium III and Chromium VI below the EQS values for these parameters.

For mercury, the limit of detection varies from 0.01 to 0.5 ug/L, with the higher detection limits again concentrated pre-2015. In a similar way to chromium, nearly all the samples in the Owenkillew River (Figure A2-3) show concentrations below detection, with the detection limit at 0.01 mg/L. Ignoring the values with high detection limits removes the suggestion that baseline mercury conditions could exceed EQS and provides a better representation of an environment with no measurable mercury. The updated mean and standard deviation values for mercury are provided in Table A2-2.

**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 | % < LOD |
|---|---|---|---|---|---|---|---|---|---|
| *Physical* | | | | | | | | | |
| pH | s.u. | 0.01 | 37 | 7.04 | 7.06 | 8.00 | 0.66 | NP | 0 |
| TSS | mg/L | 5 or 10 | 49 | 6.75 | 5 | 3 | 6.56 | NP | 73.5 |
| BOD | mg/L | 1 or 2 | 30 | 1.1 | 0.5 | 3 | 6.56 | NP | 60 |
| *Nutrients/Salts* | | | | | | | | | |
| Total Ammonia | mg/L N | 0.01 or 0.03 | 49 | 0.105 | 0.062 | 0.35 | 0.128 | NP | 26.5 |
| Nitrate | mg/L N | 0.05 or 0.2 | 47 | 0.22 | 0.16 | 0.72 | 0.24 | NP | 19.1 |
| Nitrite | mg/L N | 0.006 | 49 | 0.0077 | 0.003 | 0.025 | 0.0099 | NP | 81.6 |
| Chloride | mg/L | 0.3 or 1 | 49 | 10.9 | 10.1 | 20.6 | 5.1 | NP | 4.1 |
| Fluoride | mg/L | 0.3 | 30 | 0.15 | 0.15 | 0.15 | 0 | NP | [a]96.7 |
| Sulphate | mg/L | 0.05, 0.5 or 1 | 49 | 3.30 | 1 | 10.28 | 7.70 | NP | 63.3 |
| *Metals (Dissolved)* | | | | | | | | | |
| Aluminium | µg/L | 1.5 or 10 | 38 | 65.82 | 56.20 | 12.97 | 37.58 | N / LN | 2.6 |
| Antimony | µg/L | 2 | 30 | 1.20 | 1.00 | 2.55 | 0.66 | NP | 90 |
| Arsenic | µg/L | 0.9 or 1 | 49 | 1.22 | 0.696 | 3.86 | 1.22 | NP | 57.1 |
| Boron | mg/L | 2 or 12 | 30 | 0.0049 | 0.006 | 0.006 | 0.002 | NP | 93.3 |
| Cadmium | µg/L | 0.03 or 0.08 | 39 | 0.029 | 0.015 | 0.08 | 0.027 | NP | 84.6 |
| Chromium (III) | µg/L | 2, 6 or 20 | 40 | [b]5.7 | [b]3 | [b]20 | [b]6.1 | NP | 90 |
| Chromium (VI) | µg/L | 2, 6 or 20 | 40 | [b]4.79 | [b]3 | [b]20 | [b]5.57 | NP | 90 |
| Total Chromium | µg/L | 0.2 or 1 | 40 | [b]10.49 | [b]6 | [b]40 | [b]11.67 | NP | 90 |
| Copper | µg/L | 1 or 3 | 49 | 1.08 | 1 | 1.66 | 0.50 | NP | 67.3 |
| Copper (bio) | µg/L | 1 or 3 | 49 | 0.041 | 0.036 | 0.106 | 0.026 | NP | 67.3 |
| Iron | mg/L | 0.002, 0.0047 or 0.02 | 49 | 0.93 | 0.90 | 1.55 | 0.36 | N / LN | 0 |
| Lead | µg/L | 0.4 or 1 | 49 | 0.46 | 0.20 | 1.5 | 0.56 | NP | 75.5 |
| Manganese | µg/L | 1 or 1.5 | 49 | 81.54 | 83.7 | 156.5 | 45.5 | N / LN | 0 |
| Manganese (bio) | µg/L | 1 or 1.5 | 49 | 50.39 | 38.64 | 132.46 | 34.68 | N / LN | 0 |
| Mercury | µg/L | 0.01 or 0.5 | 47 | [b]0.053 | [b]0.005 | [b]0.5 | [b]0.14 | NP | 87.2 |
| Molybdenum | µg/L | 0.2 or 1 | 38 | 0.28 | 0.1 | 1 | 0.36 | NP | 84.2 |
| Nickel | µg/L | 0.2 or 1 | 49 | 0.74 | 0.8 | 1.58 | 0.51 | NP | 28.6 |
| Nickel (bio) | µg/L | 0.2 | 49 | 0.10 | 0.10 | 0.28 | 0.086 | NP | 28.6 |
| Selenium | µg/L | 1 or 1.2 | 49 | 0.55 | 0.6 | 1 | 0.21 | NP | 85.7 |
| Silver | µg/L | 5 | 27 | 2.5 | 2.5 | 2.5 | 0 | NP | [a]100 |
| Sodium | mg/L | 0.1 or 0.5 | 49 | 6.49 | 6.0 | 9.96 | 1.93 | NP | 0 |
| Uranium | µg/L | 5 | 27 | 2.5 | 2.5 | 2.5 | 0 | NP | [a]100 |
| Zinc | µg/L | 1.5 | 49 | 3.63 | 3.0 | 7.54 | 2.65 | NP | 18.4 |
| Zinc (bio) | µg/L | 1.5 | 49 | 0.80 | 0.80 | 1.61 | 0.43 | NP | 18.4 |

*[a] Number of non-detect samples >95%; Note fluoride statistics adjusted to reflect half detection limit, as per EA guidelines, see text for discussion.*

*[b] Values impacted by variable detection limits in baseline data, see Table A2-4 for updated values.*

**Table A2-3: Parameters analysed for SW02, 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 | % < LOD |
|---|---|---|---|---|---|---|---|---|---|
| *Physical* | | | | | | | | | |
| pH | s.u. | 0.01 | 38 | 6.58 | 6.29 | 8.42 | 1.15 | NP | 0 |
| TSS | mg/L | 5 or 10 | 50 | 5.79 | 5 | 13.1 | 5.70 | NP | 74 |
| BOD | mg/L | 1 or 2 | 30 | 1.05 | 0.5 | 3 | 1.33 | NP | 70 |
| *Nutrients/Salts* | | | | | | | | | |
| Total Ammonia | mg/L N | 0.01 or 0.03 | 49 | 0.08 | 0.031 | 0.272 | 0.107 | NP | 42 |
| Nitrate | mg/L N | 0.05 or 0.2 | 49 | 0.18 | 0.07 | 0.80 | 0.33 | NP | 57.1 |
| Nitrite | mg/L N | 0.006 | 49 | 0.025 | 0.003 | 0.042 | 0.094 | NP | 82 |
| Chloride | mg/L | 0.3 or 1 | 50 | 9.84 | 8.90 | 19.10 | 4.67 | NP | 2 |
| Fluoride | mg/L | 0.3 | 30 | 0.15 | 0.15 | 0.15 | 0 | NP | [a]100 |
| Sulphate | mg/L | 0.05, 0.5 or 1 | 50 | 1.34 | 0.51 | 5.56 | 2.41 | NP | 70 |
| *Metals (Dissolved)* | | | | | | | | | |
| Aluminium | µg/L | 1.5 or 10 | 38 | 80.29 | 86.05 | 14.25 | 39.39 | NP | 0 |
| Antimony | µg/L | 2 | 30 | 1.27 | 1 | 3 | 0.87 | NP | 90 |
| Arsenic | µg/L | 0.9 or 1 | 50 | 1.97 | 1.4 | 6.57 | 2.06 | NP | 42 |
| Boron | mg/L | 2 or 12 | 30 | 0.0052 | 0.006 | 0.0066 | 0.0027 | NP | 90 |
| Cadmium | µg/L | 0.03 or 0.08 | 40 | 0.0358 | 0.015 | 0.088 | 0.053 | NP | 85 |
| Chromium (III) | µg/L | 2, 6 or 20 | 41 | [b]5.65 | [b]3 | [b]20 | [b]6.08 | NP | 90.2 |
| Chromium (VI) | µg/L | 2, 6 or 20 | 41 | [b]4.73 | [b]3 | [b]20 | [b]5.51 | NP | 90.2 |
| Total Chromium | µg/L | 0.2 or 1 | 41 | [b]10.38 | [b]6 | [b]40 | [b]11.59 | NP | 90.2 |
| Copper | µg/L | 1 or 3 | 50 | 2.17 | 1.5 | 5 | 2.11 | NP | 40 |
| Copper (bio) | µg/L | 1 or 3 | 30 | 0.093 | 0.071 | 0.22 | 0.06 | NP | 40 |
| Iron | mg/L | 0.002, 0.0047 or 0.02 | 49 | 2.48 | 1.93 | 5.47 | 2.19 | N / LN | 0 |
| Lead | µg/L | 0.4 or 1 | 50 | 0.50 | 0.20 | 1.5 | 0.59 | NP | 78 |
| Manganese | µg/L | 1 or 1.5 | 49 | 93.22 | 78.70 | 210 | 56.75 | NP | 0 |
| Manganese (bio) | µg/L | 1 or 1.5 | 30 | 59.10 | 57.42 | 107.3 | 22.12 | NP | 0 |
| Mercury | µg/L | 0.01 or 0.5 | 47 | [b]0.0537 | [b]0.005 | [b]0.50 | [b]0.14 | NP | 78.7 |
| Molybdenum | µg/L | 0.2 or 1 | 38 | 0.33 | 0.10 | 1 | 0.36 | NP | 71.1 |
| Nickel | µg/L | 0.2 or 1 | 50 | 0.74 | 0.50 | 2.3 | 0.81 | NP | 40 |
| Nickel (bio) | µg/L | 0.2 | 30 | 0.061 | 0.024 | 0.28 | 0.08 | NP | 40 |
| Selenium | µg/L | 1 or 1.2 | 50 | 0.60 | 0.60 | 1 | 0.41 | NP | 84 |
| Silver | µg/L | 5 | 27 | 2.5 | 2.5 | 2.5 | 0 | NP | [a]100 |
| Sodium | mg/L | 0.1 or 0.5 | 49 | 6.03 | 5.56 | 10.6 | 2.04 | N / LN | 0 |
| Uranium | µg/L | 5 | 27 | 2.5 | 2.5 | 2.5 | 0 | NP | [a]100 |
| Zinc | µg/L | 1.5 | 48 | 5.61 | 5.2 | 11.49 | 3.98 | NP | 16.3 |
| Zinc (bio) | µg/L | 1.5 | 29 | 2.25 | 1.12 | 14.93 | 4.67 | NP | 16.3 |

*[a] Number of non-detect samples >95%; Note fluoride statistics adjusted to reflect half detection limit, as per EA guidelines, see text for discussion.*

*[b] Values impacted by variable detection limits in baseline data, see Table A2-4 for updated values.*

**Table A2-4: Adjustments to Parameters with Variable Detection Limits**

| Parameter | Unit | LOD(s) | n | Mean | Median | P95 | Std Dev | Distribution | % < LOD |
|---|---|---|---|---|---|---|---|---|---|
| **Owenkillew River SW05** | | | | | | | | | |
| Chromium (III) | µg/L | 2, 6, 20 or 30 | 30 | 2.47 | 3.0 | 3.0 | 0.90 | NP | 90 |
| Chromium (VI) | µg/L | 2, 6, 20 or 30 | 33 | 2.47 | 3.0 | 3.0 | 0.86 | NP | 90 |
| Total Chromium | µg/L | 2, 6, 20 or 30 | 30 | 4.93 | 6.0 | 6.0 | 1.80 | NP | 90 |
| Mercury | µg/L | 0.01 or 0.5 | 43 | 0.011 | 0.005 | 0.010 | 0.037 | NP | 87.2 |
| **Curraghinalt Burn SW02** | | | | | | | | | |
| Chromium (III) | µg/L | 2, 6, 20 or 30 | 31 | 2.47 | 3.0 | 3.0 | 0.88 | NP | 90.2 |
| Chromium (VI) | µg/L | 2, 6, 20 or 30 | 34 | 2.47 | 3.0 | 3.0 | 0.84 | NP | 90.2 |
| Total Chromium | µg/L | 2, 6, 20 or 30 | 31 | 4.94 | 6.0 | 6.0 | 1.77 | NP | 90.2 |
| Mercury | µg/L | 0.01 or 0.5 | 43 | 0.012 | 0.005 | 0.020 | 0.037 | NP | 78.7 |

**Figure A2-2. Observed Chromium (III) and Chromium (VI) concentrations at all Owenkillew River sampling stations**

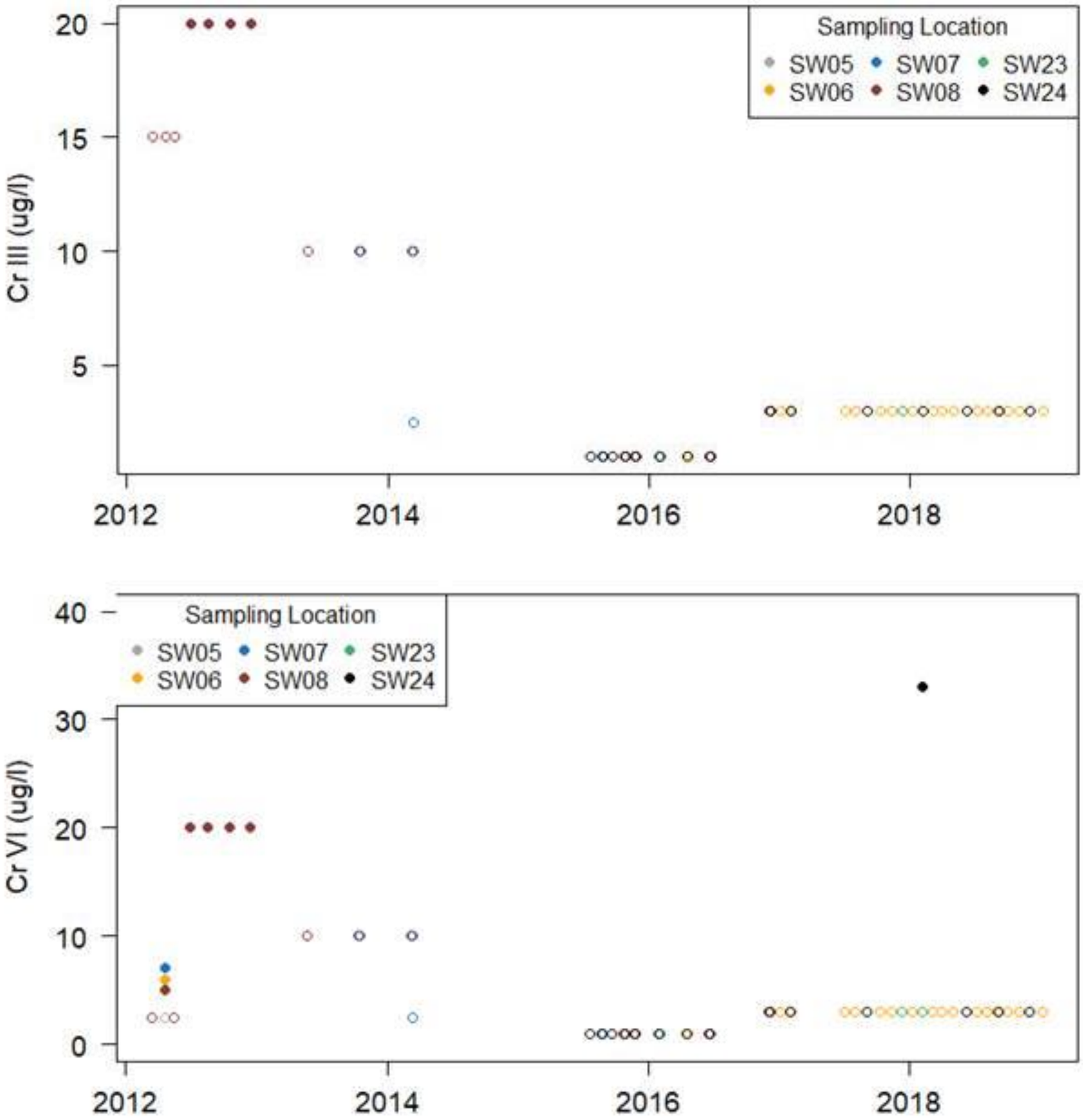
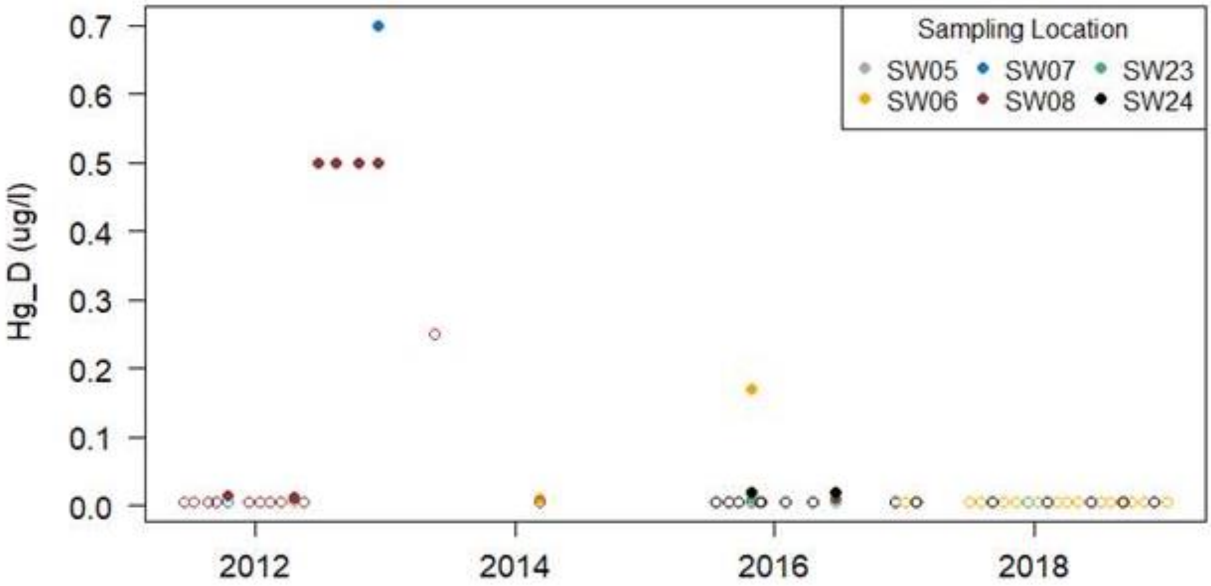


**Figure A2-3. Observed Mercury concentrations at all Owenkillew River sampling stations**



# 7 Appendix 3: "Backwards" Monte Carlo Calculations to Estimate Discharge Criteria

**Figure A3-1. Monte Carlo "Backwards" Calculation: TSS (in mg/L)**

| | |
|---|---|
| Name of discharge | Curraghinalt Mine |
| Name of river | Owenkillew River |
| Name of determinand | TSS (mg/L) |

| UPSTREAM RIVER DATA | | DISCHARGE DATA | |
|---|---|---|---|
| Mean flow | 3000 | Mean flow | 10.8 |
| 95% exceedence flow | 800 | Standard deviation of flow | 1.8 |
| Mean quality | 6.76 | Mean quality | 6.76 |
| Standard deviation of river quality | 6.56 | Standard deviation of quality | 2.25 |
| 90-percentile | 13.77 | ... or 95-percentile | 10.93 |

| RIVER DOWNSTREAM OF DISCHARGE | | DISCHARGE QUALITY NEEDED | |
|---|---|---|---|
| Mean quality | 9.26 | Mean quality | 452.06 |
| Standard deviation of quality | 7.16 | Standard deviation of quality | 147.42 |
| 90-percentile quality | 16.49 | 95-percentile quality | 725.23 |
| 95-percentile quality | 28.77 | 99-percentile quality | 887.94 |
| 99-percentile quality | 35.06 | 99.5-percentile quality | 938.00 |
| Quality target (Mean) | 9.26 | | |

**Figure A3-2. Monte Carlo "Backwards" Calculation: BOD (in mg/L)**

| | |
|---|---|
| Name of discharge | Curraghinalt Mine |
| Name of river | Owenkillew River |
| Name of determinand | BOD (mg/L) - 90%ile EQS |

| UPSTREAM RIVER DATA | | DISCHARGE DATA | |
|---|---|---|---|
| Mean flow | 3000 | Mean flow | 10.8 |
| 95% exceedence flow | 800 | Standard deviation of flow | 1.8 |
| Mean quality | 1.10 | Mean quality | 1.1 |
| Standard deviation of river quality | 0.91 | Standard deviation of quality | 0.00 |
| 90-percentile | 2.14 | ... or 95-percentile | 1.10 |

| RIVER DOWNSTREAM OF DISCHARGE | | DISCHARGE QUALITY NEEDED | |
|---|---|---|---|
| Mean quality | 1.26 | Mean quality | 31.88 |
| Standard deviation of quality | 0.91 | Standard deviation of quality | 0.16 |
| 90-percentile quality | 3.09 | 95-percentile quality | 31.88 |
| 95-percentile quality | 3.16 | 99-percentile quality | 31.88 |
| 99-percentile quality | 3.29 | 99.5-percentile quality | 31.88 |
| Quality target (90-percentile) | 3.09 | | |

**Figure A3-3. Monte Carlo "Backwards" Calculation: Total ammonia (in mg/L)**

| | |
|---|---|
| Name of discharge | Curraghinalt Mine |
| Name of river | Owenkillew River |
| Name of determinand | Total ammonia (ug/L) - 90%ile |

| UPSTREAM RIVER DATA | | DISCHARGE DATA | |
|---|---|---|---|
| Mean flow | 3000 | Mean flow | 10.8 |
| 95% exceedence flow | 800 | Standard deviation of flow | 1.8 |
| Mean quality | 105 | Mean quality | 105 |
| Standard deviation of river quality | 130 | Standard deviation of quality | 0.00 |
| 90-percentile | 226.92 | ... or 95-percentile | 105.00 |

| RIVER DOWNSTREAM OF DISCHARGE | | DISCHARGE QUALITY NEEDED | |
|---|---|---|---|
| Mean quality | 120.45 | Mean quality | 2716.6 |
| Standard deviation of quality | 142.22 | Standard deviation of quality | 8.77 |
| 90-percentile quality | 236.00 | 95-percentile quality | 2716.6 |
| 95-percentile quality | 326.52 | 99-percentile quality | 2716.6 |
| 99-percentile quality | 633.73 | 99.5-percentile quality | 2716.6 |
| Quality target (90-percentile) | 236.00 | | |

**Figure A3-4. Monte Carlo "Backwards" Calculation: Boron (in ug/L)**

| | |
|---|---|
| Name of discharge | Curraghinalt Mine |
| Name of river | Owenkillew River |
| Name of determinand | Boron (ug/L) |

| UPSTREAM RIVER DATA | | DISCHARGE DATA | |
|---|---|---|---|
| Mean flow | 3000 | Mean flow | 10.8 |
| 95% exceedence flow | 800 | Standard deviation of flow | 1.8 |
| Mean quality | 4.90 | Mean quality | 4.9 |
| Standard deviation of river quality | 2.02 | Standard deviation of quality | 1.62 |
| 90-percentile | 7.53 | ... or 95-percentile | 7.90 |

| RIVER DOWNSTREAM OF DISCHARGE | | DISCHARGE QUALITY NEEDED | |
|---|---|---|---|
| Mean quality | 155.00 | Mean quality | 28453.0 |
| Standard deviation of quality | 107.84 | Standard deviation of quality | 9217.8 |
| 90-percentile quality | 299.82 | 95-percentile quality | 45524.7 |
| 95-percentile quality | 365.80 | 99-percentile quality | 55666.9 |
| 99-percentile quality | 519.09 | 99.5-percentile quality | 58784.9 |
| Quality target (Mean) | 155.00 | | |

**Figure A3-5. Monte Carlo "Backwards" Calculation: Cadmium (in ng/L)**

| | |
|---|---|
| Name of discharge | Curraghinalt Mine |
| Name of river | Owenkillew River |
| Name of determinand | Cadmium (ng/L) |

| UPSTREAM RIVER DATA | | DISCHARGE DATA | |
|---|---|---|---|
| Mean flow | 3000 | Mean flow | 10.8 |
| 95% exceedence flow | 800 | Standard deviation of flow | 1.8 |
| Mean quality | 28.59 | Mean quality | 28.59 |
| Standard deviation of river quality | 27.17 | Standard deviation of quality | 9.43 |
| 90-percentile | 57.93 | ... or 95-percentile | 46.06 |

| RIVER DOWNSTREAM OF DISCHARGE | | DISCHARGE QUALITY NEEDED | |
|---|---|---|---|
| Mean quality | 36.60 | Mean quality | 1365.8 |
| Standard deviation of quality | 30.00 | Standard deviation of quality | 441.45 |
| 90-percentile quality | 84.73 | 95-percentile quality | 2183.2 |
| 95-percentile quality | 94.21 | 99-percentile quality | 2668.4 |
| 99-percentile quality | 154.03 | 99.5-percentile quality | 2817.6 |
| Quality target (Mean) | 36.60 | | |

**Figure A3-6. Monte Carlo "Backwards" Calculation: Chromium III (in ug/L)**

| | |
|---|---|
| Name of discharge | Curraghinalt Mine |
| Name of river | Owenkillew River |
| Name of determinand | Cr III (ug/L) |

| UPSTREAM RIVER DATA | | DISCHARGE DATA | |
|---|---|---|---|
| Mean flow | 3000 | Mean flow | 10.8 |
| 95% exceedence flow | 800 | Standard deviation of flow | 1.8 |
| Mean quality | 2.47 | Mean quality | 2.47 |
| Standard deviation of river quality | 0.90 | Standard deviation of quality | 0.82 |
| 90-percentile | 3.64 | ... or 95-percentile | 3.99 |

| RIVER DOWNSTREAM OF DISCHARGE | | DISCHARGE QUALITY NEEDED | |
|---|---|---|---|
| Mean quality | 2.94 | Mean quality | 97.30 |
| Standard deviation of quality | 0.96 | Standard deviation of quality | 31.65 |
| 90-percentile quality | 3.83 | 95-percentile quality | 155.93 |
| 95-percentile quality | 4.08 | 99-percentile quality | 190.82 |
| 99-percentile quality | 4.64 | 99.5-percentile quality | 201.55 |
| Quality target (Mean) | 2.94 | | |

**Figure A3-7. Monte Carlo "Backwards" Calculation: Chromium VI (in ug/L)**

| | |
|---|---|
| Name of discharge | Curraghinalt Mine |
| Name of river | Owenkillew River |
| Name of determinand | Cr VI (ug/L) |

| UPSTREAM RIVER DATA | | DISCHARGE DATA | |
|---|---|---|---|
| Mean flow | 3000 | Mean flow | 10.8 |
| 95% exceedence flow | 800 | Standard deviation of flow | 1.8 |
| Mean quality | 2.47 | Mean quality | 2.47 |
| Standard deviation of river quality | 0.86 | Standard deviation of quality | 0.82 |
| 90-percentile | 3.59 | ... or 95-percentile | 3.99 |

| RIVER DOWNSTREAM OF DISCHARGE | | DISCHARGE QUALITY NEEDED | |
|---|---|---|---|
| Mean quality | 2.81 | Mean quality | 71.04 |
| Standard deviation of quality | 0.89 | Standard deviation of quality | 23.11 |
| 90-percentile quality | 3.58 | 95-percentile quality | 113.84 |
| 95-percentile quality | 3.75 | 99-percentile quality | 139.31 |
| 99-percentile quality | 4.19 | 99.5-percentile quality | 147.15 |
| Quality target (Mean) | 2.81 | | |

**Figure A3-8. Monte Carlo "Backwards" Calculation: Copper (in ug/L)**

| | |
|---|---|
| Name of discharge | Curraghinalt Mine |
| Name of river | Owenkillew River |
| Name of determinand | Copper (ug/L) |

| UPSTREAM RIVER DATA | | DISCHARGE DATA | |
|---|---|---|---|
| Mean flow | 3000 | Mean flow | 10.8 |
| 95% exceedence flow | 800 | Standard deviation of flow | 1.8 |
| Mean quality | 1.08 | Mean quality | 1.08 |
| Standard deviation of river quality | 0.50 | Standard deviation of quality | 0.356 |
| 90-percentile | 1.72 | ... or 95-percentile | 1.74 |

| RIVER DOWNSTREAM OF DISCHARGE | | DISCHARGE QUALITY NEEDED | |
|---|---|---|---|
| Mean quality | 1.71 | Mean quality | 119.82 |
| Standard deviation of quality | 0.69 | Standard deviation of quality | 38.70 |
| 90-percentile quality | 2.56 | 95-percentile quality | 191.48 |
| 95-percentile quality | 2.99 | 99-percentile quality | 234.00 |
| 99-percentile quality | 3.60 | 99.5-percentile quality | 247.07 |
| Quality target (Mean) | 1.71 | | |

**Figure A3-9. Monte Carlo "Backwards" Calculation: Iron (in mg/L)**

| | |
|---|---|
| Name of discharge | Curraghinalt Mine |
| Name of river | Owenkillew River |
| Name of determinand | Fe (mg/L) |

| UPSTREAM RIVER DATA | | DISCHARGE DATA | |
|---|---|---|---|
| Mean flow | 3000 | Mean flow | 10.8 |
| 95% exceedence flow | 900 | Standard deviation of flow | 1.8 |
| Mean quality | 0.93 | Mean quality | 0.93 |
| Standard deviation of river quality | 0.36 | Standard deviation of quality | 0.31 |
| 90-percentile | 1.40 | ... or 95-percentile | 1.50 |

| RIVER DOWNSTREAM OF DISCHARGE | | DISCHARGE QUALITY NEEDED | |
|---|---|---|---|
| Mean quality | 0.96 | Mean quality | 6.06 |
| Standard deviation of quality | 0.36 | Standard deviation of quality | 1.96 |
| 90-percentile quality | 1.41 | 95-percentile quality | 9.70 |
| 95-percentile quality | 1.61 | 99-percentile quality | 11.86 |
| 99-percentile quality | 2.07 | 99.5-percentile quality | 12.52 |
| Quality target (Mean) | 0.96 | | |

**Figure A3-10. Monte Carlo "Backwards" Calculation: Lead (in ug/L)**

| | |
|---|---|
| Name of discharge | Curraghinalt Mine |
| Name of river | Owenkillew River |
| Name of determinand | Lead (ug/L) |

| UPSTREAM RIVER DATA | | DISCHARGE DATA | |
|---|---|---|---|
| Mean flow | 3000 | Mean flow | 10.8 |
| 95% exceedence flow | 800 | Standard deviation of flow | 1.8 |
| Mean quality | 0.46 | Mean quality | 0.46 |
| Standard deviation of river quality | 0.56 | Standard deviation of quality | 0.15 |
| 90-percentile | 1.00 | ... or 95-percentile | 0.74 |

| RIVER DOWNSTREAM OF DISCHARGE | | DISCHARGE QUALITY NEEDED | |
|---|---|---|---|
| Mean quality | 1.18 | Mean quality | 133.30 |
| Standard deviation of quality | 0.82 | Standard deviation of quality | 42.61 |
| 90-percentile quality | 2.22 | 95-percentile quality | 212.11 |
| 95-percentile quality | 2.91 | 99-percentile quality | 258.69 |
| 99-percentile quality | 3.97 | 99.5-percentile quality | 272.99 |
| Quality target (Mean) | 1.18 | | |

**Figure A3-11. Monte Carlo "Backwards" Calculation: Manganese (in ug/L)**

| | |
|---|---|
| Name of discharge | Curraghinalt Mine |
| Name of river | Owenkillew River |
| Name of determinand | Manganese (ug/L) |

| UPSTREAM RIVER DATA | | DISCHARGE DATA | |
|---|---|---|---|
| Mean flow | 3000 | Mean flow | 10.8 |
| 95% exceedence flow | 800 | Standard deviation of flow | 1.8 |
| Mean quality | 81.54 | Mean quality | 81.54 |
| Standard deviation of river quality | 45.5 | Standard deviation of quality | 26.9 |
| 90-percentile | 138.76 | ... or 95-percentile | 131.39 |

| RIVER DOWNSTREAM OF DISCHARGE | | DISCHARGE QUALITY NEEDED | |
|---|---|---|---|
| Mean quality | 93.84 | Mean quality | 2308.6 |
| Standard deviation of quality | 46.74 | Standard deviation of quality | 746.32 |
| 90-percentile quality | 150.18 | 95-percentile quality | 3690.5 |
| 95-percentile quality | 178.04 | 99-percentile quality | 4510.8 |
| 99-percentile quality | 247.44 | 99.5-percentile quality | 4763.0 |
| Quality target (Mean) | 93.84 | | |

**Figure A3-12. Monte Carlo "Backwards" Calculation: Mercury (in ng/L)**

| | |
|---|---|
| Name of discharge | Curraghinalt Mine |
| Name of river | Owenkillew River |
| Name of determinand | Mercury (ng/L) - 95%ile |

| UPSTREAM RIVER DATA | | DISCHARGE DATA | |
|---|---|---|---|
| Mean flow | 3000 | Mean flow | 10.8 |
| 95% exceedence flow | 800 | Standard deviation of flow | 1.8 |
| Mean quality | 11 | Mean quality | 11 |
| Standard deviation of river quality | 37 | Standard deviation of quality | 0.00 |
| 90-percentile | 23.88 | ... or 95-percentile | 11.00 |

| RIVER DOWNSTREAM OF DISCHARGE | | DISCHARGE QUALITY NEEDED | |
|---|---|---|---|
| Mean quality | 18.81 | Mean quality | 1352.3 |
| Standard deviation of quality | 44.61 | Standard deviation of quality | 4.78 |
| 90-percentile quality | 32.06 | 95-percentile quality | 1352.3 |
| 95-percentile quality | 48.00 | 99-percentile quality | 1352.3 |
| 99-percentile quality | 130.53 | 99.5-percentile quality | 1352.3 |
| Quality target (95-percentile) | 48.00 | | |

**Figure A3-13. Monte Carlo "Backwards" Calculation: Molybdenum (in ug/L)**

| | |
|---|---|
| Name of discharge | Curraghinalt Mine |
| Name of river | Owenkillew River |
| Name of determinand | Molybdenum (ug/L) |

| UPSTREAM RIVER DATA | | DISCHARGE DATA | |
|---|---|---|---|
| Mean flow | 3000 | Mean flow | 10.8 |
| 95% exceedence flow | 800 | Standard deviation of flow | 1.8 |
| Mean quality | 0.28 | Mean quality | 0.28 |
| Standard deviation of river quality | 0.36 | Standard deviation of quality | 0.0924 |
| 90-percentile | 0.60 | ... or 95-percentile | 0.45 |

| RIVER DOWNSTREAM OF DISCHARGE | | DISCHARGE QUALITY NEEDED | |
|---|---|---|---|
| Mean quality | 7.58 | Mean quality | 1382.0 |
| Standard deviation of quality | 5.26 | Standard deviation of quality | 446.91 |
| 90-percentile quality | 14.67 | 95-percentile quality | 2209.6 |
| 95-percentile quality | 17.96 | 99-percentile quality | 2700.9 |
| 99-percentile quality | 25.02 | 99.5-percentile quality | 2851.9 |
| Quality target (Mean) | 7.58 | | |

**Figure A3-14. Monte Carlo "Backwards" Calculation: Nickel (in ug/L)**

| | |
|---|---|
| Name of discharge | Curraghinalt Mine |
| Name of river | Owenkillew River |
| Name of determinand | Nickel (ug/L) |

| UPSTREAM RIVER DATA | | DISCHARGE DATA | |
|---|---|---|---|
| Mean flow | 3000 | Mean flow | 10.8 |
| 95% exceedence flow | 800 | Standard deviation of flow | 1.8 |
| Mean quality | 0.74 | Mean quality | 0.74 |
| Standard deviation of river quality | 0.51 | Standard deviation of quality | 0.244 |
| 90-percentile | 1.35 | ... or 95-percentile | 1.19 |

| RIVER DOWNSTREAM OF DISCHARGE | | DISCHARGE QUALITY NEEDED | |
|---|---|---|---|
| Mean quality | 2.02 | Mean quality | 242.63 |
| Standard deviation of quality | 1.06 | Standard deviation of quality | 78.40 |
| 90-percentile quality | 3.40 | 95-percentile quality | 387.80 |
| 95-percentile quality | 3.91 | 99-percentile quality | 473.96 |
| 99-percentile quality | 5.61 | 99.5-percentile quality | 500.43 |
| Quality target (Mean) | 2.02 | | |

### Figure A3-15. Monte Carlo "Backwards" Calculation: Silver (in ug/L)

| | |
|---|---|
| Name of discharge | Curraghinalt Mine |
| Name of river | Owenkillew River |
| Name of determinand | Silver (ug/L) |

| UPSTREAM RIVER DATA | | DISCHARGE DATA | |
|---|---|---|---|
| Mean flow | 3000 | Mean flow | 10.8 |
| 95% exceedence flow | 800 | Standard deviation of flow | 1.8 |
| Mean quality | 2.50 | Mean quality | 2.5 |
| Standard deviation of river quality | 0.00 | Standard deviation of quality | 0.825 |
| 90-percentile | 2.50 | ... or 95-percentile | 4.03 |

| RIVER DOWNSTREAM OF DISCHARGE | | DISCHARGE QUALITY NEEDED | |
|---|---|---|---|
| Mean quality | 2.52 | Mean quality | 5.34 |
| Standard deviation of quality | 0.01 | Standard deviation of quality | 1.73 |
| 90-percentile quality | 2.53 | 95-percentile quality | 8.53 |
| 95-percentile quality | 2.54 | 99-percentile quality | 10.43 |
| 99-percentile quality | 2.57 | 99.5-percentile quality | 11.01 |
| Quality target (Mean) | 2.52 | | |

### Figure A3-16. Monte Carlo "Backwards" Calculation: Uranium (in ug/L)

| | |
|---|---|
| Name of discharge | Curraghinalt Mine |
| Name of river | Owenkillew River |
| Name of determinand | Uranium (ug/L) |

| UPSTREAM RIVER DATA | | DISCHARGE DATA | |
|---|---|---|---|
| Mean flow | 3000 | Mean flow | 10.8 |
| 95% exceedence flow | 800 | Standard deviation of flow | 1.8 |
| Mean quality | 2.50 | Mean quality | 2.5 |
| Standard deviation of river quality | 0.00 | Standard deviation of quality | 0.825 |
| 90-percentile | 2.50 | ... or 95-percentile | 4.03 |

| RIVER DOWNSTREAM OF DISCHARGE | | DISCHARGE QUALITY NEEDED | |
|---|---|---|---|
| Mean quality | 4.00 | Mean quality | 286.65 |
| Standard deviation of quality | 1.08 | Standard deviation of quality | 92.70 |
| 90-percentile quality | 5.47 | 95-percentile quality | 458.30 |
| 95-percentile quality | 6.13 | 99-percentile quality | 560.20 |
| 99-percentile quality | 7.63 | 99.5-percentile quality | 591.53 |
| Quality target (Mean) | 4.00 | | |

**Figure A3-17. Monte Carlo "Backwards" Calculation: Zinc (in ug/L)**

| | |
|---|---|
| Name of discharge | Curraghinalt Mine |
| Name of river | Owenkillew River |
| Name of determinand | Zinc (ug/L) |

**UPSTREAM RIVER DATA**

| | |
|---|---|
| Mean flow | 3000 |
| 95% exceedence flow | 800 |
| Mean quality | 3.63 |
| Standard deviation of river quality | 2.65 |
| 90-percentile | 6.77 |

**DISCHARGE DATA**

| | |
|---|---|
| Mean flow | 10.8 |
| Standard deviation of flow | 1.8 |
| Mean quality | 3.63 |
| Standard deviation of quality | 1.21 |
| ... or 95-percentile | 5.87 |

**RIVER DOWNSTREAM OF DISCHARGE**

| | |
|---|---|
| Mean quality | 5.51 |
| Standard deviation of quality | 3.25 |
| 90-percentile quality | 9.16 |
| 95-percentile quality | 11.23 |
| 99-percentile quality | 18.42 |
| Quality target (Mean) | 5.51 |

**DISCHARGE QUALITY NEEDED**

| | |
|---|---|
| Mean quality | 348.47 |
| Standard deviation of quality | 113.80 |
| 95-percentile quality | 559.38 |
| 99-percentile quality | 685.08 |
| 99.5-percentile quality | 723.76 |

# 8 Appendix 4: "Forwards" Monte Carlo Calculations of Impact of Discharge on Owenkillew River Quality

**Figure A4-1. Monte Carlo "Forwards" Calculation: TSS (in mg/L)**

| | |
|---|---|
| Name of discharge | Curraghinalt Mine |
| Name of river | Owenkillew River |
| Name of determinand | TSS (mg/L) |

| UPSTREAM RIVER DATA | | DISCHARGE DATA | |
|---|---|---|---|
| Mean flow | 3000 | Mean flow | 10.8 |
| 95% exceedence flow | 800 | Standard deviation of flow | 1.8 |
| Mean quality | 6.76 | Mean quality | 50 |
| Standard deviation of river quality | 6.56 | Standard deviation of quality | 0 |
| 90-percentile | 13.77 | ... or 95-percentile | 50.00 |

| RIVER DOWNSTREAM OF DISCHARGE | | DISCHARGE QUALITY | |
|---|---|---|---|
| Mean quality | 7.14 | Mean quality | 50.00 |
| Standard deviation of quality | 6.87 | Standard deviation of quality | 0.00 |
| 90-percentile quality | 14.34 | 95-percentile quality | 50.00 |
| 95-percentile quality | 27.33 | 99-percentile quality | 50.00 |
| 99-percentile quality | 32.68 | 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 A4-2. Monte Carlo "Forwards" Calculation: BOD (in mg/L)**

| | |
|---|---|
| Name of discharge | Curraghinalt Mine |
| Name of river | Owenkillew River |
| Name of determinand | BOD (mg/L) - 90%ile |

| UPSTREAM RIVER DATA | | DISCHARGE DATA | |
|---|---|---|---|
| Mean flow | 3000 | Mean flow | 10.8 |
| 95% exceedence flow | 800 | Standard deviation of flow | 1.8 |
| Mean quality | 1.10 | Mean quality | 31.88 |
| Standard deviation of river quality | 0.91 | Standard deviation of quality | 0.00 |
| 90-percentile | 2.14 | ... or 95-percentile | 31.88 |

| RIVER DOWNSTREAM OF DISCHARGE | | DISCHARGE QUALITY | |
|---|---|---|---|
| Mean quality | 1.26 | Mean quality | 31.88 |
| Standard deviation of quality | 0.91 | Standard deviation of quality | 0.00 |
| 90-percentile quality | 3.09 | 95-percentile quality | 31.88 |
| 95-percentile quality | 3.16 | 99-percentile quality | 31.88 |
| 99-percentile quality | 3.29 | 99.5-percentile quality | 31.88 |

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

**Figure A4-3. Monte Carlo “Forwards” Calculation: Total Ammonia (in mg/L)**

| | |
|---|---|
| Name of discharge | Curraghinalt Mine |
| Name of river | Owenkillew River |
| Name of determinand | Total ammonia (ug/L) - 90%ile |

| UPSTREAM RIVER DATA | | DISCHARGE DATA | |
|---|---|---|---|
| Mean flow | 3000 | Mean flow | 10.8 |
| 95% exceedence flow | 800 | Standard deviation of flow | 1.8 |
| Mean quality | 105 | Mean quality | 390 |
| Standard deviation of river quality | 130 | Standard deviation of quality | 0.00 |
| 90-percentile | 226.92 | ... or 95-percentile | 390.00 |

| RIVER DOWNSTREAM OF DISCHARGE | | DISCHARGE QUALITY | |
|---|---|---|---|
| Mean quality | 108.20 | Mean quality | 390.00 |
| Standard deviation of quality | 141.64 | Standard deviation of quality | 0.00 |
| 90-percentile quality | 225.53 | 95-percentile quality | 390.00 |
| 95-percentile quality | 320.14 | 99-percentile quality | 390.00 |
| 99-percentile quality | 616.86 | 99.5-percentile quality | 390.00 |

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

**Figure A4-4. Monte Carlo “Forwards” Calculation: Nitrate (in mg/L)**

| | |
|---|---|
| Name of discharge | Curraghinalt Mine |
| Name of river | Owenkillew River |
| Name of determinand | Nitrate (mg/L) |

| UPSTREAM RIVER DATA | | DISCHARGE DATA | |
|---|---|---|---|
| Mean flow | 3000 | Mean flow | 10.8 |
| 95% exceedence flow | 800 | Standard deviation of flow | 1.8 |
| Mean quality | 0.22 | Mean quality | 11.3 |
| Standard deviation of river quality | 0.24 | Standard deviation of quality | 0 |
| 90-percentile | 0.46 | ... or 95-percentile | 11.30 |

| RIVER DOWNSTREAM OF DISCHARGE | | DISCHARGE QUALITY | |
|---|---|---|---|
| Mean quality | 0.29 | Mean quality | 11.30 |
| Standard deviation of quality | 0.27 | Standard deviation of quality | 0.00 |
| 90-percentile quality | 0.52 | 95-percentile quality | 11.30 |
| 95-percentile quality | 0.86 | 99-percentile quality | 11.30 |
| 99-percentile quality | 1.48 | 99.5-percentile quality | 11.30 |

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

**Figure A4-5. Monte Carlo "Forwards" Calculation: Nitrite (in ug/L)**

| | |
|---|---|
| Name of discharge | Curraghinalt Mine |
| Name of river | Owenkillew River |
| Name of determinand | Nitrite (ug/L) |

| UPSTREAM RIVER DATA | | DISCHARGE DATA | |
|---|---|---|---|
| Mean flow | 3000 | Mean flow | 10.8 |
| 95% exceedence flow | 800 | Standard deviation of flow | 1.8 |
| Mean quality | 7.67 | Mean quality | 220 |
| Standard deviation of river quality | 9.88 | Standard deviation of quality | 0 |
| 90-percentile | 16.69 | ... or 95-percentile | 220.00 |

| RIVER DOWNSTREAM OF DISCHARGE | | DISCHARGE QUALITY | |
|---|---|---|---|
| Mean quality | 9.20 | Mean quality | 220.00 |
| Standard deviation of quality | 11.35 | Standard deviation of quality | 0.00 |
| 90-percentile quality | 25.23 | 95-percentile quality | 220.00 |
| 95-percentile quality | 28.48 | 99-percentile quality | 220.00 |
| 99-percentile quality | 66.83 | 99.5-percentile quality | 220.00 |

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

**Figure A4-6. Monte Carlo "Forwards" Calculation: Chloride (in mg/L)**

| | |
|---|---|
| Name of discharge | Curraghinalt Mine |
| Name of river | Owenkillew River |
| Name of determinand | Chloride (mg/L) |

| UPSTREAM RIVER DATA | | DISCHARGE DATA | |
|---|---|---|---|
| Mean flow | 3000 | Mean flow | 10.8 |
| 95% exceedence flow | 800 | Standard deviation of flow | 1.8 |
| Mean quality | 10.90 | Mean quality | 250 |
| Standard deviation of river quality | 5.12 | Standard deviation of quality | 0 |
| 90-percentile | 17.47 | ... or 95-percentile | 250.00 |

| RIVER DOWNSTREAM OF DISCHARGE | | DISCHARGE QUALITY | |
|---|---|---|---|
| Mean quality | 12.30 | Mean quality | 250.00 |
| Standard deviation of quality | 5.92 | Standard deviation of quality | 0.00 |
| 90-percentile quality | 17.53 | 95-percentile quality | 250.00 |
| 95-percentile quality | 22.48 | 99-percentile quality | 250.00 |
| 99-percentile quality | 40.10 | 99.5-percentile quality | 250.00 |

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

**Figure A4-7. Monte Carlo "Forwards" Calculation: Fluoride (in mg/L)**

| | |
|---|---|
| Name of discharge | Curraghinalt Mine |
| Name of river | Owenkillew River |
| Name of determinand | F (mg/L) |

| UPSTREAM RIVER DATA | | DISCHARGE DATA | |
|---|---|---|---|
| Mean flow | 3000 | Mean flow | 10.8 |
| 95% exceedence flow | 800 | Standard deviation of flow | 1.8 |
| Mean quality | 0.15 | Mean quality | 1.5 |
| Standard deviation of river quality | 0.00 | Standard deviation of quality | 0.00 |
| 90-percentile | 0.15 | ... or 95-percentile | 1.50 |

| RIVER DOWNSTREAM OF DISCHARGE | | DISCHARGE QUALITY | |
|---|---|---|---|
| Mean quality | 0.16 | Mean quality | 1.50 |
| Standard deviation of quality | 0.00 | Standard deviation of quality | 0.00 |
| 90-percentile quality | 0.16 | 95-percentile quality | 1.50 |
| 95-percentile quality | 0.17 | 99-percentile quality | 1.50 |
| 99-percentile quality | 0.17 | 99.5-percentile quality | 1.50 |

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

**Figure A4-8. Monte Carlo "Forwards" Calculation: Sulphate (in mg/L)**

| | |
|---|---|
| Name of discharge | Curraghinalt Mine |
| Name of river | Owenkillew River |
| Name of determinand | Sulphate (mg/L) |

| UPSTREAM RIVER DATA | | DISCHARGE DATA | |
|---|---|---|---|
| Mean flow | 3000 | Mean flow | 10.8 |
| 95% exceedence flow | 800 | Standard deviation of flow | 1.8 |
| Mean quality | 3.30 | Mean quality | 250 |
| Standard deviation of river quality | 7.70 | Standard deviation of quality | 0 |
| 90-percentile | 7.47 | ... or 95-percentile | 250.00 |

| RIVER DOWNSTREAM OF DISCHARGE | | DISCHARGE QUALITY | |
|---|---|---|---|
| Mean quality | 5.06 | Mean quality | 250.00 |
| Standard deviation of quality | 9.33 | Standard deviation of quality | 0.00 |
| 90-percentile quality | 9.71 | 95-percentile quality | 250.00 |
| 95-percentile quality | 17.10 | 99-percentile quality | 250.00 |
| 99-percentile quality | 58.02 | 99.5-percentile quality | 250.00 |

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

**Figure A4-9. Monte Carlo "Forwards" Calculation: Aluminium (in ug/L)**

| | |
|---|---|
| Name of discharge | Curraghinalt Mine |
| Name of river | Owenkillew River |
| Name of determinand | Aluminium (ug/L) |

| UPSTREAM RIVER DATA | | DISCHARGE DATA | |
|---|---|---|---|
| Mean flow | 3000 | Mean flow | 10.8 |
| 95% exceedence flow | 800 | Standard deviation of flow | 1.8 |
| Mean quality | 65.82 | Mean quality | 200 |
| Standard deviation of river quality | 37.58 | Standard deviation of quality | 0 |
| 90-percentile | 112.90 | ... or 95-percentile | 200.00 |

| RIVER DOWNSTREAM OF DISCHARGE | | DISCHARGE QUALITY | |
|---|---|---|---|
| Mean quality | 66.36 | Mean quality | 200.00 |
| Standard deviation of quality | 38.68 | Standard deviation of quality | 0.00 |
| 90-percentile quality | 123.55 | 95-percentile quality | 200.00 |
| 95-percentile quality | 130.57 | 99-percentile quality | 200.00 |
| 99-percentile quality | 175.80 | 99.5-percentile quality | 200.00 |

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

**Figure A4-10. Monte Carlo "Forwards" Calculation: Antimony (in ug/L)**

| | |
|---|---|
| Name of discharge | Curraghinalt Mine |
| Name of river | Owenkillew River |
| Name of determinand | Antimony (ug/L) |

| UPSTREAM RIVER DATA | | DISCHARGE DATA | |
|---|---|---|---|
| Mean flow | 3000 | Mean flow | 10.8 |
| 95% exceedence flow | 800 | Standard deviation of flow | 1.8 |
| Mean quality | 1.20 | Mean quality | 5 |
| Standard deviation of river quality | 0.66 | Standard deviation of quality | 0 |
| 90-percentile | 2.04 | ... or 95-percentile | 5.00 |

| RIVER DOWNSTREAM OF DISCHARGE | | DISCHARGE QUALITY | |
|---|---|---|---|
| Mean quality | 1.27 | Mean quality | 5.00 |
| Standard deviation of quality | 0.75 | Standard deviation of quality | 0.00 |
| 90-percentile quality | 1.85 | 95-percentile quality | 5.00 |
| 95-percentile quality | 3.42 | 99-percentile quality | 5.00 |
| 99-percentile quality | 4.38 | 99.5-percentile quality | 5.00 |

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

**Figure A4-11. Monte Carlo "Forwards" Calculation: Arsenic (in ug/L)**

| | |
|---|---|
| Name of discharge | Curraghinalt Mine |
| Name of river | Owenkillew River |
| Name of determinand | As (ug/L) |

| UPSTREAM RIVER DATA | | DISCHARGE DATA | |
|---|---|---|---|
| Mean flow | 3000 | Mean flow | 10.8 |
| 95% exceedence flow | 800 | Standard deviation of flow | 1.8 |
| Mean quality | 1.22 | Mean quality | 10 |
| Standard deviation of river quality | 1.22 | Standard deviation of quality | 0.00 |
| 90-percentile | 2.51 | ... or 95-percentile | 10.00 |

| RIVER DOWNSTREAM OF DISCHARGE | | DISCHARGE QUALITY | |
|---|---|---|---|
| Mean quality | 1.30 | Mean quality | 10.00 |
| Standard deviation of quality | 1.35 | Standard deviation of quality | 0.00 |
| 90-percentile quality | 2.38 | 95-percentile quality | 10.00 |
| 95-percentile quality | 4.02 | 99-percentile quality | 10.00 |
| 99-percentile quality | 7.36 | 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 A4-12. Monte Carlo "Forwards" Calculation: Boron (in ug/L)**

| | |
|---|---|
| Name of discharge | Curraghinalt Mine |
| Name of river | Owenkillew River |
| Name of determinand | Boron (ug/L) |

| UPSTREAM RIVER DATA | | DISCHARGE DATA | |
|---|---|---|---|
| Mean flow | 3000 | Mean flow | 10.8 |
| 95% exceedence flow | 800 | Standard deviation of flow | 1.8 |
| Mean quality | 4.90 | Mean quality | 1000 |
| Standard deviation of river quality | 2.02 | Standard deviation of quality | 0 |
| 90-percentile | 7.53 | ... or 95-percentile | 1000.0 |

| RIVER DOWNSTREAM OF DISCHARGE | | DISCHARGE QUALITY | |
|---|---|---|---|
| Mean quality | 10.07 | Mean quality | 1000.0 |
| Standard deviation of quality | 3.76 | Standard deviation of quality | 0.00 |
| 90-percentile quality | 14.85 | 95-percentile quality | 1000.0 |
| 95-percentile quality | 16.80 | 99-percentile quality | 1000.0 |
| 99-percentile quality | 21.03 | 99.5-percentile quality | 1000.0 |

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

**Figure A4-13. Monte Carlo "Forwards" Calculation: Cadmium (in ng/L)**

| | |
|---|---|
| Name of discharge | Curraghinalt Mine |
| Name of river | Owenkillew River |
| Name of determinand | Cadmium (ng/L) |

| UPSTREAM RIVER DATA | | DISCHARGE DATA | |
|---|---|---|---|
| Mean flow | 3000 | Mean flow | 10.8 |
| 95% exceedence flow | 800 | Standard deviation of flow | 1.8 |
| Mean quality | 28.59 | Mean quality | 1370 |
| Standard deviation of river quality | 27.17 | Standard deviation of quality | 0 |
| 90-percentile | 57.93 | ... or 95-percentile | 1370.0 |

| RIVER DOWNSTREAM OF DISCHARGE | | DISCHARGE QUALITY | |
|---|---|---|---|
| Mean quality | 36.61 | Mean quality | 1370.0 |
| Standard deviation of quality | 29.71 | Standard deviation of quality | 0.00 |
| 90-percentile quality | 84.64 | 95-percentile quality | 1370.0 |
| 95-percentile quality | 92.77 | 99-percentile quality | 1370.0 |
| 99-percentile quality | 152.93 | 99.5-percentile quality | 1370.0 |

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

**Figure A4-14. Monte Carlo "Forwards" Calculation: Chromium III (in ug/L)**

| | |
|---|---|
| Name of discharge | Curraghinalt Mine |
| Name of river | Owenkillew River |
| Name of determinand | Chromium III (ug/L) |

| UPSTREAM RIVER DATA | | DISCHARGE DATA | |
|---|---|---|---|
| Mean flow | 3000 | Mean flow | 10.8 |
| 95% exceedence flow | 800 | Standard deviation of flow | 1.8 |
| Mean quality | 2.47 | Mean quality | 29 |
| Standard deviation of river quality | 0.9 | Standard deviation of quality | 0 |
| 90-percentile | 3.65 | ... or 95-percentile | 29.00 |

| RIVER DOWNSTREAM OF DISCHARGE | | DISCHARGE QUALITY | |
|---|---|---|---|
| Mean quality | 2.62 | Mean quality | 29.00 |
| Standard deviation of quality | 0.91 | Standard deviation of quality | 0.00 |
| 90-percentile quality | 3.76 | 95-percentile quality | 29.00 |
| 95-percentile quality | 4.26 | 99-percentile quality | 29.00 |
| 99-percentile quality | 5.45 | 99.5-percentile quality | 29.00 |

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

**Figure A4-15. Monte Carlo "Forwards" Calculation: Chromium VI (in ug/L)**

| | |
|---|---|
| Name of discharge | Curraghinalt Mine |
| Name of river | Owenkillew River |
| Name of determinand | Chromium VI (ug/L) |

| UPSTREAM RIVER DATA | | DISCHARGE DATA | |
|---|---|---|---|
| Mean flow | 3000 | Mean flow | 10.8 |
| 95% exceedence flow | 800 | Standard deviation of flow | 1.8 |
| Mean quality | 2.47 | Mean quality | 21 |
| Standard deviation of river quality | 0.86 | Standard deviation of quality | 0 |
| 90-percentile | 3.60 | ... or 95-percentile | 21.00 |

| RIVER DOWNSTREAM OF DISCHARGE | | DISCHARGE QUALITY | |
|---|---|---|---|
| Mean quality | 2.58 | Mean quality | 21.00 |
| Standard deviation of quality | 0.86 | Standard deviation of quality | 0.00 |
| 90-percentile quality | 3.66 | 95-percentile quality | 21.00 |
| 95-percentile quality | 4.14 | 99-percentile quality | 21.00 |
| 99-percentile quality | 5.19 | 99.5-percentile quality | 21.00 |

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

**Figure A4-16. Monte Carlo "Forwards" Calculation: Chromium Total (in ug/L)**

| | |
|---|---|
| Name of discharge | Curraghinalt Mine |
| Name of river | Owenkillew River |
| Name of determinand | Chromium Total (ug/L) |

| UPSTREAM RIVER DATA | | DISCHARGE DATA | |
|---|---|---|---|
| Mean flow | 3000 | Mean flow | 10.8 |
| 95% exceedence flow | 800 | Standard deviation of flow | 1.8 |
| Mean quality | 4.93 | Mean quality | 50 |
| Standard deviation of river quality | 1.8 | Standard deviation of quality | 0 |
| 90-percentile | 7.29 | ... or 95-percentile | 50.00 |

| RIVER DOWNSTREAM OF DISCHARGE | | DISCHARGE QUALITY | |
|---|---|---|---|
| Mean quality | 5.19 | Mean quality | 50.00 |
| Standard deviation of quality | 1.81 | Standard deviation of quality | 0.00 |
| 90-percentile quality | 7.46 | 95-percentile quality | 50.00 |
| 95-percentile quality | 8.47 | 99-percentile quality | 50.00 |
| 99-percentile quality | 10.78 | 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 A4-17. Monte Carlo "Forwards" Calculation: Copper (in ug/L)**

| | |
|---|---|
| Name of discharge | Curraghinalt Mine |
| Name of river | Owenkillew River |
| Name of determinand | Copper (ug/L) |

| UPSTREAM RIVER DATA | | DISCHARGE DATA | |
|---|---|---|---|
| Mean flow | 3000 | Mean flow | 10.8 |
| 95% exceedence flow | 800 | Standard deviation of flow | 1.8 |
| Mean quality | 1.08 | Mean quality | 120 |
| Standard deviation of river quality | 0.50 | Standard deviation of quality | 0 |
| 90-percentile | 1.72 | ... or 95-percentile | 120.00 |

| RIVER DOWNSTREAM OF DISCHARGE | | DISCHARGE QUALITY | |
|---|---|---|---|
| Mean quality | 1.71 | Mean quality | 120.00 |
| Standard deviation of quality | 0.63 | Standard deviation of quality | 0.00 |
| 90-percentile quality | 2.49 | 95-percentile quality | 120.00 |
| 95-percentile quality | 2.86 | 99-percentile quality | 120.00 |
| 99-percentile quality | 3.41 | 99.5-percentile quality | 120.00 |

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

**Figure A4-18. Monte Carlo "Forwards" Calculation: Iron (in mg/L)**

| | |
|---|---|
| Name of discharge | Curraghinalt Mine |
| Name of river | Owenkillew River |
| Name of determinand | Iron (mg/L) |

| UPSTREAM RIVER DATA | | DISCHARGE DATA | |
|---|---|---|---|
| Mean flow | 3000 | Mean flow | 10.8 |
| 95% exceedence flow | 800 | Standard deviation of flow | 1.8 |
| Mean quality | 0.93 | Mean quality | 2.48 |
| Standard deviation of river quality | 0.36 | Standard deviation of quality | 0 |
| 90-percentile | 1.40 | ... or 95-percentile | 2.48 |

| RIVER DOWNSTREAM OF DISCHARGE | | DISCHARGE QUALITY | |
|---|---|---|---|
| Mean quality | 0.94 | Mean quality | 2.48 |
| Standard deviation of quality | 0.36 | Standard deviation of quality | 0.00 |
| 90-percentile quality | 1.40 | 95-percentile quality | 2.48 |
| 95-percentile quality | 1.60 | 99-percentile quality | 2.48 |
| 99-percentile quality | 2.07 | 99.5-percentile quality | 2.48 |

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

**Figure A4-19. Monte Carlo "Forwards" Calculation: Lead (in ug/L)**

| | |
|---|---|
| Name of discharge | Curraghinalt Mine |
| Name of river | Owenkillew River |
| Name of determinand | Lead (ug/L) |

| UPSTREAM RIVER DATA | | DISCHARGE DATA | |
|---|---|---|---|
| Mean flow | 3000 | Mean flow | 10.8 |
| 95% exceedence flow | 800 | Standard deviation of flow | 1.8 |
| Mean quality | 0.46 | Mean quality | 10 |
| Standard deviation of river quality | 0.56 | Standard deviation of quality | 0 |
| 90-percentile | 1.00 | ... or 95-percentile | 10.00 |

| RIVER DOWNSTREAM OF DISCHARGE | | DISCHARGE QUALITY | |
|---|---|---|---|
| Mean quality | 0.53 | Mean quality | 10.00 |
| Standard deviation of quality | 0.62 | Standard deviation of quality | 0.00 |
| 90-percentile quality | 1.53 | 95-percentile quality | 10.00 |
| 95-percentile quality | 1.57 | 99-percentile quality | 10.00 |
| 99-percentile quality | 3.35 | 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 A4-20. Monte Carlo "Forwards" Calculation: Manganese (in ug/L)**

| | |
|---|---|
| Name of discharge | Curraghinalt Mine |
| Name of river | Owenkillew River |
| Name of determinand | Manganese (ug/L) |

| UPSTREAM RIVER DATA | | DISCHARGE DATA | |
|---|---|---|---|
| Mean flow | 3000 | Mean flow | 10.8 |
| 95% exceedence flow | 800 | Standard deviation of flow | 1.8 |
| Mean quality | 81.54 | Mean quality | 93.2 |
| Standard deviation of river quality | 45.5 | Standard deviation of quality | 0 |
| 90-percentile | 138.76 | ... or 95-percentile | 93.20 |

| RIVER DOWNSTREAM OF DISCHARGE | | DISCHARGE QUALITY | |
|---|---|---|---|
| Mean quality | 82.14 | Mean quality | 93.20 |
| Standard deviation of quality | 46.13 | Standard deviation of quality | 0.00 |
| 90-percentile quality | 137.70 | 95-percentile quality | 93.20 |
| 95-percentile quality | 166.92 | 99-percentile quality | 93.20 |
| 99-percentile quality | 237.23 | 99.5-percentile quality | 93.20 |

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

**Figure A4-21. Monte Carlo "Forwards" Calculation: Mercury (in ng/L)**

| | |
|---|---|
| Name of discharge | Curraghinalt Mine |
| Name of river | Owenkillew River |
| Name of determinand | Mercury (ng/L) - 95%ile |

| UPSTREAM RIVER DATA | |
|---|---|
| Mean flow | 3000 |
| 95% exceedence flow | 800 |
| Mean quality | 11 |
| Standard deviation of river quality | 37 |
| 90-percentile | 23.88 |

| DISCHARGE DATA | |
|---|---|
| Mean flow | 10.8 |
| Standard deviation of flow | 1.8 |
| Mean quality | 1000 |
| Standard deviation of quality | 0.00 |
| ... or 95-percentile | 1000.0 |

| RIVER DOWNSTREAM OF DISCHARGE | |
|---|---|
| Mean quality | 16.95 |
| Standard deviation of quality | 44.43 |
| 90-percentile quality | 28.73 |
| 95-percentile quality | 46.90 |
| 99-percentile quality | 129.61 |

| DISCHARGE QUALITY | |
|---|---|
| Mean quality | 1000.0 |
| Standard deviation of quality | 0.25 |
| 95-percentile quality | 1000.0 |
| 99-percentile quality | 1000.0 |
| 99.5-percentile quality | 1000.0 |

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

**Figure A4-22. Monte Carlo "Forwards" Calculation: Molybdenum (in ug/L)**

| | |
|---|---|
| Name of discharge | Curraghinalt Mine |
| Name of river | Owenkillew River |
| Name of determinand | Molybdenum (ug/L) |

| UPSTREAM RIVER DATA | |
|---|---|
| Mean flow | 3000 |
| 95% exceedence flow | 800 |
| Mean quality | 0.28 |
| Standard deviation of river quality | 0.36 |
| 90-percentile | 0.60 |

| DISCHARGE DATA | |
|---|---|
| Mean flow | 10.8 |
| Standard deviation of flow | 1.8 |
| Mean quality | 200 |
| Standard deviation of quality | 0.00 |
| ... or 95-percentile | 200.00 |

| RIVER DOWNSTREAM OF DISCHARGE | |
|---|---|
| Mean quality | 1.34 |
| Standard deviation of quality | 0.75 |
| 90-percentile quality | 2.37 |
| 95-percentile quality | 2.79 |
| 99-percentile quality | 3.92 |

| DISCHARGE QUALITY | |
|---|---|
| Mean quality | 200.00 |
| Standard deviation of quality | 0.00 |
| 95-percentile quality | 200.00 |
| 99-percentile quality | 200.00 |
| 99.5-percentile quality | 200.00 |

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

**Figure A4-23. Monte Carlo "Forwards" Calculation: Nickel (in ug/L)**

| | |
|---|---|
| Name of discharge | Curraghinalt Mine |
| Name of river | Owenkillew River |
| Name of determinand | Nickel (ug/L) |

| UPSTREAM RIVER DATA | | DISCHARGE DATA | |
|---|---|---|---|
| Mean flow | 3000 | Mean flow | 10.8 |
| 95% exceedence flow | 800 | Standard deviation of flow | 1.8 |
| Mean quality | 0.74 | Mean quality | 20 |
| Standard deviation of river quality | 0.51 | Standard deviation of quality | 0 |
| 90-percentile | 1.35 | ... or 95-percentile | 20.00 |

| RIVER DOWNSTREAM OF DISCHARGE | | DISCHARGE QUALITY | |
|---|---|---|---|
| Mean quality | 0.84 | Mean quality | 20.00 |
| Standard deviation of quality | 0.52 | Standard deviation of quality | 0.00 |
| 90-percentile quality | 1.45 | 95-percentile quality | 20.00 |
| 95-percentile quality | 1.83 | 99-percentile quality | 20.00 |
| 99-percentile quality | 2.15 | 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 A4-24. Monte Carlo "Forwards" Calculation: Selenium (in ug/L)**

| | |
|---|---|
| Name of discharge | Curraghinalt Mine |
| Name of river | Owenkillew River |
| Name of determinand | Selenium (ug/L) |

| UPSTREAM RIVER DATA | | DISCHARGE DATA | |
|---|---|---|---|
| Mean flow | 3000 | Mean flow | 10.8 |
| 95% exceedence flow | 800 | Standard deviation of flow | 1.8 |
| Mean quality | 0.55 | Mean quality | 10 |
| Standard deviation of river quality | 0.21 | Standard deviation of quality | 0 |
| 90-percentile | 0.82 | ... or 95-percentile | 10.00 |

| RIVER DOWNSTREAM OF DISCHARGE | | DISCHARGE QUALITY | |
|---|---|---|---|
| Mean quality | 0.60 | Mean quality | 10.00 |
| Standard deviation of quality | 0.21 | Standard deviation of quality | 0.00 |
| 90-percentile quality | 0.75 | 95-percentile quality | 10.00 |
| 95-percentile quality | 1.03 | 99-percentile quality | 10.00 |
| 99-percentile quality | 1.08 | 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 A4-25. Monte Carlo "Forwards" Calculation: Silver (in ug/L)**

| | |
|---|---|
| Name of discharge | Curraghinalt Mine |
| Name of river | Owenkillew River |
| Name of determinand | Silver (ug/L) |

| UPSTREAM RIVER DATA | | DISCHARGE DATA | |
|---|---|---|---|
| Mean flow | 3000 | Mean flow | 10.8 |
| 95% exceedence flow | 800 | Standard deviation of flow | 1.8 |
| Mean quality | 2.50 | Mean quality | 5.34 |
| Standard deviation of river quality | 0.00 | Standard deviation of quality | 0 |
| 90-percentile | 2.50 | ... or 95-percentile | 5.34 |

| RIVER DOWNSTREAM OF DISCHARGE | | DISCHARGE QUALITY | |
|---|---|---|---|
| Mean quality | 2.51 | Mean quality | 5.34 |
| Standard deviation of quality | 0.01 | Standard deviation of quality | 0.00 |
| 90-percentile quality | 2.53 | 95-percentile quality | 5.34 |
| 95-percentile quality | 2.53 | 99-percentile quality | 5.34 |
| 99-percentile quality | 2.55 | 99.5-percentile quality | 5.34 |

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

**Figure A4-26. Monte Carlo "Forwards" Calculation: Sodium (in mg/L)**

| | |
|---|---|
| Name of discharge | Curraghinalt Mine |
| Name of river | Owenkillew River |
| Name of determinand | Sodium (mg/L) |

| UPSTREAM RIVER DATA | | DISCHARGE DATA | |
|---|---|---|---|
| Mean flow | 3000 | Mean flow | 10.8 |
| 95% exceedence flow | 800 | Standard deviation of flow | 1.8 |
| Mean quality | 6.49 | Mean quality | 200 |
| Standard deviation of river quality | 1.93 | Standard deviation of quality | 0 |
| 90-percentile | 9.03 | ... or 95-percentile | 200.00 |

| RIVER DOWNSTREAM OF DISCHARGE | | DISCHARGE QUALITY | |
|---|---|---|---|
| Mean quality | 7.55 | Mean quality | 200.00 |
| Standard deviation of quality | 2.24 | Standard deviation of quality | 0.00 |
| 90-percentile quality | 10.13 | 95-percentile quality | 200.00 |
| 95-percentile quality | 11.62 | 99-percentile quality | 200.00 |
| 99-percentile quality | 17.14 | 99.5-percentile quality | 200.00 |

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

**Figure A4-27. Monte Carlo "Forwards" Calculation: Uranium (in ug/L)**

| | |
|---|---|
| Name of discharge | Curraghinalt Mine |
| Name of river | Owenkillew River |
| Name of determinand | Uranium (ug/L) |

| UPSTREAM RIVER DATA | | DISCHARGE DATA | |
|---|---|---|---|
| Mean flow | 3000 | Mean flow | 10.8 |
| 95% exceedence flow | 800 | Standard deviation of flow | 1.8 |
| Mean quality | 2.50 | Mean quality | 30 |
| Standard deviation of river quality | 0.00 | Standard deviation of quality | 0 |
| 90-percentile | 2.50 | ... or 95-percentile | 30.00 |

| RIVER DOWNSTREAM OF DISCHARGE | | DISCHARGE QUALITY | |
|---|---|---|---|
| Mean quality | 2.64 | Mean quality | 30.00 |
| Standard deviation of quality | 0.09 | Standard deviation of quality | 0.00 |
| 90-percentile quality | 2.76 | 95-percentile quality | 30.00 |
| 95-percentile quality | 2.82 | 99-percentile quality | 30.00 |
| 99-percentile quality | 2.94 | 99.5-percentile quality | 30.00 |

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

**Figure A4-28. Monte Carlo "Forwards" Calculation: Zinc (in ug/L)**

| | |
|---|---|
| Name of discharge | Curraghinalt Mine |
| Name of river | Owenkillew River |
| Name of determinand | Zinc (ug/L) |

| UPSTREAM RIVER DATA | | DISCHARGE DATA | |
|---|---|---|---|
| Mean flow | 3000 | Mean flow | 10.8 |
| 95% exceedence flow | 800 | Standard deviation of flow | 1.8 |
| Mean quality | 3.63 | Mean quality | 348 |
| Standard deviation of river quality | 2.65 | Standard deviation of quality | 0 |
| 90-percentile | 6.77 | ... or 95-percentile | 348.00 |

| RIVER DOWNSTREAM OF DISCHARGE | | DISCHARGE QUALITY | |
|---|---|---|---|
| Mean quality | 5.50 | Mean quality | 348.00 |
| Standard deviation of quality | 3.13 | Standard deviation of quality | 0.00 |
| 90-percentile quality | 8.93 | 95-percentile quality | 348.00 |
| 95-percentile quality | 10.77 | 99-percentile quality | 348.00 |
| 99-percentile quality | 18.31 | 99.5-percentile quality | 348.00 |

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