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External Memorandum

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Company:	Dalradian Gold Limited	**Project Number:**	UK6193
Copied to:		**Project Title:**	Curraghinalt Gold ESIA
File Ref:	UK6193 Calculation of Proposed Discharge Criteria for the Curraghinalt Project_v4.docx	**Date:**	12 April 2017
Subject:	**Calculation of Proposed Discharge Criteria for the Curraghinalt Mine**		

The aim of this short technical memo is to provide an initial set of proposed water quality discharge criteria for the Curraghinalt mine site. These criteria are calculated for the proposed infrastructure area and would form the permitted end-of-pipe discharge criteria during construction and operation of the mine. Discharges from the mine would be to the Pollanroe Burn at a single location. The Pollanroe Burn then discharges into the Owenreagh River, as show in Figure 1. The site layout is shown in Figure 2.

This initial set of values is provided to NIEA for review and comment.

The discharge values have been developed based on a methodology outlined in Figure 3. The stages of the assessment process comprised;

1. Initial Scoping of Key Water Quality Parameters, where the water quality parameters to be carried forward through the assessment were determined from the full set of parameters monitored during the project baseline studies
2. Compliance Calculations
3. Proposed Discharge Criteria
4. Identification of Appropriate Treatment Methodology to meet discharge criteria

A process of this nature represents best practice in mitigation design, and seeks to eliminate all significant impacts upon the receiving environment.

Stage 1: Initial Scoping of Key Water Quality Parameters

The baseline water quality assessment for the project included analysis of a full suite of water quality parameters at locations throughout the project area. This work is described in the project Surface Water Baseline Study report, that will form part of the Environmental Impact Assessment. The suite of parameters used in the baseline assessment formed the starting point for the scoping assessment for key water quality parameters. The full list of parameters is outlined in Table 1.

The first part of the process was to identify key national water quality standards for Northern Ireland. The key legislation used was:

- SR 315; Statutory Rules of Northern Ireland (SRNI), 2015. Water Framework Directive (Classification, Priority Substances and Shellfish Waters) Regulations (Northern Ireland) 2015 SR 351.
- WSR; The Water Supply (Water Quality) (Amendment) Regulations (NI) 2009 and 2010 Schedule 1 – prescribed concentrations and values and Schedule 2 – indicator parameters.

Standards for copper, manganese, nickel and zinc refer to bioavailable concentrations of these parameters, which depend on the receiving water chemistry. Calculations of the bioavailable concentrations are provided in Appendix A, with site-specific Environmental Quality Standards (EQS) calculated using the PNEC calculation method.

This legislation was supported by the following for two key parameters of concern (nitrate and TSS), in the absence of other legislative standards:

- European Union agri-environmental indicator for nitrate (http://ec.europa.eu/eurostat/statistics-explained/index.php/Agri-environmental_indicator_-_nitrate_pollution_of_water)
- 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.

Appropriate standards and parameters related to these documents are outlined in Table 2.

The second part of the process was to review the remaining parameters not covered by standards in Table 2 by comparison with geochemical predictions for mining wastes and other mine waters, to identify parameters that had the potential for elevated concentrations at the mine site (produced by mining activities). The following parameters were identified as having potentially elevated concentrations in the geochemical assessment on this basis;

- Boron
- Molybdenum
- Uranium

Once identified a further review was undertaken to identify suitable international standards that could be applied to these parameters. The most appropriate standards were identified as CCME, Canadian Council of Ministers of the Environment (CCME). Water Quality Guidelines for the Protection of Aquatic Life. Available at http://st-ts.ccme.ca/en/index,html, based on values from October 2016. CCME values are considered for selected parameters which have no other Northern Ireland standards or guidelines, see Table 3. For the purpose of this assessment these CCME guidelines are considered equivalent to the national standards in Table 2 and are used to set discharge criteria.

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' was proposed. This was considered an appropriate way to monitor against any hydrocarbon releases from the mine site. No discharge calculations for hydrocarbons were undertaken.

The final part of the process was to identify secondary, non-statutory water quality guidelines that identified other parameters of interest and/or guideline concentrations that would need to be considered in any assessment. The key guidelines were related to Fresh Water Pearl Mussels (FPM) and these are discussed in Appendix B. Appropriate guidelines and parameters are outlined in Table 4. These guideline vales are not used in the calculations for setting the discharge criteria, but the results of the compliance calculations are compared to these guideline values, with the aim that average post-development concentrations in the Owenreagh are within the range in guideline values in Table 4. For the six parameters considered in Table 4, five of them are covered by other standards (Table 2). Orthophosphate has no other standard, and no significant source of orthophosphate has been identified within mine water. Therefore, orthophosphate is not considered a parameter of concern and is scoped out.

BOD and Ammonia are regulated parameters for sewage treatment plant effluent. Following discussions with NIEA it was agreed that a single set of discharge criteria would be developed for the mine site, for the combined treated mine water and sewage effluent streams (i.e., no separate discharge criteria for sewage effluent). It was indicated that NIEA would typically look for compliance of 1.5 mg/L for BOD and a value of 0.1 mg/L for ammonia in the Owenreagh for sewage effluent discharges, with an allowed deterioration of the mid class (average) of 13% for BOD and 28% for ammonia. Discussions with sewage treatment vendors have indicated that 1.5 mg/L BOD and 0.1 mg/L for ammonia can be achieved at the End of Pipe. Faecal Coliforms have not been indicated as being a parameter that needs to be included on a discharge permit. However, the sewage treatment plant will comply with all relevant standards and no faecal coliforms would be produced by any other source within the mine site. As with the FPM values, these values provided by NIEA are not considered as standards, but the results of the compliance calculations are compared to these values, with the aim that average post-development concentrations in the Owenreagh are within the proposed criteria or changes from baseline.

A summary of the selection of key parameters for the assessment is provided in Table 5. Parameters not identified as 'Included' in the assessment are scoped out of further calculations.

Stage 2: Compliance Calculations

As agreed at previous consultation meetings with NIEA, compliance with standards/guidelines will be within the Owenreagh River. Following discussions with NIEA and reference to guidance from the England and Wales Environment Agency (LIT 10419: Modelling: surface water pollution risk assessment) the following methodology was adopted for calculating discharges from the mine site.

- *Baseline concentrations in the Owenreagh River will not be increased by more than 10% of the appropriate environmental standard for parameters that are currently below that standard under baseline conditions. For parameters that currently exceed standards in the Owenreagh, post-development concentrations will not be increased by more than 3% of the appropriate standard.*

A further requirement was adopted by DGL that 'discharge concentrations should be no greater than drinking water standards' within the on-site water treatment plant. For the calculation of practical discharge criteria the higher of the drinking water standards and the mean baseline concentration in the Pollanroe Burn is considered as a discharge limit.

Dilution calculations are undertaken to back calculate the required mine site discharge criteria to meet the methodology outlined above. It should be noted that some standards are based on average water quality and others relate to maximum or some other statistic. Calculations are made based on average water quality standards, with average criteria considered for average flow conditions and other criteria for 95%ile, low flow conditions.

Flow Conditions

Key flow conditions in the Owenreagh River and for mine site discharges are outlined in Table 6. The discharge from the mine site will be a combination of effluent from the mine site sewage treatment plant and the mine water treatment plant, with the mine water treatment plant producing the highest flow rates. There will also be a minor contribution from seepage through the DSF liner.

Baseline Water Quality

Baseline water quality in the Owenreagh River and Pollanroe Burn for parameters considered in the assessment is summarised in Table 7.

The methodology for calculating water quality averages is based on Environment Agency (2012), 'Pollution inventory reporting – general guidance notes', LIT-7665-1200_10 and the 'Common Implementation Strategy for the Water Framework Directive, Guidance Document No. 19'.

The baseline quality shows limited exceedances of environmental standards in the Owenreagh River.

Exceedances of average baseline water quality are observed for silver, due to the detection limit for the baseline studies being higher than the environmental standard. Review of UK laboratories has identified laboratories that can achieve 0.001 mg/l detection standard for silver, which is double the average standard for silver.

Exceedances of average baseline water quality are also observed for Free Cyanide; however, these result from the low value of the standard (0.001 mg/l) and the difficulty of monitoring Free Cyanide in the laboratory. The laboratory used for the baseline study water quality characterisation has a detection limit of 0.001 mg/l for free cyanide (the lowest of any mainstream commercial UK lab) but the method is not accredited. 38% of measurements were at or below detection limit and 90% were within 2x detection limit (i.e. less than or equal to 0.002 mg/l). The maximum accredited standard for free cyanide is 0.005 mg/L (i.e. the maximum environmental standard). All baseline samples were below 0.005 mg/l free cyanide (the maximum SR-351 standard concentration).

Drinking water standards for Iron and Manganese are exceeded in the baseline samples for Pollanroe Burn and Owenreagh River.

Average BOD, Total Ammonia and Nitrate baseline concentrations exceed the lower end of the FPM guidance concentrations outlined in Table 4, but sit below the upper end of the range

for Total Ammonia and Nitrate, but not for BOD.

Calculation

The post-development concentrations in the Owenreagh River are based on a dilution calculation of the form;

$$Cpost = \frac{\{(Cbase \times Fbase) + (Csewage \times Fsewage) + (Cmine \times Fmine) + (Cseepage\ x\ Fseepage)\}}{Fbase + Fsewage + Fmine + Fseepage - Fbasemine}$$

Where

C_{post} = the concentration in the Owenreagh River after development

C_{base} = baseline concentration in the Owenreagh River, see Table 7

F_{base} = baseline flow in the Owenreagh River, see Table 6

C_{sewage} = concentrations in effluent from sewage treatment plant

F_{sewage} = flow from mine sewage treatment plant, see Table 6

C_{mine} = concentrations from the mine water treatment plant. Calculated as part of this assessment to give water discharge criteria.

F_{mine} = flow from the mine water treatment plant, see Table 6

$C_{seepage}$ = concentrations in seepage through the basal liner of the DSF

$F_{seepage}$ = seepage flow through the basal liner of the DSF (equal to 1.19 m^3/day)

$F_{basemine}$ = the baseline flow contribution within the mine site, which is now managed within the mine and replaced by the F_{mine} and $F_{seepage}$ terms

Stage 3: Proposed Discharge Criteria

Predicted discharge criteria are outlined in Table 8, with the driving factor for calculations in the final column.

An assessment of the effect of discharging at the discharge criteria under average flow conditions is provided in Table 9. Final adjustments were made to the proposed discharge criteria for the following parameters;

- The TSS criteria is reduced from the ~100 mg/L limit calculated using the methods outlined in this memo. The discharge criteria is reduced to 50 mg/L to be consistent with the likely standard to be applied to the mine during construction activities. However, it is noted that during operations TSS concentrations are expected to be well below 50 mg/L.
- The free cyanide criteria is increased from 0.0049 mg/L to 0.005 mg/L so it is consistent with the accredited standard for detection of free cyanide, obtained during a review of laboratories in the UK. The discharge criteria should not be set less than the laboratory detection limit for any parameter.
- Iron and Manganese concentrations are raised from the WSR drinking water standards to the mean of observed concentrations in the Pollanroe Burn, as discussed under Stage 2.

No parameters where baseline average concentrations are below standard increase to a point that they exceed standards. Average silver concentrations, which currently exceed standards, are predicted to have a 2% rise in baseline concentrations only.

Total ammonia and nitrate concentrations are predicted to be within the range of target concentrations for FPM, in Table 4. The average ammonia concentration in the Owenreagh is predicted to be below the 0.1 mg/L limit proposed by NIEA and the increase in baseline is also consistent with the NIEA proposed maximum increase of 23% in ammonia.

Baseline average concentrations of BOD are already above the range of values for FPM (Table 4). Post-development the average BOD concentrations in the Owenreagh River are predicted to rise by 11%, above the NIEA target of 1.5 mg/L, but the increase in concentrations is within the 13% limit of increase proposed by NIEA for BOD.

Stage 4: Selection of Appropriate Treatment Technology

The table of discharge limit concentrations has been provided to water treatment specialists.

We have received confirmation that the criteria can be met through the provision of a Reverse-Osmosis treatment system for mine water treatment and a Rotating Biological Contactor for sewage treatment. Drinking water standards for iron and manganese can be achieved by the mine water treatment system. Information on the proposed treatment methodology will be provided through the permitting process.

Summary and Next Steps

This memo has provided initial discharge criteria for the Curraghinalt mine site area for the operations period. We request that these are submitted to NIEA and that NIEA review and comment on these criteria. Once agreed these criteria will be taken forward into the Environmental Impact Assessment for the mine.

It should be noted that these criteria are related to the proposed infrastructure area that discharges to the Owenreagh River. Further discussion will be held related to discharge criteria for the existing infrastructure area and for the construction period of the mine.

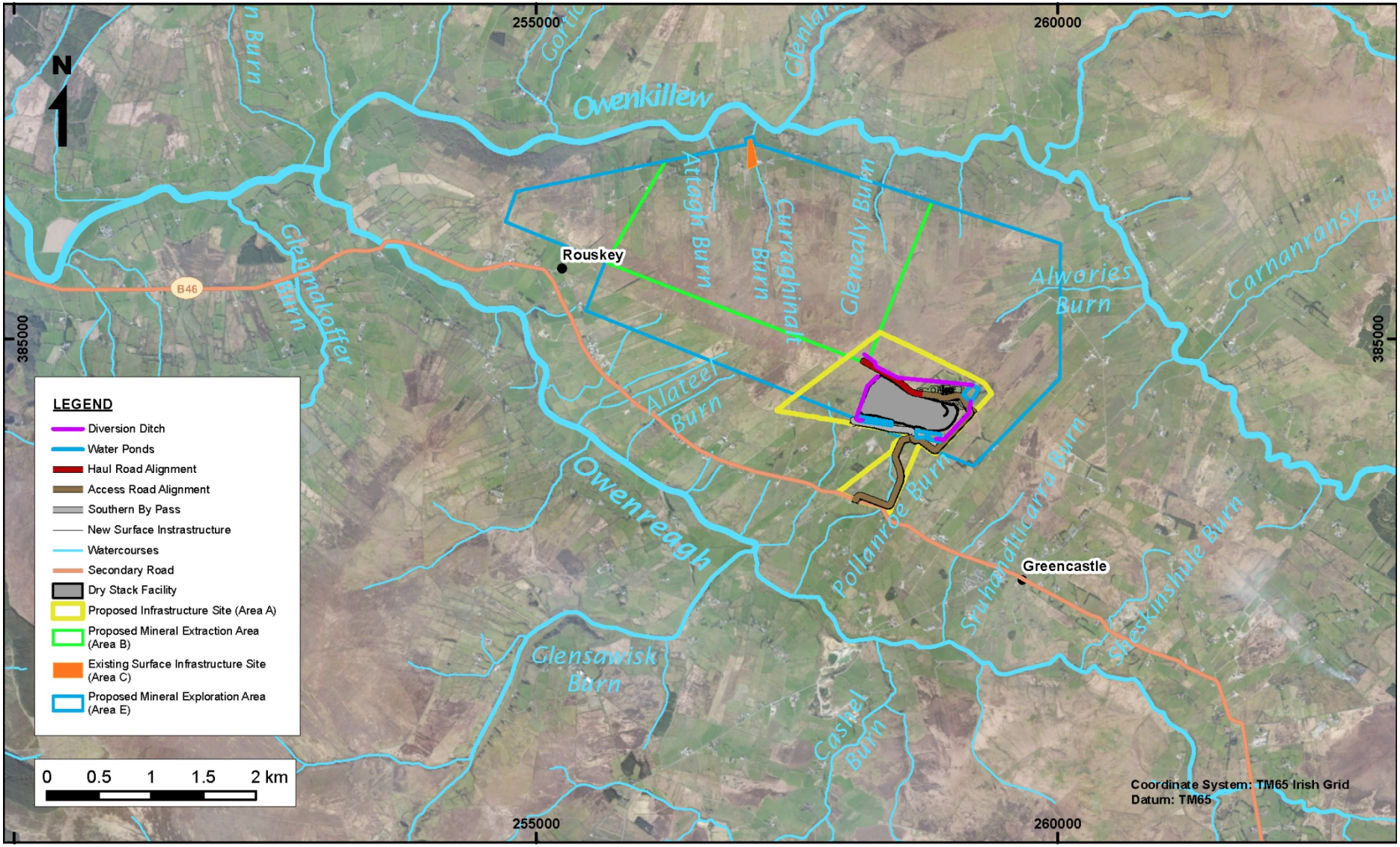

Figure 1: General setting showing site and main watercourses

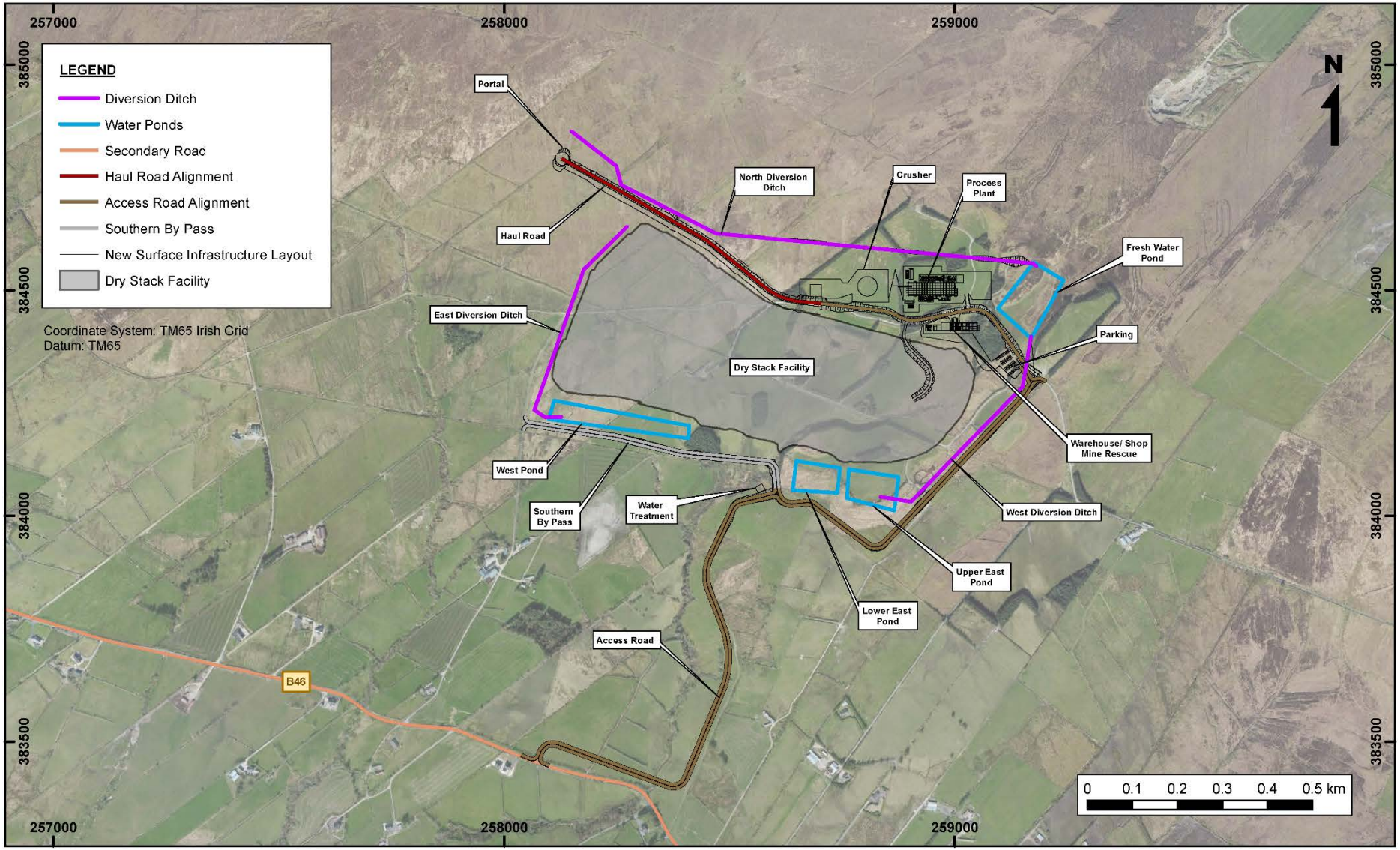

Figure 2: Proposed surface infrastructure site layout

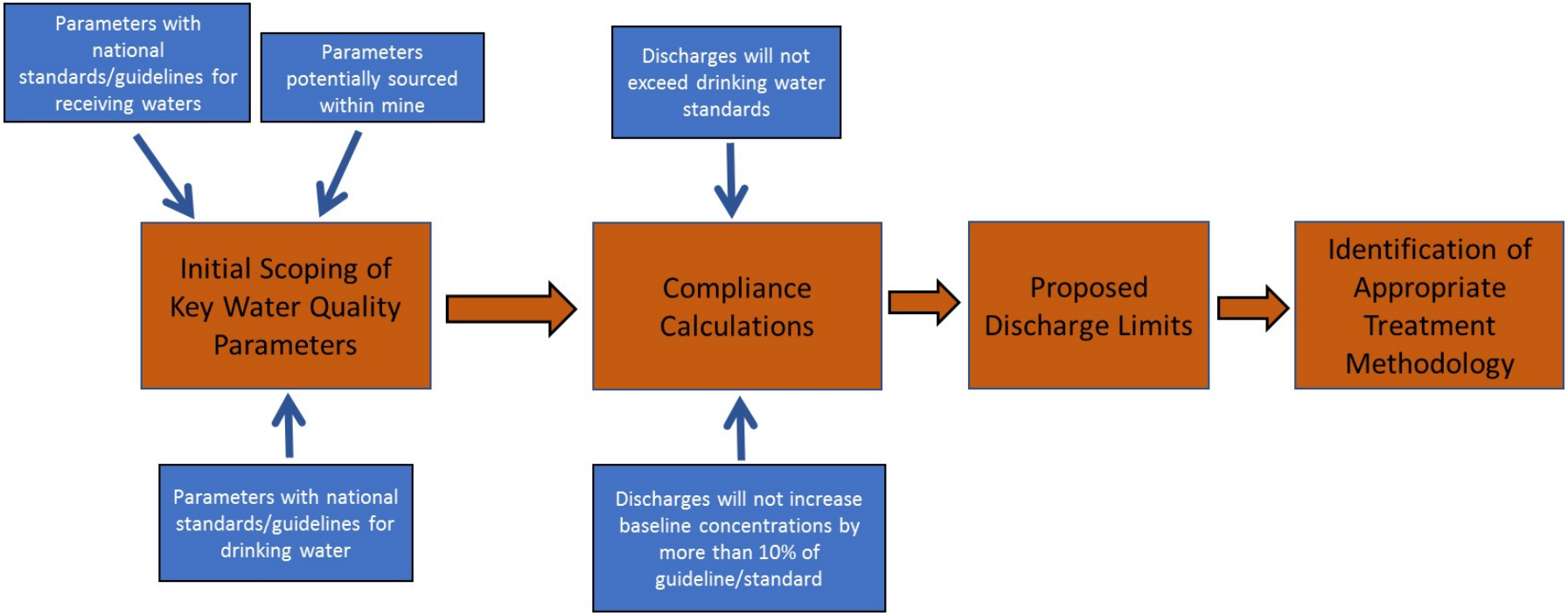

Figure 3: Schematic of Assessment Process

Table 1: Full list of parameters considered in Surface Water Baseline Assessment

Parameters	Units	Parameters	Units
Physical Parameters (Note 1)		***Metals (Dissolved and Total)***	
pH (Lab)	s.u	Aluminium	mg/L
EC (Lab)	µS/cm	Antimony	mg/L
TDS	mg/L	Arsenic	mg/L
TSS	mg/L	Barium	mg/L
Temperature	^{o}C	Beryllium	mg/L
Anions and Nutrients		Boron	mg/L
Alkalinity	mg/L as $CaCO_3$	Cadmium	mg/L
Chloride	mg/L	Calcium	mg/L
Sulphate	mg/L	Chromium III	mg/L
Fluoride	mg/L	Chromium VI	mg/L
Calcium	mg/L	Total Chromium	mg/L
Potassium	mg/L	Cobalt	mg/L
Magnesium	mg/L	Copper	mg/L
Sodium	mg/L	Iron	mg/L
Total Ammonia	mg/L as N	Lead	mg/L
Nitrite	mg/L as N	Manganese	mg/L
Nitrate	mg/L as N	Mercury	mg/L
Orthophosphate	mg/L	Molybdenum	mg/L
Cyanide Parameters		Nickel	mg/L
Free Cyanide	mg/L	Selenium	mg/L
Total Cyanide	mg/L	Silver	mg/L
Organics		Sodium	mg/L
TOC	mg/L	Strontium	mg/L
BOD	mg/L	Tellurium	mg/L
COD	mg/L	Thorium	mg/L
Microbiological		Tin	mg/L
Faecal Coliforms	CFU/100ml	Titanium	mg/L
Total Coliforms	CFU/100ml	Uranium	mg/L
Enterococci	CFU/100ml	Vanadium	mg/L
E. Coli	CFU/100ml	Zinc	mg/L
Hydrocarbons			
EPH	mg/L	Mineral Oil	mg/L

*Excluding a comprehensive suite of herbicides and pesticides which were measured on one occasion during the baseline)

Note 1: Field parameters measured: pH, EC, DO, redox potential, temperature, turbidity

Table 2: Parameters covered by Environmental Standards

Parameter	Unit	Environmental Standards				
		SR 351		WSR	EU Agri-environmental indicator	Freshwater Fish Directive
		Annual Mean	Other			
Physical						
pH	-		6.6 - 9.0 (absolute range)			
BOD	mg/L		3 (90%ile)			
Temperature	^{o}C		20 (max)			
TSS	mg/L					25
Nutrients/Salts						
Total Ammonia	mg/L N		0.2 (90%ile)	[a]0.39		
Nitrate	mg/L N			11.3	[b]5.6	
Nitrite	mg/L N			0.22		
Chloride	mg/L			250		
Fluoride	mg/L			1.5		
Sulphate	mg/L			250		
Cyanide						
Cyanide Free	mg/L	0.001	0.005 (max)			
Cyanide Total	mg/L			0.05		
Metals (Dissolved)						
Aluminium	mg/L			0.2		
Antimony	mg/L			0.005		
Arsenic	mg/L	0.05		0.01		
Cadmium	mg/L	0.00008	0.45 (max)	0.005		
Chromium (III)	mg/L	0.0047	0.032 (max)			
Chromium (VI)	mg/L	0.0034				
Total Chromium	mg/L	0.0081		0.05		
Copper	mg/L	[c]0.017		2		
Iron	mg/L	1		0.2		
Lead	mg/L	0.0012	0.014 (max)	0.01		
Mercury	mg/L		0.00007 (max)	0.001		
Manganese	mg/L	[c]0.2		0.05		
Nickel	mg/L	[c]0.01	0.034 (max)	0.02		
Selenium	mg/L			0.01		
Sodium	mg/L			200		
Silver	mg/L	0.0005	0.001 (max)			
Zinc	mg/L	[c]0.021				

[a] WSR reference standard is 0.5 mg/L ammonia as NH4. Value of 0.39 mg/L presented in table is ammonia as N

[b] Standard is 25 mg/L nitrate. Value of 5.6 mg/L presented in table is nitrate as N

[c] Site Specific EQS from PNEC calculation, based on lowest concentration in Table 3 of Appendix A

Table 3: Additional parameters with International Guideline Values

Parameter	Unit	CCME guidance
Dissolved Metals		
Boron	mg/L	1.5
Molybdenum	mg/L	0.073
Uranium	mg/L	0.015

Table 4: FPM Guideline Values

Parameter	Unit	FPM guidance
Physical Parameters		
pH	-	6.2 - 7.5
BOD	mg/L	1 - 1.4
TSS	mg/L	10
Anions and Nutrients		
Total Ammonia	mg/L N	0.01 - 0.005 (median)
Nitrate	mg/L N	0.125 - 0.5 (median)
Orthophosphate	mg/L P	0.005 (median)

Table 5: Summary of Scoping Assessment for Water Quality Parameters

Parameters	Units	Included in Assessment	Parameters	Units	Included in Assessment
Physical Parameters			***Dissolved Metals***		
pH (Lab)	s.u	Included	Aluminium	mg/L	Included
EC (Lab)	µS/cm	No NI standard and not considered parameter of concern at mine	Antimony	mg/L	Included
TDS	mg/L	No NI standard and not considered parameter of concern at mine	Arsenic	mg/L	Included
TSS	mg/L	Included	Barium	mg/L	No NI standard and not considered parameter of concern at mine
Temperature	^{o}C	Included	Beryllium	mg/L	No NI standard and not considered parameter of concern at mine
Anions and Nutrients			Boron	mg/L	Included
Alkalinity	mg/L as $CaCO_3$	No NI standard and not considered parameter of concern at mine	Cadmium	mg/L	Included
Chloride	mg/L	Included	Calcium	mg/L	No NI standard and not considered parameter of concern at mine
Sulphate	mg/L	Included	Chromium III	mg/L	Included
Fluoride	mg/L	Included	Chromium VI	mg/L	Included
Calcium	mg/L	No NI standard and not considered parameter of concern at mine	Total Chromium	mg/L	Included
Potassium	mg/L	No NI standard and not considered parameter of concern at mine	Cobalt	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	Copper	mg/L	Included
Sodium	mg/L	Included	Iron	mg/L	Included
Total Ammonia	mg/L as N	Included	Lead	mg/L	Included
Nitrite	mg/L as N	Included	Manganese	mg/L	Included
Nitrate	mg/L as N	Included	Mercury	mg/L	Included
Orthophosphate	mg/L as P	No NI standard and not considered parameter of concern at mine	Molybdenum	mg/L	Included
Cyanide Parameters			Nickel	mg/L	Included
Free Cyanide	mg/L	Included	Selenium	mg/L	Included

Parameters	Units	Included in Assessment	Parameters	Units	Included in Assessment
Total Cyanide	mg/L	Included	Silver	mg/L	Included
Organics			Sodium	mg/L	Included
TOC	mg/L	No standard requested by NIEA	Strontium	mg/L	No NI standard and not considered parameter of concern at mine
BOD	mg/L	Included	Tellurium	mg/L	Not present in measurable quantities
COD	mg/L	No standard requested by NIEA	Thorium	mg/L	Not present in measurable quantities
Microbiological			Tin	mg/L	No NI standard and not considered parameter of concern at mine
Faecal Coliforms	CFU/100ml	No standard requested by NIEA	Titanium	mg/L	No NI standard and not considered parameter of concern at mine
Total Coliforms	CFU/100ml	No standard requested by NIEA	Uranium	mg/L	Included
Enterococci	CFU/100ml	No standard requested by NIEA	Vanadium	mg/L	Not present in measurable quantities
E.Coli	CFU/100ml	No standard requested by NIEA	Zinc	mg/L	Included
Hydrocarbons					
[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 6: Flow rates used in Dilution Calculations

Parameter	Unit	[a]Owenreagh downstream of confluence with Pollanroe	[a]Baseline Contribution Mine Site Area	[b]Mine Water Treatment Plant Discharge	[c]Mine Sewage Treatment Discharge
95ile Annual	m^3/hour	1,190	10 - 15	60	0.5
Average Flow	m^3/hour	4,320	45	110	0.5

a - Calculated based on data in Surface Water Baseline Study report

b - Calculated based on mine water balance model.

c - Based on estimates for sewage plant design and based on staffing numbers

Table 7: Baseline Water Quality in the Owenreagh River and Pollanroe Burn

Parameter	Unit	Owenreagh		Pollanroe Burn	
		SW09, SW10, SW11, SWN6		SWN5, SWN8	
		Average	Max	Average	Max
Physical					
pH	-	6.90	7.74	6.8	7.4
BOD	mg/L	1.44	4.0	2.3	4.0
Temperature	°C		13.8	12.2	14.5
TSS	mg/L	*5.0*	15.0	7.0	51
Nutrients/Salts					
Total Ammonia	mg/L as N	0.040	0.093	0.058	0.085
Nitrate	mg/L as N	0.19	0.41	0.12	0.16
Nitrite	mg/L as N	*0.0030*	*0.0030*	*0.0030*	0.0030
Chloride	mg/L	12.9	22.6	8.53	10.6
Fluoride	mg/L	0.15	0.15	*0.15*	*0.15*
Sulphate	mg/L	1.05	4.41	0.73	3.49
Cyanide					
Cyanide Free	mg/L	0.0016	0.0030	*0.00050*	0.0020
Cyanide Total	mg/L	0.0028	0.0050	0.0044	0.0080
Hydrocarbons					
EPH	mg/L	*0.0050*	*0.0050*	*0.0050*	*0.0050*
Mineral Oil	mg/L	*0.0050*	*0.0050*	*0.0050*	0.021
Metals (Dissolved)					
Aluminium	mg/L	0.057	0.11	0.11	0.16
Antimony	mg/L	*0.0010*	0.0040	*0.0010*	0.0010
Arsenic	mg/L	*0.00045*	0.0021	*0.00045*	0.0013
Boron	mg/L	0.0025	0.0080	0.0062	0.0090
Cadmium	mg/L	0.000030	0.00016	*0.000015*	*0.000015*
Chromium (III)	mg/L	*0.0010*	0.0030	0.0020	0.0030
Chromium (VI)	mg/L	*0.0010*	*0.0010*	*0.0010*	0.0030
Total Chromium	mg/L	0.00051	0.0028	0.00046	0.0011
Copper	mg/L	*0.0015*	*0.0015*	*0.0015*	*0.0015*
Iron	mg/L	0.66	1.04	1.12	1.53
Lead	mg/L	0.00040	0.0029	*0.00020*	0.00020
Manganese	mg/L	0.054	0.088	0.138	0.32
Mercury	mg/L	*0.0000050*	0.000030	*0.0000050*	0.0000050
Molybdenum	mg/L	*0.00010*	0.00040	*0.00010*	0.00010
Nickel	mg/L	0.00026	0.0012	0.00037	0.00070

Parameter	Unit	Owenreagh		Pollanroe Burn	
		SW09, SW10, SW11, SWN6		SWN5, SWN8	
		Average	Max	Average	Max
Selenium	mg/L	0.00060	0.00060	0.0018	0.0052
Silver	mg/L	*0.0025*	*0.0025*	*0.0025*	*0.0025*
Sodium	mg/L	7.9	10.5	5.56	6.8
Uranium	mg/L	*0.0025*	0.0048	*0.0025*	0.0025
Zinc	mg/L	0.0029	0.0072	0.0098	0.033

Italics are below detection limit, shown as half detection limit

Table 8: Proposed Discharge Criteria

Parameter	Unit	Proposed Discharge Criteria	Driving Factor
Physical			
pH	-	6.6-9.0	Compliance with SR 351 at End of Pipe
BOD	mg/L	7.3	Compliance in Owenreagh River
Temperature	^{o}C	20	Compliance with SR 351 at End of Pipe
TSS	mg/L	50	Set to level that can be applied during construction. Lower value than required for compliance in Owenreagh River
Nutrients/Salts			
Total Ammonia	mg/L as N	0.39	Compliance with Drinking Water Standard at End of Pipe
Nitrate	mg/L as N	11.3	Compliance with Drinking Water Standard at End of Pipe. This also complies with requirement that baseline is not increased by more than 10% of standard and keeps Owenreagh River average concentration within FPM guidance limits.
Nitrite	mg/L as N	0.22	Compliance with Drinking Water Standard at End of Pipe
Chloride	mg/L	250	Compliance with Drinking Water Standard at End of Pipe
Fluoride	mg/L	1.5	Compliance with Drinking Water Standard at End of Pipe
Sulphate	mg/L	250	Compliance with Drinking Water Standard at End of Pipe
Cyanide			
Cyanide Free	mg/L	0.0050	Slightly raised above value for compliance in Owenreagh River so that limit is set to lowest accredited detection limit for free cyanide
Cyanide Total	mg/L	0.050	Compliance with Drinking Water Standard at End of Pipe
Hydrocarbons			
Visible Oil and Grease	mg/L	trace	Practical standard
Metals (Dissolved)			
Aluminium	mg/L	0.20	Compliance with Drinking Water Standard at End of Pipe
Antimony	mg/L	0.0050	Compliance with Drinking Water Standard at End of Pipe
Arsenic	mg/L	0.20	Compliance in Owenreagh River
Boron	mg/L	3.1	Compliance in Owenreagh River
Cadmium	mg/L	0.00034	Compliance in Owenreagh River
Chromium (III)	mg/L	0.019	Compliance in Owenreagh River
Chromium (VI)	mg/L	0.014	Compliance in Owenreagh River
Total Chromium	mg/L	0.033	Compliance in Owenreagh River
Copper	mg/L	0.069	Compliance in Owenreagh River
Iron	mg/L	1.12	Compliance with average baseline concentration in Pollanroe River. This also complies with requirement that baseline is not increased by more than 10% of standard
Lead	mg/L	0.0050	Compliance in Owenreagh River
Manganese	mg/L	0.14	Compliance with average baseline concentration in Pollanroe River. This also complies with requirement that baseline is not increased by more than 10% of standard
Mercury	mg/L	0.00015	Compliance in Owenreagh River
Molybdenum	mg/L	0.15	Compliance in Owenreagh River
Nickel	mg/L	0.040	Compliance in Owenreagh River
Selenium	mg/L	0.010	Compliance with Drinking Water Standard at End of Pipe
Silver	mg/L	0.0020	Compliance in Owenreagh River
Sodium	mg/L	200	Compliance with Drinking Water Standard at End of Pipe
Uranium	mg/L	0.033	Compliance in Owenreagh River
Zinc	mg/L	0.085	Compliance in Owenreagh River

Table 9: Post-development average concentrations in the Owenreagh River

Parameter	Unit	Proposed Discharge Limit	Post-development average concentration in Owenreagh	Change from Baseline
Physical				
pH	-	6.6-9.0		
BOD	mg/L	7.3	1.60	0.16
Temperature	^{o}C	20		
TSS	mg/L	103	7.51	2.5
Nutrients/Salts				
Total Ammonia	mg/L as N	0.39	0.049	0.0092
Nitrate	mg/L as N	11.3	0.47	0.28
Nitrite	mg/L as N	0.22	0.0085	0.0055
Chloride	mg/L	250	19	6.1
Fluoride	mg/L	1.5	0.18	0.035
Sulphate	mg/L	250	7.31	6.3
Cyanide				
Cyanide Free	mg/L	0.005	0.0017	0.0001
Cyanide Total	mg/L	0.050	0.0040	0.0012
Hydrocarbons				
Visible Oil and Grease	mg/L	Trace		
Metals (Dissolved)				
Aluminium	mg/L	0.20	0.061	0.0042
Antimony	mg/L	0.005	0.0011	0.00011
Arsenic	mg/L	0.20	0.0055	0.005
Boron	mg/L	3.09	0.08	0.077
Cadmium	mg/L	0.00034	0.000038	0.0000081
Chromium (III)	mg/L	0.019	0.0015	0.00046
Chromium (VI)	mg/L	0.014	0.0013	0.00034
Total Chromium	mg/L	0.033	0.0013	0.00082
Copper	mg/L	0.069	0.0032	0.0017
Iron	mg/L	1.12	0.68	0.018
Lead	mg/L	0.0050	0.00052	0.00012
Manganese	mg/L	0.14	0.056	0.0027
Mercury	mg/L	0.00015	0.0000087	0.0000037
Molybdenum	mg/L	0.15	0.0039	0.0038
Nickel	mg/L	0.040	0.0013	0.001
Selenium	mg/L	0.010	0.00084	0.00024
Silver	mg/L	0.0020	0.0025	0.000013
Sodium	mg/L	200	12.8	4.9
Uranium	mg/L	0.033	0.0033	0.00079
Zinc	mg/L	0.085	0.0050	0.0021

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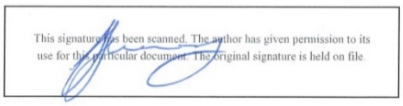

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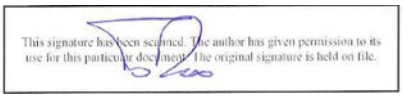

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TECHNICAL APPENDICES

APPENDIX

A METAL BIOAVAILABILITY ASSESSMENT

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External Memorandum

To:	Stephen Barnes	**From:**	Tony Rex
Company:	Dalradian Gold Ltd	**Project Number:**	U6193
Copied to:	Sam Barnes	**Project Title:**	Curraghinalt EIA
File Ref:	Metal Bioavailability Assessment Apr17 v3.docx	**Date:**	April, 2017
Subject:	**Metal Bioavailability Assessment**		

1 INTRODUCTION

Environmental Quality Standards (EQSs) for some metals are expressed in terms of bioavailable metal concentration. This criteria 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. In summary, it is the degree and rate at which a substance is absorbed into a living system or is made available at the site of physiological activity.

An EQS is the concentration of a chemical 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 and ecosystems. 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 Ca 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. However, it is considered acceptable to use in place of DOC as suspended solids are very low in the watercourses evaluated here and only elevated under high flow conditions.

M-BAT also calculates a site-specific $PNEC_{dissolved}$ based on the pH, DOC and Ca 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).

Current $EQS_{bioavailable}$ are as follows (Table 1-1):

Table 1-1: EQS Bioavailable Criteria

Metal	$EQS_{bioavailable}$ (ug/l)	$EQS_{bioavailable}$ (mg/l)	Comment
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.

1.1 Bioavailable Concentrations for the Owenreagh and Owenkillew Rivers

Bioavailable concentrations have been calculated for Cu, Zn, Mn and Ni. These have been compared with measured dissolved concentrations as illustrated in Figure 1-1 for sample sites in the Owenkillew and Owenreagh rivers; Figure 1-1 also shows bioavailable concentrations compared with the $EQS_{bioavailable}$ standard. In all cases the bioavailability concentration is below the EQS.

For all metals, with the exception of manganese, the bioavailable concentration is significantly lower than the dissolved concentration. This is largely also the case for manganese except for a few samples where the bioavailable concentration is equal to the dissolved concentration. This occurs when the water quality of the sample is characterised by a combination of relatively low (acidic) pH, low calcium concentration and high TOC.

Figure 1-2 illustrates the individual concentrations for samples from the Owenkillew and Owenreagh rivers. Maximum and minimum envelopes with an approximate average best-fit correlation line have been drawn onto these figures. The best correlate is seen with nickel whilst copper is dominated by samples returning a below-detection limit concentration of <3 ug/l. The large range in bioavailable copper is probably due to the fact that DOC is highly variable in the watercourses, ranging from 0 to 40 mg/l. pH and Ca, in comparison, are more consistent.

1.2 Estimating Bioavailable Concentration from Dissolved Concentration

The correlation envelopes in Figure 1-2 can be used, with caution, to estimate a bioavailable concentration from a given measured concentration of the metal (dissolved).

This correlation can be applied to the calculation of proposed discharge criteria where mixing calculations are employed to derive a discharge limit based on the predicted concentration in

the downstream watercourse (in the case of the effluent from the Infrastructure Site this is the Owenreagh River).

For this assessment we have taken the most conservative correlation i.e. the upper envelope line (for manganese, for example, this accommodates the samples discussed above where there is 100% metal bioavailability). The ratio of measured to bioavailable concentration derived from this analysis provides a conversion factor for determining a bioavailable concentration from a given measured metal concentration (dissolved).

The results are summarised in Table 1-2. Note: the ratios are broadly defined and based on the envelopes drawn on to the graphs in Figure 1-2.

Table 1-2: Observed and Bioavailable Ranges and Ratios

	EQS (bioavail) ug/l	Observed Range (dissolved) ug/l	Calculated (bioavail) ug/l	Ratio Measured: Bioavail
Cu	1	<3 - 5	0.05 - 0.2	1 : 0.08
Zn	10.9 + 1 = 11.9	1 - 10	~0.3 - 3.5	1 : 0.47
Mn	123	0 - ~80	0 - ~80	1 : 1
Ni	4	0 - 2	0 - 0.3	1 : 0.27
Note: All ranges and ratios estimated				

1.3 Site Specific EQS (dissolved) from PNEC Calculation

As summarised above, the M-BAT tool calculates a site-specific EQS (for the dissolved metal) based on the pH, DOC and Ca inputs.

Results of calculated EQS's are summarised in Table 1-3 below. Results are reasonably consistent between the three sample sites on the Owenreagh River.

Table 1-3: Calculated Site Specific EQS (dissolved) for the Owenreagh River

ID	n	Cu (ug/l)			Zn (ug/l)			Mn (ug/l)			Ni (ug/l)		
		Min	Max	Av	Min	Max	Av	Min	Max	Av	Min	Max	Av
SW11	8	17	59	41	22	74	58	200	520	402	10	37	29
SWN6	8	17	55	36	21	64	46	300	560	435	11	35	25
SW09	8	17	50	33	21	74	47	260	550	430	11	36	26

The minimum (i.e. most conservative) concentration, as highlighted in Table 1-3, is proposed to be adopted as a dissolved metal Project Guideline Value for the Owenreagh River along the stretch of interest.

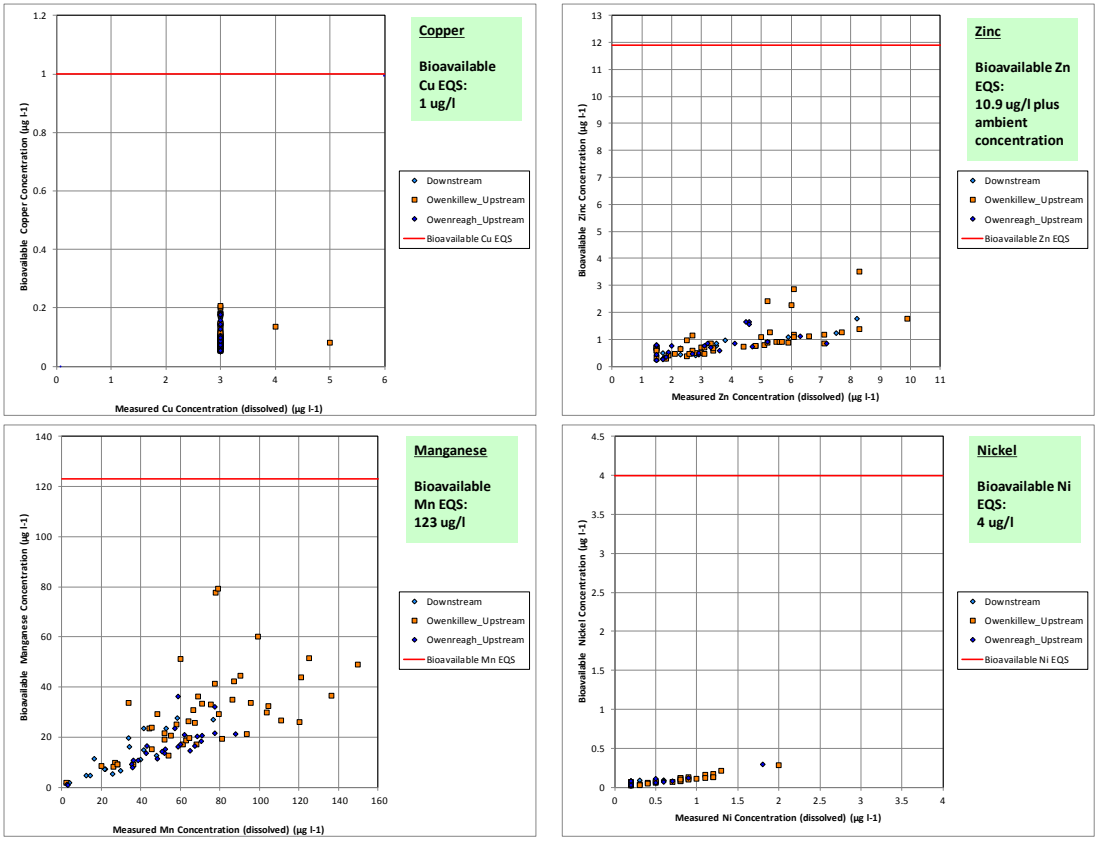

Figure 1-1: Bioavailable vs Measured Metals: Comparison with $EQS_{bioavailable}$

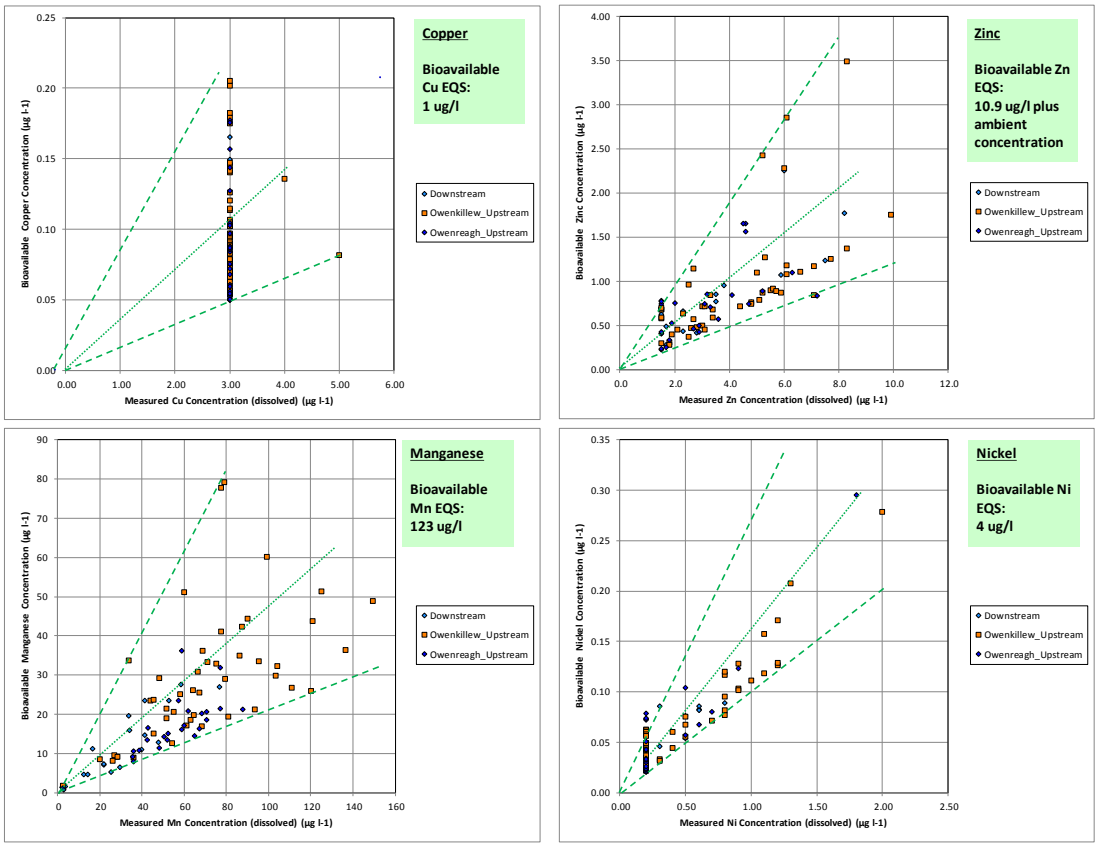

Figure 1-2: Bioavailable vs Measured Metals: Correlation Envelopes

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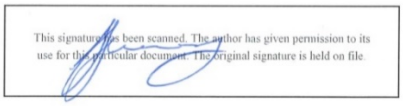

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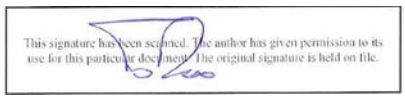

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APPENDIX

B FRESH WATER PEARL MUSSELS (FPMS) AND WATER QUALITY GUIDELINES

Appendix B: Fresh Water Pearl Mussels (FPMs) and Water Quality Guidelines

A literature study by Young (2005)[1] on behalf of Scottish Natural Heritage of the water quality requirements of the freshwater pearl mussel, and related bivalves, found that little work has been carried out on the parameters that influence their survival and distribution. Improvements in the understanding of the water quality requirements of freshwater pearl mussel in the last decade have been limited. While there have been many summaries and reviews of available data, very few primary studies have been undertaken to address this information gap (Cooksley and Blake, 2014)[2].

To address the information gap and provide the evidence base for the conservation and management of the species, a new standard for freshwater pearl mussel catchments has been developed by a working group of European freshwater pearl mussel experts, under the auspices of the European Committee for Standardization (CEN). Drafting of the standard was led by Professor Philip Boon, Scottish Natural Heritage, with inputs from participants from 10 countries. The standard was published in December 2016, as EN 16859:2017, and was implemented in the UK in February 2017 in the form of a British Standard, as BS EN 16859:2017. It is entitled: "Guidance standard on monitoring freshwater pearl mussel (*Margaritifera margaritifera*) populations and their environment".

The new standard focuses on methods for monitoring pearl mussel populations, the fish populations that provide hosts for pearl mussel larvae, physical habitat structure, flow regimes, and aspects of water quality known to be important for sustaining pearl mussels. The text also contains three 'informative annexes', covering background information on the environmental characteristics to be monitored (Annex A), targets for assessing whether freshwater pearl mussel populations are in favourable condition (Annex B), and the range of environmental conditions supporting sustainable freshwater pearl mussel populations (Annex C). These annexes do not form part of the standard itself.

No water quality "standards" are presented in BS EN 16859:2017. The annexes describe current understanding of what pearl mussels require to survive and reproduce, based on the best understanding of experts in Europe. Interim drafts of the standard, which are available on the internet, use the terms "targets" and "limits" for the water quality values presented in the annexes. This terminology has been amended. The official version of the standard explains (in Annex C): "*It is important that levels are not taken out of context and are appropriate to the location and river type for the population being studied. Note that these specific levels should not be interpreted as water quality targets but are presented to provide assistance in target-setting*."

Available literature and BS EN 16859:2017 highlights that freshwater pearl mussels are sensitive to unnaturally high levels of nutrients (phosphorus and nitrogen), BOD/ dissolved oxygen, suspended solids (or turbidity), pH, calcium and alkalinity, electrical conductivity, temperature and contaminants including mobilised metals (such as aluminium, copper, cadmium, zinc, nickel and lead) and some pesticides. Nutrients should never reach levels where they cause sustained excessive filamentous algal growth. Suspended solids are one of the greatest threats to freshwater pearl mussel populations. Chronic and episodic levels of suspended solids in rivers with sustainable populations are extremely low, with only minor peaks of short duration during periods of heavy rainfall.

Glochidium larvae and juveniles may be sensitive to low pH and metal exposure although there is little

[1] *Young, M., 2005. A literature review of the water quality requirements of the freshwater pearl mussel (Margaritifera margaritifera) and related freshwater bivalves. Study for Scottish Natural Heritage.*
[2] *Cooksley, S. and Blake, L.J., 2014. River Spey water quality and effluent chemistry. Final Report to the Cairngorms National Park Authority (CNPA).*

published research involving tolerance tests. Some recent research[3] involving pH, iron and aluminium showed survival of glochidia decreased with decreasing pH, increasing iron and increasing aluminium. The results indicated that episodes of low pH and high metal concentrations may harm glochidia and potentially contribute to local decline of fresh water pearl mussel.

The BS EN 16859:2017 standard recommends that quality parameters reviewed include phosphorous, nitrogen, BOD, pH, calcium, alkalinity, EC, temperature, heavy metals, turbidity and suspended solids. The recommended checklist for chemical water quality monitoring is summarised in Table B1 below. Note: the proposed frequency of monitoring is until means and extremes are established and thereafter repeated at a frequency dependent on risk.

Table B1: Checklist of Water Quality Monitoring Recommended for Freshwater Pearl Mussel Rivers by BS EN 16859:2017

Parameter	Method	Units
Phosphorous (MRP)	Water sample	mg/l P
Phosphorous (Total)	Water sample	mg/l P
Nitrate	Water sample	mg/l N
Ammonia	Water sample	mg/l N
Dissolved oxygen (DO)	DO probe/autologger	% saturation
BOD	Water samples	mg/l O2
pH	Autologger/ point samples	mg/l N
Calcium	Water sample	mg/l Ca
Hardness	Water sample	mg/l CaCO3
Alkalinity	Water sample	Meq/l
EC	Autologger/ point samples	µS/cm
Temperature	Autologger	^{o}C
Heavy metals and other toxic substances	Water samples	µg/l
Turbidity	Autologger	NTU/FNU
TSS	Water samples	mg/l

Water quality values presented in BS EN 16859:2017 are summarised in Table B2 below. Other water quality parameters recommended for monitoring are included in Table B3 below.

An unpublished final draft document entitled Practical Implementation of Freshwater Pearl Mussel Measures – Owenkillew Sub Basin Management Strategy has been prepared by RPS on behalf of the NIEA (RPS, 2013)[4]. This presents the favourable conditions criteria recommended by Killeen (2007)[5]. These are within the range of values given in BS EN 16859:2017, and include a value for suspended solids (Table B4).

[3] *Taskinen, J., Berg, P., Saarinen-Valta, M., Välilä, S., Mäenpää, E., Myllynen, K. and Pakkala. J. 2011. Effect of pH, iron and aluminum on survival of early life history stages of the endangered freshwater pearl mussel, Margaritifera margaritifera. Toxicological & Environmental Chemistry, 93.*

[4] *RPS (2013). Practical Implementation of Freshwater Pearl Mussel Measures. Owenkillew Sub Basin Management Strategy- Final Draft (unpublished). Prepared for the NIEA, October 2013.*

[5] *Killeen, I.J. (2007). The freshwater pearl mussel Margeritifera margaritifera (L., 1758) in three Northern Ireland SAC Rivers. Unpublished report to the Environment & Heritage Service.*

Table B2: Guideline Water Quality Values Presented in BS EN 16859:2017 Based on Levels Observed in Rivers with Sustainable Populations of Freshwater Pearl Mussels

Parameter	Levels	Notes relevant to the Curraghinalt Project
Phosphorous	Variable	The mean or median MRP or total P level in rivers should be consistent with the high status under the WFD – with noted exceptions. Naturally occurring levels of phosphorus vary according to river type so P targets set for rivers with sustainable pearl mussel populations must take account of the type of river in which they occur. Specific ranges of phosphorus have been associated with reproducing populations in a few countries, including Ireland and the UK. Moorkens (2006)[6] found that the highest median levels associated with effectively recruiting populations in rivers in Ireland are 0.005mg/l.
Nitrate	0.125 – 0.5 mg/l N	Low values of nitrate appear to be associated with sustainable populations The lower values are based on research on rivers in Ireland by Moorkens (2006) and are annual median values.
Ammonia	Ammoniacal nitrogen never exceeding a detection limit of 0.01mg/l to up to 0.05 mg/l N	The lower values are based on research on rivers in Ireland by Moorkens (2006).
BOD/ Dissolved oxygen (DO)	Less than 1mg/l to 1.4 mg/l	Rivers with reproducing populations in the UK, Ireland and Spain have BOD5 levels consistently < 1.0 mg L-1. Dissolved oxygen levels in rivers with *Margaritifera* populations should be consistently high, where productivity is insufficient to produce extremes either of supersaturation or exhaustion of oxygen supply. Saturation levels should consistently be near to 100%.
pH	6.2 - 7.3	Must be at a natural level for the river.
Heavy metals and other toxic substances	WFD limits	WFD limits for toxic substances should be strictly adhered to.
Turbidity, TSS	Medians from undetectable (consistently 0 NTU) to < 0.3 NTU with peaks <10 NTU/FTU	Data on suspended solids is sparse, some date on turbidity is available.

[6] *Moorkens, E.A. 2006. Irish non-marine molluscs – an evaluation of species threat status. Bulletin of the Irish Biogeographical Society.*

Table B3: Other Parameters that should be Monitored (BS EN 16859:2017)

Parameter	Criteria for Assessment
Calcium	Any artificial changes proposed to the calcium levels in a catchment, whether for direct conservation purposes, or indirectly through proposed development changes, should be monitored and the implications for pearl mussel clearly identified.
Alkalinity	Natural levels of alkalinity vary between rivers, so it is important to understand the baseline and natural variation for each *Margaritifera* population. Any unexpected changes should be taken as warnings and used to trigger further investigative monitoring.
EC	Any elevated levels compared with the normal baseline for each river, or the predicted baseline if the river is to return to favourable condition, should be investigated for pollution sources.
Temperature	More detailed investigative monitoring may be needed where abstraction, impoundment or other management may be affecting the temperature profile of the river.

Table B4: Favourable Conditions Water Quality Criteria from SBMS for FPM (RPS, 2013)

Attribute	Target
Orthophosphate	0.005 mg/l P
Nitrate	0.125 mg/l N
TSS	<10 mg/l
BOD	<1.40 mg/l