



Avonmore Demonstration Catchment

Desk Study

June 2022



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Information Sources Consulted

Several information sources were consulted during the preparation of this desk study including:

- WFD web application – Environmental Protection Agency (EPA) characterisation data and water quality data,
- Local Authority Waters Programme (LAWPRO) Avonbeg-Avonmore desk study and Local Catchment Assessment (LCA) information,
- Mobile Monitoring Unit (MMU) assessments (Ryan and Jordan, 2010; O’Keeffe and Barrett, 2013),
- Forest Service - DAFM data,
- Geological Survey Ireland (GSI) information (Tedd *et al.*, 2017 and personal communication),
- EPA information
- National Parks and Wildlife Service information

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Summary

The Avonmore Demonstration Catchment is one of five catchments selected by the Waters of Life Project. The Waters of LIFE is an EU LIFE Integrated Project which aims to help reverse the deterioration of Ireland's most pristine waters.

The Avonmore is located in County Wicklow, covering 141km². It consists of seven river waterbodies and three lakes. Streams and rivers in this catchment form headwaters to Avonmore River rising in northeast parts of the Wicklow Mountains and flowing southeast through Annamoe and Laragh villages.

Two of the river waterbodies in this catchment (Avonmore_010 and Avonmore_020) are Blue Dot waterbodies meaning that their Water Framework Directive (WFD) environmental objective is to achieve High ecological status. Both waterbodies are *At Risk* of not achieving their objectives, being currently at Good ecological status (2013-2018).

Across the catchment the most common pressures identified during initial characterisation were Forestry, Agriculture and Anthropogenic Pressures. The issues causing impact are primarily altered habitats due to morphological changes and acidification. Further characterisation by LAWPRO has updated the pressures, adding domestic waste water systems in the blue dot areas.

The catchment is characterised by primarily peaty soils in the upper catchment transitioning to poorly drained soils in the middle reaches and well drained soils in the lower sections. Bedrocks are igneous and metasediments rocks and thus aquifers are poor (unproductive except for local zones) or locally important (moderately productive only in local zones). Pathways are generally overland in the upper reaches and deeper in the soils in the lower regions. Due to the presence of bedrock at or near the surface in many areas, groundwater vulnerability is high or extreme and there is potential pathway to groundwater despite the poor permeability of the overlying soils.

1 Introduction

1.1 Background to Catchment

The Waters of LIFE is an EU LIFE Integrated Project (IP) which aims to help reverse the deterioration of Ireland's most pristine waters. The Project will operate in five demonstration catchments nationally to test measures for the protection and restoration of High Status in Blue Dot rivers. The five demonstration catchments were selected from WFD sub-catchments defined by the EPA. The selection process considered a number of criteria, including number and extent of significant pressures, status history and Q value amongst others. The project also includes one control catchment (the Sheen), which was selected on the basis that it consistently demonstrated High Status in the past and is currently *Not at Risk* of failing to meet its WFD objectives. See [Demonstration Catchment Selection Report for further information on the catchment selection process](#)

The Avonmore has been selected as one of the five demonstration catchments due to high forest cover in a High status objective waterbody. Forest clearfell has been identified as a significant pressure affecting water quality here. The aim of the project is to work with the pressure owners to explore ways of reducing impacts on water quality which could help recovery of the High ecological status here.

The Avonmore catchment is located in County Wicklow, covering 141km². It consists of seven river waterbodies: Avonmore_010, Avonmore_020, Cloghoge Brook_010, Avonmore_030, Avonmore_040, Glenmacnass_010, Glenmacnass_020; and three lake waterbodies: Tay, Dan and Ouler. Streams and rivers in this sub-catchment form headwaters to Avonmore River rising in northeast parts of the Wicklow Mountains and flowing southeast through Annamoe and Laragh villages (**Figure 1**).

Two of the waterbodies in this sub-catchment (Avonmore_010 and Avonmore_020) are Blue Dot waterbodies meaning that their Water Framework Directive (WFD) environmental objective is to achieve High ecological status. Both waterbodies are *At Risk* and not achieving their objectives being currently at Good ecological status (2013-2018) (**Figure 2**).

Two blue dot waterbodies formed part of the 2nd WFD cycle Avonbeg-Avonmore Priority Area for Action (PAA). It was proposed to split this PAA into two separate PAAs: Avonbeg and Avonmore for the 3rd WFD cycle. Proposed Avonmore PAA will include Avonmore_SC_010 and Avonmore_SC_020 sub-catchments.

This desk study focuses solely on The Avonmore demonstration catchment selected by the Waters of Life Project (which covers area of the Avonmore_SC_010 sub-catchment as defined under the Water Framework Directive).

1.2 Summary Information

Figure 1 shows location of the Avonmore demonstration catchment, waterbodies within the catchment, monitoring locations and the latest ecological status. A schematic layout of the catchment, with current WFD status and risk, is provided in **Figure 2**. Summary information on risk, ecological status, known pressures and associated significance for the waterbodies in the Avonmore catchment is presented in **Table 1**. Note that surface water chemical status (apart from ecological status) is also assigned to the Tay and Dan lake waterbodies. This is further summarised in the 'Receptor information and assessment' section.

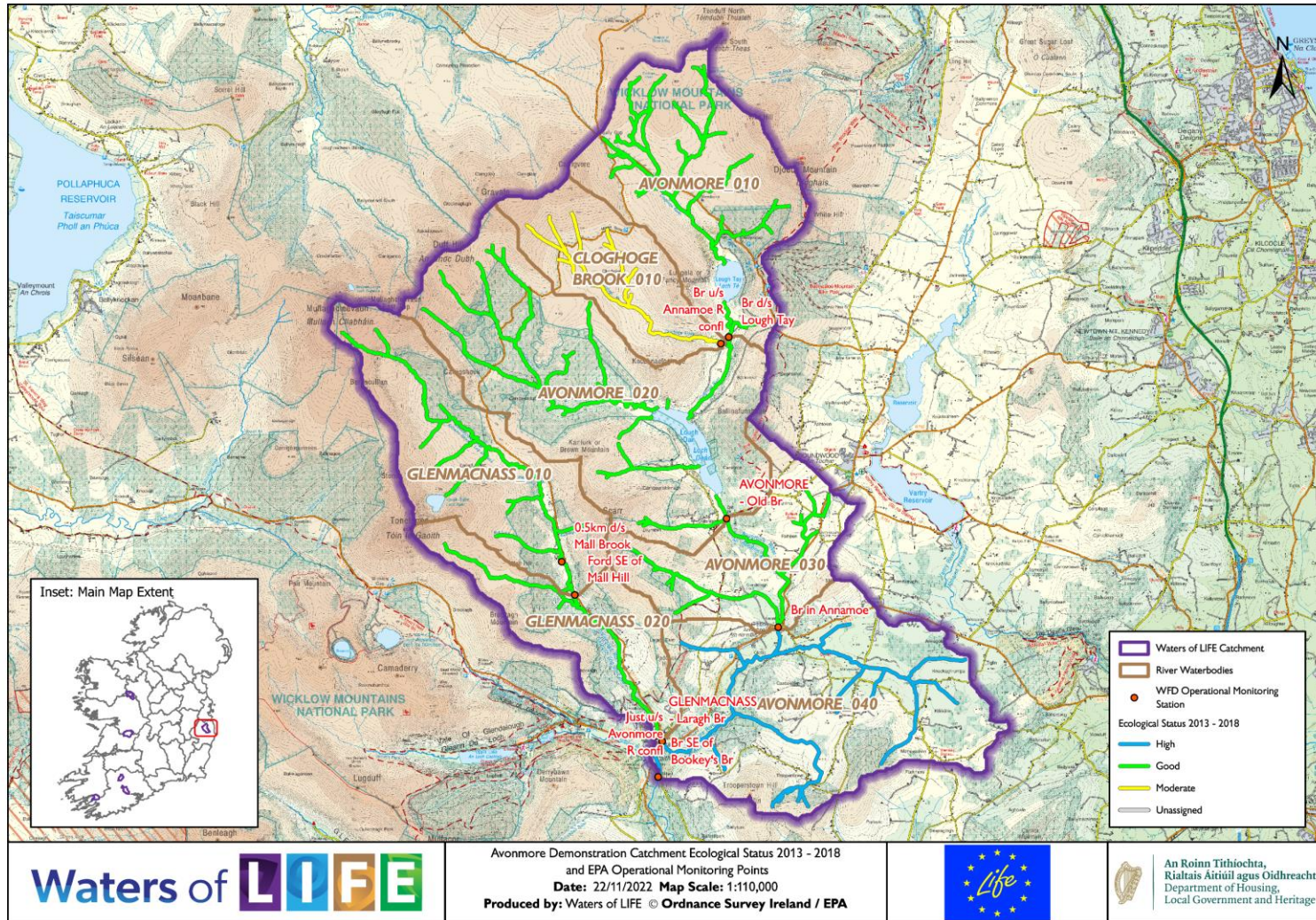


Figure 1 Avonmore Demonstration Catchment with 2013-2018 ecological status and EPA operational monitoring points of each river waterbody within.

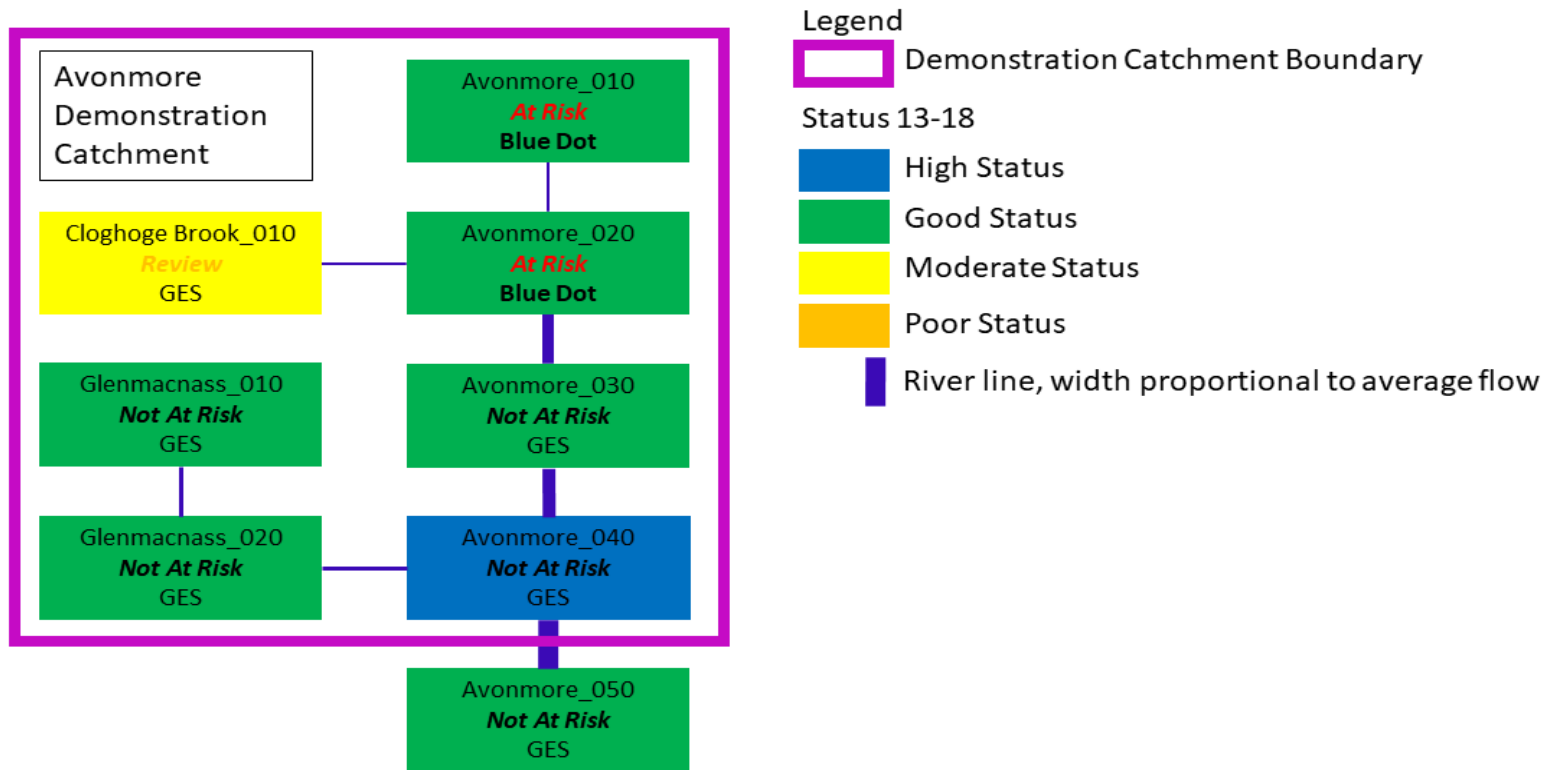


Figure 2 Schematic drawing of the Demonstration Catchment. Status of the river is represented by the colour.

Note: GES=Good Ecological Status objective

Table 1 Summary of ecological status and pressures for the Avonmore Demonstration Catchment

WB Code	WB name	WB Type	3 rd WFD cycle Risk	High status obj.	Ecological Status				No of significant pressures	Pressure category	Pressure subcategory	Significant pressure (Y/N)
					2009	2012	2015	2018				
IE_EA_10A050010	AVONMORE_010	River	At Risk	Yes	H	M	M	G	1	Atmospheric	Atmospheric	No
										Agriculture	Agriculture	No
										Forestry	Clearfelling	No
										Domestic Wastewater Treatment Systems	Single House Discharges	Yes
IE_EA_10A050020	AVONMORE_020	River	At Risk	Yes	H	H	G	G	1	Forestry	Clearfelling	Yes
IE_EA_10C010100	CLOGHOGE BROOK_010	River	Review	No	M	M	M	M	1	Extractive Industry	Peat	Yes
IE_EA_10A050050	AVONMORE_030	River	Not at Risk	No	G	G	G	G	0	No Pressure Impacts data available		
IE_EA_10A050100	AVONMORE_040	River	Not at Risk	No	G	H	G	H	0	No Pressure Impacts data available		
IE_EA_10G030200	GLENMACNASS_010	River	Not at Risk	No	M	M	M	G	0	Forestry	Forestry	No
IE_EA_10G030600	GLENMACNASS_020	River	Not at Risk	No	M	M	G	G	0	No Pressure Impacts data available		
IE_EA_10_25	Tay	Lake	At Risk	No	M	M	M	M	1	Anthropogenic Pressures	Unknown	Yes
IE_EA_10_29	Dan	Lake	At Risk	No	M	M	M	M	1	Anthropogenic Pressures	Unknown	Yes
IE_EA_10_31	Ouler	Lake	Review	No	U	U	U	H*	1	Anthropogenic Pressures	Unknown	Yes

WB – Waterbody; U – Unassigned; H – High; G – Good; M – Moderate; * Ouler ecological status has been extrapolated by the EPA and is based on the expert judgment.

2 Receptor information & assessment

2.1 Context and Setting

The Avonmore demonstration catchment consists of 10 waterbodies (seven rivers and three lakes). Three river waterbodies (Avonmore_010, Avonmore_020 and Cloghoge Brook_010) and two lakes (Lough Tay and Lough Dan) are not achieving their WFD objectives and are either *At Risk* or at *Review*. Two of these waterbodies, Avonmore_010 and Avonmore_020 are High status objective waterbodies (Blue Dot waterbodies). Restoration actions are required here to bring them back to High status. Review of issues (acidification relevant for Cloghoge Brook_010 and specific pollutant affecting status of the lakes) is also required for other waterbodies failing to achieve their WFD status in this sub-catchment.

Remaining waterbodies in Avonmore (Avonmore_030, Avonmore_040, Glenmacnass_010, Glenmacnass_020) are currently achieving their WFD objective of Good ecological status (or higher as Avonmore_040 is currently achieving High ecological status). These waterbodies require protection to maintain Good or High water quality in the future.

Headwaters of the Avonmore are located in Wicklow Mountains Special Area of Conservation (SAC) and Special Protection Area (SPA). All of the catchment is also *Margaritifera* sensitive area. It is a catchment of other extant populations and is not a designated area. Waterbodies in this demonstration catchment are also classified as acid sensitive area. Additionally, Glenmacnass_010 is a designated River Drinking Water Protected Area for a Public Water supply.

2.2 WFD Information

Water quality information has been reviewed and summary information on ecological status, biological conditions, and nutrient chemistry for The Avonmore demonstration catchment river waterbodies are provided in **Table 2**. Acidification conditions have also been reviewed as all waterbodies are acid sensitive. With low alkalinity values, pH threshold of 4.5 (Ecological Quality Standard (EQS)) for soft waters with water hardness ≤ 100 mg/l CaCO₃ is used for these waterbodies. See **Table 3** for range of pH values and '**Appendix I – pH plots**' for temporal pH variations.

Avonmore_010

- Avonmore_010 is a blue dot waterbody that is currently failing biological conditions. Operational monitoring point is located c. 1 km downstream of the outlet of Lough Tay. High biological conditions declined to Good and remained at Good since 2015 assessment (**Figure 3**). High biological conditions (Q5) have been recorded upstream of the lake.
- There is no exceedance of EQS for any nutrient. A single spike of ammonia was recorded in August 2021. Slight siltation was recorded at most recent EPA assessment.
- Acidification conditions failed during 2012-2014 (pH <4.5), causing decline to moderate ecological status 2010-2015. No failure of pH conditions was recorded since 2015, however, pH readings are low in the waterbody.

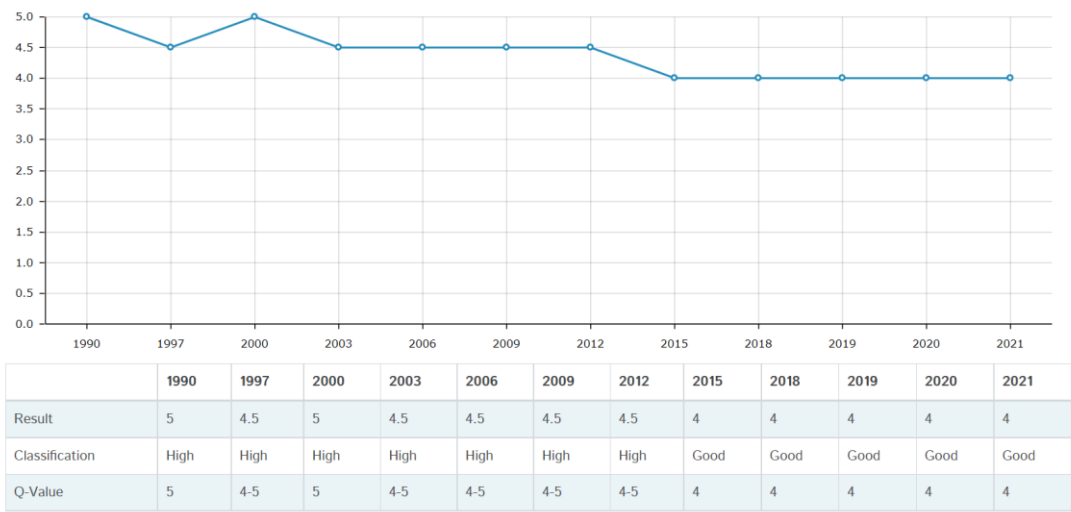


Figure 3 Q-Value chart and values for Avonmore_010 - Br d/s Lough Tay monitoring location.

Avonmore_020

- Avonmore_020 is a blue dot waterbody that is currently failing biological conditions. Operational monitoring point is located c. 0.6 km downstream of the outlet of Lough Dan. High biological conditions declined to Good and remained at Good since 2015 assessment (**Figure 4**). Siltation (noted by Q-value asterisk) was marked at the 2015 assessment. Moderate siltation has been noted in most recent (2020) assessment.
- Two river waterbodies (Avonmore_010 and Cloghoge Brook_010) together with two lakes (Lough Tay in Avonmore_010 and Lough Dan in Avonmore_020) are inputting waterbodies. Note the same year of biological decline in Avonmore_020 as in the upstream Avonmore_010 waterbody.
- Physico-chemical data have been recorded for this waterbody since 2019. No issues were observed with chemistry. Highest total ammonia value of 0.043 mg N/l was recorded in October 2019. However, nutrients (phosphate as a limiting element) are deemed to be significant issue here due to 50% algal growth recorded during 2018 EPA assessment.
- No failure of acidification conditions was recorded since 2019 measurements commenced.

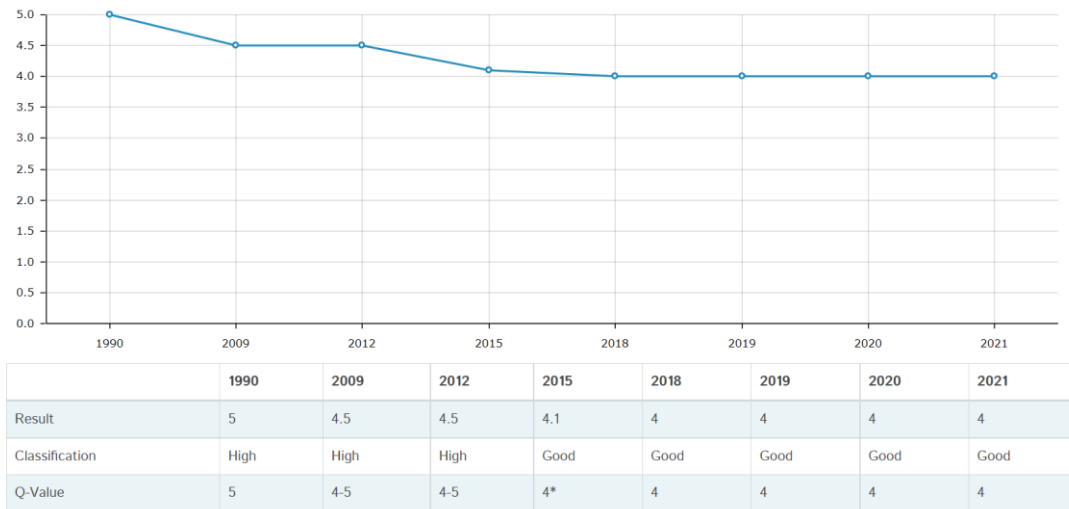


Figure 4 Q-Value chart and values for AVONMORE - Old Br monitoring location in Avonmore_020.¹

Cloghoge Brook_010

- Cloghoge Brook_010 historically has been always at High biological status (**Figure 5**). However, it was not identified as a blue dot waterbody as ecological status has been always Moderate (through all WFD assessment cycles) due to failing acidification conditions.
- pH values are low, however no failure of 4.5 WFD threshold was recorded since 2017 (lowest pH of 4.6, see **Table 3**). There is however still a risk of future pH failures.

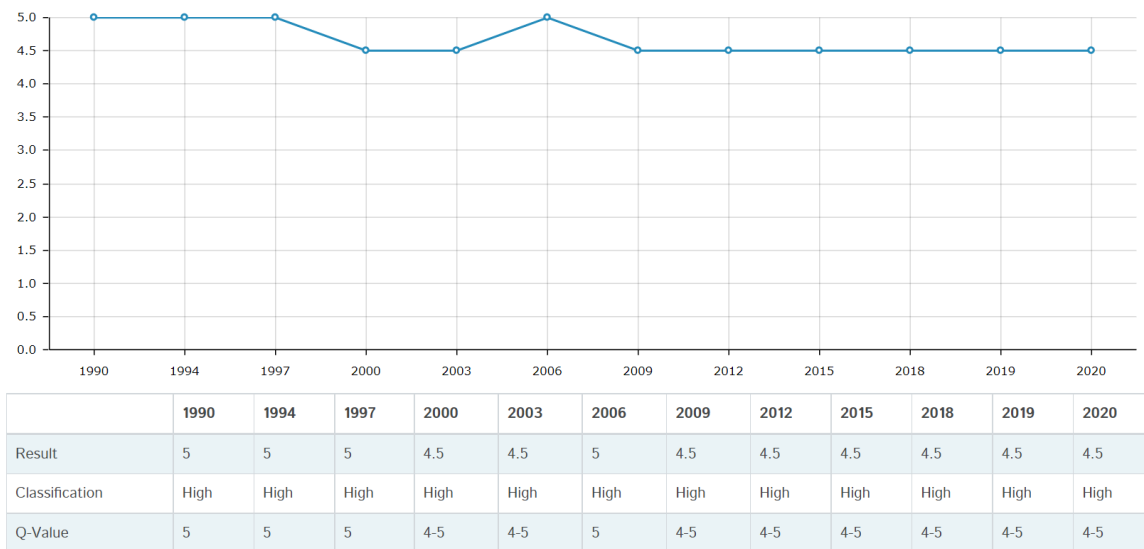


Figure 5 Q-Value chart and values for Cloghoge Brook_010 at Br u/s Annamoe R confl monitoring location.

¹ A result ending X.1 has an asterisk after the Q value (e.g., Q4*) indicating something worthy of special attention, typically heavy siltation of the substratum.

Avonmore_030, Avonmore_040, Glenmacnass_010 an Glenmacnass_020

- These waterbodies are achieving their environmental objectives, with no current water quality issues.
- In the past Glenmacnass_010 and Glenmacnass_020 failed acidification conditions. Biological conditions failed in Glenmacnass_010 in 2012 and 2015 and this has been attributed to forestry activities in the waterbody (EPA impact assessment).
- No issues were noted with Laragh Public Water Supply (groundwater abstraction in Avonmore_030 and surface water abstraction in Glenmacnass_010).

Table 2 Summary of Q-Value, physico-chemical data for river waterbodies in Avonmore Demonstration Catchment.

Waterbody	Avonmore_010		Cloghoge Brook_010	Avonmore_020	Avonmore_030	Avonmore_040	Glenmacnass_010		Glenmacnass_020		
Risk Category 3 rd WFD cycle	At Risk		Review	At Risk	Not At Risk	Not At Risk	Not At Risk		Not At Risk		
WFD objective	High		Good	High	Good	Good	Good		Good		
Monitoring station	S.E. OF SallyGap (RS10A050005)	Br d/s Lough Tay (RS10A050010)	Br u/s Annamoe R confl (RS10C010100)	AVONMORE - Old Br (RS10A050020)	Br in Annamoe (RS10A050050)	Br SE of Bookey's Br (RS10A050100)	0.5km d/s Mall Brook (RS10G030190)	Ford SE of Mall Hill (RS10G030200)	GLENMACNAS S - Laragh Br (RS10G030500)	Just u/s Avonmore R confl (RS10G030600)	
Monitoring station type	PreWFD	Operational	Operational	PreWFD	Operational	Operational	Operational	Operational	Operational	Operational	
Biological Status											
Q-values	2009	N/A	4-5	4-5	4-5	4	4	4	N/A Q-Value surveyed till 2003 Q4 to Q5, 1990 – 2003, latest Q = 4	N/A Q-Value surveyed till 2003 Q4 – Q4.5, 1981-2003, latest Q = 4	4.5
	2012	N/A	4-5	4-5	4-5	4.5	4.5	3.5			4
	2015	N/A	4	4-5	4*	4	4	3.5			4
	2018	N/A	4	4-5	4	4	4.5	4			4
	2019	5	4	4-5	4	N/A	N/A	N/A			N/A
	2020	5	4	4-5	4	4	4.5	4			4
	2021	5	4	N/A	4	N/A	N/A	N/A			N/A
comment	Blue dots surveyed annually since 2019			Note siltation in 2015 Q-Value assessment. Blue dots surveyed annually since 2019							

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Waterbody	Avonmore_010		Cloghoge Brook_010	Avonmore_020	Avonmore_030	Avonmore_040	Glenmacnass_010		Glenmacnass_020	
Monitoring station	S.E. OF SallyGap (RS10A050005)	Br d/s Lough Tay (RS10A050010)	Br u/s Annamoe R confl (RS10C010100)	AVONMORE - Old Br (RS10A050020)	Br in Annamoe (RS10A050050)	Br SE of Bookey's Br (RS10A050100)	0.5km d/s Mall Brook (RS10G030190)	Ford SE of Mall Hill (RS10G030200)	GLENMACNAS S - Laragh Br (RS10G030500)	Just u/s Avonmore R confl (RS10G030600)
Water Chemistry – note High status EQS for Avonmore_010 and Avonmore_020										
Baseline PO ₄ -P (mg/l) (2019 – 2021)	0.01	0.006	0.005	0.005	0.005	0.009	N/A	0.005	0.005	0.005
Baseline NH ₄ -N (mg/l) (2019-2021)	0.0198	0.0175	0.013	0.017	0.013	0.023	N/A	0.013	0.014	0.014
Baseline NO ₃ -N (mg/l) (2019 – 2021)	0.1	0.16	0.1	0.177	0.45	0.658	N/A	0.1	0.308	0.293
Comment	Single spike in ammonia at RS10A050010 station (Aug 2021, 0.082 mg N/l, note no high ammonia on the same day upstream of the lake).		Single high value of ortho-phosphate on 14/02/2017, 0.44 mg P/l. No other parameters elevated at that time	Measurements available since 2019, Highest ammonia value recorded was 0.043 mg N/l on 15/10/2019, low DO on the same date (however low DO also in other waterbodies on the same date)	Spikes in total ammonia 2011-2012, Note additional chemistry available u/s and d/s of Roundwood WWTP	Single spike in ortho-phosphate (0.068 mg P/l) and total ammonia (0.07 mg N/l) on 17/08/2020 Note additional chemistry available for u/s of Laragh WWTP	4	sampling points available for 2014-2015		
Hydromorphology information										

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Waterbody	Avonmore_010		Cloghoge Brook_010	Avonmore_020	Avonmore_030	Avonmore_040	Glenmacnass_010		Glenmacnass_020	
Monitoring station	S.E. OF SallyGap (RS10A050005)	Br d/s Lough Tay (RS10A050010)	Br u/s Annamoe R confl (RS10C010100)	AVONMORE - Old Br (RS10A050020)	Br in Annamoe (RS10A050050)	Br SE of Bookey's Br (RS10A050100)	0.5km d/s Mall Brook (RS10G030190)	Ford SE of Mall Hill (RS10G030200)	GLENMACNAS S - Laragh Br (RS10G030500)	Just u/s Avonmore R confl (RS10G030600)
2018 EPA siltation information		clean		slight						
2019 EPA siltation information	clean	slight to moderate		moderate						
2020 EPA siltation information	clean	slight		moderate						
HYMO – RHAT		High 2009 2019		High 2009						
Macroalgae/ macrophyte information										
2018 EPA survey info - % Filamentous Algae Cover		0		50						
2020 EPA survey info - % Filamentous Algae Cover	0	0		0						
Ecological Status information										
Eco. Status (2010 – 2015)	Moderate	Moderate	Good	Good	Good	Moderate	Good	Good	Good	Good

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Waterbody	Avonmore_010	Cloghoge Brook_010	Avonmore_020	Avonmore_030	Avonmore_040	Glenmacnass_010	Glenmacnass_020
Unsatisfactory status driven by	acidification conditions and macroinvertebrates	acidification conditions	macroinvertebrates			acidification conditions and macroinvertebrates	
Eco. Status (2013 – 2018)	Good	Moderate	Good	Good	High	Good	Good
Unsatisfactory status driven by	macroinvertebrates	acidification conditions	macroinvertebrates				
EPA Biologist comments	<p style="text-align: center;">2015</p> <ul style="list-style-type: none"> The Avonmore River remains in a satisfactory ecological condition in July 2015 however the macroinvertebrate fauna indicated a decline from high to good ecological conditions at five of the six sites classified as High in the 2012 survey. Peat siltation of the instream substrata was most notable in the upper reaches (0010 and 0020) and may be contributing to the decline observed. <p style="text-align: center;">2018</p> <ul style="list-style-type: none"> The Avonmore river was in a satisfactory ecological condition at six of the seven stations surveyed in June 2018. The macroinvertebrate fauna continues to indicate satisfactory good ecological conditions in the upper reaches however excessive instream filamentous algal growth was noted at Old Bridge (0020) indicating some signs of enrichment. High ecological conditions continue at Rathdrum (0300). The paucity of pollution sensitive macroinvertebrate fauna and dominance of pollution tolerant species indicated an unwelcome decline in the lower reaches at Lions Bridge (0500). <p style="text-align: center;">2019</p> <ul style="list-style-type: none"> Satisfactory conditions were noted in the upper reaches of the Avonmore river when surveyed in 2019. The diversity of pollution sensitive macroinvertebrates present in the most upper station surveyed (0005) indicated high ecological conditions while good ecological conditions continue downstream (0010, 0020). Excessive instream siltation was notable at Old Bridge (0020). <p style="text-align: center;">2020/ 2021:</p> <ul style="list-style-type: none"> Avonmore: Satisfactory ecological conditions were noted at all eight sites surveyed on the Avonmore river in 2020. The macroinvertebrate fauna continues to indicate high (0005) and good (0010, 0020) ecological conditions when visited again in 2021 <ul style="list-style-type: none"> Glenmacnass: Satisfactory ecological conditions continue on the Glenmacnass river in June 2020. 						
Protected Areas	Majority of waterbody in Wicklow Mountains SAC and SPA	partly Wicklow Mountains SAC and SPA	partly Wicklow Mountains SAC and SPA	majority of waterbody in Wicklow Mountains SAC and SPA	partly Wicklow Mountains SAC and SPA		
<i>Margaritifera</i> sensitive area - catchment of other extant populations*							
				River Drinking Water			

Avonmore Desk Study

Waterbody	Avonmore_010	Cloghoge Brook_010	Avonmore_020	Avonmore_030	Avonmore_040	Glenmacnass_010	Glenmacnass_020	
Potentially Dependent Waterbodies - Groundwater	Kilcullen, IE_EA_G_003, 2013-2018 Status: Good , WFD Risk: Not at Risk							
	Wicklow, IE_EA_G_076, 2013-2018 t Status: Good , WFD Risk: Review (EPA Watching Brief, Anthropogenic pressure; Impact assessment: Nitrate concentrations (6 year average) for the group of groundwater bodies are greater than 0.75 * TV (28.1 mg/l NO3); deemed not significant (03/03/2021))							
	Historic Mine (Glendalough), IE_EA_G_077, 2013-2018 Status: Poor (GW) (Poor chemical GW Status, failing lead and zinc), WFD Risk: At Risk							
Other information	acid sensitive area							
Significant issue: monitoring point / waterbody		slight siltation	pH fluctuations, but no failure from 2019	siltation, nutrient enrichment (algal growth)				

* 'Margaritifera sensitive area - Catchments of other extant populations. These mussel populations may lie (in part) within SAC, other nature conservation sites or in the wider countryside. Those populations within SAC were not considered of sufficient quality to warrant designation for the species and detailed restoration objectives, targets, plans or measures are unlikely to be developed. However, the potential effects of any plans, developments or activities on the populations, including the potential to cause 'environmental damage' as per the Environmental Liability Directive and Regulations, must be determined through SEA, EIA or other ecological assessment. The NPWS holds some detailed information on the distribution and abundance of freshwater pearl mussels in a small number of these catchment.'; N/A – not available.

Table 3 Minimum pH, maximum pH and number of failing 4.5 EQS threshold for pH values recorded in river waterbodies in the Avonmore Demonstration Catchment

	AVONMORE_010			CLOGHOGE BROOK_010			AVONMORE_020			AVONMORE_030			AVONMORE_040			GLENMACNASS_010			GLENMACNASS_010			GLENMACNASS_020			GLENMACNASS_020		
	RS10A050010			RS10C010100			RS10A050020			RS10A050050			RS10A050100			RS10G030190			RS10G030200			RS10G030500			RS10G030600		
	Min	Max	No. fails	Min	Max	No. fails	Min	Max	No. fails	Min	Max	No. fails	Min	Max	No. fails	Min	Max	No. fails	Min	Max	No. fails	Min	Max	No. fails	Min	Max	No. fails
2010	5.38	6.18	0	4.91	6.8	0				5.6	6.71	0	5.98	6.89	0				5.5	6.43	0	5.34	6.55	0			
2011	5.01	5.97	0	4.56	6.66	0				5.7	6.79	0	6.06	6.78	0				5.3	6.32	0	5.41	6.51	0			
2012	4.45	5.67	1	4.3	6.27	1				5.2	6	0	5.43	6.33	0				4.1	6.09	2	4.21	6.23	2			
2013	4.47	6.07	1	3.94	6.6	3				5.3	6.29	0	5.6	6.53	0				4.5	5.84	0	4.93	6.31	0			
2014	4.36	4.8	1	4.11	5.34	2				5.1	5.77	0	5.65	6.06	0				4.3	6.02	1	4.96	6.11	0			
2015	4.93	6.13	0	4.1	5.47	2				5.2	6.34	0	5.69	6.73	0				5.3	6.1	0	5.06	5.98	0			
2016	5	6.2	0	4.4	6.3	1				5.5	6.5	0	5.8	6.92	0				4.5	6.1	0	4.7	6.2	0			
2017	5.8	7	0	4.6	7	0				6.2	6.6	0	6.4	7.04	0				4.9	6.7	0	5.1	6.9	0			
2018	5.3	6.4	0	4.6	7.1	0				5.9	6.7	0	5.88	7.17	0				4.9	6.9	0	5.3	7	0			
2019	5.2	6	0	4.6	6.7	0	5.2	6	0	6.2	6.6	0	6.37	6.9	0	5.3	6.6	0	5.1	6.7	0	5.6	6.8	0	6.4	6.8	0
2020	5.5	6.3	0	6	7	0	5.2	5.9	0	6.2	6.6	0	6	7	0	5.7	6.5	0	5.7	6.7	0	6.1	6.8	0	6.2	7.1	0
2021	5.6	6.5	0	6.4	7	0	5.3	6	0	6.4	6.8	0	6.3	7.2	0	6.3	6.9	0	6.2	6.7	0	6.6	7	0	6.6	6.8	0

Water quality information for lakes has also been reviewed, and summary information for ecological status or potential and chemical surface water status is shown in **Table 4**.

Two lakes, Lough Tay and Lough Dan are monitored by the EPA. Both lakes are *at Risk* of failing to achieve their environmental objective and their ecological status has been Moderate for all WFD cycles.

Table 4 Summary of WFD Status for Lough Tay and Lough Dan.

Waterbody name	Tay (Lake)	Dan (Lake)
Waterbody code	IE_EA_10_25	IE_EA_10_29
Located in	Avonmore_010	Avonmore_020
Inputting waterbodies	Avonmore_010	Avonmore_020 Avonmore_010 Cloghoge Brook_010
Risk Category	<i>At Risk</i>	<i>At Risk</i>
WFD Status 2007-2009	Moderate <ul style="list-style-type: none"> • Moderate macrophyte Status or Potential • Failing Specific Pollutant Conditions (Zinc) 	Moderate <ul style="list-style-type: none"> • Moderate macrophyte Status or Potential • Failing Specific Pollutant Conditions (Zinc)
WFD Status 2010-2012	Moderate <ul style="list-style-type: none"> • Moderate macrophyte Status or Potential • Failing Specific Pollutant Conditions (Zinc) 	Moderate <ul style="list-style-type: none"> • Failing Specific Pollutant Conditions (Zinc)
WFD Status 2010-2015	Moderate <ul style="list-style-type: none"> • Moderate macrophyte Status or Potential • Failing Specific Pollutant Conditions (Zinc) 	Moderate <ul style="list-style-type: none"> • Failing Specific Pollutant Conditions (Zinc)
WFD Status 2013-2018	Moderate <ul style="list-style-type: none"> • Moderate macrophyte Status or Potential • Failing Specific Pollutant Conditions (Zinc) 	Moderate <ul style="list-style-type: none"> • Failing Specific Pollutant Conditions (Zinc)
Chemical Surface Water Status Information		
2007-2009	Good	Good
2010-2012	Failing to achieve good – Mercury and PAH	Failing to achieve good
2010-2015	Failing to achieve good – Mercury and PAH	Good
2013-2018	Good	Good

Lough Tay

- Moderate 2013-2018 ecological status is driven by Moderate **macrophyte status** and Moderate supporting chemistry conditions failing **specific pollutant conditions for Zinc**. These two elements have failed in all WFD cycles assessments. Chemical Surface Water Status is currently (2013-2018) Good. It failed in 2010-2012 and 2010-2015 assessments for Mercury and Sum(benzo-g,h,i-perylene)+(indeno(1,2,3-cd)pyrene).

Lough Dan

- Moderate 2013-2018 ecological status is driven by Moderate supporting chemistry conditions failing **specific pollutant conditions for Zinc**. These conditions failed in all WFD cycle assessments. In the past, macrophyte status failed in 2007 – 2009 ecological status assessments. Chemical Surface Water Status is currently (2013-2018) Good. It failed only once in 2010-2012 cycle assessment.

Any failures in Chemical Surface Water Status were due to mercury and Polycyclic Aromatic Hydrocarbons (PAHs). These chemicals are considered ubiquitous in the environment (derived from atmospheric deposition) and are the main causes for failures of chemical status throughout Europe.

Failure of specific pollutant conditions for ecological status is associated with higher concentrations of zinc in the lakes. Toxicity of zinc is related to its bioavailability which is dependent on physico-chemical parameters, such as pH (affecting metal solubility, and/or competing with zinc for absorption), hardness and the content of Dissolved Organic Carbon (DOC). DOC can bind zinc into non-labile form. Calcium content (but also H⁺) can compete with metals affecting its bioavailability at the biological receptors (Maycock, 2010).

It is assumed that zinc may originate from underlying geology in the catchment (although WFD Impact Assessment notes small lead and copper mine north of Lough Dan). In both lakes, the annual average concentrations fail the EQS of less or equal to 8ug/l (annual mean) for low hardness waters (< 10 mg/l CaCO₃) (Figure 6 - Figure 8). 2019-2021 baseline alkalinity (as CaCO₃) for Lough Tay (Midlake location) is 3.1 mg/l, and alkalinity for Lough Dan is 2.7 g/l for Site 1 and 2.8 mg/l or Site 2.

Considering co-dependence of zinc bioavailability (and therefore its toxicity) on pH, DOC and calcium content, some other states incorporate Bioavailability Models to estimate zinc which is bioavailable. Preliminary assessment of such modelling for Lough Tay and Lough Dan indicates low zinc bioavailability suggesting it is unlikely to be an issue to the lake biology (EPA, pers. comm.).

Ouler

- There are no monitoring data for Ouler lake and 2018 status has been extrapolated by the EPA based on expert judgement.

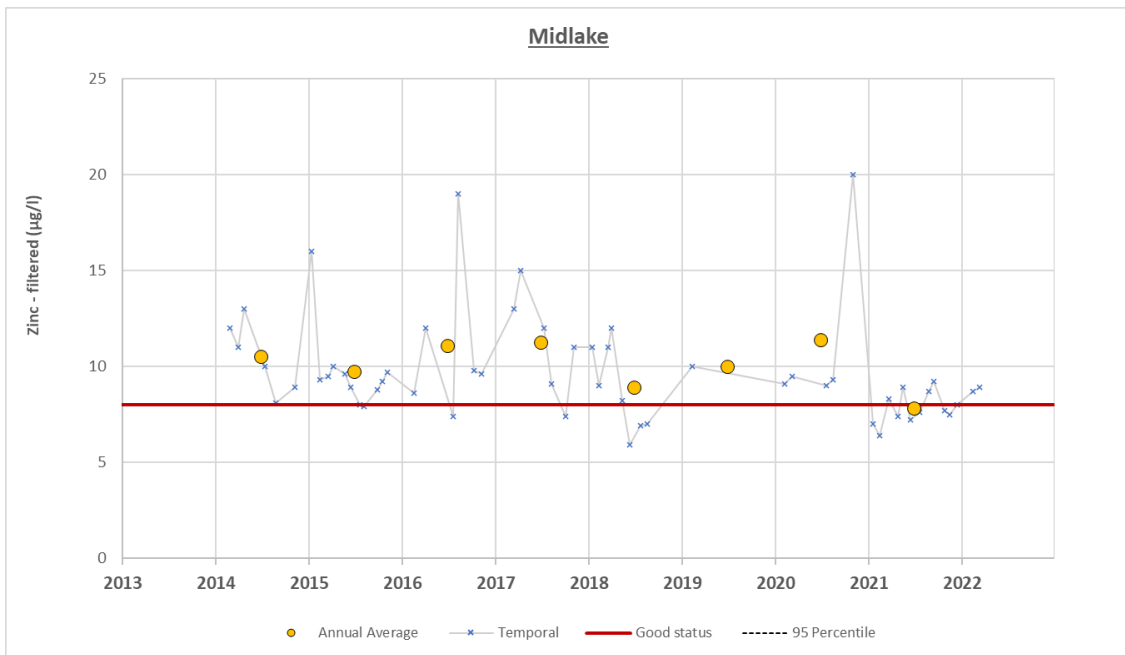


Figure 6 Temporal variations with annual mean concentration for zinc measured in Lough Tay at Midlake monitoring location.

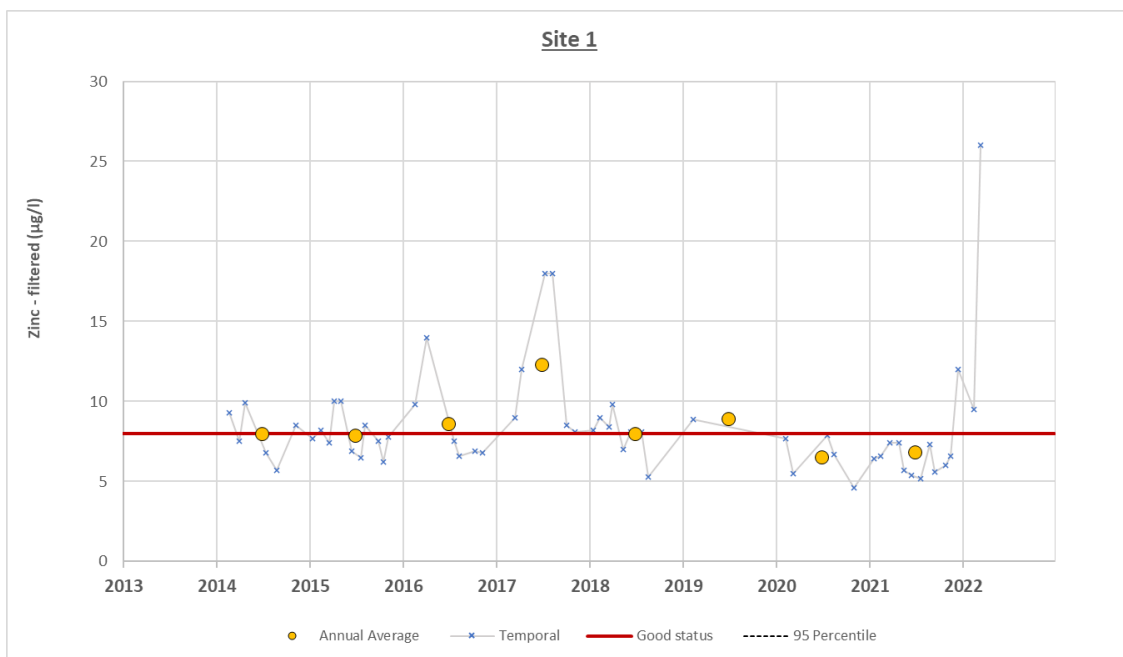


Figure 7 Temporal variations with annual mean concentration for zinc measured in Lough Dan at Site 1 monitoring location.

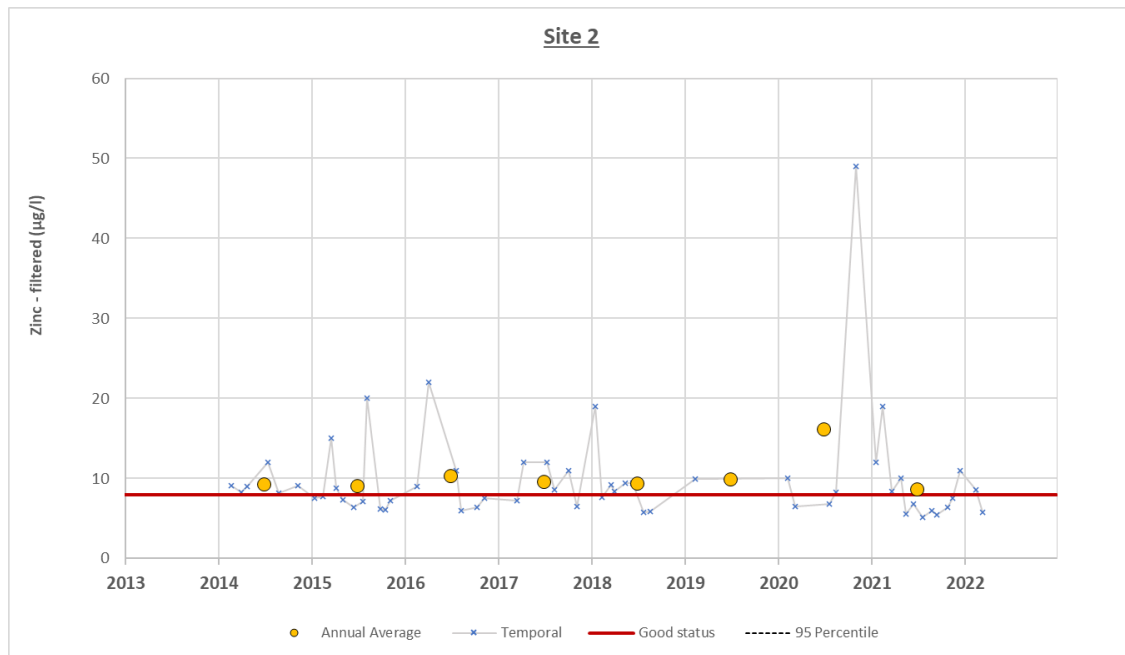


Figure 8 Temporal variations with annual mean concentration for zinc measured in Lough Dan at Site 2 monitoring location.

2.3 Lakes' other parameters – chemistry

Additionally, although the lakes' ecological status is not affected by any other parameters, considering location of the lakes in relation to the monitoring locations of the two blue dot river waterbodies, ortho-phosphate, total phosphorous and total ammonia concentrations in the lakes have been reviewed.

S.I. No. 77/2019 - European Union Environmental Objectives (Surface Waters) (Amendment) Regulations 2019 provide an environmental quality standard (EQS) for ortho-phosphate for rivers only. While there are ortho-phosphate measurements available for Lough Dan and Lough Tay, there is no assigned EQS for the lake environment. Total phosphorus is the important measure of lake trophic status and it is measured for lakes only. EQSs for Good and High status objective lakes are provided in SI No. 77/2019.

While lake total phosphorus and total ammonia should be assessed against Good status EQS (as the WFD objective of both lakes is Good status), both lakes discharge just upstream of a monitoring location for High status objective rivers. Therefore results could be compared to the river High status EQS for ortho-phosphate (≤ 0.025 mg P/l, mean EQS) and total (≤ 0.040 mg N/l, mean EQS) when reviewing data for any potential impacts for High status objective receiving river waterbodies.

Total Phosphorous (TP) EQS for lakes are ≤ 0.01 mg P/l for High status and ≤ 0.025 mg P/l for Good status. There is no EQS for TP for the rivers, however considering that total P includes ortho-phosphate it could be compared to river ortho-phosphate standards when reviewing any potential influences of lake chemistry to the receiving rivers.

Ortho-phosphate and total phosphorus

Temporal variations with annual mean concentrations of ortho-phosphate and total phosphorous measured for Lough Tay and Lough Dan are shown in in **Appendix II**. Results show no exceedance of High status **river EQS** for ortho-phosphate for both ortho-phosphate and total phosphorous sampled in lakes. Only a few temporal values for total phosphorous were higher than annual mean river EQS for ortho-phosphate at Site 2 in Lough Dan however annual mean values did not exceed the EQS **Appendix II**.

Total P annual mean values did not exceed Good status **lake EQS**, however concentrations are above High status lake EQS. It is hard to make any conclusions on this considering there is no EQS for Total P in rivers. However, considering that values do not exceed river High status EQS for ortho-phosphate suggests no major impact from the lake chemistry. Additional factor to consider is low frequency of sampling which may be not fully representative (considering river chemistry did not show any impact but high macroalgal growth was recorded).

Total ammonia

Note that total ammonia EQSs are the same for rivers and lakes. None of the annual mean ammonia concentrations exceeded the Good status annual mean EQS except for Site 1 at Lough Dan, which was caused by a single very high concentration of 0.88 mg/l as N recorded on 17/11/2021, **Figure 9**. River

water chemistry is collected on a different schedule therefore there is no corresponding chemistry sampling for the rivers on this date. While very high value was recorded at Site 1, no exceedance was found at Site 2 of Lough Dan suggesting possibly wastewater discharge close to Site 1 location.

Exceedance of high annual mean EQS (investigated in relation to the High status objective of receiving river waterbodies) was recorded for Site 1 of Lough Dan (due to the same very high single concentrations), and at Midlake of Lough Tay with the concentration of 0.084 mg/l N on 21/07/2020, **Figure 10**. While it does not affect lake chemistry and their status, this could potentially affect river waterbodies downstream, and it could suggest potential and sporadic pressures at or area draining to the lakes.

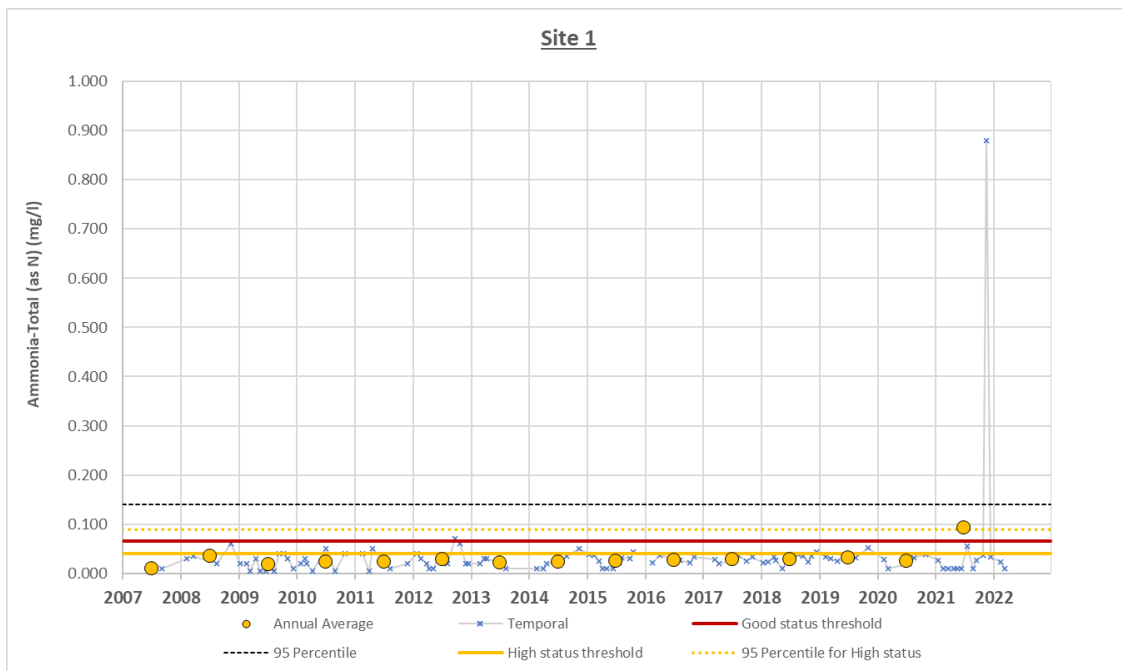


Figure 9 Total ammonia concentrations at Site 1, Lough Dan.

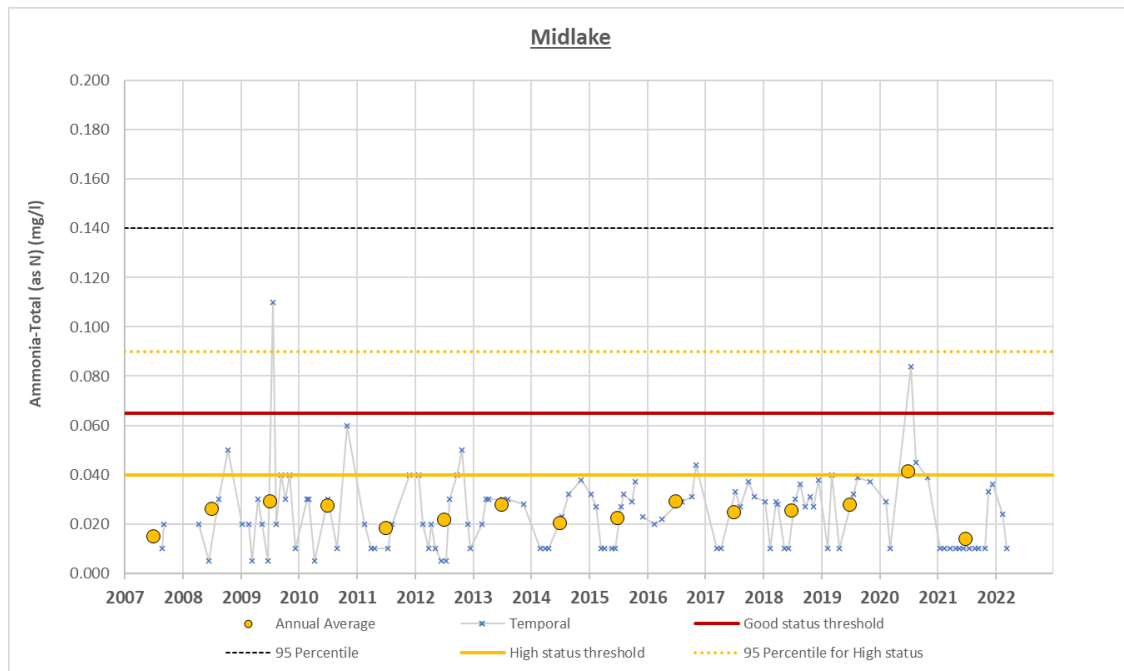


Figure 10 Total ammonia concentrations at Midlake, Lough Tay.

2.4 Supplementary Information – Mobile Monitoring Unit Investigative Assessment

As part of Water Framework Directive implementation process, the Eastern River Basin District established Mobile Monitoring Unit (MMU) to gather monitoring data and identify local pressures. Investigative assessment undertaken by the MMU in Avonmore is summarised below. For more detailed information please refer to the full MMU reports (O’Keeffe and Barrett, 2014; Ryan and Jordan, 2010).

Avonmore_020

MMU assessment of Inchavore River was carried out in 2010. Inchavore River flows into Lough Dan and is located in Avonmore_020. Assessment indicated that the river was found to be probably not at risk at the upstream reaches and probably impacted further downstream (closer to the lake) with lower macroinvertebrate diversity. Low risk scores were attributed to surrounding peat land (Ryan and Jordan, 2010).

Avonmore_010 and Avonmore_020

Further assessments of the rivers and streams in flowing into Lough Tay and Lough Dan were carried out in 2012 (O’Keeffe and Barrett, 2013). Q-Values at the EPA monitoring stations indicated High biological conditions in both Avonmore_010 and Avonmore_020 at the time of assessment (2012 Q-Value of 4-5). Biological assessments (Small Stream Risk Score, SSRS) were carried out at five locations on three occasions (May/June, September and November). Results indicated that sites 1 – 4 were ‘Probably not at risk’ on all occasions, while site 5 fluctuated between being ‘possibly at risk’ in June,

‘at risk’ in September and ‘probably not at risk’ in November sampling. Site 5 was located on the main channel of Inchavore River flowing into the Lough Dan (**Figure 11**).

High status generally requires at least three Class A taxa to be well represented with few tolerant taxa, and few or absent very tolerant taxa. Review of the SSRS field sheets from May/ June 2013 sampling indicates that sites 1 – 4 were well represented by the sensitive (class A) taxa with tolerant taxa being in few numbers. Site 5 was represented by lower macroinvertebrate diversity with *Protonemura* being the only sensitive taxa present indicating less than High biological conditions at that location.

Nutrient sampling carried out in dry conditions did not show exceedances of the EQS for High status except for two samples (see **Figure 11** for the sampling locations). One sample showed high total ammonia levels (0.139 mg/l N) at the Cloghoge River downstream of the confluence with Cloghoge Brook attributed to unrestricted deer access to the river network. Higher ortho-phosphate level (0.035 mg/l P, above the mean High status EQS but below the 95%ile limit) was also found just downstream of Lough Tay in September (although June sampling at this location did not show any exceedance).

Field observations indicated the presence of filamentous algae in assessment locations, which can be an indication of nutrient enrichment. Most prevalent aquatic plant growth was noted upstream of Lough Dan on the Cloghoge River. Summer SSRS field sheets indicate that filamentous algae were ‘present’ at all sites but site 4. Sewage odour was recorded at site 4 (May sampling) however no source was found.

Additionally, widespread bank erosion was noted with most prominent bank erosion recorded for Cloghoge Brook tributary. Unrestricted deer access to the streams was present throughout all the area and sheep access point was noted downstream of Lough Tay. Some sediment deposition was also noted throughout field observations.

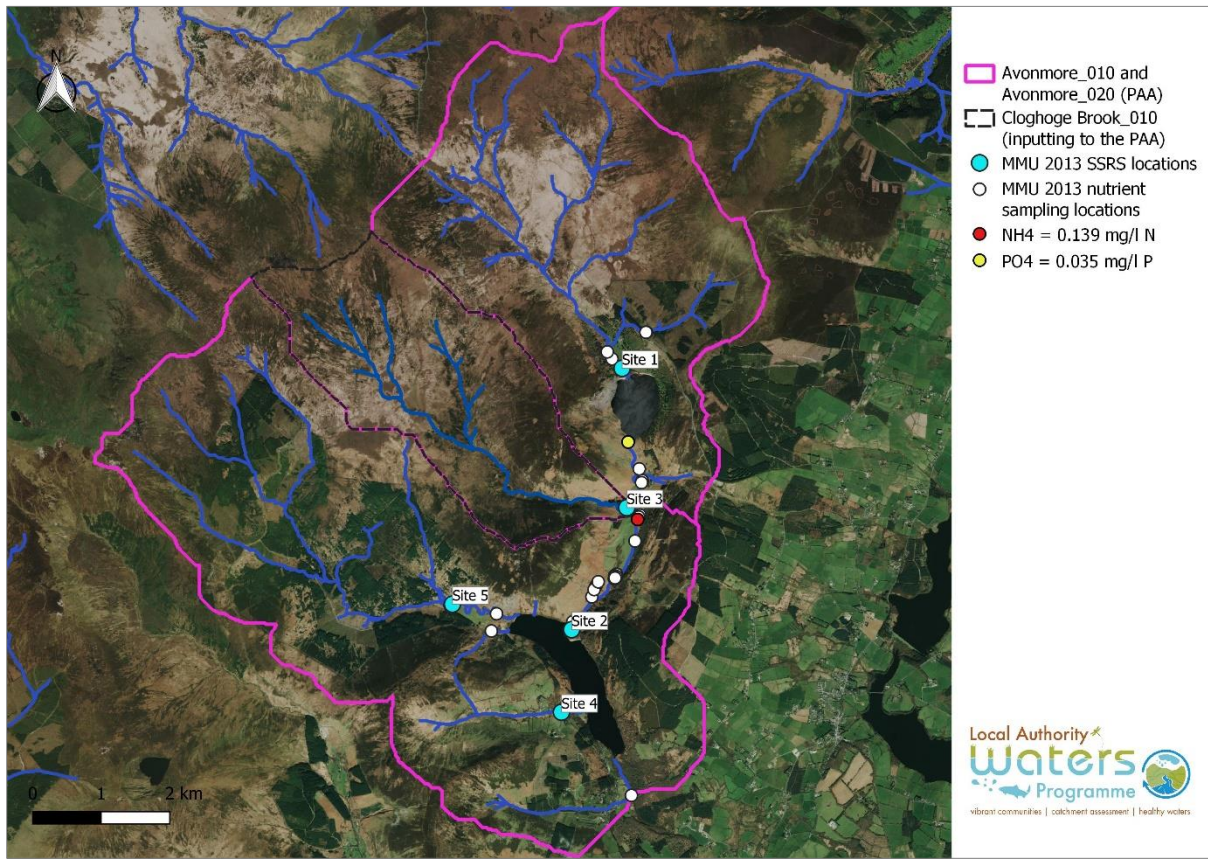


Figure 11 Location of the 2013 MMU assessment in Avonmore_010 and Avonmore_020 (data source: O’Keeffe and Barrett, 2013) © OSI/EPA.

2.5 Supplementary Information – Forestry Research

There is a large body of research investigating forest-water interactions in Ireland including acidification impacts from mature forests and nutrient and sediment loss during harvesting and planting stage of the forestry. Please refer to [LAWPRO Avonbeg-Avonmore desk study](#) for a summary of the role of forestry in increased acidification and summary of Hydrofor research project for the study area.

2.6 Supplementary Information – pH Review Project

The EPA is currently carrying out a pH Review Project which aims to provide better understanding of acidification conditions, role of quick flow pathways, impacts on ecology and drivers. The pH Review Project covers most of the waterbodies in the Wicklow Mountains, including Avonmore_010, Cloghoge_Brook_010, Avonmore_020, Glenmacnass_010 and Glenmacnass_020, as well as selected acid sensitive waterbodies in other counties. This study is currently ongoing and results are not yet available.

As part of this project EPA carries out additional biological monitoring with Acid Water Indicator Community Species (AWICsp) metric and additional chemistry sampling (c. five times per year, including DOC, cations, metals and anions). This monitoring programme is currently under review. LAWPRO additionally supported the project and carried out additional pH monitoring with continuous and high-frequency (15-minutes intervals) record of pH at selected acid sensitive waterbodies in Wicklow Mountains. One site is located in upper parts of Avonmore_010, however, monitoring programme at this site is still ongoing and results are not yet available.

2.7 Supplementary Information – further characterisation by LAWPRO (WFD 2nd cycle)

As part of the further characterisation process in the 2nd WFD cycle, LAWPRO carried out Local Catchment Assessment in the two Blue Dot waterbodies: Avonmore_010 and Avonmore_020. They concluded that nutrients (ortho-phosphate as a limiting factor) are the significant issue affecting water quality of both waterbodies. This has not been reflected by the chemistry data collected by the EPA at the monitoring locations, however, it is based on LAWPRO visual assessments of high algal cover (Filamentous Green Algae) at both EPA monitoring stations observed in September 2020. With EPA recording high algal cover in Avonmore_020 in June 2018, this confirms that nutrients are an issue. Considering that chemistry sampling did not pick up an issue and that algal growth has not been identified in other assessments, this may be an intermittent issue and challenging to record.

Avonmore_010

- Kick sampling across the waterbody in 2019 indicated conditions indicative of High Q status (at least three class A taxa found in good numbers) upstream of Lough Tay (main channel capturing all tributaries) and impact (conditions indicative of Good) was shown downstream of the lake.
- 2020 assessments showed 40% Filamentous Green Algae (FGA) cover from downstream of the lake to the monitoring location (FGA were present upstream of small left bank tributary).
- LAWPRO chemistry sampling (September 2020 and August 2021) did not show any EQS exceedance. Some of the results (September 2020) approached the annual mean EQS for High status: left bank tributary downstream of the lake showing 0.04 mg N/L for total ammonia, and the tributary and monitoring location showing 0.02 mg P/ L for ortho-phosphate. Total phosphate concentrations were measured in August 2021 and higher value of 0.09 mg P/l was recorded downstream of the lake but upstream of the river monitoring location and upstream of the tributary (while lower concentrations were found downstream).
- No siltation issue was noted (clean substrates).

Avonmore_020

- Kick sampling across the waterbody in 2019 indicated conditions indicative of High Q status (at least three class A taxa found in good numbers) at the small tributary feeding into the lake from the west. Cloghoge River and Inchavore River feeding into the Lough Dan showed

conditions indicative of Good. Downstream of Lough Dan, main monitoring location and small right bank tributary were both showing conditions indicative of Good.

- Visual assessment in 2020 at the monitoring location showed nutrient enrichment with 70% algal cover (Filamentous Green Algae), confirming ortho-phosphate as a significant issue affecting water quality here. Algal growth was at the monitoring location and upstream of the right bank tributary. Sediment deposition was checked with bathyscope method, and no sediment issue was found.
- In 2020 chemistry sampling was undertaken at three locations: monitoring location (upstream of the tributary at the right bank, at the tributary next to the monitoring location and at the forestry drain upstream of Lough Dan). No nutrient issues were found. Total ammonia value of 0.04 mg N/l was recorded at the small tributary.
- In 2021 a joint catchment walk was carried out between LAWPRO and Forest Service- DAFM at the Inchavore River feeding into Lough Dan. No immediate forestry impacts were identified on the day of the assessment. Chemistry data collected on the day showed localised increased ortho-phosphate levels (two locations at the Inchavore River), however results did not exceed the mean High status EQS (highest values recorded were 0.02 mg P/l). Total phosphorus concentrations were between 0.02 and 0.03 mg P/l. Considering the sensitivity of the catchment it was agreed that suite of additional measures could protect this catchment from potential future ortho-phosphate and sediment loss. These measures are transferable to other Blue Dot Catchments.

2.8 Conclusion on Significant Issues

Acidification – significant in Cloghoge Brook_010

Failing acidification conditions are currently driving 2013-2018 Moderate ecological status of Cloghoge Brook_010. However, pH record did not fail 4.5 WFD threshold since. Note that pH values are still low and there is a risk of future failures.

In the previous cycle, acidification has also downgraded ecological status of Avonmore_010, Glenmacnass_010 and Glenmacnass_020. Acidification issue in Wicklow Mountains waterbodies is under review with the EPA.

Ortho-phosphate – significant in Avonmore_010, Avonmore_020

Although not confirmed by the EPA or LAWPRO chemistry sampling, it was concluded that ortho-phosphate as a limiting factor for algal growth is deemed a significant issue for both waterbodies. This conclusion is based on high Filamentous Green Algae cover recorded at the monitoring locations. Lake presence upstream of the monitoring locations adds complexity to the issue as ortho-phosphate could be accumulated in the lake sediments. A high ortho-phosphate value was recorded by the MMU in September 2013 just downstream of Lough Tay in Avonmore_010.

Ammonia – potentially significant in Avonmore_010 and Avonmore_020

A single high ammonia result has been recorded in Avonmore_010 (Aug 2021, 0.082 mg N/l). There was also a high ammonia spike recorded at the lakes (0.88 mg N/l Site 1 in Lough Dan, 17/11/2021 and 0.084 mg N/l in Lough Tay, 21/07/2020) which could potentially affect the downstream river waterbodies.

Siltation – potentially an issue in Avonmore_020

EPA Q-Value surveys noted moderate siltation at Avonmore_020 monitoring location. However, LAWPRO bathyscope assessment did not indicate any siltation issue here in 2020. Considering the annual variability of sediment transport and potential for forestry activities siltation is a potential issue to be considered when assessing Avonmore_020.

Zinc – significant in Lough Tay and Lough Dan

Specific pollutant conditions for Zinc failed all WFD cycles assessments for Lough Tay and Lough Dan.

Unknown – Lough Tay

Lough Tay moderate status is also driven by Moderate macrophyte status, failing all WFD cycle assessments. Reason for failing macrophyte conditions is unknown and requires consultation with the EPA. EPA characterisation information notes steep slope in the catchment and biologists recommend caution with macrophyte status.

3 Significant pressure information

3.1 Initial EPA Characterisation

A summary of the pressures identified during the WFD initial characterisation process is shown in **Table 5**. Based on LAWPRO Local Catchment Assessment, three pressures identified in Avonmore_010 are deemed not significant and Domestic Wastewater Treatment Systems were suggested as a significant pressure in this waterbody. Note that pressure information is not yet updated on the WFD App at the time of the desk study writing.

Table 5 Pressures identified during the WFD characterisation process in Avonmore_SC_010.

WB Code	WB name	Pressure category	Pressure subcategory	Significant pressure (Y/N)	Pressure & Impact details
IE_EA_10A050010	AVONMORE_010	Atmospheric	Atmospheric	No	Acidification
		Agriculture	Agriculture	No	Altered habitats due to morphological changes
		Forestry	Clearfelling	No	Cycle 3 update: Deemed not sig - altered habitats (morph) unchecked. Overall reduction in forestry activity, therefore forestry (Clearfelling) removed as significant pressure.
		DWWTS	Single House Discharges	Yes	Nutrient pollution
IE_EA_10A050020	AVONMORE_020	Forestry	Clearfelling	Yes	Altered habitats due to morphological changes
IE_EA_10C010100	CLOGHOGE BROOK_010	Extractive Industry	Peat	Yes	Acidification
IE_EA_10A050050	AVONMORE_030	No Pressure Impacts data available			
IE_EA_10A050100	AVONMORE_040	No Pressure Impacts data available			
IE_EA_10G030200	GLENMACNASS_010	Forestry	Forestry	No	Cycle 3 Update: deemed not significant - nutrient, acidification and altered habitats (morphology changes) unchecked.
IE_EA_10G030600	GLENMACNASS_020	No Pressure Impacts data available			
IE_EA_10_25	Tay	Anthropogenic Pressures	Unknown	Yes	Chemical Pollution Other Significant Impacts (Natural Background Metal) (Chemicals - ubiquitous substance failure: Mercury. Added 'Natural Background Metal' to Other impact. Added Chemical Pollution for mercury failure.)
IE_EA_10_29	Dan	Anthropogenic Pressures	Unknown	Yes	Other Significant Impacts (Natural Background Metal)
IE_EA_10_31	Ouler	Anthropogenic Pressures	Unknown	Yes	Other Significant Impacts

3.2 Domestic Wastewater Treatment Systems

Avonmore_010

2020 LAWPRO Local Catchment Assessment showed 40% algal cover (Filamentous Green Algae) at the monitoring location in Avonmore_010 indicating nutrient enrichment. Impact was shown to be downstream of Lough Tay. No direct sources were identified. The presence of the lake adds a complexity to the assessment (potential for historic P accumulation within the lake sediments). Domestic Waste Water is deemed to be a significant pressure considering the lack of other pressures in the catchment (no agricultural practices or forestry operations were present at the time of the assessment).

Landowner engagement is very positive in the Avonmore_010 and actions are already underway to address potential septic tank pressure. A watching brief is recommended here to await the outcome of these mitigation measures in achieving improved water quality. If improvements are not achieved, further investigations are recommended in the 3rd WFD cycle. Chemistry sampling indicated higher total phosphorous values just downstream of the lake, and further investigation may be required (including potential for P accumulation in lake sediments).

Avonmore_020

Note that Domestic Wastewater Treatment Systems could also be a significant pressure in Avonmore_020 as nutrients were identified as a significant issue here. Engagement with the landowners and promotion of uptake of Domestic Wastewater Treatment Systems grant in Blue Dot areas is further recommended in this waterbody.

3.3 Forestry

Both private and Coillte forest plantations are present in The Avonmore Demonstration catchment, **Figure 12**.

Forestry is deemed a significant pressure in Avonmore_020. In 3rd WFD cycle, pressure information has been updated and is deemed not significant in Avonmore_010 and Glenmacnass_010 due to reduction in forestry activity. Biological status in Glenmacnass_010 also returned to Good in 2018, remaining at Good status in 2020.

Forest operations (felling, thinning but also planting) can contribute to the siltation and nutrient release affecting biological conditions. All forestry operations should adhere to Standards for Felling and Reforestation (Forest Service, 2019) which provide a suite of measures to protect water quality during forestry operations. Challenges exist where forestry was planted prior to the Forest Service's Forestry and Fisheries Guidelines, where trees could be planted too close to the riverbanks. This creates forestry legacy issues, creating challenges during thinning and felling activities, where

sediment loss is more difficult to control. Any current afforestation operations account for the restructuring of forestry plantations to allow setback to the river course.

Waterbodies in Wicklow Mountains are characterised by steep topography, with very thin subsoils and predominantly poorly drained and peaty soils, which results in a quick rainfall – runoff response with dominant overland flows and direct hydrological connectivity pathways to the river. This makes them prone to sediment loss during forestry activities, which could be enhanced by the drainage network.

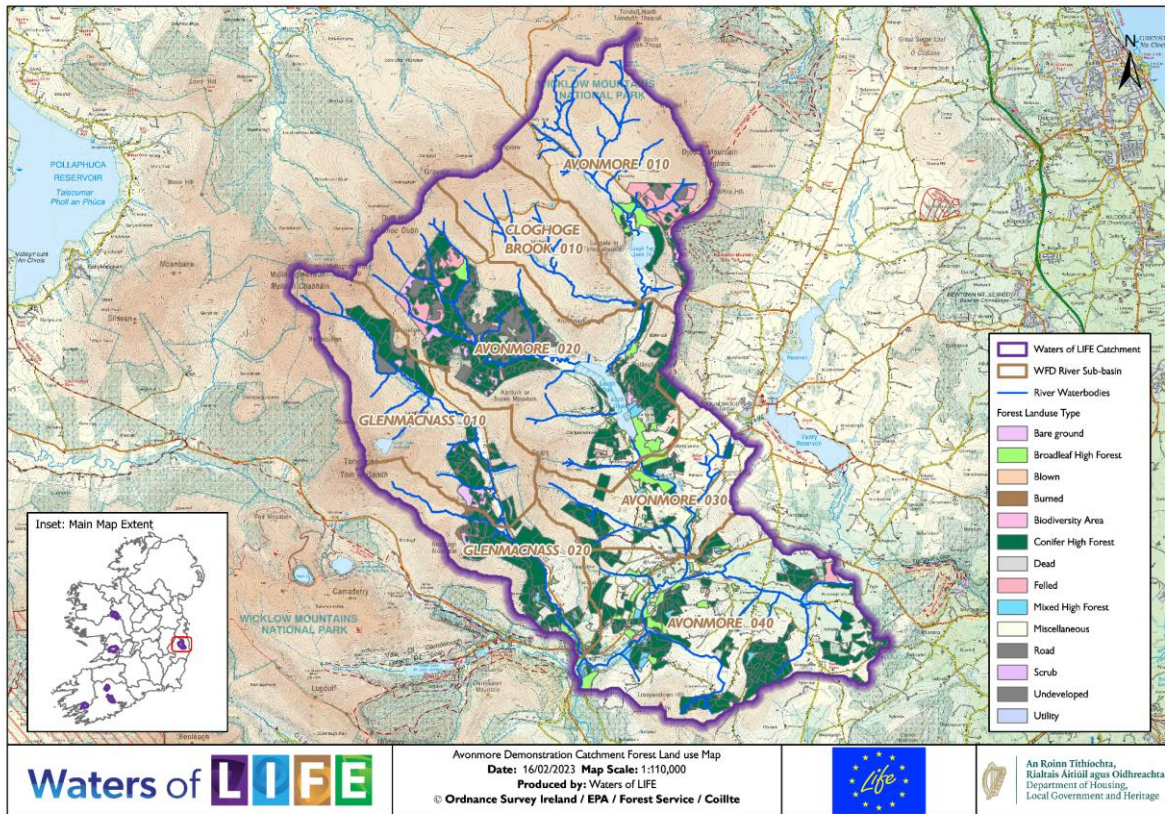


Figure 12 Forestry land use types in Avonmore_SC_010 sub-catchment (data source: Forest Service).

Avonmore_020

In Avonmore_020 the majority of the forest (82%) belongs to Coillte and dominant land use (60% of the forest) constitutes conifer high forest (**Figure 12**). Majority of the Coillte forest is concentrated at the Inchavore River feeding into Lough Dan and part of it is located east of Lough Dan. Private forestry is concentrated around the lake.

In 2021 LAWPRO and the Forest Service carried out a joint walkover of Inchavore River. No immediate impacts were identified on the day of the assessment. Chemistry data collected on the day (during wet conditions) showed localised increased ortho-phosphate levels, however results did not exceed

the mean High status EQS (highest values recorded were 0.02 mg P/l). Considering the sensitivity of the catchment it was agreed that additional measures could protect this catchment from future phosphate and sediment loss. See 'Review of possible mitigation options' section.

Avonmore_010 - not significant

In Avonmore_010, 12% of the waterbody is forested. Private forests constitute 36% and mainly include mixed and broadleaf high forests at the private estate surrounding Lough Tay. Remaining forest belongs to Coillte and the majority of the land is felled (not replanted) with a small area of conifer high forest. **Figure 12** shows the distribution of different forestry land use types. In 3rd WFD cycle characterisation, EPA determined forestry pressure to be not significant due to a reduction in forestry activity in the sub-basin. Additionally, LAWPRO visually assessed part of the previously felled area and found that most of the site is now covered with vegetation with some natural recolonisation present.

Glenmacnass_010 – not significant

Forestry covers 20% of Glenmacnass_010 waterbody and the majority of it (94%) belongs to Coillte. Dominant land cover is conifer high forest (**Figure 12**). Most of the forestry is located near the main channel at the upper parts of the waterbody (left bank), and downstream of Glenmacnass Waterfall, mainly on the right bank of the river but also northeast from R115 road. As the majority of the forest was planted prior to the Forest Service's Forestry and Fisheries Guidelines, it is possible that trees were planted too close to the riverbanks. Biological status at operational monitoring point 0.5km d/s Mall Brook dropped from Good in 2009 to Moderate in 2012 and 2015. EPA cycle 2 initial characterisation information notes that EPA biologists identified eutrophication and siltation issues associated with clearfelling and replanting and lack of adequate buffers. Status improved back to Good in the 2018 assessment and remained at Good in 2020. The pressure is deemed no longer significant as the waterbody is now meeting its objective. Improvement in status is possibly attributable to a reduction in forestry activities in the sub-basin.

Further consultation is required with Forest Service/ Coillte to confirm areas where forestry has been restructured with the required setback areas.

3.4 Extractive Industry - Peat

Cloghoge Brook_010

Due to the underlying geology and peat soils this water body has a natural tendency towards lower pH values. Peat extraction is, however, considered to be the driver for the enhanced acidification in this waterbody. Drainage of peat may alter system hydrology (increasing surface water run-off therefore reducing residence time of water and less chance for buffering reactions to occur), and lead to oxidation and mineralization of organic matter resulting in increased production of organic acids draining to the surface waters.

Historic peat extraction is mainly noted in the upper parts of this waterbody, along the Military Road (**Figure 13**). National Parks and Wildlife Service (NPWS) peat restoration works are currently under way in another waterbody in Wicklow Mountains (Liffey_010) that is having acidification issue. Impacts of this work on pH regimes is being monitored by LAWPRO and NPWS through pH review project. Learnings from this work could be applicable to the understanding of the issue in Cloghoge Brook_010.

Currently, pH conditions are above the lower EQS of 4.5, although considering the long history of failing this threshold, this waterbody is still potentially at risk of failing acidification conditions in the future.

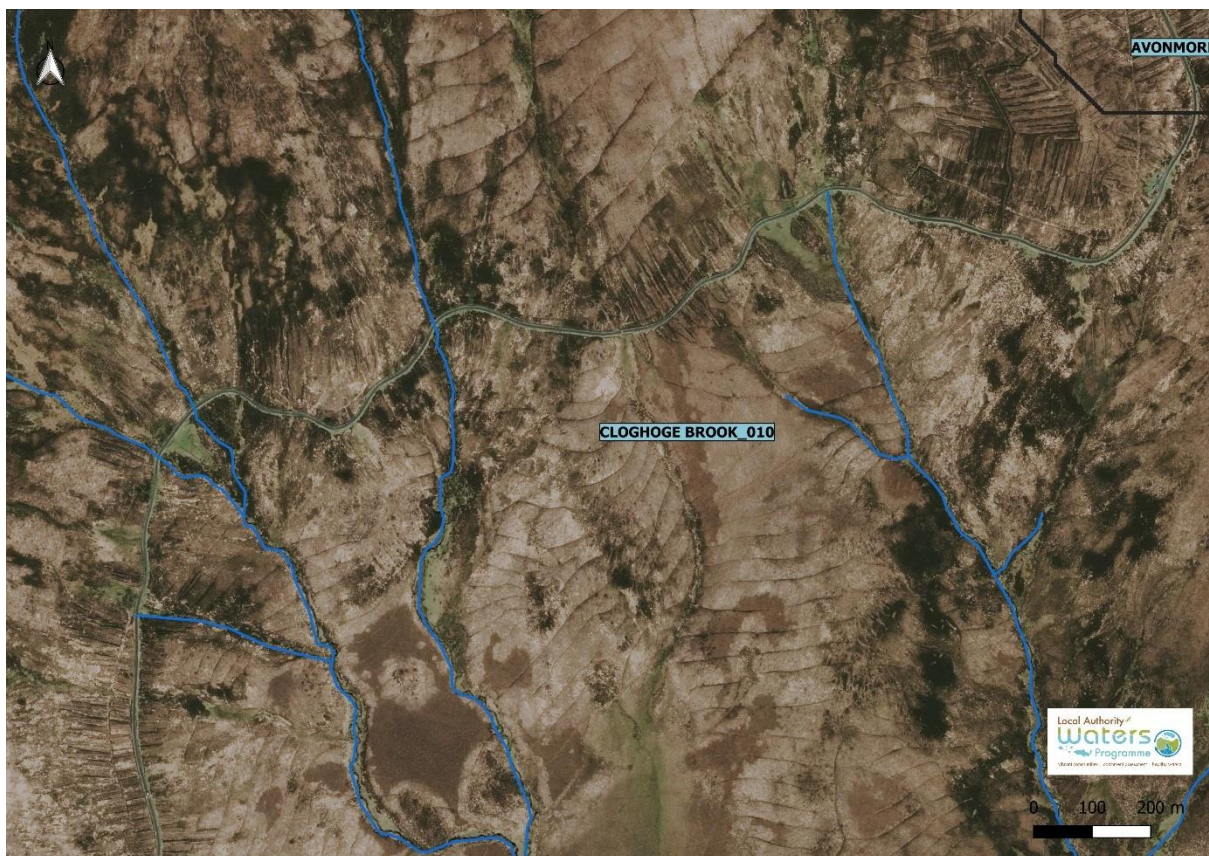


Figure 13 Peat extraction along the Military Road in Cloghoge Brook_010, © Ordnance Survey Ireland.

3.5 Anthropogenic – Unknown

Lough Tay, Lough Dan and Ouler

Anthropogenic unknown pressures are listed for the lakes located in Avonmore Demonstration Catchment mainly due to failure of specific pollutants – zinc. Consultation with the EPA is required for further understanding of the issue.

Metal concentrations could be natural in the area, however a small lead and copper mine north of Lough Dan was noted in the further characterisation information and this may require additional investigation.

3.6 Agriculture – not significant

Avonmore_010

Agriculture has been identified as a significant pressure in Avonmore_010 during the EPA initial characterisation process. Animal access was noted in places along the stream that were likely to increase noted bank erosion along the channel.

Further characterisation (2020 and 2021) with LAWPRO field work showed no siltation impacts and no animal access was noted in proximity to the monitoring location. Therefore, this pressure is deemed not significant and an update to the EPA characterisation has been proposed to remove Agriculture from the significant pressures list for this waterbody.

3.7 Atmospheric – not significant

Avonmore_010

Atmospheric deposition can cause acidification. pH conditions were low in Avonmore_010 and were causing the downgrade to Moderate Ecological Status (2010-2015).

However, LAWPRO Avonbeg-Avonmore PAA desk study showed a reduction in atmospheric deposition. Research in Roundwood and Ballinastoe, Wicklow showed decreasing trends in non-marine sulphates and pH recovery in bulk precipitation and throughfall related to the reductions in European sulphate emissions (Johnson et al., 2013). With general improvements in air quality atmospheric deposition is unlikely to be a significant pressure. It was proposed to remove this pressure from the significant pressure list for this waterbody.

Drivers of acidification are most likely increased DOC (organic acids). Acidification is further investigated by the EPA pH Review Project.

3.8 Other potential pressures – Waste Water Treatment Plants – not significant

There are two Waste Water Treatment Plants (WWTP) in Avonmore, located in Avonmore_030 and Avonmore_040. Both waterbodies are achieving their environmental objective therefore WWTP are not impacting on water quality. Both WWTPs provide tertiary treatment (P removal).

- **Roundwood (D0223-01):** primary discharge TPEFF3400D0223SW001 (discharging to Avonmore_030 and storm water overflow: TPEFF3400D0223SW002 (discharging in Varray_020). Plant design PE 1600, agglomeration PE: 1158.

- **Laragh (D0415-01):** primary discharge TPEFF3400D0415SW001 and storm water overflow TPEFF3400D0415SW002 (both discharging to Avonmore_040). Plant design PE 1000, agglomeration PE: 714.

3.9 Conclusion on Significant Pressures

River waterbodies

The main significant pressures affecting water quality in the two blue dot waterbodies are:

- **Domestic Waste Water Treatment Systems** (Avonmore_010, but could be also significant in Avonmore_020). This pressure is currently being mitigated in Avonmore_010 and an engagement regarding DWWTS grant for blue dot waterbodies should be carried out in Avonmore_020.
- **Forestry** (Avonmore_020). Additional mitigation options that account for the sensitivity of blue dot waterbodies have been agreed with the Forest Service and these should be incorporated into future licences and implemented on the ground for forestry management activities.

Additionally, identified pressure in Cloghoge Brook_010 (Good water objective waterbody) is:

- **Peat extraction.** It is suspected that disturbed peat due to the historic peat extraction activities is the cause of the enhanced DOC production which is causing acidification of this waterbody. Note that there is a recovery of acidification conditions in the recent years, however there is still a risk of status failure due to very low pH values recorded in this waterbody in the future. There is no knowledge on whether peat restoration measures were carried out in this waterbody and that is something that may be consulted with the landholders of the area.

Lake waterbodies

Significant pressure affecting water quality of lakes in this sub-catchment is unknown anthropogenic pressure. It relates to elevated concentrations of zinc. Consultation with the EPA is required to further understand pressure causing this issue.

Additionally, unknown pressure affects macrophyte growth in Lough Tay. Further consultation with the EPA is required for information on the issue and pressure that could be causing it.

4 Pathway information & analysis

4.1 Pathways

Nutrients, mainly ortho-phosphate, have been identified as the significant issue in the two blue dot waterbodies: Avonmore_010 and Avonmore_020. Considering that peaty and poorly drained soils dominate these two waterbodies, the main pathway for delivery of phosphate is via overland flow. Groundwater pathways may also exist, mainly in the areas with very thin subsoils with bedrock outcrop.

The steep topography of Wicklow Mountains adds to hydrological connectivity of the headwaters of the sub-catchment. During LAWPRO catchment walks wet ground and water seeping through the ground to form overland flow directly connected to the stream network was evident (**Figure 14** Error! Reference source not found.-**Figure 16**).

Main characteristics of the area (Avonmore_010 and Avonmore_020) are summarised in **Table 6**. Corresponding maps showing physical characteristics of all Avonmore catchment are shown in **Appendix III**. Note that with free draining soils present in Avonmore_030 and Avonmore_040, groundwater pathways dominate in these two waterbodies. However, this section focuses on the upper parts of the catchment where Avonmore_010 and Avonmore_020 are located.



Figure 14 Connectivity pathways observed during catchment walk in the area north east to the Lough Dan.



Figure 15 Connectivity pathways observed during catchment walk in the area. View of the Lough Dan.



Figure 16 View of Cloghoge River in Avonmore_020, between Avonmore_010 and Lough Dan. Darker vegetation shows more wetland conditions along the river and along the runoff pathways from the mountains into the river.

4.2 pH conditions

Additionally, this area is naturally acid sensitive. In contrast to limestones, granites contain very little bases that can neutralise acids present in rain or soil solution. Therefore, granite geology would naturally have very low buffering capacity which would provide resistance to pH change upon the addition of H⁺ or OH⁻ ions. Additional information on pH conditions is also summarised in **Table 6**.

4.3 Source-pathway-receptor

With very thin subsoils and bedrock outcrops in the area, there is a risk of direct nutrient inputs to groundwater from poorly designed, installed or maintained DWWTs.

Ortho-phosphate can be released from existing forested areas (due to historic fertilisation of the ground). Highest risk of ortho-phosphate loss into the river is during and after clearfelling where new vegetation cover has not been established yet. Fertilisation of existing and new forestry lands on poorly drained soils and forestry management operations can be additional sources of ortho-phosphate in the area.

Table 6 Avonmore_010 and Avonmore_020 physical characteristics.

Factor	Description & relevance
Land Cover/ Land Use	<p>In Avonmore_010 dominant land cover are peat bogs with some moors and heather forming agriculture commonage area. 11% of the land use is forestry with some felled site upstream of Lough Tay, mixed and broad-leaved forest surrounding the lake and mainly grassland downstream of the lake (with small area of conifer forest).</p> <p>In Avonmore_020, 23% of the land draining to the outlet is under forest (mainly Coillte land), with majority of conifer forest is located upstream of Lough Dan (Inchavore River). Rest of the land is mainly peat bog and moorland area.</p>
Soil	<p>Mainly peaty soils (blanket peat) in the upper parts of the waterbodies with poorly drained soils (shallow soils (podzols (peaty), lithosols, peats, with/or without a peaty/organic horizon, derived from mainly acidic parent material) with small areas of mineral alluvium) surrounding lakes, small proportion of free-draining soils towards Avonmore_020 catchment outlet.</p> <p>Peaty soils are usually wet and acidic by nature. Acidity in peatlands results from microbial decay processes, cation exchange (Unpeatland: abundant sphagnum acidifies its surroundings by cation exchange), and input of acids from the atmosphere.</p>
Bedrock	Ordovician Metasediment and Granites and other Igneous Intrusive rocks.

Factor	Description & relevance
	<p>pH background:</p> <ul style="list-style-type: none"> • pH natural groundwater background: Groundwater in the non-calcareous sedimentary and igneous lithological groups has the lowest pH values with medians of 6.03 and 6.07 respectively. Igneous rocks pH data show 5th %ile of 5.35, 95%ile of 7.53 and median of 6.07 (Tedd <i>et al.</i>, 2017). • Groundwater pH data available for the area show pH of 6.6 for Sraghmore Wicklow Visitor Centre and one sample from a private well in the Avonbeg_030 catchment of 7 pH units on 03/02/1997 (GSI, pers. comm.). • pH data available for Askinagap Group Water Scheme located in Ow_020 waterbody in Wicklow Mountains of similar geology and characteristics (Ordovician Metasediments and poorly drained soils with forestry/ grassland as land use) show pH from 5.1 to 6.8 pH units with a mean of 6.0 pH.
Topography	<ul style="list-style-type: none"> • Headwaters located in Wicklow Mountains. High topography may influence flashiness of the flows. If land is overgrazed, it may also affect slope erosion. • Avonmore_010: west - Carrigvore Mountain (682m), north west – 570m; North East – Djouce Mountain (750m), South East – Luggala Mountain (595m); • Avonmore_020: West (headwater) ~720m; just upstream of the Lough Dan – 534m (North) and 640m (South)
Subsoil	<ul style="list-style-type: none"> • Blanket peat, Rock, Sandstone till
Subsoil permeability	<ul style="list-style-type: none"> • Moderate mainly in the areas of peat soils, with depth to bedrock <3m in other areas. • The tills are very thin in mountainous areas. Thickness increases further down slope and also towards the southeast (GSI).
Aquifer	<ul style="list-style-type: none"> • LI – Locally Important Aquifer – Bedrock which is moderately productive only in local zones; • PI – Poor aquifer – bedrock which is generally unproductive except for local zones; • In this setting the majority of groundwater flow will occur in the top 3 metres of the rock. This flow is mostly in along a weathered zone in a lateral direction towards rivers and springs (GSI).
Groundwater vulnerability	<ul style="list-style-type: none"> • X-Extreme, Extreme and High dominant with bedrock outcrop in places • Aquifer area is near surface where there are large areas of outcrop present in the higher altitudes of the Wicklow Mountains (GSI).

5 Interim story of Demonstration Catchment

5.1 Avonmore_010

Avonmore_010 is a High Status objective waterbody (Blue Dot) and it is *At Risk* of failing to achieve its Water Framework Directive (WFD) environmental objectives. There are no inputting waterbodies. Lough Tay, which is located in this waterbody (approximately 1km upstream of the monitoring location) is at Moderate Ecological Status. Historically, Avonmore_010 achieved High biological conditions (1990-2012) and these conditions declined to Good in 2015 and remained at Good since. The 2010-2015 Ecological status was further downgraded to Moderate due to failing acidification conditions, however there was no failure of WFD pH threshold since.

LAWPRO Local Catchment Assessment identified nutrients (ortho-phosphate) as a significant issue affecting water quality. This is based on the visual observation of high Filamentous Green Algae cover. Review of the more recent EPA chemistry data also showed single spike of total ammonia at the river sampling data as well as at the Lough Tay and this could potentially suggest additional issue in this waterbody.

With steep topography, peaty and poorly drained soils, thin subsoils, granite and Ordovician Metasediments geology, there is a high hydrological connectivity in the area with the dominant overland flow pathways. Groundwater pathways are also possible in the areas of very thin subsoils and bedrock outcrop.

EPA initial characterisation identified three significant pressures for this waterbody: (i) atmospheric pressure (impacting acidification conditions), (ii) forestry and (iii) agriculture (that could impact river habitats due to morphological changes). These pressures were determined to be not significant in the Cycle 3 update. Further characterisation identified Domestic Waste Water Treatment Systems as a significant pressure here. There is good landowner engagement in the Avonmore_010 and actions are already underway to address potential septic tank pressure. A watching brief is recommended here to await any potential improvements after implementation of mitigation measures. If there is no improvement, additional investigations are required, potentially looking at phosphate accumulation in the lake sediments and investigation of any other potential sources of phosphate in the waterbody. Potential ammonia sources would also need to be investigated.

Additionally, peat restoration and blocking historic drains upstream could slow the flow and reduced energy of the system which would improve bank erosion upstream of the lake. It can also potentially improve pH conditions in the area by the reduction of Dissolved Organic Carbon inputs.

Findings of the EPA pH Review Project can further help with the understanding of the acidification issues in the area.

5.2 Avonmore_020

Avonmore_020 is a High Status objective waterbody (Blue Dot) and it is *At Risk* of not achieving its Water Framework Directive (WFD) environmental objectives. Inputting waterbodies include Avonmore_010 (which includes Lough Tay) and Cloghoge Brook_010. Lough Dan is located within Avonmore_020, and the monitoring location of Avonmore_020 is located approximately 600 m downstream of the lake outlet.

Historically, Avonmore_020 achieved High biological status (1990-2012) but status declined to Good in 2015 and has remained at Good since. Physico-chemical parameters have been measured for this waterbody since 2019. EPA noted siltation during their 2015 assessment and 50% filamentous algae cover during the 2018 assessment. LAWPRO Local Catchment Assessment recorded 70% filamentous algae cover in 2020. Based on these observations, ortho-phosphate is deemed to be a significant issue in Avonmore_020. Review of the more recent EPA chemistry data also showed a single spike of total ammonia at the Lough Dan sampling data and this could potentially suggest additional issue in this waterbody.

With steep topography, peaty and poorly drained soils, thin subsoils, granite and Ordovician Metasediments geology, there is a high hydrological connectivity in the area with the dominant overland flow pathways. Groundwater pathways are also possible in the areas of very thin subsoils and bedrock outcrop.

EPA initial characterisation identified forestry as a significant pressure. Considering ortho-phosphate as a significant issue, a catchment walk was carried out for the forestry assessment (Inchavore River). No immediate impacts were identified on the day of the assessment. However, considering the sensitivity of the catchment it was agreed that additional measures could protect this catchment from future phosphate and sediment loss from forestry activities.

Furthermore, engagement with forestry owners is required to ensure adequate measures for future forestry activities. Engagement with landowners is also required to promote uptake of the Domestic Waste Water Treatment Systems grant scheme which is available to eligible landowners in Blue Dot catchments. Potential ammonia sources would need to be investigated as well. However, considering the presence of the lake this may not be straightforward.

Findings of the EPA pH review project can further help with the understanding of the acidification issues in the area.

5.3 Cloghoge Brook_010

Cloghoge brook_010 has a Good ecological status objective. Despite long-term and consistent High biological status, ecological status has been Moderate here for all WFD cycle assessments due to failing acidification conditions. pH values are low, however no failure of 4.5 WFD threshold was

recorded since 2017 (lowest pH of 4.6). Considering history of low pH conditions, it is however still at risk of future failures.

The significant pressure identified in this waterbody is extractive Industry – peat. Peat extraction is considered to be the driver for the enhanced acidification in the waterbody. Note, that this waterbody is also naturally acid sensitive due to its geological settings and peat extraction potentially increase the acidification issue. Drainage of peat may alter system hydrology (increasing surface water run-off therefore reducing residence time of water with less chance for buffering reactions to occur). It can also lead to oxidation and mineralization of organic matter resulting in increased production of organic acids draining to the surface waters. Historic peat extraction is mainly noted in the upper parts of the waterbody.

Peat restoration in Cloghoge_Brook_010 could potentially improve acidification conditions. NPWS peat restoration works are currently underway in another waterbody in the Wicklow Mountains (Liffey_010) that is having acidification issues. Impact of this work on pH regimes is being monitored by LAWPRO and NPWS through the pH review project. Learnings from this work could be applicable to the understanding of the issue in Cloghoge Brook_010.

Additionally, acidification issue in Wicklow Mountain waterbodies is under review with the EPA through the pH review project.

5.4 Avonmore_030

Avonmore_030 has a Good ecological status objective. This waterbody is currently at Good ecological status, is *Not at Risk* and is achieving its environmental objective. Biological conditions were always achieving Good or High (in 2012) status and they remained at Good for the most recent EPA Q-Value survey in 2020. This waterbody needs to be protected to maintain Good ecological status. Additionally, Laragh Public Water Supply is a blended water supply with a groundwater abstraction at Raheen in Avonmore_030. There are no issues with the quality of the water in this supply, but the area requires further protection considering water abstraction point.

5.5 Avonmore_040

Avonmore_040 has a Good ecological status objective. This waterbody is currently at High ecological status, is *Not at Risk* and is achieving its environmental objective of at least Good ecological status. This waterbody has a history of High and Good biological conditions and High biological status was recorded in the most recent EPA Q-Value surveys in 2018 and 2020. This waterbody needs to be protected to maintain its ecological status.

5.6 Glenmacnass_010

Glenmacnass_010 has a Good ecological status objective. This waterbody is currently at Good ecological status, is *Not at Risk*, and is achieving its environmental objective following the improvements from Moderate 2010-2015 conditions (failing macroinvertebrates and pH). Biological conditions remained at Good for the most recent EPA Q-Value surveys in 2018 and 2020 and there were no failures in pH conditions over this period. This waterbody needs to be protected to maintain Good ecological status. Additionally, Glenmacnass_010 is a designated drinking water protected area, with a surface water abstraction (and groundwater in Avonmore_030) for the Laragh Public Water Supply. No issues were recorded with this water supply, which requires ongoing protection.

5.7 Glenmacnass_020

Glenmacnass_020 also has a Good ecological status objective. This waterbody is currently at Good ecological status, is *Not at Risk*, and is achieving its environmental WFD objective. Biological conditions are persistently Good for all the EPA Q-Value surveys. This waterbody needs to be protected to maintain Good ecological status.

6 Workplan

- **Field work**

Field work has already been carried out by LAWPRO in Avonmore_010 and Avonmore_020 as part of the Avonbeg-Avonmore 2nd cycle Priority Area for Action (PAA).

For summer 2022 it is recommended to visit monitoring locations of river waterbodies and collect baseline information with chemistry and carry out visual observations of algal growth. Chemistry sampling including total P may be considered to get insights into potential inputs from lake sediments. Collected data, together with the EPA Q-value surveys (planned for summer 2022 in Avonmore_010 and Avonmore_020) should be then reviewed to plan for further work if required. High resolution sampling may be considered to assess phosphorus levels downstream of the lake outflow.

In Avonmore_010, measures to address the DWWTS pressure are already underway. Any potential future fieldwork (investigating other potential sources and lake inputs) depends on whether these measures address the significant issue at the monitoring location. It is expected that improvements may not yet be achieved by Summer 2022. Similarly, in Avonmore_020, improvements are dependent now on mitigating any phosphate inputs into the lake and monitoring location. Any potential future field work (e.g., walkovers) depends on engagement with the forestry sector. Where forestry management is a possible future pressure, stream walks would be useful to identify unmapped drains connecting forestry stands to the watercourse.

- **Mitigation measures**

Workplan should concentrate on facilitating measure implementation where possible.

- Promotion of uptake of DWWTS grant in blue dot areas is required in Avonmore_020.
- Additionally, further engagement with Forest Service and forestry owners is required in the area.
- Nature based water retention measures and peat restoration should be also encouraged as a potential measure for acidification. This may be required as a restoration but also protect function in the area. Funding options and monitoring should be explored for this.

- **Information requirements**

- Consultation with the EPA (Catchment Science and Management Unit and Ecological Monitoring and Assessment Unit) regarding zinc and macrophyte issues for the lakes is required to plan any potential action for the lake waterbodies.
- Any learnings from the EPA pH review project (AWIC scores, chemistry) should be reviewed (note project is currently still ongoing).

7 Review of possible mitigation options

• **Forestry measures**

All future forestry operations should adhere to Standards for Felling and Reforestation (Forest Service, 2019). These include appropriate measures to minimise any risk of nutrient or sediment loss to the river channel. Strong enforcement of the licensing regulations is key to minimise risk of impact from future forestry operations in the Blue Dot catchments.

Forest Service, DAFM measures also include 'Ongoing restructuring of existing forest stands at clearfell / reforestation stage to incorporate appropriate water setbacks (potentially reinforced by broadleaf planting), absent in the previous rotation (DHLGH, 2022).

Following a joint field visit and subsequent discussions between LAWRO and Forest Service, DAFM in Avonmore_020, Forest Service has advised that all forestry thinning, felling and reforestation licences are subject to environmental assessment including the DAFM Appropriate Assessment procedure and specific licence conditions can be added, including the following:

- Any future clearfells should be carried out for the smaller areas (smaller forest coupe sizes)
- Rapid replanting after clearfell which will allow nutrients to be taken up faster (shorter time for potential nutrient loss to the river)
- No windrowing. Soil water nutrient concentrations are higher under the stacked material and by keeping brash material more spread there are better chances for nutrients to be taken up by vegetation or to be bound to the soil.
- Allow greening up (colonising by the vegetation) of the clearfelled coupe before clearfelling neighbouring coupe.
- No fertilisation.

• **Replacement/ upgrade of Domestic Waste Water Treatment Systems**

The Department of Housing, Local Government and Heritage have introduced a grant scheme for faulty septic tank systems that may affect water quality, covering 85% of eligible and pre-approved works (up to a maximum of €5,000). Registered landowners in High Status Objective Catchment Areas are eligible for the grant (subject to the septic tank registration process).

• **Peat restoration and Nature Based Water Retention measures**

Peat restoration and measures slowing the flow in the mountain areas can provide multiple benefits in terms of climate change mitigation, improving biodiversity but also providing additional benefits to the water quality (for example, such measures could reduce energy of the flow, reducing erosion of the banks and inputs of fine sediment). This mitigation measure could be treated as a protect measure for the waterbodies in this sub-catchment.

Moreover, considering a drinking water source in this catchment, peat restoration but also nature based water retention measures in areas without peat soils (note areas on poorly drain soils in upper

catchment) may also provide additional protect function for drinking water source. It would serve two functions benefiting water quantity (improving recharge and low flow conditions) but also quality (potential reduction in turbidity and DOC that requires treatment for drinking water).

Additionally, peat restoration may potentially improve acidification conditions of the area. Learnings from NPWS restoration works from Liffey catchment may provide additional insights on this.

Forestry schemes may be potentially used here to improve hydrology of the catchment, providing a protect function (as listed in draft River Basin Management Plan (DHLGH, 2022):

- 'Woodland Creation on Public Lands Scheme to deliver woodland-based solutions for the protection of drinking water sources and water in general. This scheme encourages public bodies to create native woodland on land owned by them as part of their own achievement of objectives regarding water, biodiversity, carbon capture and sustainability.'
- 'Woodland for Water Scheme, focused on strategically realising native woodland in areas where such features would have a marked impact in relation to the protection of water. Details will be made available as this scheme is developed further.'

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Appendix I

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pH plots

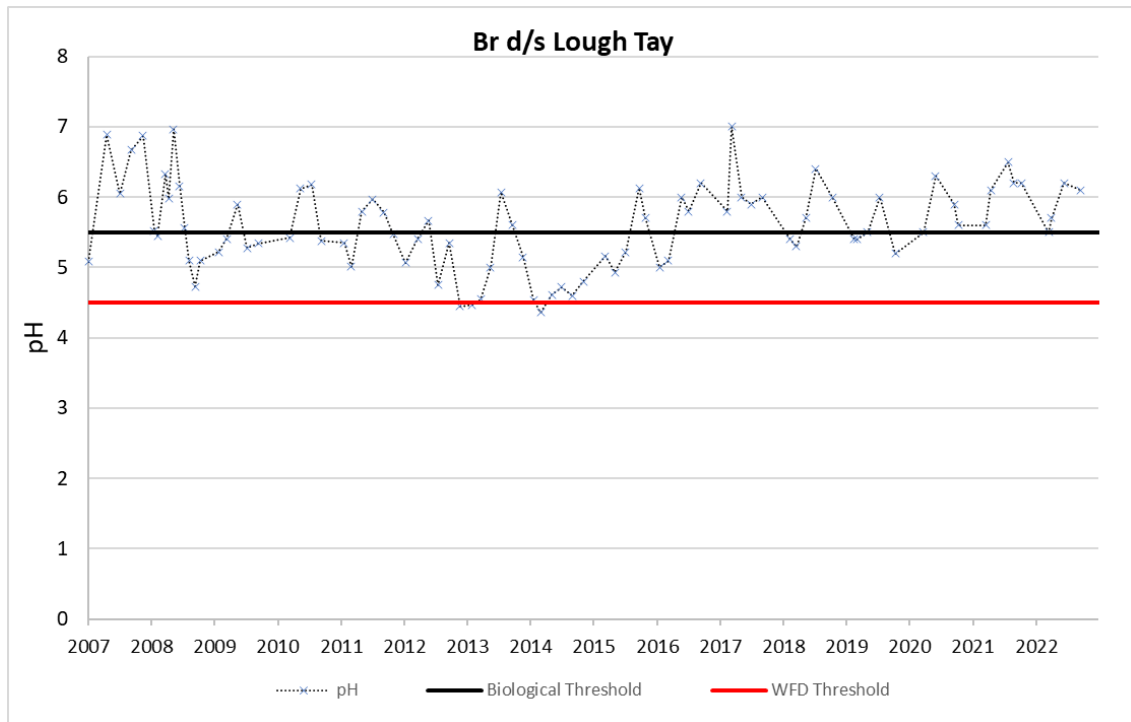


Figure 17 Temporal variations in pH values recorded in Avonmore_010.

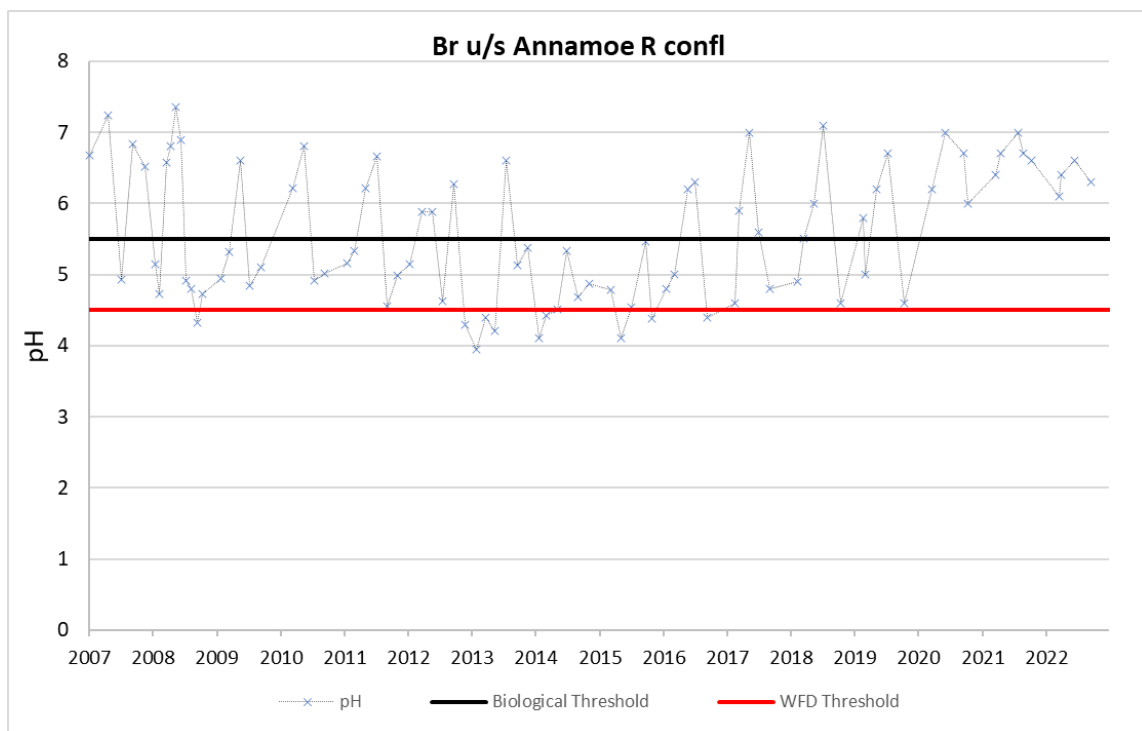


Figure 18 Temporal variations in pH values recorded in Cloghoge Brook_010.

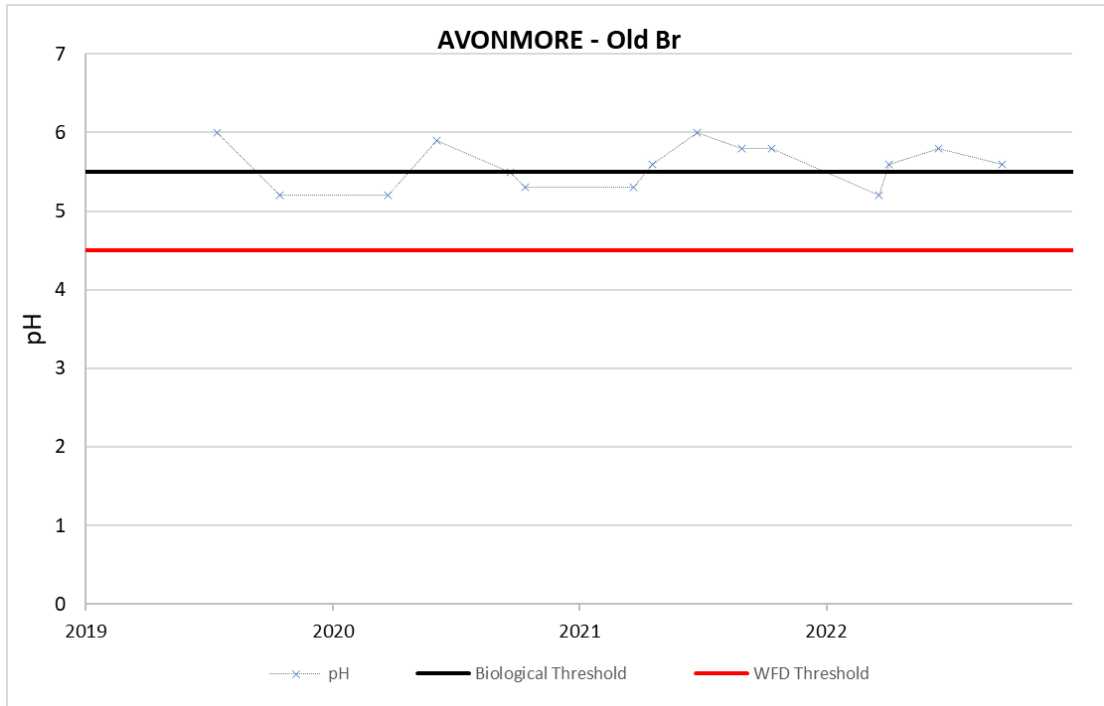


Figure 19 Temporal variations in pH values recorded in Avonmore_020.

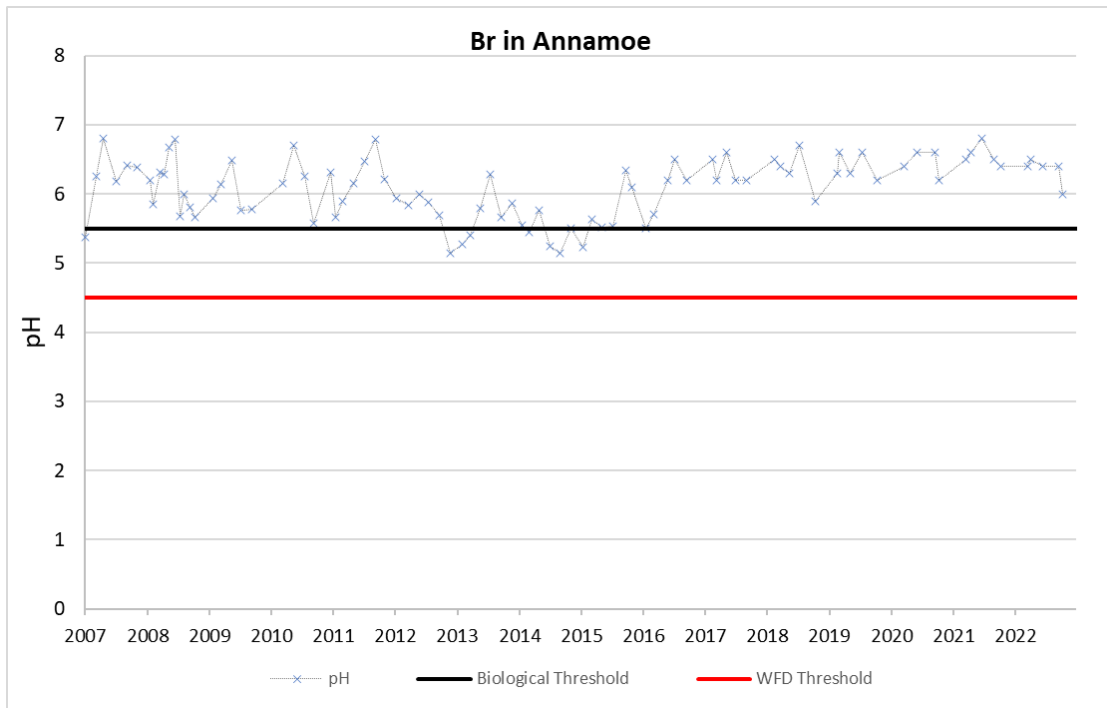


Figure 20 Temporal variations in pH values recorded in Avonmore_030.

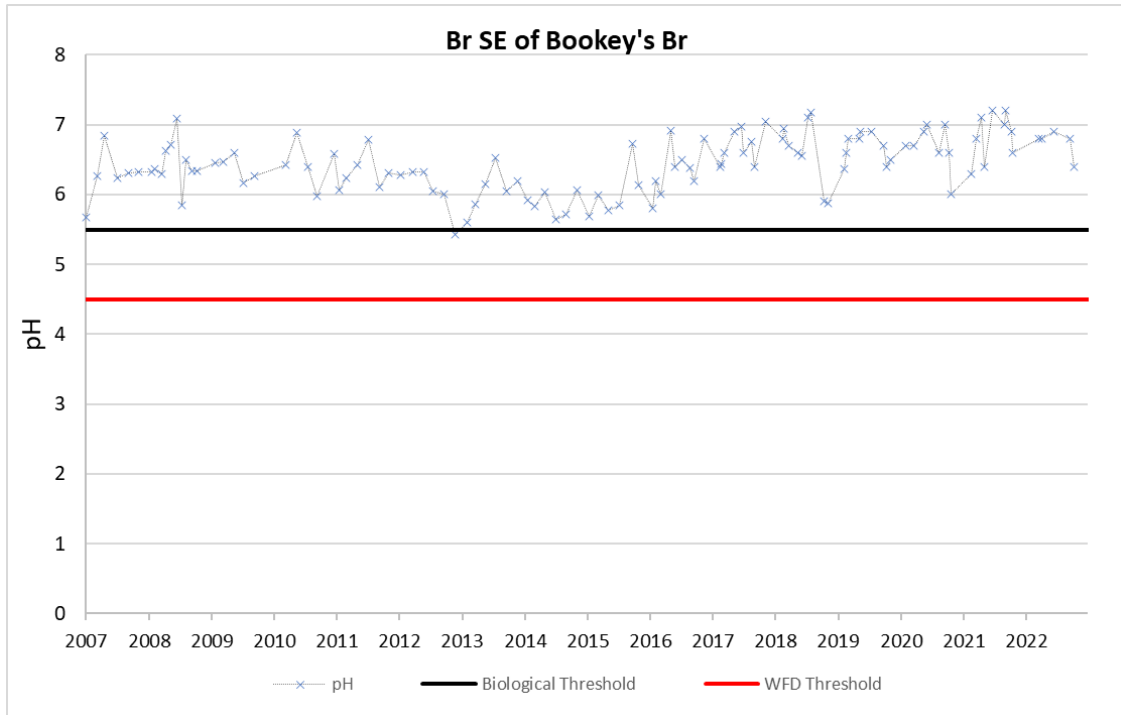


Figure 21 Temporal variations in pH values recorded in Avonmore_040.

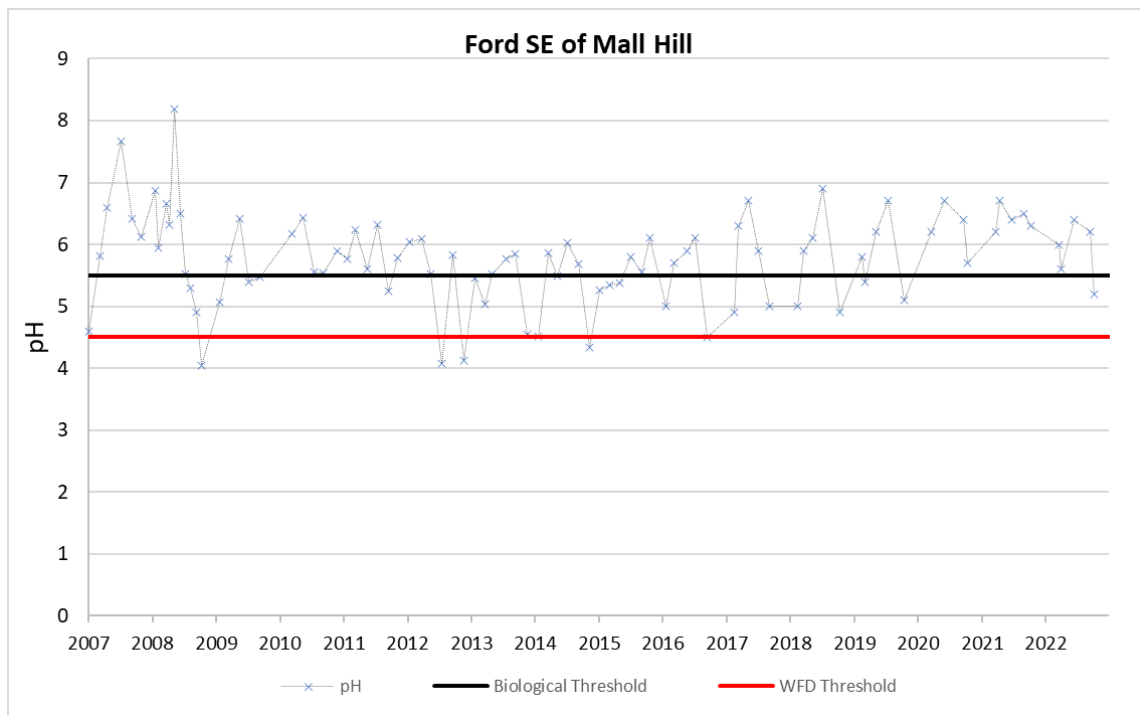


Figure 22 Temporal variations in pH values recorded in Glenmacnass_010.

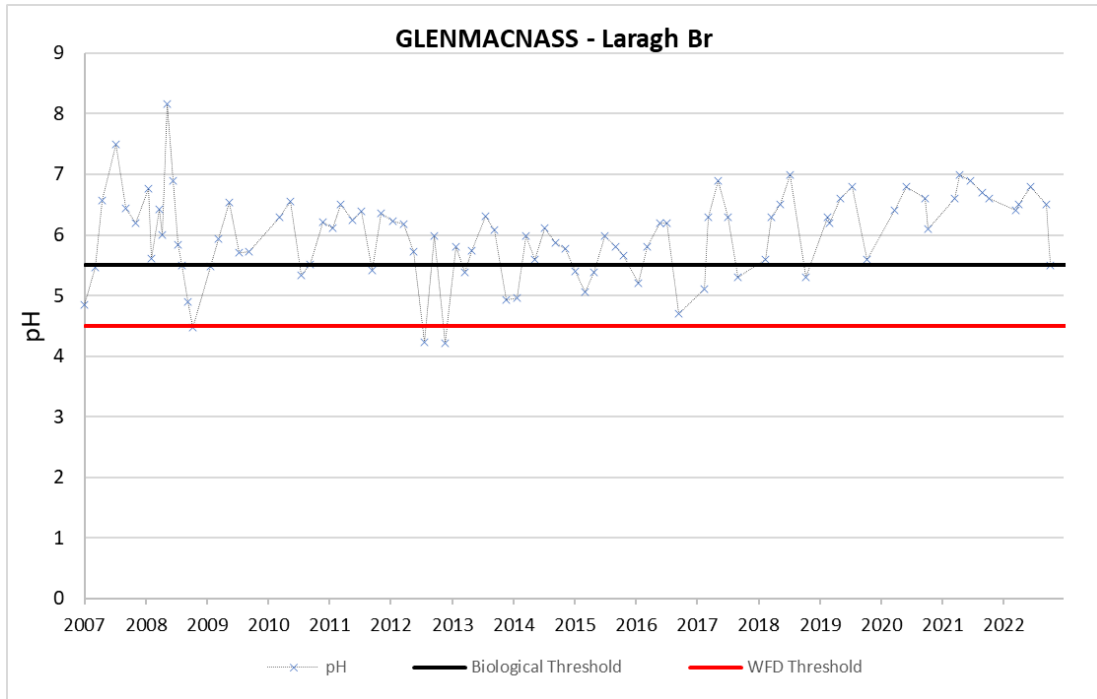


Figure 23 Temporal variations in pH values recorded in Glenmacnass_020 at Laragh Br monitoring location.

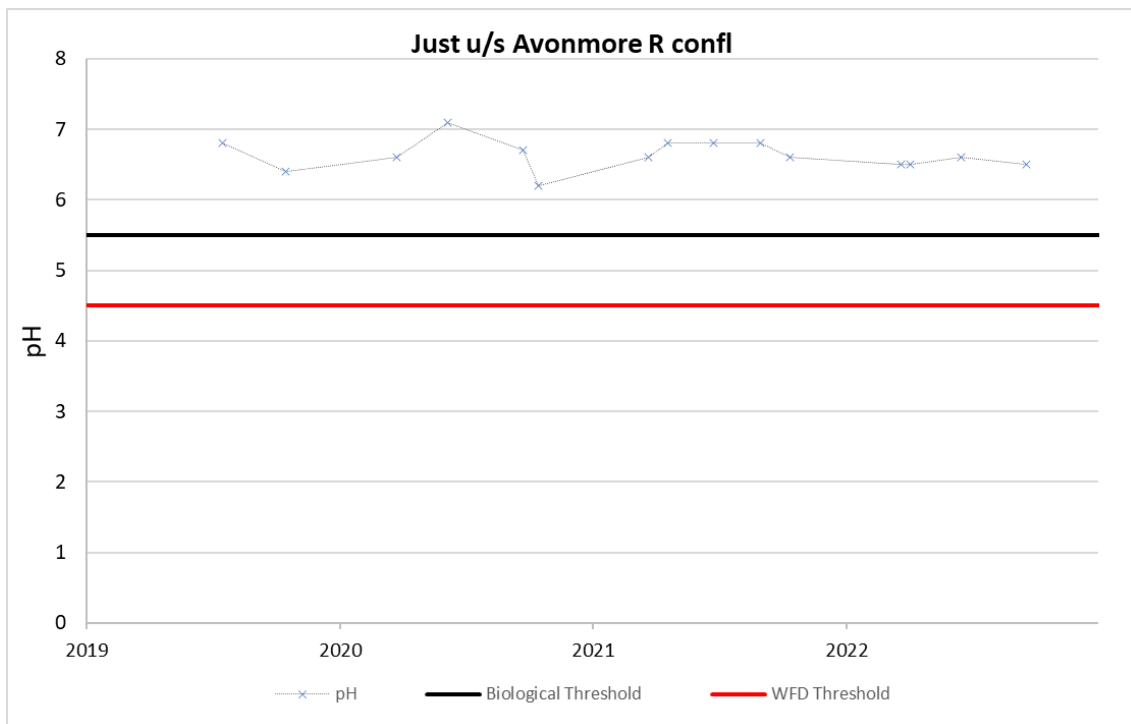


Figure 24 Temporal variations in pH values recorded in Glenmacnass_020 at 'Just u/s Avonmore R confl' monitoring station.

Appendix II

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Lakes' ortho-phosphate and total phosphorus



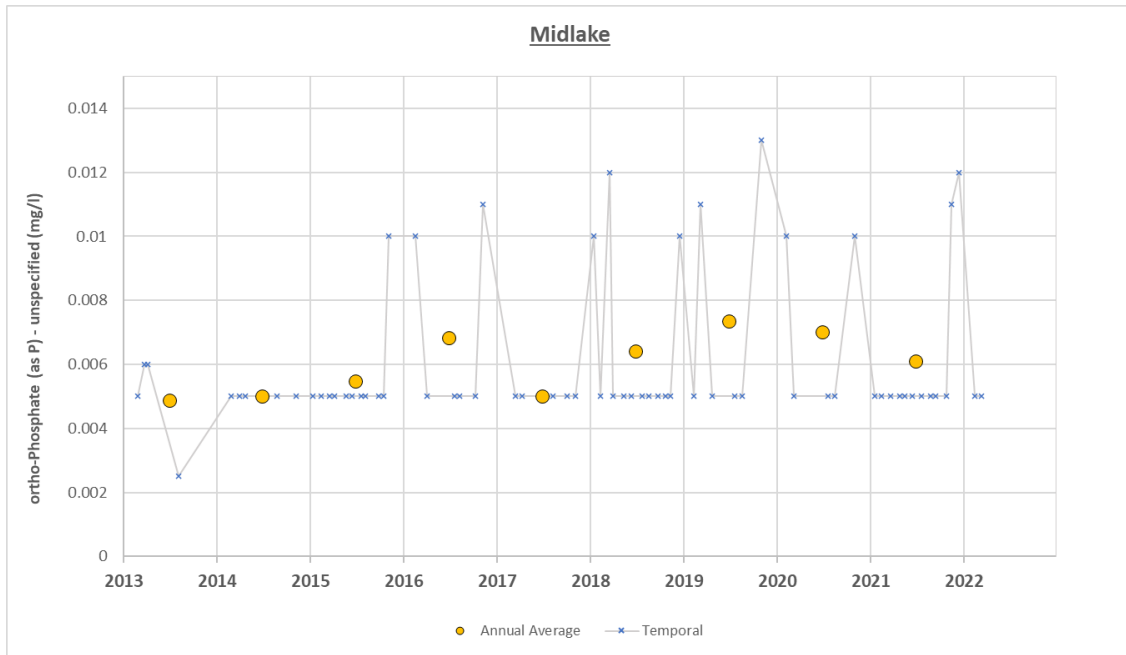


Figure 25 Ortho-phosphate concentrations at Lough Tay.

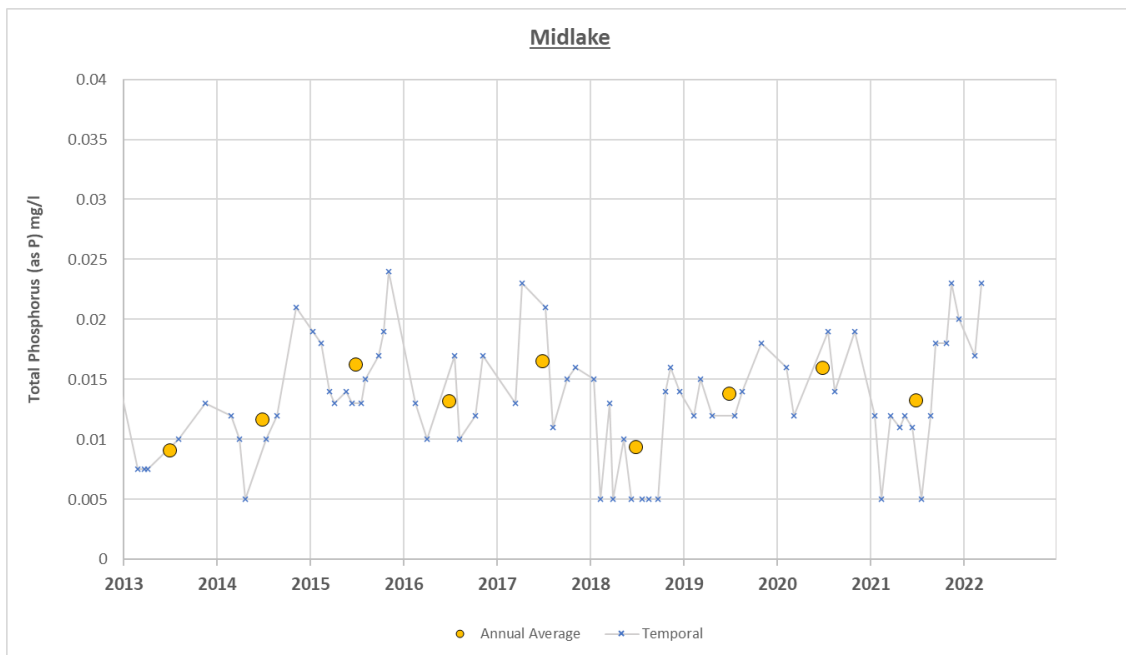


Figure 26 Total phosphorous concentrations at Lough Tay.

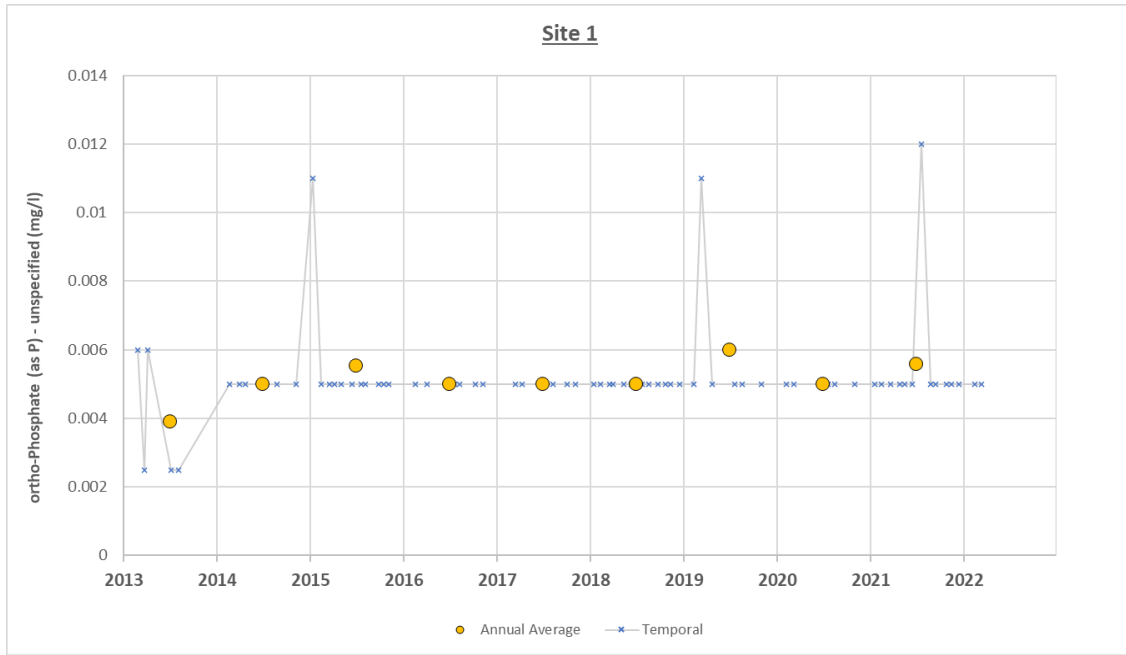


Figure 27 Ortho-phosphate concentrations at Site 1, Lough Dan.

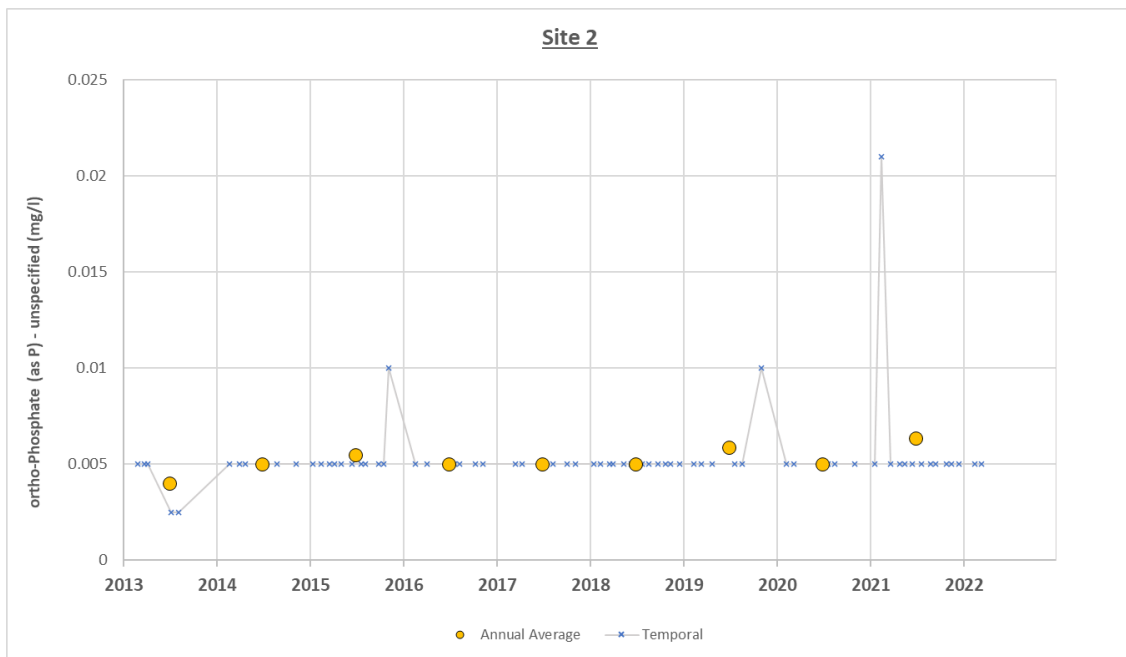


Figure 28 Ortho-phosphate concentrations at Site 2, Lough Dan.

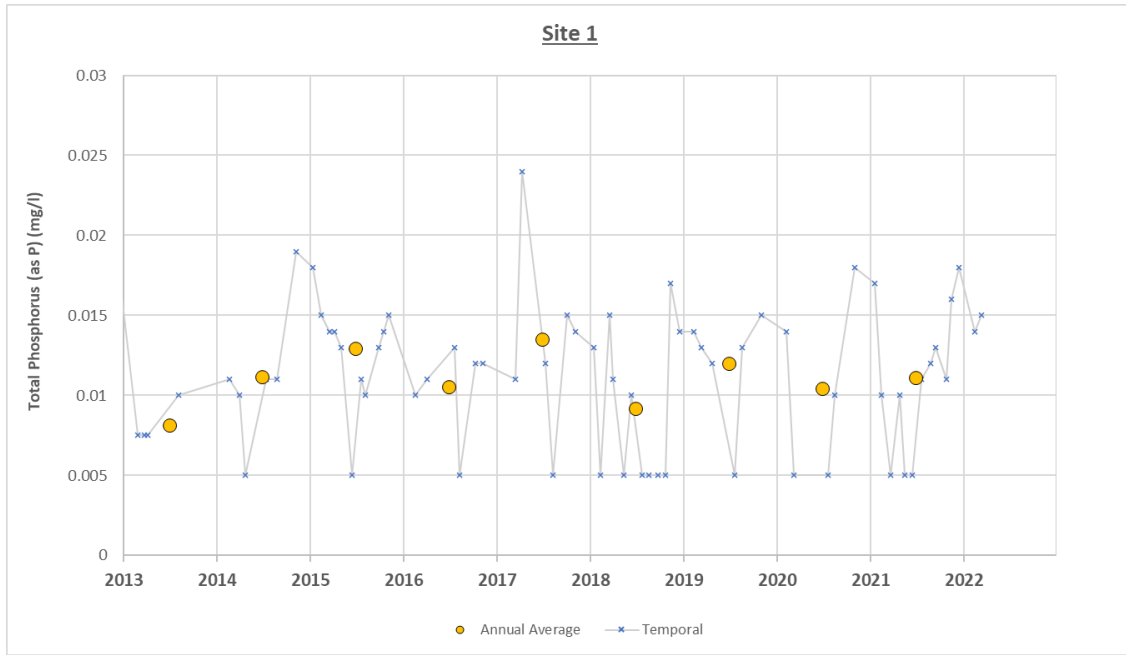


Figure 29 Total phosphorous concentrations at Site 1, Lough Dan.

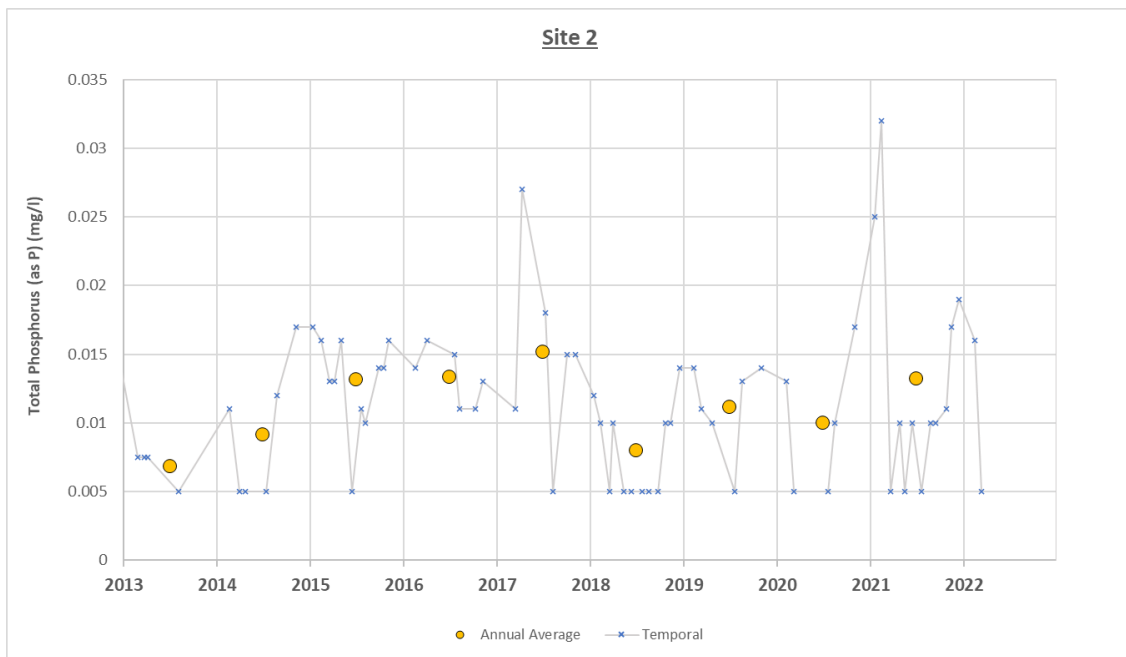


Figure 30 Total phosphorous concentrations at Site 2, Lough Dan.

Appendix III

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Subcatchment maps

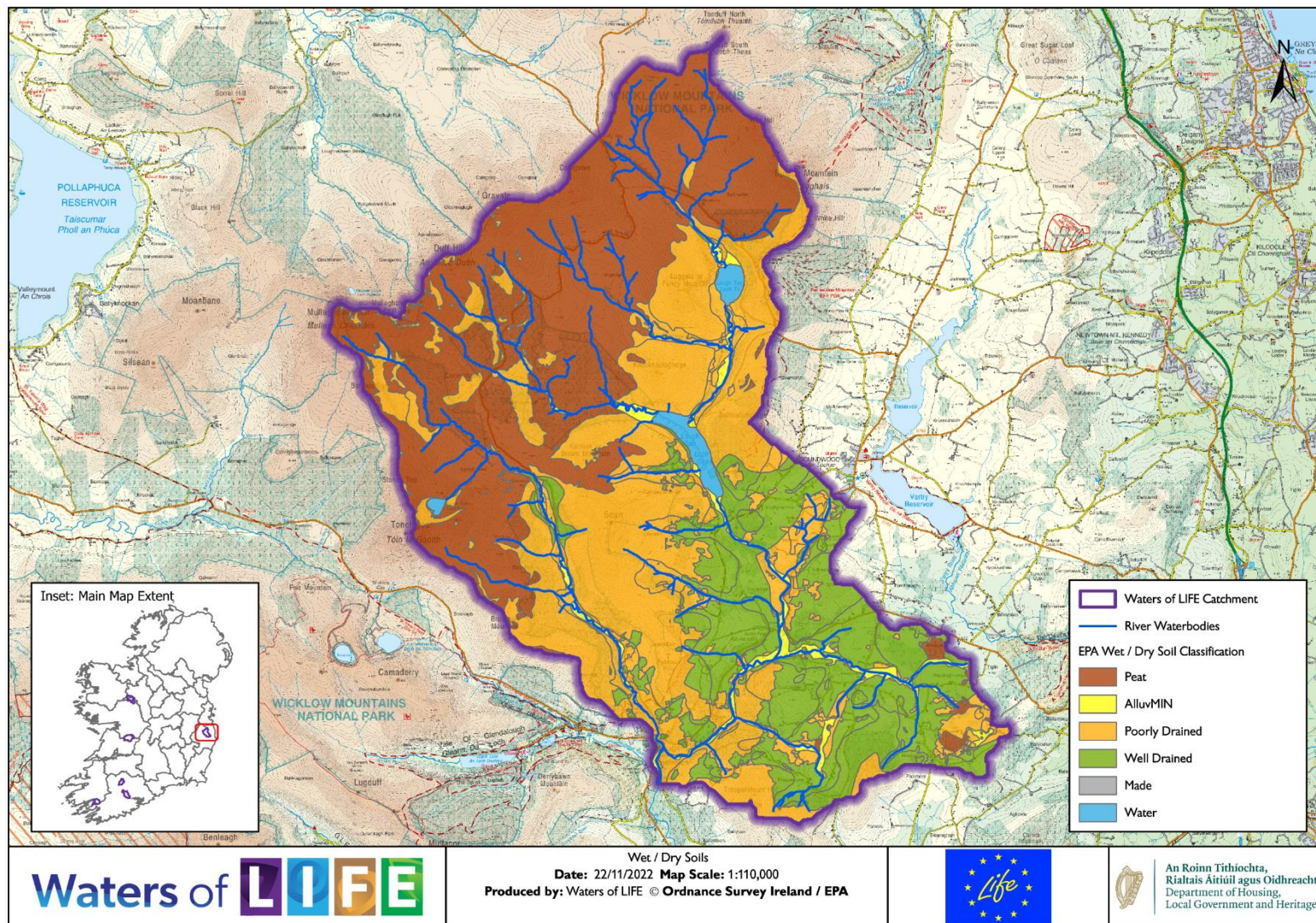


Figure 31 Wet and Dry Soils within Avonmore_SC_010 sub-catchment.

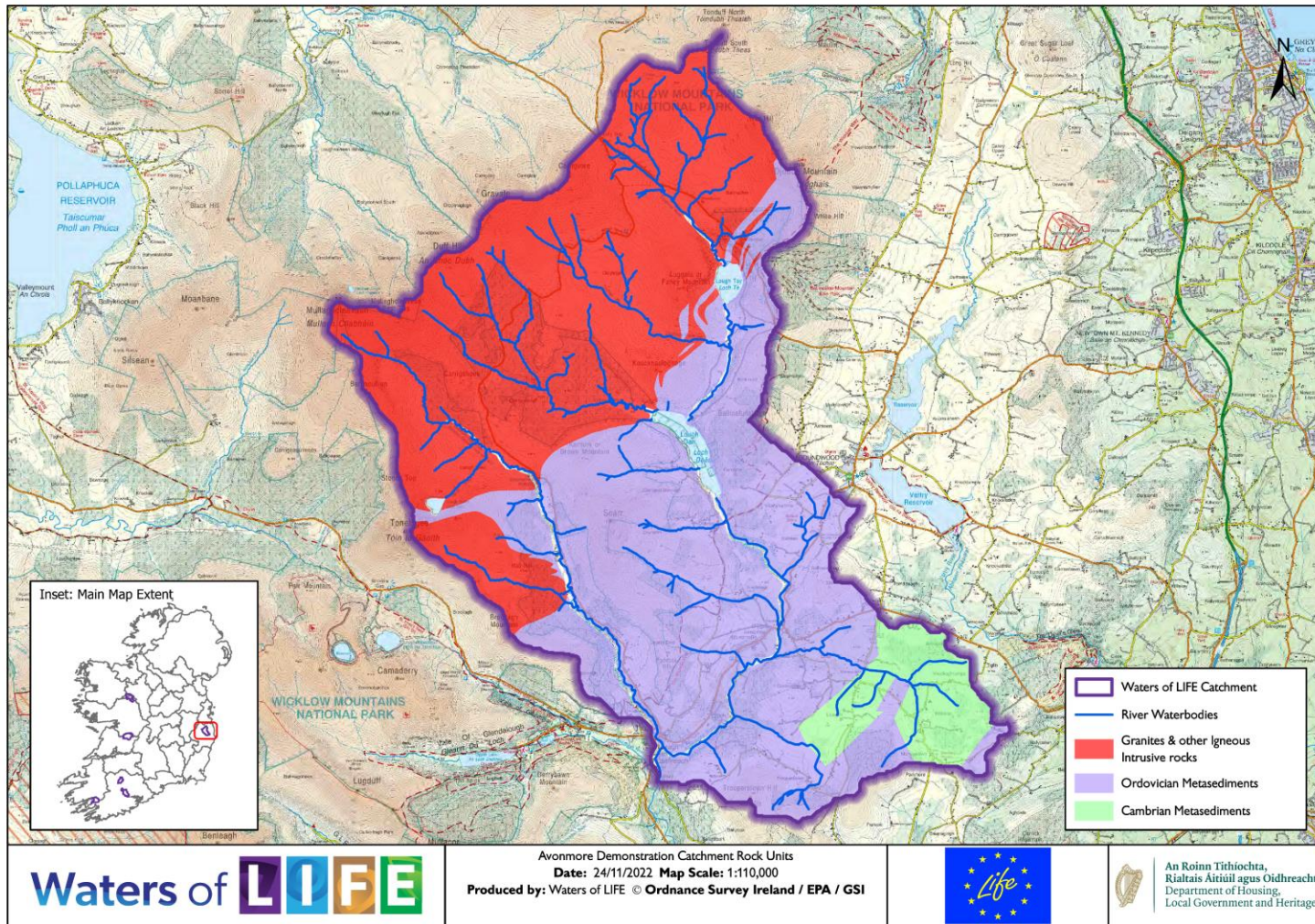


Figure 32 Rock units within Avonmore_SC_010 sub-catchment.

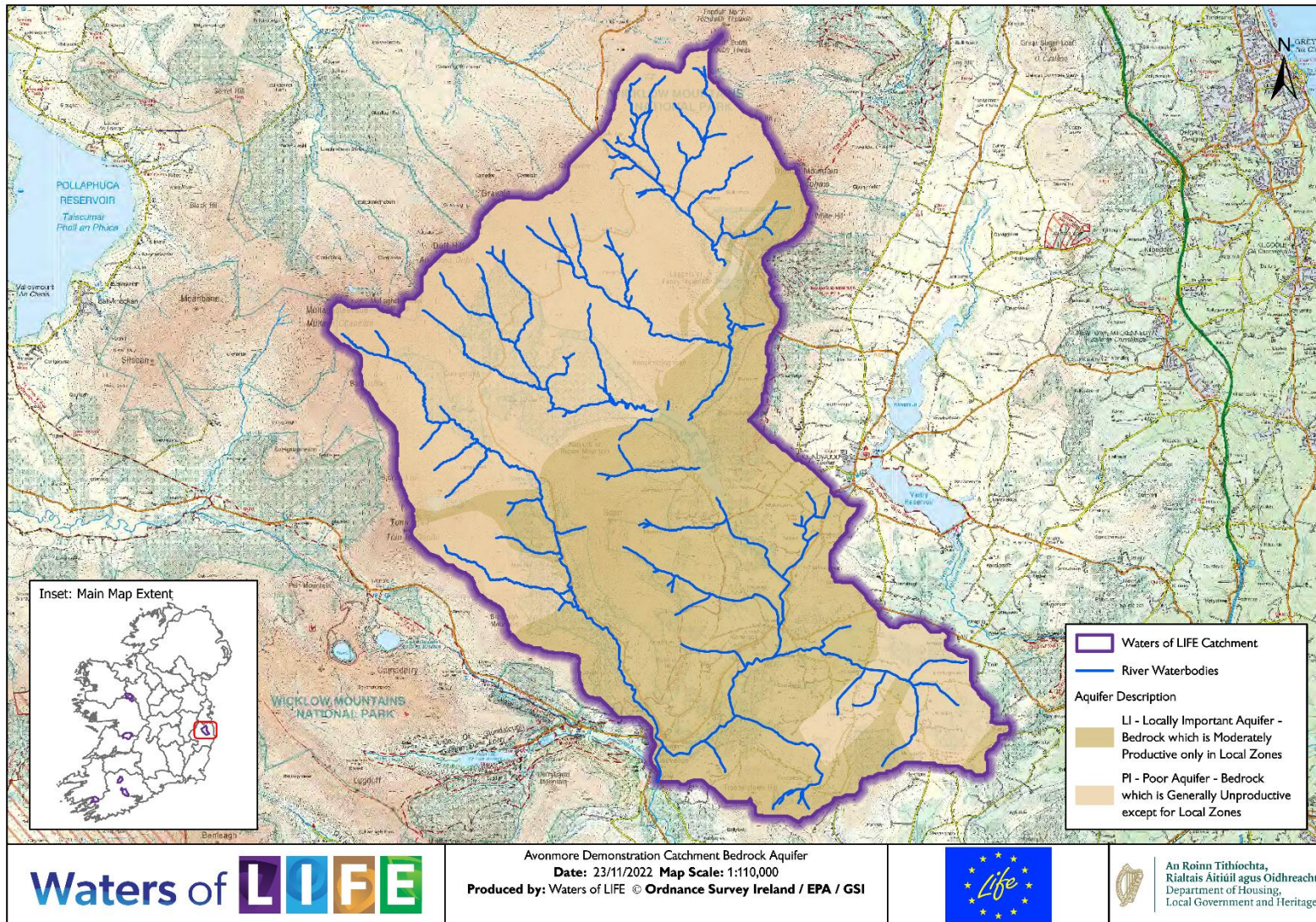


Figure 33 Aquifer type within Avonmore_SC_010 sub-catchment.

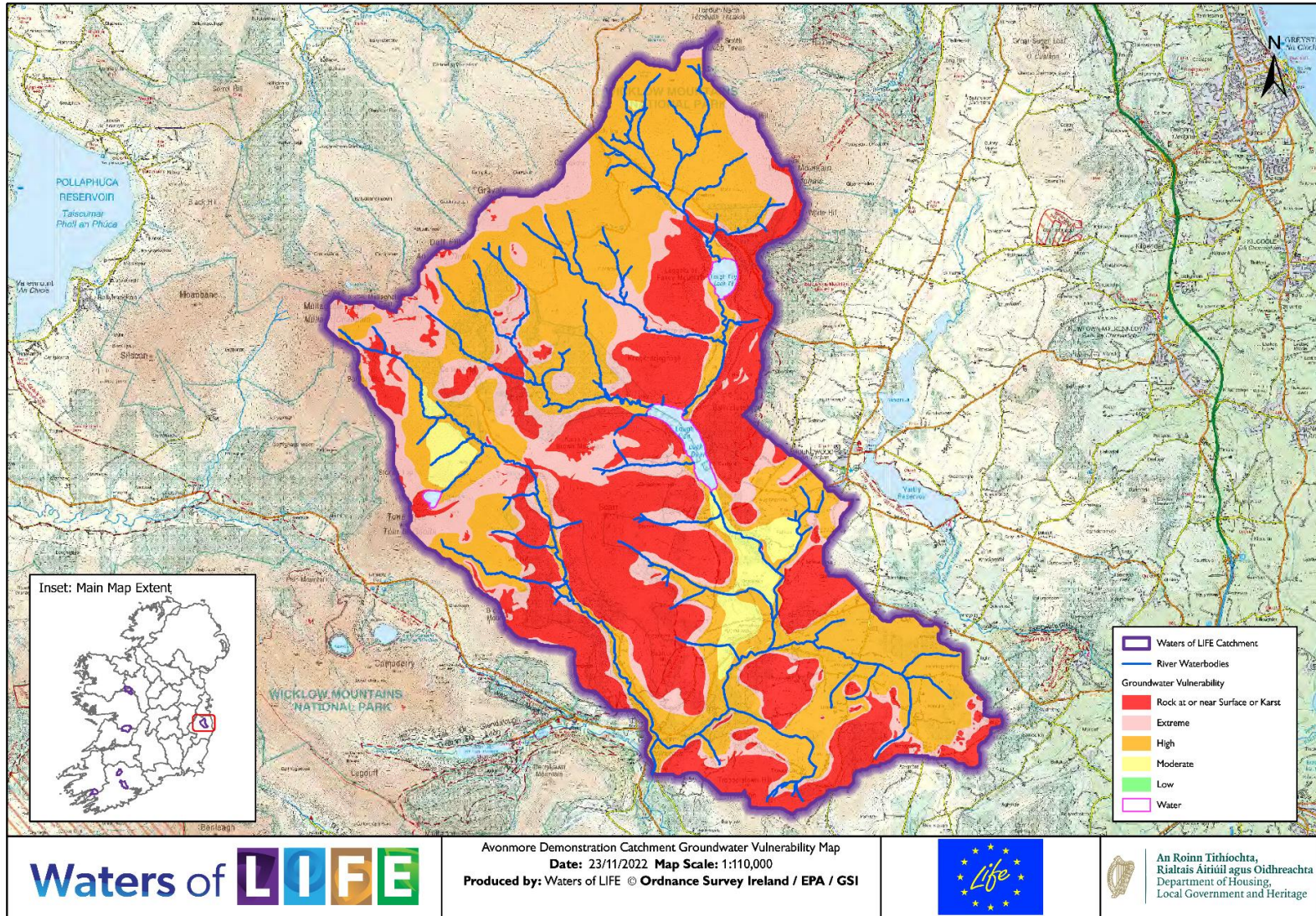


Figure 34 Groundwater vulnerability within Avonmore_SC_010 sub-catchment.