# Compliance Assessment of Welsh River SACs against Phosphorus Targets

Report No: 489

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Eithriwyd data lle (i) bod terfynau canfod yn annigonol i asesu cydymffurfiad â'r targed neu (ii) lle'r oedd y sampl yn cael ei ddal yn hwy na'r uchafswm amser dal a argymhellir o dri diwrnod rhwng y casglu a’r dadansoddiad. Nodwyd allanolion yn y data ac, os ystyrid eu bod yn debygol o fod yn achosi methiant ar eu pennau eu hunain, gwiriwyd data o ddangosyddion llygredd maethynnau eraill (galw am ocsigen biocemegol, nitrad ac amonia) i gadarnhau digwyddiadau posibl o ansawdd dŵr gwael.

Roedd data ar gael i asesu 107 o’r 125 corff dŵr (86%), gyda 18 o’r cyrff dŵr ddim yn cael eu hasesu oherwydd bod data yn annigonol neu'n brin. Yn gyffredinol, llwyddodd 39% o'r cyrff dŵr sy’n Ardaloedd Cadwraeth Arbennig a aseswyd i basio'u targedau, a methodd 61%. Roedd dosbarthiad gofodol methiannau hefyd yn anwastad, heb unrhyw fethiannau yn Afon Gwyrfai, Afon Glaslyn (Coedydd Derw Meirion), Afon Eden ac Afon Tywi, ond methiannau eang (>50% yn methu) ac weithiau difrifol (> 20µg l-1) yn Afon Wysg, Afon Gwy ac Afonydd Cleddau. Dangosodd afon Teifi batrwm canolradd gyda methiannau ar yr afon isaf ond targedau wedi’u cyrraedd ar yr afon uchaf, tra oedd gan Afon Dyfrdwy fethiannau lleol. Ar y cyfan, nid oedd fawr o wahaniaeth o ran cydymffurfio rhwng crynodiad ffosfforws y tymor blynyddol a'r tymor tyfu. Gwelwyd gwahanol batrymau : roedd rhai cyrff dŵr yn methu â chyrraedd eu targed yn gyson, ond roedd eraill yn fwy tueddol o gael uchafbwyntiau ffosfforws afreolaidd.

Mae'r canlyniadau hyn yn dangos bod llygredd ffosfforws yn broblem sylweddol yn afonydd Ardaloedd Cadwraeth Arbennig Cymru sydd yn gofyn am weithredu ar lefel dalgylch. Mae angen i hyn weithio mewn ffordd integredig i wella ansawdd ecosystemau afonydd a'u swyddogaeth, a lleihau mewnbynnau maethynnau. Y rheswm am hyn yw y gall llawer o gamau gweithredu ar lefel yr ecosystem gynyddu gwytnwch ecosystemau afonydd i lygredd maethynnau, gwella eu gallu i brosesu mewnbynnau ffosfforws, a chael buddion ehangach eraill fel cynyddu'r gallu i gynnal eogiaid ifanc ac ymateb i'r argyfwng natur. Er enghraifft, mae plannu coed priodol ar hyd glannau afonydd yn creu cysgod, gan atal tyfiant algaidd yn ogystal â gostwng tymheredd y dŵr a darparu gorchudd i bysgod.

Cynhyrchwyd haen System Gwybodaeth Ddaearyddol ar ffurf ArcGIS i gynorthwyo â chynllunio a rheoli afonydd ac wrth wneud penderfyniadau.

# Executive Summary

Revisions to Joint Nature Conservation Committee (JNCC) monitoring guidance have led Natural Resources Wales (NRW) to review its conservation objectives for river Special Areas of Conservation (SACs) in Wales, notably with respect to phosphorus where targets have been substantially tightened. Natural Resources Wales is in the process of amending its freshwater SAC Core Management Plans to incorporate the new targets. Phosphorus targets are set as the annual and growing-season means.

Nutrient concentrations in Welsh rivers and globally are a widespread problem, and stakeholders have expressed concerns that they are increasing in some locations. Additionally, reports of high macroalgal and phytoplankton biomass in parts of the River Wye during a very hot and dry spell in early 2020 created significant media concern around nutrient concentrations. This report aims to identify compliance with the revised phosphorus targets for Welsh river SACs.

Phosphorus concentration data were extracted from the NRW water quality database for a three-year period from January 2017 to December 2019 for all sample points within water bodies in the nine SACs designated for one or more river features. These were Afon Gwyrfai a Llyn Cwellyn; Afon Eden – Cors Goch Trawsfynydd; Meirionnydd Oakwoods and Bat Sites (the Afon Glaslyn); Afon Teifi; Afon Tywi; Afonydd Cleddau; River Dee & Bala Lake; River Usk; and River Wye. In total, 125 water bodies (river sections) were in scope.

Data were excluded where (i) detection limits were unsuitable to assess compliance with the target or (ii) where the holding time of the sample exceeded the recommended maximum of three days between collection and analysis. Outliers in the data were identified and, if they were considered likely to be causing a failure on their own, data from other water quality indicators (biochemical oxygen demand, nitrate and ammonia) were checked to corroborate possible episodes of poor water quality.

Data were available to assess 107 of the 125 water bodies (86%), with 18 water bodies not being assessed due to data being inadequate or lacking. Overall, 39% of assessed SAC water bodies passed their targets and 61% failed. The spatial distribution of failures was also uneven, with no failures in the Gwyrfai, Glaslyn (Meirionnydd Oakwoods), Eden and Tywi but widespread (>50% failing) and sometimes severe (> 20µg $l^{-1}$) failures on the Usk, Wye and Cleddau. The Teifi showed an intermediate pattern with failures on the lower river but the upper river meeting its targets, whilst the Dee had localised failures. On the whole, there was little difference in the annual and growing-season mean phosphorous concentrations. Different patterns were observed: some water bodies consistently failed their target, whereas others were more prone to episodic phosphorous peaks.

These results demonstrate that phosphorus pollution is a significant problem in Welsh SAC rivers that requires catchment level action. This needs to work in an integrated way to both improve river ecosystems quality and their function, and reduce nutrient inputs. This is because many ecosystem-level actions can increase the resilience of river ecosystems to nutrient pollution, improve their ability to process phosphorus inputs, and have other wider benefits such as increasing the carrying capacity for juvenile salmon and responding to the nature emergency. For example, planting appropriate trees along river banks creates shade, suppressing algal growth as well as lowering water temperatures and providing cover for fish.

A Geographic Information System layer in ArcGIS format to assist with planning and river management has been produced to assist with decision-making.

# Introduction

Natural Resources Wales (NRW) is the statutory government body with key responsibilities for the implementation of the Habitats Regulations and the Water Framework Directive (WFD) in Wales. Among other requirements, this includes certain functions in relation to the designation and management of Special Areas of Conservation (SACs) for habitats and species listed in Annexes I and II of the Habitats Directive.

In freshwaters, nutrient enrichment (eutrophication) is an important pressure globally (Bennett *et al.* 2001) including in Wales and England (Mainstone *et al*. 2008, Mainstone 2010, NRW & EA 2019). Elevated nutrient concentrations increase the risk of adverse ecological impacts such as algal blooms, loss of nutrient-sensitive species and deoxygenation of river substrates. Consequently, phosphorus targets to protect water quality and minimise the risk of negative ecological impacts have long been at the heart of the sustainable management of river ecosystems.

In 2005, the Joint Nature Conservation Committee completed its Common Standards Monitoring (CSM) guidance for river monitoring (JNCC 2005). This document steered the development of monitoring and management targets in SAC Core Management Plans developed by the Countryside Council for Wales in 2008. However, a Natural England review (Mainstone 2010) recommended the adoption of tighter targets reflecting new evidence that nutrients had negative impacts on riverine ecology at lower concentrations than was previously considered relevant. Additionally, since the ecological impacts of climate change and high nutrient levels are similar (Nõges *et al*. 2019), there may be a case for reducing nutrient targets to counterbalance the impact of climate change. Also, the predicted warmer and drier summers will reduce river flows during the growing season, resulting in increased nutrient concentrations due to reduced dilution of continuous point source inputs (Charlton *et al.* 2018).

As a result, JNCC published revised guidance (JNCC 2014, subsequently updated in 2016) that recommended a significant tightening of phosphorus targets, especially in headwater areas. Targets were also made much more explicit and included two measurements of phosphorus, an annual mean and a growing season mean. The recommended determinand is soluble reactive phosphorus (SRP) but decanted settled samples are considered an adequate surrogate (JNCC 2016).

There are nine SAC sites in Wales which support one or more designated riverine features. These are Afonydd Cleddau / Cleddau Rivers; Afon Eden - Cors Goch Trawsfynydd; Afon Gwyrfai a Llyn Cwellyn; Afon Teifi / River Teifi; Afon Tywi / River Tywi; Coedydd Derw a Safleoedd Ystlumod Meirion / Meirionnydd Oakwoods and Bat Sites (the Afon Glaslyn); River Dee and Bala Lake / Afon Dyfrdwy a Llyn Tegid; River Usk / Afon Wysg and River Wye / Afon Gwy. These SACs are designated to conserve various habitats and species listed in Annexes I and II of the Directive including Ranunculion habitat; Atlantic salmon; allis shad; twaite shad; bullhead; brook lamprey; river lamprey; sea lamprey; freshwater pearl mussel; white-clawed crayfish; otter; and floating water-plantain. These sites also support a range of rare and threatened species protected by the Sites of Special Scientific Interest (SSSIs) which underpin these SACs.

In 2008, the Countryside Council for Wales (CCW), NRW's predecessor, completed Core Management Plans for these rivers. Their water quality was assessed by Thomas *et al*. (2013) according to the targets that then applied.

NRW has so far updated targets in three of these plans (Wye, Teifi and Cleddau) to incorporate the new targets for phosphorus (NRW 2017a, b, c). The remaining targets have been identified but have not so far been incorporated into the relevant Core Management Plans (CCW 2008a, b, c, d, e, f), so their formal status is draft. NRW is in the process of revising SAC Core Management Plans to incorporate the remaining targets.

The revised targets are set according to altitude, alkalinity, and stream order (JNCC 2016), with the tightest targets in low alkalinity, high altitude headwater areas, reflecting natural variation. Targets may be set as either 'near-natural', to protect areas with minimal human impact, or 'maximum allowed', reflecting the need to accept higher nutrient concentrations where near-natural targets are unattainable (JNCC 2016). The process also includes an alignment procedure to ensure that targets are never less stringent than the WFD phosphorus target for the same water body. Finally, there is scope to adjust targets for relevant species if these are especially sensitive to nutrients. In Wales, this applies only to freshwater pearl mussel.

However, even the maximum allowed targets are significantly tighter than the previous targets. Near-natural targets range from annual and growing season means of 5-40 $\mu g\ l^{-1}$ of soluble reactive phosphorus as P, whereas maximum allowable concentrations range from 10-60 $\mu g\ l^{-1}$. The majority of previous phosphorus targets were in the range of 20-100 $\mu g\ l^{-1}$.

NRW is also responsible for the implementation and management of the Water Framework Directive (WFD) in Wales. The WFD's aims and objectives align closely with those of the Habitats Directive in relation to freshwater. In order to simplify management and achieve better alignment between the implementation of the Habitats Regulations and the WFD, NRW is working to amend management units for river SACs so that they align with water bodies used for WFD reporting. This change allows more direct comparison between Habitats Directive and WFD assessments and consequently this report uses data from water bodies as defined by WFD. Compliance with WFD is reported on the Water Watch Wales website and is not analysed further here. Phosphorus standards for the Water Framework Directive were also tightened in 2013.

The aim of this report is to assess compliance of water bodies within Welsh river SACs against the revised phosphorus targets (either published or draft in the Core Management Plans). This is not a full condition assessment of SAC features as this would require assessment of biological, habitat and other water quality targets (JNCC 2016).

# Methods

## Sample Collection and Laboratory Analysis

The standard determinand for assessing bio-available phosphorus in rivers is orthophosphate as P (NRW determinand 0180), and this determinand has been used for all data in this report. It is compliant with the CSM targets (JNCC 2016).

All samples were collected using standard NRW sampling procedures (Adam 2001) and analysed using the Standing Committee of Analysts Blue Book method (SCA 1992). In brief, river water samples are collected with a rinsed sampling container, ensuring that the sediments are not disturbed, and transferred to a 1 litre plastic sampling bottle. Samples are refrigerated and couriered to the laboratory at the earliest opportunity, with the time between sample collection and the start of laboratory analysis not exceeding three days. Samples are settled and decanted rather than filtered, with a minimum of 10ml of the sample analysed. Laboratory analysis uses the molybdenum blue method with absorbance at 880nm measured using a Gallery Plus discrete analyser (test code 2948/180/21).

## Phosphorus Data Quality Issues

Special attention in evaluating the data was given to data quality assurance. There are three significant issues that have affected NRW's river orthophosphosphate dataset and that require consideration when analysing the data: these are Limit of Detection (LOD); Anomalous Data, and Holding Time Breaches. These are described below together with the measures taken to ensure that the compliance assessment was not affected.

<u>Limit of Detection</u>

Two separate orthophosphate determination methods are relevant to this work. The 'Very Low' method has a lower LOD of 1 µg $l^{-1}$, and the 'Low' method has a LOD of 20 µg $l^{-1}$. Prior to the production of the revised JNCC guidance and updated WFD standards, the majority of Environment Agency (EA) and NRW's water sampling used the 'Low' method, which was adequate for general assessment of previous SAC and WFD targets and assessing the performance of sewage works. However, 77 water bodies now have targets <20 µg $l^{-1}$. For these water bodies, samples analysed using the 'Low' method are inadequate to assess compliance, because the target is now lower than the LOD. The NRW laboratory has now developed a unified method for orthophosphate with a detection limit of 4 µg $l^{-1}$. This will be used for all sample points from January 2020, thus eliminating the LOD issue from routine monitoring.

For this report, the vast majority of data used was collected using the 'Very Low' method, as this gives the required level of precision for assessment against the targets. 'Low' method data was only used in water bodies where the impact of 'less than' data was minimal. Values measured as 'less than' were assigned half the limit of detection for the purpose of calculating means.

Anomalous Data

Between 2014-16 anomalous high values were recorded with NRW's 'Low' LOD orthophosphate data, with measured values that could not be explained by any environmental source or pressure. Despite a detailed investigation, the cause was not identified, but changes to laboratory practice appear to have resolved the problem.

Only data collected after 1/1/2017 have been used. Moreover, to exclude the possibility of a recurrence of this problem, all potentially anomalous datapoints were double checked with the laboratory, and also compared with other indicators of pollution (see Data Extraction and Analysis below). These procedures identified a small number of values (<10) which have now been corrected on NRW's systems prior to data extraction and analysis.

Therefore, it is considered highly unlikely that anomalous data have affected this assessment.

Holding Time Breaches

After sampling has taken place, orthophosphate concentrations should ideally be processed by a laboratory as soon as possible, since processes such as sorption to the walls of the storage vessel, uptake by organisms or cell lysis in the sample can all affect the concentration (Jarvie *et al.* 2002). In general these processes tend to cause a reduction in the measured concentration, but more rarely concentrations can increase (Haygarth *et al.* 1995). The maximum time recommended by NRW guidance (Adam 2001) for processing before orthophosphate concentrations in the sample are considered unreliable is three days.

Following NRW's formation in 2013, much of the initial water quality analysis was carried out by the Environment Agency laboratory, but this was progressively transferred to the NRW laboratory. However, NRW did not have the ability to carry out the 'Very Low' analytical method for orthophosphate and so samples requiring this were subcontracted to the Environment Agency's Starcross Laboratory in Devon. Unfortunately, subcontracting this work out frequently resulted in delays resulting from the need to courier samples to Starcross, with the result that many 'Very Low' samples exceeded the holding time.

The inclusion of data that exceeded the holding time would have had the potential to bias the results towards underestimating phosphorus concentrations. Therefore, all data that breached the holding time was excluded from this analysis (635 measurements). The affected data are predominantly from 2017.

## Data Extraction and Analysis

Data on orthophosphate as P (NRW determinand 0180) covering the period 1st January 2017 to 31st December 2019 was extracted from NRW's WISKI Water Quality database. Sample points were matched to water bodies using a GIS, excluding data with holding time breaches as described above. Where possible, 'Very Low' data was used to calculate compliance. 'Low' data was used only where the target was sufficiently above the LOD to allow assessment of compliance (30 µg $l^{-1}$) and no adequate 'Very Low' data was available. This approach largely eliminated the possibility of assumptions regarding treatment of values below LOD affecting the outcome of the assessment. Outliers in the phosphorus data were identified using boxplots (Appendix 1) and where these affected the result, a series of tests were applied to assess confidence in the result as described below. However, outliers not were removed from the data as these could be indicative of episodic phosphorus peaks.

Average annual and growing-season means (March-Sept) were calculated for each sample point and the highest value used for assessment against targets.

Many previous reports have used milligrammes per litre (mg $l^{-1}$) but use of this unit generally requires use of numbers reported to several decimal places, which can cause confusion and decimal point errors. Throughout this report, we have used microgrammes per litre (µg $l^{-1}$) as the unit of choice. This is because, for the concentrations used as targets and also commonly observed in our rivers, this is an appropriate scale to use. There are 1000 µg in 1 mg and therefore a target of 0.05 mg $l^{-1}$ is equivalent to 50 µg $l^{-1}$, 0.01 mg $l^{-1}$ to 10 µg $l^{-1}$ and so on. All values have been rounded to the nearest microgramme in the tables. In some cases, values passed or failed their targets by less than a microgramme – this is noted by $^{P}$ or $^{X}$ respectively next to the relevant value

Sample points were only used where an acceptably accurate calculation of the mean was possible. This was set at a minimum of 8 samples. This meant that for some water bodies, compliance could only be assessed against the annual average target. Where more than one sample point occurred in a water body, the sample point with the highest mean was used, unless this had too small a number of samples or an inappropriate LOD as described above. Data were then compared with the relevant target for the water body.

Water bodies have generally been assessed only where sampled data were available from the relevant period, to a suitable standard, within the water body. In two cases both in the Afon Teifi, assessments were made based on data from the adjacent downstream water body. This was considered justified because the target was the same, the sample point in question was within 5km of the unsampled water body, and because the majority of flow from the downstream water body came from the upstream water body (i.e. any tributaries were considered unlikely to affect the phosphorus concentration unduly).

Previous assessments presented data as simple pass/fail. In addition to assessing compliance against targets we have mapped compliance using a colour scheme reflecting increasing magnitudes of failure to assist in planning and other decision making. CSM provides no guidance on how to do this, so we have used increments of 10 µg $l^{-1}$ as a means of visualising exceedances. Exceedances are mapped as the highest magnitude of either the annual or growing season mean.

In some cases, the mean was above the target due to a single high reading. Such a reading could be due to contamination / laboratory error or reflect a genuine event. As a precautionary measure, all data have been reported as a failure where the data reflect this. However, failures have also been sensitivity-tested to determine the impact of these high readings (Figure 1). This involved, in sequence:

1. Testing whether the median also fails the target (which would confirm that the central tendency of the dataset exceeds safe levels);

2. Identifying whether outliers exist that could affect the mean. Phosphorus outliers were identified using boxplots (Appendix 1);

3. Testing whether the mean exceeds the target value even when the largest outlier is excluded. Only the largest outlier was tested because this has the largest impact on the mean, and because the presence of multiple erroneous values in data from the same sample point is considered unlikely;

4. Investigating whether high phosphorus values coincide with outlier measurements for other indicators of pollution from the same water sample (any of Biochemical Oxygen Demand (BOD), nitrate or ammonia) (Appendix 2 and 3).

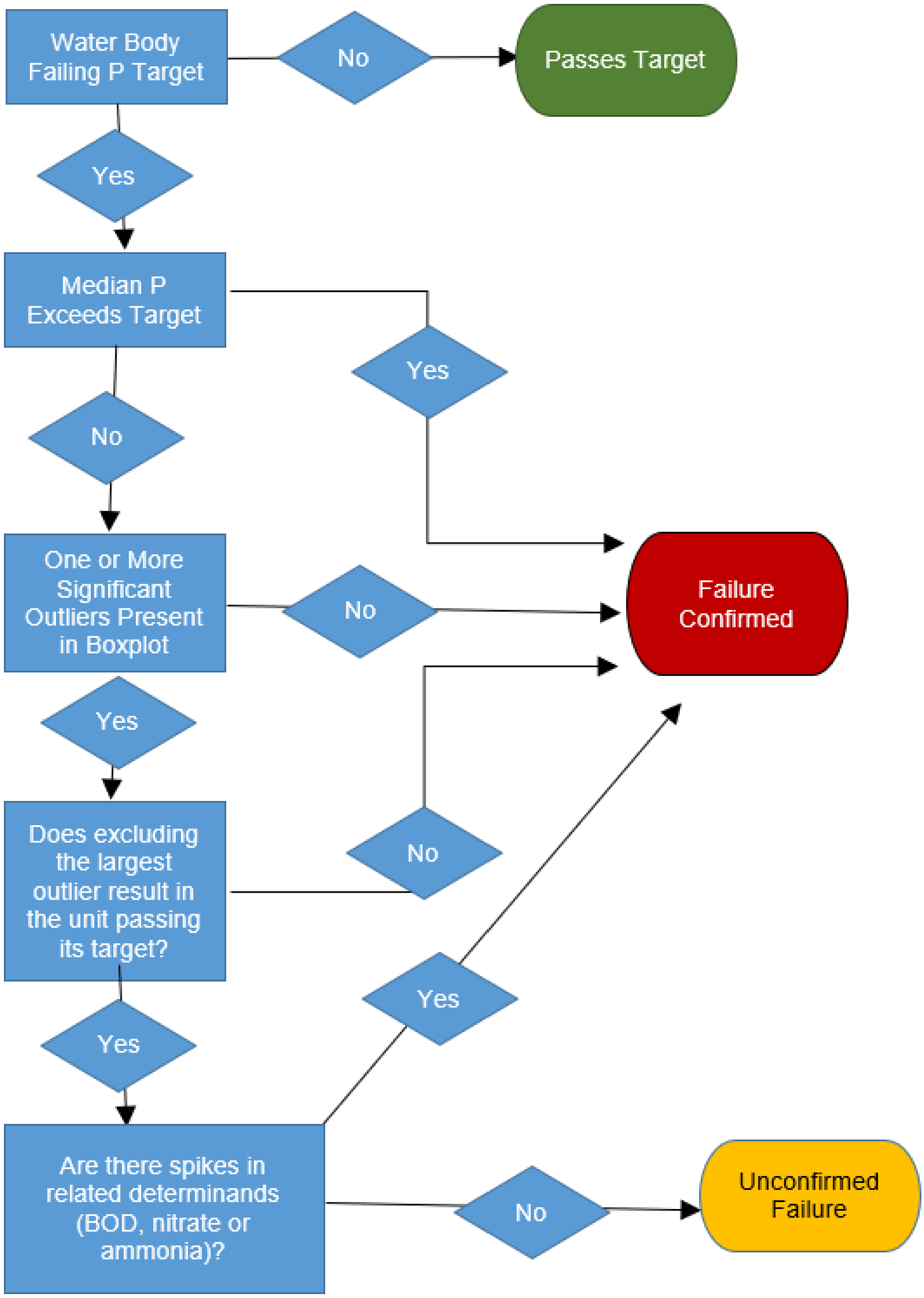


Figure 1. Summary of the Process for Sensitivity Testing Phosphorus Failures.

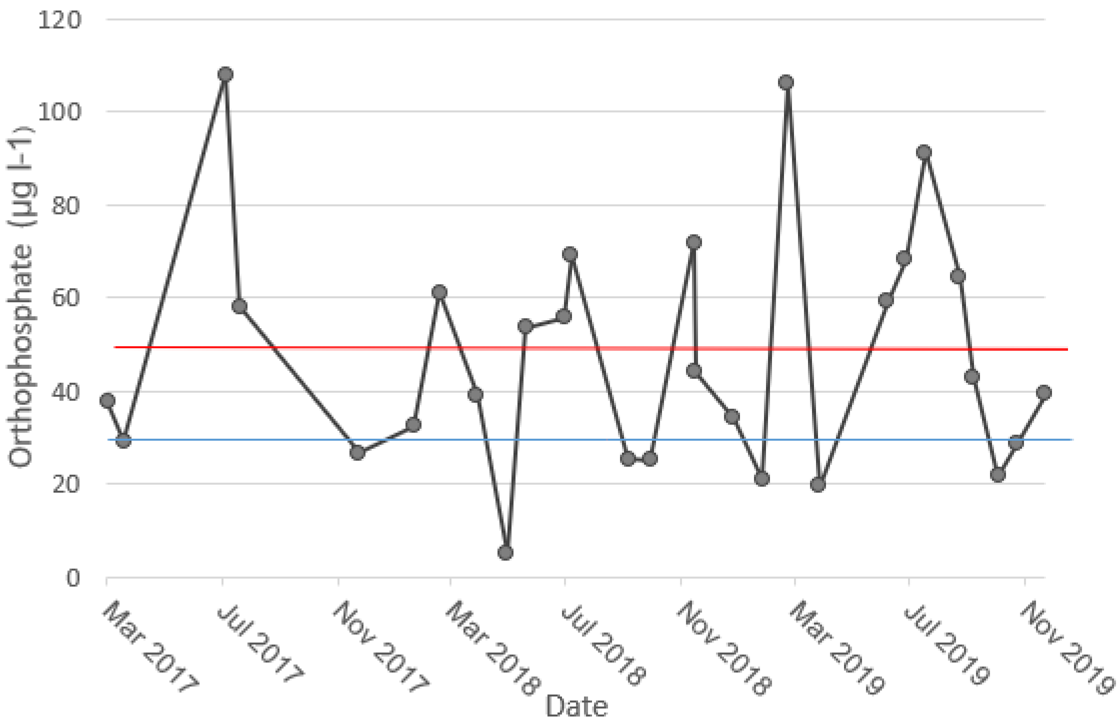


Figure 2. Example of a sample point consistently failing its orthophosphate target (Camrose Brook, Western Cleddau). The blue line indicates the target and the red line the annual mean.

Based on the process above, failing sites were then allocated one of two categories, reflecting the pattern of phosphorus concentrations observed. Consistently failing sites were those where a majority of measurements exceeded the target concentration (i.e. the median as well as the mean exceeded the target value - Figure 2). Episodically failing sites were where the median did not exceed the target value – typically failures at these sites resulted from one or more spikes in the data (Figure 3).

Coincidence with other indicators of poor water quality (see point 4. above and example in Figure 4) was identified using boxplots (Appendix 2) with high or outlier values identified in tables in the results section. High outliers for one or more of these resulted in failures being confirmed. Where a value lay within the upper tail of the distribution (shown as >Q3), it was considered weak supporting evidence and the failure was assessed as ‘Possible’. Failures lacking corroborating evidence were considered ‘Unconfirmed’.

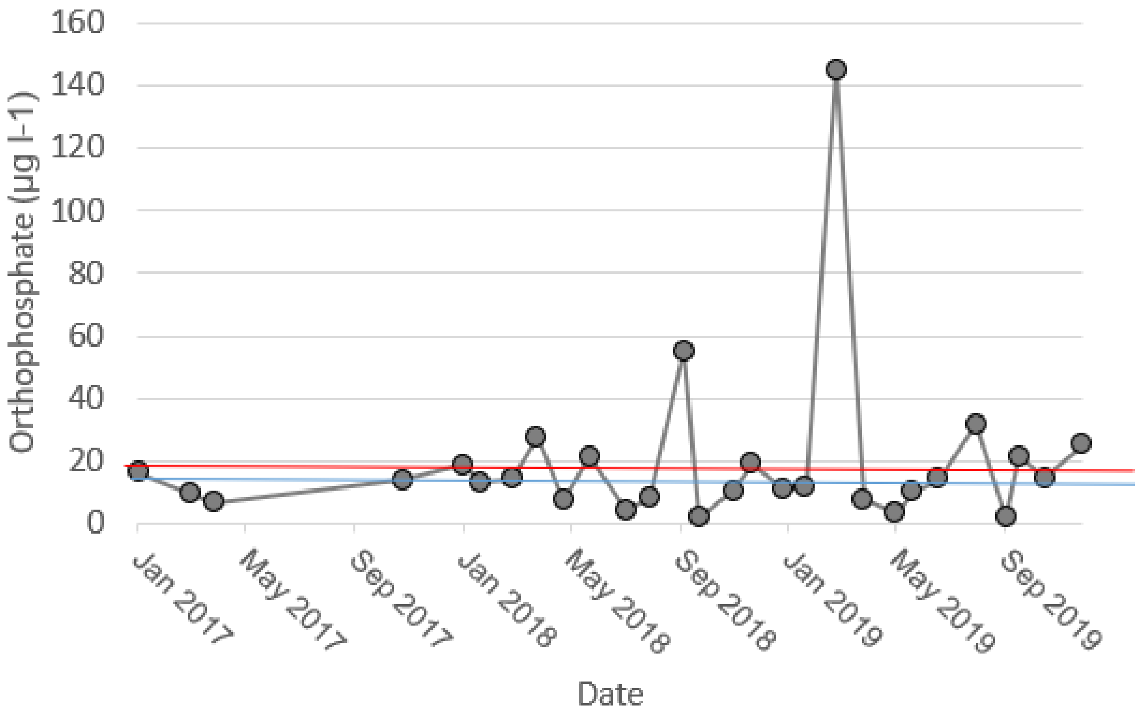


Figure 3. Example of a sample point with episodic failures of its phosphorus target (Lower Edw, Wye). The blue line indicates the target and the red line the annual mean.

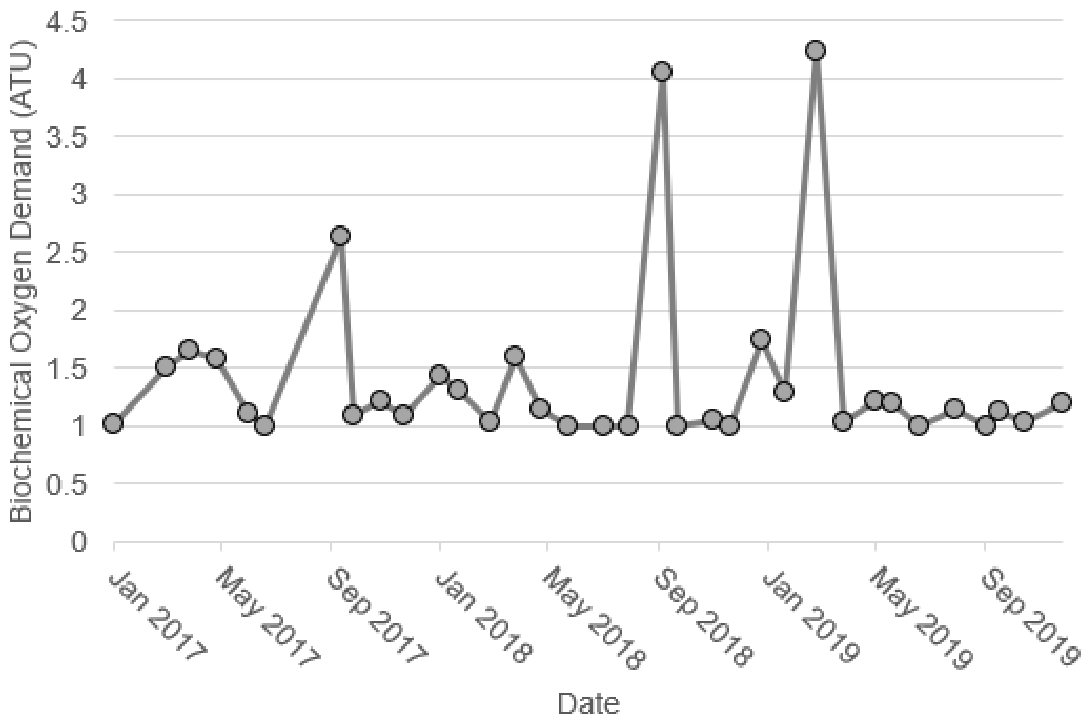


Figure 4. Plot of BOD for the lower Edw sample point in Figure 3. Correspondence between BOD spikes and orthophosphate spikes provide support for the phosphorus data.

# Results

A total of 107 water bodies in nine different SACs were assessed (Table 1), with 2659 individual phosphorus readings in scope. 100 water bodies were assessed using both the growing season and annual means, 7 water bodies with only the growing season mean and 18 waterbodies had sufficient data for an assessment to be carried out. Overall, 42 water bodies passed their targets and 65 failed (Table 1).

| | Pass | Fail | Total |
|---|---|---|---|
| Both Growing Season and Annual Mean | 37 | 63 | 100 |
| Annual Mean Only | 5 | 2 | 7 |
| Total | 42 | 65 | 107 |
| Not Assessed | - | - | 18 |
| **Grand Total** | | | 125 |

Table 1. Summary of phosphorus compliance results as number of water bodies.

The overall mean value for the dataset was 24.6 µg $l^{-1}$, with a median of 12.6 µg $l^{-1}$. The overall frequency distribution of the data is shown in Figure 5. For the dataset as a whole, 44% of measurements were < 10 µg $l^{-1}$, 65% < 20 µg $l^{-1}$ and 91% < 50 µg $l^{-1}$, though these values varied widely by sample point.

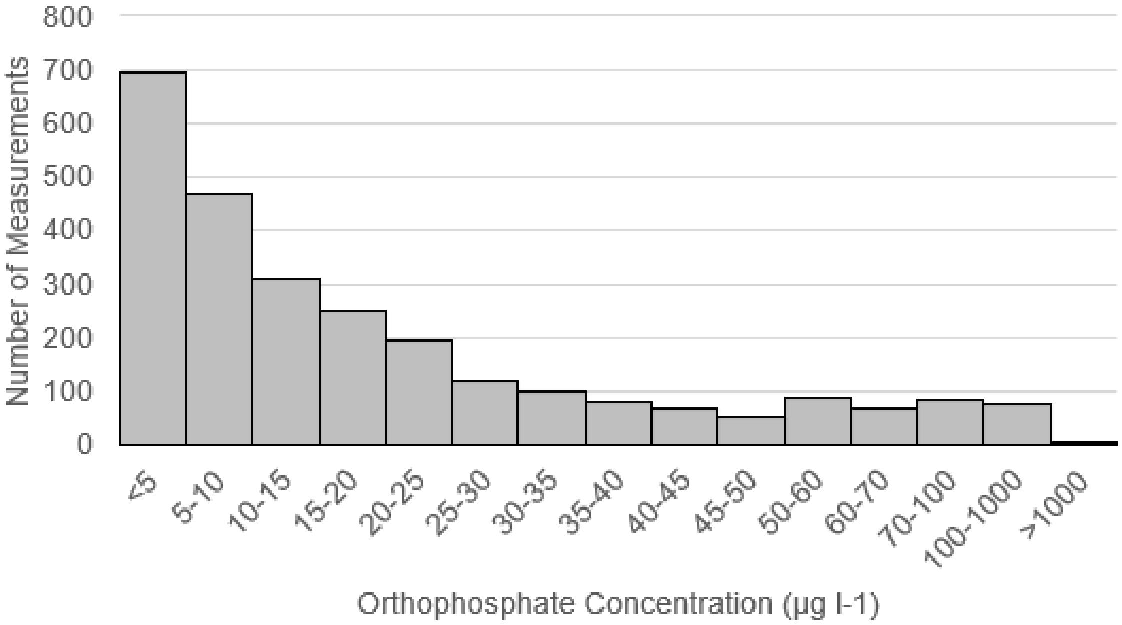


Figure 5. Frequency histogram of all orthophosphate measurements in the dataset. To accommodate all of the data, frequency categories on the right hand side of the graph are combined.

Detailed assessments by water body and SAC are shown below.

For each site, three maps have been provided: a map showing targets, a map showing mean annual orthophosphate concentrations, and a map showing compliance against the targets including magnitude of failure where relevant. Summarised data have also been tabulated and where relevant an additional table describing the nature of failures as described in the methods section.

## Afon Dyfrdwy / River Dee

The Dee is the largest catchment in North Wales and is one of two cross border SACs. It has a mixed geology including base-poor resistant rocks with overlying peat, Carboniferous limestone and sandstone outcrops. The lower part of the catchment is dominated by superficial deposits. Farming is low intensity in the upper parts of the catchment, but increasingly intensive downstream, especially below Llangollen. Reservoirs in the upper part of the catchment store water and regulate flow in the Dee. They sustain abstractions for public and industrial water supply and modify flood response in the river, reducing the frequency of flooding in the Dee between Bala and Chester.

The Dee has not yet had its targets incorporated into the SAC management plan and targets in this assessment (Figure 6) should therefore be seen as draft.

Data were available for seven of the eight river water bodies covering the Dee SAC (Figure 8; Table 2), but the Upper Ceiriog lacks data. Two locations for which data were available were not used in the assessment due to only Low detection limit data being available and / or insufficient data: these were sample points no. 26457 and 53. Concentrations in the Dee were generally low to moderate, with high concentrations in the lower river (Figure 7).

Three of these water bodies are passing and three are failing (Table 2; Figure 8). Failures on the Mynach and Dee (Ceiriog to Alwen) were confirmed using phosphorus data alone. The failure on the Meloch was due to a single high measurement of 239 $\mu g\ l^{-1}$ on 27 November 2019. BOD, oxidised nitrogen and ammonia were within normal ranges on this date and therefore this failure is unconfirmed. The failure on the Mynach was consistently above target, whereas the Meloch and Dee (Ceiriog to Alwen) failures were due to episodic high phosphorus values (Table 3).

The Mynach and Meloch are both important tributaries for juvenile salmon, so their failure to meet targets is of concern. The magnitude of failure in the Mynach in particular is relatively large and further investigation of this in order to address the problem is recommended. The LIFEDeeRiver project is due to work across the Dee catchment to improve agricultural and forestry land management practices. Problems on the Meloch are less concerning and could probably be addressed by implementing good practice measures on likely phosphorus sources.

The other failing water body is the Dee between the Ceiriog and Alwen (approximately Chirk to Corwen). This failure is only 6 $\mu g\ l^{-1}$ . Liaison with stakeholders to reduce nutrient inputs and implement best practice is recommended.

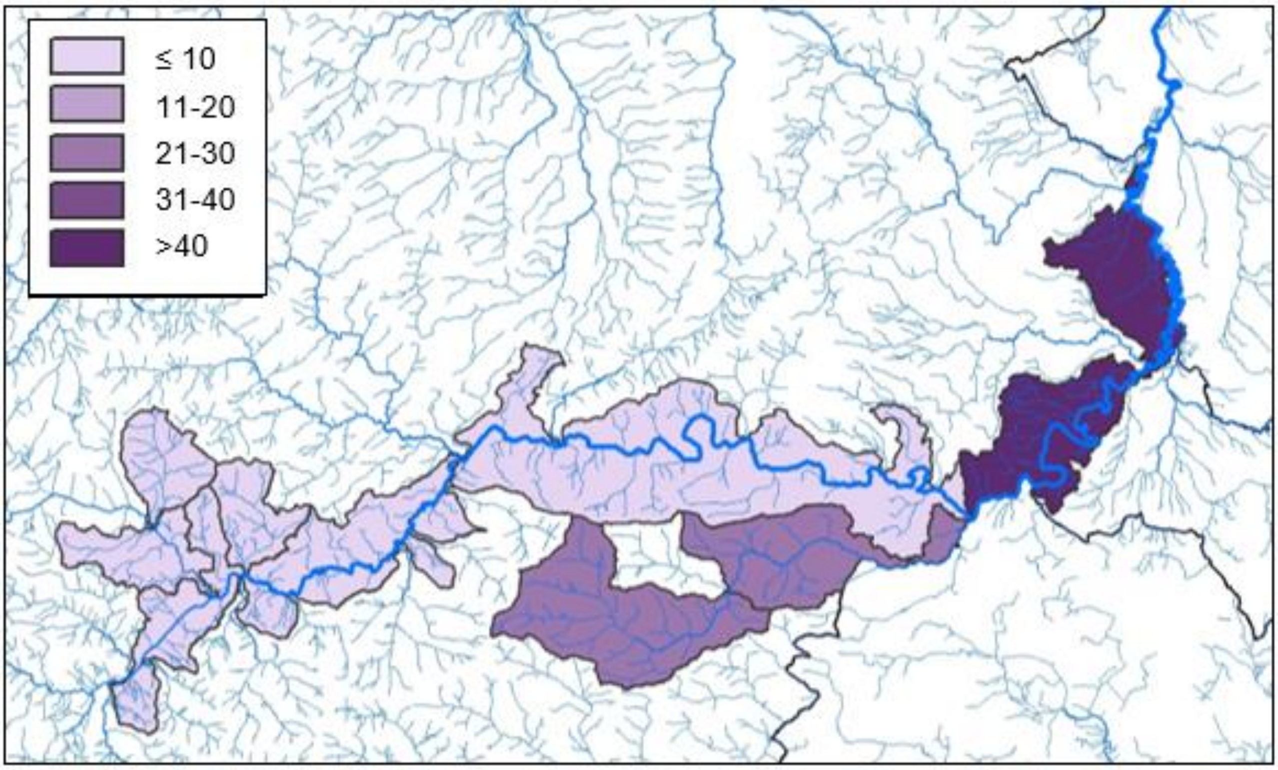


Figure 6. Map of phosphorus targets for the River Dee & Llyn Tegid SAC. All concentrations are annual means and growing season means in µg $l^{-1}$. Cross-border water bodies have been cropped to the Welsh border.

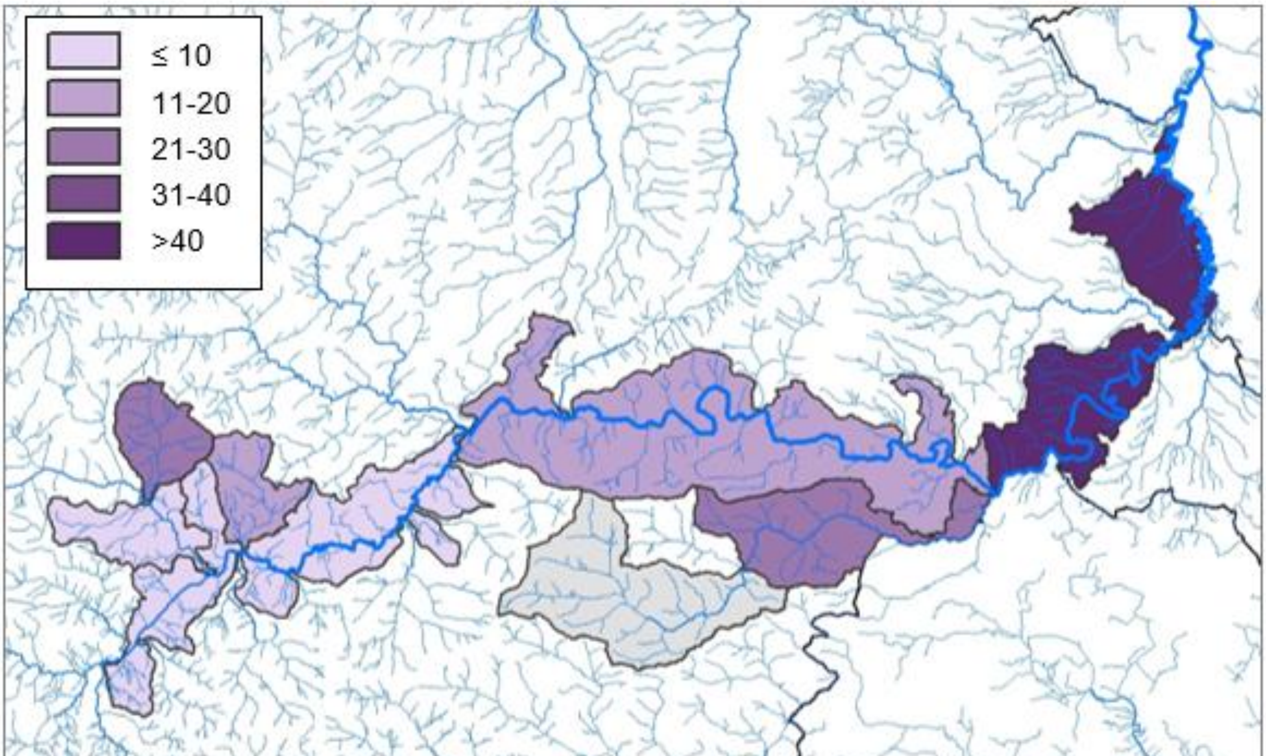


Figure 7. Annual mean orthophosphate concentrations in the River Dee SAC in µg $l^{-1}$. Greyed out water bodies could not be assessed due to lack of data.

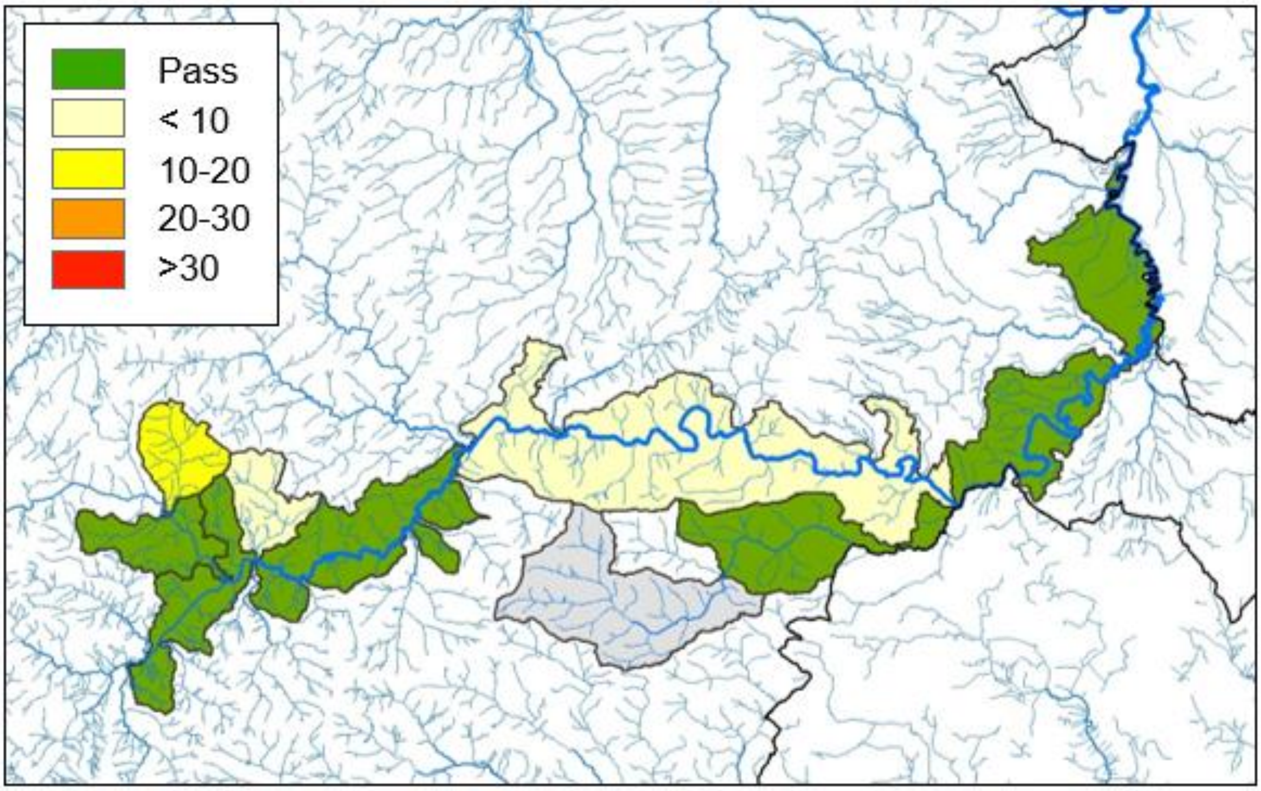


Figure 8. Phosphorus compliance map for the River Dee SAC. Water bodies shaded green pass their target. Other colours fail the target with different colours representing the magnitude of failures in µg $l^{-1}$, expressed as the larger of annual means and growing season means. Greyed out water bodies could not be assessed due to lack of data.

The distribution of monitoring sites and water bodies on the Dee would benefit from revision. The main stem water bodies are very large and may conceal substantial ecological variation. This is particularly evident for the lowest water body (Chester Weir to Ceiriog): at Bangor-on-Dee mean phosphorus concentrations are only 15 µg $l^{-1}$, whereas at Farndon concentrations were much higher at around 50 µg $l^{-1}$. Consideration should be given to subdividing this and possibly other water bodies to prevent deterioration.

There are **localised** phosphorus failures in the Dee. The magnitude of these failures is **low** to **moderate**. Although this assessment has not looked at potential sources, the relatively limited scale and extent of these failures suggests that it may be possible to tackle these issues in a relatively targeted way with relevant stakeholders without the need for large-scale investment. It is also recommended that actions be taken to increase the resilience of the river habitat to nutrient pressures.

| Waterbody ID | Waterbody Name | Site | Target (µg l⁻¹) | N Samples | Annual Mean (µg l⁻¹) | Growing Season Mean (µg l⁻¹) | Result | Status |
|---|---|---|---|---|---|---|---|---|
| GB111067051990 | Mynach | 300 | 10 | 19 | 25 | 27 | Fail | Confirmed |
| GB111067051900 | Tryweryn - Dee to Mynach | 294 | 10 | 25 | 10 | 4 | Pass | - |
| GB111067051960 | Meloch | 496 | 10 | 19 | 20 | 9 | Fail | Unconfirmed |
| GB111067052240 | Dee - Alwen to Llyn Tegid/ Bala Lake | 1 | 10 | 27 | 7 | 4 | Pass | - |
| GB111067052060 | Dee - Ceiriog to Alwen | 70 | 10 | 31 | 15 | 16 | Fail | Confirmed |
| GB111067051610 | Ceiriog - upstream of Teirw | - | 28 | No data | | | Not Assessed | - |
| GB111067051910 | Ceiriog - confluence Dee to Teirw | 578 | 28 | 31 | 22 | 26 | Pass | - |
| GB111067057080 | Dee - Chester Weir to Ceiriog | 87, 671, 689 | 50 | 60 | 15, 50, 47 | 17, 46, 49 | Pass | - |

Table 2. Phosphorus Compliance for the River Dee SAC. All orthophosphate concentrations are in µg l⁻¹.

| Waterbody ID | Waterbody Name | Site | Target (µg l⁻¹) | Median (µg l⁻¹) | Annual Mean (µg l⁻¹) | Largest Outlier (µg l⁻¹) | Mean (Outlier Excluded) (µg l⁻¹) | BOD / N / $NH_3$ confirm outlier | Failure Type |
|---|---|---|---|---|---|---|---|---|---|
| GB111067051990 | Mynach | 300 | 10 | 17 | 25 | 88 | - | - | Consistent |
| GB111067051960 | Meloch | 496 | 10 | 5 | 20 | 239 | 8 | No | Episodic |
| GB111067052060 | Dee - Ceiriog to Alwen | 70 | 10 | 9 | 15 | 85 | 12 | - | Episodic |

Table 3. Sensitivity Testing for Failing Water Bodies on the River Dee SAC.

## Afon Eden – Cors Goch Trawsfynydd

Afon Eden – Cors Goch Trawsfynydd is a small river SAC in Meirionnydd with a base-poor geology and significant peat influence. Much of the catchment lies within the Snowdonia National Park and consists of semi-natural habitats, low intensity sheep and beef cattle farming, and forestry. There are no major settlements within the catchment.

This SAC has not yet had its targets incorporated into the SAC management plan and targets (Figure 9) should therefore be seen as draft.

Data are available for three of four water bodies in this SAC, all of which are very good quality with low nutrient concentrations at the limit of detection (Table 4).

There are **no** failures of the phosphorus target in the Eden catchment. In addition, the availability of good quality phosphorus data using the 'Very Low' method indicates that a lower target should be used corresponding to the 'Near Natural' values in CSM guidance, as the current draft targets still contain significant headroom (Table 4). It is recommended that they are tightened to 10 µg $l^{-1}$.

Afon Eden therefore **passes** its phosphorus target. As this is an oligotrophic river with few nutrient inputs, this is not surprising.

No outlier analysis was carried out because no water bodies are failing.

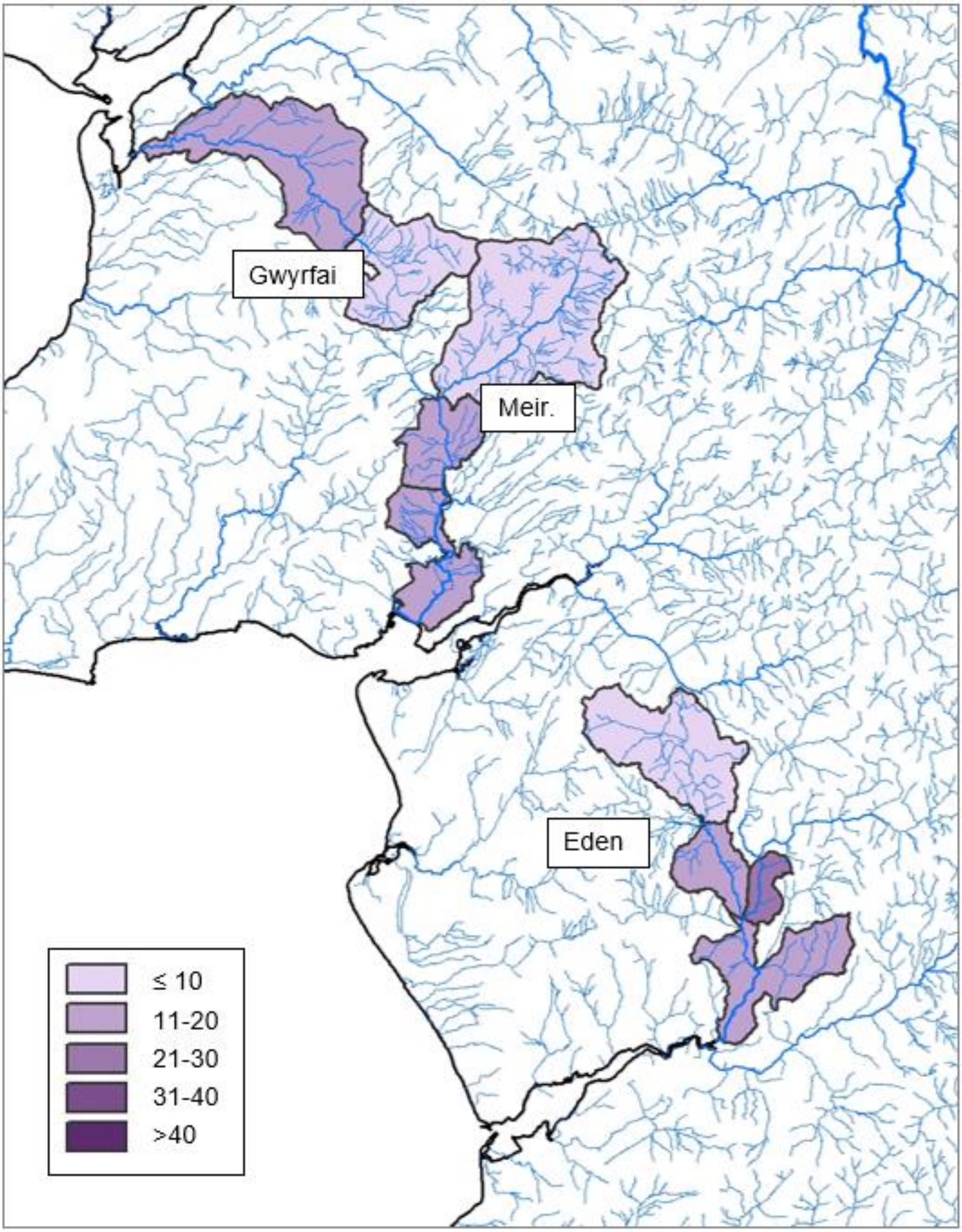


Figure 9. Map of phosphorus targets for the Afon Gwyrfai a Llyn Cwellyn, Afon Eden – Cors Goch Trawsfynydd and Meirionnydd Oakwoods SACs. All concentrations are annual means and growing season means in µg $l^{-1}$.

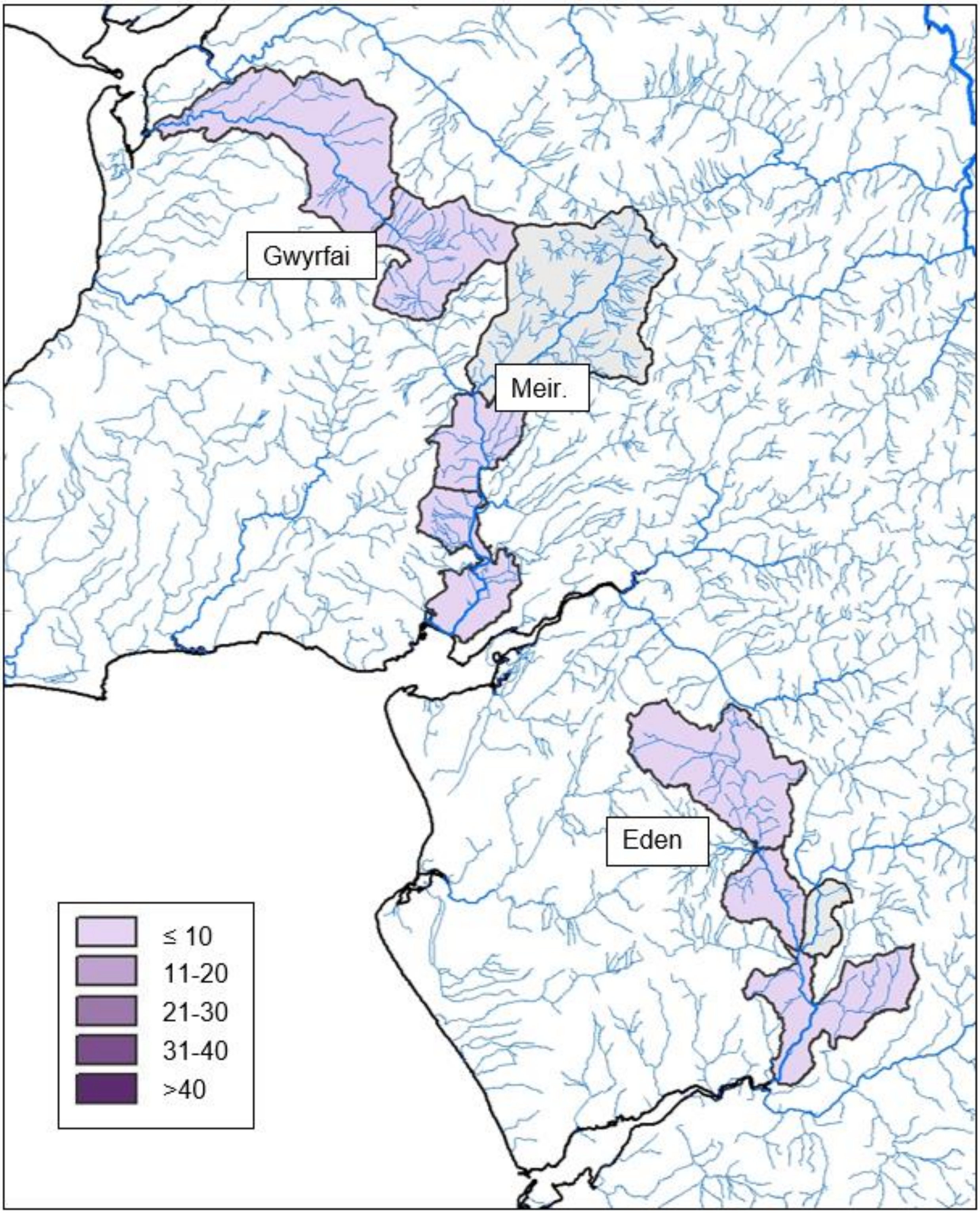


Figure 10. Annual mean orthophosphate concentrations in northwest Wales river SACs in µg $l^{-1}$. Greyed out water bodies could not be assessed due to lack of data.

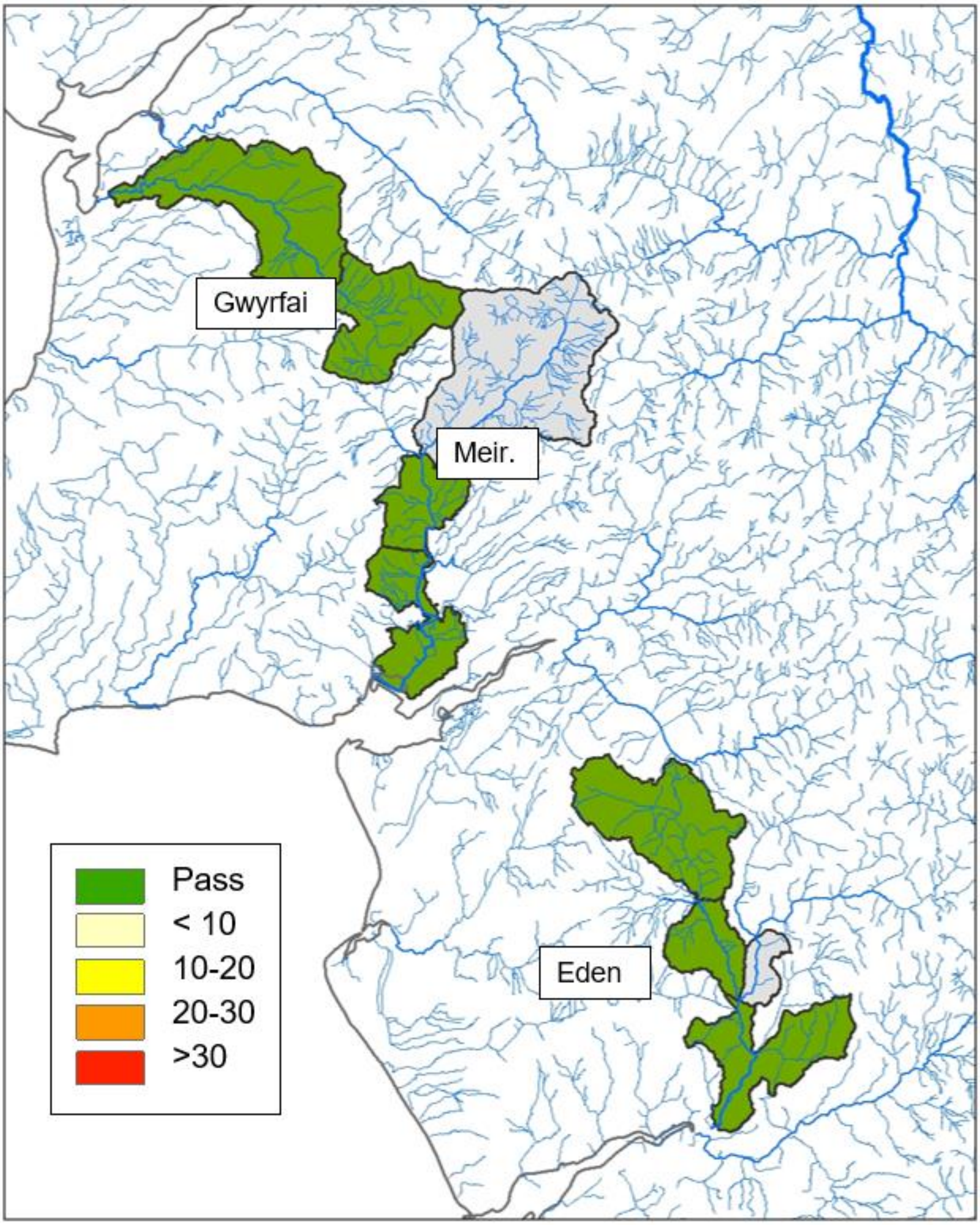


Figure 11. Phosphorus Compliance map for the Afon Gwyrfai a Llyn Cwellyn, Afon Eden and Meirionnydd Oakwoods SACs. Water bodies shaded green pass their target. Other colours fail the target with different colours representing the magnitude of failures in µg $l^{-1}$, expressed as the larger of annual means and growing season means. Greyed out water bodies could not be assessed due to lack of data.

| Waterbody ID | Waterbody Name | Sample Point | Target (µg $l^{-1}$) | N Samples | Annual Mean (µg $l^{-1}$) | Growing Season Mean (µg $l^{-1}$) | Assessment |
|---|---|---|---|---|---|---|---|
| GB110064054630 | Eden - upper | 29021 | 5 | 25 | 1 | 1 | Pass |
| GB110064048750 | Eden - lower | 20064 | 13 | 21 | 1 | 1 | Pass |
| GB110064048730 | Mawddach - middle | 20309 | 28 | 3 | - | - | Not Assessed |
| GB110064048710 | Mawddach - lower | 20003 | 13 | 28 | 1 | 1 | Pass |

Table 4. Phosphorus compliance for the Afon Eden – Cors Goch Trawsfynydd SAC.

| Waterbody ID | Waterbody Name | Sample Point | Target (µg $l^{-1}$) | N Samples | Annual Mean (µg $l^{-1}$) | Growing Season Mean (µg $l^{-1}$) | Assessment |
|---|---|---|---|---|---|---|---|
| GB110065054191 | Gwyrfai - upstream of Cwellyn | 22517 | 5 | 29 | 3 | 2 | Pass |
| GB110065054190 | Gwyrfai - downstream of Cwellyn | 22504 | 13 | 30 | 7 | 8 | Pass |

Table 5. Phosphorus compliance for the Afon Gwyrfai a Llyn Cwellyn SAC.

| Waterbody ID | Waterbody Name | Sample Point | Target (µg $l^{-1}$) | N Samples | Annual Mean (µg $l^{-1}$) | Growing Season Mean (µg $l^{-1}$) | Assessment |
|---|---|---|---|---|---|---|---|
| GB110065053860 | Glaslyn - tidal to Afon Croesor | 22808 | 19 | 10 | 8 | - | Pass |
| GB110065053910 | Glaslyn - Nanmor to Colwyn | 25553 | 13 | 30 | 2 | 3 | Pass |
| GB110065053960 | Glaslyn - upstream Colwyn | 25554 | 5 | 6 | - | - | Not Assessed |

Table 6. Phosphorus compliance for the Meirionnydd Oakwoods SAC.

## Afon Gwyrfai a Llyn Cwellyn

Afon Gwyrfai a Llyn Cwellyn is a small river SAC in Gwynedd with a base-poor geology. The river's source drains the flanks of Snowdon and the catchment includes a large natural lake, Llyn Cwellyn. Much of the catchment lies within the Snowdonia National Park and consists of semi-natural habitats, low intensity sheep farming, and forestry. Further downstream land use is more intensive. There are no major settlements within the catchment.

This SAC has not yet had its targets incorporated into the SAC management plan and this assessment should therefore be seen as draft.

Data are available for both of the water bodies in this small river. The datasets for the two water bodies assessed are good with 59 samples in total.

An additional sample point from near Waunfawr Sewage Treatment Works (STW) (55219 Waen STW) showed some concerning high values but inadequate data were available from this sample point to assess whether this constituted a wider pattern. This was due both to a small dataset and data being collected to insufficient resolution, thus preventing a mean being calculated. It is recommended that monitoring be reinstated at this sample point to determine whether this STW is causing a failure.

Both water bodies are passing both the growing season and the annual mean targets. Afon Gwyrfai a Llyn Cwellyn therefore **passes** its phosphorus target.

No outlier analysis was carried out because no water bodies are failing.

## Meirionnydd Oakwoods

This is a predominantly terrestrial SAC in northwest Wales. It includes three water bodies in the Afon Glaslyn. The uppermost water body overlaps only marginally with the site and although a draft target has been set, it may not be required.

Data are relatively limited from this site, with only one water body having a large dataset. Insufficient data were available for the Glaslyn – upstream Colwyn water body to make an assessment, and for the Glaslyn – Nanmor to Colwyn water body data were sufficient only to assess against the annual mean (Table 6).

Two water bodies on the Glaslyn passed their targets, and phosphorus concentrations were very low (Table 6). Improved evidence gathered using the very low method indicates that the LOD issue may have prevented NRW correctly following the target setting procedure in 2016 and therefore that the 'near natural' target may apply.

There are no phosphorus failures in the Meirionnydd Oakwoods SAC, which therefore **passes** its phosphorus target.

No outlier analysis was carried out because no water bodies are failing.

## Afon Teifi

Afon Teifi is a medium-sized river system straddling the boundaries of Ceredigion, Carmarthenshire and Pembrokeshire in south-west Wales, with a predominantly base-poor geology. The river rises on the western flanks of the Elenydd hills. Although mainly lowland in character, farming in the upper part of the catchment is mainly low to moderate intensity sheep and beef cattle, but farming is somewhat more intensive downstream. There are several small towns along the river including Lampeter, Newcastle Emlyn and Cardigan.

The targets shown here are published in the SAC Management Plan (NRW 2017b) and so are officially recognised. Targets for the Teifi are tighter in the upper part of the system and but include some less stringent values for several tributaries in the lower part of the system (Ceri, Cerdin, Tyweli and Clettwr) (Figure 12).

Data are available for most of the waterbodies on the Teifi (Table 7), but there is a significant gap for the main river water body 'Teifi – Afon Clettwr to Afon Ceri'. It is recommended that sampling at Henllan Bridge (34406) be reinstated to fill this gap. Most datasets have a large number of samples, but the Grannell and upper Teifi have relatively little data, resulting in insufficient data to assess compliance against growing season mean on the Grannell. Two sample points (34401 and 34408) were used to assess more than one water body.

Of the water bodies assessed in the Teifi, eight pass and eight fail. Two water bodies could not be assessed due to no (Talog) or inadequate (Brefi) data. With the exception of the Groes, the upper part of the Teifi is passing its phosphorus targets (Figure 14). In contrast, the lower part of the river is generally failing, despite targets in this area being significantly less stringent (albeit four of these failures on the Ceri and Lower Teifi are marginal). The river has also suffered from several significant pollution incidents such as those recorded in December 2016 and June 2017. Although not necessarily reflected in the phosphorus data, they indicate a general pollution problem in the lower Teifi.

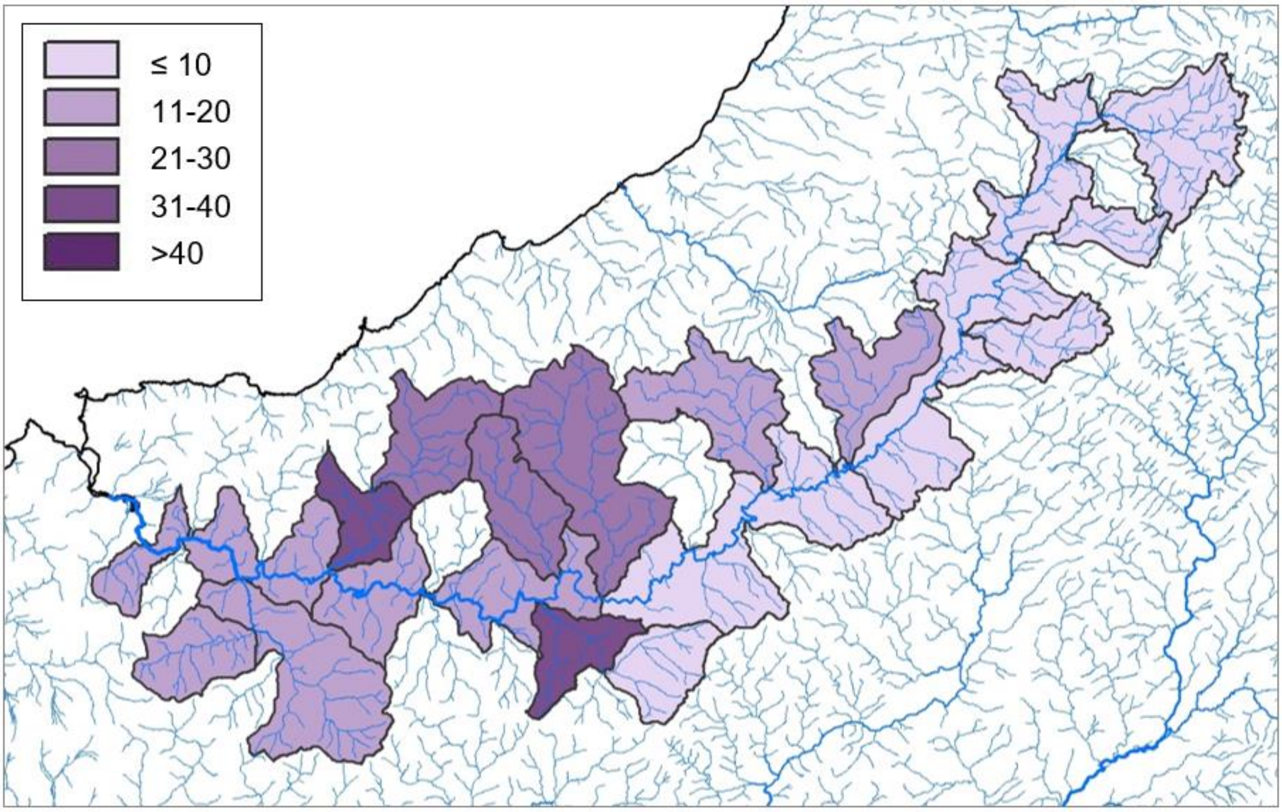


Figure 12. Map of phosphorus targets for Afon Teifi SAC. All concentrations are annual means and growing season means in µg $l^{-1}$.

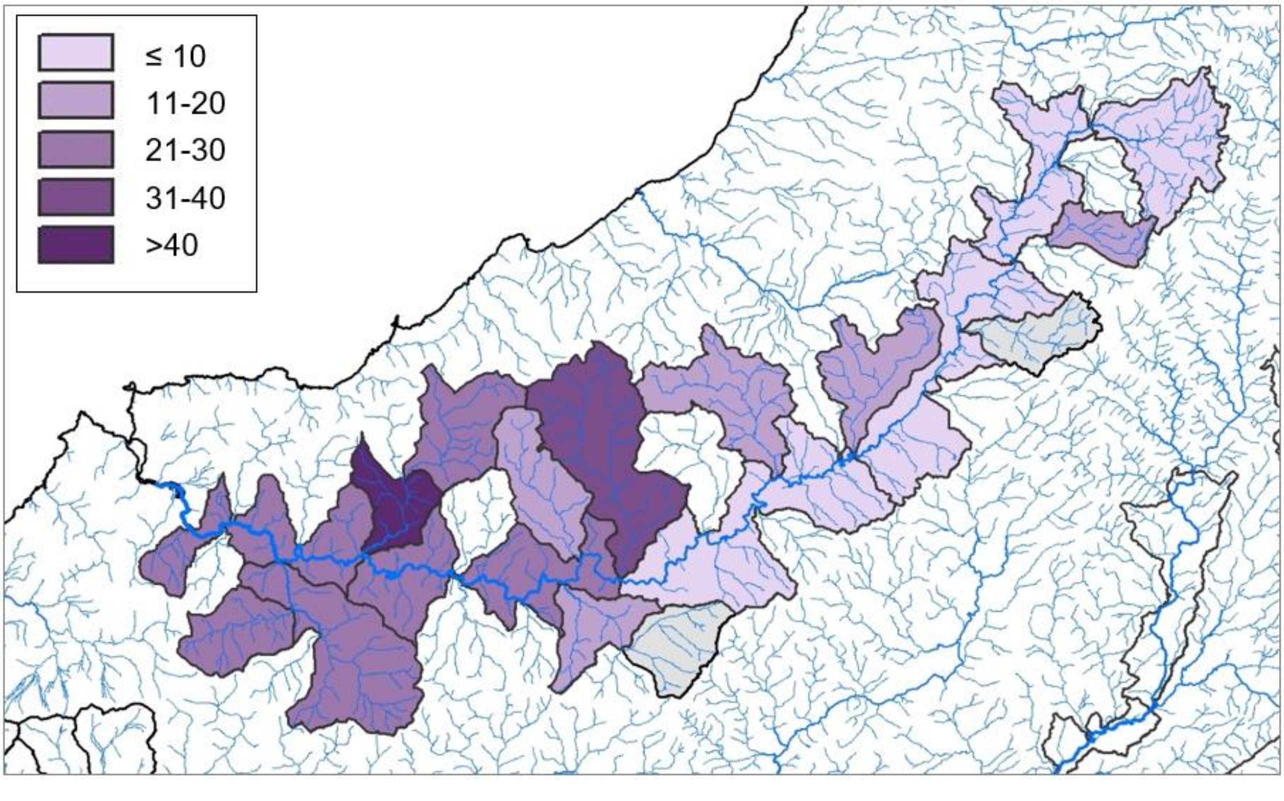


Figure 13. Annual mean orthophosphate concentrations in Afon Teifi SAC in µg $l^{-1}$. Greyed out water bodies could not be assessed due to lack of data.

All of the failing water bodies are in the lower catchment. Sensitivity testing indicated that all of these are sensitive to outlier values (Table 8). Nevertheless, the failures on the lower Teifi, Ceri, Clettwr and Cych were supported by co-occurrent elevated or outlier BOD and ammonia concentrations. On the Groes, there was no evidence of increased values for any other determinand and thus this failure is considered unconfirmed. All phosphorus failures on the Teifi were episodic.

There are **widespread** phosphorus failures in the lower Teifi catchment. The magnitude of these failures is **low**.

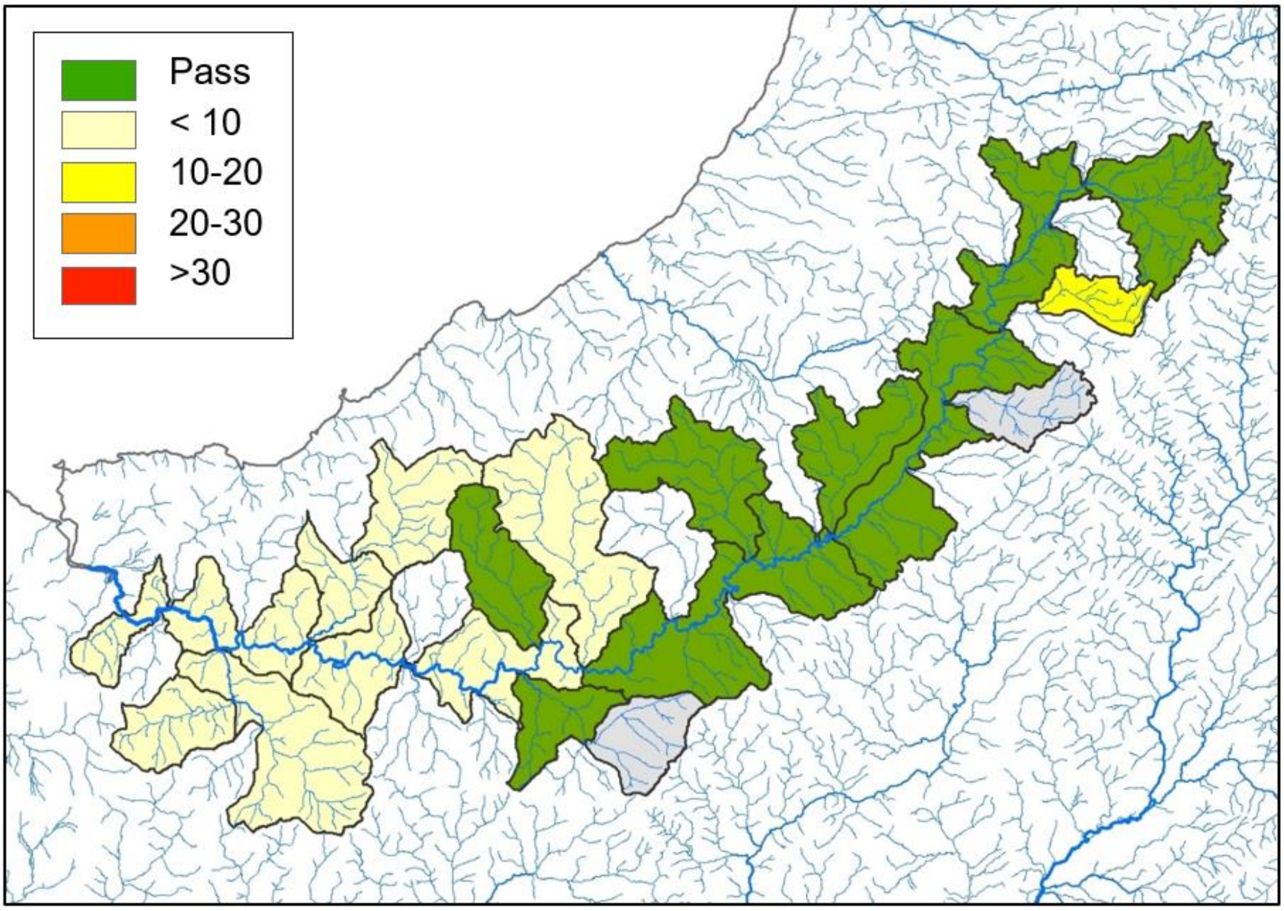


Figure 14. Map of phosphorus compliance for Afon Teifi SAC. Water bodies shaded green pass their target. Other colours fail the target with different colours representing the magnitude of failures in µg $l^{-1}$, expressed as the larger of annual means and growing season means. Greyed out water bodies could not be assessed due to lack of data.

| Waterbody ID | Waterbody Name | Sample Point | Target (µg $l^{-1}$) | N Samples | Annual Mean (µg $l^{-1}$) | Growing Season Mean (µg $l^{-1}$) | Result | Status |
|---|---|---|---|---|---|---|---|---|
| GB110062039020 | Tyweli - confluence with Talog to confluence with Teifi | 83003 | 34 | 27 | 19 | 20 | Pass | - |
| GB110062038980 | Talog - headwaters to confluence with Tyweli | 34198 | 10 | - | - | - | Not assessed | - |
| GB110062039230 | Grannell - headwaters to confluence with Teifi | 83007 | 20 | 9 | 16 | - | Pass | - |
| GB110062039140 | Cerdin - headwaters to confluence with Teifi | 34197 | 30 | 27 | 17 | 19 | Pass | - |
| GB110062039240 | Dulas - headwaters to conf Teifi | 83006 | 20 | 27 | 15 | 14 | Pass | - |
| GB110062043563 | Teifi - Afon Ceri to estuary | 34401 | 20 | 26 | $20^{X}$ | 19 | Fail | Confirmed |
| *GB110062043564* | *Teifi - Afon Clettwr to Afon Ceri** | *34401* | *20* | *26* | $20^{X}$ | *19* | *Fail* | - |
| GB110062039110 | Ceri - Dulas to conf Teifi | 34486 | 40 | 28 | 42 | 38 | Fail | Confirmed |
| GB110062039190 | Ceri - headwaters to conf Dulas | 34585 | 30 | 22 | 28 | 32 | Fail | Confirmed |
| GB110062039220 | Clettwr - headwaters to confluence with Teifi | 83009 | 30 | 24 | 32 | 35 | Fail | Confirmed |
| GB110062043490 | Groes - headwaters to confluence with Teifi | 89118 | 10 | 18 | 14 | 23 | Fail | Unconfirmed |
| *GB110062039010* | *Dulas - headwaters to confluence with Cych** | *34488* | *20* | *26* | *25* | *29* | *Fail* | - |
| GB110062039041 | Cych - headwaters to confluence with Teifi | 34488 | 20 | 26 | 25 | 29 | Fail | Confirmed |
| GB110062043565 | Teifi - Afon Dulas to Afon Clettwr | 34403 | 10 | 29 | 6 | 4 | Pass | - |
| GB110062043566 | Teifi - Afon Brennig to Afon Dulas | 34403 | 10 | 29 | 6 | 4 | Pass | - |
| GB110062039250 | Brefi - headwaters to confluence with Teifi | 87179 | 10 | 6 | - | - | Not Assessed | - |
| GB110062043501 | Teifi - conf Fflur to conf Brennig | 34407 | 10 | 26 | 4 | 5 | Pass | - |

| Waterbody ID | Waterbody Name | Sample Point | Target (μg $l^{-1}$) | N Samples | Annual Mean (μg $l^{-1}$) | Growing Season Mean (μg $l^{-1}$) | Result | Status |
|---|---|---|---|---|---|---|---|---|
| GB110062043540 | Teifi - headwaters to confluence with Meurig | 83010 | 10 | 33 | 6 | 9 | Pass | - |

Table 7. Phosphorus compliance for Afon Teifi. Asterisked water bodies were assessed using data from sample points in adjacent water bodies.

| Waterbody ID | Waterbody Name | Sample Point | Target (μg $l^{-1}$) | Median (μg $l^{-1}$) | Annual Mean (μg $l^{-1}$) | Outlier (μg $l^{-1}$) | Mean (Outlier Excluded) (μg $l^{-1}$) | BOD / N / $NH_3$ confirm outlier | Failure Type |
|---|---|---|---|---|---|---|---|---|---|
| GB110062043563 | Teifi - Afon Ceri to estuary | 34401 | 20 | 20 | 20 | 55 | 19 | <Q1 (N); >Q3 (BOD, $NH_3$) | Episodic |
| GB110062039110 | Ceri - Dulas to conf Teifi | 34486 | 40 | 36 | 42 | 151 | 38 | Outlier (BOD, $NH_3$); <Q1 (N) | Episodic |
| GB110062039190 | Ceri - headwaters to conf Dulas | 34585 | 30 | 24 | 28 | - | - | - | Episodic |
| GB110062039220 | Clettwr - headwaters to confluence with Teifi | 83009 | 30 | 25 | 32 | 119 | 28 | >Q3 (N); Outlier ($NH_3$) | Episodic |
| GB110062043490 | Groes - headwaters to confluence with Teifi | 89118 | 10 | 2 | 14 | 205 | 3 | No | Episodic |
| GB110062039041 | Cych - headwaters to confluence with Teifi | 34488 | 20 | 15 | 25 | 187 | 19 | Outlier (BOD, $NH_3$) | Episodic |

Table 8. Sensitivity Testing for Failing Water Bodies on the Afon Teifi SAC.

## Afon Tywi

The Tywi is a medium-sized river in south-west Wales that is particularly important for its migratory fish populations. The upper part of the catchment is low-intensity, base-poor geology supporting upland habitats and forestry, and contains a large artificial reservoir, Llyn Brianne, which regulates the river for abstraction lower in the catchment. Lower parts of the catchment are intensively farmed for dairy cattle. The river is highly active and notable for having an intact floodplain for much of the length of the SAC.

Only the mid and lower part of the Tywi is designated as a SAC, and this is divided into three relatively large water bodies (Figure 15). The uppermost water body overlaps with the SAC boundary only at its extreme lower end.

Data quality for two sample points is good, with 30 or more samples for each sample point. However, at sample point 31612, data quantity and detection limit were inadequate to assess the uppermost water body.

The two water bodies on the Tywi for which data are available comfortably pass their phosphate targets (Figure 16; Table 9).

There are **no** phosphorus failures in the Tywi.

No outlier analysis was carried out because no water bodies are failing.

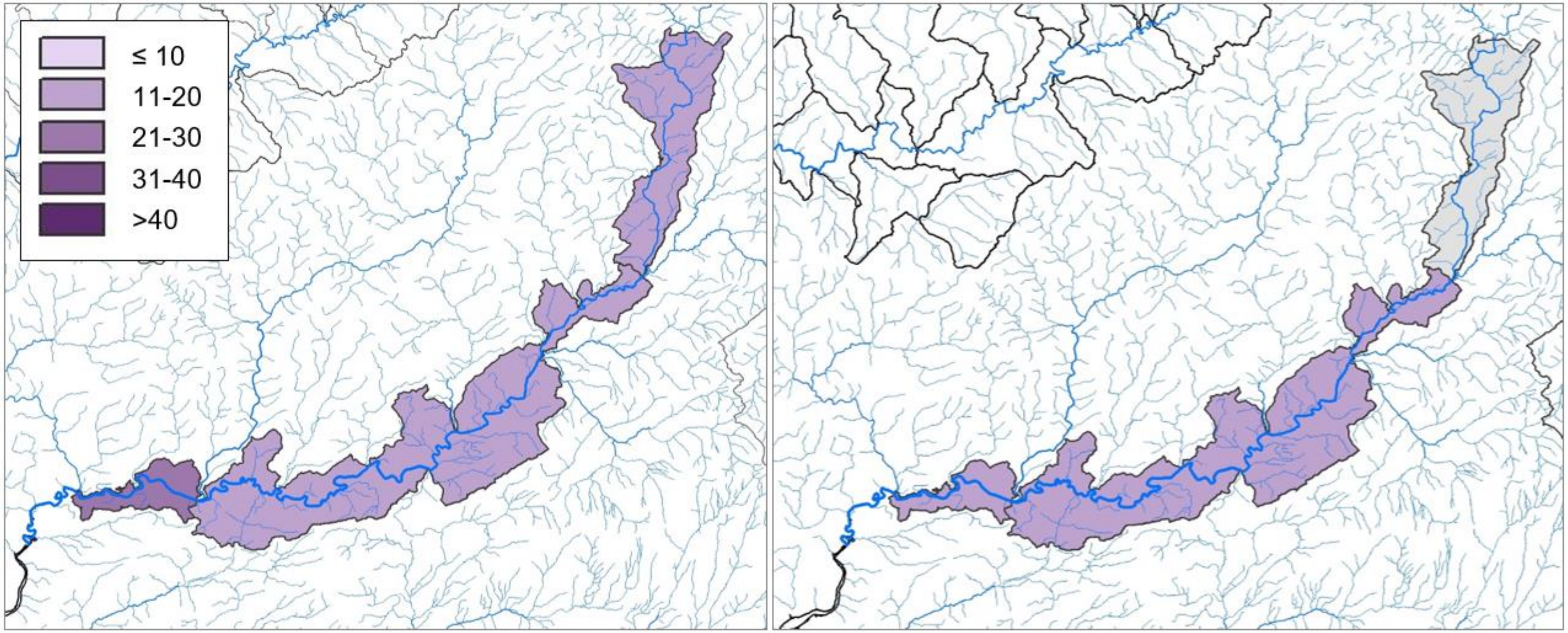


Figure 15. Map of phosphorus targets for Afon Tywi SAC (left) and results (right). All concentrations are annual means and growing season means in µg $l^{-1}$. Greyed out water bodies could not be assessed due to lack of data.

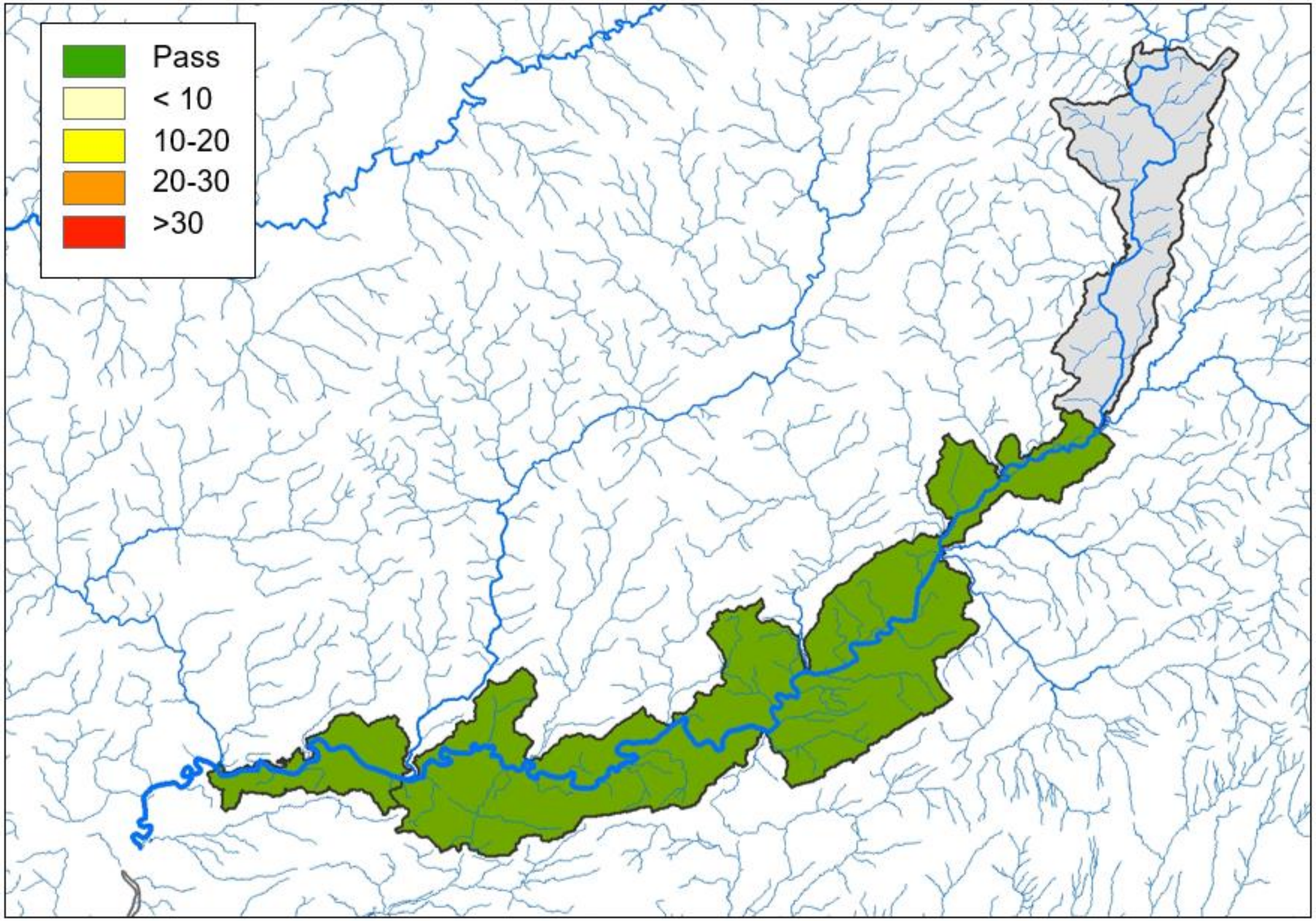


Figure 16. Map of phosphorus compliance for Afon Tywi SAC. Water bodies shaded green pass their target. Other colours fail the target with different colours representing the magnitude of failures in µg $l^{-1}$, expressed as the larger of annual means and growing season means. Greyed out water bodies could not be assessed due to lack of data.

| Waterbody ID | Waterbody Name | Sample Point | Target ($\mu g\ l^{-1}$) | N Samples | Annual Mean ($\mu g\ l^{-1}$) | Growing Season Mean ($\mu g\ l^{-1}$) | Assessment |
|---|---|---|---|---|---|---|---|
| GB110060029290 | Tywi - confluence with Cothi to spring tidal limit | 31601 | 21 | 31 | 10 | 9 | Pass |
| GB110060036350 | Tywi - conf with Doethie to conf with Llandovery Bran | 31612 | 13 | - | - | - | Not Assessed |
| GB110060036250 | Tywi (Llandovery Bran to Cothi confl) | 31616 | 20 | 30 | 13 | 13 | Pass |

Table 9. Phosphorus compliance for Afon Tywi SAC.

## Afonydd Cleddau

Afonydd Cleddau in Pembrokeshire consists of two adjacent systems discharging into the Milford Haven ria. Much of the catchment consists of intensive dairy farming. The SAC is covered by 19 water bodies, which have targets between 10 and 40 µg $l^{-1}$ (Figure 17; Table 10). The Eastern Cleddau is regulated by two reservoirs, but the Western Cleddau has more or less natural flows.

Targets in Afonydd Cleddau have been updated in the SAC Core Management Plan.

Data are available to assess 19 water bodies, with two in the upper Western Cleddau and one in the lower Eastern Cleddau assessed as unknown due to a lack of sampling data. Inspection of older data from these sites (pre-2014) indicates that it is unlikely that these water bodies are passing their targets, but further sampling is required to confirm this.

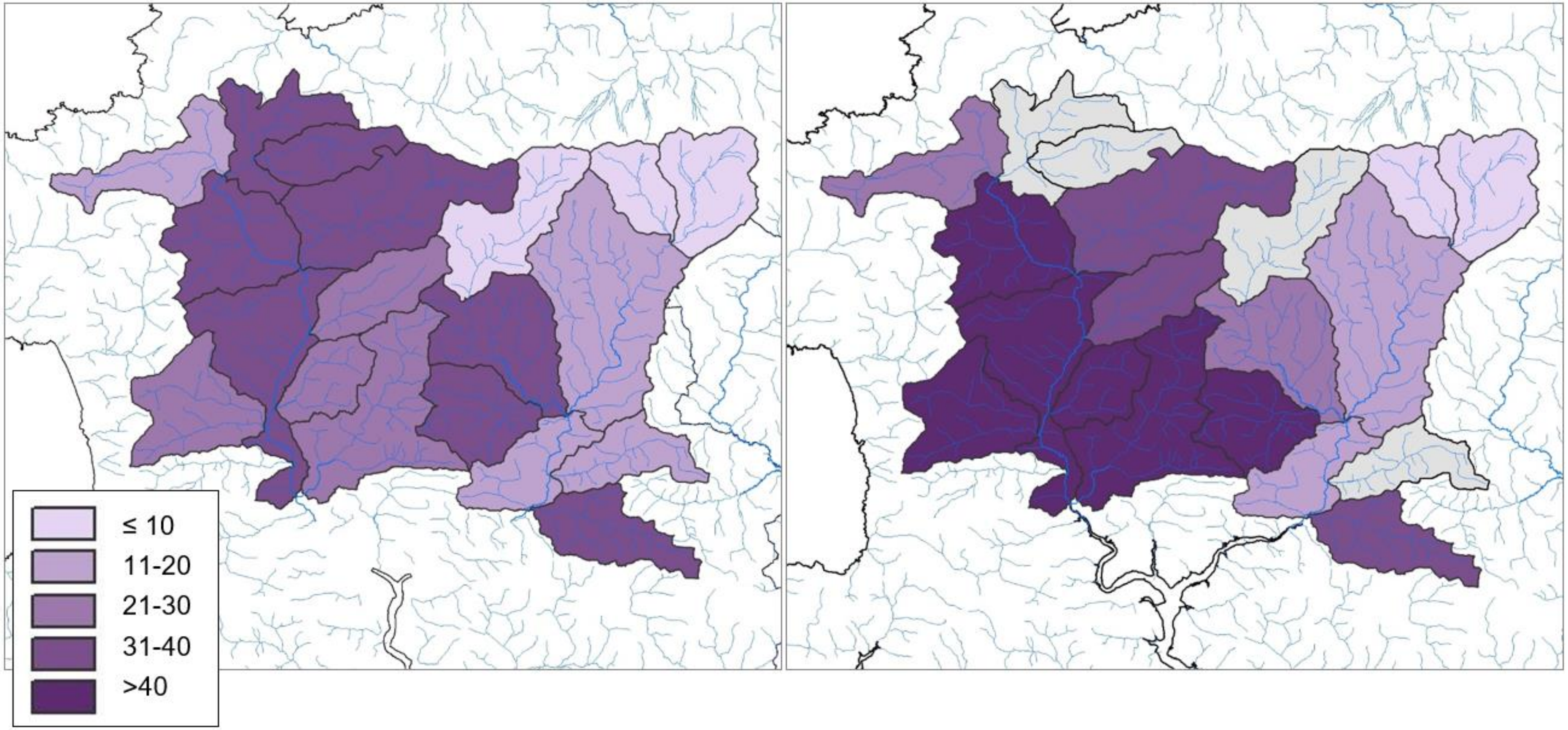


Figure 17. Map of phosphorus targets (left) and annual mean concentrations (right) for Afonydd Cleddau SAC. All concentrations are annual means and growing season means in µg l$^{-1}$. Greyed out water bodies could not be assessed due to lack of data.

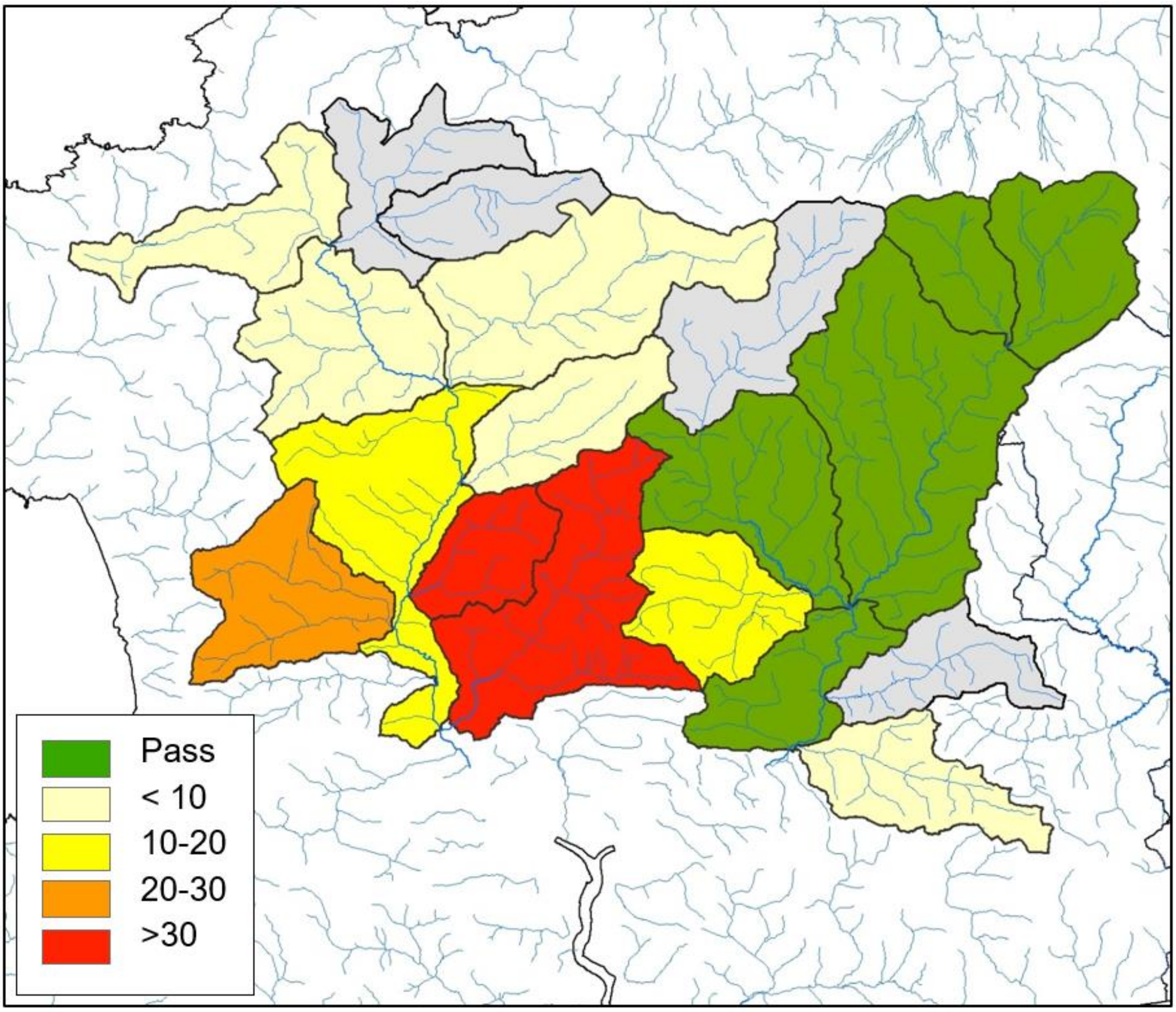


Figure 18. Map of phosphorus compliance for Afonydd Cleddau SAC. Water bodies shaded green pass their target. Other colours fail the target with different colours representing the magnitude of failures in µg $l^{-1}$, expressed as the larger of annual means and growing season means. Greyed out water bodies could not be assessed due to lack of data.

On the Western Cleddau, none of the ten water bodies passed its phosphorus target, with eight failures and two not assessed. Five of these failures were consistent, reflecting generally high phosphorus concentrations in the catchment. On the Eastern Cleddau the situation was better, with five water bodies passing, two failing and two not assessed. In contrast to the Western Cleddau, failures on the Eastern Cleddau were episodic in nature.

All of the failures were confirmed (Table 10), with both consistent and episodic failures (Table 11).

There are **extensive** phosphorus failures on the Afonydd Cleddau SAC, including failures in every water body of the Western Cleddau. The magnitude of these failures ranges from **Low** to **High**, with high magnitude failures occurring in the lower tributaries (Camrose Brook, Rudbaxton Water, Narbeth Brook and Deepford Brook).

Further investigation into the lower magnitude failures is required. Possible action could include improvements to land management practices and river / riparian habitat restoration. The higher magnitude failures are suggestive of point source pollution from failing infrastructure.

In the light of the extent and magnitude of many of these failures, it is recommended that a special project be initiated on the Cleddau rivers to reduce phosphorus concentrations in the river, with particular focus on the Western Cleddau.

| Waterbody ID | Waterbody Name | Sample Point | Target ($\mu g\ l^{-1}$) | N Samples | Annual Mean ($\mu g\ l^{-1}$) | Growing Season Mean ($\mu g\ l^{-1}$) | Assessment | Status |
|---|---|---|---|---|---|---|---|---|
| Western Cleddau | | | | | | | | |
| GB110061038670 | W Cleddau - headwaters to conf with Cleddau North | 83786 | 15 | 24 | 23 | 17 | Fail | Confirmed |
| GB110061038660 | Nant y Bugail - headwaters to conf with Cleddau N. | Sample Point Needed | 40 | - | - | - | Not Assessed | - |
| GB110061038680 | Cleddau North - H'waters to conf with W. Cled | Sample Point Needed | 40 | - | - | - | Not Assessed | - |
| GB110061038651 | Western Cleddau - Cleddau North to Anghof conf | 85017 | 40 | 26 | 42 | 44 | Fail | Confirmed |
| GB110061038690 | Anghof - headwaters to conf with Western Cleddau | 85003 | 37 | 28 | 36 | 38 | Fail | Confirmed |
| GB110061031340 | W Cleddau - Anghof conf to Cartlett Brook conf | 32803, 32804 | 40 | 20 | 49 | 52 | Fail | Confirmed |
| GB110061031350 | Spittal Brook - headwaters to conf with W. Cleddau | 85004 | 30 | 21 | 32 | 38 | Fail | Confirmed |
| GB110061031180 | Camrose Brook - headwaters to conf with W. Cleddau | 85006 | 30 | 28 | 48 | 55 | Fail | Confirmed |
| GB110061031190 | Rudbaxton Water - HW to conf with W. Cleddau | 85035 | 30 | 21 | 79 | 105 | Fail | Confirmed |
| GB110061031330 | Cartlett Brook - HW to conf with W. Cleddau | 85008 | 30 | 29 | 76 | 88 | Fail | Confirmed |
| Eastern Cleddau | | | | | | | | |
| GB110061038320 | Eastern Cleddau - headwaters to conf with Wern | 32498 | 10 | 17 | 3 | 4 | Pass | - |
| GB110061038310 | Wern - headwaters to conf with Eastern Cleddau | 32496 | 10 | 26 | 3 | 3 | Pass | - |

| Waterbody ID | Waterbody Name | Sample Point | Target (μg l$^{-1}$) | N Samples | Annual Mean (μg l$^{-1}$) | Growing Season Mean (μg l$^{-1}$) | Assessment | Status |
|---|---|---|---|---|---|---|---|---|
| GB110061038290 | E. Cleddau - conf with Wern to conf with Syfynwy | 32495 | 15 | 26 | 11 | 12 | Pass | - |
| GB110061038300 | Syfynwy - headwaters to Llys-y-fran | Sample Point Needed | 10 | - | - | - | Not Assessed | - |
| GB110061030700 | Syfynwy - Llys-y-fran to conf with E Cleddau | 32406 | 39 | 13 | 24 | - | Pass | - |
| GB110061030670 | Eastern Cleddau - conf with Syfynwy to tidal limit | 88181 | 20 | 26 | 14 | 13 | Pass | - |
| GB110061030680 | Longford Brook - HW to conf with E. Cleddau | Sample point needed | 20 | - | - | - | Not Assessed | - |
| GB110061030660 | Narbeth Brook - headwaters to conf with E. Cleddau | 32407 | 34 | 19 | 35 | 40 | Fail | Confirmed |
| GB110061030690 | Deepford Brook - headwaters to conf with Syfynwy | 86005 | 39 | 28 | 44 | 50 | Fail | Confirmed |

Table 10. Phosphorus compliance for Afonydd Cleddau SAC.

| Waterbody ID | Waterbody Name | Sample Point | Target (µg l-1) | Median (µg l-1) | Annual Mean (µg l-1) | Largest Outlier (µg l-1) | Mean Excluding Outlier (µg l-1) | BOD / N / $NH_3$ confirm outlier | Failure Type |
|---|---|---|---|---|---|---|---|---|---|
| GB110061038670 | W Cleddau - headwaters to conf with Cleddau North | 83786 | 15 | 17 | 23 | 93 | - | - | Consistent |
| GB110061038651 | Western Cleddau - Cleddau North to Anghof conf | 85017 | 40 | 36 | 42 | 109 | 40 | Outlier (BOD); <Q1 (N); >Q3 ($NH_3$) | Episodic |
| GB110061038690 | Anghof - headwaters to conf with Western Cleddau | 85003 | 37 | 33 | 36 | - | - | - | Episodic |
| GB110061031340 | W Cleddau - Anghof conf to Cartlett Brook conf | 32803, 32804 | 40 | 44, 39 | 49 | 115 (32804) | - | - | Consistent |
| GB110061031350 | Spittal Brook - headwaters to conf with W. Cleddau | 85004 | 30 | 24 | 32 | 162 | 26 | Outlier (BOD, $NH_3$); <Q1 (N) | Episodic |
| GB110061031180 | Camrose Brook - headwaters to conf with W. Cleddau | 85006 | 30 | 41 | 48 | - | - | - | Consistent |
| GB110061031190 | Rudbaxton Water - HW to conf with W. Cleddau | 85035 | 30 | 57 | 79 | 399 | - | - | Consistent |
| GB110061031330 | Cartlett Brook - HW to conf with W. Cleddau | 85008 | 30 | 76 | 76 | - | - | - | Consistent |
| GB110061030660 | Narbeth Brook - headwaters to conf with E. Cleddau | 32407 | 34 | 29 | 35 | 83 | 32 | Outlier (BOD, $NH_3$) | Episodic |
| GB110061030690 | Deepford Brook - headwaters to conf with Syfynwy | 86005 | 39 | 36 | 44 | - | - | - | Episodic |

Table 11. Sensitivity Testing for Failing Water Bodies on the Afonydd Cleddau SAC.

## River Usk

The Usk is a medium-sized catchment in southeast Wales with a primarily sandstone geology. It frequently carries heavy sediment loads after rainfall. A number of reservoirs in the upper catchment modify the river flow. The SAC consists of 23 water bodies including many of the river's tributaries. Targets have not been incorporated in the SAC management plan and should be seen as draft; they fall in the range from 10 µg $l^{-1}$ in the headwaters to 50 µg $l^{-1}$ in the middle to lower river (Figure 19; Table 12).

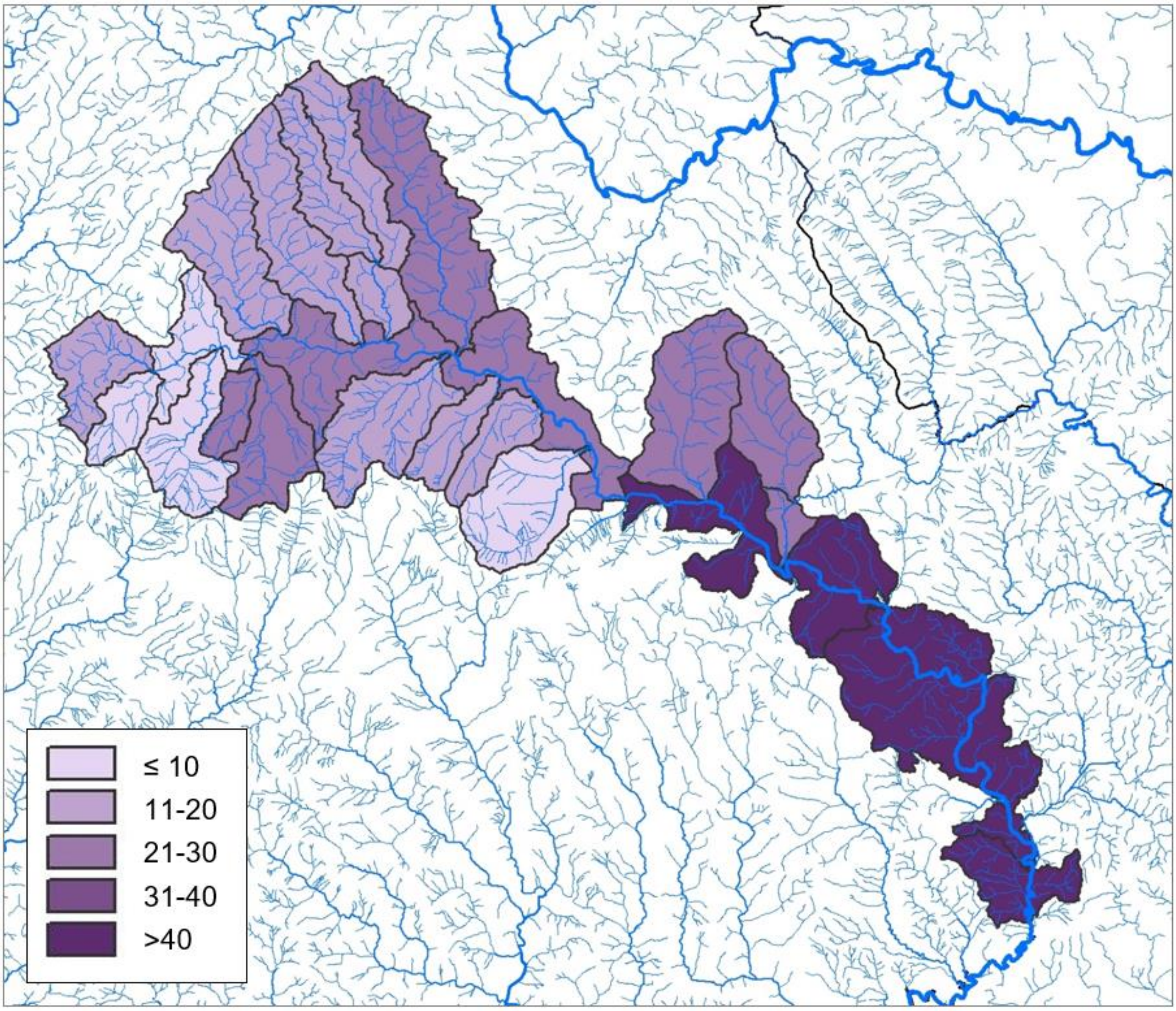


Figure 19. Map of phosphorus targets in the River Usk SAC. All concentrations are annual means and growing season means in µg $l^{-1}$.

Data availability for the Usk is moderately good with most sample points having 20 or more readings, allowing acceptable estimates of mean values. However, attention is required to the monitoring network, as the status of five water bodies could not be assessed due to a lack of data. This is a particular problem in the Yscir where none of the three water bodies could be assessed, but also applies to the Grwyne Fechan and Cynrig. The configuration of sample points in the Senni also requires addressing so that the Senni and its tributary the Cwm Treweryn can be assessed separately.

The lack of data in some parts of the Usk may also have affected target setting, and it is therefore recommended that the targets in water bodies where there is little or no phosphorus data are reviewed after three years of monitoring and tightened if necessary.

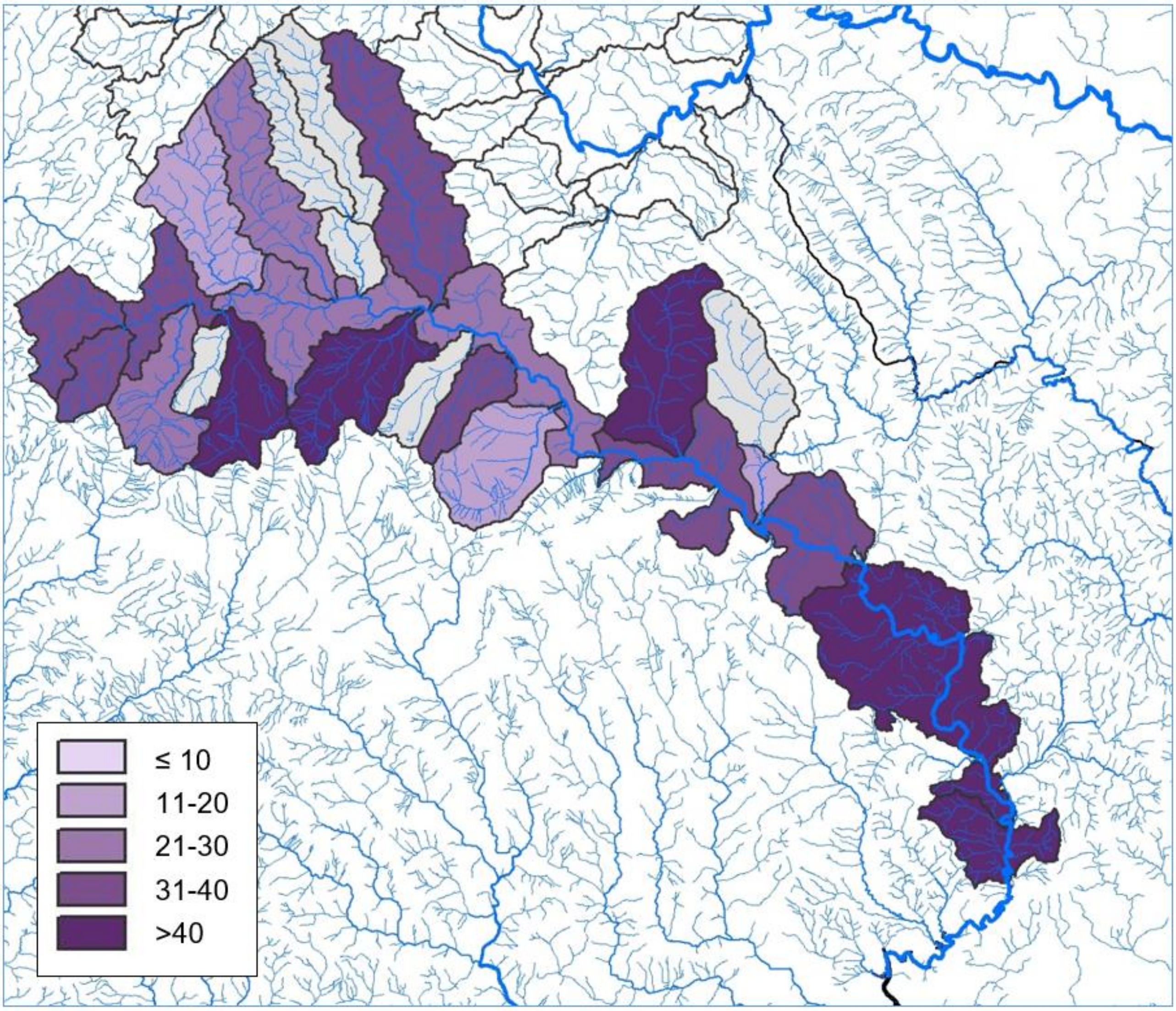


Figure 20. Map showing annual mean phosphorus concentrations (µg $l^{-1}$) in the River Usk. Greyed out water bodies could not be assessed due to lack of data.

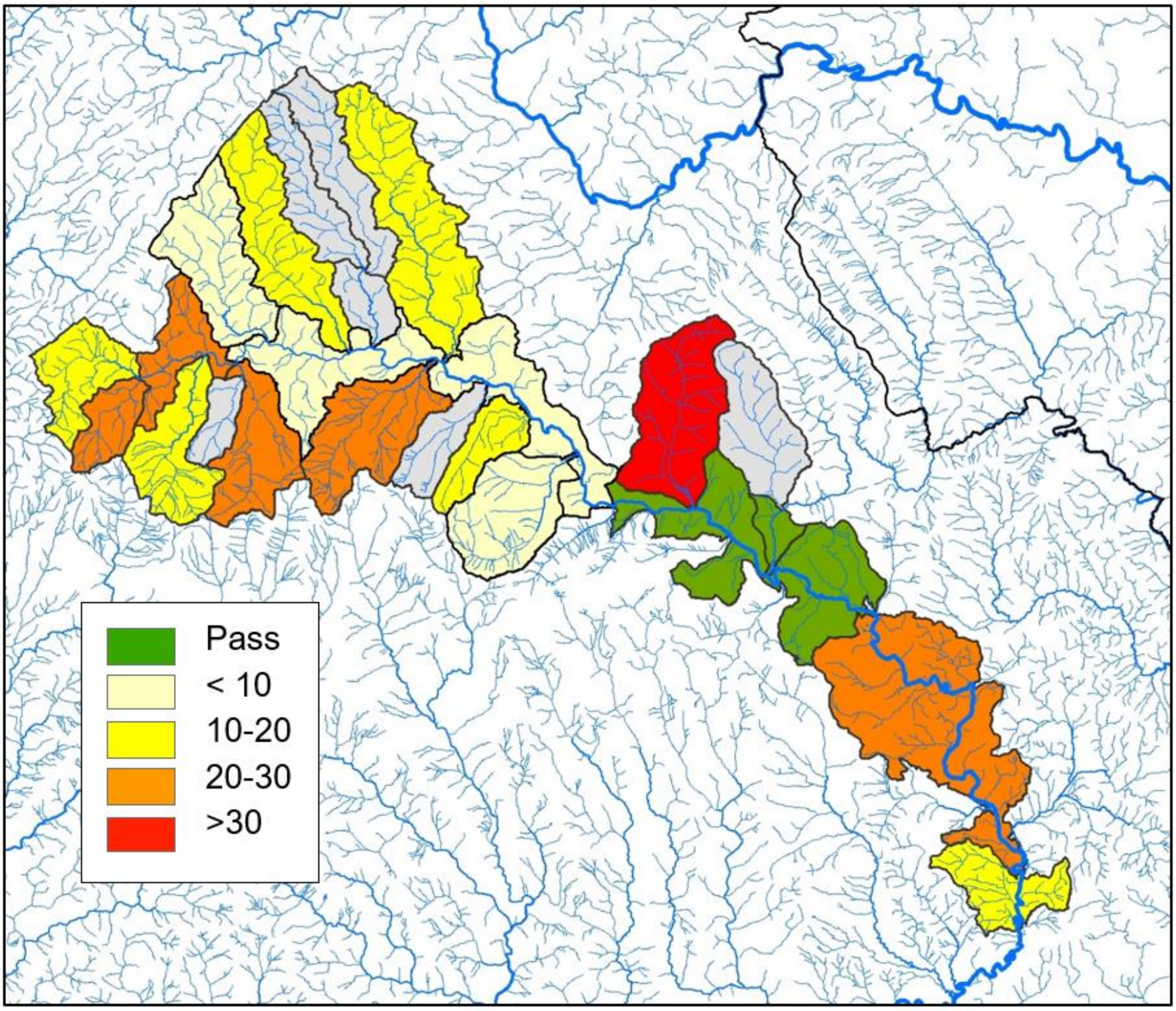


Figure 21. Compliance against phosphorus targets in the River Usk SAC. Water bodies shaded green pass their target. Other colours fail the target with different colours representing the magnitude of failures in µg $l^{-1}$, expressed as the larger of annual means and growing season means.

Compliance data shows the Usk to be in poor condition with respect to phosphorus targets, with widespread failures often of large magnitude (Figure 21). Phosphorus concentrations in the river are also relatively high in absolute terms (Figure 20). Seven water bodies had an episodic pattern of failures and eight a consistent pattern: consistent failures occurred predominantly in the main stem of the river. All of the failures were confirmed although the evidence supporting the failures in the Caerfanell and Cilieni is rather weak (Table 13).

The tributary with the largest failure is the Rhiangoll where a single very high reading of 3110 µg $l^{-1}$ on 11/4/2017 – by far the single highest value recorded in the dataset - is the cause of the failure (without this reading the mean was 23 µg $l^{-1}$ which is within the target). This sample also recorded high BOD and ammonia values of 10.7 ATU and 3.46 mg $l^{-1}$ respectively, suggesting a significant pollution event.

Only two water bodies, both in the middle Usk met their SAC targets (Figure 19; Table 12).

| Waterbody ID | Waterbody Name | Sample Point | Target (µg l-1) | N Samples | Annual Mean (µg l-1) | Growing Season Mean (µg l-1) | Assessment | Status |
|---|---|---|---|---|---|---|---|---|
| GB109056039970 | Usk - source to conf Afon Hydfer | 40866 | 15 | 29 | 31 | 30 | Fail | Confirmed |
| GB109056033030 | Afon Hydfer - source to conf R Usk | 40865 | 10 | 10 | 30 | - | Fail | Confirmed |
| GB109056039980 | Usk - conf Afon Hydfer to conf Afon Senni | 40870 | 10 | 27 | 34 | 26 | Fail | Confirmed |
| GB109056033040 | Cwm Treweryn - source to River Senni | Required | 25 | - | - | - | Not Assessed | - |
| GB109056033050 | Senni - source to conf River Usk | 40879 | 25 | 26 | 48 | 19 | Fail | Confirmed |
| GB109056033080 | Afon Crai - source to conf R Usk | 40875 | 10 | 22 | 24 | 26 | Fail | Confirmed |
| GB109056040030 | Cilieni - source to conf R Usk | 40885 | 15 | 28 | 14 | 16 | Fail | Confirmed |
| GB109056040050 | Yscir Fechan - source to conf Afon Yscir | 41575 | 18 | - | - | - | Not Assessed | - |
| GB109056040070 | Afon Yscir - source to conf Yscir Fechan | Required | 18 | - | - | - | Not Assessed | - |
| GB109056040020 | Afon Yscir - conf Yscir Fechan to conf R Usk | 40895 | 18 | - | - | - | Not Assessed | - |
| GB109056040081 | Usk - conf Afon Senni to conf Afon Crawnon | 40914 | 25 | 28 | 30 | 34 | Fail | Confirmed |
| GB109056040060 | Honddu - source to conf R Usk | 40899 | 25 | 29 | 33 | 36 | Fail | Confirmed |
| GB109056040082 | Usk conf Afon Crawnon to conf Gavenny R | 40950 | 50 | 26 | 30 | 36 | Pass | - |
| GB109056033070 | Afon Tarell - source to conf R Usk | 40897 | 20 | 26 | 42 | 43 | Fail | Confirmed |
| GB109056033020 | Afon Cynrig - source to conf R Usk | 40903 | 15 | 0 | - | - | Not Assessed | - |
| GB109056032980 | Grwyne Fawr - conf Grwyne-Fechan to conf R Usk | 40937 | 28 | 26 | 16 | 18 | Pass | - |
| *GB109056039960* | *Grwyne-Fechan - source to conf Grwyne Fawr* | Required | 28 | - | - | - | Not Assessed | - |
| GB109056033000 | Caerfanell - source to conf R Usk | 40917 | 10 | 23 | 12 | 14 | Fail | Confirmed |
| GB109056039990 | Rhiangoll - source to conf R Usk | 40926 | 30 | 18 | 195 | 336 | Fail | Confirmed |
| GB109056040040 | Nant Bran - source to conf R Usk | 40893 | 15 | 22 | 28 | 19 | Fail | Confirmed |

| Waterbody ID | Waterbody Name | Sample Point | Target (µg $l^{-1}$) | N Samples | Annual Mean (µg $l^{-1}$) | Growing Season Mean (µg $l^{-1}$) | Assessment | Status |
|---|---|---|---|---|---|---|---|---|
| GB109056033010 | Nant Menasgin - source to conf R Usk | 40913 | 15 | 18 | 31 | 26 | Fail | Confirmed |
| GB109056040083 | Usk - conf R Gavenny to conf Olway Bk | 40970 | 50 | 34 | 70 | 73 | Fail | Confirmed |
| GB109056026890 | Usk - conf Olway Bk to New Br | 41000 | 50 | 34 | 64 | 65 | Fail | Confirmed |

Table 12. Phosphorus compliance for the River Usk SAC.

| Waterbody ID | Waterbody Name | Sample Point | Target (µg $l^{-1}$) | Median (µg $l^{-1}$) | Annual Mean (µg $l^{-1}$) | Largest Outlier (µg $l^{-1}$) | Mean Excluding Outlier (µg $l^{-1}$) | BOD / N / $NH_3$ confirm outlier | Failure Type |
|---|---|---|---|---|---|---|---|---|---|
| GB109056039970 | Usk - source to conf Afon Hydfer | 40866 | 15 | 8 | 31 | - | - | - | Episodic |
| GB109056033030 | Afon Hydfer - source to conf R Usk | 40865 | 10 | 24 | 30 | - | - | - | Consistent |
| GB109056039980 | Usk - conf Afon Hydfer to conf Afon Senni | 40870 | 10 | 22 | 34 | 210 | - | - | Consistent |
| GB109056033050 | Senni - source to conf River Usk | 40879 | 25 | 20 | 48 | 690 | 22 | Outlier (BOD, $NH_3$); Q3 (N) | Episodic |
| GB109056033080 | Afon Crai - source to conf R Usk | 40875 | 10 | 21 | 24 | 68 | - | - | Consistent |
| GB109056040030 | Cilieni - source to conf R Usk | 40885 | 15 | 13 | 14 | 40 | 13 | >Q3 (BOD) | Episodic |
| GB109056040081 | Usk - conf Afon Senni to conf Afon Crawnon | 40914 | 25 | 26 | 30 | 78 | - | - | Consistent |
| GB109056040060 | Honddu - source to conf R Usk | 40899 | 25 | 24 | 33 | - | - | - | Episodic |
| GB109056033070 | Afon Tarell - source to conf R Usk | 40897 | 20 | 24 | 42 | 156 | - | - | Consistent |
| GB109056033000 | Caerfanell - source to conf R Usk | 40917 | 10 | 4 | 12 | 124 | 7 | <Q1 (BOD); >Q3 ($NH_3$) | Episodic |
| GB109056039990 | Rhiangoll - source to conf R Usk | 40926 | 30 | 23 | 195 | 3110 | 24 | Outlier (BOD, $NH_3$) | Episodic |
| GB109056040040 | Nant Bran - source to conf R Usk | 40893 | 15 | 12 | 28 | 239 | 18 | - | Episodic |
| GB109056033010 | Nant Menasgin - source to conf R Usk | 40913 | 15 | 21 | 31 | 173 | - | - | Consistent |
| GB109056040083 | Usk - conf R Gavenny to conf Olway Bk | 40970 | 50 | 59 | 70 | 217 | - | - | Consistent |
| GB109056026890 | Usk - conf Olway Bk to New Br | 41000 | 50 | 59 | 64 | - | - | - | Consistent |

Table 13. Sensitivity Testing for Failing Water Bodies on the River Usk SAC.

## River Wye

The Wye is the largest Welsh SAC river, with a catchment covering much of southern Powys and part of the Brecon Beacons National Park before crossing the border into England near Hay-on-Wye. It is divided into 43 water bodies in Wales, with two water bodies straddling the border. There are an additional three water bodies entirely in England, and the river re-enters Wales near Monmouth where it forms the border with England. The river is regulated by the Elan Valley Reservoirs for abstraction to the Forest of Dean and at Monmouth.

Targets for the river were incorporated into the SAC management plan in 2017 (NRW 2017c), and range from 10 µg $l^{-1}$ in headwater areas increasing progressively downstream to 50 µg $l^{-1}$ in the more nutrient-enriched English sections. The highest target in Wales is 39 µg $l^{-1}$ (Figure 22; Table 14).

The management plan update erroneously omitted the 'Wye - conf Afon Tarenig to conf Afon Bidno' water body target. This water body has been assessed here using the Near Natural target for its type. Additionally, an assessment has been carried out for Welsh parts of the cross-border water body 'Wye - Scithwen Bk to Bredwardine Br' as approximately 22km of this lies within Wales. The near natural target has been applied here in line with CSM guidance. Targets for these two water bodies should be viewed as draft, and the Wye Core Management Plan updated accordingly.

Much of the Upper Wye catchment is rural and until recently has been predominantly farmed for sheep and beef cattle. More recently there has been a rapid expansion of poultry units, which has been the source of considerable public concern.

Comparison of phosphorus concentrations in the Wye against targets indicate widespread failures, some of them large in magnitude (Table 14; Figure 24). Fourteen water bodies passed their targets, 28 failed and three were unknown (Table 14). Water bodies achieving their orthophosphate targets were in the Upper Wye above Rhayader, about half of the Ithon, and two water bodies in the Irfon. All of the middle Wye tributaries, the remaining Irfon and Ithon and the Llynfi failed their targets (Figure 24). The largest failures were the Wye near Newbridge, the Cammarch, Clettwr Brook, Mithil Brook, lower Irfon, Garth Dulas and the three water bodies in the Llynfi catchment. Both consistent and episodic failures were identified (Table 15).

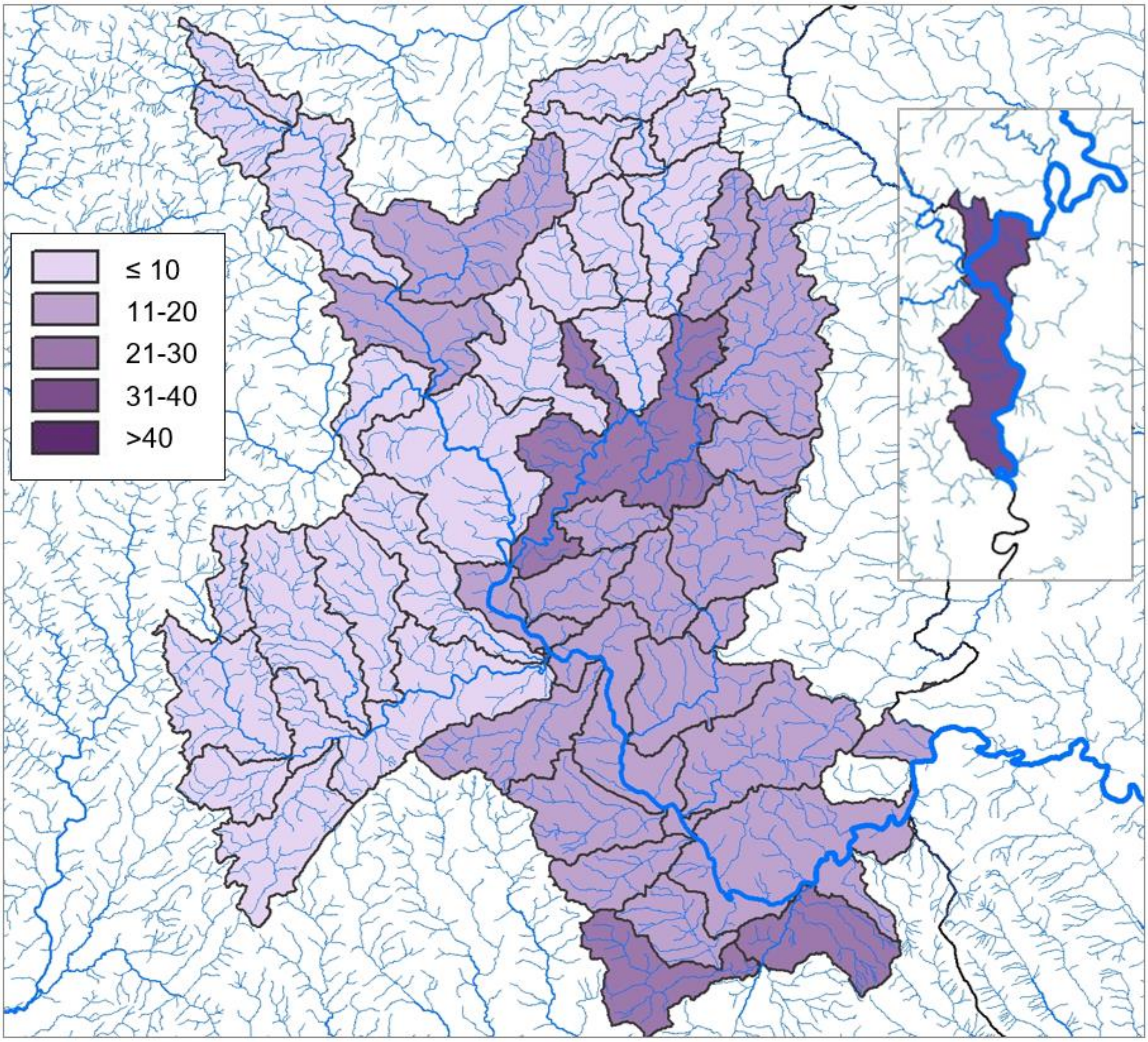


Figure 22. Map of phosphorus targets for the River Wye SAC. All concentrations are annual means and growing season means in µg $l^{-1}$. Inset shows the Wye – Walford Brook to Bigsweir water body in the lower Wye. Cross-border water bodies have been cropped to the Welsh border.

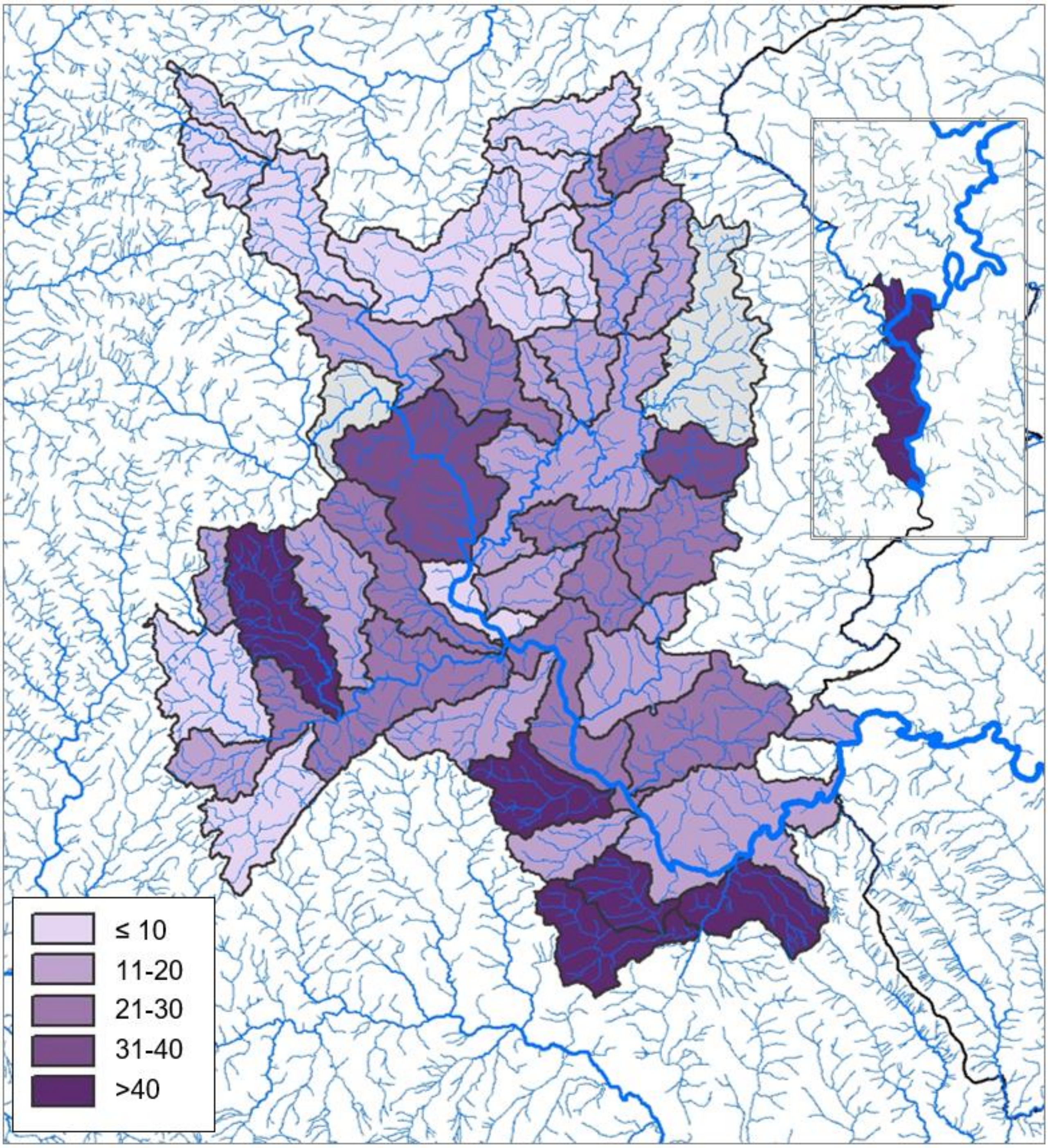


Figure 23. Map of annual mean phosphorus concentrations (µg $l^{-1}$) in the Upper Wye. Inset shows the Wye – Walford Brook to Bigsweir water body in the lower Wye. Cross-border water bodies have been cropped to the Welsh border. Greyed out water bodies could not be assessed due to lack of data.

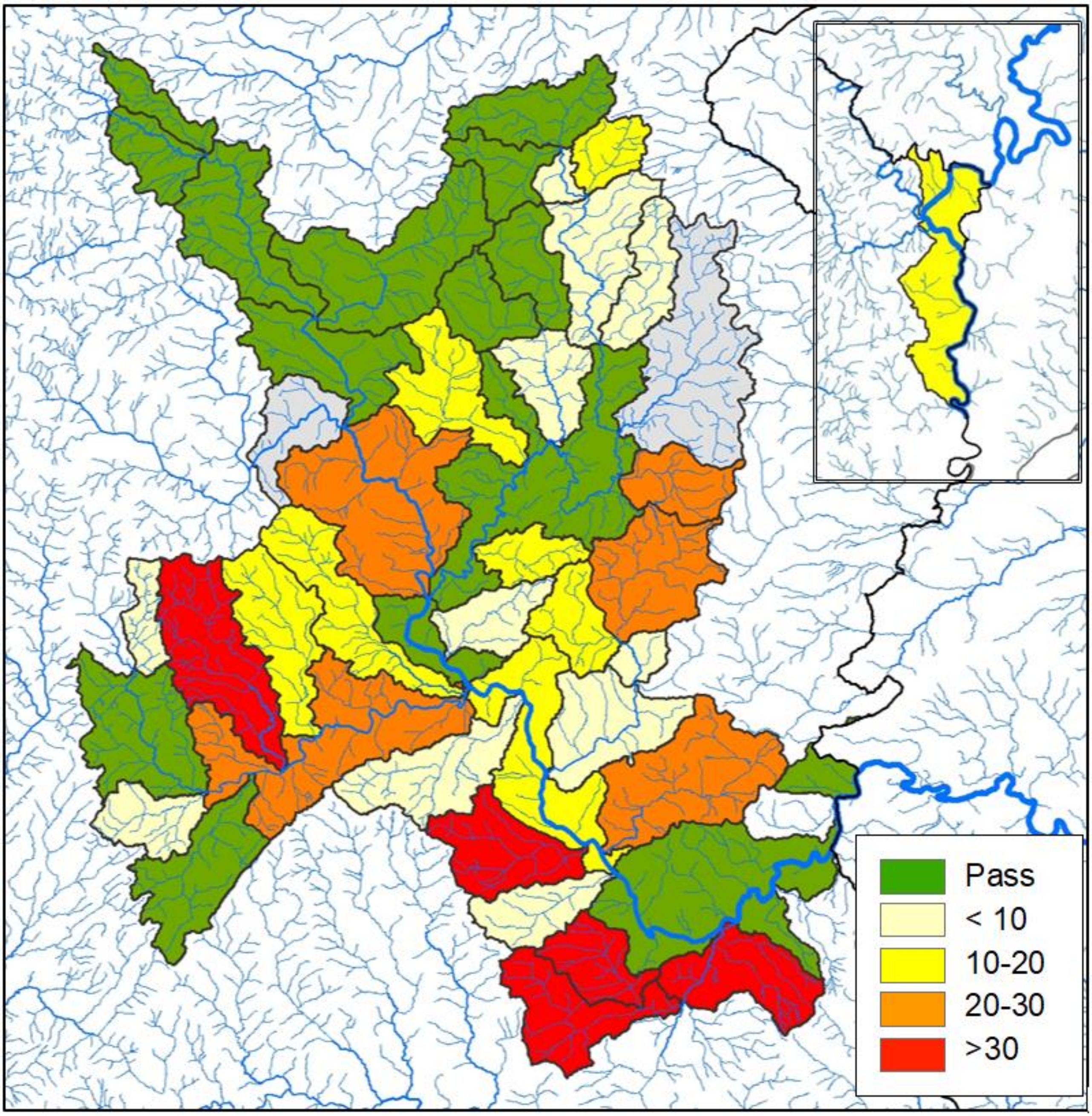


Figure 24. Map of phosphorus compliance for Welsh sections of the Wye SAC. Water bodies shaded green pass their target. Other colours fail the target with different colours representing the magnitude of failures in µg $l^{-1}$, expressed as the larger of annual means and growing season means. Inset shows the Wye – Walford Brook to Bigsweir water body in the lower Wye. Cross-border water bodies have been cropped to the Welsh border. Greyed out water bodies could not be assessed due to lack of data.

| Waterbody ID | Waterbody Name | Sample Point | Target (µg $l^{-1}$) | N Samples | Annual Mean (µg $l^{-1}$) | Growing Season Mean (µg $l^{-1}$) | Assessment | Status |
|---|---|---|---|---|---|---|---|---|
| GB109055042320 | Wye - conf Afon Tarenig to conf Afon Bidno | 50361 | 10* | 29 | 2 | 2 | Pass | - |
| GB109055042320 | Wye - conf Afon Bidno to conf Afon Marteg | 50004 | 10 | 33 | 2 | 2 | Pass | - |
| GB109055042340 | Afon Bidno - source to conf R Wye | 50003 | 10 | 29 | 1 | 1 | Pass | - |
| GB109055042280 | Wye - conf Afon Marteg to conf Afon Elan | 50177 | 20 | 34 | 11 | 14 | Pass | - |
| GB109055042310 | Afon Marteg - source to conf R Wye | 50005 | 13 | 33 | 7 | 6 | Pass | - |
| GB109055042260 | Afon Elan - Caban-coch Rsvr to conf R Wye | 50008 | 10 | - | - | - | Not Assessed | - |
| GB109055042250 | Wye - conf Afon Elan to conf R Ithon | 50010 | 10 | 29 | 37 | 38 | Fail | Confirmed |
| GB109055042180 | Ithon - source to conf Llaethdy Bk | 51354 | 10 | 29 | 8 | 8 | Pass | - |
| GB109055042160 | Llaethdy Bk - source to conf R Ithon | 51352 | 10 | 16 | 7 | 6 | Pass | - |
| GB109055042170 | Gwenlas Bk - source to conf R Ithon | 51353 | 10 | 23 | 24 | 22 | Fail | Confirmed |
| GB109055042150 | Ithon - conf Llaethdy Bk to conf Gwenlas Bk | 50086 | 10 | 29 | 13 | 13 | Fail | Confirmed |
| GB109055042130 | Camddwr Bk - source to conf R Ithon | 50820 | 13 | 17 | 20 | 17 | Fail | Confirmed |
| GB109055042140 | Ithon - conf Gwenlas Bk to conf Camddwr Bk | 50086 | 10 | 29 | 13 | 13 | Fail | Confirmed |
| GB109055042110 | Aran - source to conf R Ithon | 50084 | 15 | - | - | - | Not Assessed | - |
| GB109055041960 | Mithil Bk - source to conf R Ithon | 50825 | 15 | 18 | 40 | 37 | Fail | Confirmed |
| GB109055041900 | Howey Bk - source to conf R Ithon | 50089 | 15 | 16 | 25 | 23 | Fail | Confirmed |

| Waterbody ID | Waterbody Name | Sample Point | Target (µg $l^{-1}$) | N Samples | Annual Mean (µg $l^{-1}$) | Growing Season Mean (µg $l^{-1}$) | Assessment | Status |
|---|---|---|---|---|---|---|---|---|
| GB109055042080 | Nantmel Dulas - source to conf R Ithon | 50821 | 10 | 17 | 21 | 17 | Fail | Confirmed |
| GB109055042270 | Ithon - conf Camddwr Bk to conf R Wye | 50090 | 25 | 18 | 17 | 16 | Pass | - |
| GB109055042090 | Clywedog Bk - source to conf Bachell Bk | 50823 | 10 | 17 | 9 | 8 | Pass | - |
| GB109055042120 | Bachell Bk - source to conf Clywedog Bk | 50824 | 10 | 8 | 4 | - | Pass | - |
| GB109055042070 | Clywedog Bk - conf Bachell Bk to conf R Ithon | 50087 | 10 | 26 | 15 | 16 | Fail | Confirmed |
| GB109055037150 | Wye - conf R Ithon to conf R Irfon | 50813 | 15 | 29 | 8 | 8 | Pass | - |
| GB109055041870 | Afon Gwesyn - source to conf R Irfon | 57103 | 10 | 15 | 12 | 10 | Fail | Probable |
| GB109055036760 | Irfon - conf Afon Gwesyn to conf Cledan | 57712 | 10 | 27 | 8 | 7 | Pass | - |
| GB109055036680 | Cledan - source to conf R Irfon | 50818 | 10 | 21 | 18 | 11 | Fail | Confirmed |
| GB109055036690 | Tirabad Dulas - source to conf R Irfon | 50077 | 10 | 19 | 8 | 8 | Pass | - |
| GB109055041880 | Afon Cammarch - source to conf R Irfon | 50078 | 10 | 27 | 46 | 13 | Fail | Confirmed |
| GB109055041890 | Garth Dulas - source to conf R Irfon | 50079 | 10 | 28 | 15 | 22 | Fail | Probable |
| GB109055042190 | Chwefru - source to conf R Irfon | 50081 | 10 | 29 | 22 | 26 | Fail | Confirmed |
| GB109055037090 | Irfon - conf Cledan to conf R Wye | 50080 | 10 | 27 | 24 | 38 | Fail | Confirmed |
| GB109055037160 | Builth Dulas Bk - source to conf R Wye | 50501 | 15 | 16 | 16 | 19 | Fail | Confirmed |
| GB109055037050 | Duhonw - source to conf R Wye | 50012 | 15 | 29 | $15^{X}$ | $15^{X}$ | Fail | Probable |

| Waterbody ID | Waterbody Name | Sample Point | Target (µg $l^{-1}$) | N Samples | Annual Mean (µg $l^{-1}$) | Growing Season Mean (µg $l^{-1}$) | Assessment | Status |
|---|---|---|---|---|---|---|---|---|
| GB109055042200 | Edw - source to conf Colwyn Bk | 51355 | 15 | 28 | 30 | 39 | Fail | Confirmed |
| GB109055042370 | Camnant Brook - source to confluence R Edw | 50510 | 15 | 24 | 24 | 32 | Fail | Confirmed |
| GB109055037130 | Edw - conf Camnant Bk to conf Clas Bk | 50815 | 15 | | | | Not Assessed | - |
| GB109055037080 | Edw - conf Clas Bk to conf R Wye | 51305 | 15 | 28 | 20 | 23 | Fail | Confirmed |
| GB109055037030 | Clettwr Bk - source to conf R Wye | 50015 | 15 | 21 | 41 | 50 | Fail | Confirmed |
| GB109055037060 | Bach Howey Bk - source to conf R Wye | 50016 | 15 | 22 | 29 | 36 | Fail | Confirmed |
| GB109055036990 | Scithwen Bk - source to conf R Wye | 50017 | 15 | 21 | 19 | 21 | Fail | Confirmed |
| GB109055037115 | Wye - conf R Irfon to Scithwen Bk | 50440 | 16 | 29 | 23 | 29 | Fail | Confirmed |
| GB109055036970 | Triffrwd - source to Dulas | 50811 | 15 | 14 | 70 | 40 | Fail | Confirmed |
| GB109055036920 | Dulas Bk - source to conf Afon Llynfi | 50094 | 25 | 9 | 74 | - | Fail | Confirmed |
| GB109055036950 | Afon Llynfi - conf Dulas Bk to conf R Wye | 50098 | 25 | 26 | 77 | 90 | Fail | Confirmed |
| GB109055037116 | Wye - Scithwen Bk to Bredwardine Br (Wales) | 50018[1] | 30 | 34 | <21[2] | <23 | Pass | - |
| GB109055037111 | Wye - conf Walford Bk to Bigsweir Br | 50032 | 39 | 34 | 52 | 55 | Fail | Confirmed |

Table 14. Compliance for the River Wye SAC.

[1] This is a cross-border unit.
[2] Most of the data for this sample point was collected using the ‘Low’ method. The mean concentration for 2019, when sampling switched to ‘Very Low’ was 9 µg $l^{-1}$.

| Waterbody ID | Waterbody Name | Sample Point | Target ($\mu g\ l^{-1}$) | Median ($\mu g\ l^{-1}$) | Annual Mean ($\mu g\ l^{-1}$) | Outlier ($\mu g\ l^{-1}$) | Mean Excluding Outlier ($\mu g\ l^{-1}$) | BOD / N / $NH_3$ confirm outlier | Failure Type |
|---|---|---|---|---|---|---|---|---|---|
| GB109055042250 | Wye - conf Afon Elan to conf R Ithon | 50010 | 10 | 29 | 37 | - | - | - | Consistent |
| GB109055042170 | Gwenlas Bk - source to conf R Ithon | 51353 | 10 | 23 | 24 | 57 | - | - | Consistent |
| GB109055042150 | Ithon - conf Llaethdy Bk to conf Gwenlas Bk | 50086 | 10 | 10 | 13 | 58 | - | - | Consistent |
| GB109055042130 | Camddwr Bk - source to conf R Ithon | 50820 | 13 | 12 | 20 | 95 | 15 | - | Episodic |
| GB109055042140 | Ithon - conf Gwenlas Bk to conf Camddwr Bk | 50086 | 10 | 10 | 13 | 58 | - | - | Consistent |
| GB109055041960 | Mithil Bk - source to conf R Ithon | 50825 | 15 | 22 | 40 | 188 | - | - | Consistent |
| GB109055041900 | Howey Bk - source to conf R Ithon | 50089 | 15 | 24 | 25 | 77 | - | - | Consistent |
| GB109055042080 | Nantmel Dulas - source to conf R Ithon | 50821 | 10 | 10 | 21 | 112 | - | - | Consistent |
| GB109055042070 | Clywedog Bk - conf Bachell Bk to conf R Ithon | 50087 | 10 | 7 | 15 | 100 | 12 | - | Episodic |
| GB109055041870 | Afon Gwesyn - source to conf R Irfon | 57103 | 10 | 6 | 12 | 61 | 9 | >Q3 (N) | Episodic |
| GB109055036680 | Cledan - source to conf R Irfon | 50818 | 10 | 12 | 18 | 152 | - | - | Consistent |
| GB109055041880 | Afon Cammarch - source to conf R Irfon | 50078 | 10 | 8 | 46 | 747 | 19 | - | Episodic |
| GB109055041890 | Garth Dulas - source to conf R Irfon | 50079 | 10 | 5 | 15 | 239 | 6 | >Q3 (BOD, $NH_3$) | Episodic |
| GB109055042190 | Chwefru - source to conf R Irfon | 50081 | 10 | 17 | 22 | - | - | - | Consistent |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| GB109055037090 | Irfon - conf Cledan to conf R Wye | 50080 | 10 | 7 | 24 | 355 | 12 | - | Episodic |
| GB109055037160 | Builth Dulas Bk - source to conf R Wye | 50501 | 15 | 15 | 16 | 35 | 15 | - | Episodic |
| GB109055037050 | Duhonw - source to conf R Wye | 50012 | 15 | 14 | 15 | 70 | 13 | >Q3 (All) | Episodic |
| GB109055042200 | Edw - source to conf Colwyn Bk | 51355 | 15 | 15 | 30 | 369 | 17 | - | Episodic |
| GB109055042370 | Camnant Brook - source to confluence R Edw | 50510 | 15 | 16 | 24 | 183 | - | - | Consistent |
| GB109055037080 | Edw - conf Clas Bk to conf R Wye | 51305 | 15 | 14 | 20 | 145 | 15 | Outlier (BOD, NH3); Q3 (N) | Episodic |
| GB109055037030 | Clettwr Bk - source to conf R Wye | 50015 | 15 | 24 | 41 | 172 | - | - | Consistent |
| GB109055037060 | Bach Howey Bk - source to conf R Wye | 50016 | 15 | 21 | 29 | 99 | - | - | Consistent |
| GB109055036990 | Scithwen Bk - source to conf R Wye | 50017 | 15 | 17 | 19 | 46 | - | - | Consistent |
| GB109055037115 | Wye - conf R Irfon to Scithwen Bk | 50440 | 16 | 10 | 23 | 223 | 15 | Outlier (BOD, NH3); Q3 (N) | Episodic |
| GB109055036970 | Triffrwd - source to Dulas | 50811 | 15 | 36 | 70 | 115 | - | - | Consistent |
| GB109055036920 | Dulas Bk - source to conf Afon Llynfi | 50094 | 25 | 46 | 74 | 241 | - | - | Consistent |
| GB109055036950 | Afon Llynfi - conf Dulas Bk to conf R Wye | 50098 | 25 | 64 | 77 | 193 | - | - | Consistent |
| GB109055037111 | Wye - conf Walford Bk to Bigsweir Br | 50032 | 39 | 45 | 52 | - | - | - | Consistent |

Table 15. Sensitivity Testing for Failing Water Bodies on the River Wye SAC.

# Discussion

## General overview

Overall, of 107 water bodies assessed, 42 (39%) passed their SAC phosphorus targets and 65 (61%) failed. It should be noted that this is not a SAC condition assessment, as a full condition assessment would also require other variables such as macrophytes, invertebrates, habitat structure etc to be considered. Due to the one-out-all out way in which this is applied and the effect of other pressures, it cannot be assumed that water bodies meeting their phosphorus target are in favourable condition overall.

In the light of previously acknowledged problems with phosphorus measurement experienced by NRW during 2014-16, it was necessary to apply a comprehensive series of checks to confirm the veracity of high orthophosphate measurements where these affected the final conclusion: these included double-checking with the lab, excluding data that had breached holding time limits and checking outliers against other pollution indicators. This is a more detailed series of checks than have previously been applied to SAC water quality monitoring in Wales and we are therefore confident that the impact of any residual errors in the dataset has been minimised.

There was a strong spatial pattern: no unit failed in any of the three north-west Wales SAC rivers (Afon Gwyrfai a Llyn Cwellyn, Afon Eden – Cors Goch Trawsfynydd, Meirionnydd Oakwoods), or in the Afon Tywi. On the other hand, the extent of failures on rivers in southern, mid and eastern Wales is significant, with extensive phosphorus failures evident on the Teifi, Cleddau, Wye and Usk. These patterns likely reflect a combination of more intensive land use and higher population density, resulting in higher loading from sewage treatment works and private treatment plants.

| SAC Name | Passing | Failing (Episodic) | Failing (Consistent) | Not Assessed |
|---|---|---|---|---|
| River Dee & Llyn Tegid | 5 | 2 | 1 | 1 |
| Afon Gwyrfai a Llyn Cwellyn | 2 | 0 | 0 | 0 |
| Meirionnydd Oakwoods | 3 | 0 | 0 | 0 |
| Afon Eden – Cors Goch Trawsfynydd | 3 | 0 | 0 | 1 |
| Afon Teifi | 8 | 8 | 0 | 2 |
| Afonydd Cleddau | 5 | 5 | 5 | 4 |
| Afon Tywi | 2 | 0 | 0 | 1 |
| River Usk | 2 | 7 | 8 | 6 |
| River Wye | 14 | 11 | 17 | 3 |
| Total | 42 | 33 | 31 | 18 |

Table 16. Summary of the overall status of Welsh SACs in relation to phosphorus targets, as number of water bodies.

For these rivers, the problem is not only the proportion of failing units but also the large number of water bodies involved: the Wye for example has 45 water bodies in Wales, which accounts for 36% of the Welsh riverine SAC resource and 44% of all failing water bodies.

## Adequacy of the Sampling Network

The availability of relevant data was generally good: only 18 of 125 (14%) water bodies could not be assessed. However, a larger number of units had a restricted dataset with data missing from one or more years, either because sampling had been discontinued or because some of the data had to be excluded from the analysis. Some sampling points also lacked data from 2019, especially on the Wye and Usk where there are emerging gaps.

Revisions to the sampling network are needed to ensure that planned data collection includes adequate sampling of vulnerable areas and fills key data gaps (Appendix 3). Due to budget constraints and the impact of Covid-19 on sampler and laboratory capacity, this is likely to prove challenging in the short term at least.

Many water bodies showed a pattern of episodic poor water quality. Detecting such episodes is a particular challenge for a programme based on spot sampling, since relatively rare events can have a major impact on the outcome of assessments. Inevitably, not all such episodes will be detected by such sampling, and it is also not possible to know with any certainty whether these occur on a regular basis, or are genuine one-offs. A detailed statistical analysis may provide a better estimate of their frequency at a generic level by pooling data from across the sampling network, but this is uninformative regarding episodes at specific locations. Likewise, intensive sampling may be feasible for investigative purposes at specific locations and can provide better insights into nutrient patterns at problem locations, but is unaffordable for general routine monitoring.

An alternative to monitoring water chemistry is the use of biological tools such as the River Invertebrates Classification Tool (Davy-Bowker *et al.* 2008) or the Trophic Diatom Index (Kelly *et al.* 2008). These are routinely used for WFD monitoring and are also part of CSM. These tools have the ability to provide wider insights into river ecosystem health and also integrate the impact of nutrient pressures over a longer period in an ecological context. A macroalgal monitoring tool, RAPPER (Kelly *et al.* 2016), is also under development and has been used on the Tywi, though it is not used for WFD classification or CSM.

## Impact of Revised Phosphorus Targets

In 2012, a review of water quality against SAC targets (Thomas *et al.* 2013) found that only eight sample points failed the targets that applied at the time. However, they also noted that the applicable targets were relatively coarse and probably insufficiently protective, and that the limit of detection for much of the phosphorus data was insufficient. They recommended the adoption of tighter, more spatially explicit targets (see also Mainstone 2010; Nõges *et al*. 2014) and the collection of data using more sensitive methods. Revised JNCC monitoring guidance (JNCC 2016) provided a common framework for the new targets and NRW has implemented this for some SACs and is in the process of implementing it for others. This process has also involved the alignment of SAC management units with WFD water bodies. As a result, it is not possible to directly compare previous conclusions relating to phosphorus (Thomas *et al.* 2013), because the spatial pattern of units and detection limits have changed, and because targets have been substantially tightened. For the majority of water bodies, the target is equivalent to or tighter than WFD High Status.

Adoption of the revised targets has resulted in a greater number of failures than in the past, because targets are more stringent. For example, on the Wye, compared to the targets published in the SAC management plan prior to its 2017 revision, all water bodies bar the three Llynfi tributaries would have passed their target. The new targets are as low as 10 µg $l^{-1}$ in many tributaries of the Upper Wye including the Ithon and Irfon, and are therefore much more protective of river ecology there. Additionally, use of a much improved detection limit means that NRW now measures orthophosphate concentrations more accurately than in the past in locations where low values are prevalent.

Most of the revised targets are appropriate to the water body and should be retained. In a small number of water bodies, lack of Very Low data at the time the targets were set has resulted in targets that now appear too lax. Affected water bodies have extremely low phosphorus concentrations that comply with the near natural target in the JNCC guidance, but have had the maximum allowable target set instead. It is recommended that the targets in these water bodies be set to the relevant near natural target. These water bodies are listed in Appendix 4.

## Impact of Variability on the Mean

JNCC targets (JNCC 2016) stipulate the use of both the annual mean and a growing season mean, the rationale for which is that phosphorus is considered most likely to be harmful during the growing season when it may promote excessive growth of vascular plants, filamentous algae and even phytoplankton. Whilst it is less likely that high phosphorus concentrations are harmful when plants are dormant, the ecological benefits of using a growing season mean need to be weighed against the increased statistical uncertainty of using a smaller sample size. Whereas annual means could be calculated by up to 34 datapoints (mean number = 23), resulting in a reasonably good estimate of the mean, growing season means were always calculated using a substantially smaller dataset (mean number = 14). In general this did not result in substantial differences between the annual mean and the growing season mean, but where it did this tended to reflect the larger influence of a single high measurement rather than a consistent seasonal pattern.

From a statistical perspective, use of the mean does not appear ideal in many of the units measured, as the mean value was often strongly influenced by one or a few high readings with good water quality being evident at other times. Therefore, as a measure of the central tendency of water quality, the median would appear to be preferable. However, episodes of elevated phosphorus concentrations can have a similar impact on algal growth and taxonomic composition in streams to continuously high levels (Rier *et al.* 2016; Pearce *et al.* 2020), because many algal species are able to assimilate and store phosphorus during peak concentrations for use when levels are low. Therefore, it is likely that the ecological consequences of the different patterns of nutrient concentrations are similar. Moreover, it is important that measurement of targets takes into account evidence of any serious nutrient events or incidents. Therefore, the mean value is the best statistic to use for reporting.

About half of the recorded failures were episodic and half consistent (Table 16). These differing patterns are likely to reflect different sources and hence can help to frame an appropriate management response. Episodic peaks are most likely to result from catchment pressures: runoff from farmyards and farmland, equipment failure, spills or flooding of foul water infrastructure (including storm overflows). These tend to be disproportionately associated with extreme rainfall events, though they may also occur as a result of human error or negligence. On the other hand, consistent failures of the targets are much more likely to be caused by continuous inputs from consented activities such as sewage treatment works (STWs), as these tend to discharge at a reasonably constant rate. However, during very low flows the proportion of flow from STWs increases relative to river flow, resulting in an increase in phosphorus concentration.

## Magnitude of Exceedances

We have also provided information on the magnitude of exceedances. No formal guidance exists on this. However, the use of a simple pass-fail approach provides little context for managers and policy makers in identifying appropriate actions to tackle nutrient failures: a small magnitude failure could potentially be addressed by relatively low-cost measures such as riparian fencing or buffer strips, whereas larger magnitude failures are more likely to require costly measures such as installation of phosphate stripping at STWs or an extensive programme of catchment measures working with land managers. A literature review (Mainstone 2010) indicated that most ecological change occurs at phosphorus concentrations <50 µg $l^{-1}$, which is reflected in the magnitude scale used here.

In this context, 43% of exceedances (27 water bodies) were low in magnitude (i.e. failed their target by <10 µg $l^{-1}$) and a further 27% (17 water bodies) by <20 µg $l^{-1}$. For this type of failure it will often not be possible to definitively identify pollution sources. In many cases it should be possible to address these nutrient failures using relatively inexpensive best-practice measures (see below).

Where exceedances are larger in magnitude, this generally reflects either high inputs or severe episodic events. These will need to be tackled by continuing to apply NRW's Regulatory Principles on a case by case basis including use of best-practice measures to increase the general ecological quality and resilience of the rivers.

## Wye and Usk

Recent media interest has focussed strongly on poultry units as being the cause for concern in the Upper Wye, especially in the Ithon sub-catchment. The widespread failures and sporadically very high phosphorus concentrations observed in some parts of the Wye require action to address them. However, the overall pattern of failures in the Wye does not support the hypothesis that poultry units are the main or even a particularly important reason for nutrient failures on the Wye. Whereas about half of the Ithon catchment fails the new targets – generally by fairly small margins - there are larger and / or more extensive failures in the Irfon, Middle Wye and Llynfi subcatchments. An investigation of nutrient sources in the Upper Wye is needed that takes into account all potential nutrient sources, including smaller local sewage treatment works which may not have been included in previous work. Use of the Load Apportionment Model (Bowes *et al.* 2008) may be useful for identifying loading from different types of sources. Additionally, revised SAGIS modelling incorporating accurate and up to date phosphorus concentrations for the Upper Wye is required, as values used by previous work (Atkins and APEM 2018) were inaccurate.

The Usk is by some distance the worst performing SAC river in Wales with respect to its phosphorus targets, and is the only river where there are extensive failures in the headwaters. In part this is likely to be a consequence of overgrazing, as the dominant Old Red Sandstone geology of the river creates relatively nutrient-rich soils that are prone to runoff and bank erosion during wet weather. However, some of the measured phosphorus values are much higher and coincide with high readings of other water quality indicators such as BOD. The river has also experienced by far the highest phosphorus concentration in this dataset, on the Rhiangoll in 2017. Further investigation of the widespread failures in this river is required.

## Teifi and Cleddau

The Teifi and Cleddau include some intensive dairy farming areas, and the Western Cleddau in particular suffers from some of the highest sustained phosphorus concentrations in Welsh SAC rivers. Unlike most other Welsh rivers, the Western Cleddau lacks an upland headwater area to provide a supply of low nutrient water that can dilute downstream nutrient inputs, and this in combination with increasingly intensive agriculture in the catchment makes it vulnerable to eutrophication. The lower Teifi also has extensive failures, and it should be noted that the targets in this area are generally not as tight as in some other Welsh rivers.

## Relationship between Phosphorus, Morphology and Flow

Phosphorus is not simply a water quality problem. Instead, it can be a symptom of wider problems with river ecology. Elevated phosphorus can arise from morphological damage such as overgrazing (causing bank erosion) or dredging of rivers, which disconnects them from their floodplain and damages macrophytes which can absorb phosphorus and suppress algal growth. For example, in a Danish stream, Kronvang *et al.* (2012) found that bank erosion accounted for 20-36% of the gross P input over a three year period, and other studies have recorded much higher contributions (Fox *et al.* 2016). Although only a fairly small proportion of this phosphorus is soluble, it nevertheless has the potential to cause failures, especially in naturally nutrient-poor areas.

Riparian woodland creates shade, reducing solar radiation and water temperatures (Broadmeadow *et al.* 2011), thereby suppressing algal growth (Bowman *et al.* 2007; Sturt *et al.* 2011; Halliday *et al.* 2016; McCall *et al.* 2017). In contrast, low flows seen during droughts tend to increase periphyton biomass due to reduced scour, and increased phytoplankton biomass by increasing residence time (Hilton *et al.* 2006; Johnson *et al.* 2009) by increasing residence time. Droughts also reduce dilution of point source discharges and can lead to algal blooms and shifts in phytoplankton community structure in favour of cyanobacteria associated with hot, sunny weather (Paerl and Huisman 2008; Bowes *et al.* 2016). Therefore, measures to tackle water quality should not only focus on phosphorus inputs, but should also consider wider aspects of river ecosystem health, especially instream and riparian habitat structure, as well as actions that seek to minimise extreme flow events, for example by restoring headwater and riparian wetlands.

It is also important to note that algal blooms are not only caused by high nutrient levels , but are often a result of other physical conditions such as flow, light and water temperature (Bowes *et al.* 2016).

## Some Possible Management Responses

Improving the nutrient status of Welsh river SACs can be broken down into the following general components:-

1. Actions aimed at direct reduction of consented nutrient sources, and reducing the impact of other waste water infrastructure. This applies mainly to sewage treatment works. Although not usually consented, issues such as misconnections and management of small private septic tanks and package sewage treatment plants may also be relevant.

2. Actions aimed at identifying and reducing nutrient loading and potential nutrient pathways within the catchment, including slowing flow into the river. This could for example be done by incorporating sustainable drainage measures, moving gateways, installing cross drains, additional storage capacity for organic manures (including digestate), clean and dirty water separation, blocking ditches, installing ponds, creating swales and increasing soil capacity to absorb and hold water and slow flow to rivers. It should also consider whether storm drainage arrangements are adequate in the light of climate change, in particular the tendency for short but intense downpours that can often result in temporary surface water flooding and overwhelm infrastructure.

3. Actions to improve the natural resilience of the river. This follows the Sustainable Management of Natural Resources (SMNR) approach enshrined in NRW policy and could include for example fencing of bankside buffer zones; setting back or removing flood defences to allow nutrients to be deposited on the floodplain; planting riparian trees (especially on the south side of the river), and other restoration options. These kind of actions may either directly reduce nutrient concentrations or increase the resilience of the river to nutrients (for example by creating conditions in which algal growth is unlikely). All of these measures can be expected to have wider environmental benefits such as increasing the area and quality of fish habitat and reducing the impact of extreme weather events.

4. Working with the land management sector and other relevant sectors to identify and develop the best approaches to tackle the issues. For example, the cross-sector Agricultural Diffuse Pollution sub group of the Wales Land Management Forum seeks to reduce nutrient pollution and deliver more sustainable land management by application of Regulatory Principles and the principles of engagement of the Well-being and Future Generations Act.

5. Planning advice should reflect the findings of this report to prevent deterioration in future. However, it should be remembered that unlike processes such as Asset Management Plans (AMP), amending planning advice will generally only prevent or reduce future deterioration: it cannot deliver recovery.

For water bodies not passing their targets, some combination of these measures will be required. Morphological pressures are very widespread on Welsh rivers, resulting in reduced resilience (NRW in prep), so it is likely that river restoration measures will be required in most cases. River restoration is also a cost-effective and long-term approach to improving river quality, as it can address a wide range of issues and reduces reliance on continual adherence to best practice. River restoration delivers multiple, long-term benefits and is part of NRW’s commitment to restoring ecological networks across the wider landscape. However, it requires a larger capital outlay than other approaches and can also encounter resistance from landowners.

# Recommendations

Based on the findings of this report, it is recommended that NRW carry out the following actions:

Target Setting

- Most of the SAC phosphorus targets are appropriate and sufficient;
- The outstanding SAC Core Management Plans should have the revised phosphorus and other CSM water quality targets incorporated into them as soon as practicable and no later than the end of May 2021;
- Revisions to the targets at five water bodies are recommended to address minor technical issues (see Appendix 4);
- For a small number of water bodies, it is now apparent there are insufficient data to set targets that follow the full CSM process. It is recommended that targets are reviewed on these water bodies once sufficient monitoring data are available;
- Work with other conservation agencies and JNCC to update the JNCC guidance to improve consistency and clarity with regard to assessing compliance against targets.

Monitoring and Assessments

- The water quality monitoring network should be reviewed and data collected to fill gaps so that compliance of water bodies not assessed can be carried out;
- NRW should ensure that sufficient monitoring data are collected to repeat the compliance assessment within the next 6 years;
- NRW should assess compliance against other SAC habitat and species targets to provide the evidence base for habitat restoration, SAC management and policy and permitting work.

Management

- NRW should seek to deliver a river restoration programme that delivers wider river health and resilience as well as reducing nutrient inputs;
- The existing catchment projects should be implemented to improve land management practices, working with Farming Connect and other advisory bodies to target advice and guidance campaigns;
- Carry out an integrated analysis of relevant datasets to inform catchment level actions at a water body level, including incidents data, locations of potential nutrient sources and external datasets;
- Where not already present, catchment level working groups should be considered to facilitate partnership working between stakeholders.

Regulatory and Advisory

- In failing water bodies adoption of Regulatory Principles is required to ensure the targets can be achieved.
- Through our Regulatory Principles tighten conditions on permits and/or carry out enforcement measures where breaches are suspected;
- Produce a position statement and guidance for permitting of phosphorus and other relevant water quality parameters for internal and external use;

- Produce a position statement and guidance for NRW responses to planning applications and advice to planning authorities in relation to phosphorus and other relevant water quality parameters;
- Target future grant schemes with Welsh Government to deliver improvements in land and nutrient management;
- Consider the implications for AMP and work with water companies to identify and deliver improvements to waste water treatment infrastructure.

# Conclusions

Following the revision of JNCC common standards monitoring guidance, NRW has updated or is updating phosphorus targets for Welsh SACs. The new targets are significantly tighter and vary according to river characteristics, reflecting natural variation in river ecology.

This evidence review shows that overall, phosphorus target failures were widespread in Welsh SAC rivers: 39% of water bodies passed their SAC phosphorus targets and 61% failed. The geographic distribution of this was uneven: rivers in northern and western Wales tended to pass their targets more often. The worst performing river was the Usk, where only 12% of water bodies passed their target.

The magnitude and nature of failures was variable. Both consistent and episodic failures were evident, and monitoring also recorded some significant nutrient spikes.

Conventional approaches such as the water industries five yearly AMP process will be required. In addition the episodic nature of some of the nutrient levels in this report suggest that consideration of nutrient sources, pathways and restoring the structure and function of rivers, the riparian corridor and their associated wetlands is fundamental. Policy and management responses should consider the full range of management options to tackle this issue, taking a whole ecosystem approach so that nutrient concentrations are reduced and that Welsh rivers are as resilient as possible to water quality pressures in the face of climate change and the nature emergency.

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# Appendices

## Appendix 1. Boxplots of phosphorus concentrations.

Boxplots – Minitab. Standardised scale of plots to 100 for low P rivers and 400 for high P rivers.

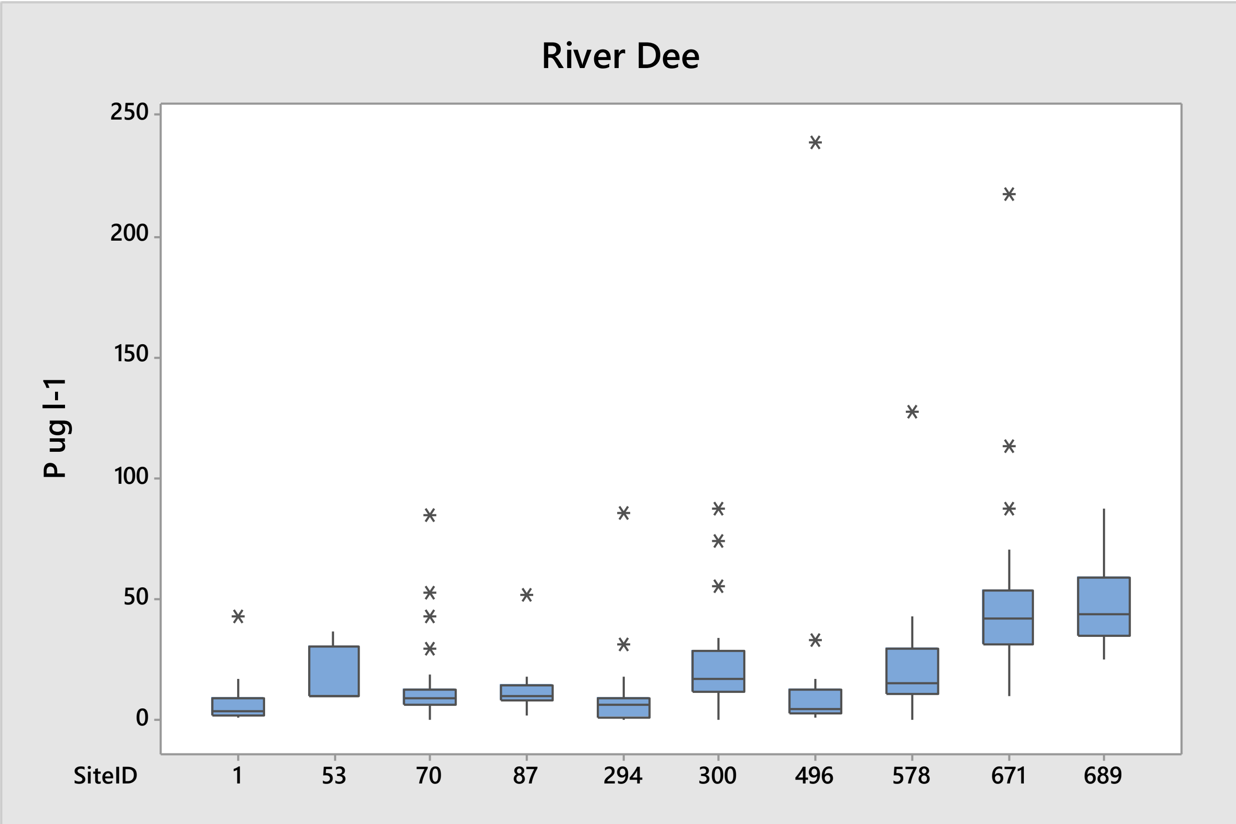


Figure 25. Boxplots of phosphorus concentrations for River Dee sample points.

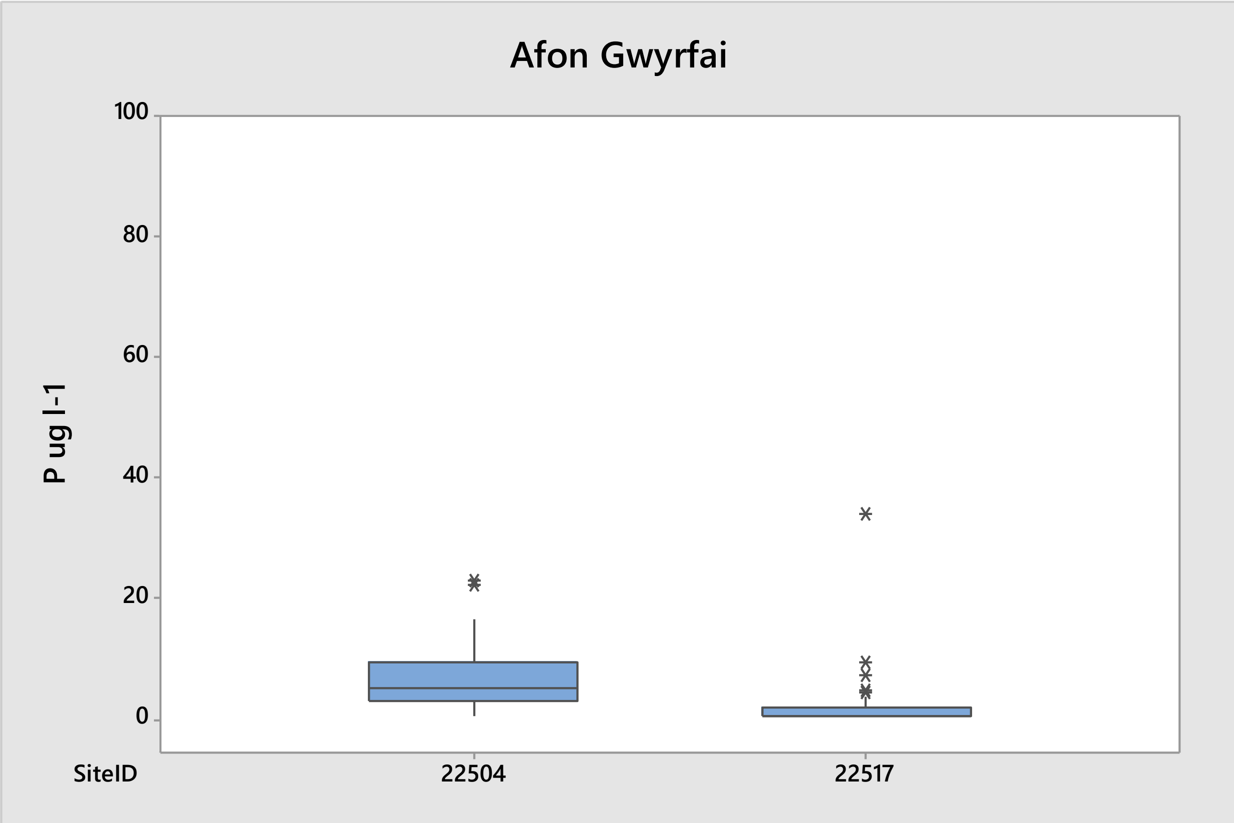


Figure 26. Boxplots of phosphorus concentrations for Afon Gwyrfai sample points.

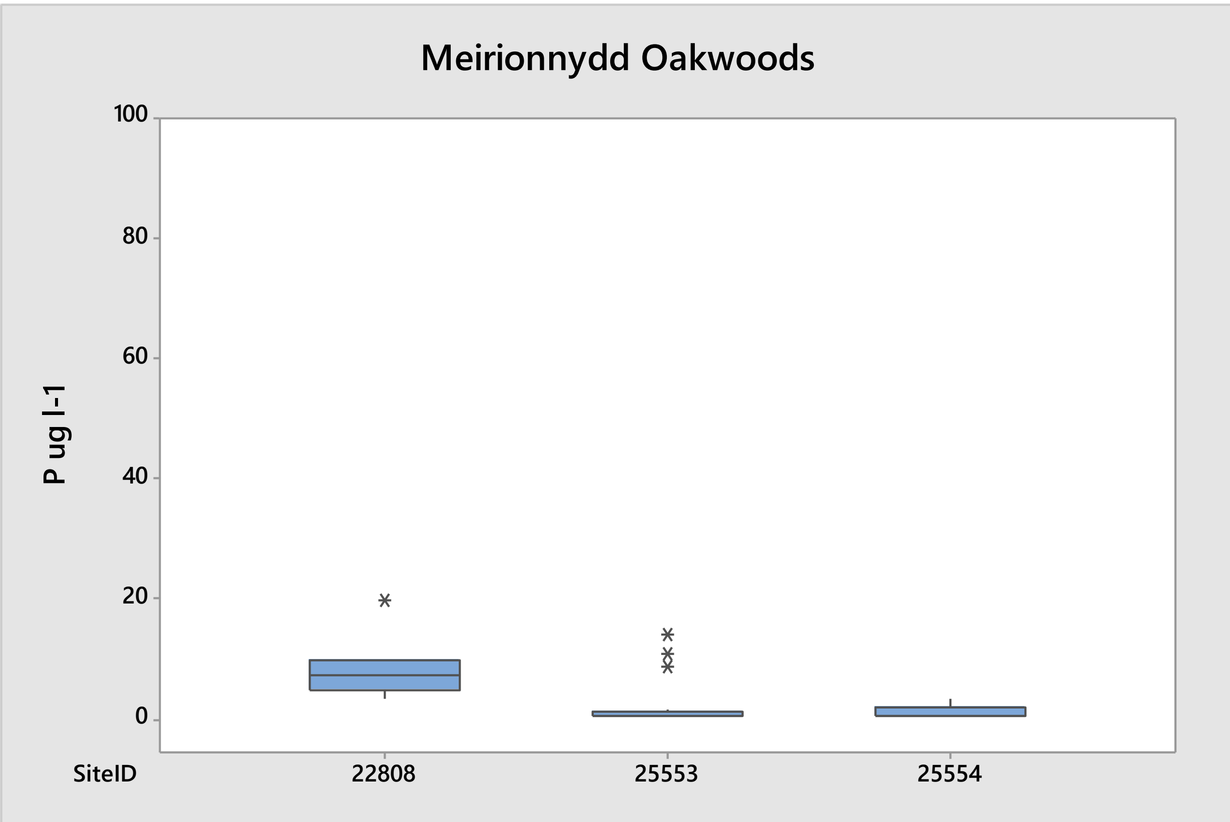


Figure 27. Boxplots of phosphorus concentrations for Meirionnydd Oakwoods sample points.

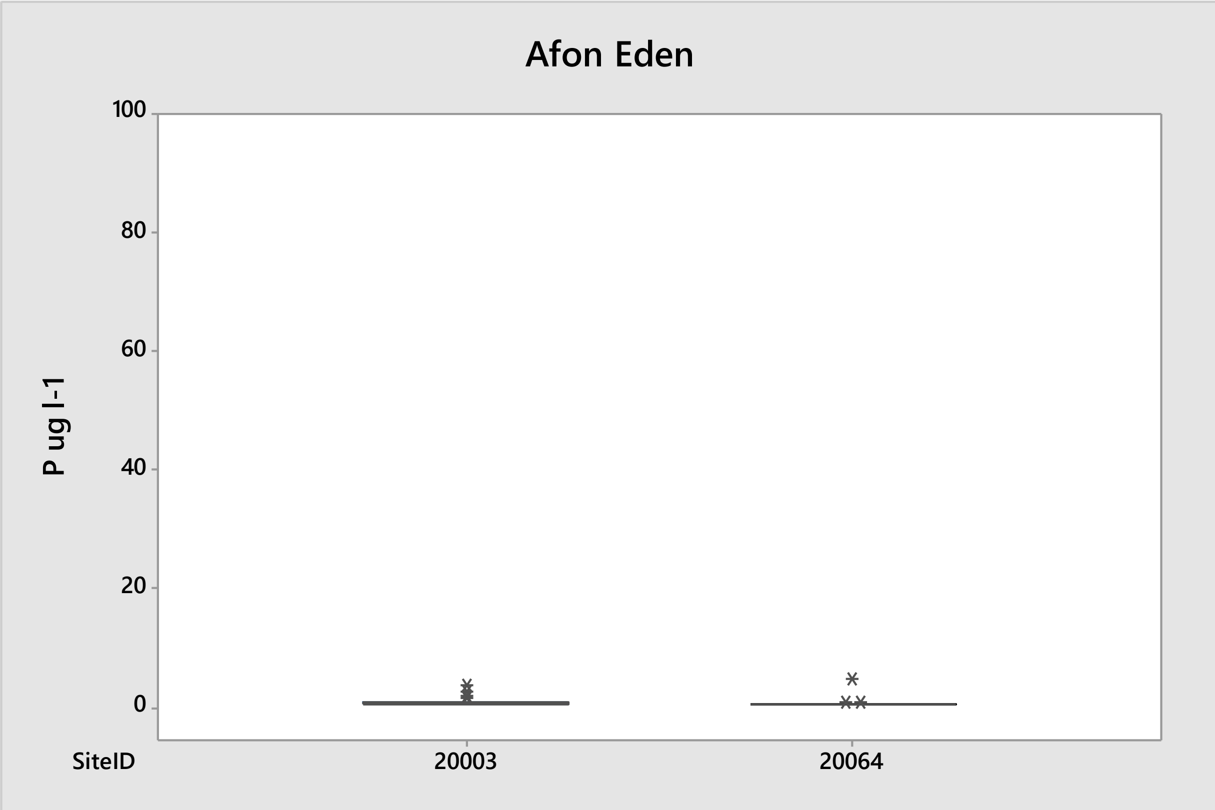


Figure 28. Boxplots of phosphorus concentrations for Afon Eden sample points.

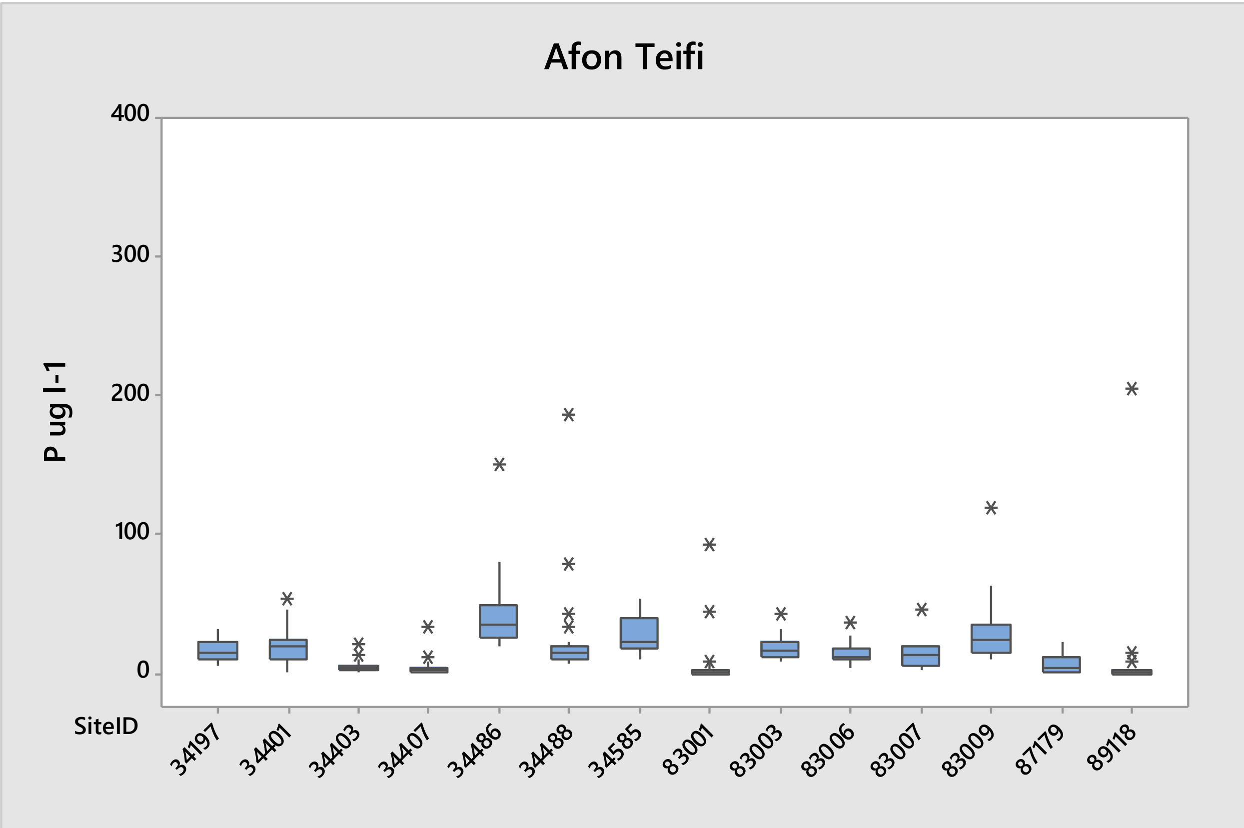


Figure 29. Boxplots of phosphorus concentrations for Afon Teifi sample points.

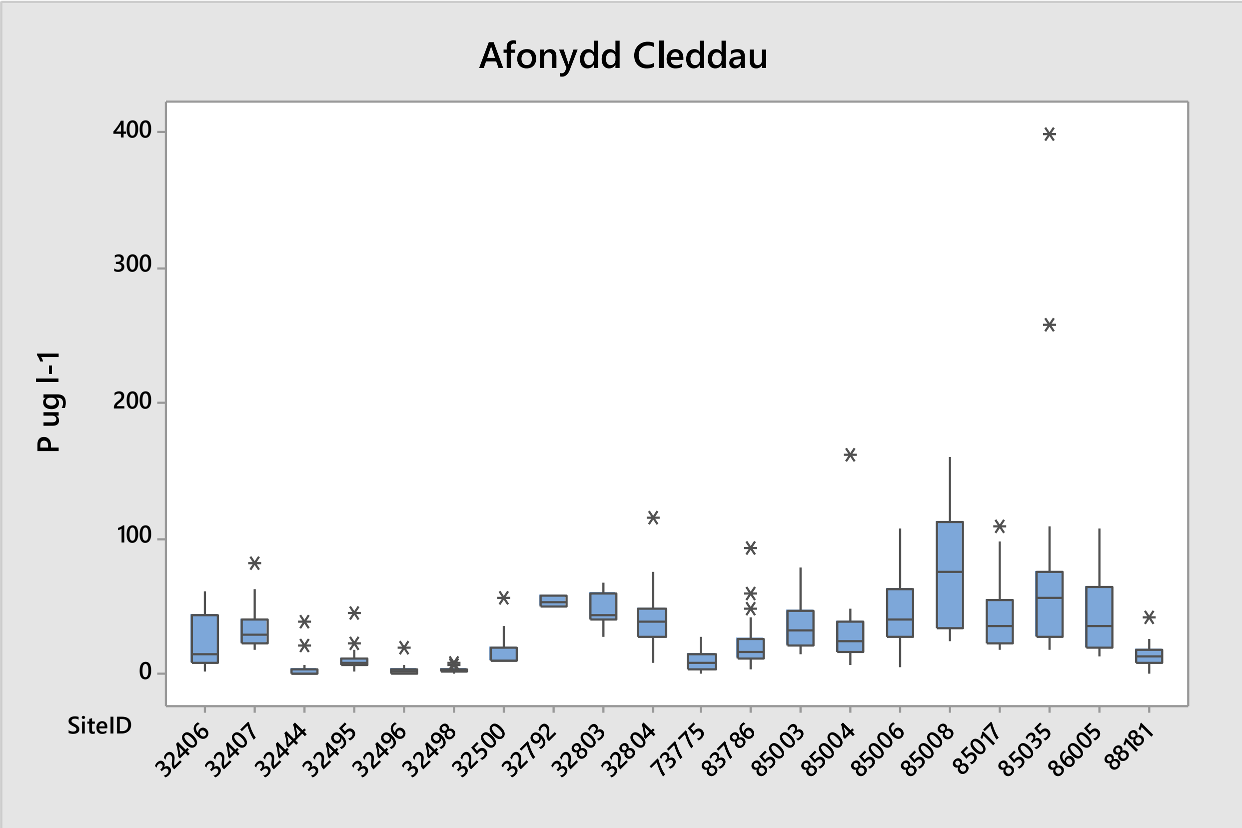


Figure 30. Boxplots of phosphorus concentrations for Afonydd Cleddau sample points.

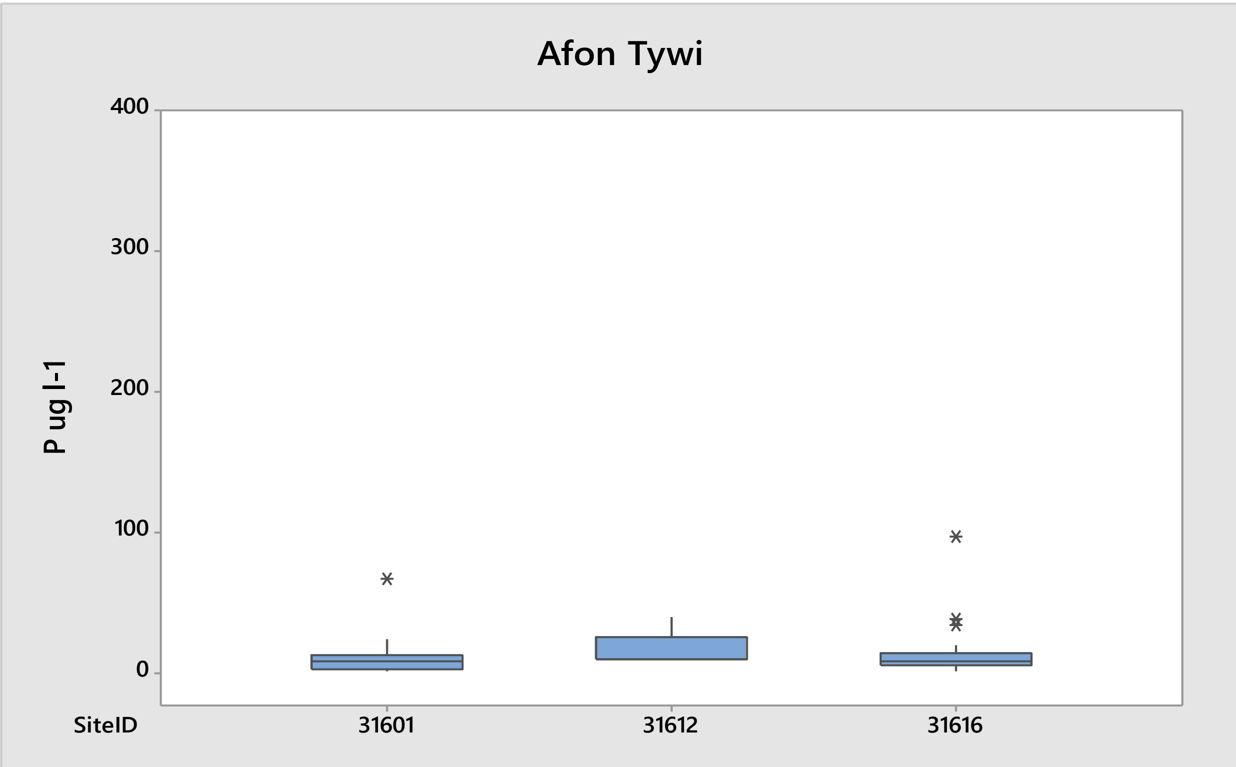


Figure 31. Boxplots of phosphorus concentrations for Afon Tywi sample points.

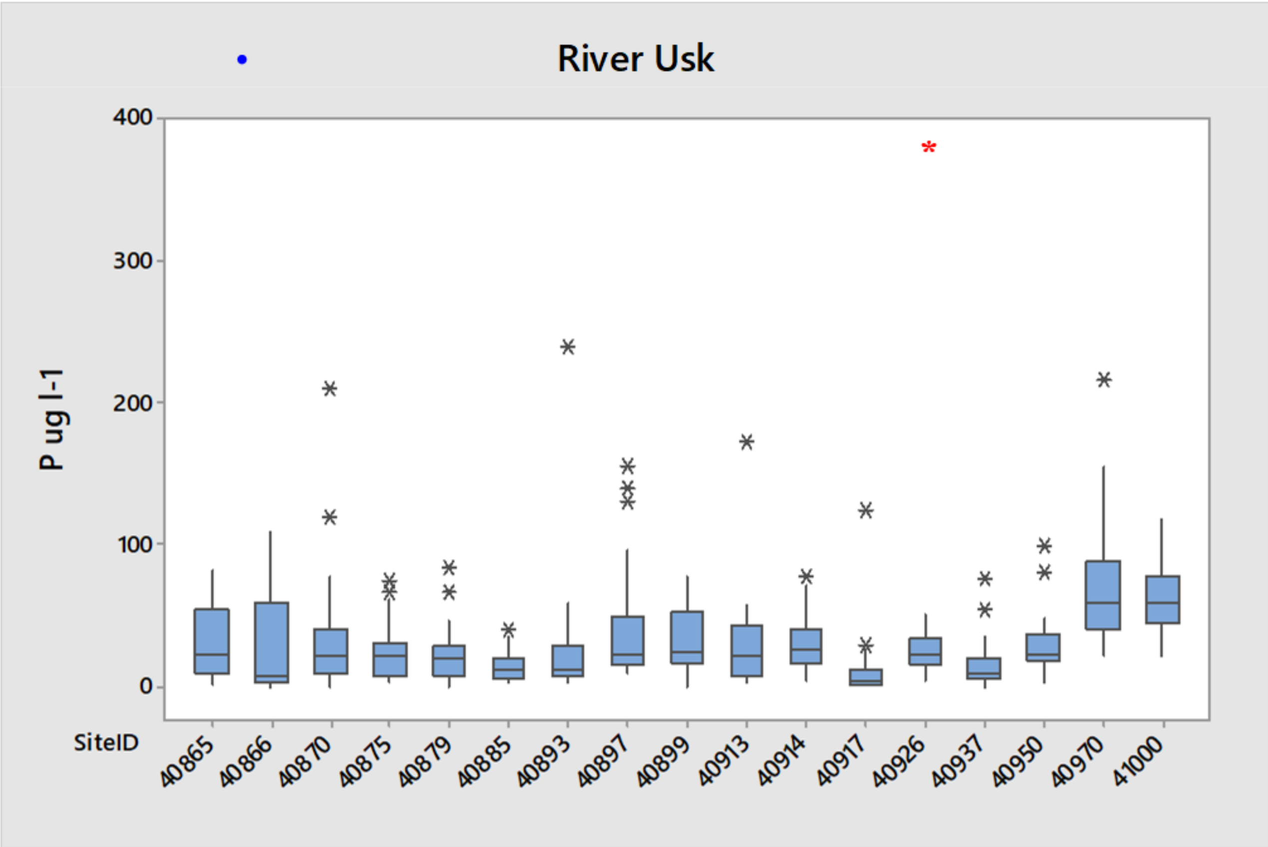


Figure 32. Boxplots of phosphorus concentrations for River Usk sample points. The red asterisk indicates an extreme value of 3110 µg l-1 which could not be accurately represented on the graph without losing resolution for other samples.

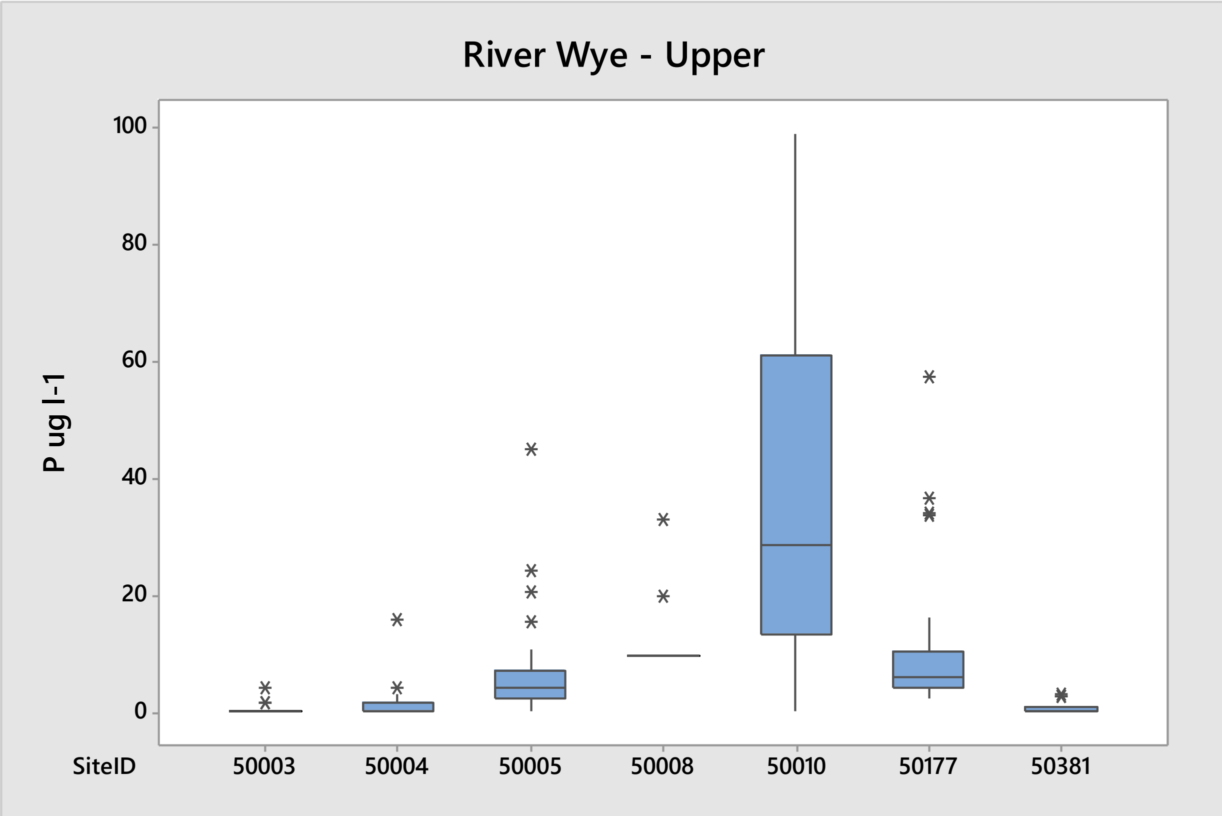


Figure 33. Boxplots of phosphorus concentrations for Upper Wye sample points, above the Ithon confluence.

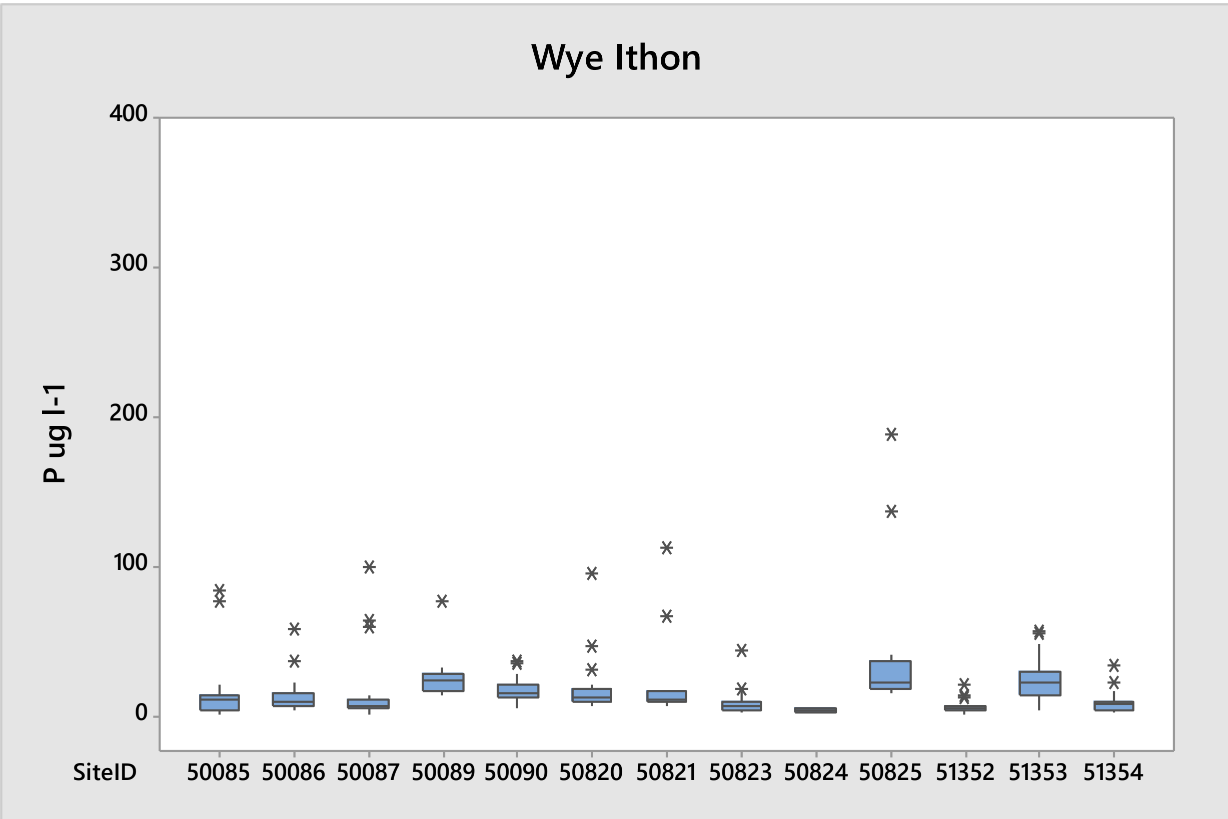


Figure 34. Boxplots of phosphorus concentrations for River Wye (Ithon) sample points.

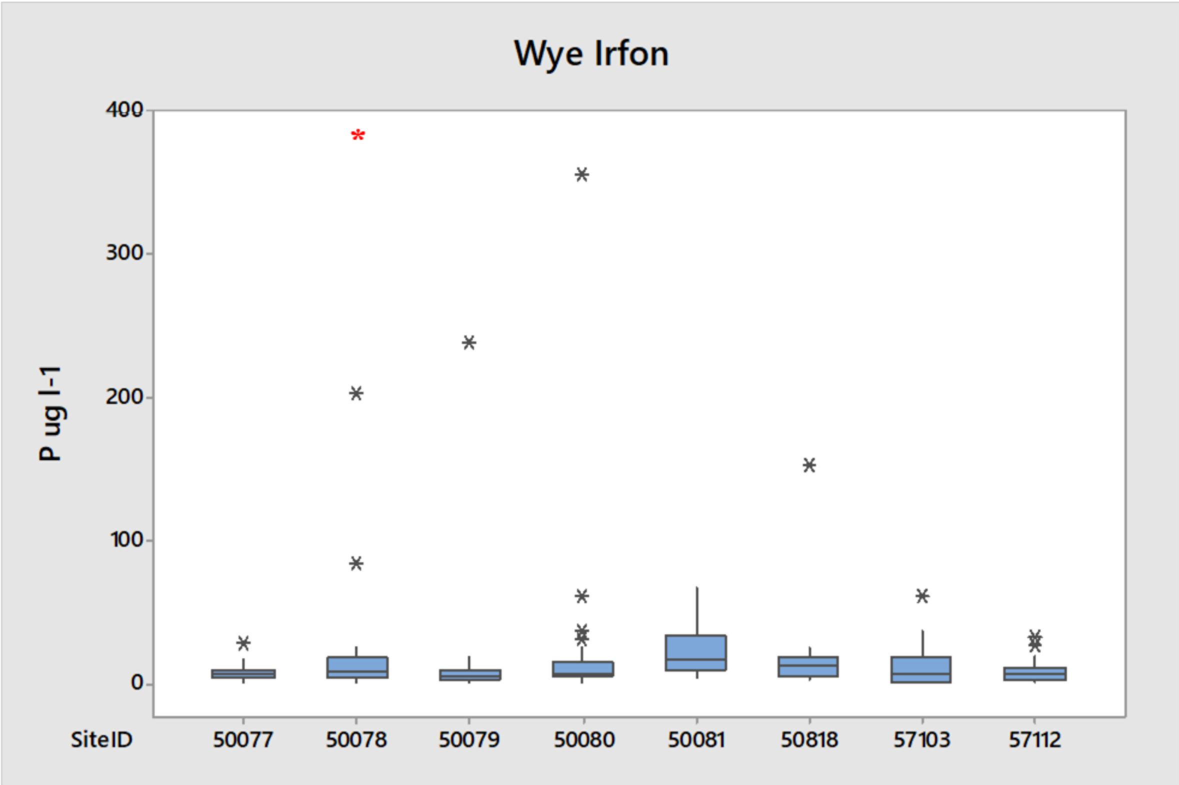


Figure 35. Boxplots of phosphorus concentrations for River Wye (Irfon) sample points. The red asterisk indicates an extreme value of 747 µg l-1 which could not be accurately represented on the graph without losing resolution for other samples.

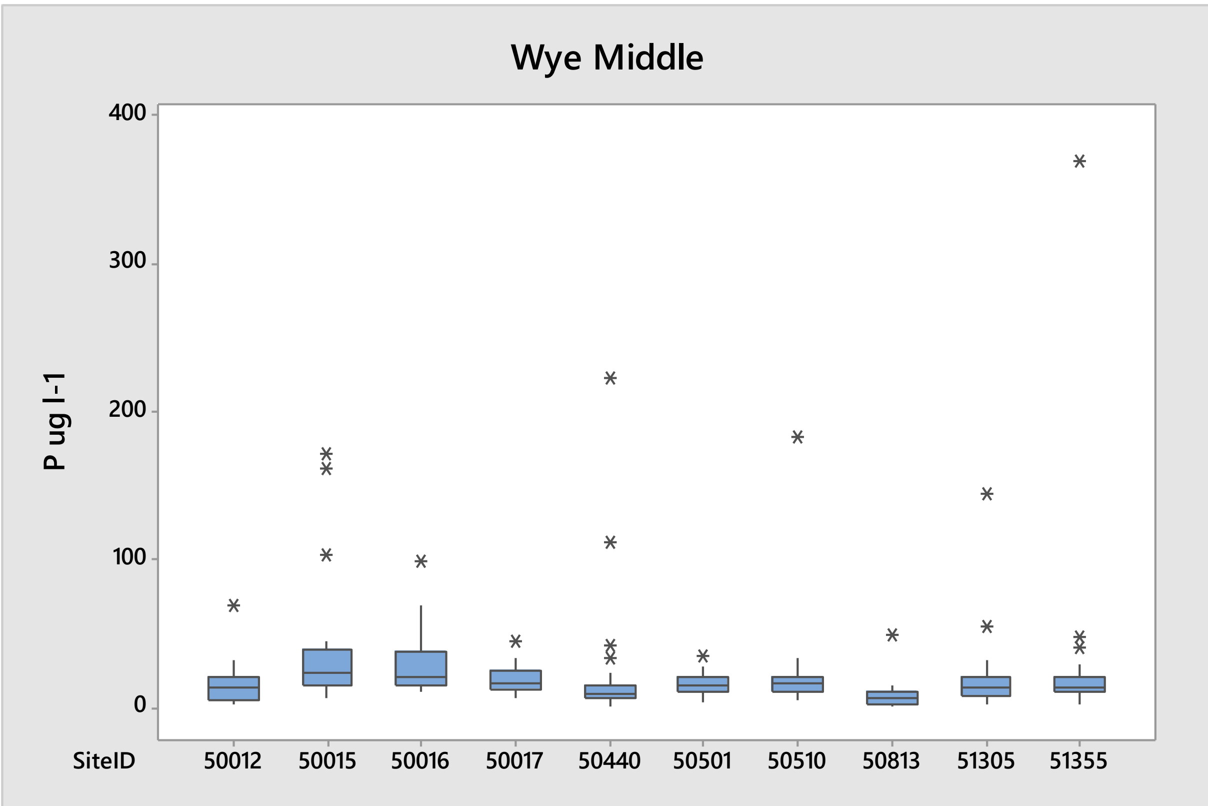


Figure 36. Boxplots of phosphorus concentrations for Middle Wye sample points.

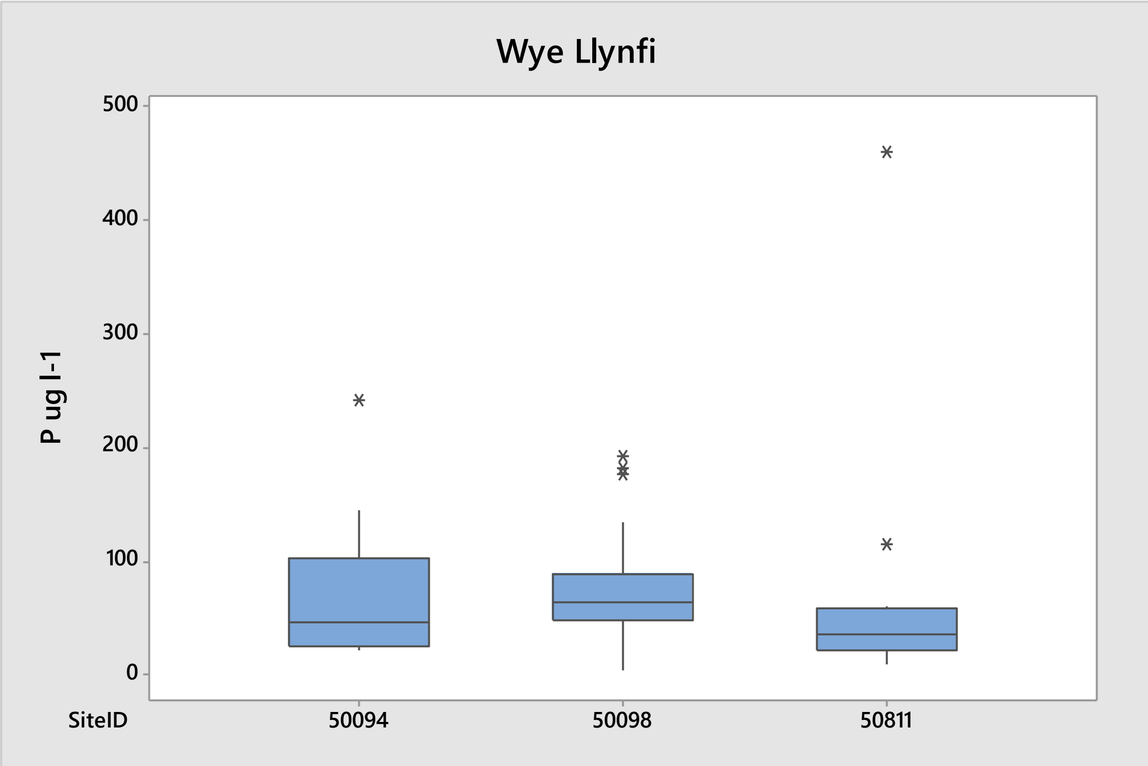


Figure 37. Boxplots of phosphorus concentrations for River Wye (Llynfi) sample points.

## Appendix 2. Assessment of Outliers for other determinands.

For sample points where a single phosphorus measurement was causing a failure, data for other determinands was also collated to rule out the possibility of laboratory error.

Data for 0085 Biochemical Oxygen Demand (BOD), 0116 Total Oxidised Nitrogen, and 0111 Ammoniacal N (using the very low method) were collated for the period 1/1/17 to 1/3/20 and boxplots of their distribution created to identify outliers (Figure 38, Figure 39, Figure 40).

| SAC | Water Body | SMPT | Date | P | BOD | N | NH3 |
|---|---|---|---|---|---|---|---|
| Dee | Meloch | 496 | 27/11/2019 | 239 | No | No | No |
| Teifi | Teifi - Ceri to Estuary | 34401 | 12/06/2019 | 54.8 | >Q3 | <Q1 | >Q3 |
| Teifi | Ceri - Dulas to Teifi | 34486 | 07/11/2017 | 151 | Yes | <Q1 | Yes |
| Teifi | Clettwr | 83009 | 05/08/2019 | 119 | No | >Q3 | Yes |
| Teifi | Groes | 89118 | 29/06/2018 | 205 | No | No | No |
| Teifi | Cych | 34488 | 17/04/2018 | 187 | Yes | No | Yes |
| Cleddau (W) | Cleddau N to Anghof | 85017 | 12/12/2019 | 109 | Yes | <Q1 | >Q3 |
| Cleddau (W) | Spittal Brook | 85004 | 12/03/2019 | 162 | Yes | <Q1 | Yes |
| Cleddau (E) | Narbeth Brook | 32407 | 02/08/2017 | 82.5 | Yes | N/A | Yes |
| Usk | Senni | 40879 | 14/12/2018 | 690 | Yes | >Q3 | Yes |
| Usk | Cilieni | 40885 | 16/08/2018 | 40.2 | >Q3 | No | No |
| Usk | Caerfanell | 40917 | 04/07/2017 | 124 | <Q1 | No | >Q3 |
| Usk | Rhiangoll | 40926 | 11/04/2017 | 3110 | Yes | No | Yes |
| Wye | Gwesyn | 57103 | 20/11/2018 | 60.5 | N/A | >Q3 | No |
| Wye | Garth Dulas | 50079 | 18/06/2019 | 239 | >Q3 | N/A | >Q3 |
| Wye | Duhonw | 50012 | 05/03/2018 | 69.6 | >Q3 | >Q3 | >Q3 |
| Wye | Edw - Clas Brook to Wye | 51305 | 12/03/2019 | 145 | Yes | >Q3 | Yes |
| Wye | Irfon to Sgithwen Brook | 50440 | 12/03/2019 | 223 | Yes | >Q3 | Yes |

Table 17. Summary of Outlier Assessment against results of other determinands potentially indicative of pollution.

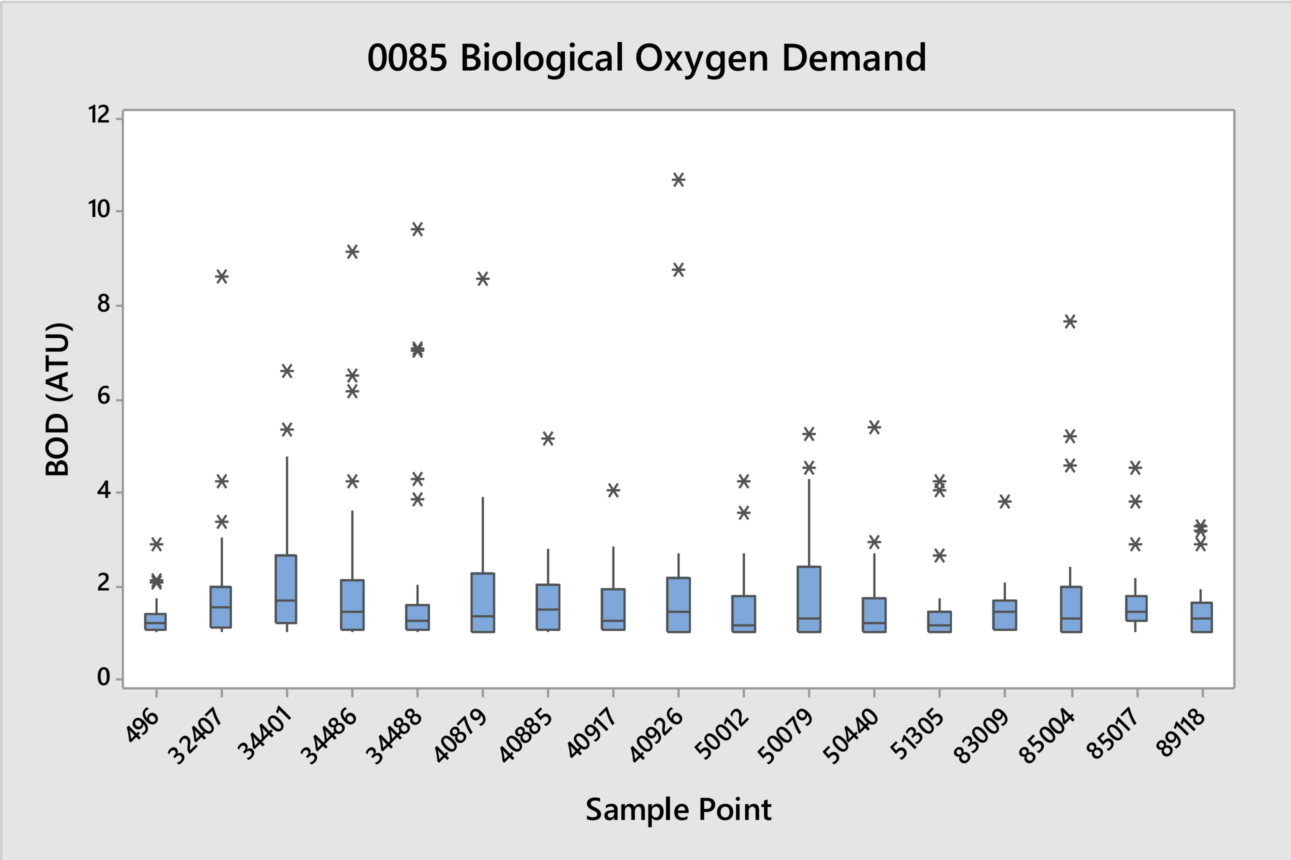


Figure 38. Boxplot of Biochemical Oxygen Demand for sample points with high phosphorus peaks.

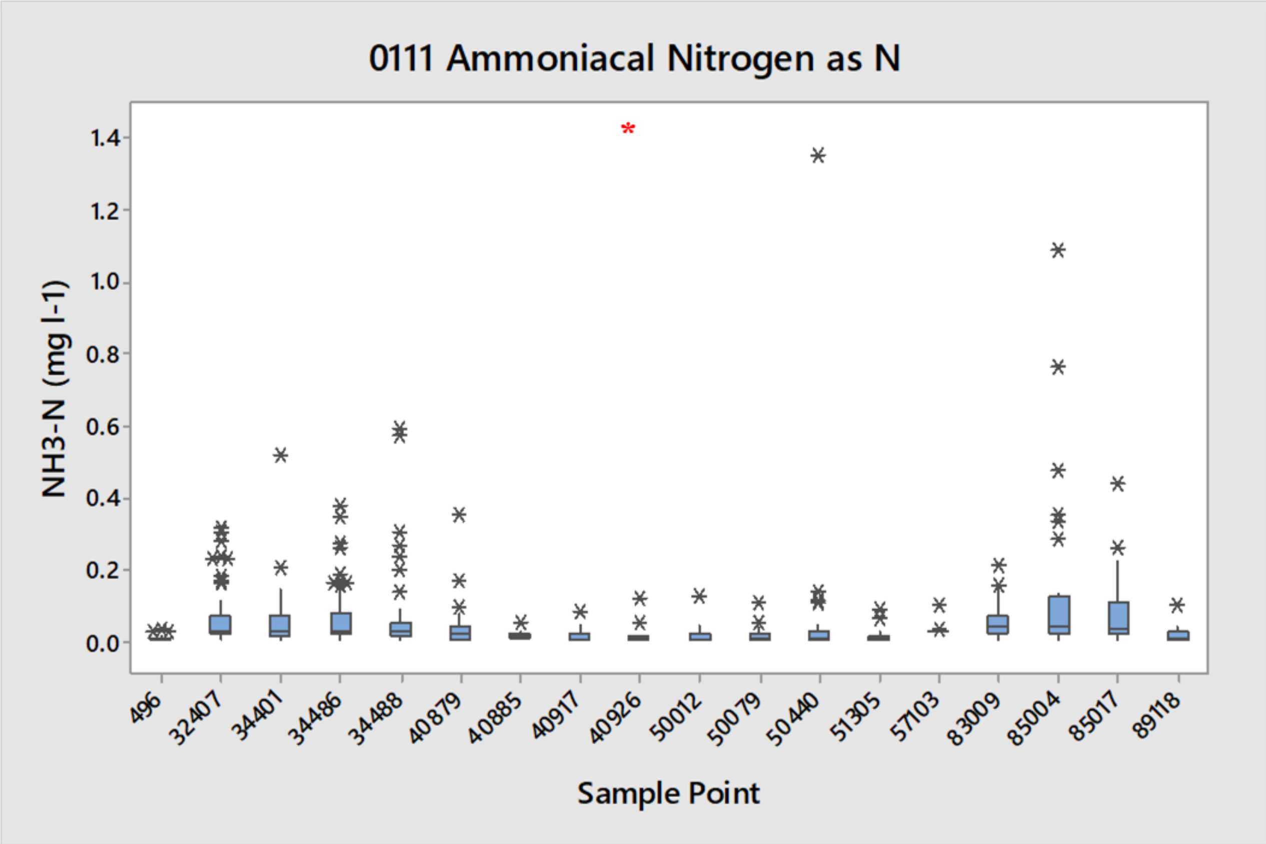


Figure 39. Boxplot of Ammoniacal Nitrogen for sample points with high phosphorus peaks. The red asterisk represents an extreme value of 3.46.

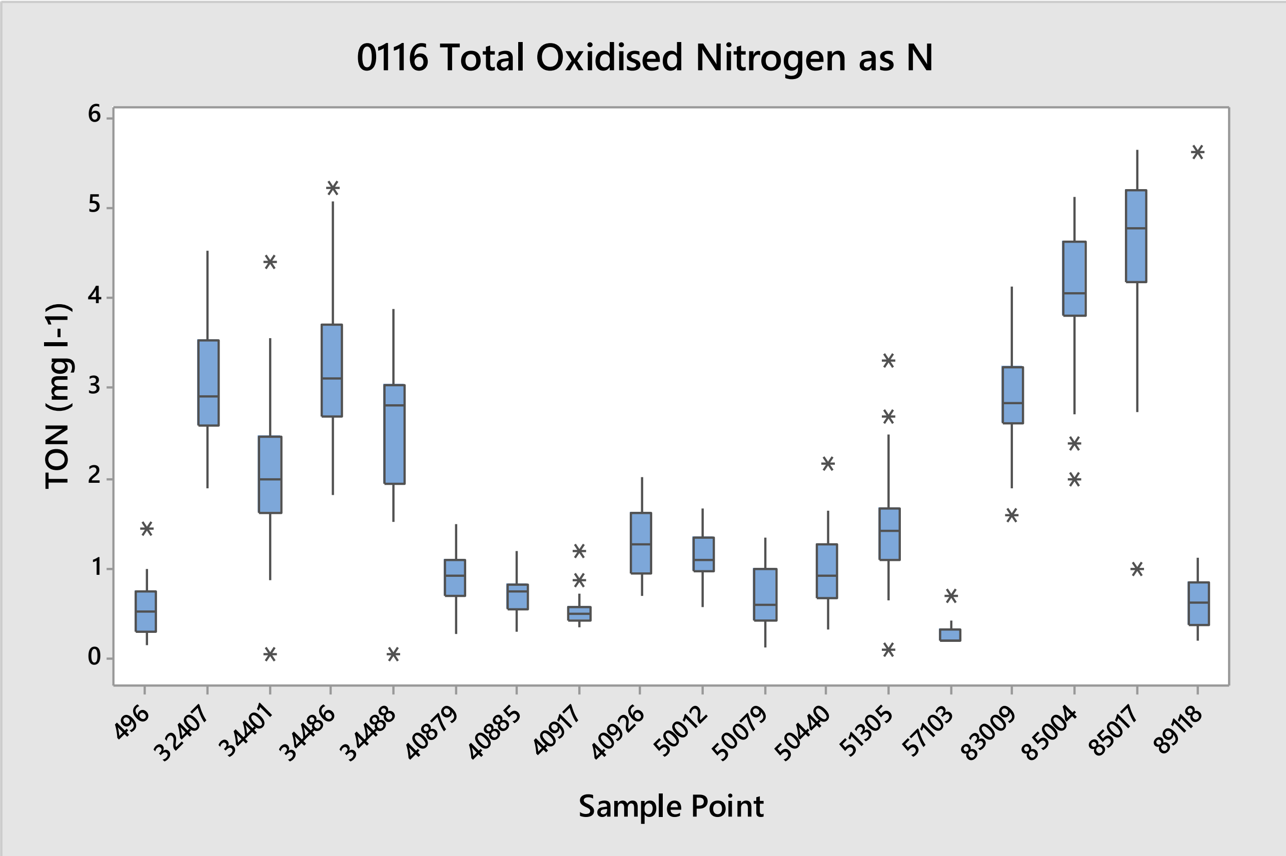


Figure 40. Boxplot of Total Oxidised Nitrogen for sample points with high phosphorus peaks.

## Appendix 3. List of Water Bodies requiring monitoring data.

This table shows water bodies where 20 or fewer samples were available. Usually this is because (a) no monitoring took place in the relevant period; (b) only quarterly monitoring was available or (c) monitoring was discontinued in early 2019. The priority column is an expert judgment assessment of the importance of monitoring the sample point, based on a combination of uncertainty in the current assessment, the importance of the water body for key SAC features, and the availability of nearby sample points that could be used to give an impression of condition.

| Sample Point | Water Body | SAC | Sampling Status | Condition | Priority |
|---|---|---|---|---|---|
| 25942 | GB110064054630 | Eden | No Data | Unknown | High |
| 20309 | GB110064048730 | Eden | Inadequate Data | Unknown | Low |
| 23332 | GB110064048710 | Eden | Limited Data | Pass | Medium |
| 25554 | GB110065053960 | Meir. | Inadequate Data | Unknown | Low |
| 22808 | GB110065053860 | Meir. | Limited Data | Pass | Medium |
| 87179 | GB110062039250 | Teifi | Inadequate Data | Unknown | Low |
| 83007 | GB110062039230 | Teifi | Limited Data | Pass | Low |
| 31612 | GB110060036350 | Tywi | Inadequate Data | Unknown | Low |
| New | GB110061030680 | Cleddau | No Data | Unknown | Medium |
| 32494 | GB110061038660 | Cleddau | No Data | Unknown | High |
| New | GB110061038680 | Cleddau | No Data | Unknown | High |
| 32406 | GB110061030700 | Cleddau | Limited Data | Pass | High |
| 40903 | GB109056033020 | Usk | No Data | Unknown | Medium |
| 40895 | GB109056040020 | Usk | No Data | Unknown | High |

| | | | | | |
|---|---|---|---|---|---|
| 41575 | GB109056040050 | Usk | No Data | Unknown | High |
| New | GB109056040070 | Usk | No Data | Unknown | Medium |
| 40865 | GB109056033030 | Usk | Limited Data | Fail | High |
| New | GB109056033040 | Usk | No Data | Unknown | High |
| New | GB109056039960 | Usk | No Data | Unknown | Medium |
| 50008 | GB109055042260 | Wye | Inadequate Data | Unknown | Medium |
| 50084 | GB109055042110 | Wye | No Data | Unknown | High |
| 50094 | GB109055036920 | Wye | Limited Data | Fail | Low |
| 50824 | GB109055042120 | Wye | Limited Data | Pass | Medium |
| 50811 | GB109055036970 | Wye | Limited Data | Fail | Medium |
| 57103 | GB109055041870 | Wye | Limited Data | Fail | High |
| 51352 | GB109055042160 | Wye | Limited Data | Pass | High |
| 50501 | GB109055037160 | Wye | Limited Data | Fail | High |
| 50089 | GB109055041900 | Wye | Limited Data | Fail | High |
| 50823 | GB109055042090 | Wye | Limited Data | Pass | High |
| 50820 | GB109055042130 | Wye | Limited Data | Fail | High |
| 50821 | GB109055042080 | Wye | Limited Data | Fail | High |
| 50090 | GB109055042270 | Wye | Limited Data | Pass | High |
| 50825 | GB109055041960 | Wye | Limited Data | Fail | Med |

## Appendix 4. List of Water Bodies where revision is recommended.

| SAC Name | Water Body ID | Water Body Name | Current Target (µg $l^{-1}$) | Reason for Amendment | Recommended Action |
|---|---|---|---|---|---|
| River Dee | GB111067057080 | Dee - Chester Weir to Ceiriog | 50 | Significant ecological variation within water body. | Subdivide water body. Upper section (Ceiriog to Clywedog) should have a target of 20 µg $l^{-1}$. Would require liaison with NE / EA. Compliance unaffected. |
| Meirionnydd Oakwoods | GB110065053960 | Glaslyn – upstream Colwyn | 10 | Not relevant to SAC as not adjacent to river feature. | Remove from dataset. |
| Afon Eden | GB110064048750 | Eden - lower | 13 | Improved data availability and protection for pearl mussel. | Reduce target to 5 µg $l^{-1}$ (pearl mussel). Compliance unaffected. |
| River Wye | GB109055042330 | Wye - conf Afon Tarenig to conf Afon Bidno | - | Erroneously omitted from Core Management Plan. | Apply target of 10 µg $l^{-1}$. Complies with target. |
| River Wye | GB109055037116 | Wye - Scithwen Bk to Bredwardine Br | 30 | Significant ecological variation within water body. | Subdivide water body at English border. Welsh section should have a target of 20 µg $l^{-1}$ reflecting current conditions. Compliance unaffected. |

## Data Archive Appendix

Data outputs associated with this project are archived on server–based storage at Natural Resources Wales.

The data archive contains:

[A] The final report in Microsoft Word and Adobe PDF formats;

[B] A GIS layer in ArcMap format on which the maps in the report are based with a pdf document detailing the data processing and structure of the GIS layers;

[C] An Excel spreadsheet entitled [SAC P Assessment Final Data.xls] summarising the phosphorus concentration means and containing the phosphorus dataset used to calculate them. Other water quality data referenced in the report are stored on NRW's WISKI system.

Metadata for this project is publicly accessible through Natural Resources Wales' Library Catalogue https://libcat.naturalresources.wales (English Version) and https://catllyfr.cyfoethnaturiol.cymru (Welsh Version) by searching 'Dataset Titles'. The metadata is held as record no 124865**.**

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