Llywodraeth Cymru
Welsh Government

First Minister SAC Rivers Summit

Tackling Phosphorus Pollution in Wales' Special Area of Conservation Rivers

Information & Evidence Pack

18/07/22

Contents

Executive Summary

Phosphorus

- Since 1945, phosphorus has emerged to play a key role in helping contribute to global food supplies across crop and animal production

- It is mainly sourced from mining Phosphate rock, which is finite and subject to global market conditions

- Phosphorus can also be sourced from animal manure, Guano and human excreta.

- Until 2013 phosphorus could be found in laundry detergents and until 2017 it could be found in dishwasher detergents in the UK

- Sewage is naturally high in phosphorus, requiring treatment before it is discharged back into water courses. It is unlikely that smaller self-contained sewage systems (like septic tanks) will have this form of treatment

- Due to the historic wide use of lead pipes and solder, Phosphorus has been used across the UK to dose the drinking water supply in to reduce the harm caused by lead ingestion

- Phosphorus is added to agricultural soils with intensive systems like wheat, dairy and potatoes being higher contributors, as phosphorus mobilises and moves towards water courses

- Phosphorus can also appear in forestry after felling

Impact of Phosphorus on Water Bodies

- When phosphorus enters water bodies it triggers boosted algae growth, which consumes the oxygen within the water eventually killing off the biodiversity. This is known as Eutrophication

- Eutrophic rivers clog up pipes and boat propellers and is toxic to organisms that drink the water

Intention of the Phosphates Summit

- The Welsh Government is aware of the complexity and interconnectedness of the phosphate issues in Wales

- There is a need for a range of collaborative measures across a number of different sectors to halt and try to reverse the damage phosphates have caused to our rivers

- Without a joined up and holistic approach any attempts to remediate our SAC rivers will fail, which will ultimately be a loss for the people of Wales and their future generations

- The intention of this summit is to discuss what we can do now collectively and collaboratively within each sector to see improvements to the currently failing SAC rivers in Wales.

Key Features of SAC Rivers

What are SACs?

Special Areas of Conservation (SAC) are protected areas in the UK, designated under:

- The Conservation of Habitats and Species Regulations 2017 (as amended) in England and Wales (including the adjacent territorial sea) and to a limited extent in Scotland (reserved matters) and Northern Ireland (excepted matters),

- The Conservation of Offshore Marine Habitats and Species Regulations 2017 in the UK offshore area.

These regulations require establishment of a network of important high-quality conservation sites that will make a significant contribution to conserving the habitats and species identified in Annexes I and II, respectively, of European Council Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora, known as the Habitats Directive.

SACs are protected by the Conservation of Habitats and Species Regulations 2017 as amended (known as the Habitats Regulations). The regulations require a 'competent authority' to carry out an assessment, known as a habitats regulations assessment (HRA), to test if a plan or project proposal could significantly harm the designated features of a European site.

If a competent authority cannot rule out all reasonable scientific doubt that the proposal would not have an adverse effect on the integrity of the site the proposal cannot be allowed to go ahead.

A competent authority is:

- A public body that decides to give a licence, permit, consent or other permission for work to happen, adopt a plan or carry out work for itself, such as a local planning authority

- A statutory undertaker carrying out its work, like a water company or an energy provider

- A minister or department of government, for example that makes national policy or decides an appeal against another competent authority's decision

- Anyone holding public office, such as a planning inspector, ombudsman or commissioner

There are nine river SACs in Wales – Cleddau, Eden, Gwyrfai, Teifi, Tywi, Glaslyn, Dee, Usk and Wye. These rivers support some of Wales' most special wildlife like Atlantic salmon, freshwater pearl mussel, white-clawed crayfish and floating water-plantain. *(see Fig 1)*

The Joint Nature Conservation Committee (JNCC) recommended that UK nature conservation organisations such as Natural Resources Wales (NRW) adopt tighter targets after considering new evidence about the environmental impacts of phosphate. In addition, the predicted warmer and drier weather resulting from climate change could reduce river flows during the summer, and so increase phosphate concentrations.

NRW compared phosphorus levels surveyed in the SAC rivers against the new tighter targets. This evidence review shows that overall, phosphorus breaches are widespread within Welsh SAC rivers with over 60% of waterbodies failing against the challenging targets set.

Figure 1: SAC River Summary

	SAC								
Species	Gwyrfai	Eden	Dee	Teifi	Tywi	Cleddau	Usk	Wye	Meirionydd Oakwoods
Salmon	X	X	X	X			X	X	
River Lamprey			X	X	X	X	X	X	
Brook Lamprey			X	X	X	X	X	X	
Sea Lamprey			X	X	X	X	X	X	
Allis Shad					X		X	X	
Twaite Shad					X		X	X	
Bullhead			X	X	X	X	X	X	
Ranunculion	X		X	X		X	X	X	X
Pearl Mussel		X							
WC - Crayfish								X	
Otter	X	X	X	X	X	X	X	X	

Please see Annex A for a detailed breakdown of characteristics per SAC river.

Phosphorus Technical Summary

Sources, uses, impacts and considerations for designing a roadmap towards sustainable solutions

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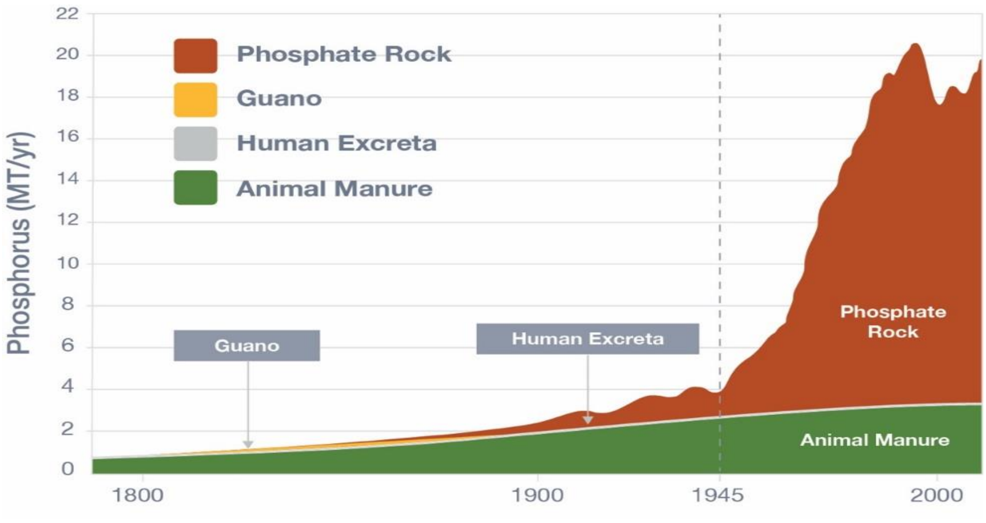
Historical Context of Phosphorus as a Fertiliser

Phosphorus (P) is a natural chemical element that is distributed naturally across World soils, mostly in sedimentary rocks associated with the mineral apatite. The element itself was discovered in 1669 years ago by a German scientist Hennig Brand and the agricultural benefits of P were first noted with the use of crushed bones, which are high in P concentrations, in the 1800s. Guano, dried bird manure was also found to be high in P concentrations (5% phosphorus by weight) and became an important source of fertiliser in the mid-1800s. John Bennett Lawes (1814-1900) was a pioneering innovator intrigued why crushed bones improved the yield of turnips and how he could make this process more effective on his own farm.

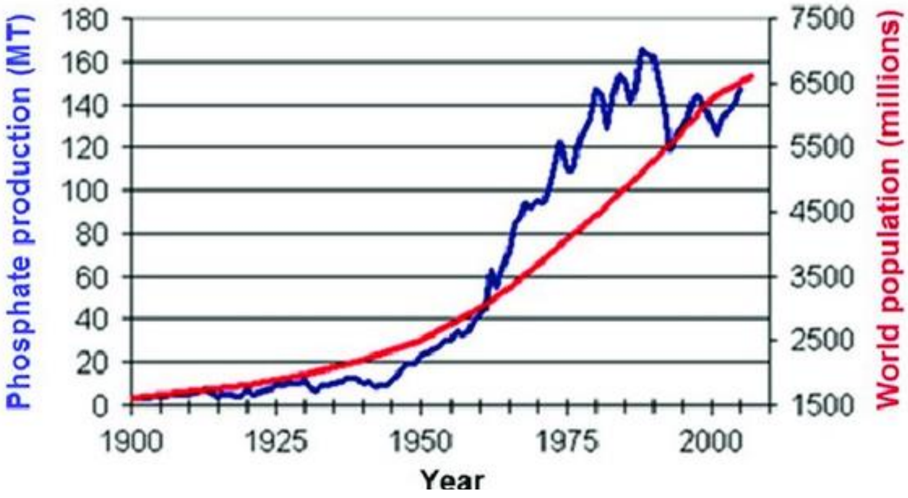
Lawes developed and patented the ‘acidulation’ process to manufacture superphosphate fertiliser, which aided the solubilisation of phosphorus in soil and thus benefitted crop yield. Lawes collaborated with Joseph Gilbert and pioneered the long-term Classical Experiments in the field at Rothamsted Research in Hertfordshire, England, which have since demonstrated considerable benefits of P fertiliser; some of these long-term fertiliser trials continue to this day. Since the ‘Green Revolution’ post 1945, phosphorus has emerged to play a key role in helping contribute to global food supplies across crop and animal production, and this can be tracked back to correlate well with the production of fertiliser from phosphate rock supplies and world population (Figure 1a and Figure 1b).

Figure 1a*[1]*. The historical change in the use of various sources of phosphorus in Global agriculture since 1800. Shows the relative transition from animal manure to guano to human excreta and the eventual increase in the use of phosphate rock since 1945. This diagram is reproduced and redrawn from a graph published from “The Story of Phosphorus” (Cordell, Drangert and White 2009a): Redrawn version used here (Elser and Haygarth 2021).



[1] *Please note* – the figure references in this chapter are self-contained. Figure references will follow on from figure 1 (p.5) from the start of the Compliance Maps section onwards for the remainder of the evidence pack.

Figure 1b. Increase of world population and phosphate rock production. Source (Carvalho 2017)



The first documented mining of phosphate rock took place in England in 1847 using picks and shovels, while mining first began in the United States in 1867 in South Carolina. Today phosphate rock is mined almost entirely by open cast or surface methods using draglines with enormous bucket wheel excavators. In the last decade most of the production of rock phosphate has been from Morocco, China, South Africa Jordan and USA, and looking ahead Morocco is emerging to be the dominant single supplier of World phosphate rock supplies (Elser and Haygarth 2021).

Impact of Phosphorus on Water

Phosphorus impacts in rivers lakes and marine margins by contributing to a state called 'eutrophication', which leads to the proliferation of singly dominant aquatic and marine species, thwarting biodiversity and allowing undesirable aquatic plants, commonly algae, to thrive and consume oxygen (Figure 2). Think of this as just as phosphorus encourages agricultural plants to grow, it also encourages non-desirable plans to thrive too, but in water systems, it does not discriminate. Ultimately rivers and lakes can turn green within the eutrophic state and weed-ridden water can clog up pipes, boat propellers and is toxic to organisms that drink the water. Whilst this has mostly been a freshwater issue, there is new evidence that there are effects on marine margins, and even in the much longer term, oceans.

Figure 2. Lake 226 at the Experimental Lakes Area in northwestern Ontario, divided in half by an impermeable curtain in the early 1970s. The top part of the lake received inputs of nitrogen and organic carbon equivalent to what might be received from domestic sewage inputs. The bottom half of the lake received similar amounts of carbon and nitrogen but also phosphorus. Jim Elser referred to the original aerial photograph as "the most powerful image in the history of limnology" due to its impact in motivating large-scale implementation of advanced wastewater treatment for P removal along with phosphate detergent bans. Figure and caption taken from Elser and Haygarth (2021). Original photo permission: IISD-ELA. Original photo: E.D. DeBruyn (Canada Department of Fisheries and Oceans).

Phosphorus from detergents

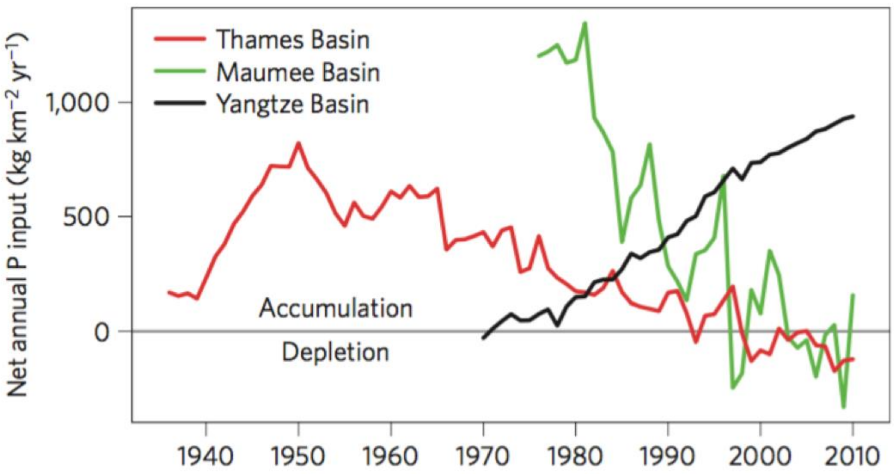
Phosphorus is a chelating agent that has excellent cleaning capabilities. Pentasodium triphosphate is the main compound that helps with this chelating process, which occurs due to phosphate's ability to form soluble and strong complexes with calcium and magnesium ions. Phosphorus in detergents is mostly thought to have been reduced and mostly removed (partly in a response to the impact of the Lake 226 study (Figure 2)), at least in many of the high GDP nations. In the USA, bans started in some states in the 1970s, a nationwide 'voluntary' ban was implemented in 1994 and more state-wide bans were implemented in the 2010s.

The European Parliament banned phosphates in consumer laundry detergents after June 2013 and in dishwasher detergents after January 2017, only relatively recently. Whilst the consensus seems to be much improvement in the UK (and Welsh) situation, in writing this article I did consult international colleagues and there are some uncertainties in this space that we might want to check up on and explore with local experts.

Phosphorus in Sewage

Sewage, and more pointedly dung and urine, are naturally high in phosphorus. Since the 1970s phosphate removal from sewage can be celebrated as a 'success story' of the industries of the high GDP nations with sewage clean up technology, largely achieved through the emergence of various wastewater treatment innovations and technologies in the late 20th century. Figure 3 shows this success in the River Thames in England as a famous example here – note the decline over the latter decades.

Figure 3. Long term trends in phosphorus in three world river basins (Powers et al. 2016). The Thames shows a long-term success story of sewage control, the Maumee shows long term success of agricultural pollution control. The Yangtze is still not under control.



Phosphorus is removed from sewage via either chemical or biological methods. Chemical precipitation occurs when phosphorus is forced to react with iron, aluminium, or calcium, to form solid precipitates that can be collected. Either the chemical precipitate (sludge) or the phosphorus-enriched bacteria can then be scooped out of the sewage treatment plant as 'biosolids'. There may be scope for exploring recycling value of these biosolids. In consulting my international peers on this, despite the broad-brush agreement of 'success' there is a need for us to carefully scrutinise local sources and leaks, and we must not be complacent here, as often we are dealing with old sewage systems and, of course, septic tanks.

Plumbosolvency: Phosphorus Dosing and Potential Contamination from Leaking Pipes

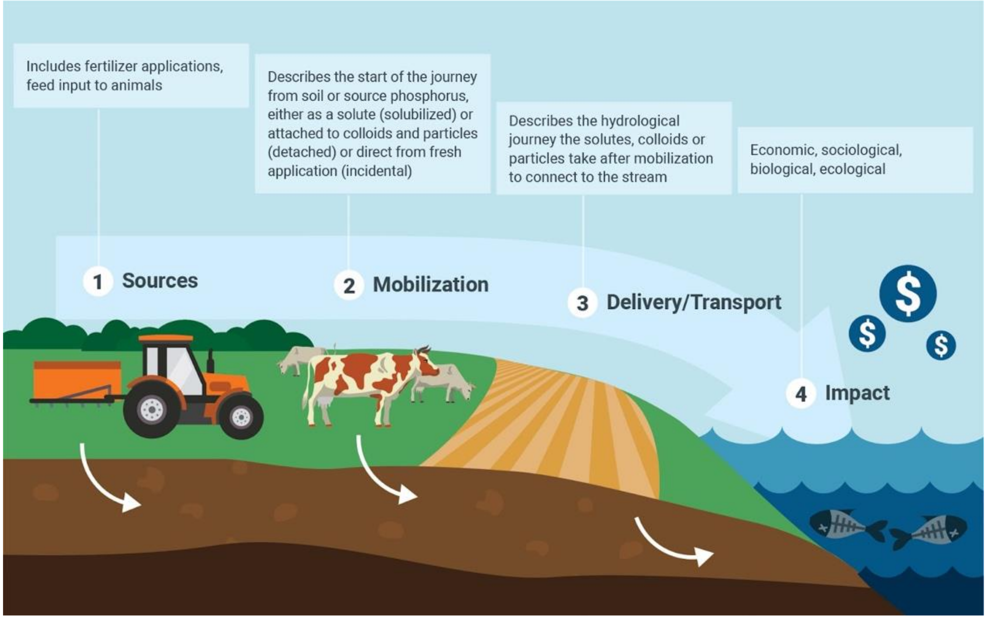
Recent work across England and Wales (Gooddy et al. 2015) cites phosphate dosing of drinking water as a corrosion inhibitor of lead piping (plumbosolvency) as a potential contributor to drinking water and waterways through leaking pipes, and stated *"phosphate dosing of drinking water supplies represents a pervasive and potentially significant source of phosphorus within the environment".* The work estimated *"drinking water leakage for the U.K. corresponds to around 1000 tonnes of phosphorus entering the environment annually".* This is certainly something that warrants further consideration by the local water companies and experts on the issue.

Phosphorus Transfers from Agriculture to Water

It is now well established that phosphorus added to agricultural soils since the Green Revolution is now emerging to contribute to river and lake water quality problems around the high GDP nations of the world. This varies according to type of agriculture, with more 'intensive' systems like dairy, potatoes, wheat being generally considered to be higher contributors, and more extensive systems like beef, sheep being less phosphorus consuming, and therefore lower contributors.

However, this is not always so simple as there is a complex interplay between P source factors and other processes on the farm. A strong guiding framework for describing the transfer of phosphorus from agriculture to water, which is highly valid for Wales, is the 'transfer continuum' conceptual model (Haygarth et al. 2005)(Figure 4).

Figure 4. The four tiers of the phosphorus transfer continuum (redrawn from Haygarth et al. 2005 this version taken directly from Elser and Haygarth 2021).



Here phosphorus transfer if broken down to four tiers: Tier 1 is 'sources' of P, which describes the 'new' P that comes into the farm, this will mostly be fertiliser P but could also be new P from animal concentrate feedstuffs too. Take careful note that manure is not new P, it is recycled within the farm or the farming system, so use of re-use of manure is generally a good thing, not a bad thing. Tier 2 is 'mobilisation' of P which describes the start of the movement of P from the soil and can take place through solubilisation (which can be both biological and chemical and may reflect long term soil P history), physical detachment (similar to soil erosion, release of particles and colloids), and finally incidental losses (wash off of newly applied fertiliser or recycled manure, before it has had time to equilibrate into the soil). Tier 3 refers to 'delivery', the hydrological transport processes that carry the P across or through soil to the river channel. Delivery can vary in intensity, depending on high or low flows and is sometimes called a transport factor.

Finally, Tier 4 is 'impact' that describes the resulting consequences of the P on the downstream water body, be that ecological or financial. Impact may well be many miles from source and many years after the start of the journey of the phosphorus from the source (see legacy and time lags – below). This P transfer continuum (source, mobilisation, delivery, impact) has proven itself to be a robust framework from which to understand and approach P mitigation methodologies, for example see the cost curve work that was funded by Defra in the early 2000s and the related project that came after this on diffuse pollution inventory and farmscoper family of projects (more on these to follow).

Phosphorus Transfers from Forestry to Water

Forestry is generally considered a low contributor (similar or lower than extensive agriculture) but there are some 'peaks' in concentrations especially around time of change in management, such are felling or planting. Studies in upland Wales at Plynlimon showed that soluble reactive phosphorus (SRP) does respond with a peak concentration in stream after felling, but that this signal tends to be dampened further downstream. Colin Neal, a well-respected hydrochemist, wrote that *"SRP concentrations at Plynlimon are much lower (by a factor of five) than the cleanest of the rural lowland rivers and typically two orders of magnitude lower than the agriculturally, urban and industrially influenced rivers"* (Neal 2002). A 25y study on the impacts of conifer afforestation and climate on water quality River Halladale in North Scotland noted total P increased after fertiliser applications but claimed no impact on ecological status (Shah, Nisbet and Broadmeadow 2021). The total P concentrations varied between10 and 40 µg L^{-1}, with a maximum of 155 µg L^{-1}. Whilst not particularly high, it is not trivial either and I would cautiously conclude that the contribution of Forestry seems to be mostly low but should certainly not be ignored and that there may case for more monitoring to understand this, especially with climate change changing future rainfall runoff patterns.

Legacy Phosphorus, Travel Time and Time Lags and Climate Change

The term 'legacy' phosphorus has emerged to acknowledge and describe the often very slow travel times that are being experienced in the transport of phosphorus from land to water. Look again at Figure 3 and note how many decades it took to clean up the Thames and the Maumee, this is because of the legacy effect. It helps us account for phosphorus stored in soils and catchments that persists as (a 'legacy' of) historic fertiliser (or recycled) inputs. The term can also be applied catchment wide too. This component of understanding and the science is still relatively immature and emerging but is something we need to take seriously. The simple and overriding point is, that if we stopped putting any new phosphorus into Wales today, it may well be many years until we saw any change in the downstream water quality. This is the power of the legacy effect, and we need to consider this in any new plan we make towards nutrient neutrality.

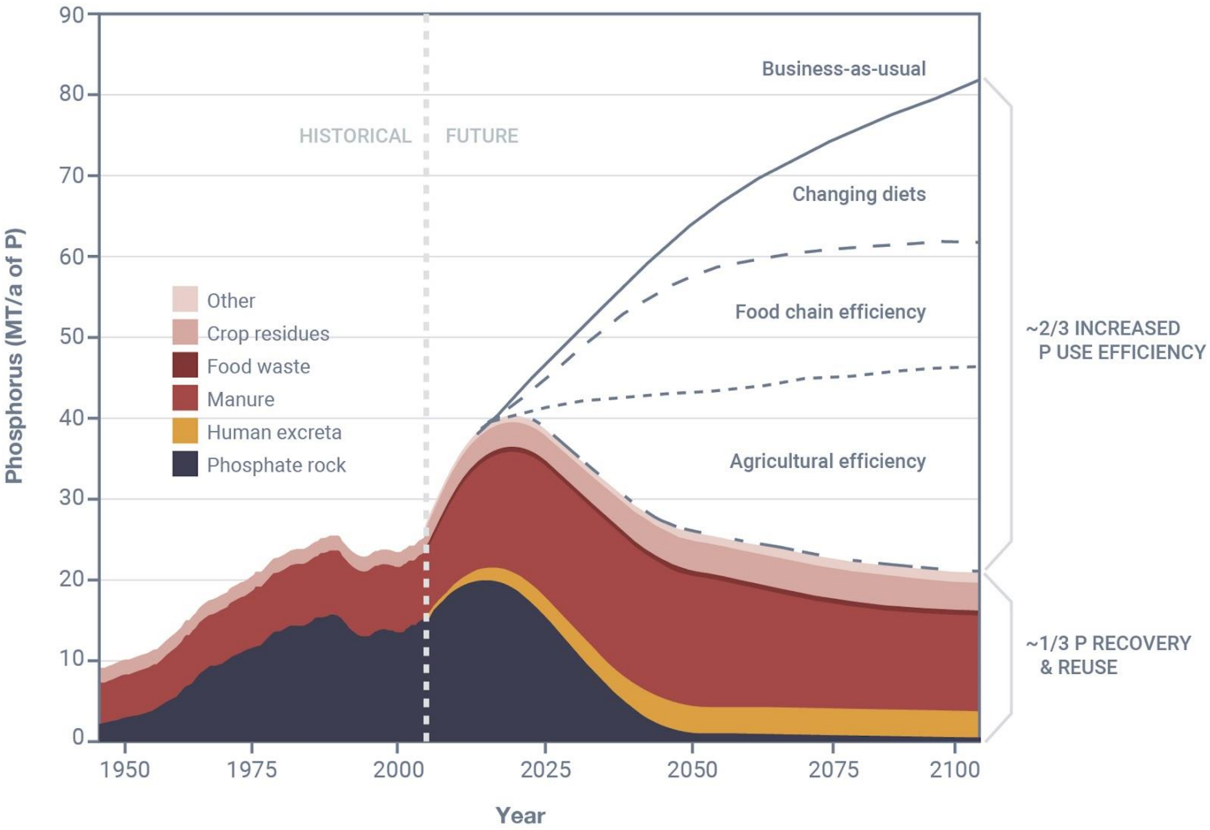
Another unfortunate and confounding issue that needs to be considered is that climate change will influence the speed at which phosphorus moves through soil and catchments in coming decades. New research has shown that changes in rainfall and run off patterns may well increase phosphorus transfers by up to c.30% in the next few decades simply because of the changes in physical dynamics of water movement (Ockenden et al. 2017). This is a relatively new area, but the evidence is beginning to mount up.

Future Options for Phosphorus Reduction and Recycling

There is no doubt that as we move forward, we need to imagine, and plan for a future where we are less reliant on new imports of phosphate rock fertiliser to drive food production. However, this needs to be tempered with understanding of the benefits that judicious use of new fertiliser can still bring when used appropriately in the right time and place.

New thinking and literature is emerging at pace in this space, and a reasonable place to start would be chapters 8 and 9 of *Phosphorus Past and Future* (Elser and Haygarth, 2021). Here they break the issue into phosphorus "reducing" and phosphorus "recycling", but also address the issue of governance and leadership as having an important role to play in tacking this 'wicked problem'. It is important to state that all sectors represented are indeed part of a joined-up system, where we all use and rely on phosphorus to varying degrees. One example of big global thinking is an analysis undertaken by Cordell *et al*. 2009 (Figure 5), where they back-casted an analysis of phosphorus use in-order to plan to achieve sustainable targets the eliminated a reliance on new phosphorus. Delivering on this may be complicated and ambitious, but the example does frame some of the complexities that we are dealing with and the relationship between phosphorus and population size. A new study from the UK has emerged recommending new strategies to improve food system P efficiency and reduce P accumulation and losses (Rothwell et al. 2022).

Figure 5. The Cordell Scenario. A backcasting analysis of global phosphorus use to achieve a sustainable target that eliminates reliance on mined phosphate rock by the year 2050. Figure and Legend taken from Elser and Haygarth 2021, originally from (Cordell et al. 2009b).



There are plentiful papers published suggesting ways to mitigate phosphorus loss from agriculture and the transfer continuum is a useful framework from which to build different strategies of source control, mobilisation control, delivery control and impact control. The "cost curve" approach (Haygarth et al. 2009) detailed priorities for cost and efficiency for mitigating agriculture in a range of agricultural typology across England and Wales is one example. Also notable is the method-centric 'User Manual' for the mitigation of diffuse water pollution from agriculture led out of IGER in Aberystwyth in the early 2000s (Cuttle et al. 2016). Although a few years old now, these 'cost curve' and 'user manual' approaches provide excellent frameworks that may well still be applicable in Wales (in a refreshed state). Some excellent more contemporary research has also been done by the RePhOKUs team on the River Wye, led by Paul Withers (and part of the previously mentioned studies on food system efficiency by Rothwell et al. 2022)).

There are other scientific discussions going around about the efficiency of plant utilisation of phosphorus, in that plants are not very efficient in using phosphorus in the soil, with many forms of applied phosphorus stored away in inaccessible or organic forms, that plants find difficult to attain. This is unfortunate and highlights where new plant and soil innovations need to take place so that plant soil phosphorus efficiency can still be much improved (George et al. 2018).

Considerations for Designing a Roadmap Towards Sustainable Solutions

1. We are all experts here. This is a collective and complex 'wicked' problem; it is not the problem of any one sector as we all use food, and we all have a role to play in finding a solution

2. If we stopped putting any new phosphorus into Wales today, it may well be many years until we saw any change in the downstream water quality. This is the power of the legacy effect, and we need to consider this in any new plan we make towards nutrient neutrality

3. We should try to find innovations to better use the phosphorus already in the 'system' to better effect, and reduce our reliance on 'new' phosphorus

4. We must not be complacent with detergent and sewage P. Despite a broad-brush agreement of 'success' there is a need for us to carefully scrutinise local sources and leaks, as often we are dealing with old sewage systems and, of course, septic tanks. Can we consider exploring recycling value of these biosolids?

5. Plumbosolvency (phosphorus dosing and potential contamination from leaking lead pipes) warrants further consideration by the local water companies and experts on the issue

6. Agricultural contributions are complex and varied, reflecting an interplay between source and delivery factors in the Welsh landscape. The transfer continuum is a good means to frame mitigation plans, and there are studies published to help guide the way. The 'cost curve' and 'user manual' approaches provided frameworks for reducing P loss from agriculture that may be useful start points

7. There may be a case for more monitoring to understand future changes in P transfers from different types of land use (including forestry), especially with climate change changing future rainfall runoff patterns

8. There is an imperative need for strong and appropriate leadership to help coordinate this and take it forward, it is complex and challenging

   NB: for associated references and a note from the author, please see **Annex C.**

Compliance Maps (for failing SACs)

Figure 2 – Cleddau Compliance Map

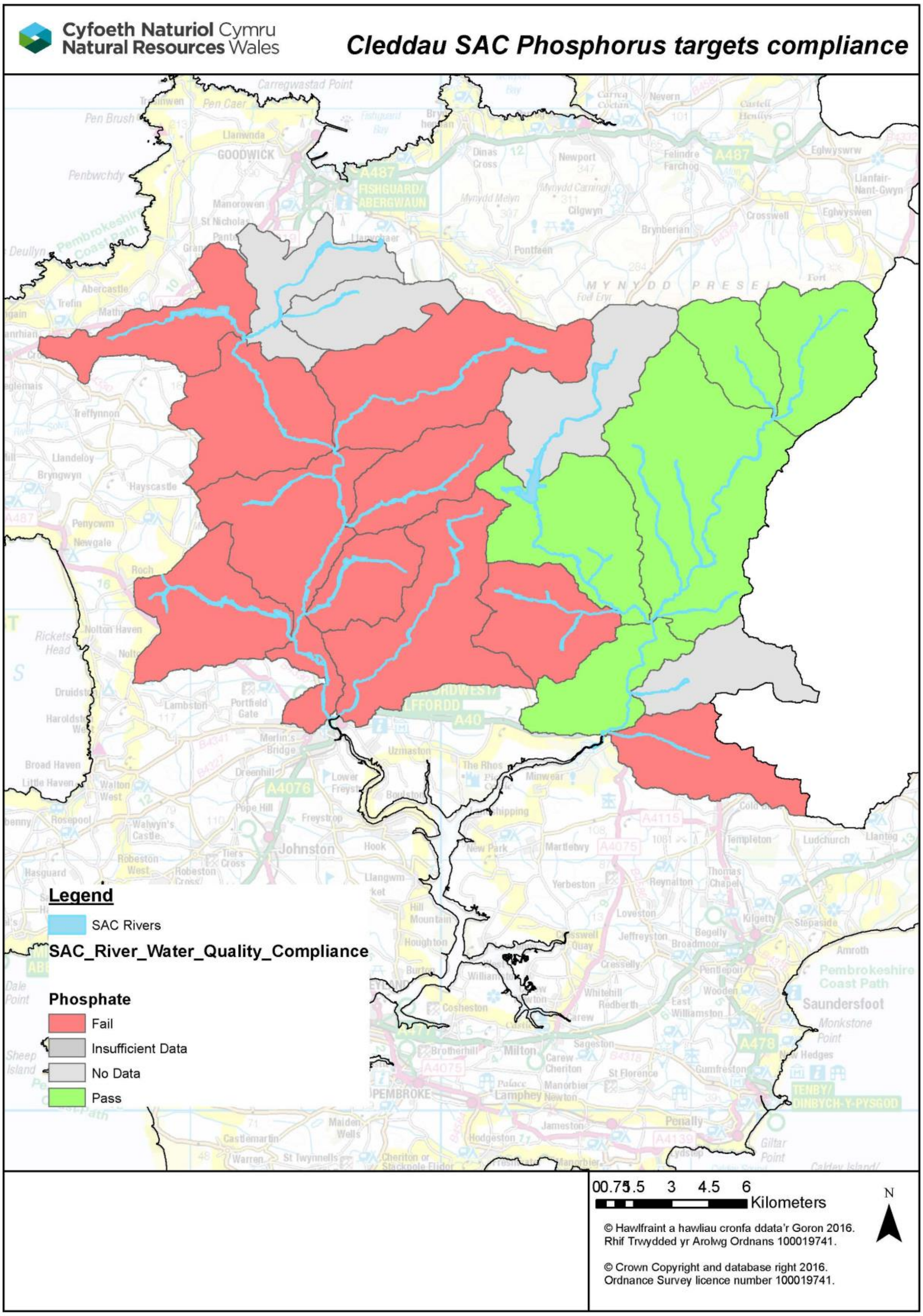


Figure 3 – Dee Compliance Map

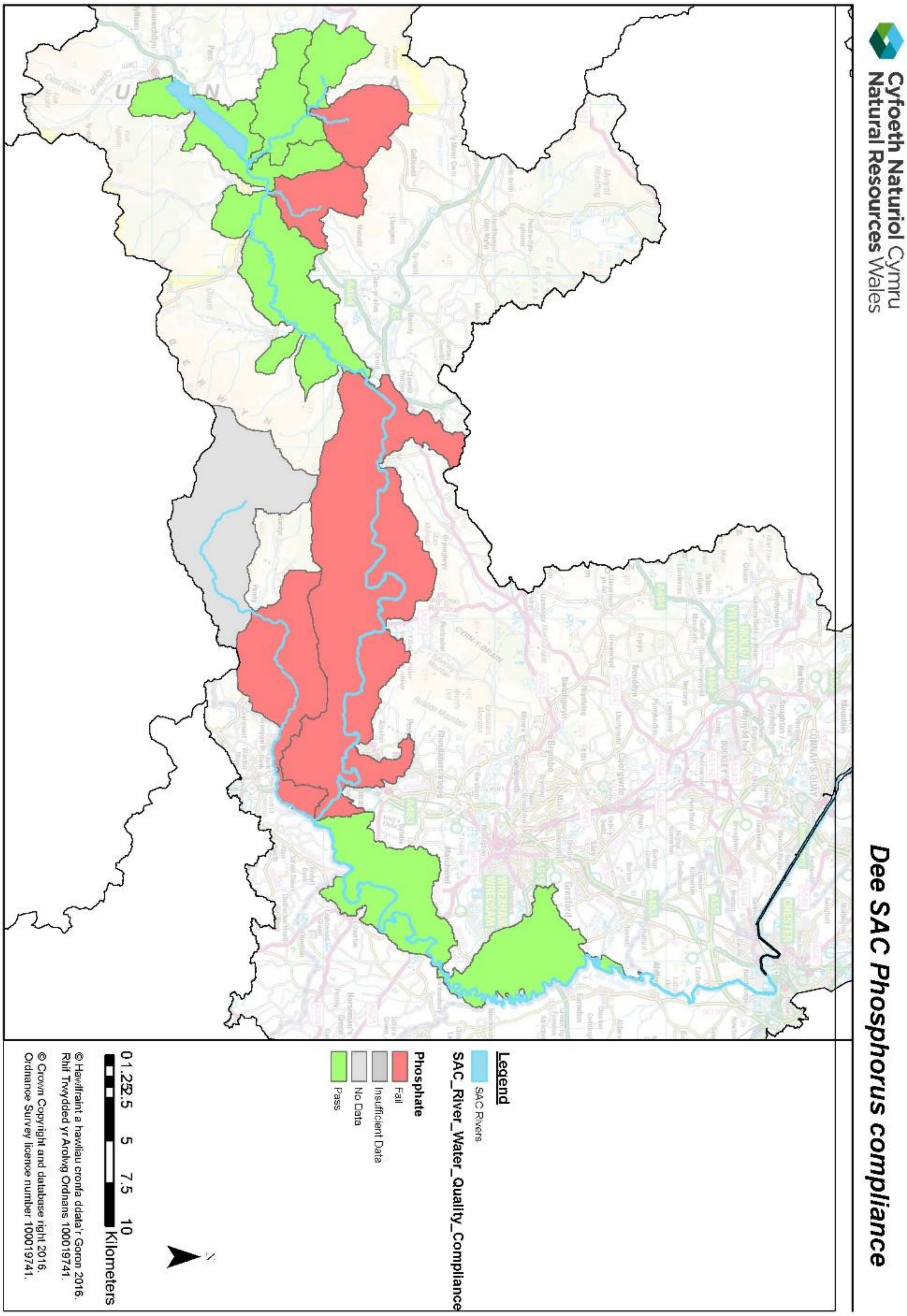


Figure 4 – Teifi Compliance Map

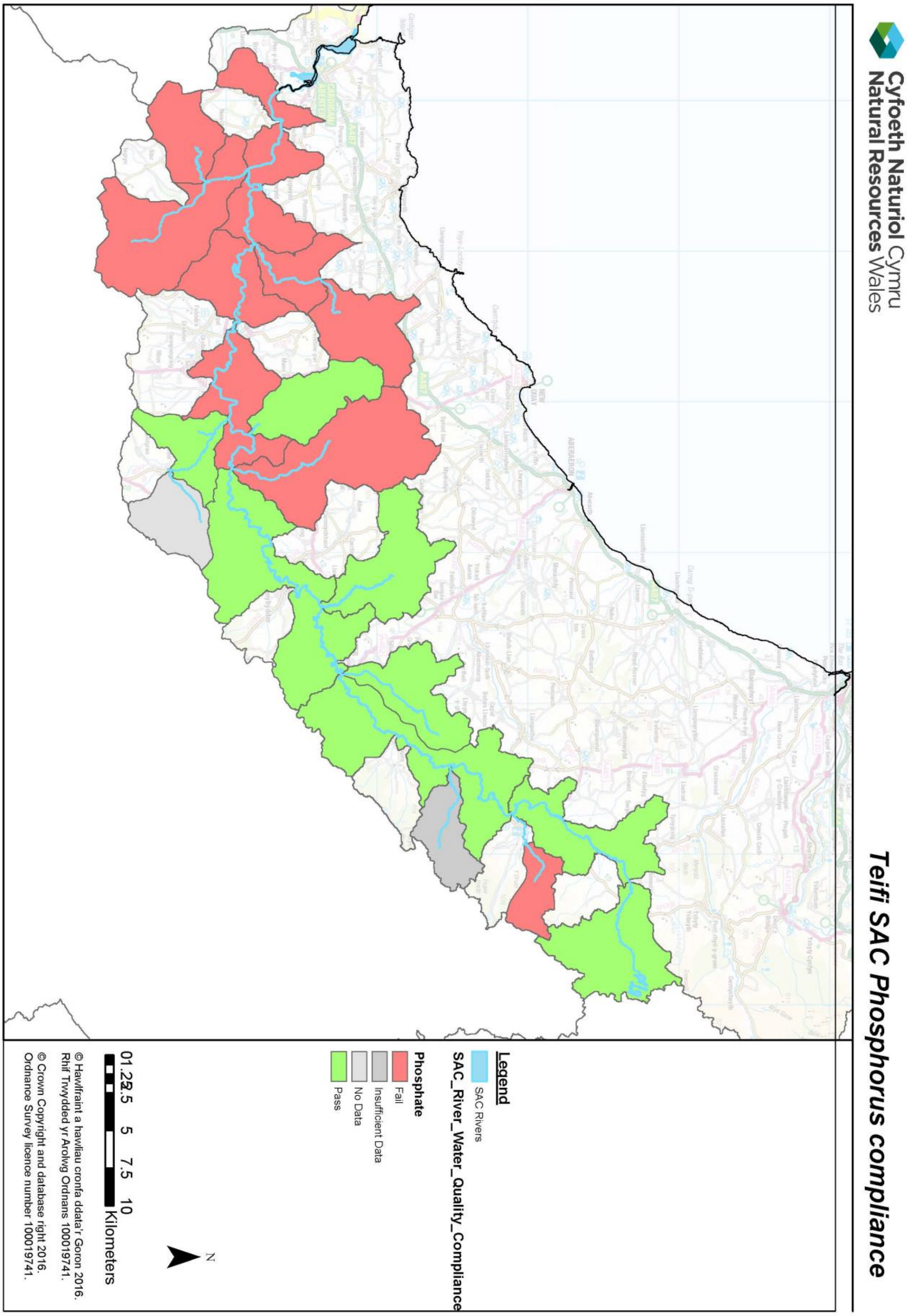


Figure 5 – Usk Compliance Map

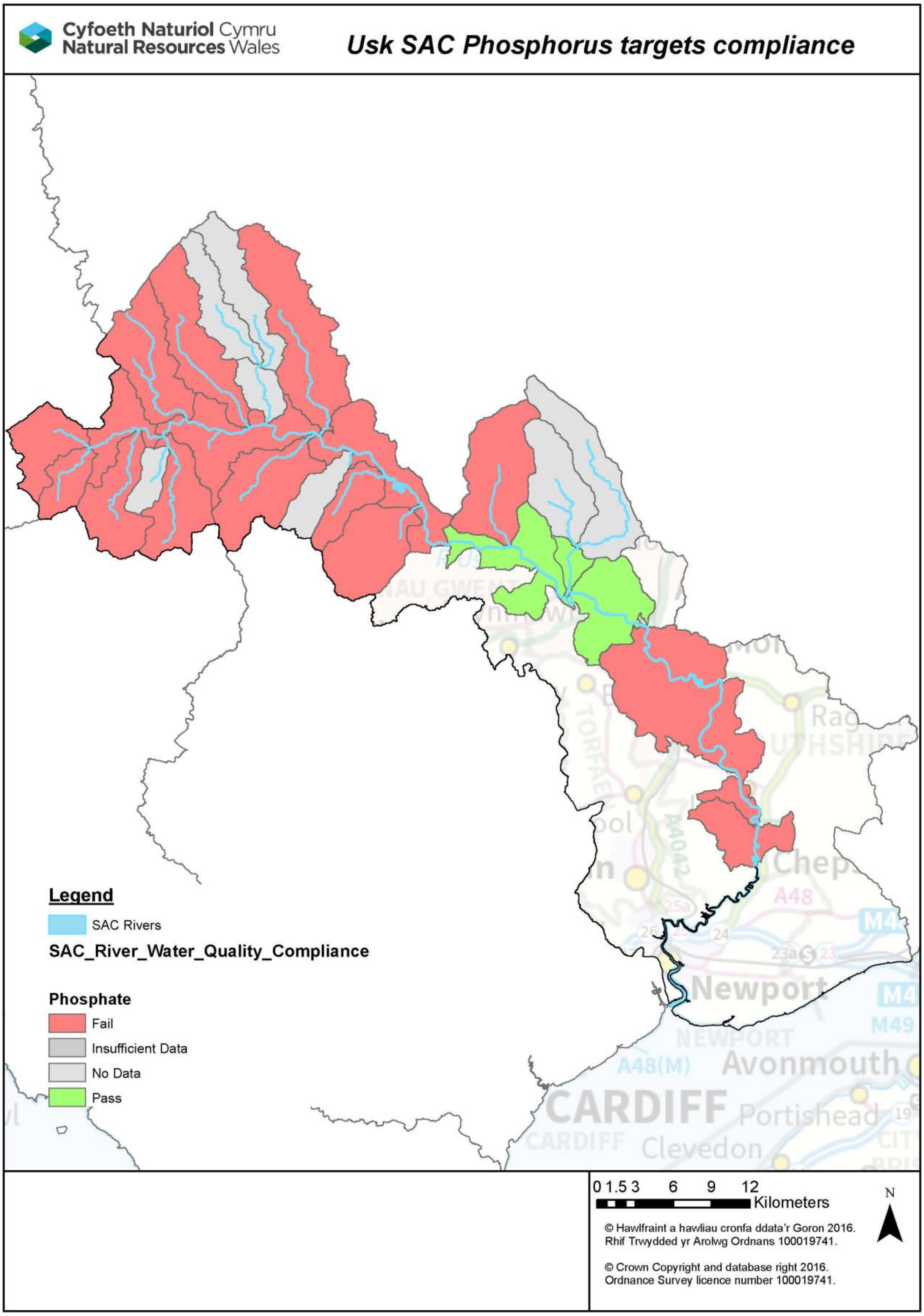


Figure 6 – Wye Compliance Map

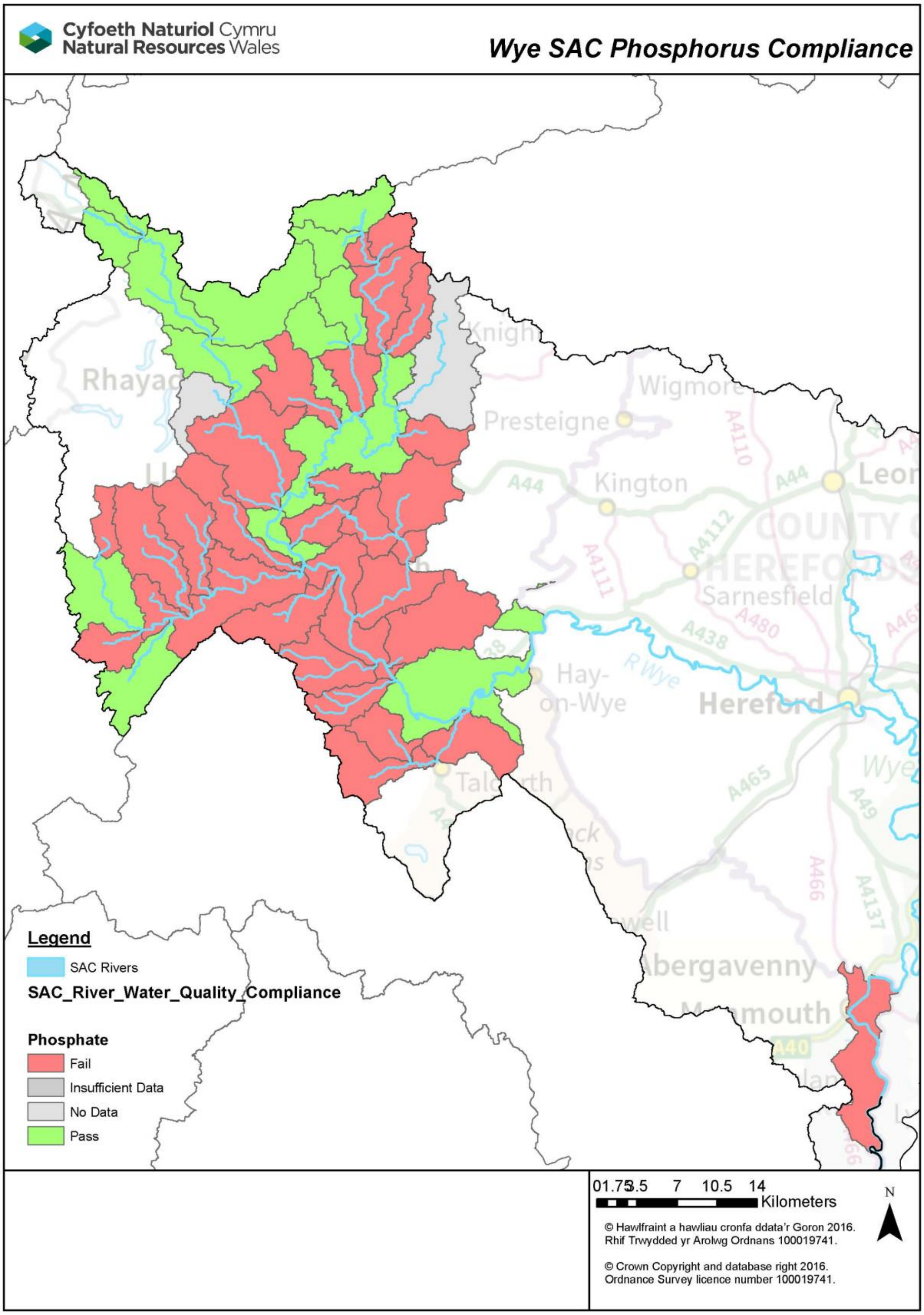


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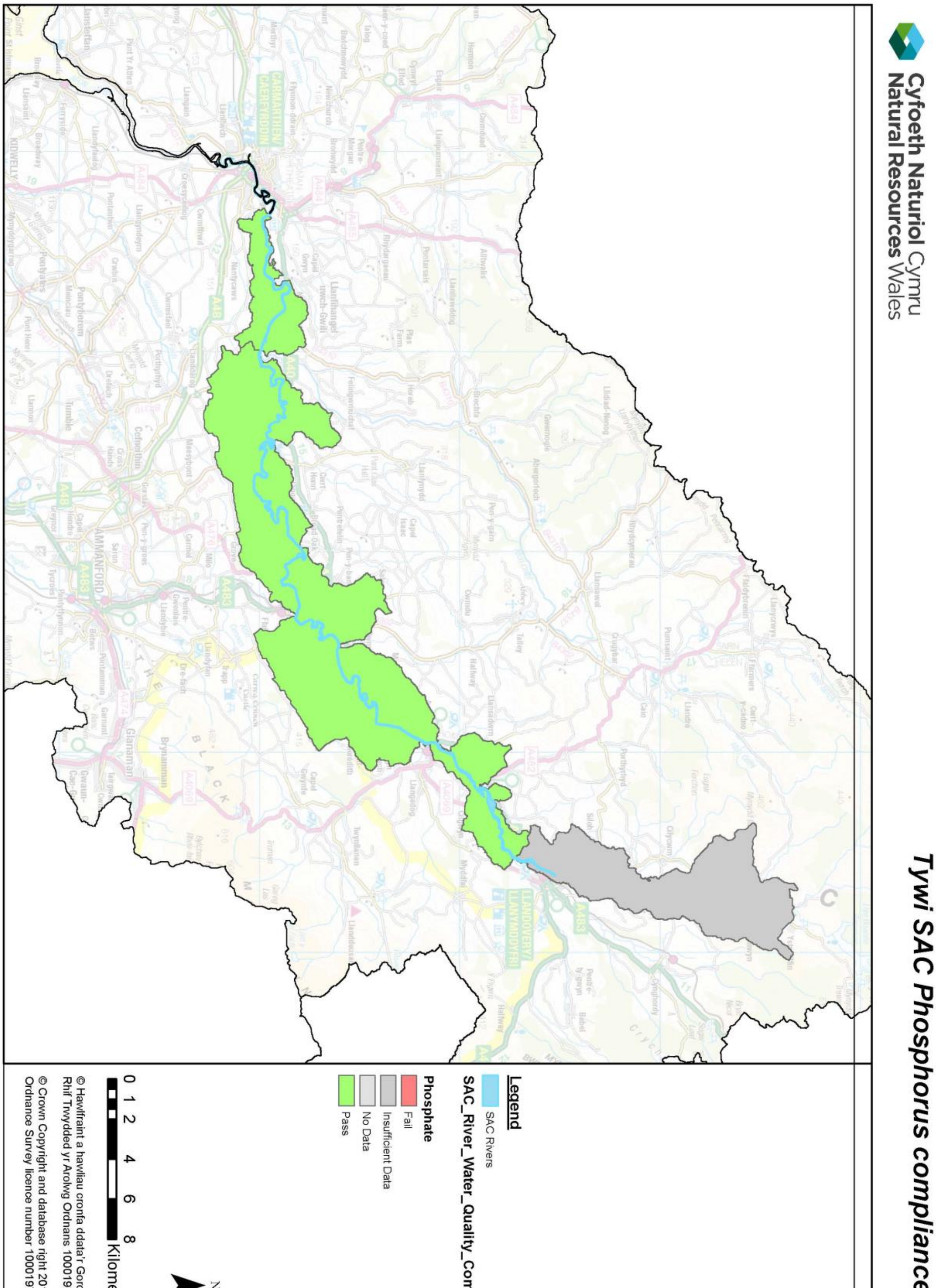
Figure 7 – Tywi Compliance Map



Overview - Phosphorus Load per SAC River

Figure 8: Source Apportionment Load to SACs

Data:	Total Load (kg/day)			
	Usk	Wye	Dee	Teifi
% STW	21%	23%	45%	67%
% Rural Land Use	67%	72%	24%	28%
% Storm Overflows	1%	2%	10%	3%
% Other	11%	3%	21%	1%
Total P load kg/d	180	67	122	45
STW kg/d	37.8	15.4	54.9	30.2
Rural Land Use Kg/d	121	48.2	29.3	12.6
Storm Overflows Kg/d	1.8	1.34	12.2	1.35

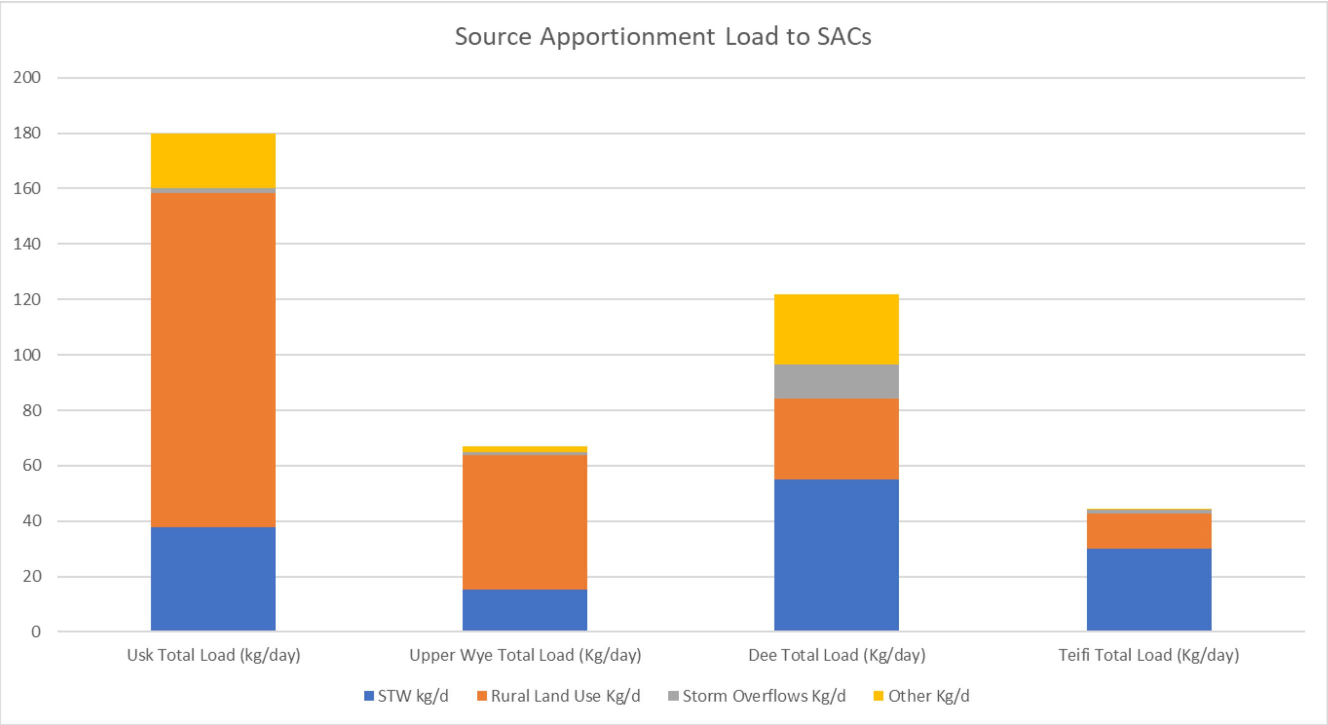


Figure 9: Phosphorus Load Overview – River Dee

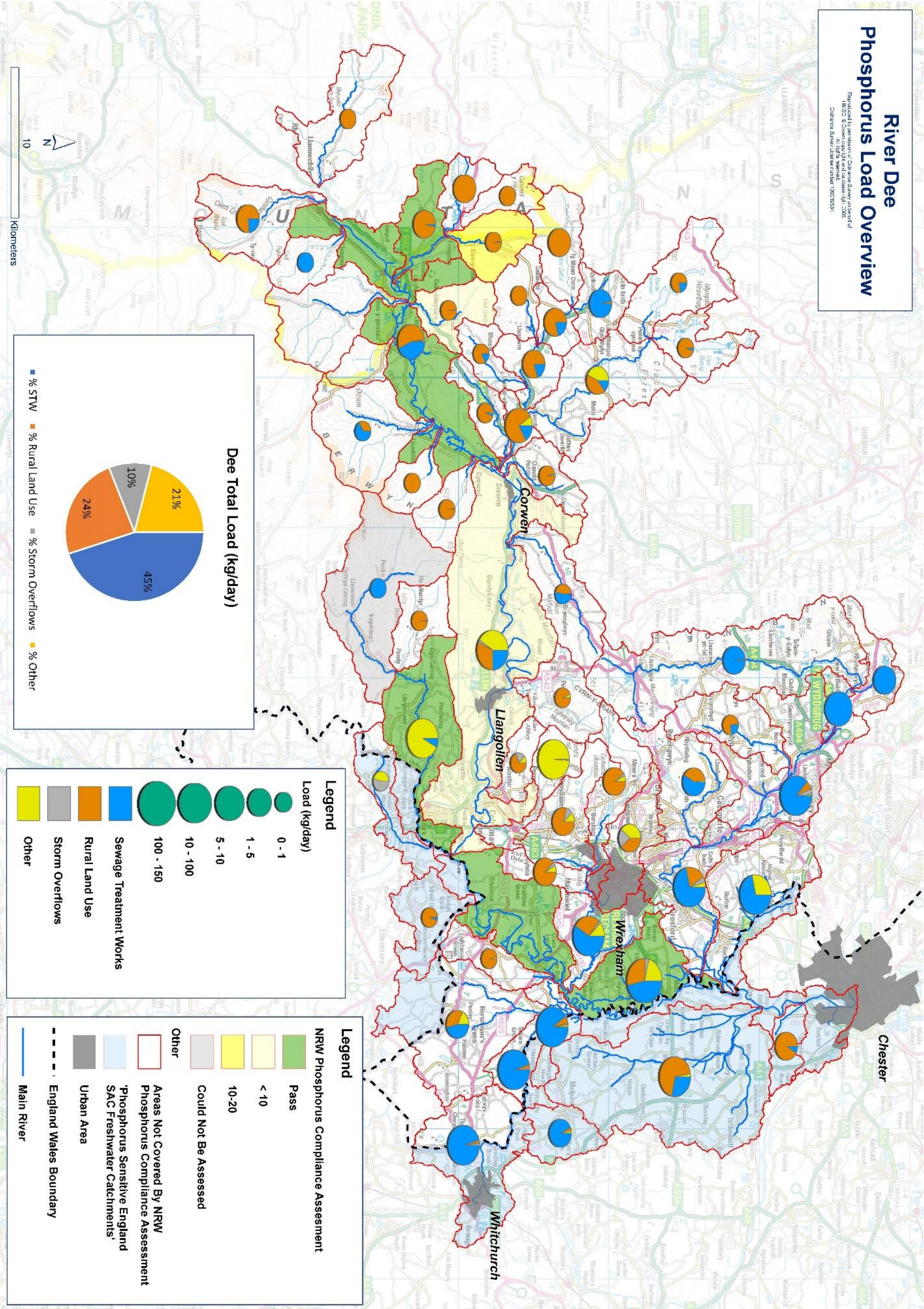


Figure 10: Phosphorus Load Overview – River Teifi

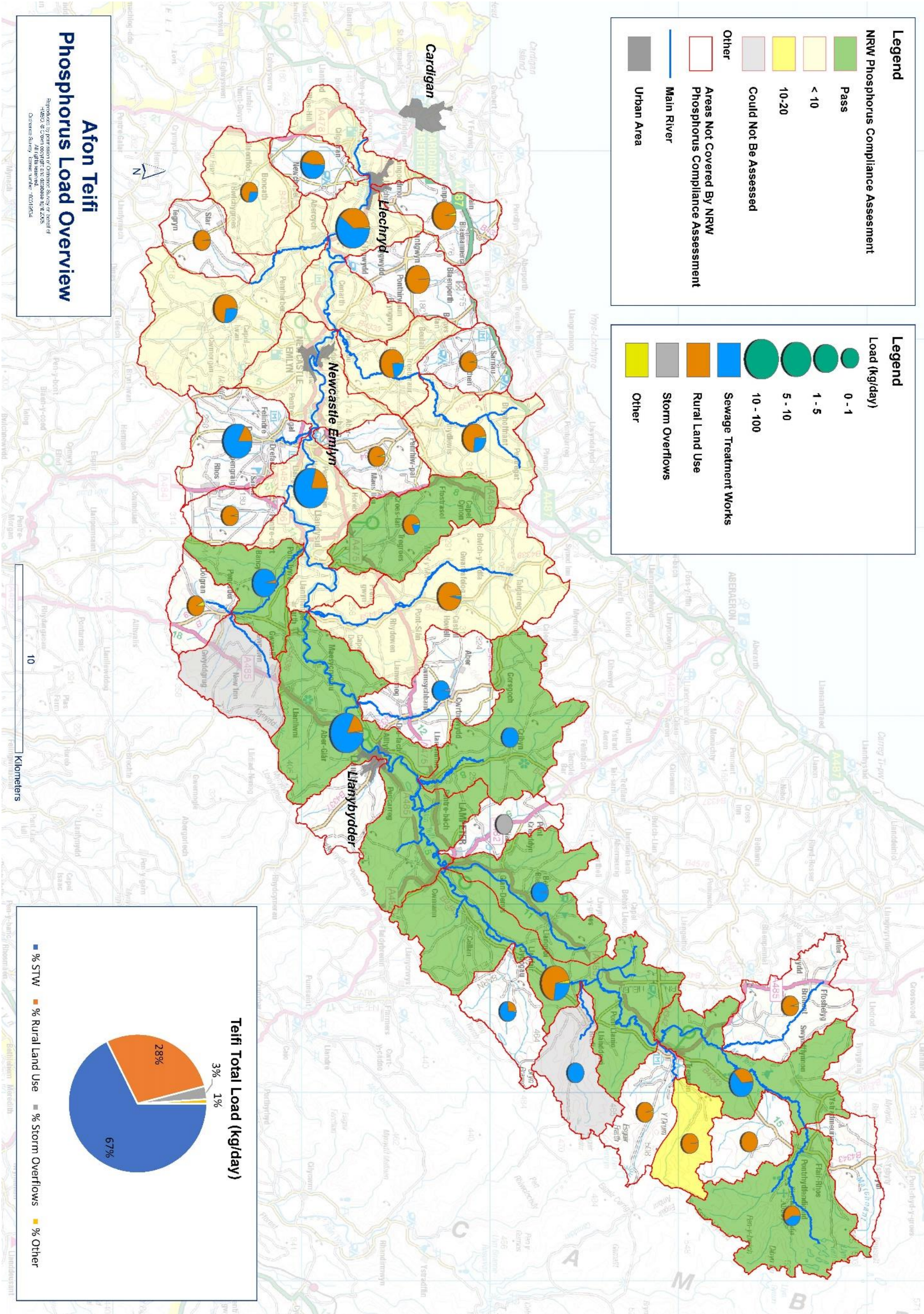


Figure 11: Phosphorus Load Overview – River Usk

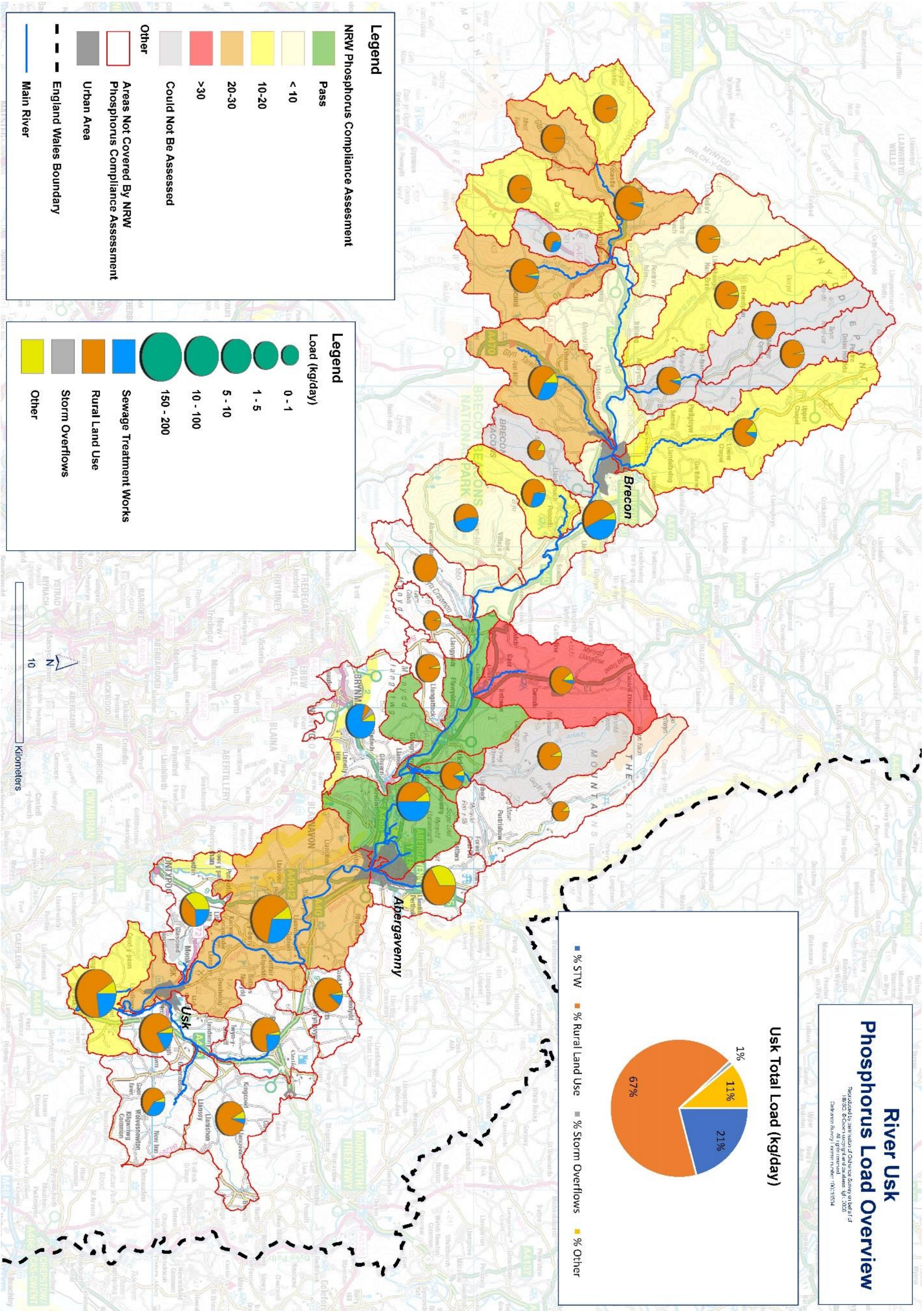
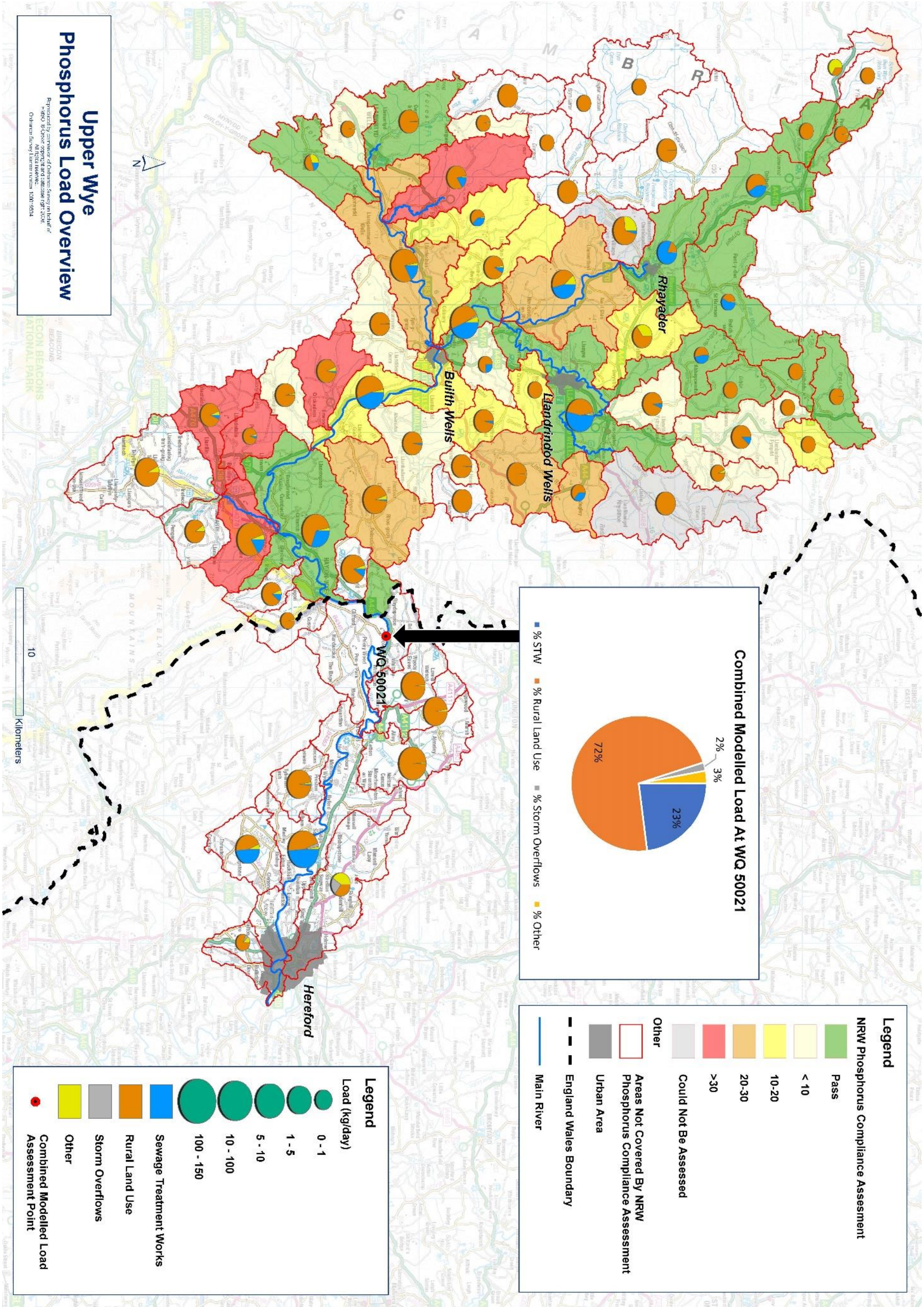


Figure 12: Phosphorus Load Overview – River Wye



Detail – Phosphorus Load per SAC River (Source Apportionment Reports)

Dee

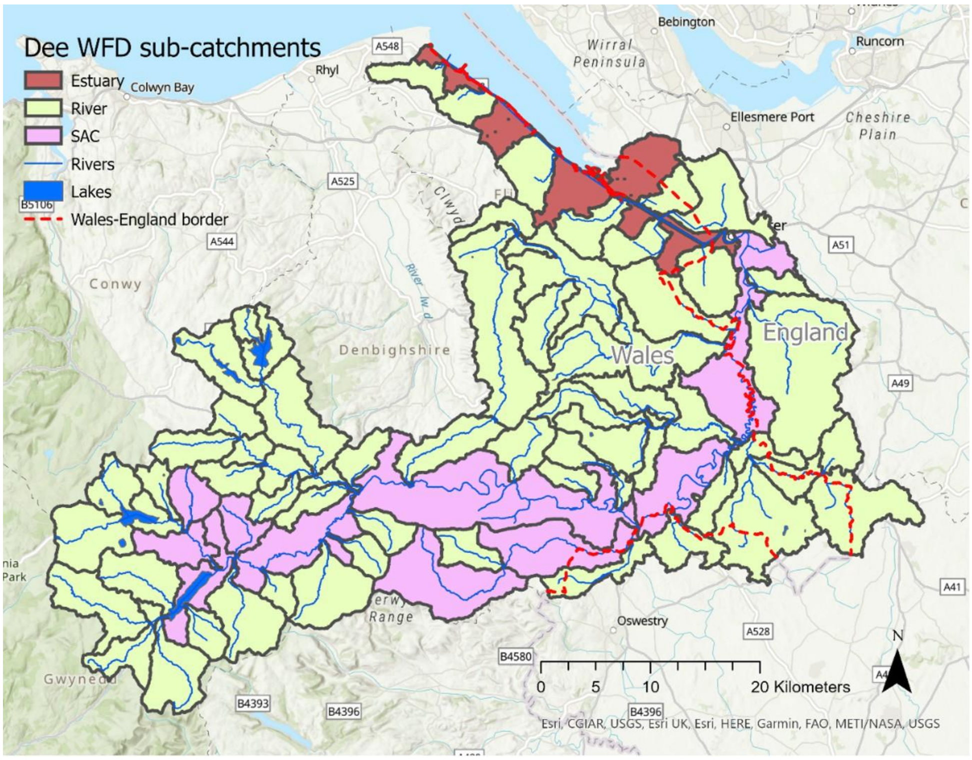
Modelling the River Dee

The purpose of this note is to provide an overview of the computer modelling approach being used to develop plans to help ensure waterbodies in the River Dee SAC achieve water quality objectives for phosphorus. The modelling work is still in progress and subject to the conclusions of NRW's quality assurance. *(Applies to all rivers in this section)*

Much of the River Dee is designated as a Special Area of Conservation (SAC) under the Conservation of Habitats and Species Regulations 2017, as amended (referred to as the 'Habitats Regulations'). In January 2021, Natural Resources Wales (NRW) published a report on the compliance assessment for tightened phosphorus targets showing that c.38% of waterbodies in the River Dee SAC fail to achieve the targets, with one of eight waterbodies in the SAC not assessed. In response, NRW and Dŵr Cymru Welsh Water (DCWW) implemented a programme of water quality modelling to develop an improved understanding of the sources of phosphorus for the whole catchment (England and Wales), and to explore possible approaches for improving water quality within the SAC. Note that whereas the term 'phosphorus' is used in this document, the form of phosphorus that has been modelled is known as 'orthophosphate', the form measured and compared with environmental targets. This may be understood to represent the most bioavailable form of phosphorus.

Note that several waterbodies are not part of the River Dee SAC. They are only subject to quality standards designated under the Water Framework Directive (WFD). Figure 13 shows the SAC and WFD regulated waterbodies as well as the estuarine stretches.

Figure 13: **River Dee along Welsh and English Border**



Water Quality Modelling *(Applies to all rivers examined here)*

Water quality modelling enables the effectiveness of controls on sources of pollution and interventions to be tested in a virtual environment to help identify those that are likely to be most effective. Modelling helps to provide confidence that measures will deliver the envisaged environmental outcomes.

Computer models, however, provide only a simplified representation of complex natural systems and consequently, their limitations must be considered as part of the process of developing plans of action. Indeed, modelling is most useful when deployed as part of a 'weight of evidence' approach where it is used in combination with information from other sources, including local knowledge and input from other subject matter experts. Key stages in the modelling process include:

- Models are updated and calibrated so that they provide a reasonable representation of recent catchment conditions.
- Important limitations and uncertainties are identified and characterised.
- Water quality improvement scenarios are simulated following regulatory guidance to identify the most effective combinations of measures.

NRW uses water quality models to define new discharge quality permits for DCWW's wastewater point source discharges assets and where necessary to target further monitoring and investigations. Permit conditions for water company assets are subsequently formalised and implemented through normal investment planning and delivery processes.

Source Apportionment Graphical Information

The SAGIS modelling system has been used to create the virtual representation of the River Dee.

SAGIS is derived from earlier modelling approaches (SIMCAT and RQP) that have been in use in the UK for several decades which have underpinned the investment made by the UK Water Industry in measures to improve water quality. Together with SIMCAT, SAGIS (also known as SAGIS-SIMCAT) is the standard tool used by regulators and the water industry to identify assets where controls on effluent quality are required. The SAGIS build version used in this study was Is 1.0.8112.21765. The version of SIMCAT was 15.7.

Model Data

There are two main types of data contained within SAGIS model databases, namely, measurement data and sector data (further information is provided in Appendix B):

- **Measurement Data –** river flow (for the period 2015 to 2019) and quality (phosphorus) measurements, as well as sewage treatment works discharge flow and quality (for the data period 2016 to 2019). A five-year period for river flow was used because period statistics are less likely to be impacted by unusual conditions within a single year whereas a four-year period for river quality was used due to concerns over anomalous measurements in 2014 and 2015. Where measured effluent quality data was not available a default value of 5 mg/L was applied. For treatment works with descriptive permits, discharge flow was estimated as the population served multiplied by 165 litres per person. For other sites discharge flow was based on either measured data or the permitted discharge flow

- **Sector Data** – inputs from sources other than sewage treatment works.

    - Estimates of diffuse inputs are included in the model by sector as an annual load input by waterbody. Contributions from urban, industry, septic tanks and rural land use have been estimated. Within the modelling process waterbody loads are distributed across the river reaches in the originating waterbody. NRW has commissioned further work to understand the contribution of forestry

    - Storm Overflows – SAGIS includes representation of inputs from intermittent discharges such as CSOs and storm tanks

    - The complex hydrology of the Dee catchment, driven by the Dee Regulation Scheme, was considered with regard to the flows in the model

Model Calibration

SAGIS calibration is a process through which the level of agreement between observed and simulated values is optimised.

Within the calibration process, the parameters controlling the sector input loads (the total input load) and variability (the variability associated with the total input load) are adjusted along with the determine and decay rate (i.e. a parameter representing a combination of effects, including in-river losses arising from uptake into the environment, deposition to sediment, and chemical transformation).

Model Confidence

Following the calibration process, the level of agreement between measured and simulated values is assessed. The level of agreement helps to identify locations or regions where modelled values diverge from measured values, and therefore where the model may be inappropriate to support decision making (or at least to identify where there may be uncertainty associated with the outcomes of actions that are supported by model outputs).

For the River Dee SAC, the level of agreement between observed and simulated concentrations was evaluated for monitoring locations in England and Wales, with the results indicating:[2]

- In England, model performance was assessed at 12 locations. Nine of the sampling locations were situated outside of the Dee SAC and were therefore of peripheral importance for this study. River quality at one location (outside the SAC) was considered unsuitable for characterising model performance due to the lower number of samples (Moderate). There was a Good level of agreement between observed and

[2] In the model for all SAC's the following criteria have been used to characterise model certainty/confidence:

- Good. Where there is a difference of <0.005mg/L between observed and simulated values.
- Moderate. Where there is a difference of >0.005mg/L between observed and simulated values but the difference is not statistically significant (or the number of samples is <12).
- Poor. Where there is a difference of >0.005mg/L between observed and simulated values.

simulated values at six locations (of which three locations are within the SAC). The remaining five locations were classed as Poor

- In Wales, model performance was assessed at 56 locations, with a Good level of agreement at 37 locations (eight within the SAC). One location (located outside the SAC) was classed as Moderate due to the low number of samples (less than 12, but more than 8 samples) so was considered unsuitable for characterising model performance. The remaining 18 locations were classed as Poor but only 2 of them are in SAC waterbodies. This approach to model calibration was suggested by the consultant and both NRW and DCWW approved to ensure the best model calibration in the SAC waterbodies.

In these cases where agreement is either moderate or poor the model can be used to help target further monitoring and investigation.

Model Results

At the furthest point downstream in the (modelled) river, the results show that under current conditions approximately 122kg of phosphorus is discharged from the catchment on a daily basis. Effluent from sewage treatment works accounts for 45% of the average daily load (kg/d) with rural land use contributing 24%, storm overflows contributing 10% and a further 21% from other sources including industry, septic tanks, and urban run-off.

The model shows that under current conditions effluent accounts for 46% of the average phosphorus concentration (mg/l). The concentration and load apportionment are different because inputs from different sources tend to occur under differing river flow conditions. For example, inputs from treatment works occur continuously (i.e. under high and low flow conditions) whereas inputs from diffuse sources tend of to occur under higher river flow conditions where there is a higher level of dilution available in the receiving water. This means that, on balance, a kilogram of phosphorus discharged from a treatment works will have a relatively greater impact on the in-river concentration than the equivalent input from diffuse sources.

SAGIS also provides an estimate of the contribution from storm overflows in the catchment, which account for approximately 10.2% of the load (kg/d) but 2.9% of the concentration (mg/l). Consequently, storm overflows were found to have limited impact on annual average concentrations (the form in which standards for phosphorus are expressed). This information is visualised in Figure 14 and 15 below.

The modelling also takes account of decay effects which, in this context, represents a combination of influences, including in-river losses due to uptake into the environment, deposition to sediment, and chemical transformation. Consequently, the loads at the furthest downstream point are not necessarily equivalent to the total input loads. The availability of water quality monitoring data and sewage treatment work performance data means that SAGIS modelling provides a robust framework for use in decision-making for wastewater investment planning. In general, estimates of loadings from diffuse sources from other sectors, within SAGIS, have a greater degree of uncertainty.

Scenario Modelling[3]

Figure 14: Dee Total Load (kg/day)

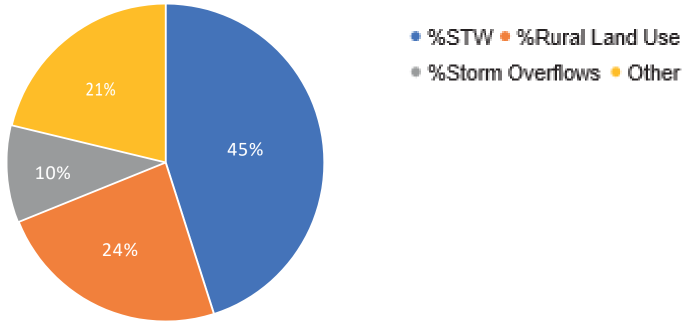
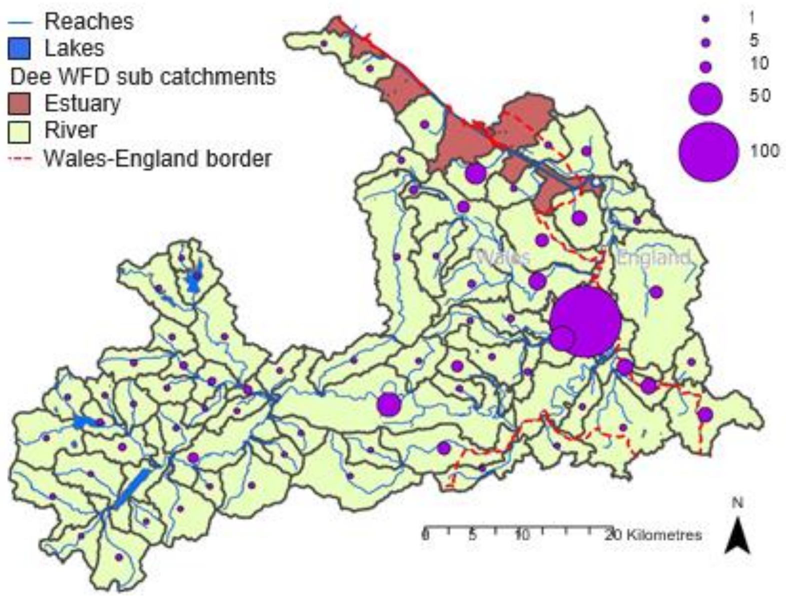


Figure 15: Phosphorus Apportionment by Source



Teifi

Modelling the River Teifi

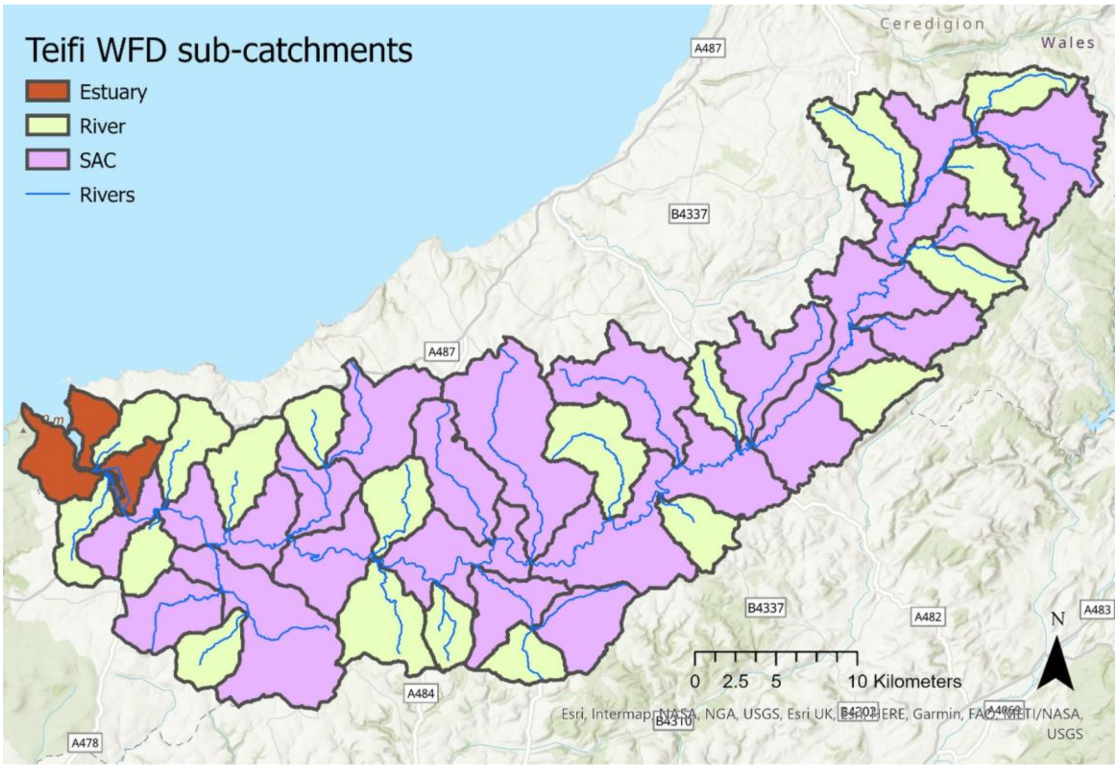
Most of the Afon Teifi is designated as a Special Area of Conservation (SAC) under the Conservation of Habitats and Species Regulations 2017, as amended (referred to as the 'Habitats Regulations'). In January 2021, Natural Resources Wales (NRW) published a report on the compliance assessment for tightened phosphorus targets showing that c.44% of waterbodies in the Afon Teifi SAC fail to achieve the targets. In response to these exceedances, NRW and Dŵr Cymru Welsh Water (DCWW) implemented a programme of water quality modelling to develop an improved understanding of the sources of phosphorus for the catchment, and to explore possible approaches for improving water quality within the

[3] The SAGIS model has been calibrated and will be used shortly to test the theoretical impact of changes in effluent quality at a range of WwTW in the catchment (i.e. 'what if' scenarios). Scenarios are not necessarily meant to represent practical options, but rather, help inform on the scale of the challenge of bringing the river into compliance with the JNCC targets and investment needed to meet it. This applies to ALL rivers. See **Annex B** for more Information.

SAC. Note that whereas the term ‘phosphorus’ is used in this document, the form of phosphorus that has been modelled is known as ‘orthophosphate’, the form measured and compared with environmental targets. This may be understood to represent the most bioavailable form of phosphorus.

Note that several waterbodies, mostly in the lower catchment, are not part of the Afon Teifi SAC. They are only subject to quality standards designated under the Water Framework Directive (WFD). Figure 16 shows the SAC and WFD regulated waterbodies.

Figure 16: **River Teifi**



Water Quality Modelling

See above for River Dee.

Source Apportionment Graphical Information

See above for River Dee.

Model Data

There are two main types of data contained within SAGIS model databases, namely, measurement data and sector data (further information is provided in Appendix B):

- **Measurement data** – river flow (for the period 2016 to 2019) and quality (phosphorus) measurements, as well as sewage treatment works discharge flow and quality (for the data period 2016 to 2019). A four-year period for river flow was used because period statistics are less likely to be impacted by unusual conditions within a single year. A four-year period for river quality was used due to concerns over anomalous measurements in 2014 and 2015. Where measured effluent quality data was not available a default value of 5mg/L was applied. For treatment works with descriptive permits, discharge flow was estimated as the population served multiplied by 165 litres per person per day. For other sites discharge flow was based on either measured data or the permitted discharge flow.

- Sector data – inputs from sources other than wastewater.
  - Estimates of diffuse inputs are included in the model by sector as an annual load input by waterbody. Contributions from urban, industry, septic tanks and rural land use have been estimated. Within the modelling process waterbody loads are distributed across the river reaches in the originating waterbody. NRW has commissioned further work to understand the contribution of forestry.
  - Storm Overflows – SAGIS includes representation of inputs from intermittent discharges such as CSOs and storm tanks.

Model Calibration

See above for River Dee.

Model Confidence

For the Afon Teifi SAC, the level of agreement between measured and simulated concentrations was evaluated at the monitoring locations. Model performance was assessed at 27 locations. 10 of the monitoring locations were situated outside of the Teifi SAC and were therefore of peripheral importance for this study. River quality at one location (within the SAC) was considered unsuitable for characterising model performance due to the lower number of samples (Moderate). There was a Good level of agreement between measures and simulated values at 23 locations (of which 13 locations are within the SAC). The remaining 3 locations (all located within the SAC) were classed as having a Poor level of agreement between observed and simulated values. In cases where confidence is either Poor or Moderate the model can be used to help target further monitoring and investigation.

Model Results

At the furthest downstream point in the (modelled) river, the results show that, under current conditions, approximately 45kg of phosphorus is discharged from the catchment on a daily basis.

Effluent from sewage treatment works accounts for 67% of the average daily load (kg/d) with rural land use contributing 28%, storm overflows contributing 3% and a further 1% from other sources including septic tanks, and urban run-off.

The model shows that under current conditions effluent accounts for 61% of the average phosphorus concentration (mg/l).

The concentration and load apportionment are different because inputs from different sources tend to occur under differing river flow conditions. For example, inputs from treatment works occur continuously (i.e. under high and low flow conditions) whereas inputs from diffuse sources tend to occur under higher river flow conditions where there is a higher level of dilution available in the receiving water. This means that, on balance, a kilogram of phosphorus discharged from a treatment works will have a relatively greater impact on the in-river concentration than the equivalent input from diffuse sources. SAGIS also provides an estimate of the contribution from storm overflows in the catchment, which account for approximately 3.4% of the load (kg/d) but 0.7% of the concentration (mg/l). Consequently, storm overflows were found to have limited impact on annual average concentrations (the form in which standards for phosphorus are expressed). This information is visualised in Figure 17 and 18.

The modelling also takes account of decay effects which, in this context, represents a combination of influences, including in-river losses due to uptake into the environment, deposition to sediment, and chemical transformation. The loads at the furthest downstream point are not necessarily equivalent to the total input loads. The availability of water quality monitoring data and sewage treatment works performance data, means that SAGIS modelling provides a robust framework for use in decision-making for wastewater investment planning. In general, estimates of loadings from diffuse sources from other sectors, within SAGIS, have a greater degree of uncertainty.

Scenario Modelling

Figure 17: Teifi Total Load (kg/day)

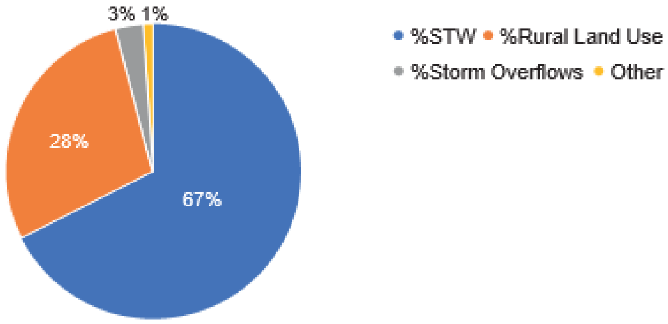
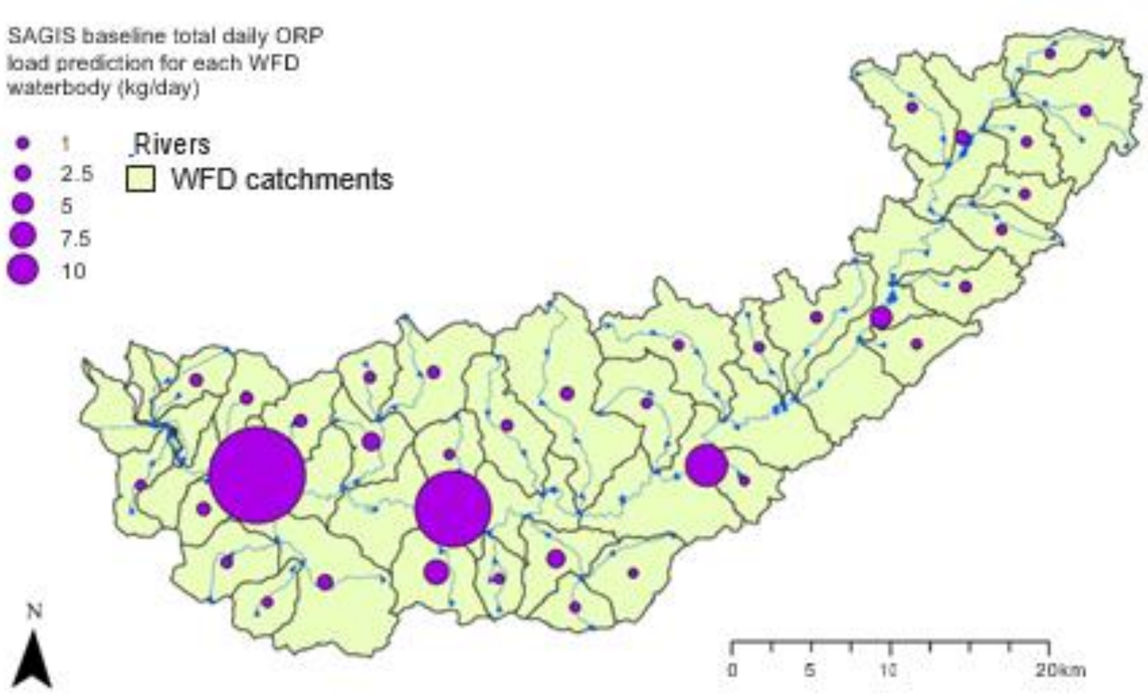


Figure 18: Phosphorus Apportionment by Source



Usk

Modelling the River Usk

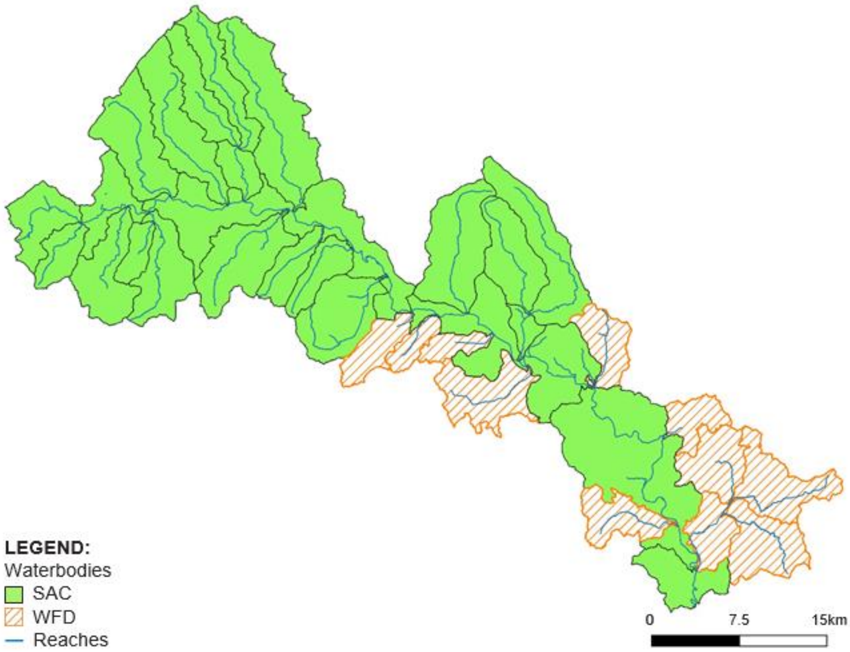
Most of the River Usk catchment is designated as a Special Area of Conservation (SAC) under the Conservation of Habitats and Species Regulations 2017 (referred to as the 'Habitats Regulations'). In January 2021 Natural Resources Wales (NRW)

published a report on the compliance assessment for tightened phosphorus targets showing that 88% of waterbodies in the River Usk SAC fail to achieve the targets. In response, NRW and Dŵr Cymru Welsh Water (DCWW) have implemented a programme

of water quality modelling to develop an improved understanding of the sources of phosphorus within the catchment and to explore approaches for improving water quality. Note that whereas the term 'phosphorus' is used in this document, the form of phosphorus that has been modelled is known as 'orthophosphate', the form measured and compared with environmental targets. This may be understood to represent the most bioavailable form of phosphorus.

Note that several waterbodies, mostly in the lower catchment, are not part of the River Usk SAC. They are only subject to quality standards designated under the Water Framework Directive (WFD). Figure 19 shows the SAC and WFD regulated waterbodies.

Figure 19: **River Usk**



Water Quality Modelling

See above for River Dee.

Source Apportionment Graphical Information

See above for River Dee. The SAGIS build version used in this study was 1.0.8074.18769.

Model Data

There are two main types of data contained within SAGIS model databases, namely, measurement data and sector data (further information is provided in Appendix B):

- **Measurement data –** river flow (for the period 2015 to 2019) and quality (phosphorus) measurements, as well as sewage treatment works discharge flow and quality (for the data period 2016 to 2019). A five-year period for river flow was used because period statistics are less likely to be impacted by unusual conditions within a single year whereas a four-year period for river quality was used due to concerns over anomalous measurements in 2014 and 2015. Where measured effluent quality data was not available a default value of 5 mg/L was applied. For treatment works with descriptive permits, discharge flow was estimated as the population served multiplied by 165 litres per person per day. For other sites discharge flow was based on either measured data or the permitted discharge flow.

- Sector data – inputs from sources other than wastewater.

    - Estimates of diffuse inputs are included in the model by sector as an annual load input by waterbody. Contributions from urban, industry, septic tanks and rural land use have been estimated. Within the modelling process waterbody loads are distributed across the river reaches in the originating waterbody. NRW has commissioned further work to understand the contribution of forestry.

    - Storm Overflows – SAGIS includes representation of inputs from intermittent discharges such as CSOs and storm tanks. A method development study was undertaken to develop an approach to use available sewer model data to improve the representation of storm overflows within SAGIS for the Usk. This was not intended as a substitute for or alternative to sewer modelling, but rather was a means of maximising the value and benefit from the investment made in creating EDM and sewer model data. The SAGIS model was updated to reflect inputs from 26 intermittent discharges for which sewer model data were available.

Model Calibration

See above for River Dee.

Model Confidence

For the Usk SAC model the level of agreement between observed and simulated concentrations was evaluated at 32 locations, with a good level of agreement at 27 locations. Of the five locations where the agreement was sub-optimal, river quality data for two locations was considered unsuitable for characterising model performance due to low sample numbers, and data for three locations showed the difference between observed and simulated concentration was not statistically significant (moderate). Several regions were identified where relatively large adjustments were applied as part of the calibration process and therefore where the sector apportionment should be treated with caution. This can arise where there are sources of pollution that are not represented in the model but that are active. In these cases, the model can be used to help target further monitoring and investigation.

Model Results

At the furthest downstream point in the (modelled) river, the results show that, under current conditions, approximately 180kg of phosphorus is discharged from the catchment on a daily basis. Effluent from sewage treatment works accounts for 21% of the average daily load (kg/d) with rural land use contributing 67%, storm overflows contributing 1% and a further 11% from other sources including septic tanks, and urban run-off.

The model shows that under current conditions effluent accounts for 23% of the average phosphorus concentration (mg/l). The concentration and load apportionment are different because inputs from different sources tend to occur under differing river flow conditions. For example, inputs from treatment works occur continuously (i.e. under high and low flow conditions) whereas inputs from diffuse sources tend to occur under higher river flow conditions where there is a higher level of dilution available in the receiving water. This means that, on balance, a kilogram of phosphorus discharged from a treatment works will have a relatively greater impact on the in-river concentration than the equivalent input from diffuse sources.

The modelling also takes account of decay effects which, in this context, represents a combination of influences, including in-river losses due to uptake into the environment, deposition to sediment, and chemical transformation. Consequently, the loads at the furthest downstream point are not necessarily equivalent to the total input loads.

SAGIS also provides an estimate of the contribution from storm overflows in the catchment, which account for approximately 1% of the load. Storm overflows were found to have a limited impact on annual average concentrations (the form in which standards for phosphorus are expressed). This information is visualised in Figure 20 and 21. The availability of water quality monitoring data and sewage treatment works performance data, means that SAGIS modelling provides a robust framework for use in decision-making for wastewater investment planning. In general, estimates of loadings from diffuse sources from other sectors, within SAGIS, have a greater degree of uncertainty.

Scenario Modelling

Figure 20: Usk Total Load (kg/day)

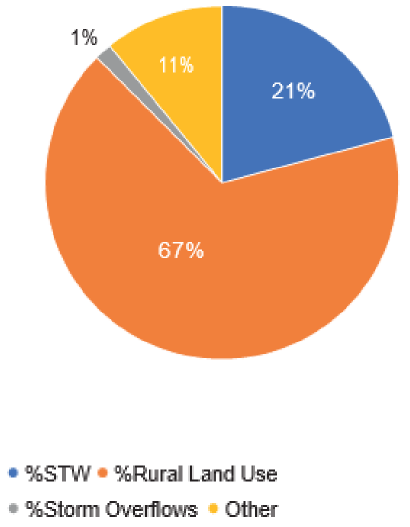
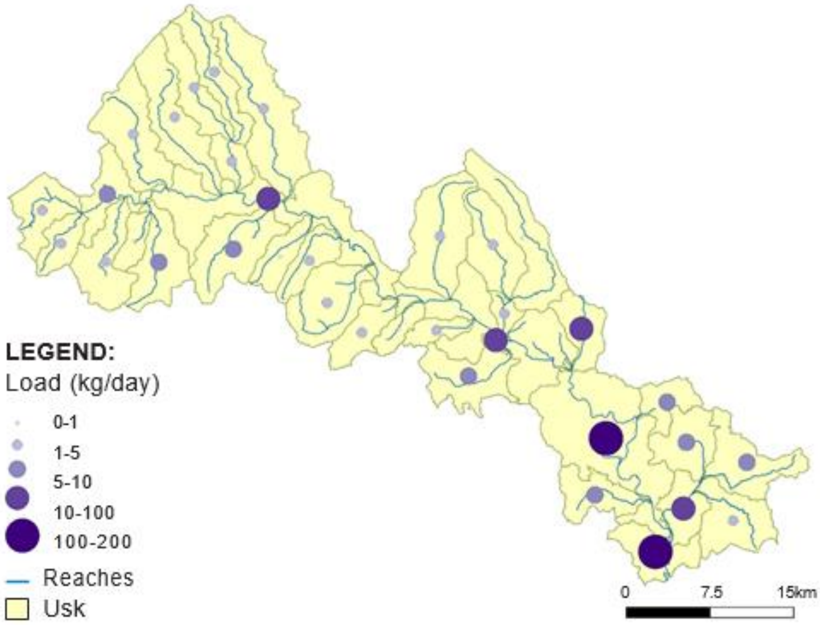


Figure 21: Phosphorus Apportionment by Source



Wye

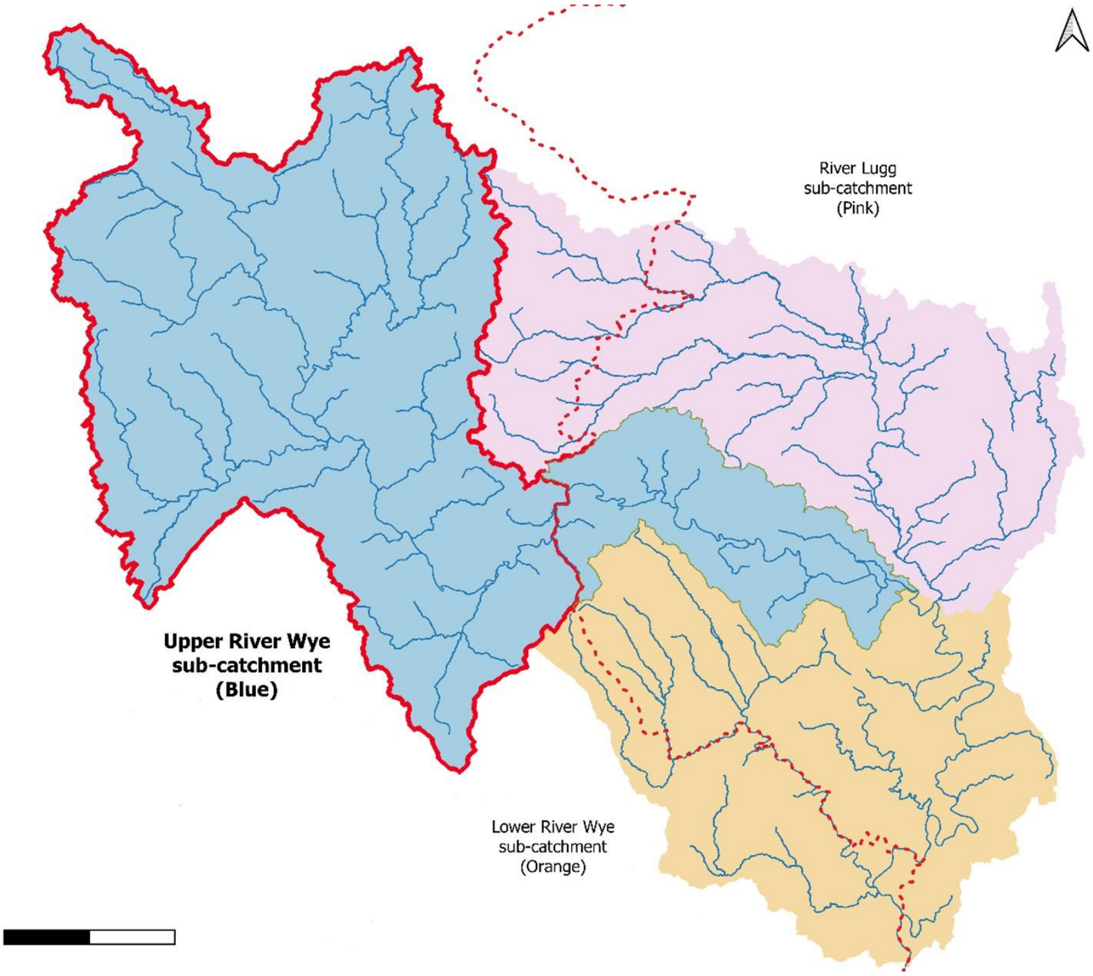
Modelling the River Wye

Most of the upper River Wye catchment is designated as a Special Area of Conservation (SAC) under the Conservation of Habitats and Species Regulations 2017 (referred to as the 'Habitats Regulations'). In January 2021 Natural Resources Wales (NRW) published a report on the compliance assessment for tightened phosphorus targets showing that c67% of water bodies in the River Wye SAC fail to achieve the targets.

In response, NRW and Dŵr Cymru Welsh Water (DCWW) have implemented a programme of water quality modelling to develop an improved understanding of the sources of phosphorus within the catchment, and to explore approaches for improving water quality. Note that whereas the term 'phosphorus' is used in this document, the form of phosphorus that has been modelled is known as 'orthophosphate', the form measured and compared with environmental targets. This may be understood to represent the most bioavailable form of phosphorus.

This note focuses on the section of the upper River Wye SAC in Wales (area within the red boundary in Figure 22). DCWW is working with the Environment Agency to update their water quality model for the catchment region situated in England.

Figure 22: **River Wye**



Water Quality Modelling

See above for River Dee.

Source Apportionment Graphical Information

See above for River Dee. The SAGIS build version used in this study was 1.0.7790.19022.

Model Data

There are two main types of data contained within SAGIS model databases, namely, measurement data and sector data (further information is provided in Appendix B):

- **Measurement data –** river flow (for the period 2015 to 2019) and quality (phosphorus) measurements as well as sewage treatment works discharge flow and quality (for the data period 2016 to 2019). A five-year period for river flow was used because period statistics are less likely to be impacted by unusual conditions within a single year whereas a four year period for river quality was used due to concerns over anomalous measurements in 2014 and 2015. Where measured effluent quality data was not available a default value of 5 mg/L was applied. For treatment works with descriptive permits, discharge flow was estimated as the population served multiplied by 165 litres per person per day. For other sites discharge flow was based on either measured data or the permitted discharge flow.

- **Sector data** – for inputs from sources other than sewage treatment works.

    - Estimates of diffuse inputs are included in the model by sector as an annual load input by waterbody. Contributions from urban, industry, septic tanks and rural land use have been estimated. Within the modelling process waterbody loads are distributed across the river reaches in the originating waterbody. NRW has commissioned further work to understand the contribution of forestry.

    - Storm Overflows – SAGIS includes representation of inputs from intermittent discharges such as CSOs and storm tanks.

Model Calibration

See above for River Dee.

Model Confidence

For the Upper Wye model, the level of agreement between observed and simulated concentrations was evaluated for monitoring locations in England and Wales separately. In Wales, model performance was assessed at 54 locations, with a good level of agreement at 49 locations. Of the five locations where the agreement was not as good, river quality data for two locations was considered unsuitable for characterising model performance due to low sample numbers, data for two locations showed the difference between observed and simulated concentration was not statistically significant (moderate), and with data for one location specifically excluded following agreement by DCWW and NRW. In these cases, the model can be used to help target further monitoring and investigation.

Model Results

At the assessment location (quantified at water quality monitoring station 50021 which, although situated in England, is less than 2km from the border with Wales), the model shows that, under current conditions, approximately 67kg of phosphorus is discharged from the Welsh part of the upper River Wye catchment daily. Effluent from sewage treatment works accounts for 23% of the average daily load (kg/d) with rural land use contributing 72%, storm overflows contributing 2% and a further 3% from other sources including septic tanks and urban run-off. The model shows that under current conditions effluent accounts for 35% of the average phosphorus concentration (mg/l).

The concentration and load apportionment are different because inputs from different sources tend to occur under differing river flow conditions. For example, inputs from treatment works occur continuously (i.e. under high and low flow conditions) whereas inputs from diffuse sources tend to occur under higher river flow conditions where there is a higher level of dilution available in the receiving water. This means that, on balance, a kilogram of phosphorus discharged from a treatment works will have a relatively greater impact on the in-river concentration than the equivalent input from diffuse sources.

The modelling also takes account of decay effects which, in this context, represents a combination of influences, including in-river losses due to uptake into the environment, deposition to sediment, and chemical transformation. Consequently, the loads at the furthest downstream point are not necessarily equivalent to the total input loads.

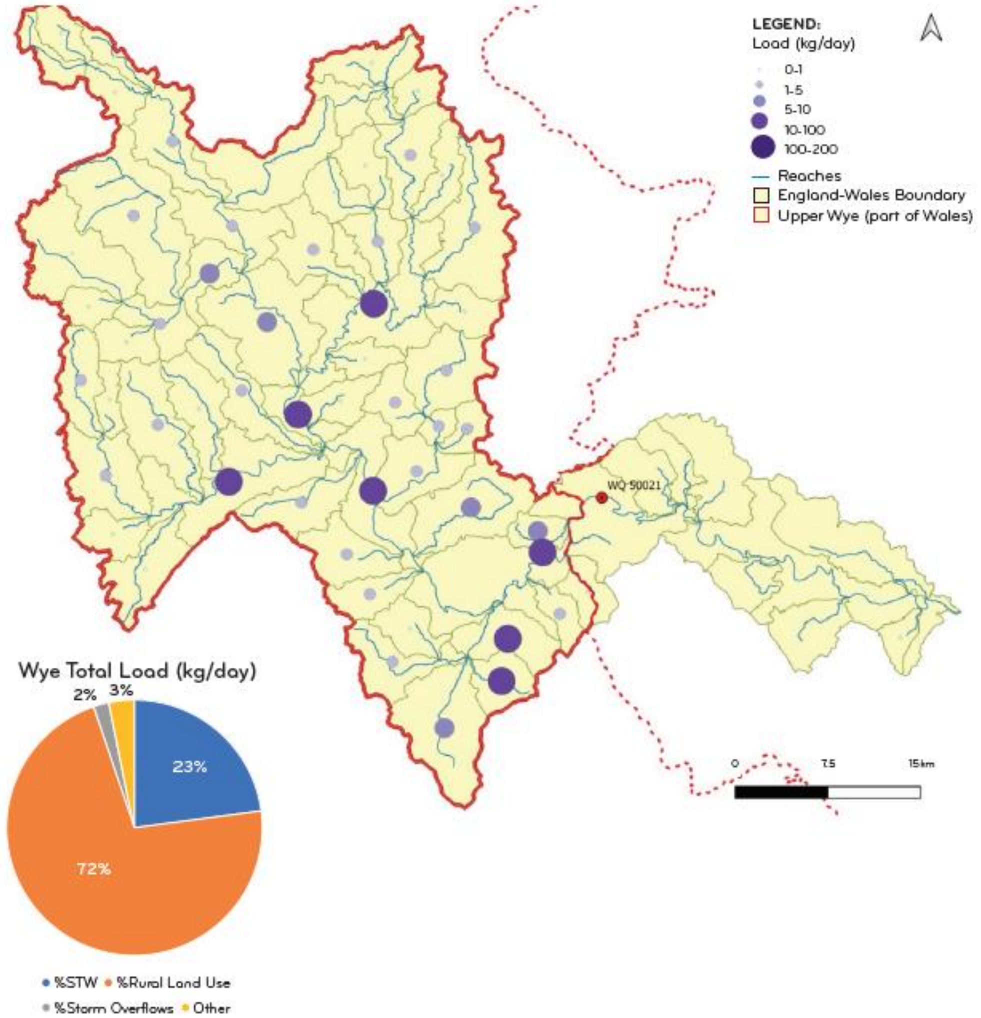
The modelled load apportionment information is presented in Figure 2 which shows load apportionment at the water quality monitoring location 50021 (also shown in Figure 2) which situated in the middle of waterbody GB109055037116 that spans England and Wales. Although situated in England the water quality monitoring location is less than 2km from the Welsh border and serves as a convenient reporting location. Note that apportionment will differ at different locations within the catchment.

The modelling also takes account of decay effects which, in this context, represents a combination of influences, including in-river losses due to uptake into the environment, deposition to sediment, and chemical transformation. The loads reported are therefore not necessarily equivalent to the total input loads.

SAGIS also provides an estimate of the phosphorus contribution from the storm overflows in the catchment. These were estimated at approximately 2% of the catchment load (at monitoring location 50021). This information is shown in Figure 23. The availability of water quality monitoring data and sewage treatment works performance data, means that SAGIS modelling provides a robust framework for use in decision-making for wastewater investment planning. In general, estimates of loadings from diffuse sources from other sectors, within SAGIS, have a greater degree of uncertainty.

Scenario Modelling

Figure 23: Wye Phosphorus Apportionment by Source and Total Load (kg/day)



Impacts on Development & Planning

The 2021-2026 Programme for Government contains a commitment to build 20,000 new low carbon social homes for rent. Housing plays a vital role in ensuring basic needs for individuals are met. Good quality housing affordable housing can positively impact on health, mental health and education.

Welsh Government Housing Need estimates show that under central estimates, the additional annual housing need for Wales is estimated as 7,400 units per year up to 2023/24. This is split into 3,900 additional market housing units (52% of the additional housing need) and 3,500 additional affordable housing units (48% of the additional housing need).

Recently published monthly management information for April 2022 shows that 1,300 people presenting as homeless were placed into temporary accommodation during the month. At the end of March, 7,999 individuals were in temporary accommodation. The delivery of more affordable housing is critical to ensuring we provide people with long-term stable homes.

In order to increase the supply of new homes, it is critical the capacity of the sector is maintained or grown. Delays to house building, due to phosphate issues, may disproportionately impact on the small home builders as they do not have alternative sites outside affected areas they could move to.

Evidence has been provided from key stakeholders outlining the impact of phosphates on affordable housing delivery. This includes from Registered Social Landlords (RSLs) through the sector representative Community Housing Cymru (CHC), Local Authorities through the Welsh Local Government Association (WLGA), and from the House Builders Federation Wales (HBF). It should be noted that the data provided is a snapshot of the situation as a response has not been received from all members.

Whilst evidence can be provided on the impact of the current pipeline of delivery, the full impact on the 20,000 social housing target and the five-year programme of affordable housing delivery has yet to be fully ascertained. The impact of phosphates is likely to be greater in the final two years of this term of government as earlier schemes approved prior to the NRW phosphates advice will continue to be delivered over the next year or so.

Local Authority Evidence

In October 2021, Local and National Park Authorities provided an impact statement on Phosphates. It identified 329 settlements[4] as affected by phosphates across SAC catchments, only 10 have adequate phosphate stripping in place. The following growth areas in Future Wales – The National Plan 2040 are affected:

- National Growth Area: Wrexham and Deeside
- Regional Growth areas; Llandrindod Wells; Builth Wells; Brecon; Teifi Valley (Lampeter, Llandysul, Newcastle Emlyn)

The statement showed that, at that time, a total of 171 housing sites across affected authorities, had been identified as impacted by phosphates. This equates to a theoretical total of 9763 housing units and an anticipated 1725 affordable units. It should be noted however that realised housing delivery is typically lower than allocations.

[4] As set out in the Local Development Plan Manual at 5.20 - https://gov.wales/sites/default/files/publications/2020-03/development-plans-manual-edition-3-march-2020.pdf

The issue for Wrexham is particularly acute, the latest draft of their Local Development Plan (LDP) shows 7,750 homes, including 2,355 affordable homes impacted by phosphates. Progress on LDP reviews has also been delayed in areas affected by phosphates. Whilst some local planning authorities may be able to divert development away from affected areas to maintain progress their LDP reviews others are on stop where this is not possible.

RSL Evidence

In May 2022, CHC advised that nine housing associations reported their schemes had been negatively impacted by the phosphorus issue. Eight provided data showing 28 schemes (1,046 affordable homes) are at a standstill. Some housing associations have stopped considering sites in affected areas, this will impact the pipeline of affordable homes and development in these areas will stop.

Market Housing Developers

Information received from HBF Wales shows that for larger developers there are a total of 2,545 units impacted by phosphates, of which 662 are affordable units.

The majority of units are in North Wales with 2238 units impacted, of which 553 are affordable. Furthermore, the main areas where these units are located are in Wrexham and Flintshire. A full breakdown can be seen below.

Figure 24: Breakdown of Market Housing Developers

Location	Total Units	Affordable
South Wales	**307**	**109**
Brecon	51	17
Monmouth	256	92
North Wales	**2,238**	**553**
Wrexham	1200	216
Flintshire	1038	337
Total	**2,545**	**662**

Interim measures and solutions being explored by the Housing Sector

The immediate need for housing has seen the sector explore short term, interim measures that could allow housebuilding to continue, without impacting on the SAC Rivers, whilst longer term solutions are identified.

Measures being explored by the sector include;

- commuted sums
- offering to abandon an extant planning consent elsewhere in the SAC to directly offset the impact of the new site consent
- onsite package treatment works; and

- filter reed beds.

These interim measures are likely to be costly (ranging between £2,400 per unit to £5,000 per unit) and will be redundant once a solution is identified and implemented.
Whilst these measures could alleviate the issue in the short term, allowing for housing development to continue, they are not solutions. There are concerns about some of the temporary measures suggested including costs for future connections to the mains (when capacity is available), and responsibility for ongoing management and maintenance.

One housing association reports that Powys Local Authority are exploring the application of a planning condition as a potential interim measure. This would effectively permit the development but allow no occupation of the site until phosphate treatment works are completed.

Housing providers, both in the affordable and market sector, are keen that these measures are seen as temporary actions that could enable housing delivery to take place. The measures are suggested in an effort to be constructive and recognise that there will be a need to be compromise while longer term solutions are identified. Nevertheless, all measures would need further exploration. The housing sector is keen to work with NRW, the water companies and Welsh Government to drive these proposals forward and identify and deliver more permanent solutions.

A recent study by Lichfields[5] commissioned by the building industry's Nitrate and Phosphate Strategy group found that the building restrictions arising from guidance has cost the Herefordshire £316m in lost investment, equating to 2,500 new homes including 1,000 likely to be classed as affordable being on hold. Consequences of this include 5,200 direct construction jobs not created, as well as a further 6,300 in the construction supply chain, £28 million forgone in new residents' spending in local shops and services, and a further 350 jobs lost in these sectors as a result. Herefordshire Council would also have benefited from £5 million more each year in council tax payments, and £54 million in planning contributions towards infrastructure from developers had their projects gone ahead, the report says.

[5] Cost to Herefordshire of building 'moratorium' laid bare | Hereford Times

Current Interventions

The Welsh Government made available £9.5million of capital funding to improve water quality in Wales during 2021-22.

This funding has included:

- £2.5m to NRW to negotiate Land Management agreements across the protected sites network, with an element of this specifically to help tackle phosphate issues on the Wye

- £1.115m allocated to support the Nature Recovery Action Plan – partnership between NRW and Afonydd Cymru on measures for restoring salmon and trout in Welsh waterways

- £1m allocated for a Research & Development Projects which aims to develop effective innovative solutions to minimise the long-term impact of metal mine water discharges, improve the ecological status of Welsh rivers and support a healthy farming industry

    - This includes innovative projects such as Coleg Sir Gar's Gelli Aur Sustainable Farming Centre.

- £802,000 for Water Quality Improvement Projects led by NRW to tackle areas affected by increased levels of pollutants, such as Phosphate and improve marine biodiversity

- A £500k contribution from the Nature Networks Fund to the Afon Teifi SAC Catchment Phosphate Reduction and Mitigation Project (PRAM Project) £500k Ceredigion CC. This project will directly improve the condition of this SAC through reducing phosphate inputs, improving water quality and reversing the decline in nature. Further specific information on this can be found within NRW's evidence section

- £2m is being provided over four years (2019-2023) to the NRW led Dee LIFE programme through the Green Infrastructure (GI) Capital Grant scheme. – details of the programme provided in NRW's section

The Welsh Government has also committed further funding towards:

- £5.06 m has been allocated to the Opportunity Catchments and Natural Flood Based Solutions schemes for the period of 2022-2025

- £3.4m is being provided over four years (2022-2026) to the NRW led 4Rivers for LIFE. – details of the programme provided in NRW's section

Training and guidance interventions

- The WG's Planning Directorate has worked with NRW to design a training programme on Habitat Regulations Assessment (HRA). The training programme has two distinct elements namely a) a general refresh of the Regulations and b) a light-touch refresh of the Regulations plus a deeper dive into phosphate issues as they affect SAC Rivers which will run in the autumn. The training programme is to be designed for planners and ecologists working in the 25 local planning authorities in Wales, the Planning Inspectorate and Welsh Government

- Local planning authorities have been reliant on guidance from Natural Resources Wales to help prepare local development plans and determine planning applications. The SAC Rivers Planning Sub-Group has encouraged and worked with Natural Resources Wales to revise their guidance to local planning authorities. The guidance has been developed to include more detail on the screening of specific development types, including domestic extensions, which local planning authorities had previously been taking an inconsistent approach. The revised guidance also looks at how phosphorus reduction technology for private treatment works should be considered and how the disposal of sludge should be taken into account by local planning authorities. NRW are looking to publish the guidance at the end of July

- The Water Resources (Control of Agricultural Pollution) (Wales) Regulations 2021 will help in driving action to tackle nutrient pollution

- Whilst consistent and clear regulation is a key element, it is only when it is used in combination with advice, guidance, improving knowledge and skills as well as innovation and investment can we expect to reduce the risk of all forms of agricultural pollution and protect our environment, whilst supporting farming to be a sustainable and thriving industry for the future

Investment in previous years:

- Between 2018 and 2021 a total of £44.5m was made available to support farmers in reducing farm pollution.

- Between 2018 and 2020 £22m was made available for farmers through the Sustainable Production Grant to improve nutrient management and to reducing farm pollution.

- A further £22.5m was for 2021 allocated to support farmers with capital infrastructure improvements on farms in Wales.

River Basin Management Plans (RBMP)

River Basin Management Plans (RBMPs) take a holistic approach to managing our waters, looking at the water within the wider ecosystem and taking into account the movement of water through the hydrological cycle from source to sea. Each RBMP must apply to a river basin district (RBD), which is an area of land made up of one or more neighbouring river basins and associated coastal waters.

RBMPs are prepared on a six-yearly cycle.

The consultation on the 3rd RBMP in Wales outlines the Programme of Measures NRW aim to deliver to prevent deterioration.

The RBMP will work towards achieving the objectives for Protected Areas and aim to achieve good overall status which will also benefit the riverine Special Areas of Conservation (SACs).

The proposed Programme of Measures for this RBMP cycle include:

- preventing and resolving misconnections

- delivery of the Water Industry investigations and improvements to sewage discharges
- promoting Sustainable Drainage Systems (SuDS)
- additional relevant actions from the Thematic Plan[6] for protected sites

Opportunity Catchments:

- For the third cycle of River Basin Planning (2021-2027), NRW has identified Opportunity Catchments. These will be integrated as a priority work area for both NRW and external partners across the public and private sector
- Opportunity Catchments focus on delivery of longer-term multiple benefits for waterbodies, water dependent habitats and species and wellbeing
- The Dee, Usk, Wye, Teifi and Cleddau SAC rivers fall within the boundary of NRWs Opportunity Catchments
- NRW plans to outline local measures to deliver waterbody improvements within Opportunity Catchments (and where applicable outside of these areas). These will align with recommendations within the 'Compliance Assessment of Welsh River SACs against Phosphorus targets'[7] report
- Actions are intended to deliver wider river health and resilience as well those aimed at reducing nutrient inputs to gain improvements to water quality will also be included
- Examples of actions include Targeted nutrient reduction visits (example of this in Cleddau/ Milford Haven), reducing sediments from entering the Afon Gallen using riparian habitat management techniques

NRW Projects

River Restoration Programme

[6] https://naturalresources.wales/about-us/our-projects/nature-projects/life-n2k-wales/life-n2k-thematic-action-plans/?lang=ens These were funded through LIFE Natura 2000 Programme for Wales

The LIFE Natura 2000 Programme for Wales has developed a strategic forward plan to manage and restore Natura 2000 in Wales. Working with stakeholders it has determined the key challenges facing these European protected sites, species and habitats and identified the actions required, priorities, costs and funding opportunities to address them. The Programme was run by Natural Resources Wales (NRW) and funded by the European Union scheme LIFE+ Nature. The purpose of the Programme is to enable Wales to make significant progress towards bringing Natura 2000 species and habitats into favourable condition and help meet its commitments under the European Habitats and Birds Directives. The Programme also aims to provide a platform to seek further funding for Natura 2000 related projects from all potential sources, and to integrate Natura 2000 funding into other financial instruments and policy areas

[7] https://naturalresources.wales/evidence-and-data/research-and-reports/water-reports/compliance-assessment-of-welsh-river-sacs-against-phosphorus-targets/?lang=en

NRW are developing a River Restoration programme across Wales, looking at interventions to reduce diffuse pollution, and improve water quality. This programme includes the SAC rivers.

NRW has secured Welsh Government capital funding for river restoration works for some of the SAC rivers, including

- land management interventions such as farm infrastructure improvements on the Dee catchment
- developing a river restoration plan on parts of the Cleddau, Teifi, Tywi and Usk SACs

The Dairy Project

NRW's "The Dairy Project", aims to reduce agricultural pollution, where officers have already visited over 800 dairy farms in Wales. (see figure 20)

The officers have carried out pollution control visits offering advice and guidance to dairy farmers, helping ensure they are compliant with legislation and reduce the risk of pollution.

Prosiect Slyri

The Welsh Government's Rural Communities Rural Development Programme has provided funding to the Prosiect Slyri, based at Gelli Aur College, which NRW are partners on. This project applies innovative and proven concept technology to reduce air and water pollution to reduce the overall volume of slurry by up to 80%.

An example being a de-watering and purification system used to filter slurry, transforming the water to a suitable quality for recycling or discharging to a clean watercourse.

The system also utilises nutrients from the slurry to produce good quality fertiliser.

The aim of this is to efficiently extract nutrients from manures that could save on the cost of commercial fertilisers and reduce serious environmental impact.

Specific SAC river projects

The Four Rivers for LIFE project

The Four Rivers for LIFE, is a large river res

toration project across four river SAC rivers (Teifi, Tywi, Cleddau and the Usk), which will run for 5 years.

This is partly EU funded with match funding from Welsh Government, Dwr Cymru, Brecon Beacons National Park Authority, Woodland Trust, etc. Totalling a £9.1 million investment.

This project aims to significantly improve the conservation status of multiple habitats and species on four SAC Rivers in mid and South Wales. As a holistic river restoration project, it will take a nature-based approach to address multiple pressures across the catchments of the four SACs.

This project will also project improve the conservation status of all of the Annex I habitats and Annex II and V species across all the SACs.

The methods used for this project, and the learning and knowledge, will be shared with other river restoration and fisheries communities across the UK and Europe. The project will also work with the IUCN NCUK's River Restoration and Biodiversity group.

The project will also support the development of a conservation strategy for all other SAC rivers in Wales based on the techniques, approaches and principles developed during the project and compliments the existing LIFE River Dee project.

The project will carry out measures to address diffuse pollution across the four catchments as well as increasing the resilience of the rivers by restoring natural processes and habitat features.

Actions include:

- on yard interventions to improve drainage and water storage
- fencing for the riparian corridor
- a pilot trial of a weather station to provide guidance to farmers on slurry spreading

These actions will contribute to improving the condition of the river habitats as well as protected species including salmon, sea and river lamprey, twaite and allis shad and freshwater pearl mussel.

The outputs will include:

- Removal of at least three weirs
- Construction of fish passage solutions on at least ten structures causing obstruction to fish passage
- Introduction of gravel, boulders and large woody material (LWM) along at least 20km of river
- Reconnection of river to floodplain by removal of artificial bank protection and/or re-meandering of at least 5km of river
- Restoration of freshwater, wetland and other natural habitats in at least 100ha of floodplain
- Creation of at least 100km of buffer strips and streamside corridors by riparian planting and fencing
- Work with land managers (farmers, foresters, local authorities and other catchment users) to reduce pollution by nutrients, sediments, large plastics and chemicals in at least 350 farms totaling 35,000ha of the project area catchment, including use of innovative technology solutions to encourage precision farming
- Establish three focal sub-catchments for improvements for *M. margaritifera,* and restore at least 15km of pearl mussel habitat in this following best practice guidance and using experience from other LIFE projects
- Captive breeding and release of *M. margaritifera* from adult mussels, following the Welsh Pearl Mussel Strategy and IUCN Guidance, with release of at least 10,000

juvenile mussels (3+ age) in suitable habitat during the project (or in the 5 years immediately post project)

- Introduce a novel biological control agent (a rust fungus) for Himalayan balsam *Impatiens glandulifera* in at least 8 trial sub-catchments to achieve long term control across the project area

- Reduce the extent of 4 invasive plant species (*I. glandulifera*; skunk cabbage *Lysichiton americanum*; Japanese knotweed *Fallopia japonica*; giant hogweed *Heracleum mantegazzianum*) in at least 8 sub-catchments totaling at least 60km of river. The control strategy will identify upstream extents of infestations, targeting areas where eradication is feasible

The LIFE River Dee project

The LIFE River Dee project started in September 2019 and will run for 5 years.

This was initially funded by the European LIFE Nature and Biodiversity fund.

The total proposed cost is around £7million with match funding by NRW, EA, Dŵr Cymru/Welsh Water (DCWW) and Snowdonia National Park Authority.

The overall aim of this project will be to rehabilitate and restore natural processes, features and physical habitats within the Afon Dyfrdwy a Llyn Tegid / Dee and Bala Lake SAC. This will improve the conservation status of all of the Habitats Directive Annex I habitats and Annex II and V species across the whole SAC

Actions include

- improving agricultural and forestry land management practices to reduce the input of nutrients and sediment entering the SAC

- restoring or improving natural riverine physical processes, features and habitats in at least 55 km of river

- This is carried out with actions such as fencing, tree planting for bank stabilisation and enhancement of the riverside habitat, installing drink bays and yard works

The outputs of the project include:

- Fish passage improved at a minimum of 6 weirs across Dee catchment for range of species present

- 16km in-channel habitat improvement/re-meandering

- 2,000 tonnes of gravel for spawning habitat imported to Afon Alwen to provide increased spawning areas

- Over 5km of historic bank protection removed

- 16km double fencing and tree planting on tributaries

- 360m of embankment breached to allow reconnection of 5ha of floodplain habitat

- 400m fencing and improved access to river corridor for recreational users
- 318ha/12% of UK resource of 3620 progressed towards Flood Control System (FCS)
- Improved water management in 517ha of forestry in the SAC catchment
- 50% of the targeted farms have implemented interventions that reduce nutrient and sediment inputs
- At least 30 adult mussels transported from River Dee to hatchery for captive rearing programme
- Collection of spat and encystment onto salmonids
- Glochidia grown on to 3–4-year-old juveniles

Teifi SAC Catchment Phosphate Reduction and Mitigation Project (PRAM Project

Ceredigion County Council have appointed an officer to work on the Afon Teifi SAC Catchment Phosphate Reduction and Mitigation Project (PRAM Project).

The project will evaluate the feasibility for the planning and development of two integral constructed wetlands for reducing phosphates. It will implement phosphate reduction interventions on the ground which will include 9KM of riparian fencing and tree planting in the most severely livestock damaged areas. The project will also implement a number of small Sustainable Drainage (SuDS) schemes in the main towns on the Teifi

The project has received £500,000 from the Welsh Government Nature Networks Fund to "directly improve the condition of this SAC through reducing phosphate inputs, improving water quality and reversing decline in nature".

Other partner funded opportunities and initiatives

The Welsh Government's Nature Networks Fund is making available £497,457 to the reconnecting the salmon rivers of Wales project by Swansea University which includes work on five rivers in the country, including the Teifi SAC to "halt the decline of salmon and other migratory fish in Wales."

Funding this financial year has been made available for three SAC rivers posts – for the Wye, Usk and Cleddau.

Tasks include

- delivering habitat and water quality improvements where possible in the time available
- engagement with landowners
- planning for future restoration requirements based on evidence including the phosphate compliance report

Incident Management and Pollution Prevention

NRW respond to reported environmental pollution incidents according to their Incident Categorisation Guidance. Incident management is one of NRW's most important core functions and is maintained on a 24-hour 365-day basis.

- NRW have an integrated incident categorisation policy as part of their overall approach to delivering natural resource management and the prevention of environmental damage

- The categorisation of potential and actual incidents allows NRW to use a risk-based approach to prioritise their work to ensure they secure the highest benefits to the environment, people and economy of Wales with the resources available

Preventing incidents from occurring in the first place is NRW's ultimate goal, both to ensure our natural resources are appropriately managed, and as an intrinsic part of our incident preparation and regulatory work.

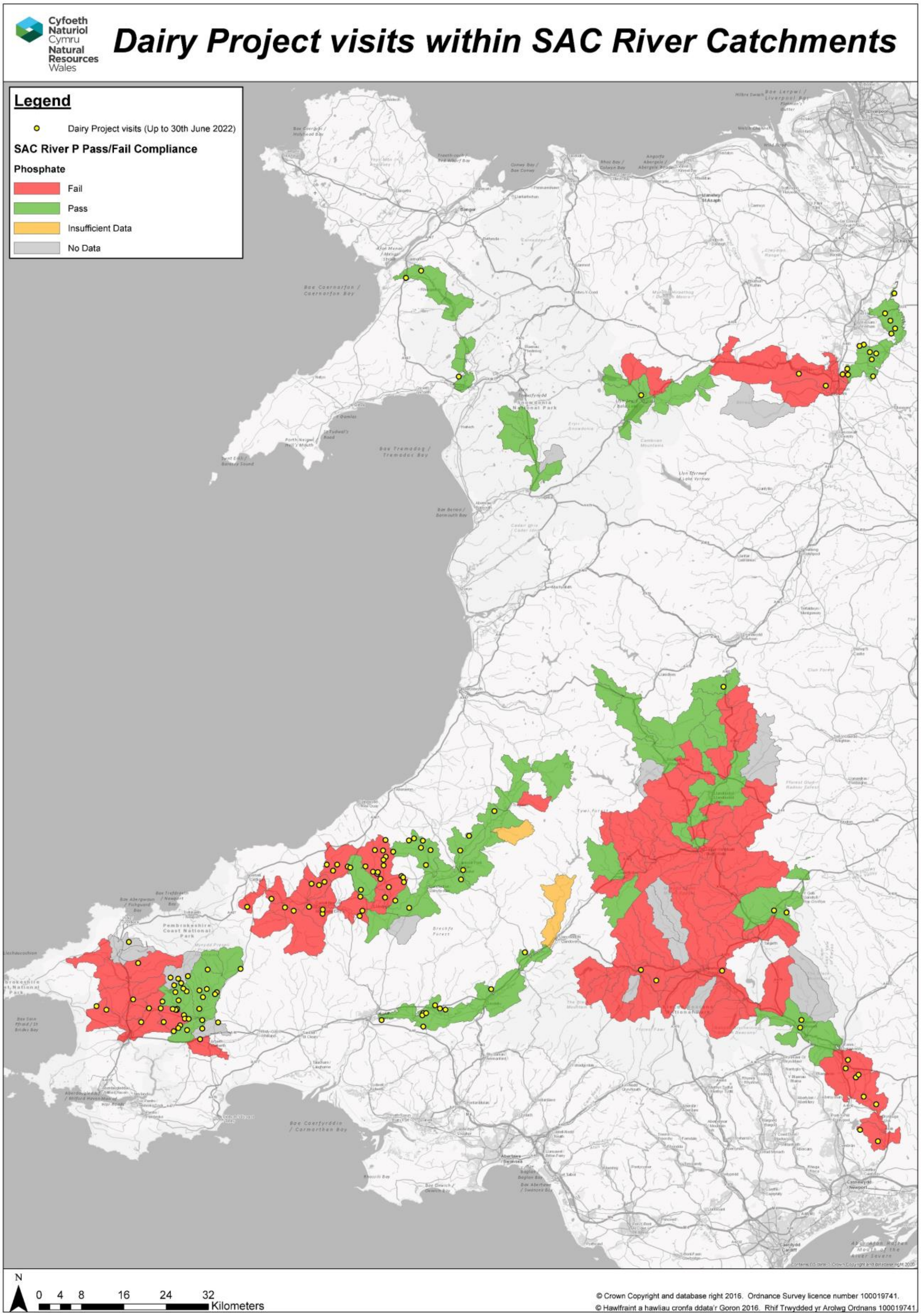
Much of NRW's day-to-day pollution prevention work is carried out by the local Environment Teams, working across Wales. Their work includes:

- delivering advice and guidance to farmers and landowners in rural areas

- and to householders, businesses, and industry in more urban settings

This work is often targeted in Water Framework Directive (WFD) failing catchments.

Figure 20: Dairy Project Visits



Summary Diagrams of Ongoing Projects

Figure 26: Cleddau

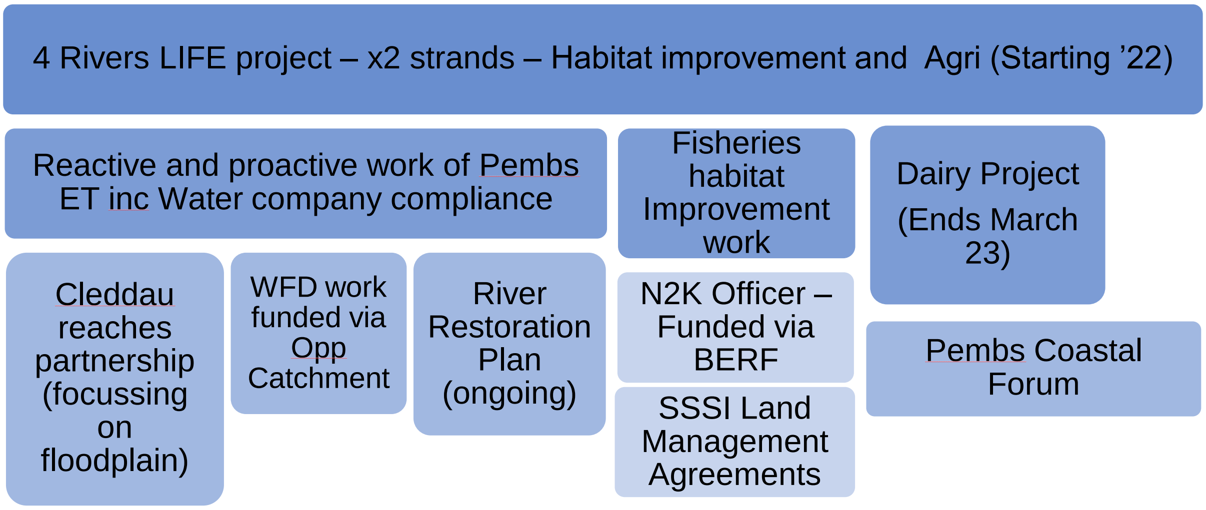


Figure 27: Dee

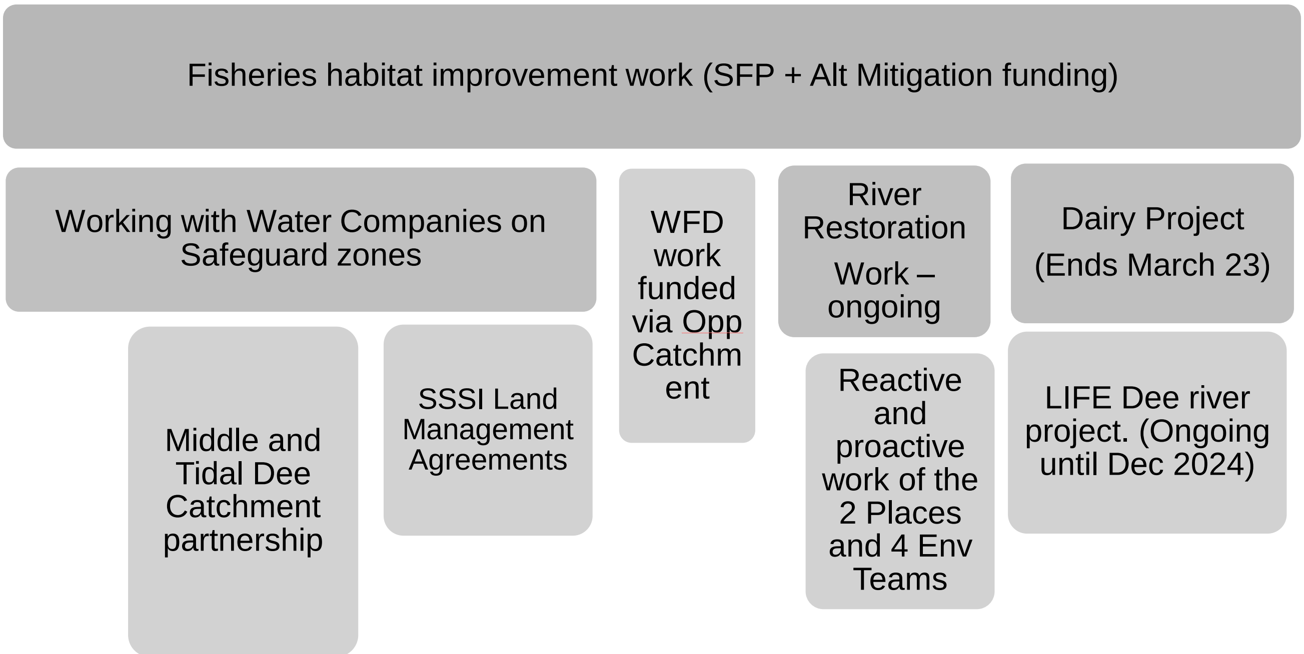


Figure 28: Teifi

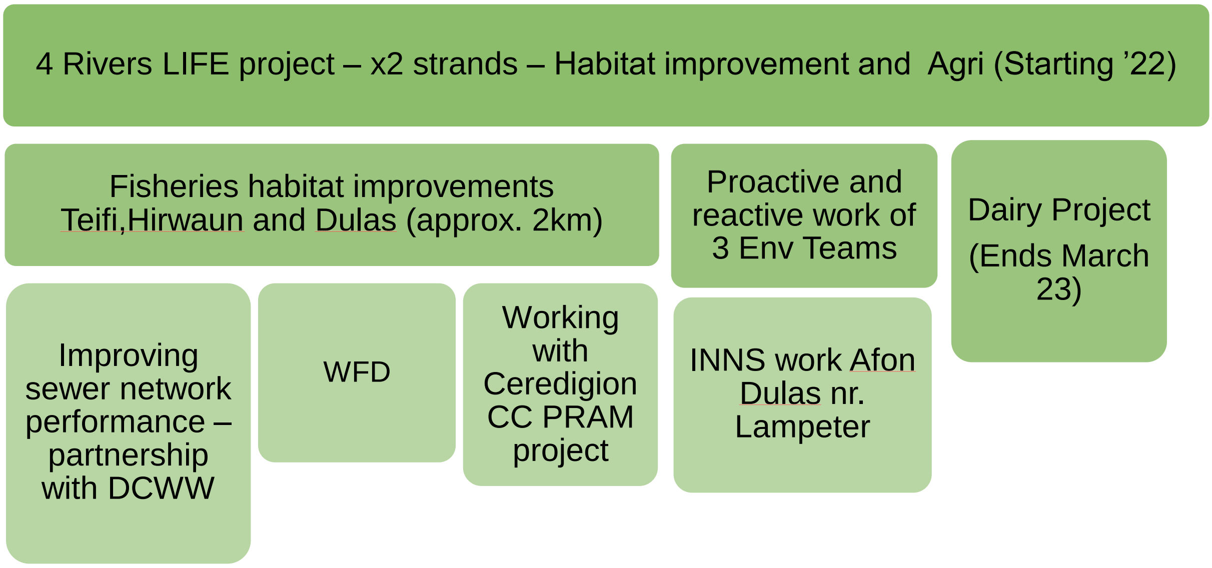


Figure 29: Usk

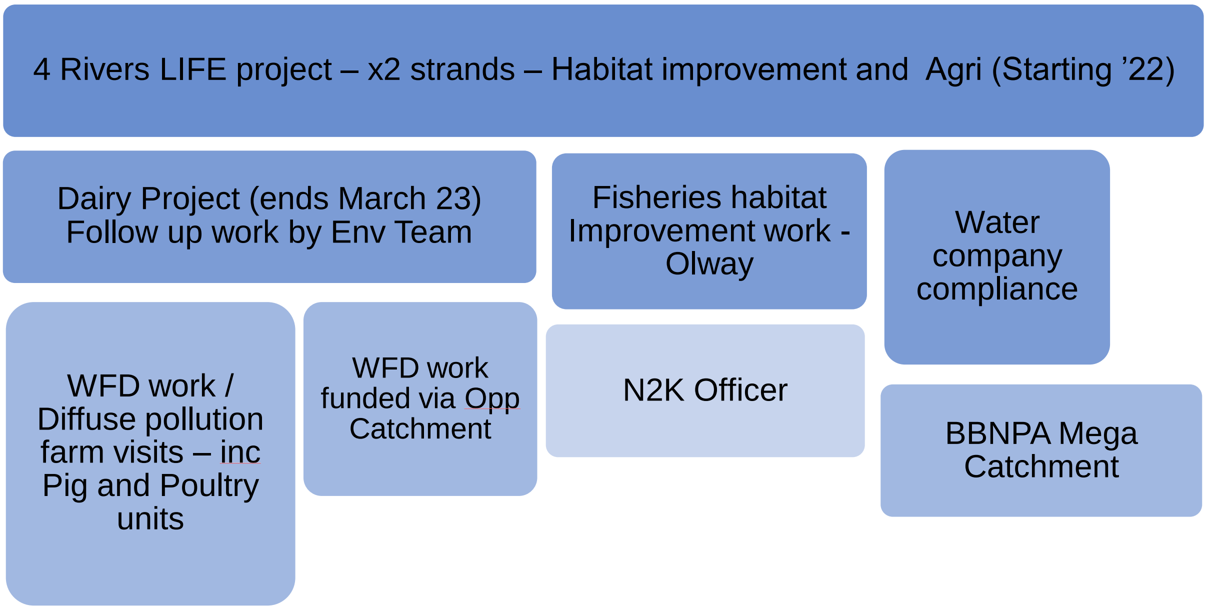


Figure 30: Wye

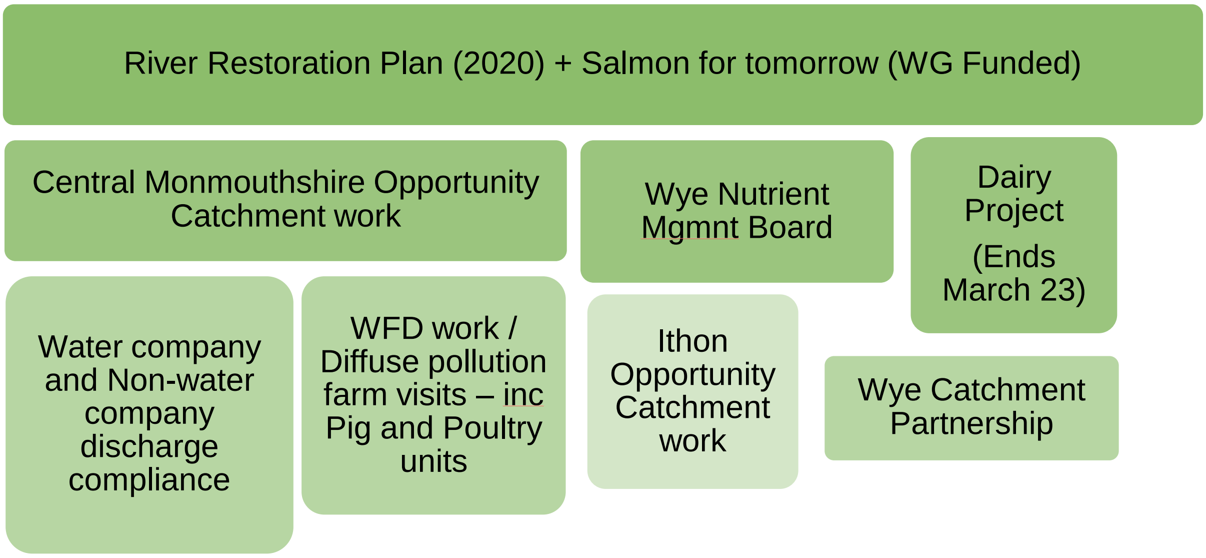
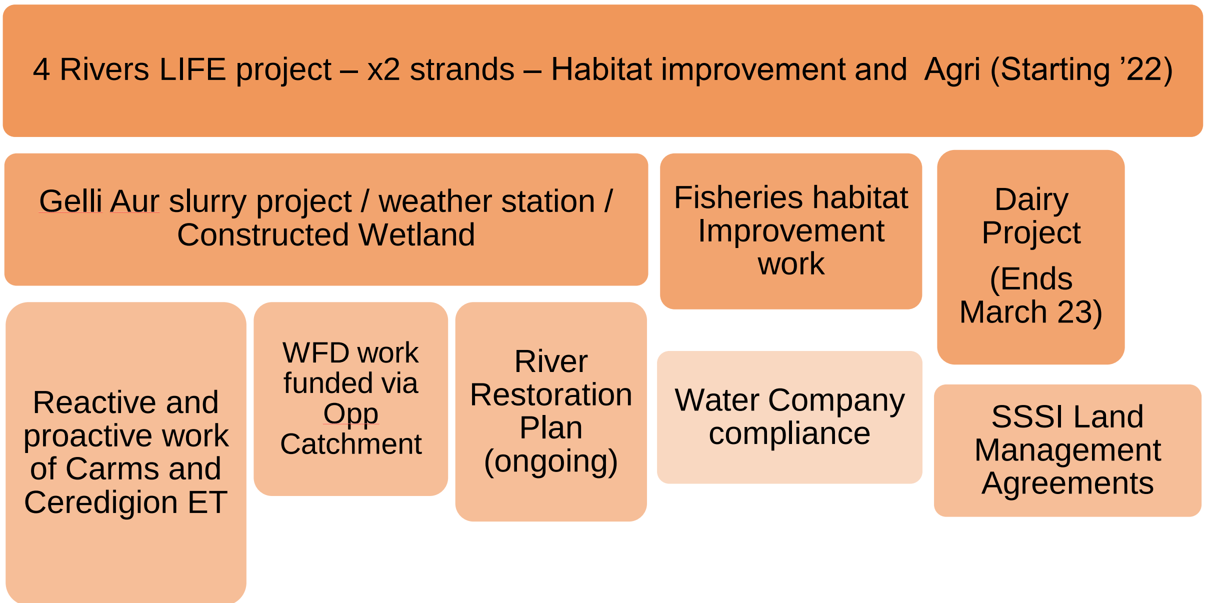


Figure 31: Tywi



Annex A: SAC River Characteristics

Cleddau

General site character:

- Inland water bodies (standing water, running water) (26%)
- Bogs, Marshes, water fringed vegetation, fens (17%)
- Heath, Scrub, Maquis and Garrigue, Phygrana (17%)
- Dry grassland, Steppes (2%)
- Improved grassland (9%)
- Other arable land (0.3%)
- Broad-leaved deciduous woodland (26%)
- Coniferous woodland (2%)
- Mixed woodland (0.2%)
- Other land (including towns, villages, roads, waste places, mines, industrial sites) (0.5%)

Species that are a primary reason for selection of this site:

- Brook lamprey[8] *(Lampetra planer)*
  - The Cleddau rivers are a predominantly lowland catchment in the Pembrokeshire peninsula. The substrates consist mainly of sand, gravel and well-aerated silt, providing an excellent mosaic of lamprey spawning and nursery habitat. This is reflected in electrofishing surveys carried out by the Environment Agency, which indicate the presence of ammocoetes throughout the catchment
- River lamprey *(Lampetra fluviatilis)*
  - The Cleddau Rivers in south-west Wales arise at fairly low altitude, and this moderate to low-gradient catchment with a mixture of gravels and silts provides large areas of good lamprey habitat. Electrofishing data indicates that ammocoetes are widespread throughout the SAC, and adult **river** lampreys *Lampetra fluviatilis* are evident during the spawning season
- Bullhead *(Cottus gobio)*
  - The Cleddau differs from the Teifi system, also in south-west Wales, in its gentler gradients and more meso-eutrophic nature. The generally finer substrates present and more widespread shading means that bullhead *Cottus gobio* in the Cleddau Rivers are more likely to depend on macrophytes and woody debris for cover and represent a lowland type population. Electrofishing data indicates that bullhead are very widespread throughout the catchment
- Otter *(Lutra lutra)*
  - The Eastern and Western Cleddau Rivers flow through a largely lowland landscape, eventually joining and flowing into Milford Haven, which is part of the Pembrokeshire Marine SAC. These slow-flowing rivers have a diversity of bank-side habitats, and good water quality ensures good stocks of otter *Lutra*

[8] Follow link for more information (all blue text)

Lutra prey species. The otter population on these rivers has shown excellent signs of recovery during the last 10–20 years

Annex II species present as a qualifying feature, but not a primary reason for site selection:

- Sea lamprey (*Petromyzon marinus)*

River Dee and Bala Lake

General site character

- Tidal rivers, Estuaries, Mud flats, Sand flats, Lagoons (including saltwork basins) (4%)
- Salt marshes, Salt pastures, Salt steppes (2%)
- Inland water bodies (Standing water, Running water) (90%)
- Improved grassland (2%)
- Broad-leaved deciduous woodland (2%)

Annex I habitats that are a primary reason for selection of this site:

- Water courses of plain to montane levels with the *Ranunculion fluitantis* and *Callitricho-Batrachion* vegetation
    - Species occurrence description not yet available.

Annex II species that are a primary reason for selection of this site:

- Atlantic salmon *(Salmo salar)*
    - Habitat occurrence description not yet available.
- Floating water-plantain (*Luronium natans)*
    - Habitat occurrence description not yet available.

Annex II species present as a qualifying feature, but not a primary reason for site selection:

- Sea lamprey (*Petromyzon marinus)*
- Brook lamprey (*Lampetra planeri)*
- River lamprey (*Lampetra fluviatilis)*
- Bullhead *(Cottus gobio)*
- Otter *(Lutra lutra)*

Eden

General Site Characteristics:

- Inland water bodies (Standing water, Running water) (10%)
- Bogs, Marshes, Water fringed vegetation, Fens (83%)
- Dry grassland, Steppes (1.3%)
- Improved grassland (0.7%)
- Broad-leaved deciduous woodland (5%)

Annex I habitats present as a qualifying feature, but not a primary reason for selection of this site:

- Active raised bogs *(Priority feature)*

Annex II species that are a primary reason for selection of this site:

- Freshwater pearl mussel *(Margaritifera margaritifera)*
    - This tributary of the Afon Mawddach lies within a little-modified catchment and supports the only population of freshwater pearl mussel *Margaritifera margaritifera* in Wales that is regarded as viable. Recruitment is evident, with some juveniles recorded in recent years, although the population is comparatively small at an estimated 1500 individuals
- Floating water-plantain *Luronium natans*
    - Floating water-plantain *Luronium natans* is not especially abundant or strongly flowering in the Afon Eden but it does represent a rare and significant survival, and this population, scattered along ~100 m of meander pools, is an exceptional instance of the species' growth in naturally slow-flowing waters

Annex II species present as a qualifying feature, but not a primary reason for site selection:

- Atlantic salmon *(Salmo salar)*
- Otter *(Lutra lutra)*

Gwyrfai a Llyn Cwellyn

General site character:

- Inland water bodies (Standing water, Running water) (100%)

Annex I habitats that are a primary reason for selection of this site:

- Oligotrophic to mesotrophic standing waters with vegetation of the Littorelletea uniflorae and/or of the Isoëto-Nanojuncetea
    - Llyn Cwellyn, north Wales, is an oligotrophic glacial lake (Type 3) representative of oligotrophic lakes found in the mountains of Snowdonia. It is a relatively large, deep lake, in contrast to Llyn Idwal, also in Snowdonia. Because of its depth the lake stratifies during the summer, with a thermocline developing at 10-15 m depth that has a marked effect upon the ecology of the site. Although the site has acidified since the late 19th century, water quality remains high and Llyn Cwellyn supports one of the few native Welsh populations of Arctic charr *Salvelinus alpinus* ('Torgoch' in Welsh). The macrophyte flora of Llyn Cwellyn is characterised by abundant shoreweed *Littorella uniflora*, water lobelia *Lobelia dortmanna*, quillwort *Isoetes lacustris*, bulbous rush *Juncus bulbosus* and alternate water-milfoil *Myriophyllum alterniflorum*. The rare awlwort *Subularia aquatica* is abundant in places and 1831 Floating water-plantain *Luronium natans* occurs at this site. Six-stamened waterwort *Elatine hexandra* has been recorded in shallow water off the north shore and bog pondweed *Potamogeton polygonifolius* occurs in stream inflows in the south
- Water courses of plain to montane levels with the Ranunculion fluitantis and Callitricho-Batrachion vegetation

- The Gwyrfai is a good example of the small, steep rivers that occur in north-west Wales. It is dominated by base-poor rock and contains extensive beds of the most oligotrophic end of sub-type 3 of this habitat, dominated by stream watercrowfoot *Ranunculus penicillatus* ssp. *penicillatus*, intermediate water-starwort *Callitriche hamulata*, aquatic mosses *Fontinalis* spp. and bulbous rush *Juncus bulbosus*. The conservation value of the site is enhanced by the presence of good adjacent river corridor habitat, and by the presence of Llyn Cwellyn, a good example of a *Littorella Lobelia* - *Isoetes* oligotrophic lake

Annex II species that are a primary reason for selection of this site:

- Atlantic salmon *(Salmo salar)*

    - The Afon Gwyrfai in north-west Wales is representative of the small montane rivers in this region. It contains a largely unexploited salmon population with a characteristically late run. Environment Agency electrofishing data indicates the presence of healthy juvenile populations downstream of Llyn Cwellyn

- Floating water-plantain *(Luronium natans)*

    - Llyn Cwellyn and its outflow, the Afon Gwyrfai, support one of the largest and most diverse populations of floating water-plantain *Luronium natans* anywhere in Britain. There are extensive submerged, vegetative beds of this species in the clear, oligotrophic waters of the lake and (generally) several small flowering colonies around its edge whilst, downstream from the lake, *L. natans* occupies a highly unusual – and vulnerable – habitat along several hundred metres of slow-moving river. The diversity of growth forms and their range across the Cwellyn-Gwyrfai makes this an internationally significant site for the species

Annex II species present as a qualifying feature, but not a primary reason for site selection:

- Otter *Lutra lutra*

Teifi

General site character:

- Tidal rivers, Estuaries, Mud flats, Sand flats, Lagoons (including saltwork basins) (20%)
- Salt marshes, Salt pastures, Salt steppes (1.7%)
- Inland water bodies (Standing water, Running water) (45.1%)
- Bogs, Marshes, Water fringed vegetation, Fens (8.9%)
- Heath, Scrub, Maquis and Garrigue, Phygrana (2.7%)
- Humid grassland, Mesophile grassland (1.7%)
- Improved grassland (7.5%)
- Broad-leaved deciduous woodland (10.5%)
- Inland rocks, Screes, Sands, Permanent Snow and ice (1.1%)
- Other land (including Towns, Villages, Roads, Waste places, Mines, Industrial sites) (0.8%)

Annex I habitats that are a primary reason for selection of this site:

- Water courses of plain to montane levels with the Ranunculion fluitantis and Callitricho-Batrachion vegetation

- The Teifi in west Wales is a large river flowing over hard rock, with some spectacular gorges in the lower section. It is mainly mesotrophic but also has oligotrophic sections in the upper reaches and represents an outstanding example of a sub-type 3 river with water-crowfoot *Ranunculus* vegetation in western Britain. The river has a spatey flow regime, and in-stream vegetation is dominated by stream water-crowfoot *Ranunculus penicillatus* ssp. *penicillatus*, water-starworts *Callitriche hamulata* and *C. obtusangula* and the aquatic moss *Fontinalis squamosa* in a diverse macrophyte community characteristic of oligo-mesotrophic base-poor rocks. A small amount of *R. penicillatus* ssp. *pseudofluitans* is present where one tributary flows over base-rich rocks. The river is also noteworthy for an unusually low-gradient section flowing through Cors Caron, a large area of 7110 Active raised bog that is an SAC in its own right

Annex I habitats present as a qualifying feature, but not a primary reason for selection of this site:

- Oligotrophic to mesotrophic standing waters with vegetation of the Littorelletea uniflorae and/or of the Isoëto-Nanojuncetea

Annex II species that are a primary reason for selection of this site:

- Brook lamprey *(Lampetra planeri)*
    - The Teifi is a predominantly mesotrophic river in west Wales supporting a large population of brook lamprey *Lampetra planeri*. A mixture of habitat and substrate types provides the combination of spawning gravels adjacent to silt beds that are favoured by this and other lamprey species. A large number of tributaries have been included in the SAC; these are thought to be important for lampreys in the Teifi because the main channel is prone to severe floods that may result in washout of smaller ammocoetes
- River lamprey *(Lampetra fluviatilis)*
    - The Teifi is a large catchment of high conservation value in west Wales. It contains a healthy population of river lamprey *Lampetra fluviatilis*. The semi-natural channel containing a mixture of substrates and in-stream features provides excellent habitat for juvenile lampreys
- Atlantic salmon *(Salmo salar)*
    - The Teifi is a medium-sized mesotrophic river system in west Wales. In 1999 the salmon *Salmo salar* rod catch in the Teifi was the third-largest in Wales, and the system has not experienced the steep decline in stock numbers seen in many other rivers in the area. This is likely to reflect the high quality of the catchment, with a semi-natural channel largely unaffected by poor water quality or artificial barriers to migration. However, in common with many other Welsh rivers, acidification in the upper reaches is a cause for concern. In common with many other rivers in west Wales, grilse are the main stock component. There is a small traditional coracle fishery that exploits the salmon and sea trout *Salmo trutta trutta*

- Bullhead *(Cottus gobio)*
    - The Teifi represents bullhead *Cottus gobio* in west Wales. Water quality is generally good, and the diversity of semi-natural habitat and predominance of stony substrates provides excellent bullhead habitat throughout much of the catchment. Environment Agency electrofishing data shows this species to be widespread throughout the system. Bullheads show marked differences in growth and longevity between upland and lowland streams, and the Teifi includes sections representing both types of habitat
- Otter *(Lutra lutra)*
    - The Teifi in west Wales holds otter *Lutra lutra* throughout much of its catchment. The river has suitable resting and breeding sites along its length. Evidence from surveys and sightings suggest the tidal reach is being increasingly used by otters
- Floating water-plantain *(Luronium natans)*
    - The Teifi is a mixed habitat supporting floating water-plantain *Luronium natans* at the western margins of its range in the UK. This species has been recorded in the nutrient-poor standing waters of the Teifi pools in the headwaters of the river. It has also been recorded in a moderately nutrient-rich stretch of the river immediately downstream of Cors Caron

Annex II species present as a qualifying feature, but not a primary reason for site selection:

- Sea lamprey (*Petromyzon marinus)*

Tywi

General site character

- Tidal rivers, Estuaries, Mud flats, Sand flats, Lagoons (including saltwork basins) (9%)
- Salt marshes, Salt pastures, Salt steppes (2%)
- Shingle, Sea cliffs, Islets (7%)
- Inland water bodies (Standing water, Running water) (62%)
- Bogs, Marshes, Water fringed vegetation, Fens (6%)
- Heath, Scrub, Maquis and Garrigue, Phygrana (4%)
- Improved grassland (3%)
- Broad-leaved deciduous woodland (7%)

Annex II species that are a primary reason for selection of this site:

- Twaite shad *(Alosa fallax)*
    - A large spawning population of twaite shad *Alosa fallax* occurs in the Tywi, south Wales, and is considered to be self-sustaining. Spawning sites occur throughout the lower reaches of the river between Carmarthen and Llangadog, with most spawning occurring downstream of Llandeilo. Water quality and quantity are considered adequate to maintain this internationally vulnerable species, and there are no impassable obstructions along the migration route, though one weir at Manorafon may be an obstacle during low flow conditions.

The presence of Llyn Brianne reservoir at the headwaters provides the potential to manipulate river flows to aid shad migratio

- Otter *(Lutra lutra)*
    - The Afon Tywi is one of the best rivers in Wales for otters *Lutra lutra*. There are abundant signs of otters and they are regularly seen on the river. The water quality is generally good and there is an ample supply of food. There are suitable lying-up areas along the riverbank, but there few known breeding sites on the main river, although cubs have been seen.

Annex II species present as a qualifying feature, but not a primary reason for site selection:

- Sea lamprey (*Petromyzon marinus)*
- Brook lamprey (*Lampetra planeri)*
- River lamprey (*Lampetra fluviatilis)*
- Allis shad *(Alosa alosa)*
- Bullhead *(Cottus gobio)*

Usk

General site character:

- Tidal rivers, Estuaries, Mud flats, Sand flats, Lagoons (including saltwork basins) (26.8%)
- Salt marshes, Salt pastures, Salt steppes (4.5%)
- Inland water bodies (Standing water, Running water) (37.9%)
- Bogs, Marshes, Water fringed vegetation, Fens (3.8%)
- Heath, Scrub, Maquis and Garrigue, Phygrana (3.4%)
- Dry grassland, Steppes (8%)
- Humid grassland, Mesophile grassland (1.4%)
- Improved grassland (2%)
- Broad-leaved deciduous woodland (10.1%)
- Other land (including Towns, Villages, Roads, Waste places, Mines, Industrial sites) (2.1%)

Annex I habitats present as a qualifying feature, but not a primary reason for selection of this site:

- Water courses of plain to montane levels with the Ranunculion fluitantis and Callitricho-Batrachion vegetation

Annex II species that are a primary reason for selection of this site:

- Sea lamprey *(Petromyzon marinus)*
    - The Usk is a medium-sized catchment in south Wales, important for its population of sea lamprey *Petromyzon marinus*. Survey of juveniles and observation of spawning adults indicates that this species is mainly restricted to the lower reaches of the catchment. The site supports a range of Annex II fish species

- Brook lamprey *(Lampetra planeri)*

  - The Usk in south Wales supports a healthy population of brook lamprey *Lampetra planeri* and is considered to provide exceptionally good quality habitat likely to ensure the continued survival of the species in this part of the UK

- River lamprey *(Lampetra fluviatilis)*

  - The Usk in south Wales supports a healthy population of river lamprey *Lampetra fluviatilis* and is considered to provide exceptionally good quality habitat likely to ensure the continued survival of the species in this part of the UK. The river also supports important populations of 1096 Brook lamprey *Lampetra planeri*, for which it is also selected

- *Twaite shad* *(Alosa fallax)*

  - The River Usk is one of the largest rivers in south Wales, and twaite shad *Alosa fallax* has long been known to spawn there. The Usk is one of only four sites in the UK where a known breeding population of twaite shad occurs (the Rivers Wye and Tywi are other SAC sites). Water quality and quantity are considered favourable for this species. The main channel is largely unmodified and a variety of aquatic habitats are present, including good quality spawning gravels and deep pools used for cover by adults and fry. However, Trostrey and Rhadyr Weirs may be a barrier to shad migration under low flow conditions

- Atlantic salmon *(Salmo salar)*

  - The river Usk is a river famous for its salmon *Salmo salar*, with a high proportion (*c*. 30–40%) of multi sea winter fish recorded in the rod catch. In 1999 the Usk had highest estimated egg deposition of any British river south of Cumbria and was one of the few rivers in England and Wales to exceed its spawning target for salmon. The Usk has a mixed catchment with a largely unmodified river channel, no significant obstructions to salmon migration, good quality spawning gravels and a diversity of habitats providing excellent habitat for salmon parr. The most important tributaries for salmon spawning are included within the site boundary

- Bullhead *(Cottus gobio)*

  - The Usk represents bullhead *Cottus gobio* in the southern part of its range in Wales. It is considered to have exceptionally high-quality habitat with good water quality, abundant cover and a variety of aquatic habitats. Bullhead are widespread throughout the Usk system

- Otter *(Lutra lutra)*

  - The River Usk is an important site for otters *Lutra lutra* in Wales. They are believed to be using most parts of the main river, from Newport upstream, and in recent years signs of otters have increased. In 1991 an expansion upstream of known otter ranges was recorded on several tributaries, including the Honddu, Senni and Crai. The upper Usk may have acted as a 'refuge' during the decline of the 1950s and had subsequently acted as a 'source' population for recolonisation of south-east Wales

Annex II species present as a qualifying feature, but not a primary reason for site selection:

- Allis shad *(Alosa alosa)*

Wye

General site character:

- Tidal rivers, Estuaries, Mud flats, Sand flats, Lagoons (including saltwork basins) (9.5%)
- Salt marshes, Salt pastures, Salt steppes (1.5%)
- Inland water bodies (Standing water, Running water) (52.5%)
- Bogs, Marshes, Water fringed vegetation, Fens (3.1%)
- Heath, Scrub, Maquis and Garrigue, Phygrana (1%)
- Dry grassland, Steppes (5.3%)
- Humid grassland, Mesophile grassland (2.4%)
- Improved grassland (10.4%)
- Broad-leaved deciduous woodland (12.3%)
- Inland rocks, Screes, Sands, Permanent Snow and ice (0.2%)
- Other land (including Towns, Villages, Roads, Waste places, Mines, Industrial sites) (1.8%)

Annex I habitats that are a primary reason for selection of this site:

- Water courses of plain to montane levels with the Ranunculion fluitantis and Callitricho-Batrachion vegetation
    - The Wye, on the border of England and Wales, is a large river representative of sub-type 2. It has a geologically mixed catchment, including shales and sandstones, and there is a clear transition between the upland reaches, with characteristic bryophyte-dominated vegetation, and the lower reaches, with extensive *Ranunculus* beds. There is a varied water-crowfoot *Ranunculus* flora; stream water crowfoot *R.penicillatus* ssp. *pseudofluitans* is abundant, with other *Ranunculus* species – including the uncommon river water-crowfoot *R. fluitans* – found locally. Other species characteristic of sub-type 2 include flowering-rush *Butomus umbellatus*, lesser water-parsnip *Berula erecta* and curled pondweed *Potamogeton crispus*. There is an exceptional range of aquatic flora in the catchment including river jelly-lichen *Collema dichotum*. The river channel is largely unmodified and includes some excellent gorges, as well as significant areas of associated woodland

Annex I habitats present as a qualifying feature, but not a primary reason for selection of this site:

- Transition mires and quaking bogs

Annex II species that are a primary reason for selection of this site:

- White-clawed (or Atlantic stream) crayfish *(Austropotamobius pallipes)*
    - The Welsh River Wye system is the best site known in Wales for white-clawed crayfish *Austropotamobius pallipes*. The tributaries are the main haven for the species, particularly at the confluences of the main river and the Edw, Dulas Brook, Sgithwen and Clettwr Brook

- Sea lamprey *(Petromyzon marinus)*

- The Wye is an extensive river system crossing the border between England and Wales and the sea lamprey *Petromyzon marinus* population is found in the main stem below Llyswen. The site provides exceptionally good quality habitat for sea lamprey and supports a healthy population

- Brook lamprey *(Lampetra planeri)*

  - The Wye is an extensive river system spanning the border between England and Wales and the brook lamprey *Lampetra planeri* population is widely distributed in its catchment. The river provides exceptionally good quality habitat for brook lamprey and supports a healthy population

- River lamprey *(Lampetra fluviatilis)*

  - The Wye is an extensive river system crossing the border between England and Wales, and the river lamprey *Lampetra fluviatilis* population is widely distributed in the catchment. The Wye provides exceptionally good quality habitat for river lamprey and supports a healthy population

- Twaite shad *(Alosa fallax)*

  - Twaite shad *Alosa fallax* have long been abundant in the Wye, an extensive river system spanning the border between England and Wales. Twaite shad often spawn at or just above the tidal limit, but in the Wye they migrate over 100 km upstream, the highest spawning site being at Builth Wells. Data held by the Environment Agency indicate that, of the three selected rivers, the largest spawning areas for this species occur on the Wye. The river has relatively good water quality, adequate flows through an unobstructed main channel and a wide range of aquatic habitats conducive to supporting this fish species. In particular, there are a number of deep pools essential for congregation before spawning

- Atlantic salmon *(Salmo salar)*

  - Historically, the Wye is the most famous and productive river in Wales for Atlantic salmon *Salmo salar*, with high-quality spawning grounds and juvenile habitat in both the main channel and tributaries; water quality in the system is generally favourable. It is also one of the most diverse river systems in the UK, with a transition from hard geology, high gradients, rapid flow fluctuations and low nutrient-content in its upper reaches, to a more nutrient-rich river with lower gradient, more stable flow and softer geology in the lowlands. The effect of river engineering work on migration and spawning has been limited, although there is a localised influence from the Elan Valley reservoirs, through inundation of spawning and nursery habitat and fluctuations in flow and water levels in the upper Wye. The most important tributaries for spawning are included in the SAC. Although in the past non-native salmon may have been released to the system, the impact of this is likely to have been minimal. The Wye salmon population is particularly notable for the very high proportion (around 75%) of multi sea winter (MSW) fish, a stock component which has declined sharply in recent years throughout the UK. This pattern has also occurred in the Wye, with a consequent marked decline in the population since the 1980s. However, the Wye salmon population is still of considerable importance in UK terms

- Bullhead *(Cottus gobio)*

    - The Wye represents bullhead *Cottus gobio* in an extensive river system crossing the border between England and Wales. The Wye is one of the most diverse river systems in the UK, with a range of nutrient conditions and aquatic habitats and generally good water quality for fish species. The diversity of habitat types in the Wye means that it is likely to represent most of the habitat conditions in which bullhead occurs in Britain, highlighting the conservation importance of this river

- Otter *(Lutra lutra)*

    - The Wye holds the densest and most well-established otter *Lutra lutra* population in Wales, representative of otters occurring in lowland freshwater habitats in the borders of Wales. The river has bank-side vegetation cover, abundant food supply, clean water and undisturbed areas of dense scrub suitable for breeding, making it particularly favourable as otter habitat. The population remained even during the lowest point of the UK decline, confirming that the site is particularly favourable for this species and the population likely to be highly stable

Annex II species present as a qualifying feature, but not a primary reason for site selection:

- Allis shad *(Alosa alosa)*

Annex B: SAGIS Model Data

There are two main types of data contained within SAGIS model databases, namely, measurement data and sector data. Measurement data are derived from routine monitoring activities, and include river quality information obtained by NRW, and river flow information reported at national river flow gauges. Models are calibrated to the measurement data so that models are expected to recreate (virtually) conditions that span the period over which the measurement data was obtained. The model for the River Dee SAC has been developed using data covering the period 2016 to 20193. There are two important points relating to how the river quality data are processed prior to inclusion in the model:

- Data obtained as part of reactive pollution monitoring were excluded from the summary statistics to ensure the model data are not unduly distorted by infrequent or random events.

- Data was checked for outliers which had the potential to distort summary statistics, but no samples were found which had a statistically significant impact on the results.

The sector data contained within the model databases represent estimates of inputs from sources other than wastewater treatment works, primarily diffuse sources. Estimates of diffuse inputs are included in the model by sector as an annual load input, by waterbody4. Within the modelling process these waterbody loads are distributed across the river reaches within the originating waterbody. An occasional consequence is that within the modelling process inputs from certain sectors may be distributed to river reaches in which they are not expected to occur although this tends to primarily affect river reaches situated in headwater locations.

Agricultural input estimates are based on data from the Phosphorus and Sediment Yield Characterisation In Catchment model (PSYCHIC; Davison et al., 2008; Stromqvist et al., 2008), which provides an estimate of phosphorus ‘losses’ to waterbodies at a 1km2 grid scale, but which have been aggregated to a waterbody scale for use within SAGIS5. Modelled transfer pathways include release of soil phosphorus, detachment of sediment and associated particulate phosphorus, incidental losses from

manure and fertiliser applications, losses from hard standings and the transport of all the above to watercourses in underdrainage (where present) and via surface pathways. The model is sensitive to a number of crop and animal husbandry decisions, as well as to environmental factors such as soil type and field slope angle. The PSYCHIC model utilises the mean climate drainage model (MCDM, Anthony, 2003) to calculate the evapotranspiration, soil moisture deficit and soil drainage. The presence of artificial drainage systems the relative importance of different sub-surface drainage pathways are based on the Hydrology of Soil.

Types (HOST; Boorman et al., 1993) classification. PSYCHIC has been applied across the UK in support of government policy (e.g. Anthony et al., 2005; Gooday et al., 2015) and has also been applied to a number of European catchments (Silgram et al., 2008).

The current phosphorus data within SAGIS for England and Wales is from the PSYCHIC model (Davison et al., 2008) based agricultural census data for 2010.

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Annex C: Phosphorus Technical Summary Author's Note and References

This document was prepared to help frame the phosphorus discussion to give an international perspective and temporal context to the summit. It is not exhaustive, and in often draws material from my book *Phosphorus Past and Future* (2021) particularly Chapters 5, 6, 8, and 9; where there is no credit of material given it is either sourced from this book or from accepted knowledge. I have provided pertinent references where appropriate. The document is intended to serve as a stimulus for provoking wider and deeper discussion and new thoughts, hopefully leading towards locally owned solutions.

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