Herefordshire Council

Agenda

Environment and Sustainability Scrutiny Committee

Date:	**Monday 25 September 2023**
Time:	**10.00 am**
Place:	**Herefordshire Council Offices, Plough Lane, Hereford, HR4 0LE**
Notes:	Please note the time, date and venue of the meeting. For any further information please contact: **Simon Cann, Democratic Services Officer** Tel: 01432 260667 Email: simon.cann@herefordshire.gov.uk

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Agenda for the meeting of the Environment and Sustainability Scrutiny Committee

Membership

Chairperson	**Councillor Louis Stark**
Vice-chairperson	**Councillor Helen Heathfield**
	Councillor Dave Davies
	Councillor Robert Highfield
	Councillor Rob Owens
	Councillor Justine Peberdy
	Councillor Richard Thomas

Agenda

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10. DATE OF THE NEXT MEETING

Date of next meeting: Monday 27 November 2023 10.00 am

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www.herefordshire.gov.uk/downloads/file/1597/hereford-city-bus-map-local-services-

Herefordshire Council

The seven principles of public life

(Nolan Principles)

1. **Selflessness**

   Holders of public office should act solely in terms of the public interest.

2. **Integrity**

   Holders of public office must avoid placing themselves under any obligation to people or organisations that might try inappropriately to influence them in their work. They should not act or take decisions in order to gain financial or other material benefits for themselves, their family, or their friends. They must declare and resolve any interests and relationships.

3. **Objectivity**

   Holders of public office must act and take decisions impartially, fairly and on merit, using the best evidence and without discrimination or bias.

4. **Accountability**

   Holders of public office are accountable to the public for their decisions and actions and must submit themselves to the scrutiny necessary to ensure this.

5. **Openness**

   Holders of public office should act and take decisions in an open and transparent manner. Information should not be withheld from the public unless there are clear and lawful reasons for so doing.

6. **Honesty**

   Holders of public office should be truthful.

7. **Leadership**

   Holders of public office should exhibit these principles in their own behaviour and treat others with respect. They should actively promote and robustly support the principles and challenge poor behaviour wherever it occurs.

Herefordshire Council

Minutes of the meeting of Environment and Sustainability Scrutiny Committee held at Herefordshire Council Offices, Plough Lane, Hereford, HR4 0LE on Thursday 19 January 2023 at 10.30 am

Present: **Councillor Louis Stark (chairperson)**
Councillor Trish Marsh (vice-chairperson)

Councillors: Carole Gandy, David Hitchiner (Substitute), Elissa Swinglehurst, Yolande Watson and William Wilding (Remote)

In attendance: **M Averill (Service Director Environment and Highways), B Boswell (Head of Environment Climate Emergency and Waste Services), S Cann (Secretary), J Coleman (Secretary), L Duberley (Service Manager Built and Natural Environment), N Percival (Waste Services Manager), S Peters (Waste Transformation Lead), A Rees-Glinos**

Officers:

31. APOLOGIES FOR ABSENCE

Apologies were received from Cllr Ellie Chowns, Cllr Gemma Davies and Cllr Jennie Hewitt.

32. NAMED SUBSTITUTES

Cllr David Hitchiner substituted for Cllr Ellie Chowns.

33. DECLARATIONS OF INTEREST

None.

34. MINUTES

The minutes of the meeting held on 18 November 2022 were agreed as a correct record and signed by the Chair.

35. QUESTIONS FROM MEMBERS OF THE PUBLIC

There were no questions received from members of the public.

36. QUESTIONS FROM MEMBERS OF THE COUNCIL

There were no questions received from Councillors.

37. WASTE AND RECYCLING

The Committee agreed to look at the item in in the context of the waste hierarchy and divided it into three sections for discussion:

Section 1 - Household waste and the front end of the waste hierarchy (reduce and reuse).

The Committee noted that progress was being made and accepted assurances that the Council was on track to meet the targets within the strategy. Some members questioned the inclusion of the words ‘significant’ and ‘ambitious’ within recommendation (a) and suggested they came across as self-congratulatory.

The Committee suggested that the content of paragraph 19 of the strategy (particularly points 19A and 19C) needed to be stronger and felt greater emphasis should be placed on the circular economy. As an example of how recycling could be encouraged, the Committee pointed to a household recycling centre (HRC) in the neighbouring authority of Monmouthshire, which contained an off-ramp from the main HRC, leading to a repurposed building, where anything with a useful onward life could be deposited for recycling and purchased by the public. It was pointed out that there was no equivalent service within Herefordshire and that the situation should be rectified, temporary classrooms could potentially be repurposed and located at local HRCs where practical.

The Committee acknowledged the benefits of pop-up recycling shops, but highlighted the inconsistency associated with such stores. The Committee stated that charity shops regularly lacked the capacity to process items and that a dedicated on-site recycling building (including a shop that was accessible to the general public) would be a quick and cost-effective way to boost recycling in the county. The Committee requested that an update be provided on 19A and 19C.

The Committee agreed that in relation to reducing waste, the Council needed to get its own house in order and point to what it was doing to encourage the public and local community to follow its example. A joined up approach within the waste hierarchy was needed with all players engaged and the Committee enquired when a waste analysis of residual waste would be available.

The Committee expressed its concerns about reports from Welsh Water in relation to the damage from overflow from blocked pipes, a significant factor in many of these blockages was the incorrect disposal of non-flushable items such as kitchen towels and wet wipes. Education on correct disposal of these and other such items would be crucial in tackling this problem and the Committee suggested that the Council could consider working together with Welsh Water on this issue.

Members of the Committee pointed out that quite often charity shops would not accept certain items and that encouraging and assisting people/communities to set-up and staff repair shops could be something for the Council to incorporate in its strategy.

The Committee enquired about facilitation and how much was being done to bolster the infrastructure to allow people to reuse, repair and reduce waste once they had been educated.

The Committee suggested that the recycling centre booking system presented an excellent opportunity to challenge what people were taking to the centres and educate them on methods and facilities available for efficient waste disposal, however a nuanced approach should be taken when engaging with the public. It was felt that working closely with the charitable sector to communicate best practice for recycling would also be useful.

The head of environment climate emergency and waste services responded to the Committee’s comments and enquiries. It was explained that the team had responded to over 23 recommendations contained within the Task and Finish report and that significant and impressive progress had been made in this area. The team had extended and varied the waste disposal contract to enable the new waste collection contract, this had been a huge piece of work and the team had done an ‘amazing’ job to deliver this within the timescales. Targets set for reducing landfill were significantly ahead of schedule and the figure was likely to be under 1% within the year, which was three years ahead of schedule.

The head of service highlighted improvements that had been made in relation to recycling opportunities within the county through food waste collection, increased card and paper segregation and a full value garden waste scheme. A number of pilot schemes had also been launched, one particular success was the nappy scheme, which was launched six months previously and had been completely oversubscribed within 36 hours of launch, with more vouchers having to be released to meet demand. Social media engagement relating to the scheme had been hugely positive and the council had been working closely with anti-natal care to ensure the scheme’s continued success.

The waste transformation lead explained that a repair shop grant scheme had started in the autumn - with assistance from volunteers and expertise from surrounding areas, including Ledbury and Malvern, the first store in Herefordshire would be opening in a month and would provide a template for others to follow. Herefordshire Council would be working closely with third parties and charities through the journey of education and engagement and this would be a base to take things forward, with other organisations coming forward to apply for the grant and set up more repair shops within the county.

The head of service pointed out that the current waste disposal contract had been due to terminate in 2024, but had been extended to 2029, which in waste terms was a short time. The Council was currently reviewing options for 2029 and beyond and was engaging with local partnerships and the department of levelling up. The team were also working with the current contractor and looking at national best practice to establish what could be done with reuse facilities presently and in the future.

The head of service also drew the attention of the Committee to a newly contracted bulky waste reuse collection service, which would no longer automatically classify bulky items as waste, but would instead see them classed as a potentially reusable item. The team were working on getting bulky items out of the waste stream and into the reuse stream and were revisiting the “getting it right” campaign to get the right messages, to the right places to the right people.

Section 2 - Household waste at the back end (recycling, recovery and disposal).

The Committee asked whether information and data was available regarding the number of people choosing not to recycle and what was the Council doing to address this situation?

The head of environment climate emergency and waste services assured the Committee they would be provided with a copy of the consultation report, which contained relevant data on the matter in question.

The Committee asked for clarity on terminology used in paragraphs 8C and 17 of the report in relation to the terms ‘contract monitoring’ and ‘best practice review of contact management’. It also asked what the Council was doing in terms of inspections to check that the contracts in place were being adhered to?

The head of service explained that contract monitoring involved ensuring there was better accountability and transparency around the journey of waste after it had been collected, and obtaining assurances about where that waste goes. With Mercia the waste journey was clear, but the Council wanted Mercia to undertake work with subcontractors to go further down the supply chain, for even greater transparency. It was noted that the assurance and contractual agreement to go right down the whole supply chain was now in place.

Regarding the review of contract management, this involved working jointly with Worcestershire County Council and an external consultancy to see how improvements could be produced in relation to best practice and continual improvement. In terms of monitoring and inspecting what the contractor was doing the team went through monthly reports and reviews with colleagues at Worcestershire County Council and regular meetings and reports with the contractor were taking place.

The waste services manager explained that in terms of monitoring the journey of waste, every load of waste had a weighbridge note that went with it so that its movement could be tracked. All locations where waste was sent had a data return, which was checked by Defra on a regular basis, plans were being worked on to see if the Council could go further in tracing waste to its end destination.

It was noted that KPIs (to monitor that contractors were doing as agreed) were currently being looked at as part of forthcoming commissioned contract management review.

The waste services manager answered a question from the Committee regarding the collection of soft plastics. National trials were currently taking place in relation to recycling soft plastics and Herefordshire was keen to be involved in these. The impact of a future soft plastics tax remained to be seen, but could see a drop-off of such materials in coming years.

Section 3 - Business waste, in particular food waste from small businesses and fly tipping.

The Committee asked questions in relation to:

- The way small businesses, especially takeaways, disposed of waste food and what checks were in place to monitor this?
- Could a phosphate benefit be derived from food waste?
- Were any kind of in-field waste schemes in place within Herefordshire, whereby farmers would allow foodbanks access to unwanted crops?
- Communications of tyre disposal on the Council website.
- Was the Council taking a consistent line on carbon reduction, especially in relation its fleet of waste trucks? Was there a carbon reduction scoring system in place as part of the decision matrix?

The head of service and waste services manager addressed the points raised by the Committee and explained that:

- The Council offered a waste recycling service through a commercial food waste collection. The waste was disposed of in an environmentally friendly manner in a facility outside of the county. Small businesses were not told where or how to dispose of waste, but there was a wealth of information available to them via regular communications. The community protection team work closely with the waste team to ensure businesses were being supported and were complying with the rules.
- Phosphate benefits derived from food and in-field schemes were currently being discussed with relevant partners and third parties.

- It was pointed out that tyres could no longer be placed in landfill, however many garages and recycling centres would dispose of them for a small fee, where they would be chipped and reused for playground surfacing and other suitable purposes. Instances of the fly tipping of tyres should be reported to the community protection team who can investigate incidents where there is a pattern.
- The Council was keen to promote and encourage business cases to deliver carbon reduction wherever possible. In relation to the fleet of waste trucks, half of the fleet was refurbished in 2013-2014. The fleet was currently owned by the contractor and was ageing, but recycling of the existing fleet had been used to extend the lifespan of other vehicles.

This concluded the questions. The Committee discussed and drew up a number of recommendations, which were proposed and approved unanimously:

It was unanimously resolved that:

1) The committee notes the significant progress to date through the Waste Transformation Programme and is assured that the Council is on track for early delivery of the ambitious new targets within the new Integrated Waste Management Strategy, and

2) The following recommendations should be considered by the Executive for inclusion:

a) *There should be additional information provided (via the self-serve booking system and located within) local recycling centres, identifying additional opportunities to re-use and repair items that would otherwise be sent to waste or re-cycling.*

(i) As part of this, working with charitable sector partners to expand and communicate the diversity of options for re-use.

b) Strengthened communication is provided on the opportunities available to reduce, repair re-use and recycle locally - targeted at those who do not currently process their waste in this method.

c) That the Executive set in place a reporting and communications campaign to ensure that the public are made aware of how each of our waste streams are used (recycling, waste for energy recovery and for disposal to landfill), and explains where each waste stream is directed to and how each stream is re-processed."

d) *That Smart KPIs are agreed with our contractors responsible for recycling, waste for energy recovery and disposal to landfill.*

e) Infrastructure is provided at recycling centres to enable and maximise opportunity to allocate their items for re-use.

f) Measures are taken to ensure that when local food outlets are inspected by environment health information is provided about the opportunities and additional options available to them to recycle their waste.

g) Development of the business cases within the proposed capital programme *should ensure consistent criteria relating to environmental and sustainability measures applied to their fullest extent in relation to reaching carbon neutrality, and repair and re-use of redundant equipment and buildings.*

h) Alongside this, development of a carbon scoring system to be able to assess how specific projects contribute to carbon reduction targets in relation to other options.

38. REVIEW OF THE CLIMATE AND ECOLOGICAL EMERGENCY REVIEW

The Chair noted that the report had already been discussed during previous General Scrutiny meetings and the report was taken as read. Committee members were invited to make general points about the report.

The Committee members made a number of points during the discussion:

- There was a need for greater visibility of manure management plans on planning websites.
- There was a need for KPIs within the delivery plan for neighbourhood development plans (NDPs).
- The work of the Herefordshire Biological Records Centre (HBRC) was praised. It was also suggested that publicity should be given to the fact that members of the public are able to come forward and upload their own data onto the HBRC system.
- A lack of consistency in relation to language was noted and that jumping between terms such as 'net zero, net neutral and carbon neutral' should be avoided where possible.
- Concerns were raised regarding enforcement of legislation and regulations in relation to significant hedgerow removal.

The head of environment climate emergency and waste services) and the service manager built and natural environment, responded to the Committee:

- It was pointed out that manure management plans were published as a planning condition.
- Regarding neighbourhood delivery plans it was explained that these would vary from area to area, but that the inclusion of KPIs within the deliver plan could be discussed with the planning team.
- The praise for the HBRC was welcomed.
- The head of environment climate emergency and waste services accepted comments in relation to inconsistent language and terminology and gave an assurance this would be addressed.
- The service manager for built and natural environment acknowledged hedgerow legislation enforcement was challenging and resource heavy, but explained that the planning and ecology teams were working closely together to tackle the issue. There was now a graduate in post and an apprentice due to start who would be focusing heavily on hedgerow legislation enforcement going forward. Improved information on the website regarding where and how members of the public could report breaches of hedgerow regulation was also something that could be put in place to make the process more efficient.

The Committee raised a number of further points:

- It was noted that partners had received an update on the Nature Strategy, but the Committee had not had sight of it. This was seen as part of a wider failing in terms of the Committee not being kept 'in the loop' and updated on relevant reports and activity.
- The Committee noted that at Scrutiny Management Board many of the highest scoring business cases for retrofitting had been rejected on affordability grounds. A 'blue sky' approach was required and the Council needed to look at everything available in its 'tool box'. For example, looking into building carbon negative houses upon green areas.
- There was a no evidence of a biodiversity net gain option and there should be a recommendation included on this.
- The Committee asked if there was a mechanism in place for the monitoring of manure management plans. What assurances were there that management plans were being complied with?

The head of environment climate emergency and waste services and service manager built and natural environment addressed these points:

- The head of service was not aware the committee had wanted to see the Nature Strategy, but was happy to share it with them. The acting statutory scrutiny officer suggested that this would be recorded as an action and that officers and democratic services needed to work together to ensure that members and proposers were kept up to date on reports and activity relevant to their Committee.

  Action: Clarity of instruction required from report authors and democratic services to ensure members were kept up to date on relevant reports and activity.

- The head of service acknowledged retrofits were an enormous challenge and that there was a need to pull in additional funding where available. Options such as carbon negative housing would be considered as a component of the local plan refresh.
- The service manager explained that in relation to biodiversity net gain, the team were currently awaiting guidance from Defra and that there was only so much that could be done until that detail came through. In the meantime work was carrying on behind the scenes including the updating of the natural environment evidence base, which overlaps with the core strategy. There had been engagement with LUC consultancy on landscape characteristic assessment on open spaces within the county and to provide mapping on bio diversity data sets. This would all feed into the strategy and mapping that would sit behind the biodiversity net gain policy. There had also been involvement in a project initiated by the local wildlife trust on local wildlife sites review and this would hopefully continue on an annual basis.

Action: that a Biodiversity net gain recommendation be included in the review and that progress in this area be fed back to the Committee.

- The service manager stated that monitoring of manure management plans wasn't fully in place at the moment, but stressed that there would be an onus for local authorities to pick up monitoring as part of the Environment Act.

The Committee made closing comments with a view to proposing a number of recommendations for the review.

The Committee suggested that there was a need for a climate and ecological emergency champion drawn from within the council membership. The individual could liaise with members and officers and look at what other parts of the country were doing to resolve problems similar to those faced by Herefordshire.

The Committee noted that the Task & Finish Group had found it difficult, when dealing with planners, to convey the urgency of having a checklist for planning applicants, particularly one that drew their attention to the requirements the Committee wanted them to follow in relation to environment and ecology planning developments.

It was resolved that:

3) The Environment and Sustainability Scrutiny Committee note the update provided in Appendix 1 which provides an update on the actions following the executive response to the Climate and Ecological Emergency Task & Finish Group and
4) The following recommendations should be considered by the Executive for inclusion:

    (a) That the ESSC would like to see included on the service delivery dashboard for planning, a performance measure encompassing a timeline for the creation of a local planning list, including environmental and ecology compliance checklists at the prevalidation stage of the planning application.
    (b) A climate and ecological emergency ‘champion’ is appointed to look at what practices other local authorities are leading on with a view to informing and influencing the work of Herefordshire Council.

39. PROGRESS REPORT JANUARY 2023

The Committee took reports on the local plan for Herefordshire and local flood risk management strategy action plan as read. A discussion took place in relation to water course consent forms and the flood risk management action plan, an addition to the existing findings was proposed and approved

It was resolved that:

1) The scrutiny report on the Local Plan; a review of the development of a new Local Plan for Herefordshire, at Appendix 1, is approved by the Environment and Sustainability Scrutiny Committee for submission to Cabinet for consideration.

2) That the Environment and Sustainability Scrutiny Committee’s findings at Appendix 2 in relation to the Local Flood Risk Management Strategy Action Plan be approved and submitted to Cabinet for consideration.

(a) The following finding be added to Appendix 2 of the Local Flood Risk Management Strategy Action Plan:

“*Herefordshire Council reviews the water course consent form and involves the ecology team and looks at the connections and linkages between the flood risk management and the nature strategy and the Habitats Regulation Assessment (HRA).”*

40. WORK PROGRAMME

The Committee gave consideration to its Work Programme as set out on pages 83-90 of the agenda.

In respect of a potential item on greenways, assurances given to the Chair by Cllr John Harrington in relation to consultation with small business' on this matter, prompted the Committee to place the item on the reserve list.

The Committee felt that a proposed item on farming was too broad and generic and following discussion on the subject the Committee opted to instead focus on the supplementary planning document (SPD) on agriculture.

The Committee also planned to include the Commission on the River Wye as an item in its next meeting.

It was resolved that: The committee work programme be noted.

41. DATE OF THE NEXT MEETING

The Committee noted its next meeting date as 10 March 2023.

The meeting ended at 13:22 **Chairperson**

Herefordshire Council

Title of report: River water pollution

Meeting: Environment and Sustainability Scrutiny Committee

Meeting date: Monday 25 September 2023

Report by: Head of environment, climate emergency and waste services

Classification

Open

Decision type

This is not an executive decision

Wards affected

(All Wards);

Purpose

This report presents information for the committee to consider regarding the factors contributing to the pollution of rivers and watercourses, the roles and responsibilities of lead agencies and a summary of the council's duties and powers to support the lead agencies to address river pollution.

Recommendation(s)

That:

a) **The committee notes the Council's progress and leadership to date, and**

b) **The committee determines any other actions or recommendations it may seek to make.**

Alternative options

1. None identified, this report provides an update to the Environment and Sustainability Scrutiny Committee.

Key considerations

2. The rivers Wye ("the Wye") and Lugg ("the Lugg") are considered important in terms of nature conservation due to their aquatic habitats and species. Both contain Special Areas of Conservation ("SACs") and both are Sites of Special Scientific Interest ("SSSIs"). A map showing the Rive Wye SAC and sub-catchment is included as Appendix 2.

3. Phosphate ("P") limits are being exceeded at 31 points in the river catchment. This has arisen from both point-source P releases from Waste Water Treatment Works ("WWtW") and diffuse pollution from agricultural practices.

Further information on the subject of this report is available from
Ben Boswell, Tel: 01432 261930, email: bboswell@herefordshire.gov.ukl

4. Natural England are the lead conservation body and they categorise the condition of SSSIs as one of the following:

   a) favourable - habitats and features are in a healthy state and are being conserved by appropriate management

   b) unfavourable (recovering condition) - if current management measures are sustained the site will recover over time

   c) unfavourable (no change) or unfavourable (declining condition) - special features are not being conserved or are being lost, so without appropriate management the site will never reach a favourable or recovering condition

   d) part destroyed or destroyed - there has been fundamental damage, where special features have been permanently lost and favourable condition cannot be achieved

5. In May 2023, Natural England downgraded the condition status of the Wye from unfavourable recovering to unfavourable declining meaning that they must now take further steps and measures to bring about the favourable conservation status of the river. The Natural England assessment of the River Wye and Lugg SAC SSSI is included as Appendix 5.

6. Welsh Water publish specific source apportionment of phosphorous. They are able to do this fairly accurately by calculating total phosphorous in the river system and subtracting that entering from their own plants, hypothecating how much comes from other sources leaving the remainder to agriculture.

7. At present, the source apportionment data released by Welsh Water (DCWW) (Appendix 4) shows effluent from sewage treatment works accounts for 23% of the average daily P loading (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

<u>Lancaster University - Re-focusing Phosphorus use in the Wye Catchment</u>

8. In May 2022 Lancaster University published a ‘Re-focusing Phosphorus use in the Wye Catchment’ (RePhokus) report (Appendix 1) which provided catchment stakeholders with a better evidence base for driving policy and administrative change that is required to improve the ecological functioning of the River Wye and its provision of ecosystem services.

9. The RePhokus is an independent academic project which drew on available data to estimate the quantity of phosphorous entering the catchment from each source, how it moves through the catchment, how some is retained in the soil and how some enters the river.

10. In March 2023 Lancaster University published a further report ‘Soil Phosphorus Status and Water Quality in the River Wye Phase 2: Land Use Change and Phosphorus Balances in the Wye Catchment’ (Appendix 3). This report further developed the evidence base linking livestock farming to phosphorus (P) surpluses, soil P status and water quality impacts in the Wye catchment, and a better understanding of the potential impact on P surpluses and water quality of future land use change.

<u>Duties and powers</u>

11. The Environment Agency is the regulatory body responsible for water quality. They have a duty to cooperate with Natural England to take steps and measures to prevent the further deterioration of the river. This responsibility includes monitoring pollution/phosphate levels and managing diffuse pollution through the regulation and enforcement of both ‘farming rules for water’ and ‘Storing silage, slurry and agricultural fuel oil’.

12. In 2014 when high levels of phosphates were first identified within the River Lugg watercourse, it was agreed by Natural England and the Environment Agency that the implementation of new measures were necessary in order to bring the river back into compliance; this led to the development of the Nutrient Management Plan (NMP). The evidence base supporting the plan provided an analysis of local data and concluded that the source apportionment of phosphate within the River Lugg catchment area was roughly equal between point sources (sewage treatment works) and diffuse pollution (livestock and arable agriculture). The NMP therefore set out a series of measures in order to target pollution from both sources.

13. Water company reduction targets are determined by agreement between DCWW, the Environment Agency and Ofwat. They are reported to the Nutrient Management Board (NMB) but the Board has no formal role in this technical process. Ofwat are the "economic regulator" protecting the interest of customers who pay for water, whilst the Environment Agency focus on water quality.

14. DCWW has committed to cleaning up rivers and it is hoped that water treatment plants on the Wye which are causing the greatest ecological damage will be prioritised for investment. However, DCWW say that they are approaching the technical limits of what can be achieved on the Wye, that further upgrades would be costly compared to benefit and would carry high carbon costs. They further advise that they are already meeting their "fair share" obligations and that it would be unfair to ask their customers to pay to go beyond their fair share.

15. DCWW are currently delivering identified improvements through their Asset Management Plan (AMP) AMP7 programme (2020-25) and are finalising the next AMP8 programme (2025-2030.)

16. Herefordshire Council, as the local planning authority, have a role as the 'competent authority' to assess projects and plans under the Conservation of Habitats and Species Regulations 2010 (as amended) ("the Habitat Regulations").

    a) This means that the Council is legally required to assess the potential impact of projects and plans, on European Sites including the River Lugg catchment area as part of the River Wye SAC through a screening opinion carried out by the competent authority.

    b) Where likely significant effects are identified a subsequent Habitat Regulation Assessment ("Appropriate Assessment") is legally required to be undertaken.

    c) In the instance of the addition of phosphate into the river as a result of the development, these effects are required to be mitigated and only if it is considered that the development will not, adversely affect the integrity of the European site, can permission be granted.

    d) As a result of the decision of the European Court of Justice ("the ECJ") in Cooperatie Mobilsation for the Environment UA v College van gedeputeerde staten van Limburg (C-293/17), NE has stated that the current Nutrient Management Plan (NMP) could no longer be relied upon to provide the certainty to bring the river back into compliance with relevant targets and that all future development within the Lugg catchment must demonstrate nutrient neutrality.

17. Under the General Power of Competence, a power introduced by section 1(1) of the Localism Act 2011 the Council is permitted to do anything an individual can do, unless prohibited by law (and subject to public law principles).

18. Herefordshire Council commissioning and decision making.

    a. Through the Council's governance process all decisions are required to consider the environmental impact. For example as part of the Waste Disposal contract extension and variation phosphate pollution was considered and a contract requirement was included to ensure any digestate from the Anaerobic Digestion of local municipal food waste is not permitted to be used anywhere within the River Wye catchment area.

Identify key partners and their roles and responsibilities

19. The current membership of the Nutrient Management Board is shown in the below table, however the Environment Agency is currently leading a governance review of the board.

Nutrient Management Board		
Partner		Roles and Responsibilities
Original membership	Herefordshire Council (Chair)	Local Planning Authority – Herefordshire Chair of NMB
	Natural England	Lead conservation body
	Environment Agency	Regulatory body for water quality (England)
	Natural Resources Wales	Regulatory body for water quality (Wales)
	Welsh Water DCWW	Utilities – water
	Powys County Council	Local Planning Authority – Powys
	Countryside Land Association	
	National Farmers Union	
	Catchment Partnership	
	Chair of the Stakeholder group	
Co-opted	Farm Herefordshire	
	Hfds Building Lobby Group	
	Hfds Wildlife Group	
	Wye Salmon Association	
Invited	Monmouthshire County Council	Local Planning Authority – Monmouthshire
	Forest of Dean District Council	Local Planning Authority – Forest of Dean
	Bannau Brycheiniog (Brecon Beacons)	National Park Authority

Herefordshire Council - Strategic Investment in Phosphate Mitigation

20. Herefordshire Council has chosen to voluntarily exercise its General Power of Competence to build constructed integrated wetlands in the Lugg Catchment to provide development headroom and some improvement called “river betterment” to provide phosphate credits to developers in the catchment who are unable to otherwise demonstrate nutrient certainty.

21. The Luston wetland site is a world first and is currently trading credits, enabling nutrient neutral development in the River Lugg catchment area.

22. Herefordshire Council commissioned Ricardo consultants to undertake a study of preferred mitigation options for private schemes to enable developers to mitigate the nutrient budget of

their development. The Council has also developed further publicly available guidance on its webpages and is developing a mechanism to provide a pre-planning advisory service for HRA.

23. Herefordshire Council developed the UK's first development Phosphate Calculator which has subsequently been adapted and is used nationally by Natural England.

24. In May 2023 Herefordshire developed and submitted a £2.1m Expression of Interest to Department for Levelling Up, Housing and Communities (DLUHC) and the Department for Environment, Food and Rural Affairs (DEFRA) to the Local Nutrient Mitigation Fund to develop further phosphate mitigation projects including:

    a. Further investment in integrated wetlands

    b. A new pilot scheme to provide grants to support riparian buffer strips

    c. A new pilot scheme to replace antiquated sceptics tanks with modern and efficient Package Treatment Plants

    d. Developing a new pre-application service to support private schemes brought forward by developers

25. The Council has been a driver for supporting improvement around the Nutrient Management Board and has invested in a significant national influencing role to progress river restoration.

Cabinet Commission – Restoring the River Wye'

26. The Council has actively lobbied government for a Water Protection Zone (WPZ) and, following a Full Council resolution on 22 Jan 2022, the Leader of the Council formally wrote to Rebecca Pow MP, Parliamentary Under Secretary of State for DEFRA seeking a WPZ for the River Wye and Lugg Catchment. This request was rejected.

    a. https://www.herefordshire.gov.uk/downloads/file/23397/water-protection-zone-riverwye-and-lugg-catchment-letter-to-r-pow-feb-2022

27. As a result, a Cabinet Commission has been established to consider how the council can use its powers to progress the restoration of the Wye and Lugg and to identify an acceptable way forward.

28. On 29 September 2022 Cabinet agreed the Terms of Reference (Appendix 1) and Membership for the 'Cabinet Commission – Restoring the River Wye'.

29. The terms of reference were developed in consultation with Powys County Council (PCC), Monmouthshire County Council (MCC), Forest of Dean District Council (FoDDC). Natural England (NE), Environment Agency (EA) and Natural Resource Wales (NRW) also provided comments.

30. The Commission reconvened informally on the 7th September 2023.This was the first informal meeting of the Commission since the May 23 Election. Cllr Swinglehurst being the new Member for Herefordshire and Cllr Fraser the new member for Forest of Dean. The Commissioners noted the following changes since March and the Herefordshire Cabinet report:

    a. The Ministerial Roundtable in May

    b. The Agency Review of Governance of NMB

    c. The Commitment to a Secretary of State led plan for the Wye

    d. The decision not to agree a cross border task force

e. Further progress on the Welsh national action plan

f. Further progress on securing governance of Welsh NMBs

g. The Levelling Up Bill in England

h. The review of permits in Wales

31. Commissioners considered how best they could support these processes and narrow down to fill in any remaining gaps. Now that there is a national commitment to a plan for the Wye, no further purpose would be served by pressing on with the Commission's own plan for the river. Rather the desire was to ensure the wider plans were resourced, deliverable, likely to be effective and could command public acceptance.

32. The remaining gaps fell in the arena of "place based scrutiny of public services" ensuring the plan is a good one and political articulation of the expectations of Councils on behalf of their residents particular on resourcing and securing action. Commissioners saw making representation /acting as a conduit from the local frontline to government, where necessary as a key role for them. The structure linking through to Welsh Government (WG) make this possibly easier in Wales, but could also be useful in addressing any cross-border complexities, as well as filling real or perceived gaps on the English side.

33. Depending on how the NMB governance discussion falls joint public scrutiny activity could usefully take place within NMB. However, if the new NMB governance arrangements did not give adequate room for the role of elected members in undertaking scrutiny then consideration would be given to establishing a joint Wye Catchment Scrutiny Committee of all the Councils. In which case, officers from the three Councils would then prepare a short options paper for the Commission to consider.

34. Commissioners discussed extending an invitation to Bannau Brycheiniog (Brecon Beacons National Park Authority) to join the Commission as a fifth LPA and Commissioners wished to do this.

House building

35. The latest RePhokus report (2023) shows an excess of 1,700,000kg of Phosphate entering the Wye Catchment each year. We now know just 800kg of mitigation is needed to meet our entire Local Plan Housing need of 4,400homes. With 450kg of offset already in train, the gap to fill is just 350kg of offset.

36. We all want to be assured of high environmental standards, however, this means the maximum potential impact, without further mitigation, is less than 0.023% of excess Phosphate entering the catchment each year.

The Impact of Intensive Poultry Farming

37. There has been widespread media and public concern about the impact of intensive poultry units within the catchment.

38. The design and construction of new development must take into account important characteristics of the environment and conserve, preserve or otherwise respect them in a manner that maintains or enhances their contribution to the environment, including their wider context. New development should demonstrate an efficient use of resources. It should respect wider natural corridors and other natural areas, providing green infrastructure where necessary. (Landscape Policy LD1-4 Herefordshire Local Plan Core Strategy 2011-2031

39. In achieving the above, the following will be considered:

a. The effect of the proposal on the landscape including AONBs and any mitigation/ enhancement that is necessary or desirable

b. The impact on any protected sites (natural and historic sites and heritage assets and potential for avoiding and/ or mitigating any impacts, or providing enhancement, should the development be acceptable

c. The requirements of the management plans of the AONBs

d. Whether the existing infrastructure is adequate- additional provision will be required where it is not.

e. Whether the development is at risk from flooding, whether it can be permitted taking into account any risks, and the sequential approach and any mitigation that may be necessary to ensure the development is safe and flood risk is not increased elsewhere

f. The impact of the development on any land contamination or risk to the development from ground instability including the mining legacy- Proposals must undertake appropriate remediation measures and verification works where contamination and /or stability issues are identified

g. The potential for the development to cause pollution and any mitigation measures to avoid pollution or make environmental improvements where existing problems occur

h. The provision of water supply and the development's impact on groundwater, watercourses and any protected abstractions

i. Any potential impact on the sterilisation of mineral resources and consideration of the potential for the prior extraction of those mineral resources ahead of development

j. Proposals for waste minimisation and management

40. Development that is not able to be satisfactorily accommodated in respect of the above will not ordinarily be permitted Herefordshire takes its responsibility to the environment seriously and we also value our rural economy. Therefore, any proposals that might result in the intensification of farming activity must demonstrate full nutrient neutrality. Since the nutrient neutrality requirements came into force in 2019, Herefordshire has not approved any new expansion of intensive poultry units in the county, other than the replacement of existing units which have reached the end of life. Any new proposal, which resulted in further intensification, are highly unlikely to be approved until the river returns to health, unless it can demonstrate nutrient neutrality. The Council considers these types of applications in line with the Conservation of Habitats and Species Regulations 2017 (as amended) which set out a very clear mechanism for considering the effects of development.

41. Our catchments leaky soils are in poor health and organic matter is a key way of improving them. Herefordshire Council is working with our statutory partners and the supply chain to find ways to remove phosphate entering the environment from poultry manure; however these have to be the right solutions in the right locations.

42. Given both these factors, the key task is to improve the management of phosphate within the supply chain to prevent it entering the river.

43. The recent proposed amendments to the Levelling Up Bill to negate the need for Nutrient Neutral development were defeated in the House of Lords and the need for phosphate mitigation still stands.

Community impact

10. The work to progress the restoration of the River Wye and River Lugg will positively contribute to the following ambitions within the County Plan 2020-2024.

    a. Protect and enhance the county's biodiversity, value nature and uphold environmental standards through "River Betterment."

    b. Seek strong stewardship of the county's natural resources.

    c. Invest in low carbon projects

    d. Support an economy which builds on the county's strengths and resources

    e. Develop environmentally sound infrastructure that attracts investment

    f. Spend public money in the local economy wherever possible

11. Farming, agriculture, home building and tourist industries as well as resident access to countryside leisure amenity are all essential to the vibrancy and life of rural communities. The restoration of both the River Wye Catchment will enable help assure the vibrancy and future prosperity of all our communities.

Environmental Impact

12. The River Wye and River Lugg are considered important in terms of nature conservation, as a consequence both rivers are designated as Sites of Special Scientific Interest (SSSI). In addition the lower stretch of the River Lugg; from Hope under Dinmore, along with the River Wye are also designated as a Special Area of Conservation ("SAC") under the European Community Habitats Directive (Council Directive 92/43/EEC).

13. The special features for which the River Wye is designated include a range of aquatic habitats and species. Improving the water quality will support the council's commitment to address the climate and ecological emergency through the protection and enhancement of these, and other important wildlife habitats.

14. The Integrated Wetlands project has been designed to enable Nutrient Neutral Development in the River Lugg SAC by enabling nutrient neutral development and to provide a net river betterment. The net improvement to the river quality will be delivered through the reservation of 20% of the phosphate credits for the river betterment.

15. In addition to improving water quality in the River Lugg, the wetlands will also support the Council's commitment to address the climate and ecological emergency as the wetlands will also become excellent wildlife habitats and will help to sequester local carbon emissions.

Equality duty

16. Under section 149 of the Equality Act 2010, the 'general duty' on public authorities is set out as follows:

    A public authority must, in the exercise of its functions, have due regard to the need to –

    a) eliminate discrimination, harassment, victimisation and any other conduct that is prohibited by or under this Act;

    b) advance equality of opportunity between persons who share a relevant protected characteristic and persons who do not share it;

c) foster good relations between persons who share a relevant protected characteristic and persons who do not share it.

17. The public sector equality duty (specific duty) requires us to consider how we can positively contribute to the advancement of equality and good relations, and demonstrate that we are paying 'due regard' in our decision making in the design of policies and in the delivery of services.

18. As a committee report this will not have an impact on our equality duty.

Resource implications

19. There are no resource implications associated with providing this progress update to the Environment and Sustainability Scrutiny Committee.

Legal implications

20. The legal framework around nutrient neutrality is set out in other parts of this report. It is within the remit of the Environment and Sustainability committee to consider stewardship of natural resources, green spaces, integrated wetlands & water quality.

Risk management

21. There are no risks associated with providing a progress update to the Environment and Sustainability Scrutiny Committee

Consultees

- None

Appendices

- Appendix 1 - Re-focusing Phosphorus use in the Wye Catchment (RePhOKUs) May 2022
- Appendix 2 - Map of the River Wye Special Area of Conservation (SAC)
- Appendix 3 - Soil Phosphorus Status and Water Quality in the River Wye, Phase 2: Land Use Change and Phosphorus Balances in the Wye Catchment (RePhOKUs) March 2023
- Appendix 4 - DCWW Source Apportionment Modelling issued February 2023 SAC Rivers:
  - https://corporate.dwrcymru.com/en/community/environment/river-water-quality/sac-rivers
- Appendix 5 - River Wye and Lugg SAC SSSI assessment of indicative site condition using CSMG - Natural England May 2023

Background papers

- River Wye SAC Nutrient Management Plan Phosphate Action Plan November 2021
  - https://www.herefordshire.gov.uk/downloads/file/23069/river-wye-sac-nutrient-management-plan-phosphate-action-plan-november-2021
- Cabinet Commission Prospectus for our River Restoration – Cabinet Report 03/03/23

- https://councillors.herefordshire.gov.uk/documents/s50108618/Cabinet%20Commission%20Prospectus%20for%20our%20River%20Restoration.pdf

- Cabinet Commission - Restoring the Wye – Cabinet Report 29/09/22
  - https://councillors.herefordshire.gov.uk/documents/s50103959/Cabinet%20Commission-%20Restoring%20the%20Wye.pdf
- Nutrient Certainty - Luston Integrated Wetland – Cabinet Report 28/07/22
  - https://councillors.herefordshire.gov.uk/documents/s50102764/Nutrient%20Certainty%20-%20Luston%20Integrated%20Wetland.pdf
- Nutrient Certainty – Cabinet Report 26/05/22
  - https://councillors.herefordshire.gov.uk/documents/s50100959/Nutrient%20Certainty.pdf
- Phosphate Credit Pricing and Allocation Policy Cabinet Report 26/05/22
  - https://councillors.herefordshire.gov.uk/documents/s50100960/Phosphate%20Credit%20Pricing%20and%20Allocation%20Policy.pdf
- The construction and management of Integrated Wetlands as tertiary treatments for waste water treatment works to reduce phosphate levels within the River Lugg catchment area – Cabinet Member Report 10/08/20
  - https://councillors.herefordshire.gov.uk/documents/s50081736/The%20construction%20and%20management%20of%20Integrated%20Wetlands%20as%20tertiary%20treatments%20for%20waste%20water%20treatm.pdf

Report Reviewers Used for appraising this report:

Please note this section must be completed before the report can be published		
Governance	John Coleman	Date 15/09/2023
Finance	Click or tap here to enter text.	Date Click or tap to enter a date.
Legal	Sean O'Connor	Date 13/09/2023
Communications	Mark Batchelor	Date 13/09/2023
Equality Duty	Click or tap here to enter text.	Date Click or tap to enter a date.
Procurement	Lee Robertson Date 14/09/2023	
Risk	Kevin Lloyd	Date 14/09/2023

Approved by	Mark Averill, Service Director Environment and Highways	Date 15/09/2023

Please include a glossary of terms, abbreviations and acronyms used in this report.

Re-focusing Phosphorus use in the Wye Catchment

RePhOKUs

Paul J. A. Withers, Shane A. Rothwell, Kirsty J. Forber and Christopher Lyon

May 2022

Re-focusing Phosphorus use in the Wye Catchment

RePhoKUs

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May 2022

Contents

1. Overview

This report presents the results of research work on elemental phosphorus (P) inputs and outputs in the Wye catchment, links to river water quality and stakeholder responses to the challenges of maintaining future food and water security in the region. This work was carried out as part of the RePhoKUs project which investigated how P use in the UK food system could become more efficient, sustainable and resilient at catchment, regional and national scales (Section 2). Although an essential nutrient for crop and animal production, rock phosphate is a finite resource which should not be wasted, and leakage of food system P into water is causing widespread damage to the quality and biodiversity of inland and coastal waters in the UK and globally.

The Wye catchment is one of three study catchments within the RePhoKUs project examining how P is used and the drivers of P efficiency, surplus and loss at the catchment scale, local vulnerability to market failures in P supply and the consequences for catchment water quality. The River Wye is a nationally important river with ongoing river P pollution that is compromising the natural capital, provision of ecosystem services and economic development of the region (see Section 2). Previous government and industry research (1994-2008) has shown the Wye landscape has a high risk of P loss in land runoff due to the nature of the soils and topography, the patterns of farming and the local climate. However, a better understanding of the cycling of P in the wider food system in the Wye catchment is needed to drive the potential system change that is required to meet the river's water quality targets for eutrophication control.

RePhoKUs has built on this previous work by (a) providing a better understanding of the annual P input pressure exerted on the Wye catchment and the fate this P pressure within the food system using a well-established Substance Flow Analysis (SFA) methodology (Section 3), (b) investigating the links between P input pressure and river P concentrations and fluxes at different scales (Section 4), (c) analysing the distribution of soil P fertility levels in the Wye catchment and how long they can sustain crop yields in the absence of P inputs (section 5) and (d) assessing stakeholder adaptive capacity to enact system change. In the final section (Section 7), the collective findings and recommendations from the RePhoKUs work are discussed in the context of our current understanding of strategies for sustainable P management in the catchment.

The aim of the report is to provide catchment stakeholders with a better evidence base for driving policy and administrative change that is required to improve the ecological functioning of the River Wye and its provision of ecosystem services.

Note on Terminology
RePhoKUs research uses elemental P (not phosphate P) for all food system stores and flows, and recognises three forms of river P concentrations: soluble reactive P (SRP), total dissolved P (TDP) and total P (TP). Regulatory agencies set river P concentrations as orthophosphate P and refer to phosphate-P. Elemental P is synonymous with TP, and SRP is considered synonymous with orthophosphate-P.

Photo courtesy of Shane Rothwell

2. The RePhoKUs Project: Re-Focusing Phosphorus Use within the UK Food System

RePhoKUs project team

PROJECT AIM:

The aim of RePhoKUs is to enhance the resilience and sustainability of the UK food system by developing and prioritising adaptive strategies that reduce the vulnerability of UK farming to future P scarcity at multiple scales, and that enhance the balanced delivery of multiple ecosystem systems for future food and water security.

WHY:

There is an important gap in knowledge as to the current state of P use within UK agriculture, the wider food system, its impact on the natural environment and vulnerability to a future disruption in P supply. The UK has no known deposits of rock phosphate (RP) and so is completely dependent on imports of manufactured inorganic P from other countries (including Russia) to support food production. The recent sharp rise in the cost of fertilisers and livestock feeds and the war in Ukraine has exposed this UK vulnerability. In addition, eutrophication caused by food system P leaking into our waterbodies is very costly to society and devalues many ecosystem services linked to water quality including, biodiversity, recreation and quantity for drinking. Therefore, improving the efficiency and sustainability of P use in food systems contributes to two objectives simultaneously – (1) increasing resilience to sudden or extreme changes in the global supply and price of P, and, (2) reducing water pollution caused by a build-up and poor management of P in the landscape beyond what is needed for immediate food production and the subsequent negative impacts on the natural environment.

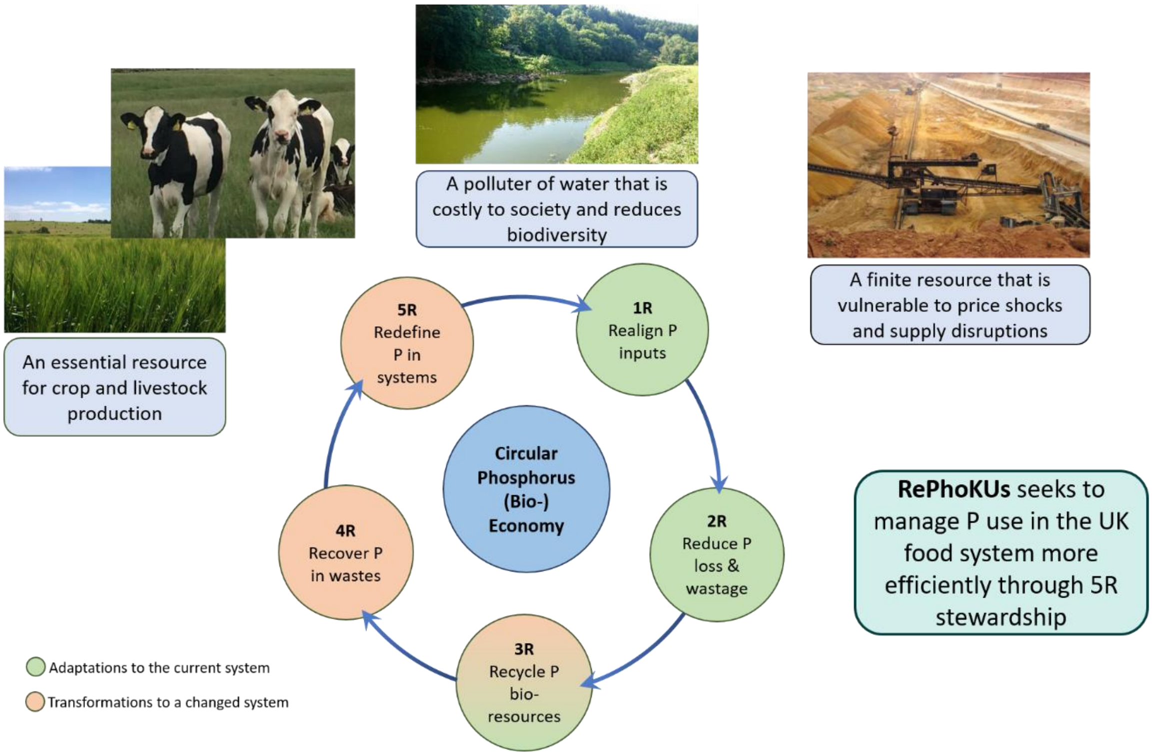
WHAT:

The RePhoKUs project combines different biophysical, social and economic approaches to examine the synergies and conflicts arising from how P is currently distributed within the food system to stimulate discussion and provide evidence for potential policy approaches to more sustainable P use, such as 5R P stewardship (Withers et al., 2015). The project involves an extensive stakeholder engagement process at farm, catchment and national scale.

Key outputs from the project include (1) a national strategy to reduce the vulnerability of the food system to shocks and stress due to P supply disruptions or price fluctuations. (2) a roadmap of the use and cycling of P in the UK food system and the regional imbalance between P demand and supply, (3) assessment of catchments for their vulnerability to P loss to water and options for more sustainable P management, (4) the residual agronomic value of soil legacy soil P reserves and how long they might last without affecting crop production, (5) stakeholder responses to the need and capacity for change at national, regional and catchment scales.

WHO:

The project is a collaboration between Lancaster University; Agri-Food and Biosciences Institute, Belfast;, University of Leeds; University of Technology, Sydney; and the UK Centre for Ecology and Hydrology and is funded by the Global Food Security's 'Resilience of the UK Food System Programme' with the UK's Biotechnology and Biological Science Re- search Council (BBSRC), the Economic and Social Research Council (ESRC), the Natural Environment Research Council (NERC) and the Scottish Government. More information at: [http://wp.lancs.ac.uk/rephokus/.](http://wp.lancs.ac.uk/rephokus/)



Partners

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E·S·R·C Economic & Social Research Council

NERC Science of the Environment

3. The Wye Catchment

3.1 Introduction

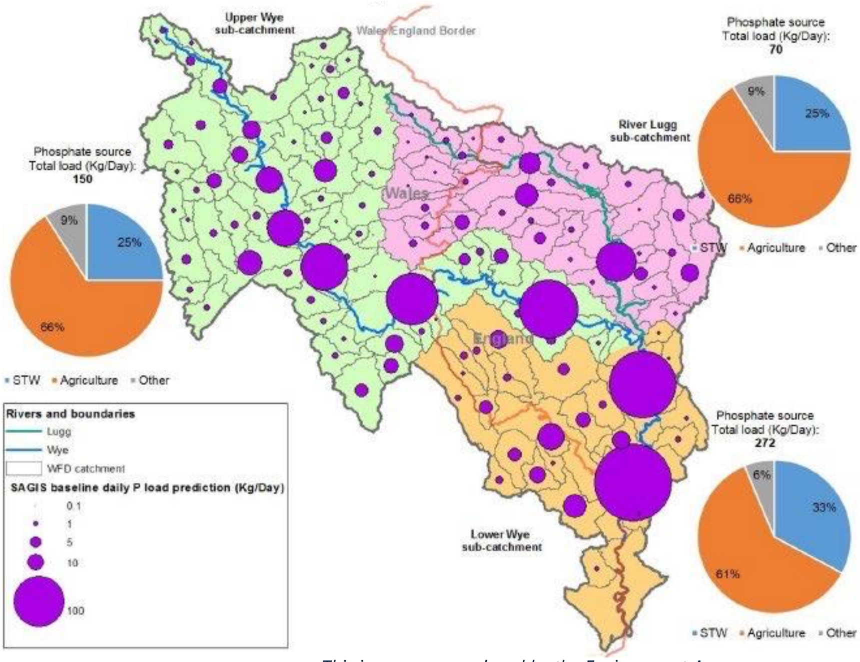
The River Wye is a nationally important UK river; it rises in the Plynlimon mountains in Wales and flows ca. 215 km in a broadly south-easterly direction to the Severn Estuary in England. Mean annual rainfall varies from 2450 mm in the upland north-west to 717mm in the lowland east. The River Wye and its main tributary the River Lugg is a Site of Special Scientific Interest (SSSI) and Special Area of Conservation (SAC) with a nationally significant rod fishery and a thriving regional tourist industry. The catchment (4017 km^2) includes 47 waterbodies all with high recreational value.

Agriculture is the major land use with pastoral farming (sheep and beef) in the uplands, and more intensive arable/mixed farming (cereals, potatoes, hops, soft fruit, dairy, and poultry) on the fertile and highly productive soils in the lowlands. Poultry farming, in particular, has expanded rapidly in the region in recent years along with important cash crops such as maize and potatoes. A mixed geology gives rise to sandy and very silty soils which are prone to erosion. Heavier silty soils are widely underdrained.

3.2 Water Quality

Sections of the main river and its tributaries are failing to achieve the statuatory eutrophication control targets for good or high ecological status due to P pollution (Natural Resources Wales, Environment Agency and Natural England, 2021). Comparison of mean annual orthophosphate concentrations (rolling three year average) against current targets of 0.03-0.05 mg L^{-1} shows phosphate (note not total P) limits are already being exceeded at 31 points in the river catchment, with further failures likely in the future.

Multiple sources of P including sewage effluent discharges from wastewater treatment centres and rural septic tank systems, light industrial discharges, and surface and sub-surface runoff from agricultural land, farmyards and urban areas all contribute to the phosphate loading to the rivers. With advanced P-stripping now implemented at the wastewater treatment centres serving major population centres, source apportionment modelling suggests that 60-70% of the total phosphate load now comes from agriculture (Figure 1).



This image was produced by the Environment Agency

Figure 1 Distribution of phosphate-P loads to the Upper Wye, Lugg and Lower Wye operational sub-catchments and their apportionment from wastewater, agriculture and other sources as modelled by the regulatory agencies (taken from Nautral Resources Wales, Envrionment Agency and Natural England report "*River Wye SAC Nutrient Management Plan Phosphate Action Plan*" 2021) .

3.3 Need for Action

Although the Wye is a Catchment Sensitive Farming (CSF) high priority catchment and has had high levels of investment over the last 14 years to encourage farmers to voluntarily adopt management practices to mitigate diffuse transfer of pollutants from agricultural land, the river water quality remains poor and appears to getting worse. In 2020, a thick algal bloom extended for over 140 miles of the river (Figure 2).

Following a recent Dutch case law ruling, local county councils have placed restrictions on all planning applications that will lead to an increase in P loading to sensitive sections of the river and have recommended designation as a statuatory Water Protection Zone.

Political tensions in the catchment are consequently high due to conflicting stakeholder priorities, and different administrations spanning the Wales-England border are responsible for policy development, regulation and advice. Stakeholder activity is coordinated through the Wye Catchment Partnership supported by the local rivers trust (Wye and Usk Foundation) along with additional citizen science monitoring projects.

A Phosphate Action Plan has been prepared to restore the ecological functioning of the River Wye by reducing river phosphate concentrations to below set limits (Natural Resources Wales, Environment Agency and Natural England, 2021). A strong evidence base is needed to support this strategic mitigation plan.

Figure 2: Algal bloom on the lower Wye in June 2020.

3.4 Key Messages:

- The River Wye is a **nationally important river** with a variety of important habitats of high scientific and conservation value and supporting recreational value for a thriving tourist industry.
- **Highly fertile productive soils** support a wide range of intensively farmed crops and livestock, with recent rapid expansion of the poultry industry, maize and potatoes.
- **Water quality in many areas of the catchment continues to fail** current eutrophication control standards due to high phosphate concentrations in the rivers.
- **A strong evidence base is needed to drive a catchment Phosphate Action Plan**.

4. Phosphorus Substance Flow Analyses for the Wye Catchment

A Substance Flow Analysis (SFA) was undertaken to quantify the stocks and flows of elemental P within the Wye catchment. The SFA maps all significant materials associated with different sectors of the food system and that are entering, leaving or circulating within the catchment, and is a useful mass balance model for identifying significant inefficiencies, losses and accumulations of P in the landscape. The SFA uses publicly available regional and national statistics, industry data, previous scientific studies and local expert opinion. Further details of the SFA methodology are given in Rothwell et al. (2020, 2022).

For the Wye catchment, the model used established coefficients for crop yields and agricultural P offtake (AHDB, 2022), livestock P excretion coefficients from Defra (pers. comm.) and human P use coefficients from Rothwell et al. (2022). Regional fertiliser application rates were taken from the British Survey of Fertiliser Practice (Defra, 2019) and crop areas in the catchment were determined from UKCEH land cover data (Rowland et al. 2017; 2020).

Cattle populations were taken from the Cattle Tracing System and Agricultural Survey geo-located population data (provided by the APHA under license, APHA, 2019), and sheep and pig populations were based on the last complete Defra detailed regional census in 2016 (both Defra Pers. Comm.). Poultry numbers were taken from local investigative work (https://cutcher.co.uk/linklog/2021/07/15/counting-chickens), and confirmed by expert opinion following discussion with the poultry industry. Losses to water from waste water treatment and agriculture were taken from the Separate model (Zhang et al., 2014). Quantities of P entering and leaving the waste management sector were not included due to lack of available catchment data. All data are mass of elemental P in tonnes per annum (t yr^{-1}).

4.1 Substance Flow Analysis Findings

The model output (Figure 3) shows that the Wye catchment imports a total of ca. 6500 t yr^{-1} of P and exports ca. 3100 t yr^{-1} giving an overall catchment P use efficiency of only 48%. The largest P import into the catchment is in livestock feed (ca. 5000 t P yr^{-1}) and the largest internal flow of P is in livestock manure (ca. 6100 t P yr^{-1}), signifying that the livestock sector dominates P use in the catchment. Fertiliser P imports are ca. 1150 t yr^{-1}.

Discussions with local stakeholders have identified that there are currently movements of poultry manure both into and out of the catchment, though these are difficult to quantify and for the purpose of this model are assumed to cancel each other out. Details of livestock sector P inputs, outputs and efficiencies are shown in Table 1.

Table 1: Details of estimated phosphorus flows and sector efficiency for different livestock types, all flow values are tonnes P per year.

	Cattle and sheep	Pigs	Poultry
Feed P	1017	119	4473
Grass P	2802	-	-
Manure P	3365	89	2579
Meat P*	325	30	1846
Milk P	122	-	-
Egg P	-	-	48
Efficiency %	16	25	42

*Liveweight

Annual soil P inputs in the catchment are ca. 7500 t P as manure (82%), fertiliser (15%) and biosolids (3%), and crop and grass P offtake is ca. 4200 t P giving a P uptake efficiency of 57% which is lower than the UK national average of 65%. The imbalance between agricultural P input (fertiliser, manure and biosolids) and offtake (grass and crops) means that around 3000 t of surplus P are accumulating in agricultural soils in the Wye catchment every year, a rate equivalent to 17 kg P ha^{-1}, which is considerably higher than the national average of 7 kg ha^{-1} (Rothwell et al., 2022).

The agricultural P surplus together with the net food P imports gives the total Net Anthropogenic P Input (NAPI) pressure on the catchment, amounting to 19 kg P ha^{-1} yr^{-1}. Losses to water were estimated as 83 t P yr^{-1} from wastewater treatment centres and 225 t yr^{-1} from agricultural land.

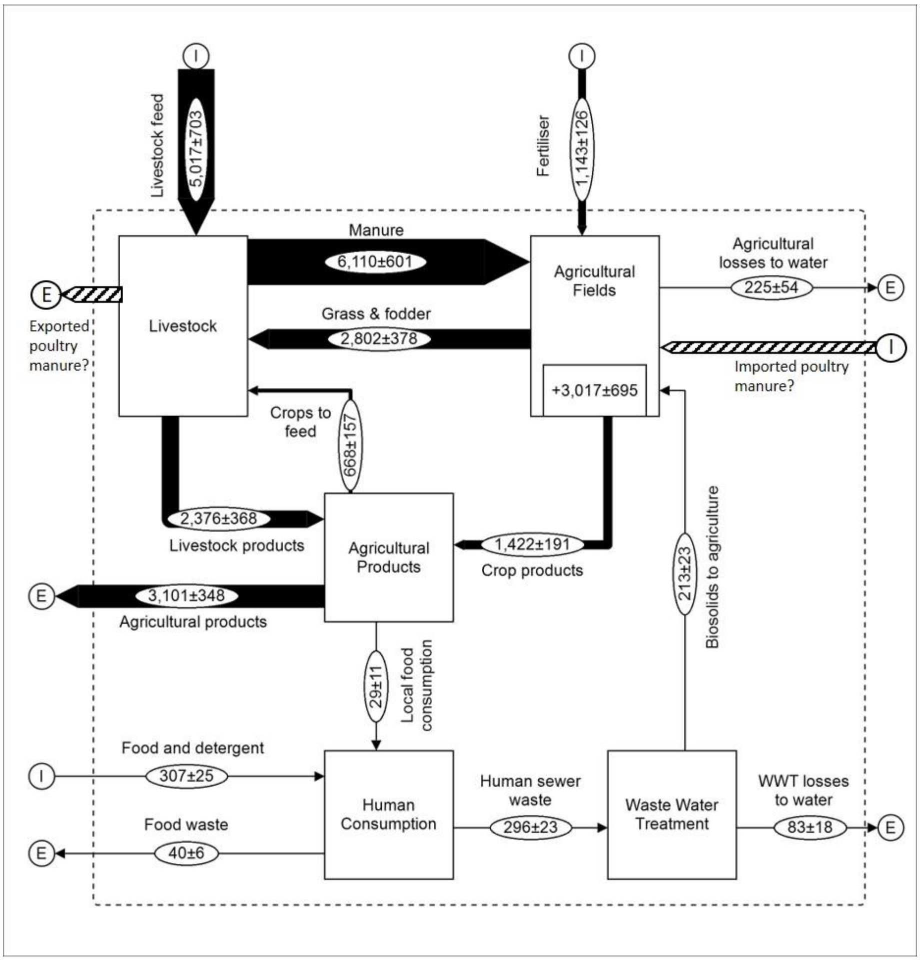


Figure 3: Phosphorus Substance Flow Analysis for the Wye catchment

4.2 Key Messages:

- The Wye catchment **imports a total of ca. 6500 t P yr^{-1}** as animal feed (78%), fertiliser (18%), food & detergents (5%).
- **Exports** of P from the Wye catchment in agricultural products are **ca. 3100 t P yr^{-1}**.
- **Soil P inputs** in the catchment are potentially **ca. 7500 t P yr^{-1}** as manure (82%), fertiliser (15%) and biosolids (3%).
- **Crop and Grass P offtake was ca. 4200 t P yr^{-1}**.
- When agricultural losses to water are accounted for, agricultural **soil surplus accumulation is therefore ca. 3000 t P yr^{-1} or 17 kg ha^{-1} yr^{-1}** over managed agricultural land (excluding rough grazing).

5. Linking Phosphorus Surplus to Water Quality Impacts

A full analysis of river P concentrations and loads at existing routine water quality monitoring sites in the Wye catchment was outside the scope of the RePhoKUs study, but such data was generally difficult to access. A previous analysis of Environment Agency (EA) gauged sites by Jarvie et al. (2003) covering the six-year period from 1995-2000 found river annual total P (TP) loads ranging from <0.05 – 0.93 kg ha^{-1}, with 29-72% (mean 50%) in orthophosphate form. Highest P loads and flow-weighted concentrations were in the Frome, Lugg and Monnow sub-catchments.

Some more recent, limited river P data was available but was not useable to investigate the link between catchment P input pressure and river total P (TP) concentrations and/or loads over time and in space due to a lack of data resolution and quality. Likewise, appropriate high resolution data for fertiliser and manure inputs, and crop yields were unavailable. Some historic higher resolution river P data was available from previous Defra research projects NT1027, PE0116 (PARIS) and PE0202 (PSYCHIC) spanning 1994-2008. These projects measured annual TP loads varying from 0.16-2.96 kg ha^{-1}, with 29-82% (mean 60%) in orthophosphate form, but it should be noted that these data do not reflect the current wastewater and farming sources operating in the Wye catchment.

5.1 Wider Regional and Catchment Analysis

The RePhoKUs project did investigate the relationship between P input pressure (NAPI) and river TP loads at both the regional scale and catchment scale as part of a wider analysis. NAPI is calculated as the sum of P applied as fertiliser, manure P, and P from humans (dietary, detergent, and plumbosolvency), minus the total amount of P harvested in crops and grass (Sobota et al., 2011). The same data sources for the SFA model were used to calculate the NAPI values. For the regional analysis, NAPI values were calculated for the year 2010 to match availability of latest river P load data from Harmonised Monitoring Scheme (provided by UKCEH). Total P load was estimated by summing the most downstream HMS monitoring points from each region and expressed as kg ha^{-1}.

The catchment analysis included data from 69 large catchments spanning the 1990s-2010s. Three consecutive years of NAPI data with corresponding high resolution river TP loads were calculated for each catchment, averaged to give single NAPI and river TP load values and expressed as kg ha^{-1}.

Regional scale*:* a highly significant positive relationship between NAPI and river TP loads indicates that as P pressure increases the impact on water quality is likely to increase (Figure 4). At this scale, both the agricultural P surplus and human P pressure, unless P stripping at wastewater treatment centres is widely used (South East is an outlier on Figure 4C due to prevelance of P removal technology at waste water treatment works), drive P losses to water.

Catchment scale: a significant positive relationship between NAPI and riverine TP load is also apparent ($P<0.05$), although there is clearly much greater variability. This difference can be attributed to (a) issues of data resolution required to calculate NAPI values accurately at smaller scales and (b) catchment characteristics other than the P input pressure influence river TP loads; for example reflecting P losses from the way P inputs or the land surface is managed leading to direct P loss during application or large erosion events.

5.2 Source Contributions

Relationships between concentration (C) and flow (Q) can be used as indicators of biological and hydrological functioning, and provide information on catchment nutrient sources and their delivery mechanisms. Historic research project catchments with high resolution flow and P concentration (SRP and TP) data were used to examine CQ relationships in the Wye catchment. The CQ relationship is log-transformed, and b is a unitless exponent respresenting the slope of the relationship (Moatar et al., 2017). The relationship can be analysed across all river flows, or can be split at the median flow to distinguish different behaviours at high (b50+) or low (b50-) flows. Chemodynamic concentration ($b>0.1$) or “up” patterns (Figure 5) are attributed to enhanced mobilisation of dissolved and particulate P during high flows, due to reconnection of pollution sources via surface or subsurface routes (Moatar et al, 2017). This pattern of P delivery is transport limited, since delivery to the stream is controlled by connection pathways rather than the abundance of a source.

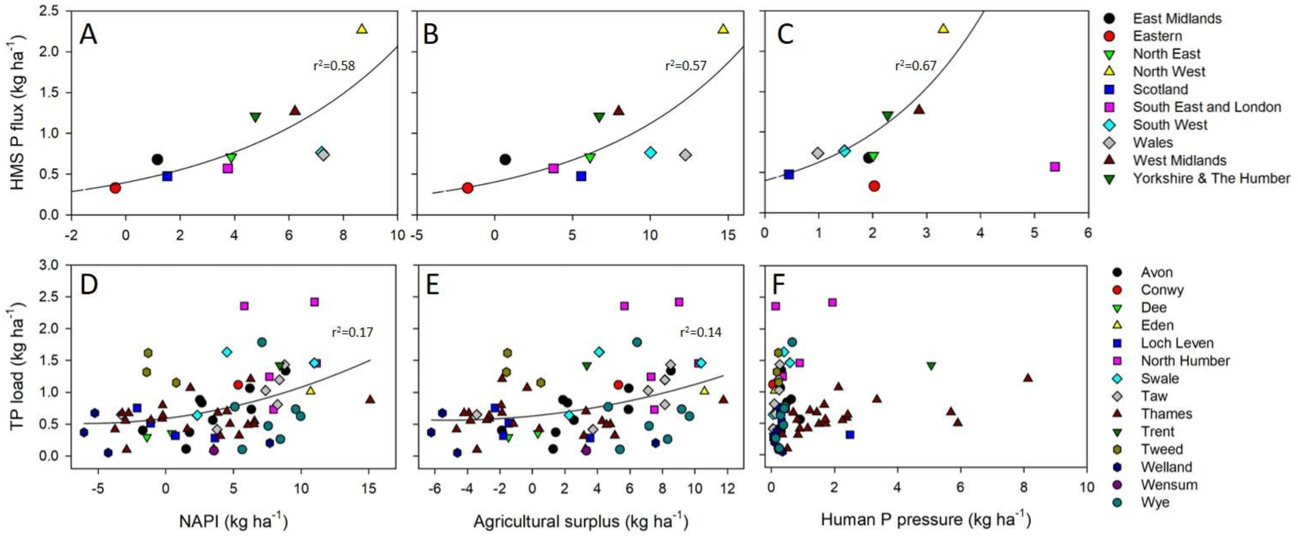


Figure 4: The relationship between Net Anthropogenic Phosphorus Inputs (NAPI); Agricultural surplus; human P pressure and riverine TP load (kg ha^{-1}). Panels A, B and C depict the UK NUTS1 regions, and D, E and F depict different UK sub-catchments within 14 river catchments.

Chemostatic (b>-0.1<0.1) or "flat" behaviour implies a homogenous distribution of a P source, which may be small as in upland catchments or large as in intensively farmed catchments. In this type of P behaviour, changes in hydrological connectivity do not affect solute concentrations, or that flow pathways are stable across time.

Chemodynamic dilution (b <0.1) or "down" relationships are attributed to dilution of solutes during high flows. This pattern of P delivery is source limited, since delivery is determined by P source abundance or rate of release, rather than transport capacity.

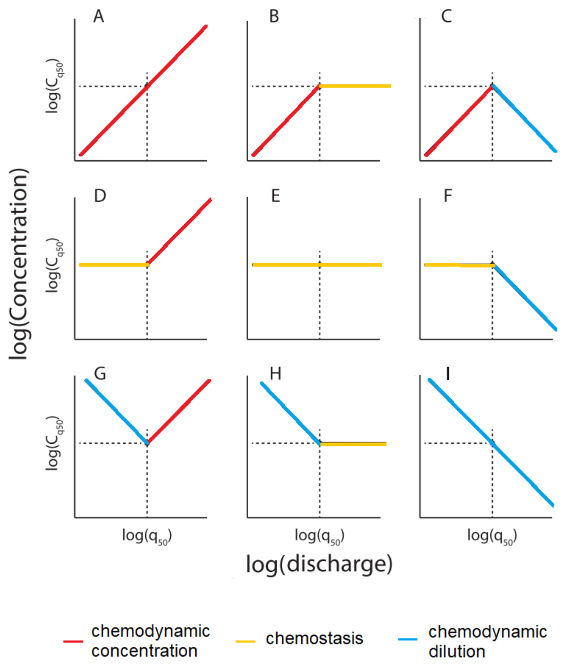


Figure 5: Conceptual schematic of the nine possible concentration (C) flow (Q) relationships when the hydrograph is segmented at the median flow. Edited from Moatar et al. (2017).

Typically, chemodynamic concentration patterns of P delivery are associated with diffuse source P losses from agriculture during storm events or river bank erosion, whereas chemodynamic dilution patterns of delivery are associated with more continuously discharged P losses from point sources in the catchment, such as wastewater treatment centres, industrial units, septic tanks and farmyards.

Splitting the hydrograph distinguished high concentrations of all forms of P at low flows ("down" behaviour), and high flows ("up" behaviour), in the different sub-catchments (Table 2). Patterns which implied high P concentrations at low flows (G, H and I) normally indicative of a point source signal made up 55% of the catchments. The D pattern of 'up' behaviour was the most common for all P forms (27% of catchments), and 64% of catchments have an "up" pattern (A, D and G) for TP at high flows (b50+). This implies that during high flows, P is mobilised from pollution sources as surface and subsurface hydrological connections are made, which is classical of an agricultural signal. B and E patterns were not detected.

This work highlights the difference in P pollution signals between high and low flows across multiple sub-catchments within the Wye, and therefore the need to understand and consequently mitigate catchment P pollution differently across space and time. For example, "up" behaviour at high flows implies the need to reduce source and transport pathways from land to water, whilst "down" behaviour at low flows implies the need to control point sources, such as septic tanks, farmyards, or discharges from waste water treatment works where discharge is not solely dependent on rainfall. It is the combination of source and transport controls that will have the most impact in reducing river P concentrations.

Table 2: The slopes of the split hydrograph at low flows (b50-) and high flows (b50+) for sub-catchments in the Wye for soluble reactive phosphorus (SRP), total dissolved phosphorus (TDP) and total phosphorus (TP). "Down", "flat" and "up" behaviour are shaded blue, yellow, and red respectively.

Catchment	Size (km^2)	b50-			b50+		
		SRP	TDP	TP	SRP	TDP	TP
Frome	77.7	-0.149	-0.126	-0.116	-0.085	-0.093	0.046
Erwood	1282.1	-0.314	-0.222	-0.422	0.091	-0.004	0.182
Garren Brook	91	0.025	-0.017	-0.011	0.702	0.475	0.582
Redbrook	4010	-0.246	-0.327	-0.201	-0.123	-0.136	-0.004
Stretford Brook	55.9	-0.782	-0.730	-0.600	-0.223	-0.195	-0.121
Dore	41.4	0.240	0.043	0.098	-0.189	-0.222	-0.126
Worm Brook	73.4	0.138	0.048	0.001	0.430	0.419	0.482
Rosemaund	0.31	0.054	0.128	0.084	0.483	0.498	0.717
Whitchurch	6.46	0.034	-0.082	0.235	1.501	0.844	0.882
Dinedor	8.69	-0.146	-0.126	-0.184	0.689	0.785	1.143
Kivernoll	9.87	-0.505	-0.447	-0.438	0.133	0.191	0.485

5.3 Key Messages:

- Analysis of NAPI – river TP load relationships at both the regional and catchment scale suggest that **reducing the overall P input pressure/surplus** on the landscape **is critical in tackling river TP pollution.**
- CQ analysis for the Wye catchment shows a highly variable **combination of point source and diffuse source P signals** in different sub-catchments.
- **Both source and transport measures to mitigate P transfer** from land to water are required to improve water quality.
- Previous analysis of P concentrations and loads across the Wye catchment shows that the **dissolved P** (orthophosphate or soluble reactive P) signal **is at least 50% of total P loads.**

6. Legacy Soil P Reserves and their Agronomic Value

Annual surpluses of P beneficially build-up soil P fertility (typically measured as Olsen-P on farms) for optimising crop yields, but as soil P increases the risk of P loss in land runoff to adjacent waterbodies and consequently eutrophication risk also increases (Withers et al., 2017). A soil Olsen-P status of 16-25 mg L^{-1} (P Index 2) is considered the agronomic optimum for a wide range of crops (AHDB, 2021), and the levels and distribution of soil Olsen-P within a catchment can give an indication of the extent of 'legacy' soil P reserves that have accumulated from previous annual P surplus loading on catchment soils.

The potential trade-off between soil P fertility and runoff P loss risk in the Wye catchment was assessed by (a) collation of soil analysis results for Olsen-P for the 5-year period 2017-2021 in the Eastern part of the catchment where farming intensity is greatest, (b) a meta-analysis of previous research data on likely rates of Olsen-P accumulation in Wye soils with increases in surplus P loading, and (c) a laboratory study investigating the agronomic value of legacy soil P to crops and potential release of dissolved P into solution and potentially into land runoff. Soil analysis results were compiled by Cobb-Agri Ltd analysed at a common laboratory.

6.1 Soil P Fertility in the Wye Catchment

The collated 5-year soil analysis results (Cobb Agri typically sample 20% of farms each year) provide a database of 13000 field samples with which to assess catchment soil P fertility in intensively farmed areas. The results show that 55% of fields have more P than the recommended agronomic optimum (P Index 2) and that 15% of soils have very high soil P fertility (P Index 4 and 5+) (Figure 6A). This percentage of P-rich soils (> P Index 2) is well above the UK national average of 43% (PAAG, 2021). A limited sub-catchment analysis (data not shown) also suggested that areas with high soil P status had the highest livestock manure P production.

The meta-analysis of previous research on representative Wye soils suggest that Olsen-P will increase at a rate ca. 9 mg kg^{-1} (or mg L^{-1}) for every 100 kg P ha^{-1} of annual surplus P input (Figure 6B). This rate of increase (ca. 250 kg P_2O_5 ha^{-1} to raise soil Olsen-P by 10 mg L^{-1}) is similar to current nationally recommended guidelines (AHDB, 2021). The current annual surplus P loading of 17 kg P ha^{-1} to Wye soils would therefore be expected to increase Olsen-P by < 2 mg kg^{-1} y^{-1}. This clearly shows that long-term trends in soil analysis results are required to fully capture the cumulative impacts of annual surplus P accumulation in the catchment.

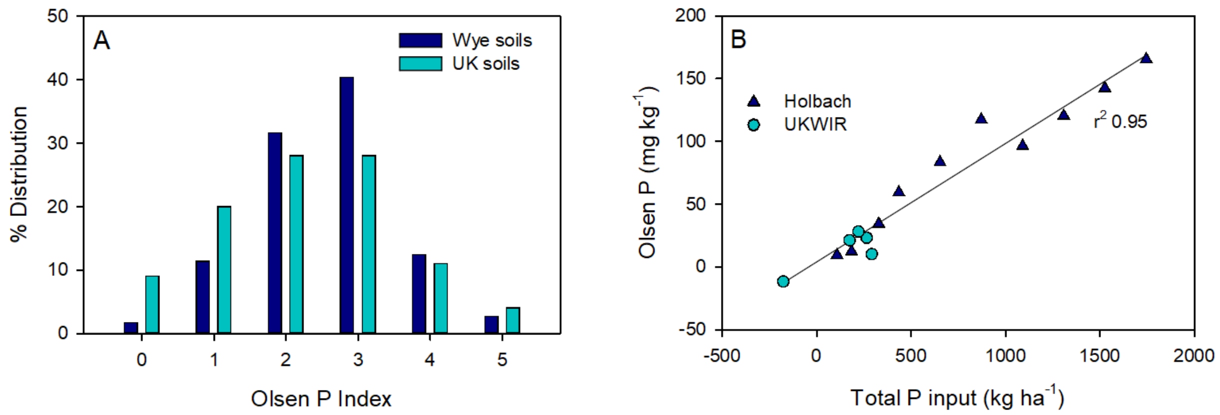


Figure 6: (A) Percentage distribution of Olsen-P indices for Wye soils compared to UK soils and (B) the relationship between surplus total P inputs (kg ha^{-1}) and Olsen-P concentrations (mg L^{-1}) at ADAS Rosemaund. Results are shown for two separate experiments: Holbach (arable) and UKWIR (grassland), testing fertiliser and/or manure treatments together with a common regression line.

6.2 Value of Legacy Soil P Reserves

Cumulative annual P surpluses over many years lead to a reservoir of 'legacy' soil P reserves. Two important questions for sustainable P management in catchments are: (a) could legacy soil P could be agronomically important i.e. could crops use this reservoir of P instead of applying inorganic P fertilisers and manures, and (b) does this reservoir of legacy P pose a long-term threat to water quality?

A trial was conducted at Lancaster University under controlled environmental conditions to try and answer these two questions. Soils were collected from the three RePhoKUs study catchments (Upper Bann, Upper Welland and the Wye), and their crop-available legacy P reserves were drawn down by repeated grass harvests (Figure 7A). Soil porewater samples were also taken to monitor soil dissolved P (SRP) release to the soil solution. Soils sampled from the Wye catchment were representative of the majority of the Eastern half of the catchments where farming is most intensive (Figure 7B).

The trial demonstrated that some legacy P could potentially be utilised in all of the catchment soils we tested. Using actual crop yield and soil P data from the farms we sampled, we estimate legacy P could supply anywhere between 2 and 20 years P without impacting on crop yield. The legacy P in the Wye soils, in particular, appeared to be crop available. For example, legacy P in a sandy loam soil typical of the lower part of the Wye catchment with a soil P of Index 4 might support a typical arable rotation for 10 years with no yield penalty.

The trial also found that Wye soils release high levels of SRP into their porewaters, especially when Olsen P levels are above the agronomic optimum, which was not observed in the other catchment soils (Figure 8A). The porewater SRP concentration at P Index 2 is also ca. 0.1 mg L^{-1} which is considerably greater than the current Wye river targets of 0.03-0.05 mg L^{-1} required for eutrophication control. This pattern of high P release is attributed to the particular physical and chemical properties of the Wye soils (high silt content) that mean they have a low ability to hold on to applied P (i.e. they have a low P buffering capacity).

A B

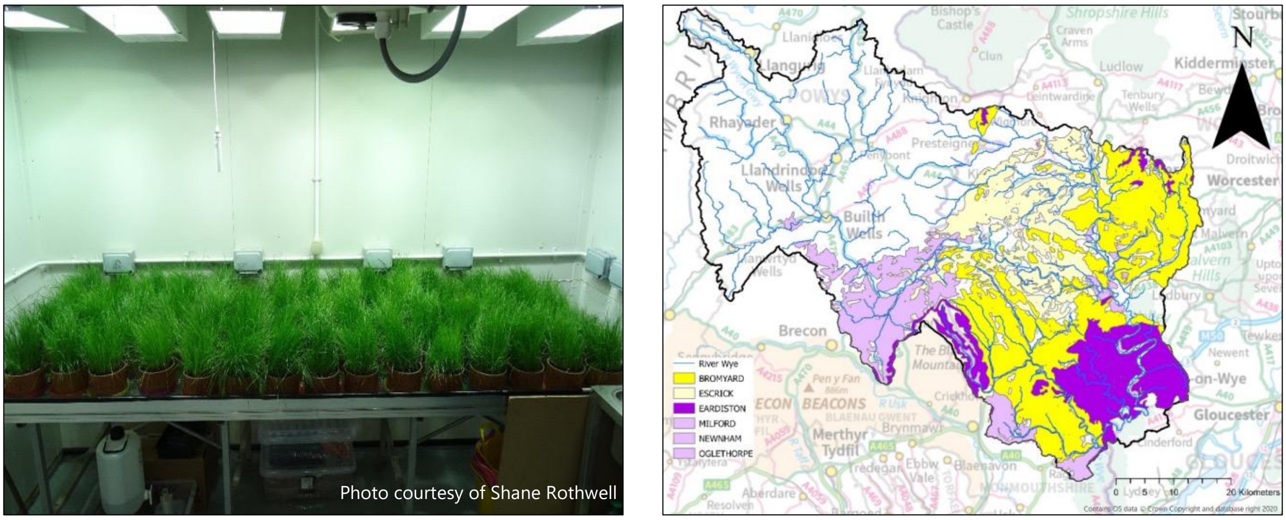
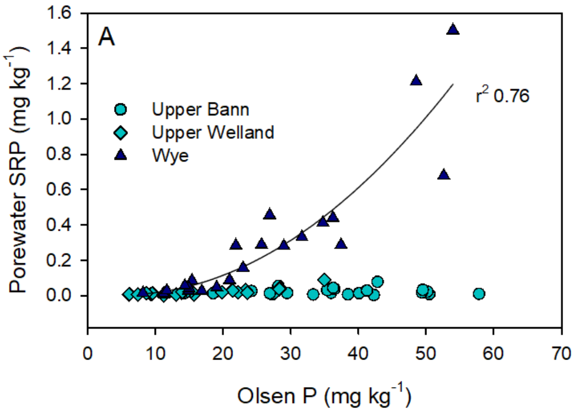


Figure 7: (A) Grass harvests draw down legacy P from catchment soils in a pot trial at Lancaster University, and (B) the distribution of the soils sampled from the Wye catchment used in the trial. Bromyard (yellow) and Eardiston (purple) were the two soils used, the other soil types shown in the lighter shades are from the same soil series and will likely exhibit similar properties of P behaviour.



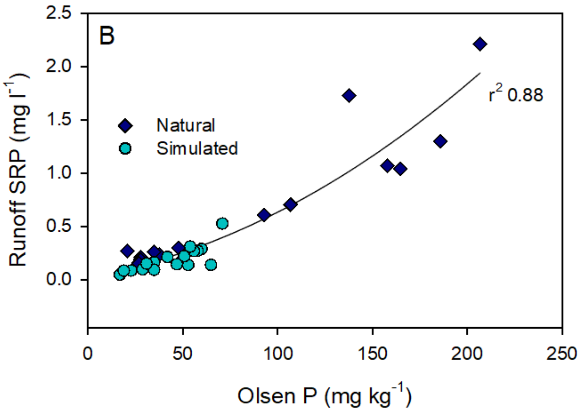


Figure 8: (A) Relationship between soil Olsen P status (mg kg^{-1}) and soluble reactive P (SRP) concentrations (mg L^{-1}) in the soil porewater in the legacy pot trial (Wye soils are highlighted in dark blue), and (B) SRP concentration (mg L^{-1}) in storm runoff increase as soil Olsen-P increases under either natural or simulated rainfall at ADAS Rosemaund (data are from Withers, unpublished).

While this low P buffering capacity explains why the legacy P reserves were particularly crop available in the Wye soils, this may also pose an increased diffuse P pollution risk because of the influence of soil Olsen-P on SRP release to runoff waters. (Withers et al., 2017). Previous experiments conducted at ADAS Rosemaund in the Wye catchment under both natural and simulated rainfall have similarly shown increasingly high rates of SRP release in runoff as soil Olsen-P concentrations increase (Figure 8b). Previous monitoring of field drains and streams in the Wye catchment also indicate high rates of SRP release even under best management. For example, the Foxbridge field drain draining soil P Index 2 land at ADAS Rosemand showed 3-year annual median and mean SRP concentrations in drainflow of 0.13 and 0.18 mg L^{-1}, respectively (Withers and Hodgkinson, 2009; Withers et al., 2009).

Drawing down soil P levels in Wye soils to at least the agronomic optimum (P Index 2) by continuing to offtake P in crops without any P input in needed to help mitigate this P loss risk. The pot experiment results suggest this could take up to a decade at typical crop P offtake rates. The RePhoKUs studies also confirm previous research on SRP release rates to land runoff, and suggests that farming at soil P Index 1 will be required to achieve current target SRP (orthophosphate) concentrations for Wye rivers.

6.3 Key Messages:

- **Soil P fertility levels** in the Eastern part of the catchment are already much **greater than the national UK average** and are indicative of a landscape receiving too much surplus P.
- **Wye soils are more P-leaky** than many other soils because of their poor ability to hold onto applied P in fertilisers and manures, and **pose a high risk of P loss to draining streams**.
- **Regular soil analysis surveys in the catchment are needed** to help (a) monitor the impact of land nutrient management change on soil Olsen-P concentrations, and (b) help establish relationships between surplus P loading, soil P status and river P concentrations.
- **Legacy soil P reserves can be safely drawn down** to the current agronomic optimum (Olsen-P Index 2) without risk of yield loss, but this may take many years.
- Concentrations of SRP from Wye soils, even at P Index 2, are likely to exceed current river SRP targets.
- Management options to farm at soil P Index 1 should be explored.

7. Stakeholder Responses in the Wye Catchment

7.1 Overview of Stakeholder Workshops

A series of interviews, interactive workshops, and an online questionnaire was conducted with stakeholders across the RePhoKUs study catchments to assess their adaptive capacity to make system and management change. Adaptive capacity refers to 'the capacity of catchment P stakeholders to address harmful P exports to aquatic systems or disruption to P supply' (Lyon et al., 2022).

The two key features of adaptive capacity are the assets or resources available to the catchment stakeholders and the ability of those stakeholders to effectively use those resources to sustainability manage P. A shortfall in either, or both capacities, means the catchment has low adaptive capacity and is vulnerable to P supply disruptions and/or water quality problems. On the other hand, strong assets and the willingness to use them would mean the catchment has high adaptive capacity and a good chance of sustainably managing P to avoid supply disruption risks and reduce P pollution to restore water bodies (Withers et al., 2015).

Catchment stakeholders included farmers, farming representatives from water companies, CSF organisations, agriculture and environmental groups such as rivers trusts, and government agencies (Figure 9).

The questions asked of stakeholders in these activities covered their:

- Occupation or roles;
- Knowledge of P and activities such as P use, training, and policies;
- Views on risks, challenges, and hinderances to more sustainable P management;
- Views on what is helping the movement toward sustainable P stewardship;
- Views on what is needed to improve P stewardship in the catchment.

Figure 9: Wye stakeholders debate adaptive capacity

7.2 Stakeholder Responses

Stakeholders, including farmers, were largely unconcerned with P supply issues such as price shocks, or aware of the origins of imported fertilisers or feed P supplements. They felt that any sharp price increase, or import restriction, would be temporary and/or reasonably easy to weather by using substitutes like livestock manures, or applying less or no P. Note that these responses were obtained before the recent sharp rise in the costs of fertilisers, and the future implications of the Ukraine war on P import supply. Currently Russia provides a large proportion of the fertiliser P imported into the UK.

Stakeholders considered water quality issues more challenging as these more directly involved agricultural P and land management practices and operational efficiency at wastewater treatment centres. Stakeholder responses are considered under a series of adaptive capacity indicators and summarised below and listed in Table 3.

Readiness to change practices: Most participants, including farmers and water companies, were willing to explore and adopt practices for better P stewardship. However, not all stakeholders were equally represented, especially farmers. Some responses also suggested that there was reluctance from some groups to change practices, or would game existing regulations, such as those for poultry unit capacity, to avoid regulatory requirements for pollution management.

Hands-on knowledge and training: The current knowledge and training offered by CSF, and Catchment Based Approach (CaBA), schemes were received well by the farmers and other stakeholders. However, responses indicated that these programmes lack predictable funding and resources, and operate at too small a scale to achieve the critical mass of mitigation actions required for water quality improvement.

A key finding was the value of hands-on face-to-face learning, especially for farmers. Such training provided knowledge uptake because it included building strong relationships and trust between stakeholders – 'the right information through the right channels' (comment from a catchment stakeholder).

Building strong stakeholder relationships (Stakeholder synergy): The presence of CSF groups, charities, water companies with extension services, and other citizen iniatives and activities meant that there was a high level of interaction between catchment stakeholders with an interest in P issues. Responses confirmed that this level of awareness and communication, despite some disagreements, is helpful for knowledge sharing for more widespread uptake and enacting behaviour changes by stakeholders, should more resources be made available.

Legislation, regulation, and resources: Responses indicated that upgrading wastewater P removal and water company infrastructure, training more farmers and other stakeholders, meeting costs associated with new practices, and other stakeholder initiatives required investment from government in the forms of improved regulation and financial resources. Water companies and farmers operate under regulations that could be strengthened for improved P stewardship or wastewater P removal. Such changes may be initially costly, but financial incentives such as those under the new Environmental Land Management Scheme (ELMS) could be made available to offset any expense risks.

Despite a very active forum for stakeholder interaction and knowledge exchange, the overall adaptive capacity in the Wye catchment is considered low because there are insufficient resources to implement effective regulatory, training, incentive, technical and infrastructure support at the scales necessary to enable measurable improvements in water quality. More resources and expansion of existing schemes to encourage broader participation, sustained over many years are needed to meet the P challenge.

7.3 Key Messages:

- Stakeholders were generally not unduly concerned about future disruptions to P import supply, or cost, and considered the **challenge of addressing poor water quality more pressing** (N.B. This work was before the current price increases in P fertilisers and supply uncertainties of the Ukraine War).
- Nascent stakeholder capacity to adapt current practices to help improve water quality is high, but the **scale and levels of uptake of catchment mitigation measures is insufficient to show demonstrable benefit**.
- A **firmer evidence base and greater regulatory, training, incentive, technical and infrastructure support is needed** to make the incremental and transformative change required in different sectors for river water quality in the Wye to improve.
- Overall catchment **adaptive capacity is low**.

Table 3: Adaptive capacity thematic indicators from the online post-workshop questionnaire (from Lyon et al. 2022).

Adaptive capacity thematic indicators	*"What do you think is currently **hindering** the catchment organisations or farming community efforts to improve phosphorus stewardship?"*	*"What do you think is currently **helping** the catchment organisations or farming community to improve phosphorus stewardship?"*	*"What kinds of activities or **supports** would need to be put in place to help catchment organisations or the farming community improve phosphorus stewardship?"*	*"What do you think is the **potential** for this catchment to adopt measures to greatly improve phosphorus stewardship? "*
Readiness to change and established practices	– Reluctance to change, short-termism, excuse-making, cheating, self-interest – Farmers resistance to change Apparent resistance from farmer's union Vested interests in the status quo – Fear of the unknown – Overcoming inertia/dependency for farming types or practices Lock-in to farming types (e.g. poultry/livestock) – Continued permitting of P-loaded livestock and poultry – Focus on maize crops, – Continued permitting of large poultry units Agriculture as an industry is a powerful interest resistant to regulation and change – Subsidy-led farming history – Lack of soil health, heavy cultivation	– Renewed interest and impetus for in soil management or P-friendly practices – More interest in conservation agriculture – Soil management importance has shot up the agenda for many and potentially increased uptake of countryside stewardship – Buy-in from supply chain but overall not much – Public awareness – Already wide uptake of farm P-loss reduction measures – Uptake by "clusters" of farmers – Efforts of deeply committed individuals – Awareness and evidence-based farming is increasing, shifting farming away from grandfathered method	– Awareness raising – Supply-chain wide buy-in to P sustainability – Practical examples or demonstrations – Public awareness – Improved promotion and awareness campaigns – Industry engagement at grass roots with existing groups by industry recognised and technically competent advisors who do not have their own agenda – Payments for environmental practices – Approval for alternative uses for manures for livestock/poultry dependent farmers	– Possible - and should be aligned with the significant impetus that will be given to climate change and the ecological emergence – Possibly advise P-index 1, but may be risky and too soon – Get farmers on board – Yes, if it was high enough profile, encouraged farmer participation, with tangible benefit
Knowledge & training	– Lack of clarity in yield response to P – Getting the message across to overcome farmer hesitancy	– Greater/better scientific evidence and data of causes and solutions	– Dedicated advisors, bespoke website – Clarity on causes and reasons for P pollution	– There is always potential we just need to get the right information to

	– Lack of knowledge – Lack of information on how to best manage soil P – Poor communication of actual cost of P loss to a business – Knowledge gap – Mixed messaging, siloed advice rather than holistic approaches to soil and farm management – Lack of availability of science to support farming at P-index 1 – Access to affordable quality advice – Lack of understanding – Lack of knowledge or confidence that stakeholders are doing the right thing – Lack of knowledge of P-friendly farming, economic benefits, value of P – Lack of clear communication – Excessive amount and timing of P applications – Lack of catchment advisors, lack of clarity about practical steps, lack of joined-up approaches – Government project managers and advisors with little or no technical knowledge – Information overload for farmers	– Research like the researchers' project – Publicity, media attention, knowledge sharing – Consistent messages to the farming communities about the cost-effectiveness of effort by showing outcomes – Peer-to-peer learning and – CSF advice well received – Knowledge exchange and discussion groups for small groups of likeminded farmers to share ideas – Countryside Stewardship Scheme – Education, such as research project workshops – Education – Increased research	– Educate farmers, feed, and fertiliser suppliers on the costs of P pollution – 1:1 hands-on farm advice – Educating young farmers – Bespoke catchment P planning tools – Interactive fur video tutorials/animations to educate – Free advice on P and livestock diets for farmers – Better data on local P dynamics to target interventions – Nutrient Management Plans – Communication – More handholding, training, and demonstrations for farmers – Trusted sources of advice (CSF) – Research and knowledge on practical measures that can be implemented for farm businesses – Better yield response data – Peer to peer learning – Pilot in smaller subcatchment with farming unions support – Real examples: No-till farmers attending the workshop were an inspiration – Benchmarking among farmers within similar sections of agriculture	farmers through the right channels. I think Agronomists are a good way in! – Yes it is possible, easier with some soils than others possibly. Targeted use of countryside stewardship options could go a long way. – If demonstration farms are supported and benefits such as C-sequestration and NFM are made – Manure & nutrient management planning informed by increased soil sampling

			– Better for agronomists e.g. P-stewardship in BETA conservation training – Knowledge and practical demonstrations of low P farming More education – Practical demonstration of lower P-index farming over the mid to long term to show farmers and agronomists that the accepted norm of P-index2 is not the be all and end all of phosphate management – On farm demonstrations and accompanying data – More workshops like this – Funding for independent advisers and mentors to support farmers through transition to farming systems that don't import P in bag or manures.	
Stakeholder synergy	– Catchment organisations attacking agriculture industry inhibits partnerships – Alarmist headlines that damage relationships – Tone of debate (farming community under attack by environmental groups)	– Expanded NMB participation and strong leadership – Shared commitment across catchment organisations – Intergovernmental agreement on the P problem and measures to address it – Catchment partnership meetings – Activity of catchment organisations	– Catchment organisations engaging and working with farmers, not confronting them	– Courage to really push on this issue. – Different parties have different priorities; but need a common economically driven aim to overcome

Funding, technology, & infrastructure	– Village/small sewage treatment works are a major problem – Lack of Natural England/catchment sensitive farm practice training and the existence of funding infrastructure (e.g. concrete yards) that support livestock intensification rather than sustainable low-input profitable grass based solutions – Financial and planning constraints – Deep cuts to public sector resources – Lack of financial reward or discipline – Market forces/Brexit – Short-term funding inhibits developing strong local relationships with catchment organisations	– Water company P removal infrastructure – Technology gains – Cost-management – Public good for public money ethos	– Assistance with farm infrastructure for handling manure and slurry – Poultry manure processing facility (energy or other products, such as ash fertiliser) – Local economic development for manure export industry – New ways to profit from manure exports – Reworked post-Brexit subsidy system to hardwire efforts into the system – Long-term funding and commitment from government – Financial assistance (for farmers)	– New technology to access soil legacy P to reduce reliance on imports – Harder to achieve would be a move away from heavy farm machinery trafficking fields and reducing large amounts of soil disturbance. – If time and resources are made available
Legislation, regulation, & enforcement	– Lack of enforcement/inspections by EA; lack "boots on the ground" Failure of voluntary compliance Lack of statutory powers and prosecutions of those who flout rules – Planning regulations	– New regulations, Farming Rules for Water, which focus on nutrient/P management Increasing farming costs and capped returns – Adoption of Mid-tier Stewardship	– Compulsory non import, non-spread zones, no plough zones, audit trail out of the county for poultry manure or processed equivalent by products, digestate removal from county, stop RHI and greening subsidy for maize; payment schemes – Forceful solutions and penalties A united approach, with carrots and sticks, e.g. payments and fines	– Great potential possibly with ELMS – If they political will is there, and before irrevocable damage – The potential is good, but making farmers think about Phosphate applications and giving them the information to take it seriously will be a challenge particularly

			– Tax P, ban or tax users for non-compliance – Permission to move away from RB209 – Robust support for ELMS – Knowledge dissemination in ELMS targeting – Enforcement – Legislation for P was with NVZ restrictions	as there is already a great deal of rules and regulations to be aware of as well as getting the actual work done. The Rural Payments Agency would have to make Phosphate management part of cross compliance. – Consumer-side – stop externalising environmental costs for food

8. Improving Phosphorus Sustainability in the Wye Catchment

8.1 Reducing P Losses to Water

Achieving the reductions in river P concentrations required for good or high ecological status is generally confounded by the multiple wastewater, agricultural, industrial and urban sources contributing variable loads of dissolved and particulate P along different hydrological pathways, and variable rates of P retention and ecological response once in the water column (Withers and Jarvie, 2008). This is especially the case in the Wye catchment because the majority of the P load entering the river is from agriculture which is more difficult to mitigate because of its diffuse nature, and dependence not only on current P management but also the 'legacy' of P surpluses that have accumulated in the landscape over many years.

A combination of current and historic high annual P input pressure (NAPI) on the Wye landscape, poorly-buffered silty soils that release high concentrations of dissolved phosphorus into storm runoff, highly dispersible soils that erode easily and make rivers turn red, steep runoff-prone slopes and moderate to high rainfall provide the perfect storm for accelerated P loss in surface runoff and drainflow into the river.

Hence, although river P concentrations notably declined after the introduction of advanced P-stripping at wastewater treatment works serving major populations centres during the late 1990s (see Jarvie et al., 2003), river P concentrations maybe starting to increase again (Figure 10) in line with an increase in farming intensity and P input pressure in the catchment.

Farming in the Wye catchment without contributing ecologically-damaging P concentrations to the draining rivers is therefore very challenging. The RePhoKUs comparisons between P input pressure and river P pollution across regions and different research catchments in the UK clearly show that the greater the P input pressure on a landscape, the greater the loads and concentrations of P in the rivers. Such relationships often break down within individual catchments (such as the Wye) because of greater uncertainty over NAPI values, poor availability and resolution of river P data and/or an overriding influence of other factors affecting P mobilisation and delivery to the river (e.g. extreme storm events).

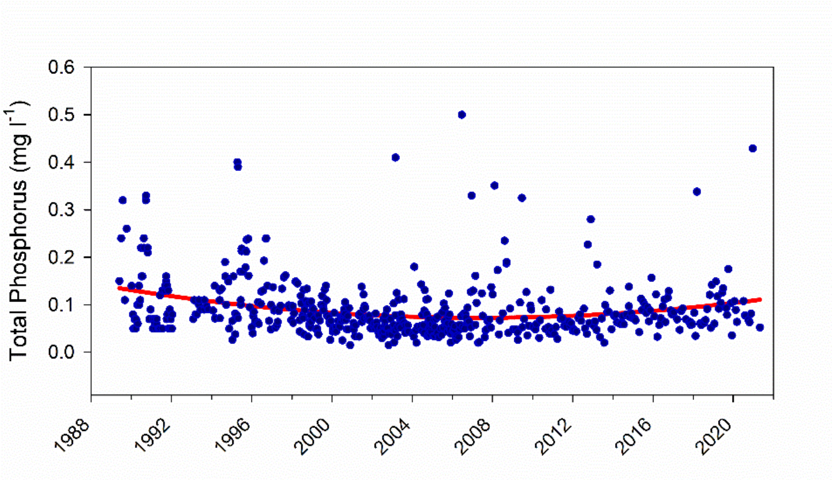


Figure 10: The concentration (mg L^{-1}) of total phosphorus (TP) at the outlet of the Wye (Redbrook) from 1989 to 2021 (data provided by Natural Resources Wales). An overall trend line is given. (NB. Data is based on low resolution and inconsistent sampling).

The RePhoKUs results suggest that water quality in the Wye catchment will not improve until the high annual P input pressure is reduced. Current CSF strategies to reduce P leakage to water are reliant on farm scale mitigation actions centred on sensitive land and nutrient management (e.g. reducing land runoff and erosion rates, fencing waterways and installing buffer strips, ponds and wetlands), but with little evidence to-date that they are having a marked impact (Davey et al., 2020).

There is currently no emphasis on the wider system level change that may be required to reduce the catchment annual P input pressure. However, achieving a catchment zero P surplus, or encouraging agriculture to draw down legacy P reserves, requires a level of governance that is beyond the responsibility of the individual farmer or industry. It is a collective catchment stakeholder responsibility.

8.2 Reducing P Input Pressure in the Wye Catchment

8.2.1 Drivers of the Wye Agricultural P Surplus

The very high P input pressure being exerted on the Wye catchment is driven by the large agricultural P surplus which is symptomatic of a livestock-dominated farming pattern with a low efficiency of P use (Rothwell et al., 2020): the efficiency with which imports of P in feed, fertiliser and food into the Wye catchment were converted into useful product for consumption or export was low at only 48%. This is very similar to the overall P use efficiency for the UK food system at 43% (Rothwell et al., 2022), but is higher than that found in the Northern Ireland food system (22%) which is more reliant on more P-inefficient ruminant production systems (Rothwell et al., 2020). Other countries with a high non-ruminant population have very similar P efficiencies: Belgium (59%), The Netherlands (66%) and Denmark (44%), (van Dijk et al., 2016). This low P inefficiency demonstrates the large amounts of unused P that is wasted or lost annually in the Wye catchment.

The main driver of the large annual P surplus is the quantities of livestock manure that are produced each year (over 6000 t P). Manure production has significantly increased in the last 5 years due to the rapid expansion of the poultry industry and poultry have now overtaken cattle as the main producer of manure P in the catchment (Table 1). Total manure P production alone exceeds the requirement for P by cropland and grassland in the catchment by 45%. Combined with the annual inorganic fertiliser use (still over 1100 t), this excess P is accumulating in catchment soils, and adding to the already substantial legacy soil P reserves in the catchment.

Whilst the soil analysis survey did not cover the whole catchment, the proportion of over-fertilised soils is already considerably greater than the UK national average, with some evidence that those areas the highest percentages of over-fertilised soils are those which have the greatest manure P loadings.

8.2.2 Addressing the Agricultural P Surplus

A reduction in the agricultural soil P surplus in the Wye catchment is dependent on addressing the catchments manure mountain. Optimising livestock dietary P intake to reduce rates of livestock P excretion will help, but additional and more fundamental solutions involving significant system level change will be needed to bring the catchment into P balance.

Figure 11 is a scenario SFA that demonstrates the scale of change required. In this example, fertiliser import into the catchment is reduced by 75%, and 80% of all pig and poultry manure P is exported out of the catchment to regions that require P fertiliser. This leaves the catchment with a near zero surplus of only 0.1 kg ha^{-1} yr^{-1}.

However, historic annual catchment P surpluses over many years mean large legacy P reserves have accumulated in the catchment soils, which also pose an environmental risk due to high vulnerability of Wye soils to leak dissolved P and erode particulate P in storm runoff. Reducing these legacy P reserves would actually require the catchment being in a negative P balance where more P is taken off in crops than is applied. Figure 12 shows another scenario SFA where again, fertiliser P is reduced by 75%, 80% of pig and poultry manure P is exported and additionally 50% of all cattle manure P is exported from the catchment. This would bring the catchment into a drawdown rate of -4 kg ha^{-1} yr^{-1}.

Addressing this legacy soil P now is a significant long-term challenge for agriculture. The RePhoKUs pot trial results suggest it could take a decade or more to reduce soil Olsen-P concentrations to the agronomic optimum, and also that Wye soils at the agronomic optimum may still generate runoff SRP concentrations well above current targets for good and high ecological status in rivers. Therefore, it is imperative that options are explored for managing soils below the current soil P agronomic optimum (i.e. farming at P Index 1) while maintaining farm profitability. Reducing the soil P concentration to the agronomic optimum level will also require careful management of these soils and the correct strategies for doing this, so as to balance agronomic and environmental targets.

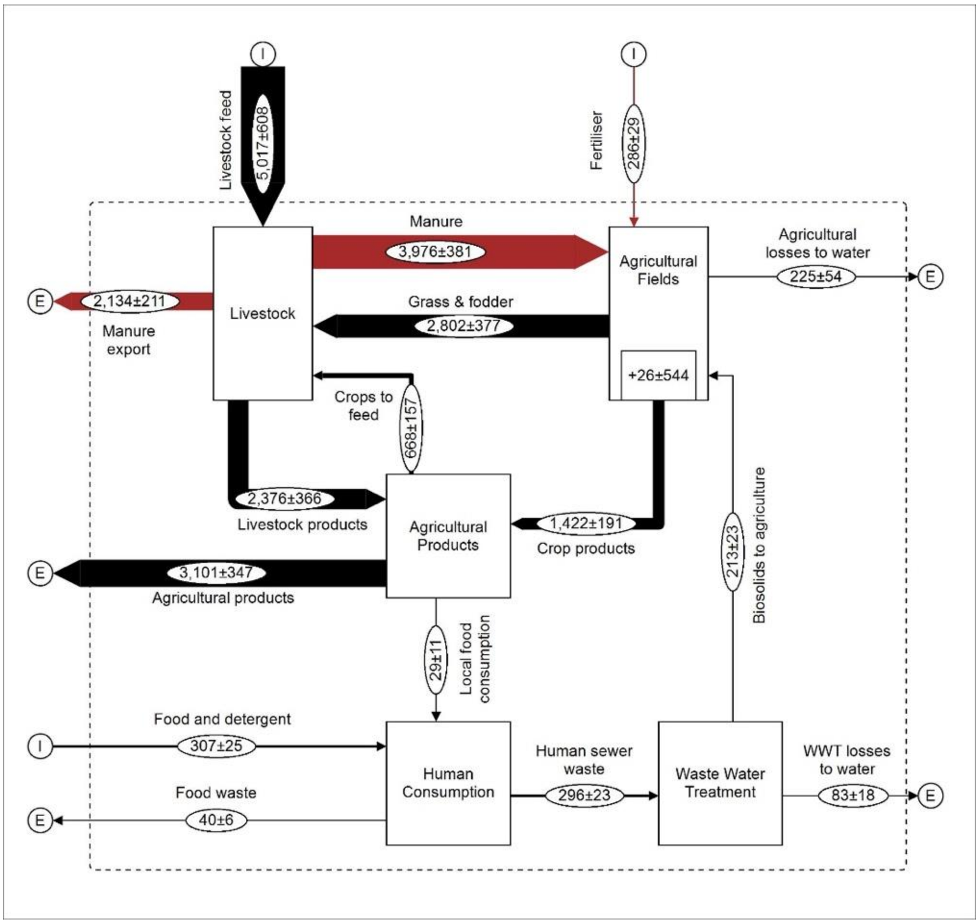


Figure 11: Catchment zero P balance scenario SFA for the Wye catchment area.

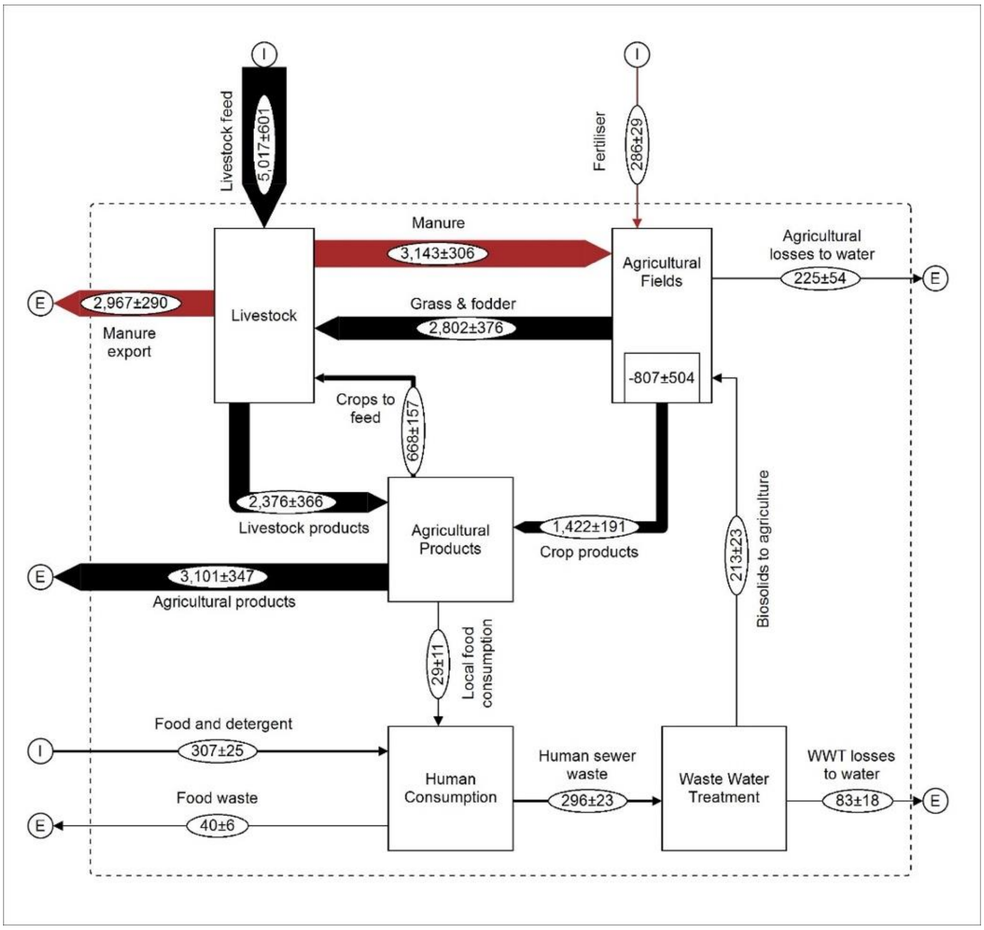


Figure 12: Catchment P drawdown scenario SFA for the Wye catchment area.

8.2.3 Achieving a Sustainable P Balance

Sustainable food systems use P resources efficiently (i.e. more production with less P inputs), maximise recycling of residue P (i.e. re-use P), and minimise P surplus, wastage and loss. These are the guiding principles of 5R P stewardship and a circular nutrient economy which seeks to balance P use in food production with the protection of our water environment (Withers et al., 2015), and are applicable to the food system in the Wye catchment as in any other region. This essentially means operating at least a zero P surplus at the catchment scale.

Reducing P inputs into the catchment might be achieved by lowering P demand (for example by destocking or through human dietary change), by recovering P from manures to substitute for imports of fertilisers and feed supplements, by utilising legacy soil P reserves instead of applying fresh P, or a combination of these. The National Food Strategy (National Food Strategy, 2021) recommends cutting meat consumption by 30% over the next decade but this requires national policy development, and reducing livestock numbers without clear alternatives may also impact on rural livelihoods and the economy.

The potential for increasing recycling (P circularity) within the Wye catchment is limited because most livestock manures, which represent the largest internal P flow, and wastewater biosolids recycled back to land. There is insufficient data on which to quantify the amounts of P flowing into the waste management sector (e.g. from livestock carcases) in the Wye catchment, but quantities of P lost in food waste are relatively small (40 t). Recovery of P from the waste sector, or further improvements in the efficiency of P removal at wastewater treatment centres would also only add to the P loading pressure on the catchment. There is simply too much residue (manure) P already recirculating within the Wye catchment, and alternative solutions need to be developed.

Hence options to recycle P sustainably must consider the wider national food system by exporting excess manure P out of the catchment. The value of organic manures for maintaining soil organic matter can still be realised where their application can meet crop P requirements, but when applied in excess they become an environmental hazard and must be exported. Given the costs and impracticalities of regularly transporting bulky livestock manures long distances, this means that technological solutions are needed to either make livestock manures more transportable (e.g. by dewatering dairy slurry (Lyons et al., 2021), or recover inorganic P from manures and biosolids in a fertiliser-grade form (e.g. as struvite or calcium phosphate, Tonini et al., 2019). Recovered P can then potentially directly substitute for imported inorganic P fertilisers into the catchment, or be exported out of the catchment to other areas of the country with a P deficit, such as in Eastern England.

Research is needed to help develop reliable cost-effective technological solutions for manure treatment, and to confirm the effectiveness and safety of recovered P fertilisers for use on a wide range of crops.

However, achieving a zero surplus at the catchment scale will not address the loss of P in storm runoff from soils that already have far more P than they need for agricultural production. Given the unnecessarily high levels of crop-available Olsen-P in Wye soils, the catchment will need to operate a negative P surplus in the future in order to draw-down soil P fertility to at least the agronomic optimum. Soil P drawdown is clearly a long-term strategy, and CSF measures designed to reduce the mobilisation of soil and applied P in land runoff, and the delivery of any mobilised P to the watercourse, consequently become particularly important for mitigating agriculture's impact on water quality.

More field-based research is needed to confirm the results of the legacy pot trial that annual P inputs in fertilisers and manures can be withhold for a number of years without any risk of yield loss.

Improvements in the ecological functioning of the Wye river therefore rely on a combination of catchment-scale measures to reduce the annual P input pressure on the landscape, industry measures to reduce point source effluent discharges and sewage overflows, and farm-scale measures to effectively utilise legacy soil P reserves and minimise the loss of P in runoff and erosion.

In turn this requires better governance of P at the catchment scale and a collective stakeholder responsibility to enact the level of system change required to mitigate river P pollution. The Wye Catchment Partnership, the Wye and Usk Foundation, Wye Agri-Food Partnership and the Friends of the Wye are examples of the active stakeholder forums that exist in the Wye to facilitate such change. Investment in higher resolution and targeted routine water quality monitoring programmes is needed to monitor progress, and WUF and citizen science is already helping in this regard.

The RePhoKUs project has helped provide the evidence base to allow stakeholders to take the innovative actions and management changes required to maintain the high ecological biodiversity and recreation status that the Wye river is famous for.

8.3 Key Recommendations for Action:

- Policies to mitigate river P pollution from agriculture should change emphasis and seek to **reduce the P input pressure on catchments in addition to the current emphasis on mitigating transport and delivery of P** from land to water. Catchments cannot continue to absorb annual agricultural P surpluses without risk of long-term endemic P loss to water.
- **Better enforce and support existing regulation** (e.g impending Water targets and existing Farming Rules for Water) with policies, tools and governance towards achieving at least net zero P surplus at catchment and regional scale.
- **Reduce livestock manure P loading through a reduction in animal numbers and by processing manure to produce renewable fertilisers** to replace imported fertiliser, and by exporting manure to other regions. Research is needed to support technological development of safe and effective recovered P fertilisers and feed supplements.
- Provide **incentives to draw-down areas of high-risk P-rich soils** to at least the agronomic optimum. Research is also needed to explore farming at soil P Index 1.
- **River monitoring data generally needs to be made more accessible, consistent and at a higher resolution** to be able to make robust comparisons to catchment nutrient loading pressures and soil P build-up and monitor progress of the P Action Plan.
- **Substantially scale-up and provide for stable resourcing and long-term funding of local catchment officers, complementary land stewardship schemes and permanent knowledge sharing and coordination platforms to build stakeholder trust and understanding of P issues**, and support uptake of both incremental and more transformative structural changes in practice.
- **High resolution crop census data, and fertiliser and manure input data needs to be made more widely available** to allow accurate quantification of P cycling within the catchment.

9. Summary of Key Findings

- The Wye catchment has a high risk of agricultural P loss due to high P input pressure, poorly-buffered and highly dispersible P-rich soils, steep slops and moderate to high rainfall.

- Farming generates an annual P surplus (i.e. unused P) of ca. 3000 t (17 kg P ha^{-1}) in the Wye catchment, which is accumulating in the agricultural soils. This P surplus is nearly 60% greater than the national average, and is driven by the large amounts of livestock manure produced in the catchment.

- The risk of P loss in land runoff due to accumulation of soil P is greater in the Wye catchment than in other UK soils due to poor soil P buffering capacity and high dispersibility during storm events.

- Analysis of long-term river P concentration data for the Wye catchment outlet at Redbrook suggests river P pollution may be gradually rising again, but more consistent and higher frequency water quality monitoring is required to confirm.

- Clear evidence of positive links between annual P input pressure (and P surplus) and river P concentrations and loads exists at regional and catchment scales and this should drive a greater emphasis on redcuing the P input pressure in the Wye catchment.

- EA/NRW water quality monitoring programmes are not considered adequate to capture river quality impacts of short-term or small area changes in agricultural practice. Similarly, the general provision of up-to-date census data is not at a sufficiently fine resolution to accurately quantify spatially distributed P input pressure in catchments. These are both generic problems confounding provision of robust evidence of cause and effect.

- Water quality in the Wye catchment, and many other livestock-dominated catchments, will not greatly improve without reducing the agricultural P surplus and drawing-down P-rich soils to at least the agronomic optimum. This will take many years.

- A combination of reducing the number of livestock and processing of livestock manures to recover renewable fertilisers that can substitute for imported P products is needed to effectively reduce the P surplus.

- Catchment stakeholders have a nascent capacity to change practice but require a firmer evidence base and on-the-ground support to implement both incremental and transformative change in practices to improve river water quality. Experience in Northern Ireland suggests support schemes have a measurable impact on behavioural change.

Acknowledgements

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References

AHDB (2022). Nutrient Management Guide (RB209). Section 1: Principles of nutrient management and fertiliser use. Available at: Nutrient Management Guide (RB209) | AHDB

APHA (2019). Animal and Plant Health Agency, Worcester DEFRA/APHA, County Hall, Spetchley Road, Worcester, WR5 2NP.

Rowland, C.S.M., C.G.; Morton, R.D.; O'Neil, A.W. . 2020. Land cover map 1990 (vector, gb). . NERC Environmental Information Data Centre. . doi:https://doi.org/10.5285/304a7a40-1388-49f5-b3ac'

Rowland, C.S.M., R.D.; Carrasco, L.; McShane, G.; O'Neil, A.W.; Wood, C.M. . 2017. Land cover map 2015 (vector, gb). NERC Environmental Information Data Centre. . doi:https://doi.org/10.5285/6c6c9203-7333-4d96-88ab-78925e7a4e73

Davey, A.J.H., Bailey, L., Bewes, V., Mubaiwa, A., Hall, J., Burgess, C., Dunbar, M.J., Smith, P.D. and Rambohul, J. (2020). Water quality benefits from an advice-led approach to reducing water pollution from agriculture in England. Agriculture Ecosystems & Environment 296.

Defra (2019). British Survey of Fertiliser Practice. Available at: https://www.gov.uk/government/collections/fertiliser-usage.

National Food Strategy (2021). National Food Strategy Independent Review: The Plan. Available at: https://www.nationalfoodstrategy.org

Natural Resources Wales, Environment Agency and Natural England (2021). River Wye SAC Nutrient Management Plan Phosphate Action Plan, November 2021. Available at: https://www.herefordshire.gov.uk/downloads/file/23069/river-wye-sac-nutrient-management-plan-phosphate-action-plan-november-2021

Jarvie, H.P., Neal, A., Withers, P.J.A., Robinson, A., Salter, N. (2003). Nutrient water quality of the Wye catchment, UK: exploring patterns and fluxes. Hydrology and Earth System Sciences 7, 722 - 743.

Moatar, F., Abbott, B., Minaudo, C., Curie, F., and Pinay, G. (2017). Elemental properties, hydrology, and biology interact to shape concentration- discharge curves for carbon, nutrients, sediment, and major ions. Water Resources Research, 53, 1270–1287.

PAAG (2021). Collation of data from routine soil analysis in the UK 2019/2020. Professional Agricultural Analysis Group. Available at: https://www.nutrientmanagement.org/latest-information/news/paag-report-on-soil-analysis-2019/

Rothwell, S.A., Doody, D.G., Johnston, C., Forber, K.J., Cencic, O., Rechburger, H. and Withers, P.J.A. (2020). Phosphorus stocks and flows in an intensive livestock dominated food system. Resources, Conservation and Recycling 163, 105065.

Rothwell, S.A., Forber, K.J., Dawson, C.J., Salter, J.L., Dils, R,M., Webber, H., Maguire, J., Doody, D.G., and Withers, P.J.A. (2022). A new direction for tackling phosphorus inefficiency in the UK food system. Journal of Environmental Management 314, 115021.

Sobota, D.J., Harrison, J.A. and Dahlgren, R.A. (2011). Linking dissolved and particulate phosphorus export in rivers draining california's central valley with anthropogenic sources at the regional scale. Journal of Environmental Quality 40, 1290-1302.

Lyon, C., Jacobs, B., Martin-Ortega, J., Rothwell, S.A., Price, L., Stoate, C., Doody, D.G., Forber, K.J. and Withers, P.J.A. (2022). Exploring adaptive capacity to phosphorus challenges through two United Kingdom river catchments. Environmental Science & Policy. Under review.

Lyons, G.A, Cathcart, A., Frost, J.P., Wills, M., Johnston, C., Ramsey, R. and Smyth, B. (2021). Review of two mechanical separation technologies for the sustainable management of agricultural phosphorus in nutrient-vulnerable zones. Agronomy,11,836. https://doi.org/ 10.3390/agronomy11050836

Tonini, D., Saveyn, H. G. M. and Huygens, D. (2019). Environmental and health co-benefits for advanced phosphorus recovery Nature. Sustainability 2 1051– 1062. https://doi.org/10.1038/s41893-019-0416-x (2019).

Withers, P.J.A., van Dijk, K.C., Neset, T.-S.S., Nesme, T., Oenema, O., Rubæk, G.H., Schoumans, O.F., Smit, B. and Pellerin, S. 2015. Stewardship to tackle global phosphorus inefficiency: The case of Europe. AMBIO. 44(S2), pp.193–206.

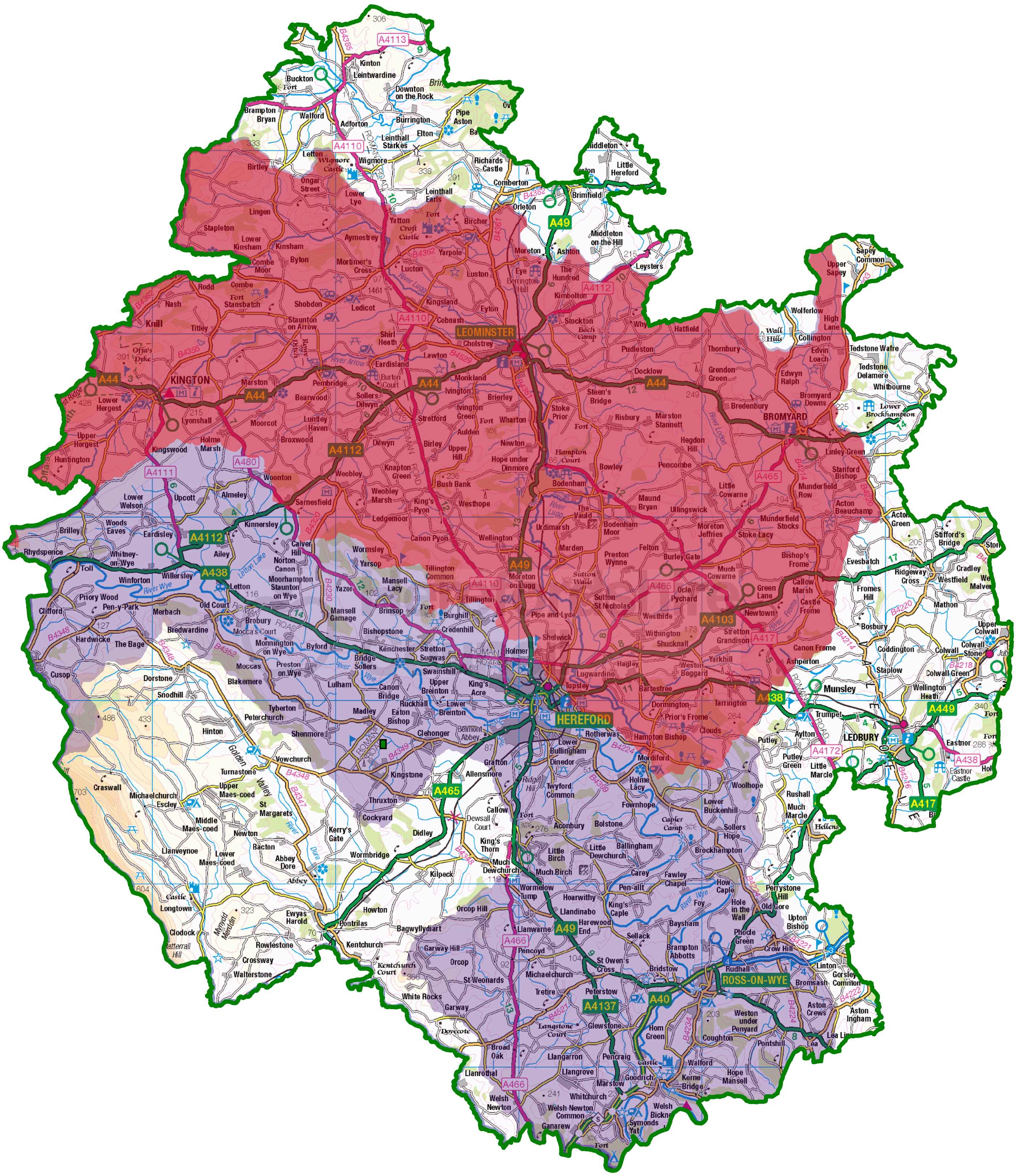
Withers, P.J.A. and Hodgkinson, R.A. (2009). The effect of farming practices on phosphorus transfer to a headwater stream in England. Agriculture, Ecosystems and the Environment 131, 347-355.

Withers, P.J.A. and Jarvie, H.P. (2008). Delivery and cycling of phosphorus in UK rivers: implications for catchment management. Science of the Total Environment 400, 379-395.

Withers, P.J.A., Jarvie, H.P., Hodgkinson, R.A., Palmer-Felgate, E.J., Bates, A., Neal, M., Howells, R., Withers, C.M. and Whickham, H. (2009). Characterization of phosphorus sources in rural watersheds. Journal of Environmental Quality 38, 1998-2011.

Withers P.J.A., Hodgkinson, R.A., Rollett, A., Dyer, C., Dils, R., Collins, A.L., Bilsborrow, P.E., Bailey, G. and Sylvester-Bradley, R. (2017). Reducing soil phosphorus fertility brings potential long-term environmental gains: A UK analysis. Environment Research Letters 12, 063001.

Zhang, Y., Collins, A.L., Murdoch, N., Lee, D. and Naden, P.S. (2014). Cross sector contributions to river pollution in England and Wales: Updating waterbody scale information to support policy delivery for the Water Framework Directive. Environmental Science & Policy 42, 16-32.



River Wye SAC Catchment:
River Lugg (SAC) sub-catchment - Red
River Wye (SAC) sub-catchments - Purple

NORTH

Herefordshire Council

Scale (approx) 1: 300,000 at A4

Herefordshire Council

Plough Lane
Hereford
HR4 0LE

Soil Phosphorus Status and Water Quality in the River Wye, Phase 2: Land Use Change and Phosphorus Balances in the Wye Catchment

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March 2023

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Summary

This report covers Phase 2 follow-on work for the Environment Agency (EA) aimed at further development of the evidence base linking livestock farming to phosphorus (P) surpluses, soil P status and water quality impacts in the Wye catchment, and a better understanding of the potential impact on P surpluses and water quality of future land use change. Phase 1 highlighted a strong linkage between catchment P input pressures, manure P loadings to the land surface and build-up of soil P across the English part of the Wye.

Livestock farming has had a major impact on land use patterns and P cycling in the Wye catchment over the last 150 years, traditionally with cattle and sheep farming but more recently due to the rapid expansion of the poultry industry. Annual livestock manure P loading to the soil has consistently exceeded annual catchment crop P requirements, and even in 1870 there was an estimated P surplus of over 4 kg P/ha. This increased to 23 kg P/ha in 1975 as agricultural systems intensified, but has declined since to a similar level to that in the 1920's (ca. 9 kg P/ha).

The historic analysis of surplus P loading suggests the cumulative build-up of surplus P in Wye soils has left a 'legacy' soil P reserve equivalent to 1.86 t P for every hectare of arable and productive grassland in the catchment. Only 30-60% of this legacy P input can be accounted for in the top 30 cm of soils based on a limited survey of soil total P contents of sandy and silty soils in unfarmed and farmed soils. These data suggest migration of P into the subsoil and significant losses of P to water. As surplus P inputs continue to be added each year, progressive P saturation of, and accelerated P leakage from, Wye soils is a major concern. Further work should examine the degree of subsoil P accumulation and P saturation of Wye soils across the catchment.

An updated Substance Flow Analysis (SFA) for 2021 confirms a current catchment P surplus of ca. 3000 tonnes (revised area loading of 11.4 kg P/ha) using national livestock excretion coefficients. This value is well above the UK P surplus of 5.7 kg P/ha for this year. Using local poultry P excretion coefficients supplied by the poultry industry, the catchment P surplus declines to 7 kg P/ha. A national review of livestock excretion P coefficients is warranted.

The 2021 P surplus in six sub-catchments of the English Wye varied from 1.9 kg P/ha in Yazor Brook to 16.2 kg P/ha in Garren Brook and illustrates the wide variation in manure P production across the catchment. Manure P production drives the sub-catchment P surplus and soil Olsen- P levels continue to be greatest in those catchments with the greatest manure P production. River P export (expressed as SRP) also tended to be greater in sub-catchments with higher P surpluses, but the water quality monitoring programme on which this relationship is based needs to be improved. Detailed sub-catchment maps of soil P results at 1 km^2 resolution are presented to facilitate engagement with relevant stakeholders in high-risk areas.

Scenario analysis of the impact of potential land use change on catchment P cycling and P losses to water suggests the conversion of permanent pasture to cereal cropping to provide more home-grown grain for the poultry industry would reduce the P surplus, but increase P losses to water due to the greater erosion risk. Farmscoper modelling indicated that losses to water would increase by 0.026 kg P/ha for every 10% of grassland converted. Conversion of permanent grassland to maize for anaerobic digestion plants would increase both the surplus and P losses to water; losses to water would increase by ca. 0.004 kg P/ha for every 10% of grassland converted.

1. Introduction

Soil nutrient balances, expressed as a loading of nitrogen (N) or phosphorus (P) per hectare, provide a method for estimating the annual nutrient loading of N and P to agricultural soils. They give an indication of the potential risk associated with losses of nutrients to the environment; losses which can impact on water quality. Nutrient balances are a useful high-level indicator of farming's pressure on the environment and how that will change over time with or without intervention.

Livestock farming is concentrating and intensifying in parts of England. As a result, broadly, there is a clear trend with below-average nutrient balances in the North East, East Midlands and South East in contrast to above-average nutrient balances in the North West, West Midlands and South West (Cordell et al., 2022). At a catchment level, the nutrient surpluses can be considerably higher than regional averages where livestock farming is predominant.

The Environment Agency are researching the fate of phosphorus (P) in poultry manure, and other organic manures, in the River Wye and River Lugg SAC catchments, from places of production to where the manures are recovered to land; how that is impacting on soil P indices in the catchments today and will change over time with or without intervention; and the existing links between soil P and P sources from agricultural land entering the rivers from land runoff and drainage.

A previous study and report (Phase 1) by Lancaster University summarised evidence on the current distribution of soil P levels in the Eastern (English) part of the Wye catchment and links to catchment P balances and P loading from livestock manures (Withers et al., 2022a). The Phase 1 report provided recommendations for more in-depth analysis of catchment P input pressures and their higher resolution mapping. This proposed study (Phase 2) will further develop the evidence base linking livestock farming to water quality by examining the impact of historic and potential future trends in land use on catchment P balances and cycling in the Wye catchment, and identifying potential high-risk sub-catchments based on the distribution of P input pressure, soil P levels and P loss risk to water associated with different soil types.

2. Specific Objectives/Deliverables

2.1 Overall EA objective

To investigate the potential linkages between livestock manure use, surplus P accumulation in soil and river P concentrations at existing and proposed monitoring sites in the R. Wye catchment in order to better manage P loss to water through the regulation of P inputs and soil P status. This is the wider objective of what this work forms a part.

Specific work tasks in Phase 2:

1. Undertake an historic analysis of trends in land use, livestock numbers and fertiliser use and their impact on temporal changes in agricultural P balances and legacy soil P accumulation in the Wye catchment.
2. Undertake a scenario analysis of potential future changes in land use and livestock numbers on P flows and cycling in the Wye catchment using Substance Flow Analysis.
3. Examine the current distribution of P balances and soil P levels across selected Wye sub-catchments using high resolution mapping (subject to data availability).

3. Methods

3.1 Historic analysis of surplus P loading

A historic analysis of the temporal trends in annual and cumulative surplus P loading in the Wye catchment as a result of land use change was undertaken to provide a better evidence base of the trajectory of farming pressures and manure P loading in the Wye catchment and the resultant build-up of legacy P in Wye soils.

Agricultural census data on areas and average yields of agricultural crops and numbers of livestock for the main counties within the Wye catchment (Herefordshire, Powys (Brecon, Radnorshire and Montgomeryshire prior to 1974) and Monmouthshire (largely synonymous with Gwent from 1974 to 1996)) were collated at 5-year intervals from 1870 onwards (Defra, 2023). Census data started in 1866 and are also included, but these early years are considered less reliable. Between 1974 and 1998, Herefordshire was combined with Worcestershire and during those years, the Herefordshire portion was assumed to be the same proportion of the total as in 1995, when data on each county and combined was available. In the last decade, county level census data were only available in 2013, 2016 and 2021, and all census data after 1995 were reported in somewhat less detail compared to earlier years.

Using the available census data and standard material P coefficients, the Wye catchment's annual agricultural P surplus was calculated as an annual soil P balance; the difference between annual P inputs to the soil in fertiliser and manure and annual P outputs from the soil in P offtake in all arable crops and grassland. Calculated input and output P values for a county were assumed to be evenly distributed and summed for the whole Wye catchment according to the percentage of each county within the Wye catchment boundary, and after accounting for changes in county boundaries. The three counties used in this analysis comprised 98% of the Wye catchment area. The annual P surplus was expressed as a total P loading (tonnes) and as an areal P loading (kg P/ha) across the arable and productive grassland area (excluding rough grazing). The cumulative P surplus generated over the period of analysis (1866-2021) was taken as an indication of the amount of legacy P that has accumulated in Wye soils over the last 150 years and potentially available to be exploited.

Annual overall fertiliser P inputs (kg P/ha) to arable crops and grassland from 1974 onwards were taken from British Survey of Fertiliser Practice (BSFP) data collected from the regions local to the Wye catchment (West Mercia (or Region 5 prior to 1992) and Wales (or Region 16 prior to 1992)), (Defra, 2022a). Prior to 1974, regional annual overall fertiliser P application rates were estimated from the relationship between BSFP regional overall P rate values and annual overall P rate values for the whole of England and Wales (E&W), which were based on total UK fertiliser P consumption statistics (Cooke, 1958; Thompson, 1968; Defra, 2022a). This analysis showed that rates and trends in fertiliser P use on arable and grassland in Herefordshire closely followed those in England and Wales, and that rates of fertiliser P use in Wales were ca. 80% of those used in Herefordshire.

Livestock manure P inputs were estimated as P excreted based on standard coefficients for the amounts of excreta P produced annually by each type and class of livestock in each county (Defra 2023; Rothwell et al., 2022). No adjustment was made for trends in excretal P coefficients for ruminants over the last 150 years due to changing dietary P intake, since it was assumed that temporal trends in manure P inputs to land would be driven much more by animal numbers and the volume of excreta produced rather than the P content of the excreta from healthy animals. This may be an over-simplification as cattle fed lower P diets excrete less (Ferris et al., 2010), but the level of feeding with P-rich oilcakes was already prevalent in the earlier years. Phosphorus excretion from non-ruminants is significantly less when phytase is added to the diet to breakdown phytate in cereal-base rations (Defra, 2006). For non-ruminants, current P excretion coefficients (from 2010) assume at least 70% supplementation with phytase, but phytase supplementation was not commonplace before 1995. It was therefore assumed that P excretion from pigs and poultry was 25% greater prior to 1995, 15% greater in 2000, and 5% greater in 2005 than current values from 2010 (Defra, 2006).

Annual biosolid P inputs were based on water company returns to the EA in E&W on the amounts of biosolids applied to agricultural land and their average P content. Biosolid inputs to agricultural land started in ca. 1965 (Davis, 1989), and annual application rate data were available up to 2019. Biosolid inputs to Herefordshire were assumed to be typical of those in E&W, whilst biosolids inputs in Wales were assumed to be 45% of those in E&W based on regional returns (Water UK 2010).

Offtakes of P in arable crops in each year were estimated from annual county census data on crop areas, production volumes and established P contents of harvested produce and crop residues (AHDB, 2022; Rothwell et al., 2022). Where county data on production volumes were not available, regional or average E&W or UK crop yields were used. Annual yields of temporary and mixed species permanent grass were computed from the national DM yield response to applied N in fertiliser, manures and atmospheric deposition (Qi et al., 2018), offtakes assumed 70-80% utilization established from industry recommendation (Rothwell et al., 2022), and a grass P content of 3 g/kg (AHDB, 2022), but reducing to 2.5 g/kg in the years prior to N use (Warren and Johnston, 1964). Grass production from the area of rough grazing in each county was based on Qi et al. (2018) and assumed a utilization of 25% (Haygarth et al., 1998).

Fertiliser N rates to temporary and permanent grass in each year were estimated from BSFP in the same way as for P and supplemented by an allowance for manure available N calculated from the volumes of farmyard manure and slurry spread annually and their available N content (Smith et al., 2016) together with estimates of the volumes of excretal N deposited at grazing assuming 40% of cattle and 95% of sheep excreta are deposited at grazing (Defra, 2022a). Trends in atmospheric total N deposition were taken from Fowler et al. (2004) and available N deposition was assumed to be 50% of total N based on the proportions falling as wet deposition (Phoenix et al., 2012).

Analysis of data from the Rothamsted archive suggested there was no justification for adjusting for trends in crop P content over the last 150 years. Some dilution of cereal grain P mineral density was observed when varieties changed from long straw to short straw in the mid-1960's, but impacts on phytate appear small (Fan et al., 2008).

3.2 Scenario analysis of future land use change

3.2.1 2021 baseline SFA

To provide a baseline Substance Flow Analysis (SFA) from which to assess the potential impact of future land use change, the detailed Wye catchment P SFA produced under the RePhoKUs project (Withers et al., 2022b) was updated with the latest crop and livestock census data (Defra 2023, Welsh Government pers. comm). Census data appears to significantly underestimate the poultry population in the catchment, therefore a figure of 20 million birds was used after consultation with the poultry industry.

Crop P offtake was determined on census crop areas, established crop P offtake coefficients (Rothwell et al., 2022) and regional average crop yield data (Defra, 2023). Grass P offtake was determined from census grass area, predicted grass yield using the model developed by Qi et al. (2018), utilisation and P content described above. Fertiliser input is determined from census crop areas and regional P fertiliser rates from the British survey of Fertiliser Practice (Defra, 2022a).

Livestock product (meat as live weight, milk and eggs) was estimated using the livestock population data and P content and production co-efficients established from Rothwell et al. (2022). Livestock manure P excretion was calculated from livestock population data and established livestock manure excretion coefficients (Rothwell et al., 2022). The SFA assumed that all livestock manure produced in the catchment remains in the catchment, as per the previous model. There is, however, some movement of poultry litter both into and out of the catchment area, though for the purposes of this model, they are assumed to cancel each other out. Recent investigations by the local poultry industry have produced P flows for feed, product and manure that differ from those established in this model using the current standard national Defra co-efficients. For comparison, a second baseline SFA has been produced using these industry produced data.

Loss to water from agriculture was taken from the Separate model (Zhang et al., 2014) and loss from waste water plants was estimated from balance using the P load from the human population in the catchment and a P removal efficiency established from Rothwell et al. (2022).

3.2.2 Land use change scenarios

SFA models that explore potential future land use change and their impact on the catchment P flows and overall P balance were developed. One set of scenarios were based on the conversion of grassland to cereals to supply feed for the recently-expanded poultry population. In the models the cereal production area was increased by 25, 50 and 100% from the 2021 baseline with the permanent grassland area reduced appropriately. It was assumed that the grazed livestock (cattle and sheep) produced on the converted grassland were de-stocked, so the cattle and sheep population was reduced proportional to the reduction in permanent grassland. The poultry population was assumed to remain unchanged at the 2021 baseline. All relevant material and P flows associated with the change in land use and reduced livestock population were adjusted accordingly.

A second set of scenarios based on the conversion of grassland to maize for AD feedstock were also developed. These scenarios assumed an increase in maize area in the catchment by 50, 100 and 200% from the 2021 baseline. Again, the cattle and sheep population were reduced proportional to the reduction in permanent grassland area and the poultry population remained unchanged. The baseline model assumes that 50% of the 2021 maize offtake goes to AD plants and the remaining goes to livestock feed within the catchment. In the scenarios all additional maize production above the baseline is assumed to go to AD. The digestate products of AD are assumed to be returned to agricultural land within the catchment.

Changes to losses to water from agriculture in the scenarios were estimated using Farmscoper v5 (ADAS, 2021). A baseline figure was established using the 2021 survey data and then new Farmscoper model outputs were produced for all the scenarios using the new crop and grass areas, and livestock population estimates. The percent change in the Farmscoper scenario outputs from the 2021 baseline was used to adjust the Separate model estimate used in the catchment model. Farmscoper distributes the changed land use and reduced livestock numbers across farm types based on the relative likelihood of those crops or livestock being found on certain farm types. No changes in uptake of mitigation strategies (e.g. buffer strips) were assumed in the scenarios. Farmscoper only covers the English part of the Wye catchment, so the magnitude of change was assumed to be relevant for the whole of the catchment. In the absence of more up-to-date processed-based modelling estimates, this approach provides a basic estimate of losses to water under land use change for the Wye.

To assess the impact of the land use change scenarios on P dynamics in the Wye catchment, three indicators were chosen to compare to the established baseline: Total P surplus (t), agricultural P loss to water (t) and agricultural soil P efficiency (%) which is the ratio of effective outputs from the soil surface (crops and grass) and P inputs (manure, fertiliser and biosolids).

The model is produced using STAN software (Cencic and Rechberger 2016) which applies data reconciliation and error propagation to balance the model according to assigned uncertainty of the data. Uncertainty of data flows was assessed using the systematic approach described by (Zoboli et al 2016).

3.3 High resolution mapping of soil P levels in the Wye catchment

3.3.1 Sub-catchment soil P level maps

In collaboration with local agronomists, recent analysis results for soil Olsen-P status (mg/L and P Index) across the Eastern (English) half of the Wye catchment area were collated and statistically summarised (see Phase 1 report). The sampled farms spanned the sub-catchment areas of the rivers Lugg, Frome, Monnow, Garren, Yazor and the larger river Wye. The soil P results were aggregated across 1 km^2 to give a mean P Index and assess the proportion of samples with Olsen-P values above the agronomic optiumum. Soil P data for the Arrow sub-catchment were too sparse to include.

The sub-catchment areas were matched to the location of river flow gauging stations across the Wye catchment, and boundaries of the upstream drainage area were downloaded from the National River Flow Archive (UKCEH, 2023).

3.3.2 Sub-catchment P balances

Soil P balances were determined for 6 sub-catchments of the rivers Lugg, Arrow, Frome, Monnow, Garren and Yazor (Figure 14 appendix). The methodology was the same as for the catchment SFA above using the same crop and livestock co-efficients and regional fertiliser data. Sub-catchment crop areas and livestock numbers were obtained from the Defra 2021 census and Welsh Government. However, different to the whole catchment SFA, census poultry numbers were principally used, rather than industry estimates due to difficulties assigning a spatial distribution to the whole catchment industry estimate. The only exception to this were the poultry numbers for the Yazor sub-catchment that used an industry estimate as the Defra census data returned zero broilers due to data redaction owing to the number of farms present. Biosolid P input was assumed to reflect the rate of application across the whole catchment.

The balance uses a simple input/output approach and again assumes that manure produced in the sub-catchment stays in the sub-catchment. At this scale, there is likely some export of manure out of the area, though without more detailed local investigation, determining this is difficult. The balance, particularly the manure component should therefore be treated with a degree of caution.

3.3.3 Sub-catchment P balance and water quality

To assess potential links between the catchment P surplus and river P pollution, annual river P exports at the outlet of the sub-catchments and at Redbrook (whole catchment oulet) were calculated as the product of annual average flow at the gauging station, and the average flow-weighted SRP concentration, which was based on monitored SRP concentrations at the nearest water quality monitoring station to the gauging station for the period 2010-2021. This long time series was necessary because of the low and inconsistent sampling frequency of more recent data, large data gaps and/or a marked and consistent reduction in SRP concentrations after 2010 compared to earlier years (e.g. Frome and Garren). For the Monnow and Lugg sub-catchments, available data after 2010 was either totally absent or too sparse and for these two catchments the SRP data going back to 2000 was used. These estimates of sub-catchment river P export therefore come with large uncertainty and must be treated with caution.

4. Results and Discussion

4.1 Historic analysis of land use change and surplus P loading

4.1.1 Land use change

Temporal trends in land use have been separated into the English (Herefordshire) and Welsh (Powys and Monmouth) parts of the Wye catchment in view of the distinct differences in landscape and land use characteristics between the two areas. In Herefordshire, permanent grass increased at the expense of arable land up until the second World War when much grassland was ploughed up for crop production (Figure 1b). This general increase reflects the need for grass to feed an expanding cattle and sheep population (Figure 1c). After the war, areas of permanent grass and arable crops were equal until 1975 when the grassland area decreased as cattle and later sheep numbers started to decline and the arable area increased. The expansion of the arable area was mainly as cereals until 1985 and potatoes until 2000, with maize areas increasing rapidly after 2000 (Figure 1a). Cereals also have started to increase again from 2005. Pig numbers have fluctuated wildly and are now the same as in the 1870's. In contrast poultry numbers increased exponentially to a current level of ca. 11 million birds, although it is now well known that numbers are actually much greater than this because of the inaccuracy of census data for livestock with a high turnover rate in house.

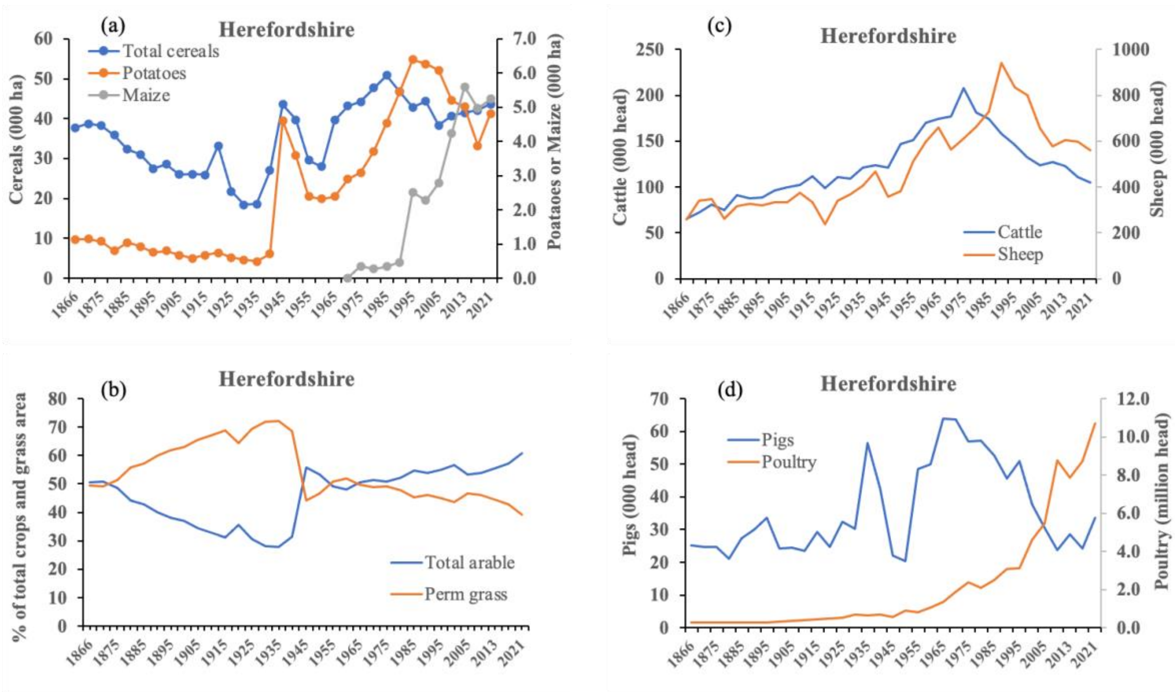


Figure 1. Temporal changes in (a) the areas of cereals, potatoes and maize; (b) the areas of arable (crops and temporary grass) and permanent grass as a proportion of the total area of crops and grass; (c) the numbers of cattle and sheep and (d) the numbers of pigs and poultry in Herefordshire from 1866-2021 using county level statistics.

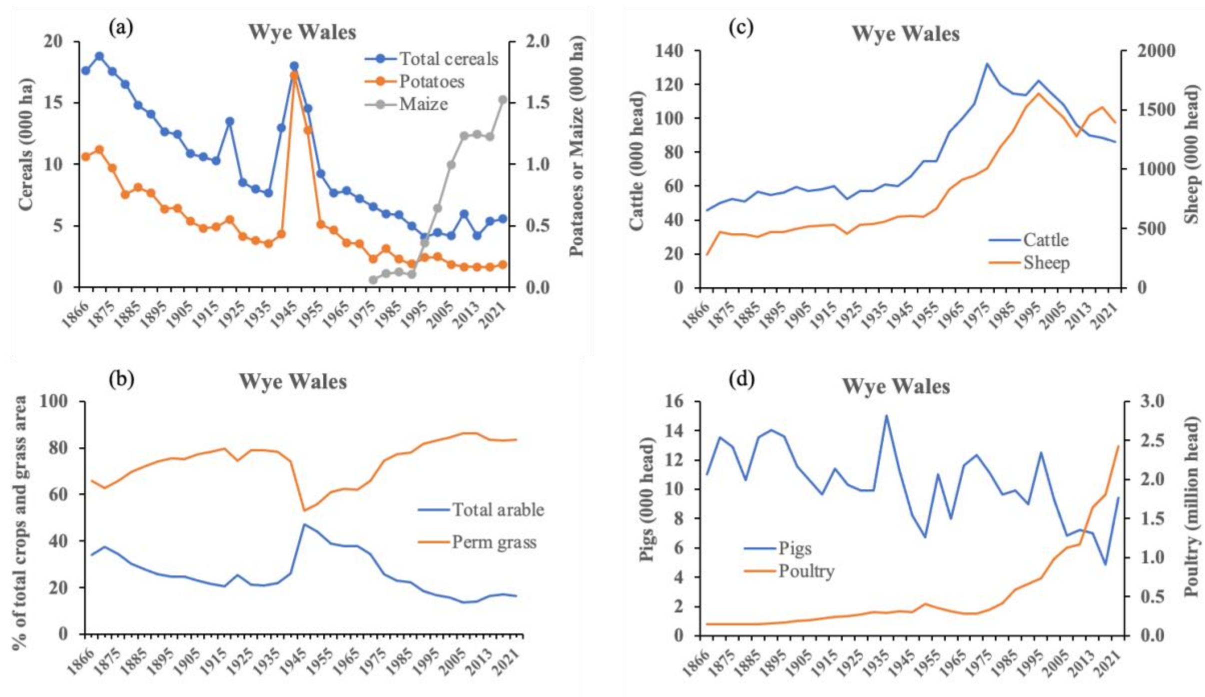


Figure 2. Temporal changes in (a) the areas of cereals, potatoes and maize; (b) the areas of arable (crops and temporary grass) and permanent grass as a proportion of the total area of crops and grass; (c) the numbers of cattle and sheep and (d) the numbers of pigs and poultry in the Wye in Wales from 1866-2021.

Temporal trends in land use in Wye Wales followed a similar pattern to those in Herefordshire up until the War as cattle and sheep numbers increased (Figure 2c). However, unlike Herefordshire, arable crops (e.g. cereals and potatoes) continued to decline after WW2 in favour of an expansion in permanent grass despite a slight fall in ruminant livestock numbers after 1995 (Figure 2a and b). Some of this grassland expansion is due to conversion of rough grazing land (as total arable and grass areas have increased in Wales), but may also be due to a trend for more production from grass rather than bought-in cereals. Of the arable crops, only maize has shown a large increase as in Herefordshire, and more recently cereal areas have started to increase again since 2000. Pig numbers have generally declined over time, but as in Herefordshire, there has been an explosion in poultry numbers, which are known to be a large underestimate.

Cereals, potatoes and maize are a high-risk crop for P loss in and runoff due to their generally higher soil P status, greater erosion risk and vulnerability to compaction during harvesting. Since 2005, these crops have changed by +13%, -21% and +88%, respectively in Herefordshire and by +33%, 1% and +53%, in Wye Wales. Recent increases in the cereal area may be driven by the need for more home-grown cereals to feed the growing poultry industry, whilst increases in the maize area are being driven by the need for feedstock for anaerobic digestion (AD) plants.

4.1.2 Surplus P loading

The analysis of the annual surplus P loading to Wye soils since 1866 provides a contextual evidence base to the patterns of historic P use in the catchment, the extent of P accumulation in the Wye catchment landscape and an estimate of the likely magnitude of the total legacy soil P reserves that pose a long-term source of P loss to draining rivers. The analysis is constrained by some uncertainties: (a) the accuracy of spot census surveys in June and December each and the inconsistent reporting of this data, especially since 1980; (b) county level census statistics may not fully represent that portion of the Wye catchment in that county; (c) exports and imports of manures out of and into the catchment are not quantified and are assumed to balance out, and (d) fertiliser consumption data prior to 1966 is based on literature and industry estimates rather than actual survey data. However, these uncertainties are not considered to compromise the general trends observed or the estimation of legacy soil P reserves.

<u>Fertiliser:</u> Fertiliser P use increased steadily from its first use in the 1850's up to 1913 and more slowly thereafter until the early 1930s when use declined during the depression years (Cooke 1958), Figure 3a. Consumption increased again sharply after the second World War as UK agriculture intensified and reached a peak in the early 1980s with an overall application rate of ca. 15 kg P/ha. Since then, annual consumption has shown a general decline, probably reflecting reduced farm profit margins and greater farmer awareness of the financial benefits of better nutrient planning and increased efficiencies of P use (Figure 3a). Significant falls in consumption occurred in individual years due to the oil crisis in the early 1950s, and in 1975 and in 2008 when the cost of phosphate rock increased sharply (+400%) due to a combination of market forces, rising energy costs and/or export bans (Brownlie et al., 2023). The industry is currently experiencing another large price hike in fertiliser costs, with further uncertainties over future supplies due to the Ukraine war. Current overall inorganic P fertiliser inputs across the catchment for arable crops and grass average only 5 and 2 kg P/ha, respectively for the English Wye and 10 and 4 kg P/ha, respectively for the Welsh Wye.

<u>Manures:</u> Phosphorus inputs to Wye soils in livestock manures increased relatively slowly up to 1945 (with small declines during the 1880 and post WW1 depression years), but then increased sharply up to ca. 1980 and the early 1990s as the livestock industry expanded (Figure 3b). Thereafter annual manure P inputs have remained fairly static at around 5000 tonnes tempered by a succession of major disease outbreaks (BSE in the 1980s and foot and mouth in 2001) and a general fall in animal numbers, except for poultry. The poultry industry is the only sector which is still expanding.

<u>Biosolids:</u> Inputs of P from wastewater biosolids applied to land commenced in the 1960's and gradually increased, rising more sharply after the ban on dumping of sewage to sea in 1998. Total biosolid P inputs reached an apparent peak in 2005 (Figure 3b), but after accounting for some misreporting of volumes spread, are typically just over 300 tonnes. Although application rates of biosolid P are very high where they are spread (over 100 kg P/ha), their overall contribution to the total catchment manure P is very small (ca. 6%) because of the relatively small area of land receiving biosolids.

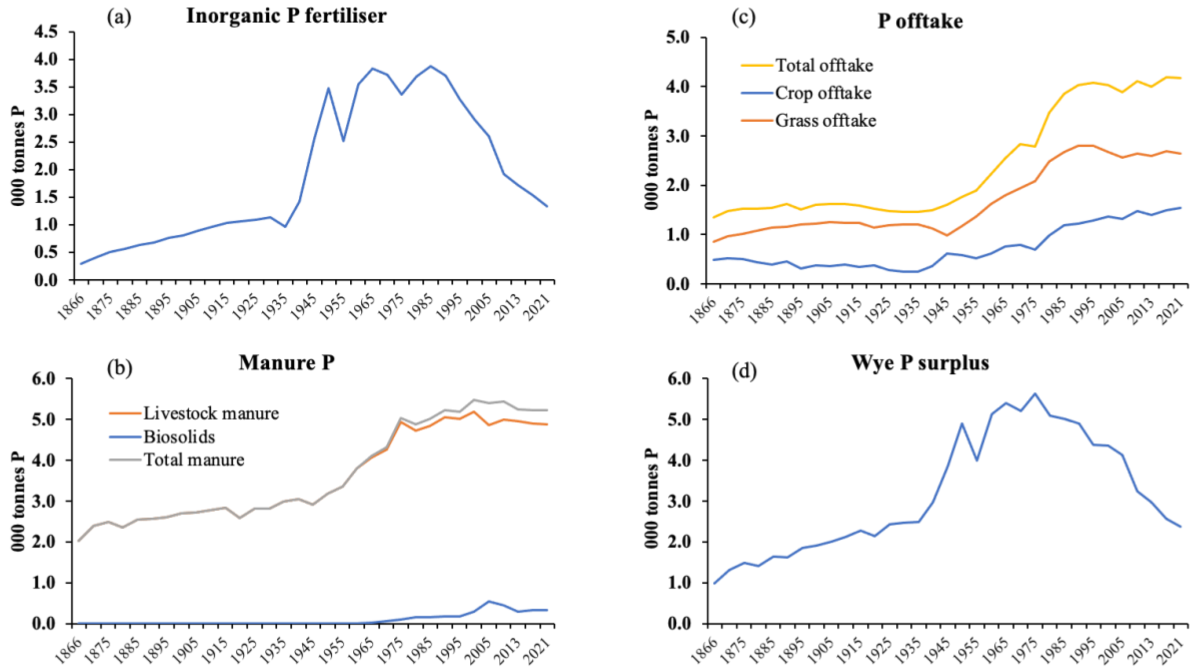


Figure 3. Temporal trends in the amounts of phosphorus (P) cycling annually in the Wye catchment as (a) fertiliser, (b) manures, (c) crop offtake and (d) in surplus accumulating in soils from 1866 to 2021.

<u>*Crop Offtake:*</u> Amounts of P removed in arable crops and grassland across the Wye catchment remained fairly constant until after the second World War when crop P offtakes increased exponentially with the introduction of new higher yielding varieties, increased nitrogen (N) use, better disease control and streamlined soil and crop management (Dungait et al., 2012). Total P offtake reached a peak in the 1990s and has remained relatively constant since. The temporal trends in P offtake were similar for both arable crops and grassland, with the latter accounting for approximately 70% of total P offtake in the Wye catchment (Figure 3c).

<u>*Surplus P loading:*</u> Even in 1870, there was a surplus of P inputs to the Wye catchment area of ca. 1000 t (4 kg P/ha), reflecting the continuing contribution of animal production in the region and low amounts of crop P offtake, largely due to N and to a lesser extent P limitation (Figure 3d). In the late 19th century, P was already being applied in bones, guano and superphosphate (Thompson, 1968), whilst inorganic fertiliser N use on crops and grass did not commence until after the second World War. Similarly, there were large imports of oilseed cake to supplement grass intake and animal feed rations to sustain an expanding livestock industry (Thompson, 1968). Surplus P increased steadily until 1940 (12 kg P/ha) and then more rapidly when N and P fertilisers use increased. Surpluses of P reached a peak in 1975 (23 kg P/ha), and have steadily declined since to a current level (ca. 9 kg P/ha) that is the same as in the 1920's. Note that these current estimates of surplus are based on county level census statistics, and will be different to the more accurate P surplus calculated in the SFA (see section 4.2). The current UK P surplus for 2021 is estimated at 5.7 kg P/ha (Defra, 2022b).

4.1.3 Legacy phosphorus

The total amount of surplus P that has accumulated in the Wye catchment soils over the last 150 years can be calculated at over 500,000 tonnes (Figure 4), and represents a potential reserve of legacy soil P that can be relied upon to sustain crop and grassland production when inorganic fertiliser imports become prohibitively expensive. For example, the sharp 2008 fertiliser price increase resulted in farmers taking a 'P holiday', leading to a decline in national fertiliser P consumption but without any reduction in agricultural output. This cumulative surplus equates to an average legacy soil P reserve over the cropped and productive grassland area of the Wye catchment in 2021 of ca. 1.86 t P/ha. The value of these legacy P reserves in sustaining crop yields was reported in the RePhoKUs project

(Withers et al., 2022b). Interpretation of the results from the pot based legacy P trial undertaken at the Lancaster Environment Centre suggest that a typical arable crop rotation could be sustained for between 2 and 10 years on the farms analysed without any P input before experiencing yield penalty.

If this total soil P reserve was distributed over 30 cm depth of soil, and taking account of average soil bulk density (1.3 g/cm^3), the cumulative surplus P loading would be expected to increase the soil total P content by 465 mg/kg. A recent but limited study of topsoil total P concentrations in farmed and unfarmed areas in the Wye catchment suggested an accumulation of 286 mg/kg total P in very sandy soils and 134 mg/kg in silty soils. These data suggest that there has been significant migration of surplus P into the subsoil and/or substantial loss of P to the wider environment. Subsoil P enrichment will increase the risk of P mobilisation and loss in drain flow during storm events and/or lead to P leaching into groundwater. These data also question the degree to which intensely farmed Wye soils are already saturated with P sufficiently to cause P migration down the soil profile and a reduced capacity to absorb further additions of P without significant P leakage to water (Chakraborty and Prasad, 2021).

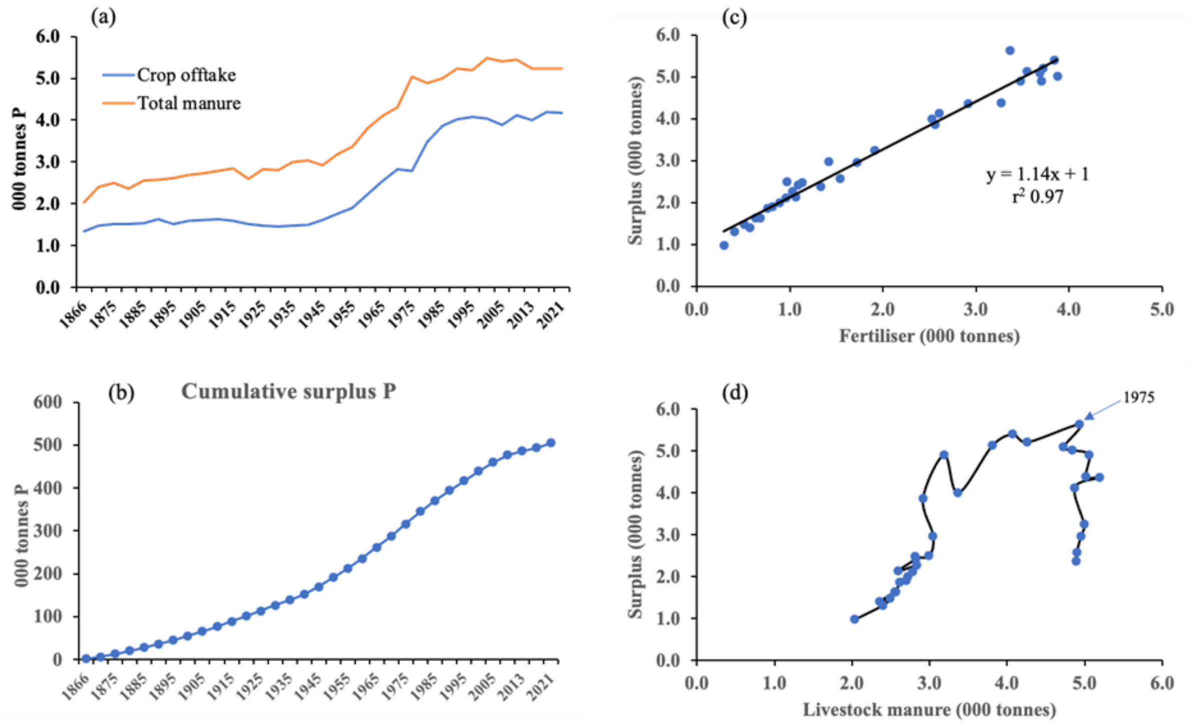


Figure 4. The temporal trend in the amounts of (a) annual total manure inputs relative to crop annual P offtake and (b) the cumulative P surplus that has accumulated in Wye soils since 1866. Annual surpluses correlate strongly with inorganic fertiliser inputs (c) but the main driver of the annual P surplus is the pattern of livestock farming (d).

4.2 Updated catchment SFA and scenario analysis of future land use change

4.2.1 Catchment SFA

The 2021 Wye catchment SFA model output (Figure 5) shows that the catchment imported ca. 6500 t P and exported ca. 3500 t P. The largest P import into the catchment is as livestock feed (ca. 5300 t) and mineral P fertiliser use in the catchment imports ca. 1200 t P. The largest internal flow of P is as livestock manure (ca. 5300 t) and the catchment exports ca. 3500 t P in agricultural products. Agricultural soil P efficiency for the catchment is around 52% meaning that nearly half of applied P is accumulating as legacy P or lost to the aquatic environment. For comparison, UK national soil P efficiency is around 65% (Rothwell et al., 2022). The input/output balance leaves and annual P surplus of ca. 3000 t P yr for the catchment, this is an average of 11.4 kg/ha across managed agricultural land in the catchment. This areal average value is different from previous estimates (Withers et al., 2022b) due to different agricultural land areas reported from different data sources used in different years. However, the total catchment P surplus remains consistent. Losses to water are estimated at ca. 93 t P from waste water treatment and ca. 225 t from agricultural sources. However, the agricultural data from the Separate model uses 2010 agricultural census data so is outdated.

Using the poultry industry supplied data (Figure 15, appendix), the catchment imports reduce to ca. 5500 t P of which ca. 4200 t P was in livestock feed. The P in manure flow reduces to ca. 4000 t P and catchment exports increase slightly to ca. 3700 t P. Soil P efficiency is calculated as 65% using these data which is the same as the national average. Using these data, the catchment surplus reduces to ca. 1700 t P yr which is the equivalent of an average 7 kg P/ha across the catchment.

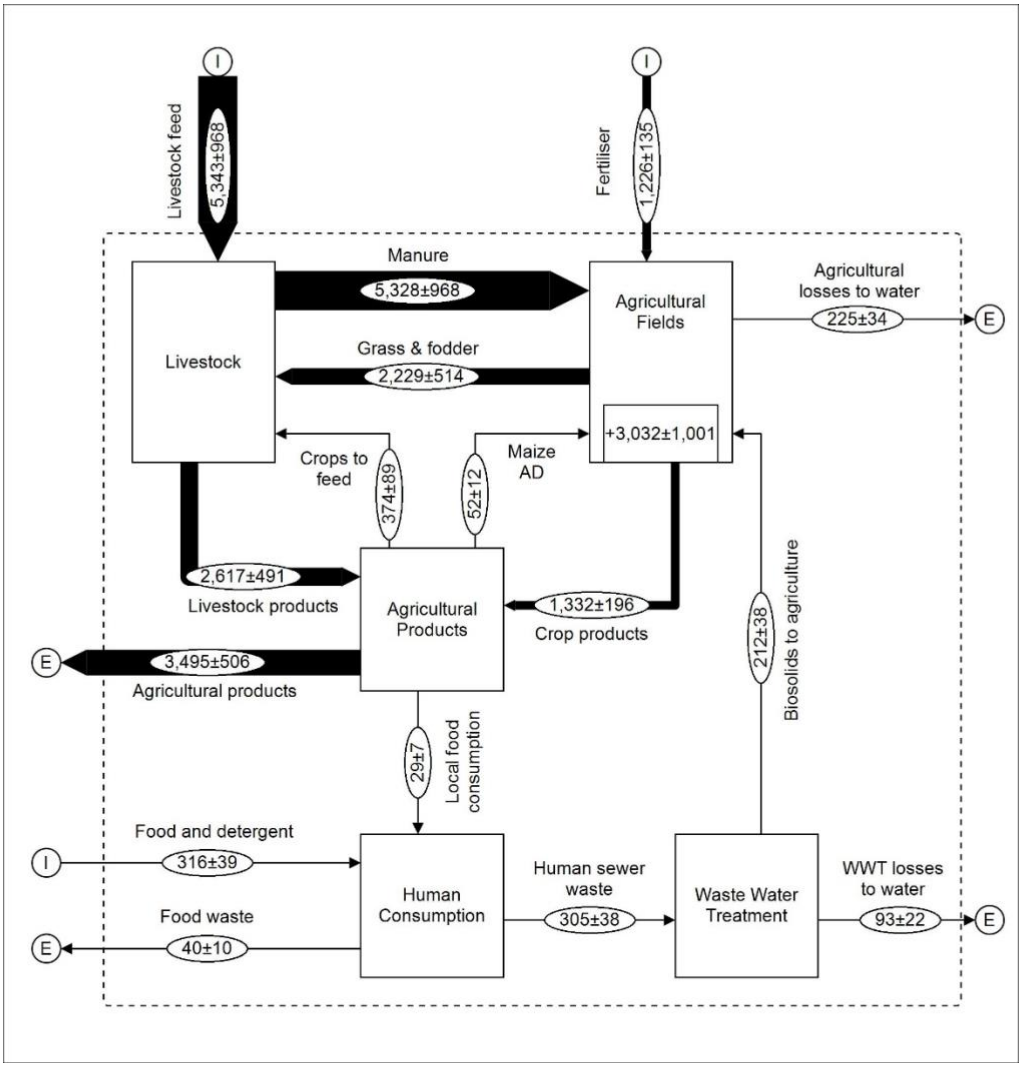


Figure 5. Substance Flow Analysis (SFA) for the Wye catchment. All flows are ± uncertainty (t/P/yr) for the year 2021.

The industry argues that feed conversion efficiency has increased considerably in recent years. Their bird excretion estimates are based on recorded feed volumes, numbers of birds produced and samples of poultry litter (including bedding) from 120 farms, and wet chemistry was used to establish P contents of the feed and manure. With this, P flows in feed, product and manure were estimated. The industry generated numbers vary significantly from those generated using the current Defra co-efficients, but have yet to be substantiated and clearly warrants further investigation. Whether these are representative of the wider poultry industry also remains unclear.

4.2.2 Land use change scenarios

The land use change scenario analysis indicated that an increase in cereal production to supply the poultry industry (Figures 16, 17, 18, appendix) would reduce total catchment agricultural P imports from the 2021 baseline to between ca. 6400 (-2.4%) and 5700 t (-13%). This is likely because less feed P is required by the reduced ruminant population (Table 1) and more of the poultry feed demand is met by grain produced in the catchment area. The system indicators (Table 2) suggest that the catchment P surplus decreases with increased cereal area by between 136 and 790 t/yr to a lowest value of ca. 2200 t P with a 100% increase in cereal production from the 2021 baseline. This is likely due to the shift from livestock production to arable (Table 1), which is generally much more efficient in its P use (Rothwell et al., 2022), and less manure production. Importantly though, these scenarios assume that the poultry population remains at its 2021 level. Any increase in the catchment poultry population would likely limit any reduction in surplus due to the increased manure production.

Farmscoper analysis suggests that the increase in cereal area is likely to increase agricultural losses to water by 0.026 kg P/ha for every 10% of grassland converted (up to an additional 76 t/yr in the 100% cereal increase). This is likely due to the increased risk of soil erosion from tillage-based agriculture over permanent pasture, although the risk of soil erosion can be reduced by good management practices (which were not included in this analysis). Ploughing up permanent grassland also increases N leakage, and greatly reduces soil carbon stocks, especially in the first few years after conversion (Whitmore et al., 1992; Johnston et al., 2009). Catchment soil P efficiency increases with the larger cereal area, increasing from the 2021 baseline by between 3 and 16% up to a maximum of 61% in the 100% cereal change scenario.

Table 1. Changes to relevant crop and grass areas, and livestock populations in the land use change scenarios.

	2021 Baseline	**Cereals 25%**	**Cereals 50%**	**Cereals 100%**	**Maize 50%**	**Maize 100%**	**Maize 200%**
Permanent grass area (ha)	177,856	167,217	156,579	135,301	174,884	171,911	165,965
Cereal production area (ha)	42,556	53,195	63,834	85,111	42,556	42,556	42,556
Maize production area (ha)	5,946	5,946	5,946	5,946	8,919	11,891	17,837
Cattle population (head)	173,632	165,126	156,620	139,608	171,255	168,878	164,125
Sheep population (head)	2,230,870	2,121,583	2,012,296	1,793,723	2,200,332	2,169,794	2,108,718

Converting grassland to maize land use for AD would slightly increase the total catchment agricultural P import by around 2.5% in all three scenarios, with likely increases in fertiliser import slightly outweighing reductions in feed P import from the reduced ruminant population (Figures 19, 20, 21, appendix). The system indicators (Table 2) show that the catchment P surplus is slightly higher than the 2021 baseline in all three scenarios, with the highest surplus (3172 t P) occurring with a 50% increase in maize area. This surplus increase is most likely due to the increased P fertiliser import and use to meet the maize crop demand. The surplus then actually decreases slightly with increasing maize area, likely due to the increasing influence of reducing the ruminant population which is inherently P inefficient (Rothwell et al., 2022).

Losses to water from agriculture are predicted to increase by 0.004 kg P/ha for every 10% of grassland converted to maize (up to an additional 22 t/yr in the 200% maize scenario), again likely due to the increased risk of erosion from bare soils typical with maize production. However, again, good management practice can mitigate some of these impacts. Agricultural soil P efficiency is not significantly altered in these maize scenarios increasing up to a maximum of 55% in the maize 200% scenario.

Table 2. Impact of the land use change scenarios on the three system indicators. Change from the 2021 baseline is shown as both a mass change (t P) where relevant and a % change.

		Land use change scenarios								
Indicator	**2021 baseline**	**Indicator value**	**Mass change**	**% change**	**Indicator value**	**Mass change**	**% change**	**Indicator value**	**Mass change**	**% change**
Cereal scenarios		**Cereals 25%**			**Cereals 50%**			**Cereals 100%**		
Surplus (t P)	3032	2896	-136	-4.5	2683	-349	-12	2242	-790	-26
Ag loss to water (t P)	225	244	19	8.4	259	34	15	301	76	34
Ag soil efficiency (%)	52	54	n/a	2.9	56	n/a	7.2	61	n/a	16
Maize scenarios		**Maize 50%**			**Maize 100%**			**Maize 200%**		
Surplus (t P)	3032	3172	140	4.6	3148	116	3.8	3102	70	2.3
Ag loss to water (t P)	225	231	6	2.7	237	12	5.3	247	22	10
Ag soil efficiency (%)	52	52	n/a	-1.0	53	n/a	0.6	55	n/a	4.8

4.3 High resolution mapping of soil P levels in the Wye catchment

4.3.1 Distribution of soil Olsen-P

The distribution of soil Olsen-P Indices across the Eastern (English) half of the Wye catchment at 1 km^2 resolution is shown in Figure 6, and more detailed sub-catchment maps of soil P results are presented in Figures 7-11 to facilitate engagement with farmers and relevant stakeholders in high-risk areas of P loss related to elevated soil P levels and erosion-prone soils. The mean soil P Index and percentage of sample results above the agronomic optimum (P Index 2) was high in the Garren Brook (4.1 and 94%, respectively), and relatively similar across other sub-catchment areas (2.1-2.6 and 37-56%, respectively).

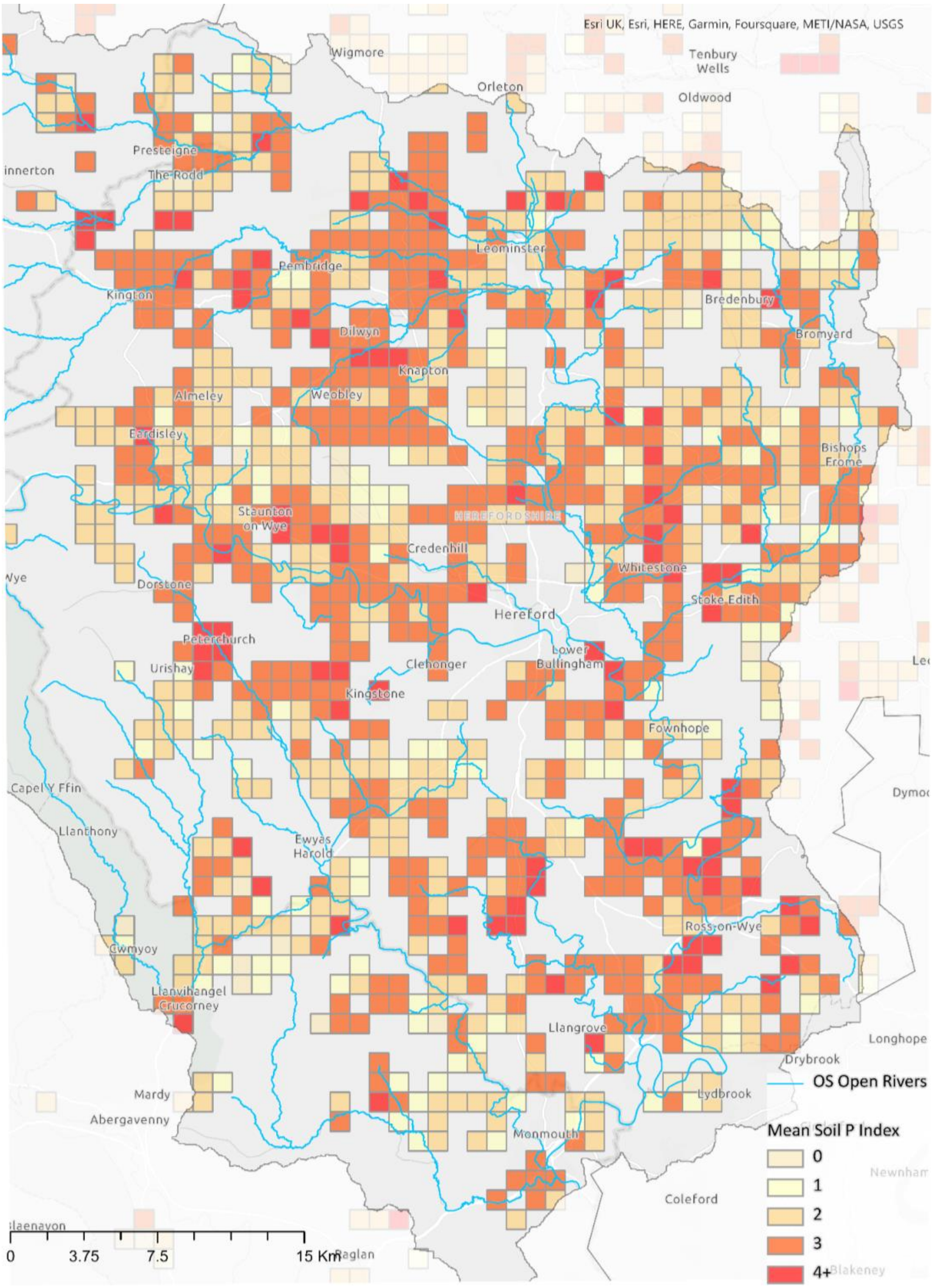
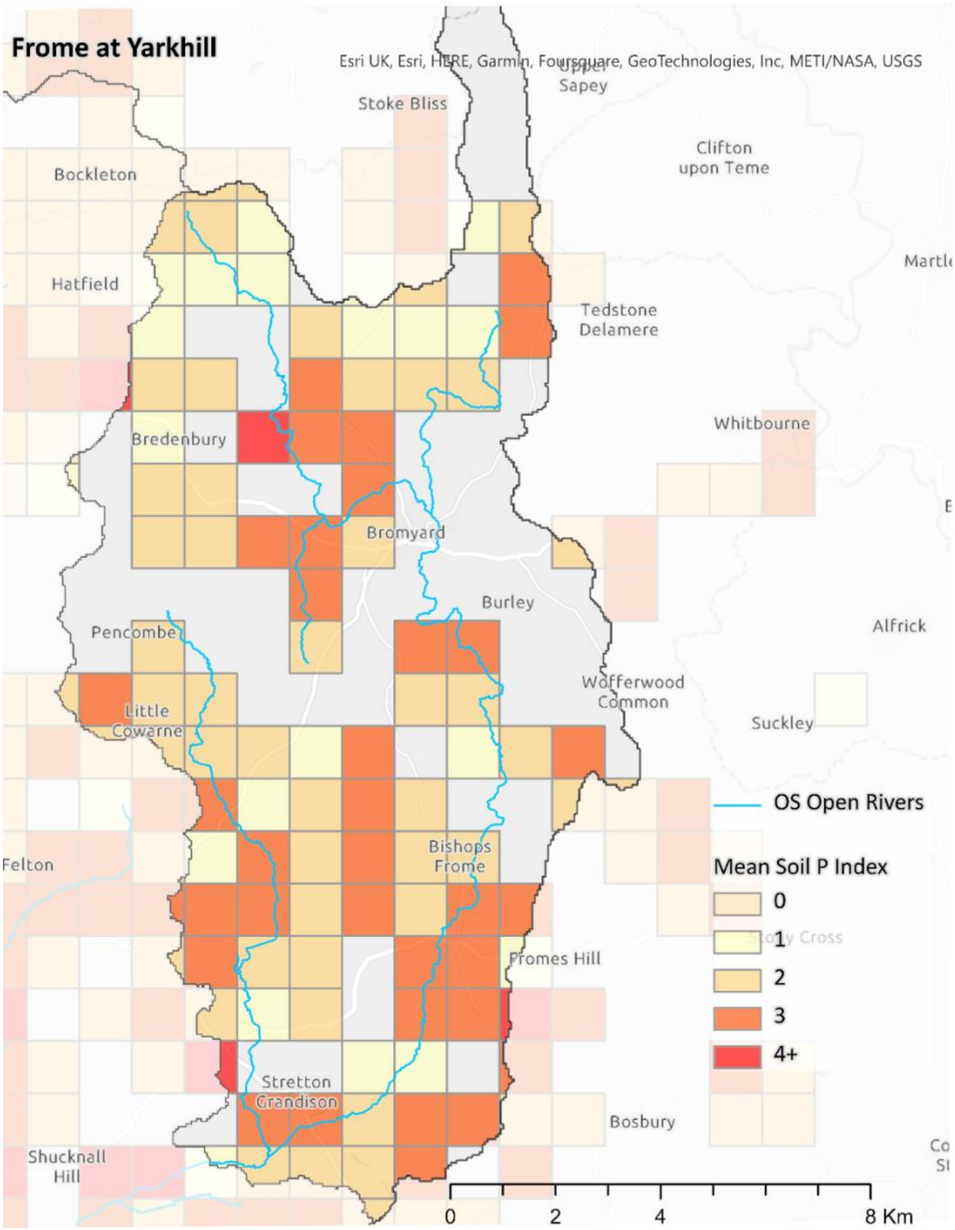


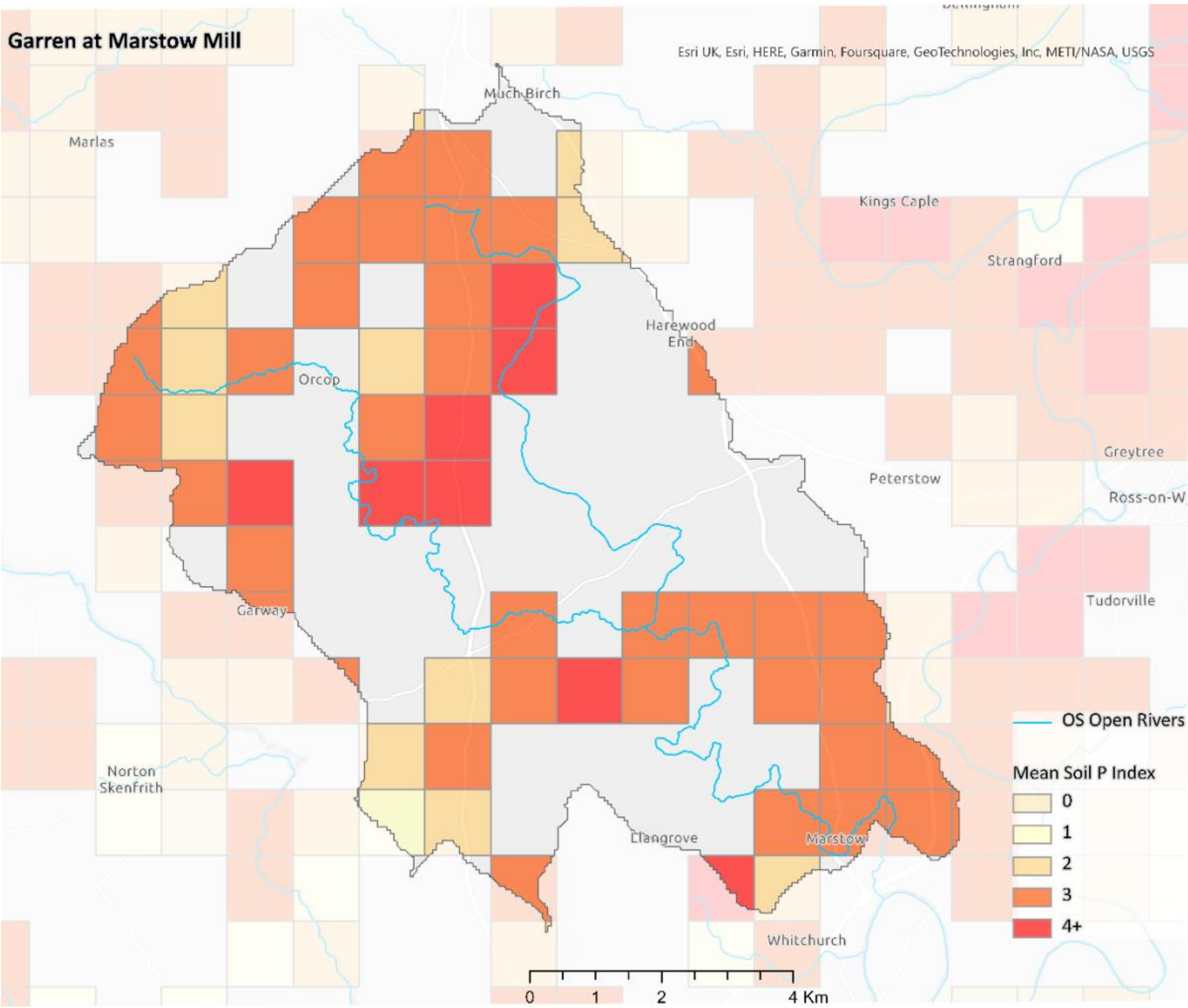
Figure 6. Wye mean Soil P Index distribution at 1 km^2

4.3.2 Subcatchment soil P maps



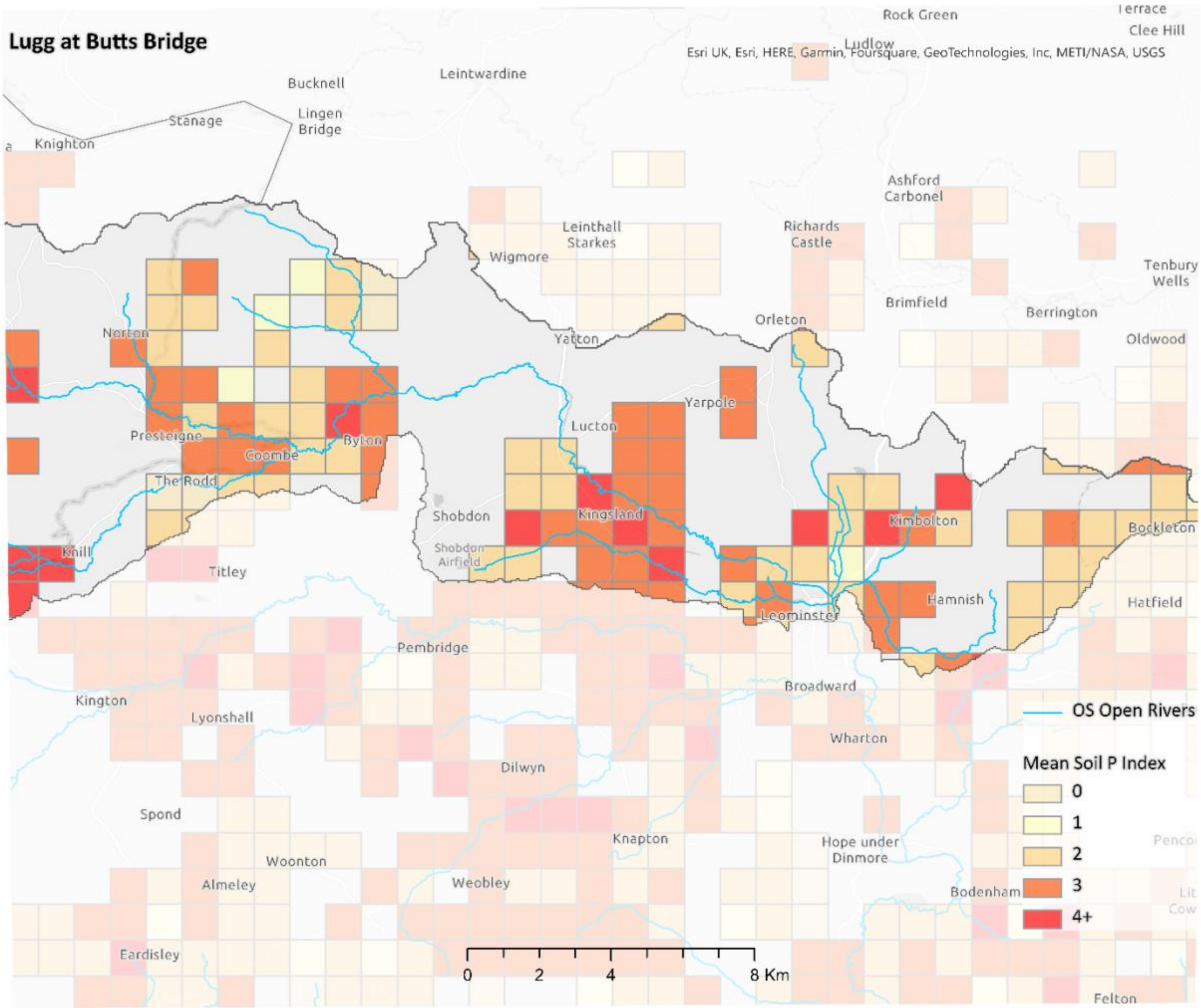
	P Index	Ha	No. samples	% distribution of P index
Frome at Yarkhill	0	21	6	1
	1	427	74	17
	2	1159	191	45
	3	765	133	30
	4	190	26	7
	5	6	2	0
Area weighted mean soil P index	2.3			
% area above agronomic optimum				37

Figure 7. Frome at Yarkhill mean Soil P Index at 1 km^2 (catchment boundary from National River Flow Archive (UKCEH, 2023))



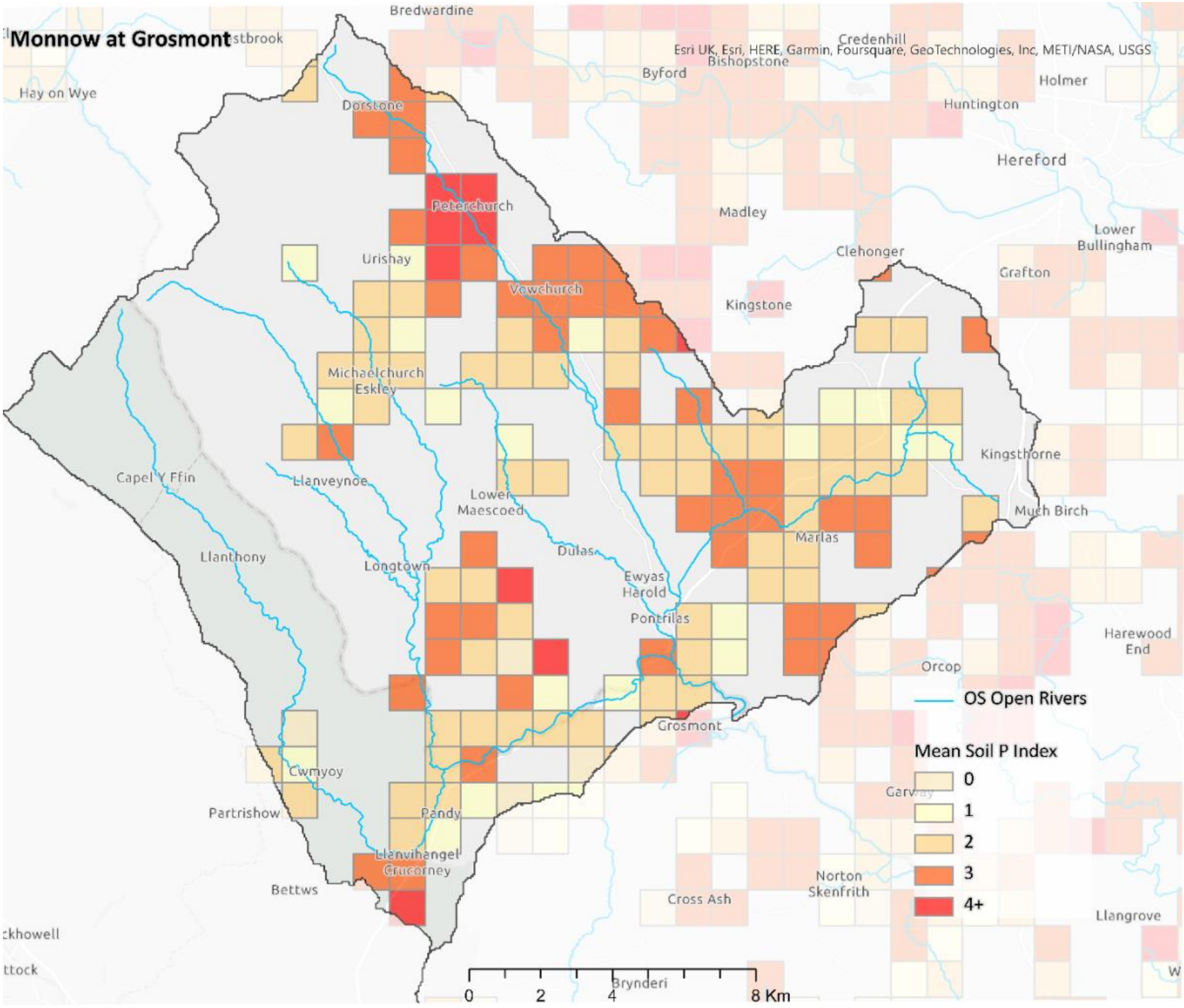
	P Index	Ha	No. samples	% distribution of P index
Garren at Marstow Mill	1	9	3	1
	2	61	14	5
	3	223	56	18
	4	567	134	45
	5	343	51	27
	6	47	8	4
Area weighted mean soil P index	4.1	3	1	0
% area above agronomic optimum				94

Figure 8. Garren at Marstow Mill mean Soil P Index at 1 km^2 (catchment boundary from National River Flow Archive (UKCEH, 2023))



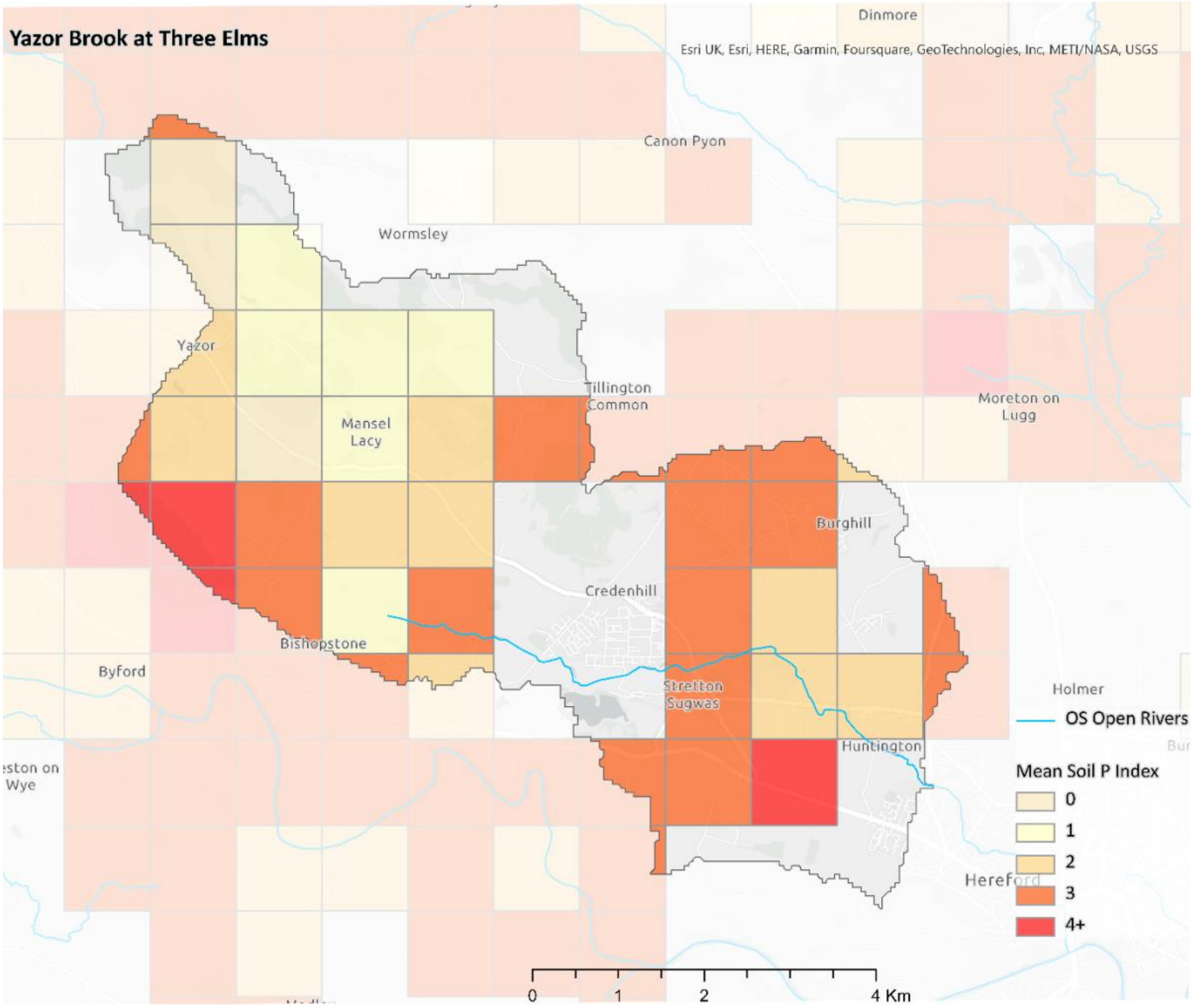
	P Index	Ha	No. samples	% distribution of P index
Lugg at Butts Bridge	0	87	18	3
	1	265	70	10
	2	768	164	30
	3	991	186	39
	4	371	63	15
	5	43	8	2
	6	6	1	0.2
Area weighted mean soil P index	2.6			
% area above agronomic optimum				56

Figure 9. Lugg at Butts Bridge mean Soil P Index at 1 km^2 (catchment boundary from National River Flow Archive (UKCEH, 2023))



	P Index	Ha	No. samples	% distribution of P index
Monnow at Grosmont	0	53	18	1
	1	457	134	12
	2	1538	369	40
	3	1479	289	39
	4	257	52	7
	5	26	5	1
Area weighted mean soil P index	2.4			
% area above agronomic optimum				46

Figure 10. Monnow at Grosmont mean Soil P Index at 1 km^2 (catchment boundary from National River Flow Archive (UKCEH, 2023))



	P Index	Ha	No. samples	% distribution of P index
Yazor Brook at Three Elms	0	106	18	10
	1	247	34	23
	2	281	42	26
	3	338	70	32
	4	93	22	9
Area weighted mean soil P index	2.1			
% area above agronomic optimum				40

Figure 11. Yazor Brook at Three Elms mean Soil P Index at 1 km^2 (catchment boundary from National River Flow Archive (UKCEH, 2023))

4.3.3 Sub-catchment P balances

There was a large variation in the soil P balances across the sub-catchments (Table 3), the largest being around 16.2 kg/ha in the Garren, the lowest was 1.9 kg/ha for the Yazor Brook. Manure P production within the sub-catchment was a strong predictor of P balance with areas of highest manure P production having the largest P surplus (Table 3). Similarly, those sub-catchments with highest manure P production had the highest mean soil P Index (Figure 12) suggesting that manure P production may be associated with high soil P status. The high manure P production in the Garren sub-catchment was largely attributed to poultry (67% of total manure P), whilst in most other sub-catchments poultry manure represented 24-34% of manure P production, except in the much smaller Yazor Brook sub-catchment where it accounted for 61%. However, as we assume all manure produced in the sub-catchment remains in the sub-catchment this result should be treated with caution as there is likely some export out of the sub-catchment which cannot be accounted for in this case.

4.3.4 Linking catchment P surpluses to river water quality

Calculated river SRP export across the sub-catchments varied from 0.14 to 0.43 kg/ha, and there was a significant positive (but weak) relationship between the sub-catchment P surplus and river P export (Figure 13). Whilst consistent with previous research (Withers et al., 2022b), insufficient river water quality monitoring data makes it difficult to evidence this linkage with more certainty.

Table 3. Sub-catchment P inputs and offtakes, total and areal soil P balances, all values are per year for 2021

Sub-catchment	P input (t)		P offtake (t)		Ag area ex. rough grazing (ha)	P balance (t)	P balance (kg/ha) ag area	P balance (kg/ha) total land area
Monnow	Fertiliser	37	Crops	102	24361	129	5.3	3.6
(354 km^2)	Manure	377	Grass	203				
	Biosolids	15.3						
Lugg	Fertiliser	63	Crops	167	27880	115	4.1	3.1
(371 km^2)	Manure	411	Grass	213				
	Biosolids	10.2						
Frome	Fertiliser	41	Crops	36	12657	114	9	7.9
(144 km^2)	Manure	261	Grass	5.24				
	Biosolids	9.6						
Garren	Fertiliser	26	Crops	75	8542	138	16.2	15.2
(91 km^2)	Manure	236	Grass	55				
	Biosolids	6.5						
Arrow	Fertiliser	8	Crops	12	8902	100	11.2	7.9
(126 km^2)	Manure	186	Grass	88				
	Biosolids	2.3						
Yazor	Fertiliser	11	Crops	41	2908	5	1.9	1.3
(42.3 km^2)	Manure	40	Grass	8				
	Biosolids	2.2						

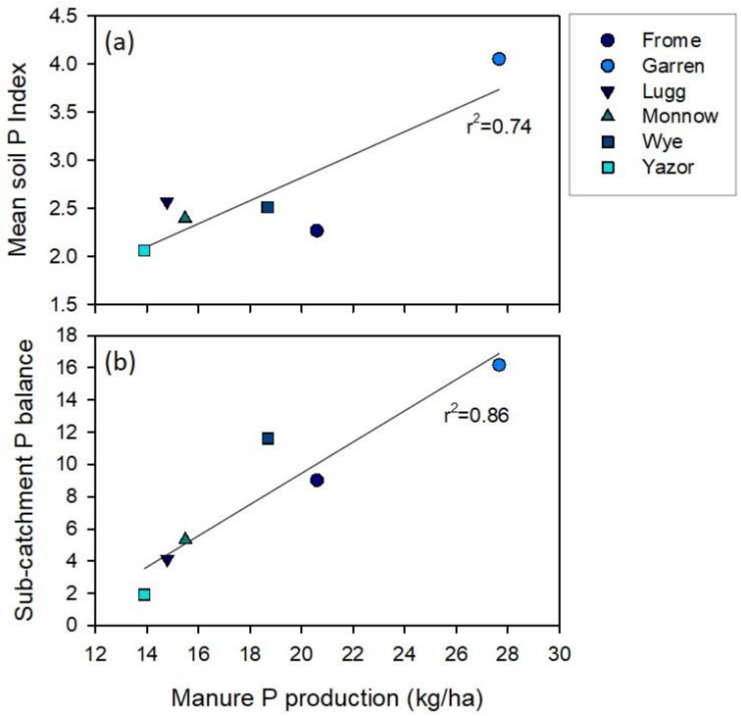


Figure 12. Relationship between manure P production and mean soil P index (a) and manure P production and P balance (b) for selected sub-catchment areas. The overall values for the entire Wye catchment are included for reference.

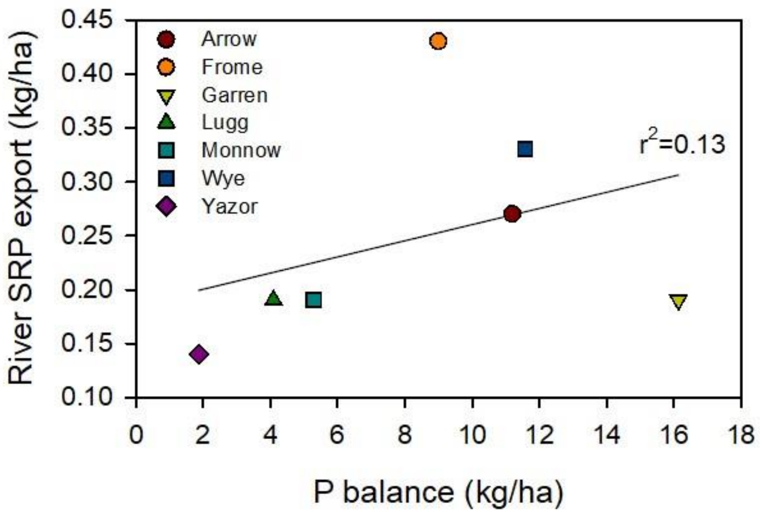


Figure 13. Catchment annual P surplus is positively but weakly related to the average annual SRP export at sub-catchment outlets.

5. Conclusions

1. An historic analysis of census-derived land use and livestock numbers indicates the Wye catchment has been in P surplus for the last 150 years. From a value of 4 kg P/ha in 1870 to 8.6 kg P/ha in 2021, peaking in 1975 (23 kg P/ha) coincident with rapid agricultural intensification after the second World War. The current surplus is the same as it was in the 1920s. Trends in the annual P surplus were related most to the amount of fertiliser P imported into the catchment because manure P loading to soils is more than sufficient to meet crop P requirements.

2. The cumulative accumulation of surplus P over the last 150 years amounts to an average of 1.86 tonnes for every hectare of crop and productive grassland in the catchment. This legacy P input would be expected to increase soil total P content to a depth of 30 cms in Wye soils by 465 mg/kg. This is considerably more than the difference in total P content between unfarmed and farmed topsoils from recent (albeit limited) sampling, and suggests that there has been considerable movement of P into the subsoil. This is a particular concern for long-term mobilisation of P in drain flow and potentially leaching to groundwater.

3. An updated 2021 SFA for the Wye catchment confirmed livestock feed as the major P input leading to an annual surplus of 3000 tonnes or 11.4 kg P/ha using national excretion coefficients for poultry. However, local poultry industry data suggest lower P excretion rates from broilers and layers and using these figures, feed P inputs and the annual P surplus drops to 1750 t and 6.8 kgP/ha, respectively. Both estimates are above the 2021 UK average of 5.7 kg P/ha.

4. Scenario analysis that explored the conversion of permanent grassland to cereals saw a reduction in total catchment P surplus of between 136 and 790 t/yr at 25% and 100% land use change respectively from the 2021 baseline. Catchment average losses to water from agriculture were predicted to increase by 0.026 kg P/ha for every 10% of grassland converted to cereals. Scenario analysis of converting permanent grassland to maize predicted very small increases in catchment P surplus from the 2021 baseline and an increased catchment average agricultural loss to water by 0.004 kg/ha for every 10% land area conversion.

5. There was a wide distribution of P surpluses (1.6 to 16.2 kg P/ha calculated as a soil P balance) across six sub-catchments of the Wye (Arrow, Frome, Garren, Lugg, Monnow, and Yazor). Sub-catchment P surpluses were driven by the manure production and those catchments with higher P surpluses tended to have higher soil P status and to a lesser extent greater river P export.

6. Recommendations

1. Catchment nutrient mapping using SFA is a valuable tool to assess nutrient input pressures and cycling, and for examining potential scenarios of system and land use change to reduce river nutrient pollution. It relies on high resolution and accurate catchment data and relevant material nutrient coefficients. Local data supplied by the poultry industry in the Wye suggests that Defra’s national P excretion coefficients for poultry, which are based on 2006-2010 research may be too high. It is therefore recommended that these national coefficients need to be reviewed and that higher resolution catchment census data is made more available.

2. The historic analysis of the annual P soil P balance and limited soil total P analysis of unfarmed and farmed soils suggests shows that the cumulative surplus that has accumulated in the Wye catchment soils over the last 150 years cannot all be accounted for in the topsoil. This suggest that Wye soils may be more P-saturated and that legacy soil P has migrated to the subsoil. This needs further investigation as it increases the risk of further P loss to water in drain flow and to groundwater.

3. Current inconsistencies in river water quality monitoring programmes are confounding understanding of the impact of variable farming pressures and P surpluses on river P pollution. Relationships between farm and catchment P surpluses and river P pollution need better evidencing with improved and consistent water quality monitoring programmes going forward.

Acknowledgements
The help and support of Cobb-Agri Ltd in obtaining farm soil analysis records within the river corridor and wider catchment, and of Lancrop Laboratories Ltd in providing specific data summaries of relevant soil analysis results for the years 2017-2021 are gratefully acknowledged. The help and support of Ken Stebbings, Paul Walsh and Neil in Welsh Government in providing agricultural census data and useful discussion is gratefully acknowledged.

References
ADAS (2021). FARMSCOPER (Farm Scale Optimisation of Pollutant Emission Reductions). https://adas.co.uk/services/farmscoper/

AHDB (2022). Nutrient Management Guide (RB209). Section 1: Principles of nutrient management and fertiliser use. Available at: https://projectblue.blob.core.windows.net/media/Default/Imported%20Publication%20Docs/RB209%202022/RB209_Section1_2022_220224_WEB.pdf.pdf

Brownlie, W.J., Sutton, M.A., Cordell, D., Reay, D.S., Heal, K.V., Withers, P.J.A., Vanderbeck, I. and Spears, B.M. (2023). Phosphorus price spikes: A wake-up call for phosphorus resilience. Frontiers in Sustainable Food Systems 7, 1088776

Cassidy, R., Thomas, I.A., Higgins, A., Bailey, J.S. and Jordan, P. (2019). A carrying capacity framework for soil phosphorus and hydrological sensitivity from farm to catchment scales. Science of the Total Environment 687, 277–286.

Cencic, O., and Rechberger, H. (2008). Material Flow Analysis with Software STAN. Journal of Environmental Engineering and Management 18(1), 3-7.

Chakraborty, D. and Prasad, R. (2021). Stratification of soil phosphorus forms from long-term repeated poultry litter applications and its environmental implication. Environmental Challenges 5, 100374.

Cordell, C., Jacobs, B., Anderson, A. et al. (2022). UK Phosphorus Transformation Strategy: Towards a circular UK food system. RePhoKUs Report 2022. https://doi.org/10.5281/zenodo.7404622

Cooke, G.W. (1958). The nation's plant food larder. Journal of Science, Food and Agriculture 9, 761-772.

Davis, R.D. (1989). Agricultural utilization of sewage sludge: A review. J CIWEM 3, 351-355.

Defra (2006). Nitrogen and phosphorus output of livestock excreta. Final report, Defra project WT0715NVZ.

Defra (2022a). British Survey of Fertiliser Practice 2021. https://www.gov.uk/government/statistics/british-survey-of-fertiliser-practice-2021

Defra (2022b). Soil Nutrient Balances UK 2021 https://www.gov.uk/government/statistics/uk-and-england-soil-nutrient-balances-2021

Defra (2023). Structure of the agricultural industry in England and the UK at June. https://www.gov.uk/government/statistical-data-sets/structure-of-the-agricultural-industry-in-england-and-the-uk-at-june

Dungait, J. A. J., Cardenas, L. M., Blackwell, M. S. A., Wu, L., Withers, P. J. A., Chadwick, D. R., Bol, R., Murray, P. J., Macdonald, A. J., Whitmore, A. P. and Goulding, K. W. T. 2012. Advances in the understanding of nutrient dynamics and management in UK agriculture. Science of the Total Environment. 434 (15 September), pp. 39-50.

Fan, M-S., Zhaoa, F-J., Fairweather-Tait, S.J., Poulton, P.R., Dunham, S.J. and McGrath, S.P. (2008). Evidence of decreasing mineral density in wheat grain over the last 160 years. Journal of Trace Elements in Medicine and Biology 22, 315–324.

Ferris, C.P., McCoy, M.A., Patterson, D.C. and Kilpatrick, D. J. (2010). Effect of offering dairy cows diets differing in phosphorus concentration over four successive lactations: 2. Health, fertility, bone phosphorus reserves and nutrient utilisation. Animal 4:4, 560-571.

Fowler, D., O'Donoghue, M., Muller, J.B.A., Smith, R.I., Dragostis, U., Skiba, U., Sutton, M.A. and Brimblecombe, P. (2004). A chronology of nitrogen deposition in the UK between 1900 and 2000. Water Air and Soil Pollution: Focus 4, 9-23.

Haygarth, P.M., Chapman, P.J., Jarvis, S.C. and Smith, R.V. (1998). Phosphorus budgets for two contrasting grassland farming systems in the UK. Soil Use and Management 14, 160-167.

Johnston, A.E., Poulton, P.R. and Coleman, K. (2009). Chapter 1. Soil organic matter: its importance in sustainable agriculture and carbon dioxide fluxes. Advances in Agronomy 101, 1–57.

Phoenix, G. K., Emmett, B. A., Britton, A. J., Caporn, S. J. M., Dise, N. B., Helliwell, R., Jones, L., Leake, J.R., Leith, I.D., Sheppard, L.J., Sowerby, A., Pilkington, M.G., Rowe, E.C., Ashmore, M.R. and Power, S. A. (2012). Impacts of atmospheric nitrogen deposition: responses of multiple plant and soil parameters across contrasting ecosystems in long-term field experiments. Global Change Biology, 18(4), 1197–1215.

Qi, A., Holland, R.A., Taylor,G. and Richter, G.M. (2018) Grassland futures in Great Britain – Productivity assessment and scenarios for land use change opportunities. Science of the Total Environment 634, 1108-1118.

Rothwell, S.A., Forber, K.J., Dawson, C.J., Salter, J.L., Dils, R.M., Webber, H., Maguire, J., Doody, D.G., Withers, P.J.A., (2022). A new direction for tackling phosphorus inefficiency in the UK food system. Journal of Environmental Management 314, 115021.

Smith, K.A. and Williams A.G. (2016). Production and management of cattle manure in the UK and implications for land application practice. Soil Use and Management 32 (Suppl. 1), 73-82.

Thompson, F.M.L. (1968). The second agricultural revolution, 1815-1880. Economic History Review 21(1), 62-77.

UKCEH (2023). National River Flow Archive Search Data | National River Flow Archive (ceh.ac.uk)

Warren, R.G. and Johnston, A.E. (1964). The Park Grass Experiment. Rothamsted Experimental Station Report for 1963, 240-262.

Water UK (2010). The Recycling of Biosolids to Agricultural Land. Issue 3. https://assuredbiosolids.co.uk/wp-content/uploads/2018/05/Recycling-Biosolids-to-Agricultural-Land.pdf

Withers, P.J.A., Forber, K.J. and Rothwell, S.A. (2022a). Soil Phosphorus Status and Water Quality in the River Wye. Report to the Environment Agency.

Whitmore, A.P., Bradbury, N.J. and Johnson, P.A. (1992). Potential contribution of ploughed grassland to nitrate leaching. Agriculture, Ecosystems and the Environment 39, 221-233.

Withers P.J.A., Rothwell S.A., Forber J.K. and Lyon C. (2022) Re-focusing Phosphorus use in the Wye Catchment, RePhoKUs Report May 2022, https://doi.org/10.5281/zenodo.6598122

Zhang, Y., Collins, A.L., Murdoch, N., Lee, D. and Naden, P.S. (2014). Cross sector contributions to river pollution in England and Wales: Updating waterbody scale information to support policy delivery for the Water Framework Directive. Environmental Science and Policy 42, 16-32.

Zoboli, O., Laner, D., Zessner, M., Rechberger, H., (2016). Added values of time series in material flow analysis the Austrian phosphorus budget from 1990 to 2011. Journal of Industrial Ecology 20(6), 1334-1348.

Date: January 2023

Appendix

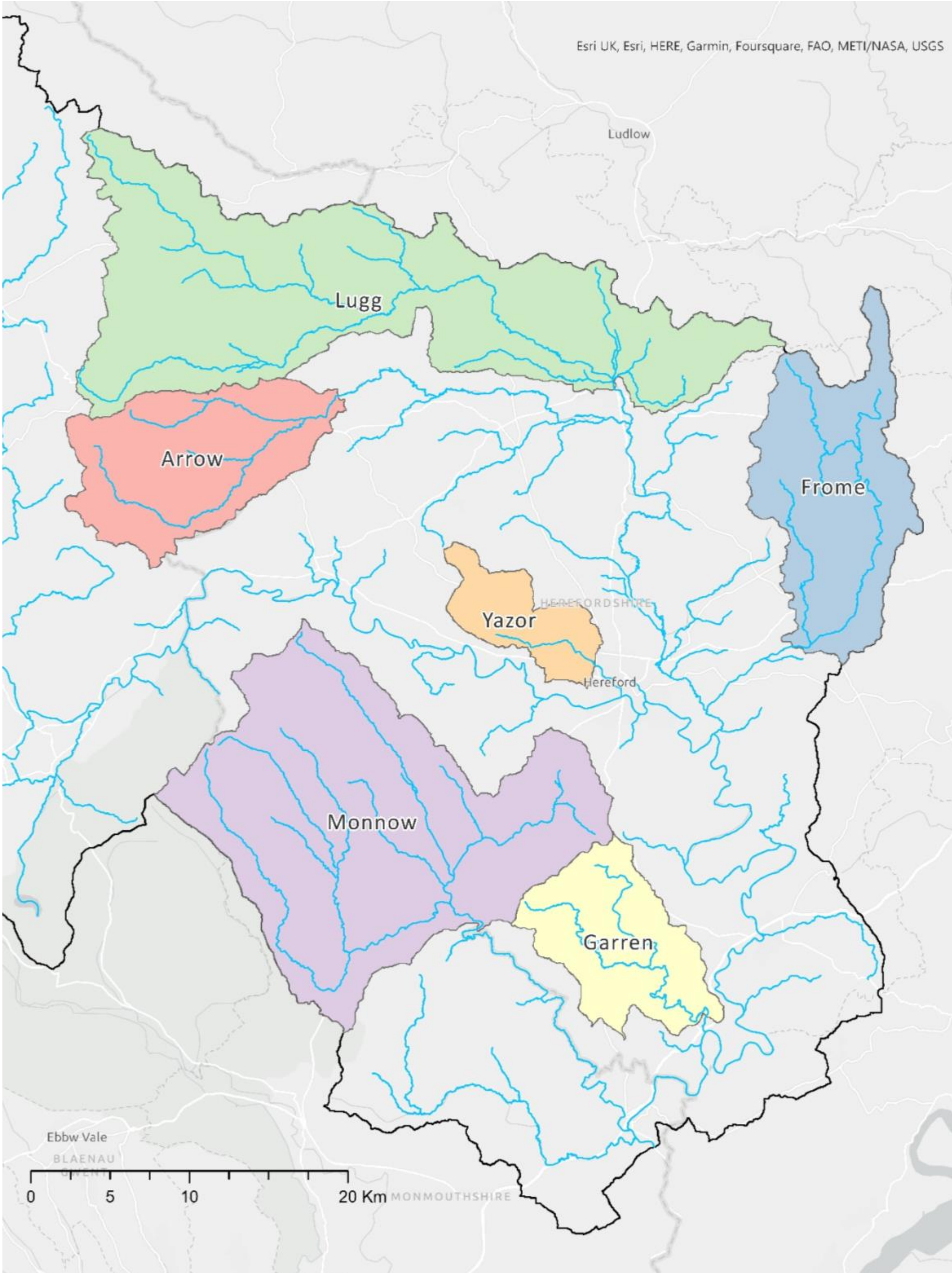


Figure 14. The chosen sub-catchments in the Wye catchment. Catchment boundaries for the Lugg, Arrow, Frome, Yazor, Monnow and Garren are from the National River Flow Archive (UKCEH, 2023).

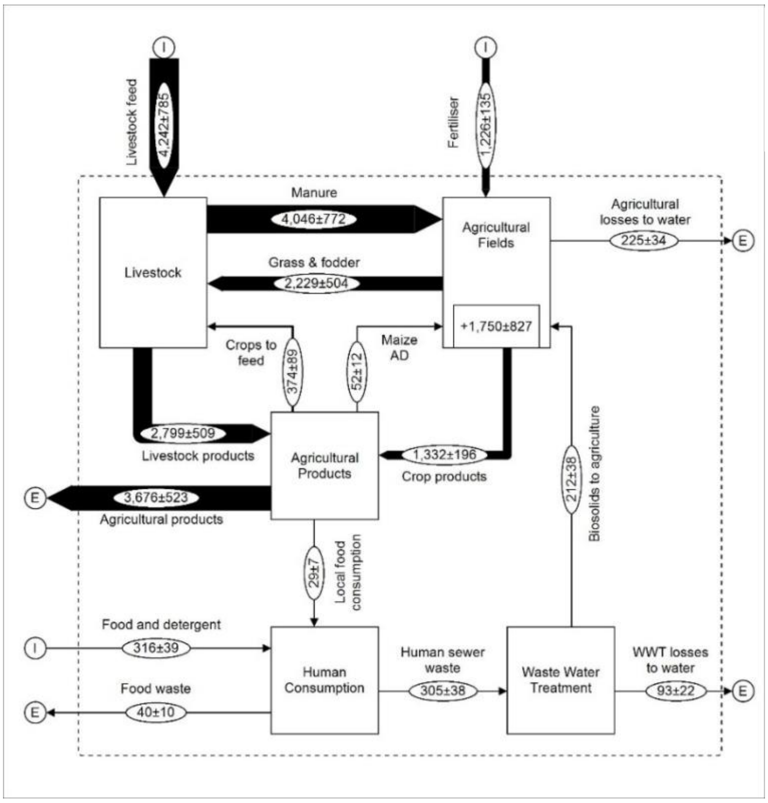


Figure 15. Wye catchment SFA using the industry produced P data related to poultry production. All flows are t/P/yr ± uncertainty for the year 2021.

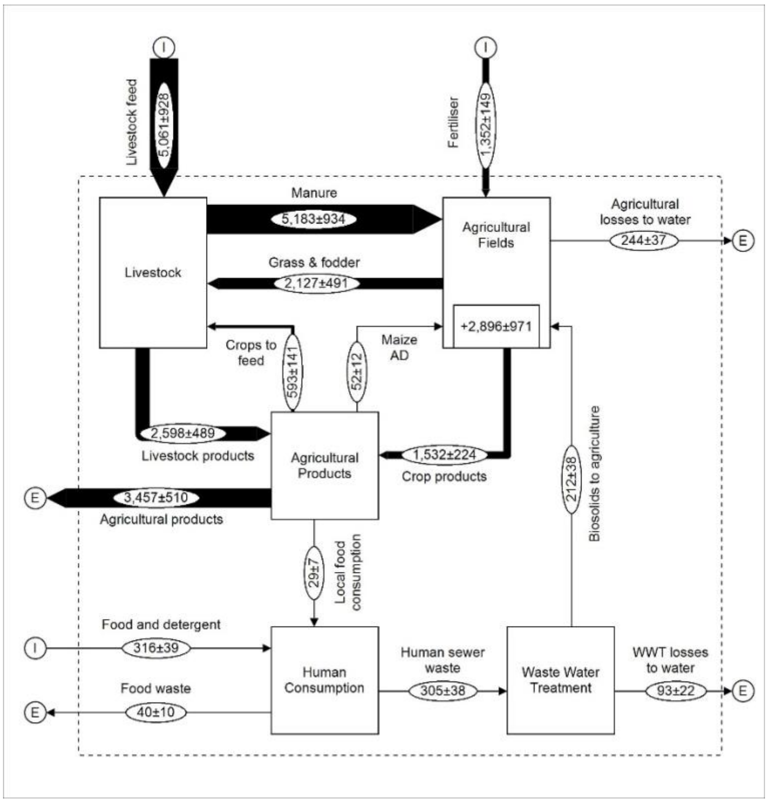


Figure 16. Wye catchment SFA for the cereals 25 scenario. All flows are t/P/yr ± uncertainty using the 2021 SFA as the reference year for scenario change.

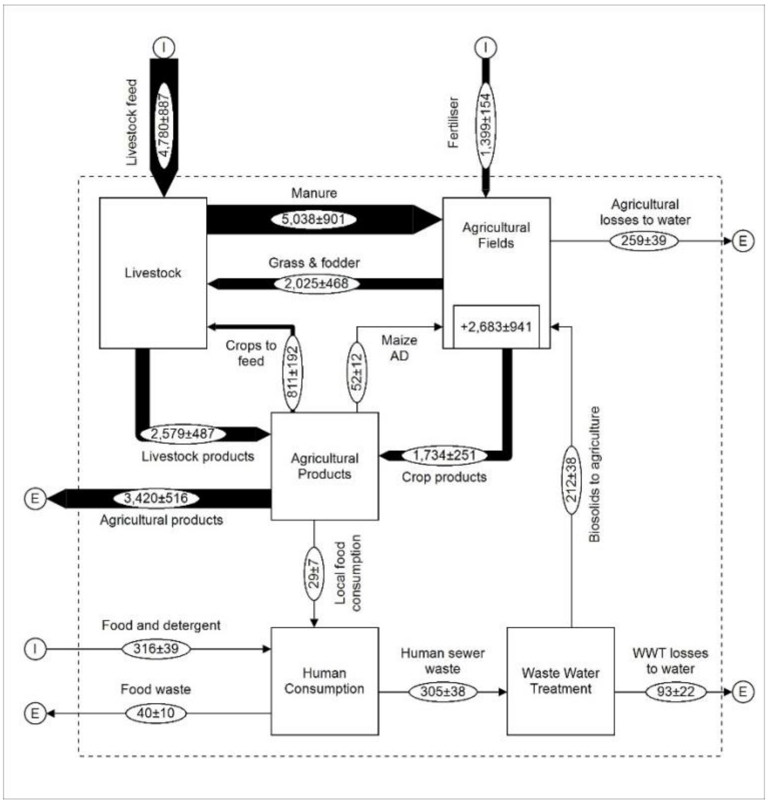


Figure 17. Wye catchment SFA for the cereals 50 scenario. All flows are t/P/yr ± uncertainty using the 2021 SFA as the reference year for scenario change.

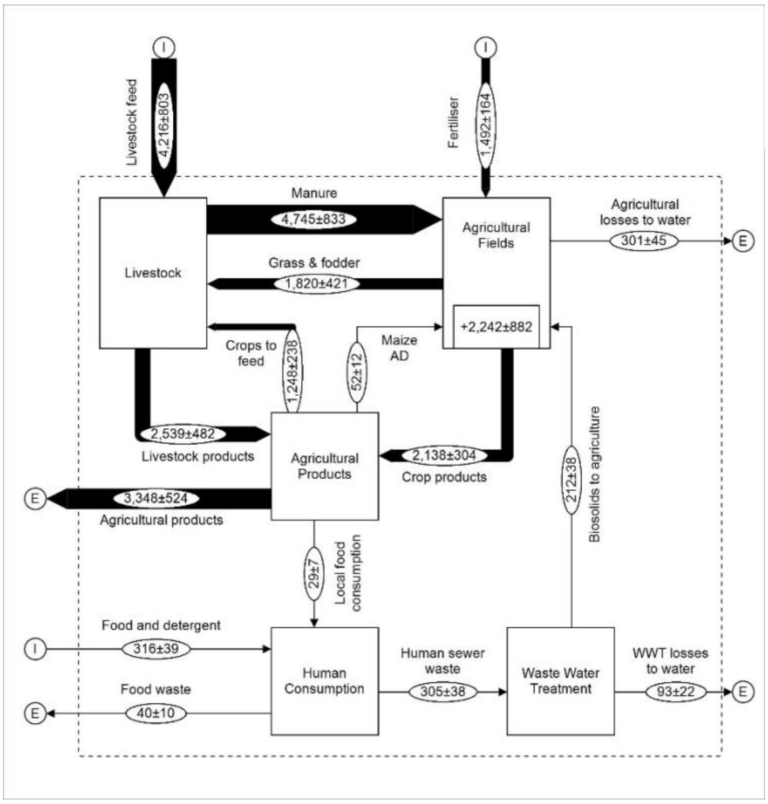


Figure 18. Wye catchment SFA for the cereals 100 scenario. All flows are t/P/yr ± uncertainty using the 2021 SFA as the reference year for scenario change.

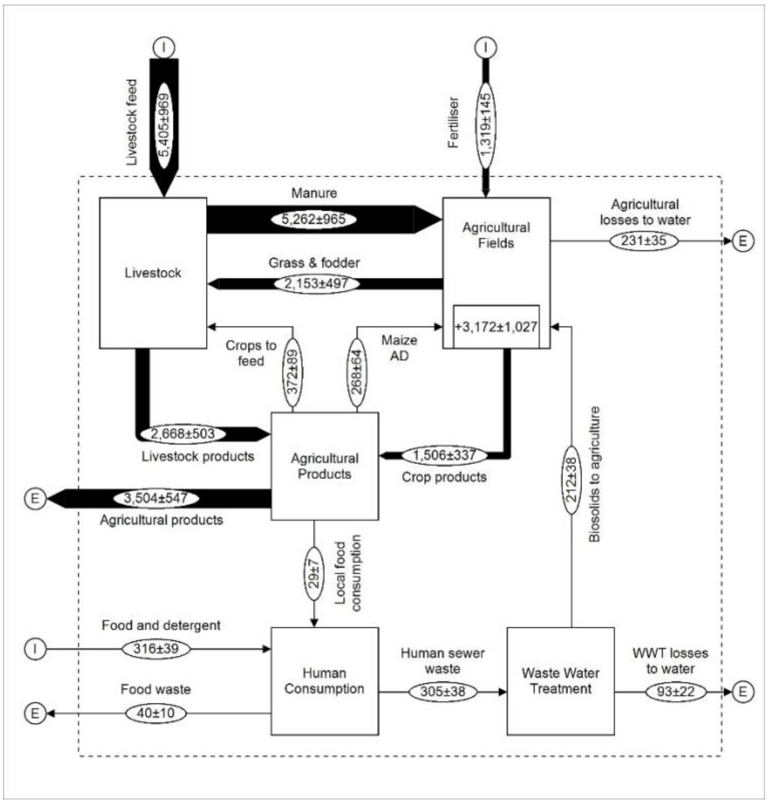


Figure 19. Wye catchment SFA for the maize 50 scenario. All flows are t/P/yr ± uncertainty using the 2021 SFA as the reference year for scenario change.

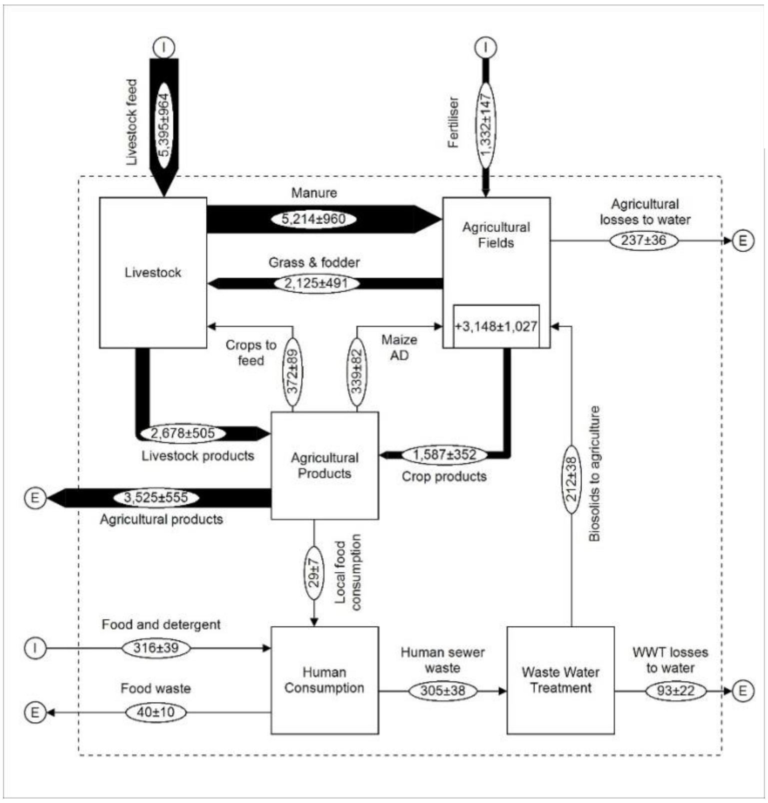


Figure 20. Wye catchment SFA for the maize 100 scenario. All flows are t/P/yr ± uncertainty using the 2021 SFA as the reference year for scenario change.

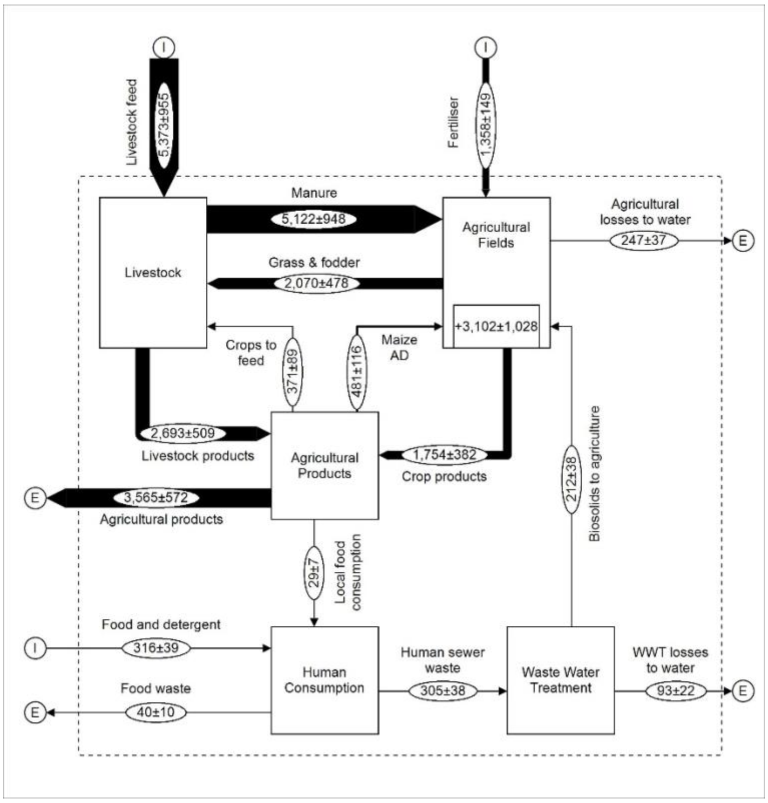


Figure 21. Wye catchment SFA for the maize 200 scenario. All flows are t/P/yr ± uncertainty using the 2021 SFA as the reference year for scenario change.

May 30th 2023

By e-mail

Natural England
County Hall,
Spetchley Road,
Worcester
WR5 2NP

T 0208 026 1280

Dear Stakeholder

River Wye and Lugg SAC/SSSI assessment of indicative site condition using CSMG. Natural England March 2023

We are writing to inform you of a recent indicative site condition assessment of the River Wye and Lugg Sites of Scientific Special Interest (SSSI).

The River Wye (and part of the River Lugg) is designated SSSI and Special Areas of Conservation (SAC), giving it the highest level of protection in the UK. This means making sure that it can support the life that depends on it, the business that depend on it and is healthy and thriving to provide enjoyment for generations to come

There is much work currently being undertaken by multiple stakeholders to support this work. We at Natural England work closely with the Environment Agency, using monitoring data and evidence collected by the EA to understand the health of the rivers and identify where best to make interventions.

Assessment
Natural England categorises the conditions of SSSI's based on condition assessments undertaken in line with Common Standards Monitoring Guidance (CSMG). These assessments are published on the Natural England Designated Site Viewer, which can be viewed here > Designated Site Viewer. For full details on condition assessments please see Appendix 2.

The River Wye and Lugg designated sites have a relatively complex set of aquatic plant and animal life, aka interest features, and conducting a full condition assessment of every feature of the river is a significant operation.

A full two-year assessment is planned to commence in 2024, but in the interim, ther Area Team has conducted a small-scale assessment, looking at four specific indicators to create an indicative assessment of the site as a whole.

Using CSMG with data and evidence from the Environment Agency, our assessment reviewed:

- Atlantic salmon
- Macrophytes
- Native white-clawed crayfish
- Water quality

The attribute that has received the most attention is water quality, as it is fundamental to the health of the river and in light of the “nutrient neutrality advice” in place for rivers failing water quality targets. Natural England regularly reviews the water quality targets, and the data is available here > environment.data.gov.uk/water-quality .

Assessment findings: summary
In summary, the river was largely previously classed as ‘unfavourable - recovering’. As per CSMG if any one of the features is classed as either ‘unfavourable’, ‘unfavourable - no change’ or ‘unfavourable - declining’, the whole unit of the river is classed as such, irrespective of the status of the other interest features.

As at least one feature in both the Wye and the Lugg are showing declines, and we cannot be assured that all necessary management is currently in place, despite the significant efforts of many stakeholders, we have updated the SSSI condition status for the Wye and Lugg as ‘unfavourable – declining’, as shown in Table 1. For an explanation of the categories please see Table 2.

Assessment findings: River Lugg
Our recent assessment has identified that the River Lugg is showing declines in Atlantic salmon, and white Clawed Crayfish.

The Lugg is failing its water quality targets and the water quality in the Lugg is declining. Nutrient Neutrality advice remains in place for the Lugg.

Assessment findings: River Wye
In the River Wye we can see declines in macrophytes, salmon and white-clawed crayfish.

The Wye is not currently failing its water quality targets. Although the River Wye is close to its phosphate targets on some of the monitoring points, the latest evidence indicates levels have been stable. Nutrient Neutrality advice does not apply to the Wye as it is not failing its water quality targets.

For a more detailed review of the evidence used to determine condition, please read Appendix 1. For full details on condition assessments please see Appendix 2.

Action to address the issues
Clearly this change of condition is of concern for all with an interest in the Rivers. However, in light of the recent media coverage on the Wye and the health of UK rivers generally, we feel it is important to communicate this change transparently and provide an assurance as to what this means.

Our recent findings do not suggest a sudden decline in the Wye and Lugg SSSIs, and instead reflects the overall decline in health which we are all working collaboratively to halt, and to restore the health of the rivers.

We and other partners do not yet fully understand all the reasons for these declines, so further investigations are being conducted by the Environment Agency and other partners to build greater understanding. Meanwhile there is much activity by multiple partners to improve the health of the river and the outcomes for the species that depend on it.

Improving the condition of the river and reversing declines in species such as salmon and white-clawed crayfish is complex and challenging but are issues we must address.

Reducing phosphates in the river Wye SAC is also a complex issue, but one which we know is fundamental to the health of the river. Both the Environment Agency and Natural England together with our stakeholders are committed to reducing phosphate levels. The Nutrient Management Plan Board oversees the delivery of the Nutrient Management Action Plan to deliver reductions in phosphate. This is an iterative plan with further actions required to tackle this challenging issue. We are working with Herefordshire Council and Partners to improve the operations of the NMB board. Both the Environment Agency and Natural England continue to work with stakeholders to deliver the environmental improvements required to reverse the declining condition of this wonderful river.

Table 1: Change in Condition for River Wye and Lugg

Unit	River	Reach	Previous Condition on CMSi	Updated Condition on CSMi
1	River Wye	Tidal river - Estuary to Brockweir Bridge	Favourable	Unfavourable - Declining
2	River Wye	Brockweir Bridge to Monmouth	Unfavourable - Recovering	Unfavourable - Declining
3	River Wye	Monmouth to Ross	Unfavourable - Recovering	Unfavourable - Declining
4a	River Wye	Ross to Lugg Confluence	Unfavourable - Recovering	Unfavourable - Declining
4b	River Wye	Lugg Confluence to Hereford	Unfavourable - Recovering	Unfavourable - Declining
5	River Wye	Hereford to Bredwardine Bridge	Unfavourable - Recovering	Unfavourable - Declining
6	River Wye	Bredwardine Bridge to Whitney Toll	Unfavourable - Recovering	Unfavourable - Declining
7	River Wye	Whitney Toll to Hay	Unfavourable - Recovering	Unfavourable - Declining
1	River Lugg	Bodenham Weir to Confluence with Wye	Unfavourable - Recovering	Unfavourable - Declining

2	River Lugg	Bodenham Weir to Leominster	Unfavourable - Recovering	Unfavourable - Declining
3	River Lugg	Leominster to Mortimers Cross	Unfavourable - Declining	Unfavourable - Declining
4	River Lugg	Mortimers Cross to Presteigne		Unfavourable - Declining

Table 2: The following table explains the condition categories.

SSSI Condition categories	
Condition status	**Explanation**
Favourable condition	The designated feature is being adequately conserved and the results from monitoring demonstrate that the feature is meeting all the mandatory site-specific monitoring targets set out in the Favourable Condition Tables (FCT). The FCT sets the minimum standard for favourable condition for the designated feature and there may be scope for the further (voluntary) enhancement of the feature.
Unfavourable recovering condition	Often known simply as 'recovering'. The Feature is not yet fully conserved, but all the necessary management measures are in place. Provided that the recovery work is sustained, the feature will reach favourable condition in time. At least one of the designated features mandatory attributes is not meeting their targets (as set out in the site specific FCT).
Unfavourable no-change condition	The feature is not being conserved, and will not reach favourable condition, unless there are changes to the management or external pressures and this is reflected in the results of monitoring over time; with at least one of the mandatory attributes not meeting its target (as set out in the site specific FCT) with the results not moving towards the desired state. The longer the feature remains in this poor condition, the more difficult it will be, in general, to achieve recovery.
Unfavourable declining condition	The feature is not being conserved and will not reach favourable condition unless there are changes to management or external pressures. The feature condition is becoming progressively worse, and this is reflected in the results of monitoring over time, with at least one of the designated features mandatory attributes not meeting its target (as set out in the site specific FCT) with the results moving further away from the desired state. The longer the feature remains in this poor condition, the more difficult it will be, in general, to achieve recovery.

Part destroyed condition	Lasting damage has occurred to part of a designated feature, such that it has been irretrievably lost and will never recover (no amount of management will allow the feature to ever reach favourable condition).
Destroyed condition	Lasting damage has occurred to an entire designated feature such that the feature has been irretrievably lost (no amount of management will bring this feature back). This feature will never recover e.g., a finite mineralogical feature has been totally removed from its surroundings without consent and is therefore lost forever.

Yours faithfully

Emma Johnson
Area Manager - West Midlands Team, Natural England

Appendix 1: Detailed Evidence Summary Wye and Lugg SSSI

Natural England November 2022

This document summarises the key evidence used to undertake an interim assessment of the condition of some of the features on both the River Wye and River Lugg Sites of Special Scientific Interest (SSSIs). Further detailed information on the attributes/targets used is available in the Monitoring Specifications for the River Wye and River Lugg SSSIs. If you would like a copy of the Monitoring Specifications, please e-mail west.mindlands.enquiries@naturalengland.org.uk

Macrophytes, Diatoms and Macroinvertebrates

Macrophytes, Diatoms and Macroinvertebrates form a mandatory part of the condition assessment for the interest feature 'rivers and streams' (The River Wye is a H3260 Ranunculion type river).

The target status for macrophytes, diatoms and macroinvertebrates is High Ecological Status (HES).

All of WFD waterbodies within the Wye/Lugg SAC are classified as either moderate or good WFD status for macrophytes and phytopbenthos (combined) and therefore fail to meet the designated site target. Units 2 and 3 declined in status from Good to Moderate between 2014 and 2015. Units 4 saw a class improvement between 2016 and 2019 from moderate status to good. Units 5 and 6 have remained at moderate status since reporting in 2014.

Macroinvertebrates fail to meet the target in part or all of units 4, 5 and 6.

Table 1. Classification of macrophytes and macroinvertebrates as displayed on Catchment Data Explorer https://environment.data.gov.uk/catchment-planning/ManagementCatchment/3117

Unit		WFD WBID	Plant community	Macro-invertebrates
			SAC/SSSI Target is HES	SAC/SSSI Target is HES
2	Brockweir Bridge to Monmouth	GB109055037111	Moderate*	
3	Monmouth to Ross	GB109055037111	Moderate*	
		GB109055037112	Good**	
4	Ross to Lugg Confluence	GB109055037112	Good**	High
	Lugg Confluence to Hereford	GB109055037112	Good**	High
		GB109055037113	Moderate	Good*
5	Hereford to Bredwardine Bridge	GB109055037113	Moderate	Good*
6	Bredwardine Bridge to Whitney Toll	GB109055037113	Moderate	Good*
		GB109055037116	Unknown as NRW	

7	Whitney Toll to Hay	GB109055037116	Unknown as NRW	
1	R Lugg (Wye SAC) Wye Confluence to Bodenham Weir	GB109055036790	Moderate	
		GB109055042030	Moderate	
2	Bodenham Weir to Leominster	GB109055042030	Moderate	
3	Leominster to Mortimers Cross	GB109055042030	Moderate	
4	Mortimers Cross to Presteigne	GB109055042030	Moderate	

* Indicates evidence that the situation is declining
** Indicates evidence that the situation is improving

Atlantic salmon

Both rivers are deemed to be iconic for their salmon population. Salmon are a notified feature of the River Wye SSSI and SAC, and a feature component of clay river health in the Lugg. The salmon population of the River Wye is at a critical state, with the salmon run estimated at around 2000 to 3000 down from 50,000 a year, with angling catches down 94% from their peak in 1967 (River Wye Salmon Action Plan 2019).

Fundamental to the assessment of stock is the site Conservation Limit. The Conservation Limit (CL) defines the minimum number of fish we want to see spawning in the river. The CL for each river is set at a stock size (defined in terms of eggs deposited) below this limit further reductions in spawner numbers are likely to result in significant reductions in the number of juvenile fish produced in the next generation. The conservation objective for the River Wye & Lugg is to meet or exceed its CL in at least four years out of five.

NRW & the EA published their **Proposed new salmon and sea trout rod fishing byelaws for the Wye in England 2021,** the report states

"*…. evidence emerging from the salmon stock assessments indicates* ***a continued decline in the status of salmon in the River Wye****, with substantial deficits in the number of spawning adults apparent in the Wye and neighbouring rivers such as the rivers Severn and Usk*."

Table 3 and figure 1 provides a summary of the Wye Salmon stock assessment. The Wye stock assessment covers the whole catchment including the River Lugg.

Since 2015 there has been a decline in fry across the catchment. Recruitment was especially poor in 2016. The poor fry numbers have been reflected in low parr numbers in 2017 (Figure 2).

Table 2. CSMG targets for Atlantic salmon from

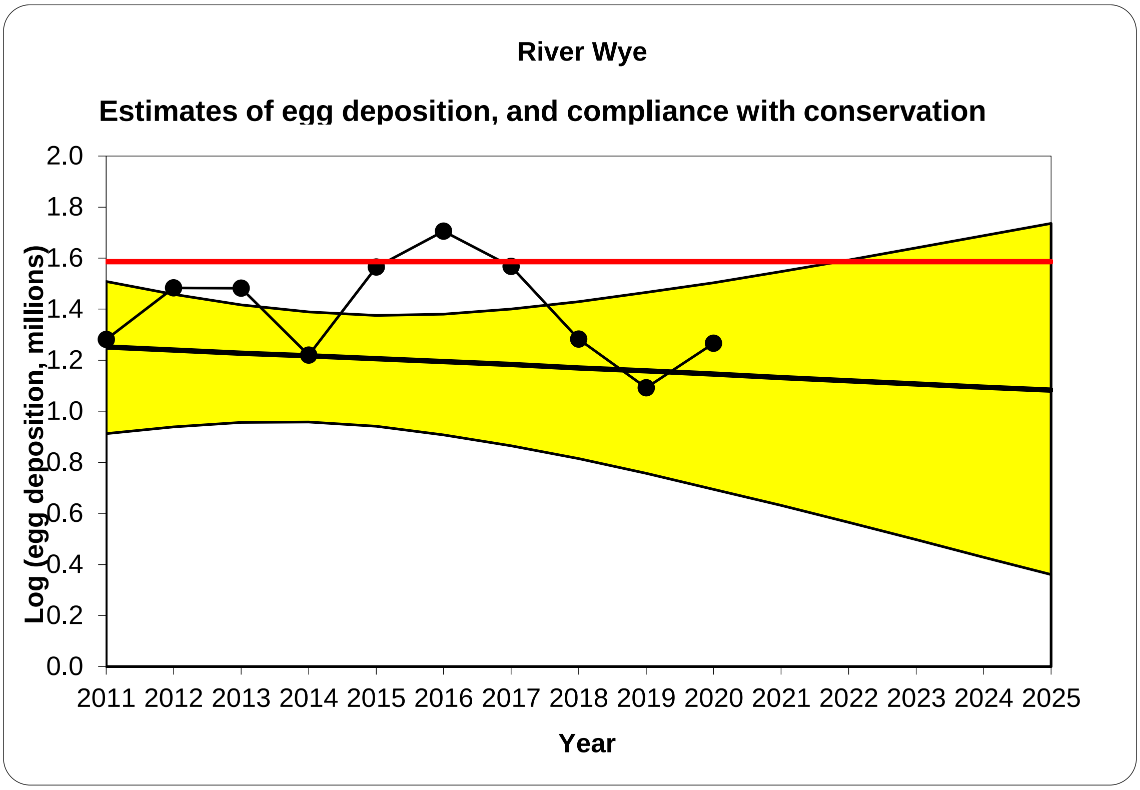
https://hub.jncc.gov.uk/assets/9b80b827-b44b-4965-be8e-ff3b6cb39c8e

Favourable Condition Table 5 – Atlantic salmon (*Salmo salar*)

Details of the standard method for population assessment can be found in the monitoring protocol for Atlantic salmon.

Attribute *=discretionary	Target	Method of Assessment	Comments
POPULATION			
a. Spatial extent	Should reflect distribution under near-natural conditions.	Electrofishing	Juvenile Atlantic salmon should be present in all areas of the catchment to which they have natural access. This does not include areas above naturally impassable barriers, but areas where access has been limited by man-made obstructions should be identified. See the associated monitoring protocol for further details.
b. Population density: juveniles	These should not differ significantly from those expected for the river type/reach under conditions of high physical and chemical quality.	Quantitative, semi-quantitative and timed electrofishing	Juvenile densities vary naturally between rivers and between survey sites on rivers, depending on the productivity and natural habitat character of the system. Observed densities therefore need to be assessed in relation to the expectation for each river and each river reach. See the associated monitoring protocol for further details.
c. Population density: adult run size	Total run size at least matching an agreed reference level, including a seasonal pattern of migration characteristic of the river and maintenance of the multi-sea-winter component.	Fish counters where available Rod catch data	The numbers of returning salmon should be sufficient to ensure that all naturally available spawning and nursery habitat is utilised. Different rivers have different seasonal patterns of adult migration associated with the environmental characteristics of the catchment and river system. Multi-sea winter fish are an important component of a natural salmon run and have declined considerably in recent years. The data available to assess this attribute vary widely across the UK. See the associated monitoring protocol for further details.

Figure 1 River Wye salmon spawning compliance assessment 2020



Key to graphs	
	20th percentile trend line (in a 10 year period around 2 annual egg deposition values would be expected to fall below this line)
	Annual egg deposition estimates
	Conservation Limit
	Upper and lower boundaries of the Bayesian Credible Interval.

Table 3 summary of salmon stock status on the Rivers Wye: provisional assessment results for 2020[1]

Salmon stock status on the Rivers Wye	
Current compliance status (2020)	At Risk
Predicted (+5yr) compliance status (2025)	Probably at Risk
Trend*	Declining (-)
Conservation Limit	38.57 million eggs
Management Target	48.69 million eggs
Egg deficit on MT**	24.52 million eggs
Spawner deficit***	8,175

- *Declining trend: Slight (-); Moderate(--); Steep (---)*

*** Egg deficit based on 5-year mean 2016-2020*

*** Spawner deficit expressed as 8lb fish equivalents; where average fecundity = 3,000 eggs per fish*

White Clawed Crayfish (Atlantic Crayfish)

Native white clawed crayfish are a notified feature of the River Wye and an indicator of the health of the clay river feature in the River Lugg. Surveys were undertaken in 2013 by Hills ecology on Units 3-7 of the River Wye and Units 1-4 of the River Lugg.

The result of this survey indicate that the species is in 'unfavourable' condition for units 1-4 of the River Lugg, and either unfavourable or part destroyed for units 3-7 of the River Wye due to either the absence of white clawed crayfish, and/or the presence of non-native signal crayfish. Further investigation into habitat availability and historic survey data may be required to determine whether the status is unfavourable-declining, or part destroyed (https://www.therrc.co.uk/sites/default/files/files/Designated_Rivers/wyedrafttechnicalreport.pdf).

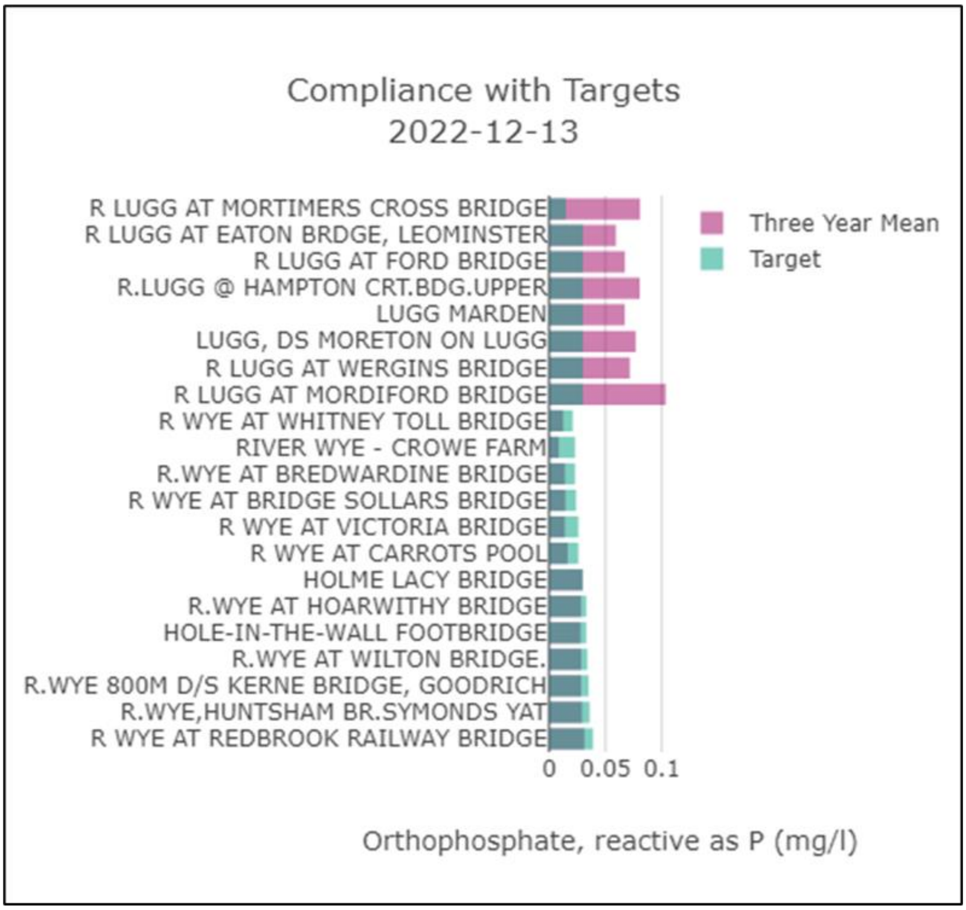
[1] Source NRW Technical Case 2021

Water Quality Analysis – River Wye & Lugg

Water quality is not a notified feature of the SSSIs, it is one of the attributes assessed to indicate the health of the Rivers. Water quality targets are set out in the Monitoring Specifications for both the River Lugg SSSI and the River Wye SSSI.

Figure 2. River Wye & Lugg Ortho-P Current Compliance with Targets.

Figure 2 illustrates that for each monitoring location on the River Lugg, the Ortho-P target for the three-year mean target is currently being exceeded. The water quality data presented for the River Wye illustrates for each monitoring location that water quality is not currently exceeding the three year mean target.



EA WFD Classification – Phosphate (up to 2019)

The water body - **Lugg - conf Norton Bk to conf R Arrow –** deteriorated from High to Moderate status for Phosphorus between the 2015 – 2019 classification.

The river Wye remain, increased or stayed at high or good throughout this period.

Table 4. EA Phosphate classification for the Wye & Lugg main river sections.

Catchment	Water Body	Physico-chemical element	2015	2016	2019
River Lugg	Lugg - conf Norton Bk to conf R Arrow Water Body	Phosphate	High	Good	Moderate

River Lugg	Lugg - conf R Arrow to conf R Wye Water Body	Phosphate	Good	Good	Good
River Wye	Wye - Bredwardine Br to Hampton Bishop Water Body	Phosphate	High	Good	High
River Wye	Wye - Hampton Bishop to conf Kerne Br Water Body	Phosphate	High	High	Good
River Wye	Wye - conf Walford Bk to Bigsweir Br Water Body	Phosphate	Good	High	High

Water Quality Trends

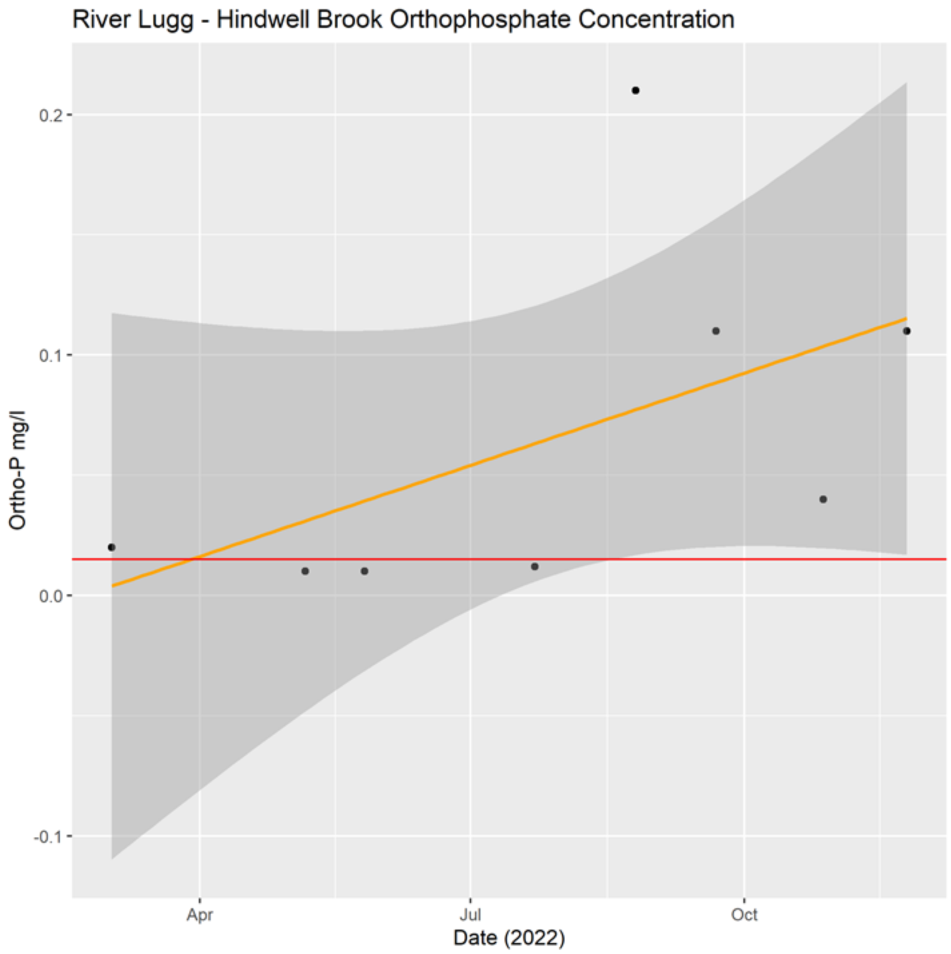
The following graphs illustrate the trend in water quality over the past 20 years in the Wye and Lugg catchments. The monitoring locations are ordered upstream to downstream.

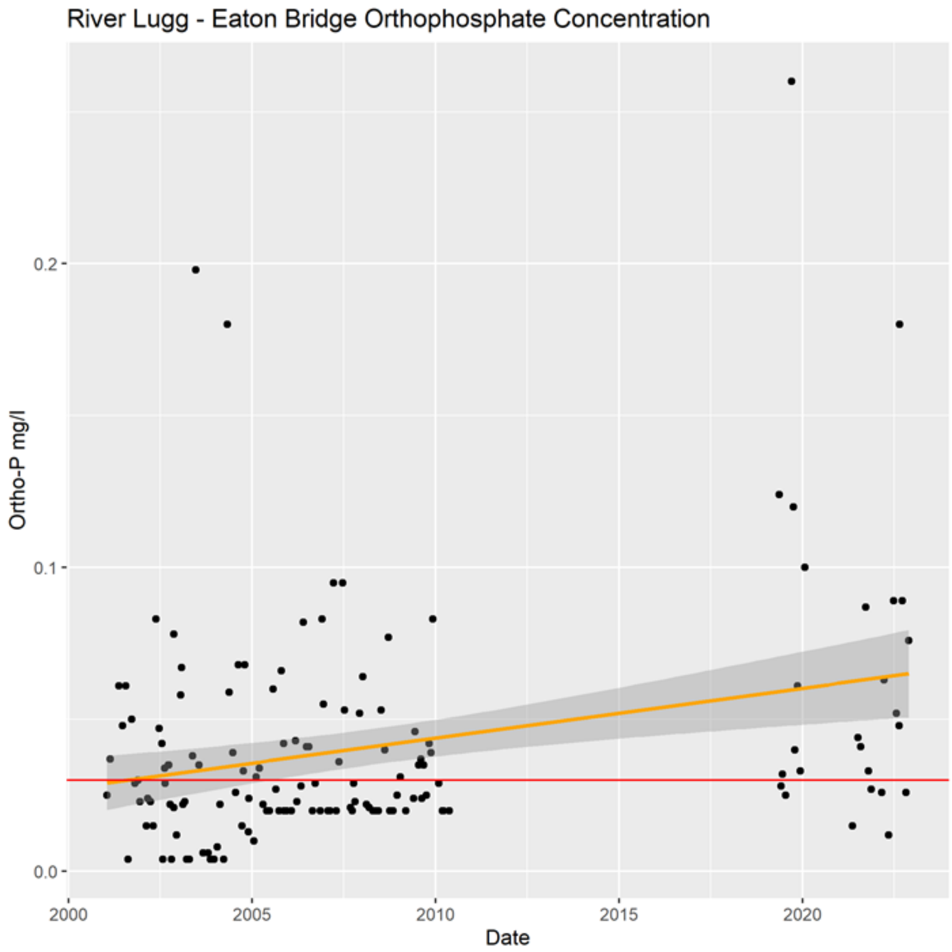
The **red line** is the site target for Ortho-P

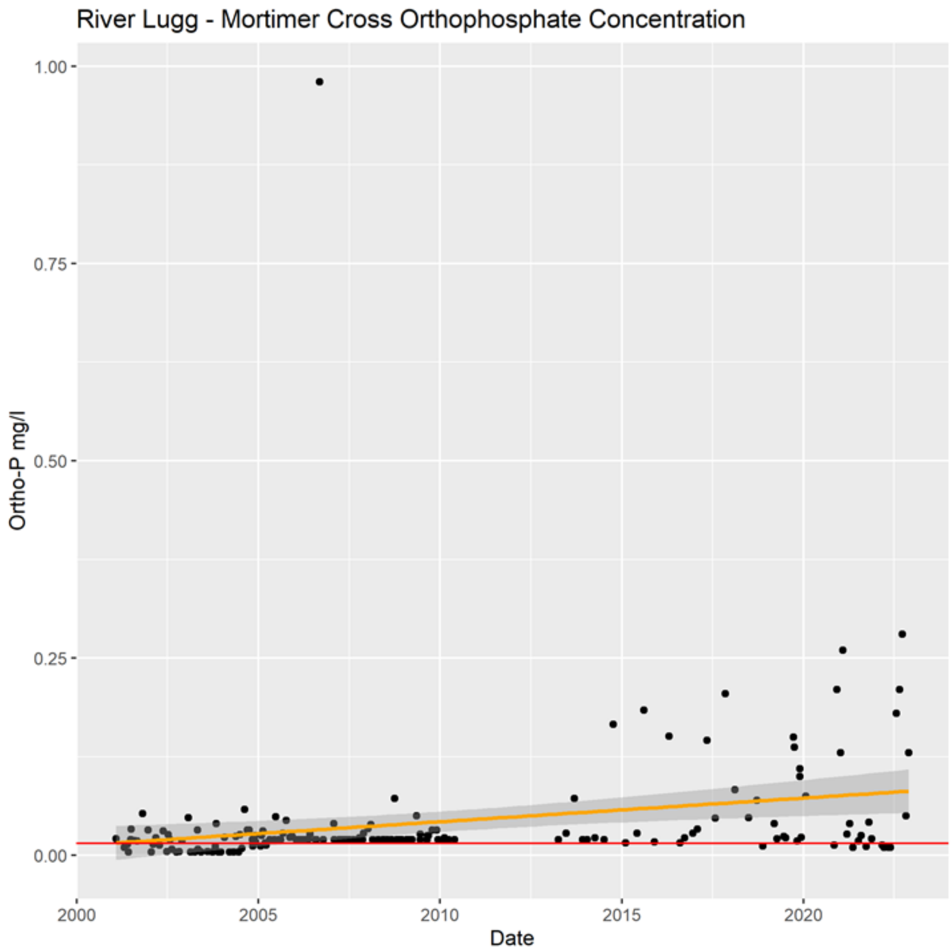
The **orange line** plots a linear regression line with 95% Confidence Interval (CI)

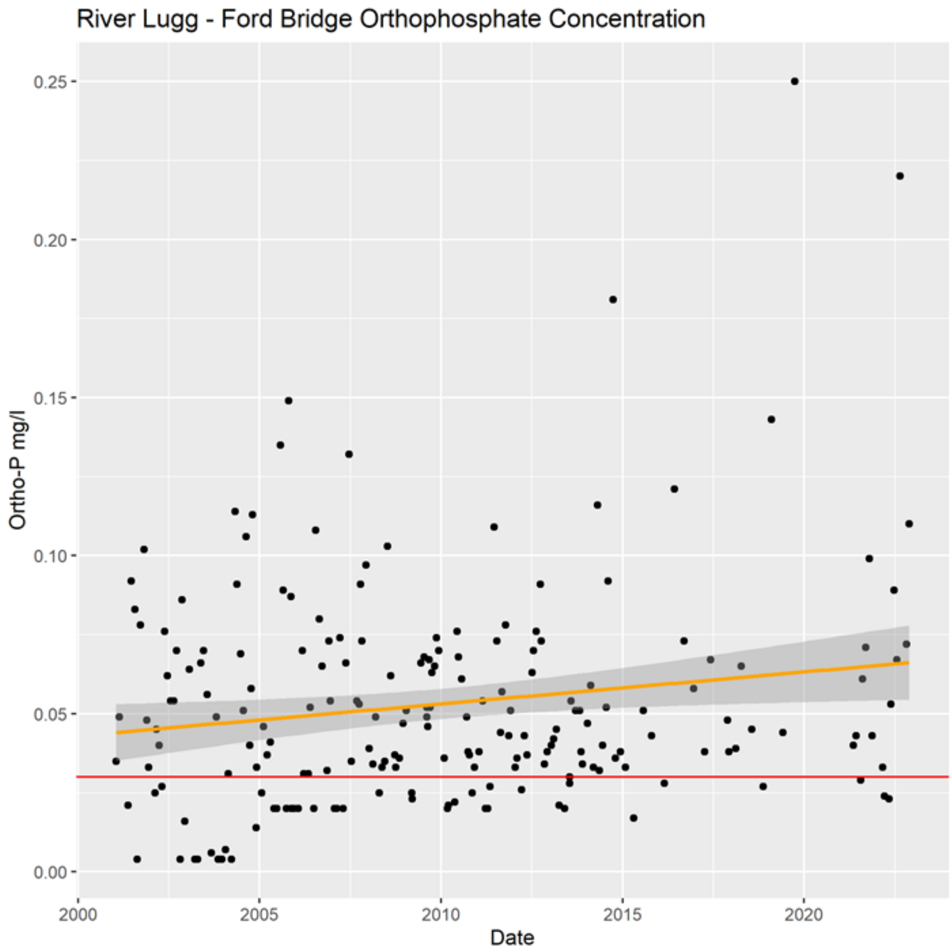
River Lugg

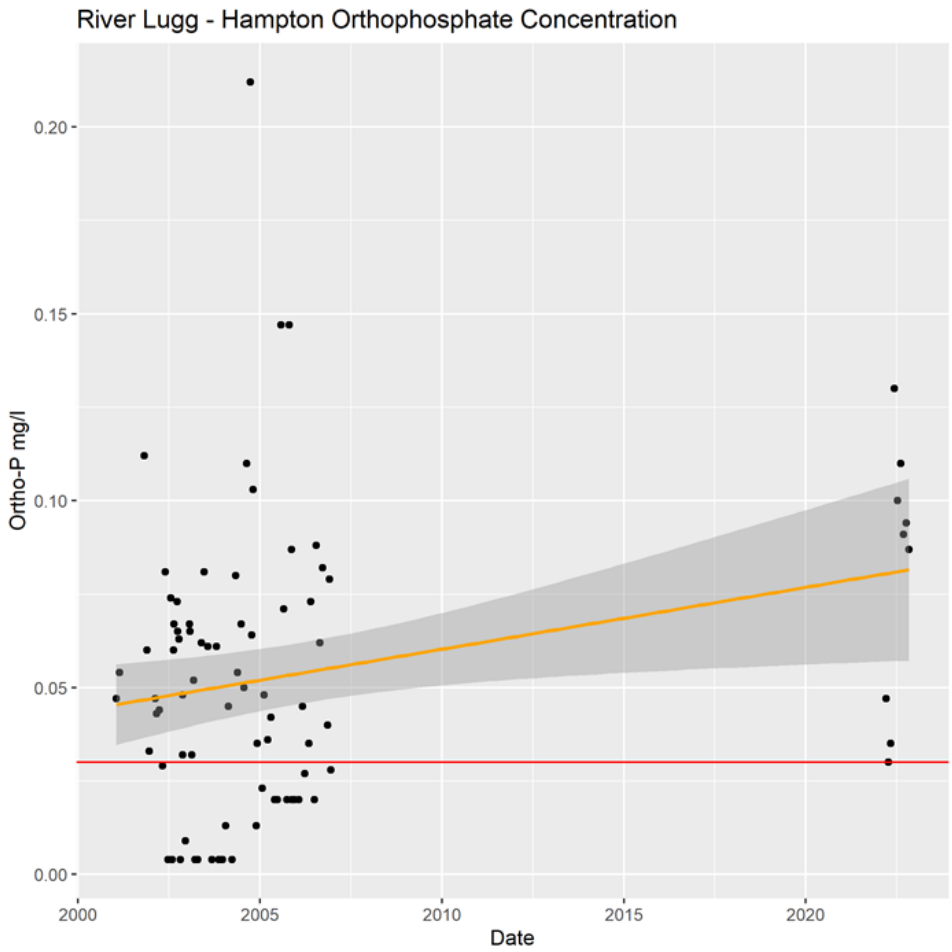
Each of the plots for the monitoring locations along the River Lugg (u/s à d/s) show Ortho-P concentrations either increasing or stable over the past 20+ years – demonstrated by the positive or neutral linear regression lines.


River Lugg - Hindwell Brook Orthophosphate Concentration
Ortho-P mg/l
0.2
0.1
0.0
-0.1
Apr
Jul
Oct
Date (2022)

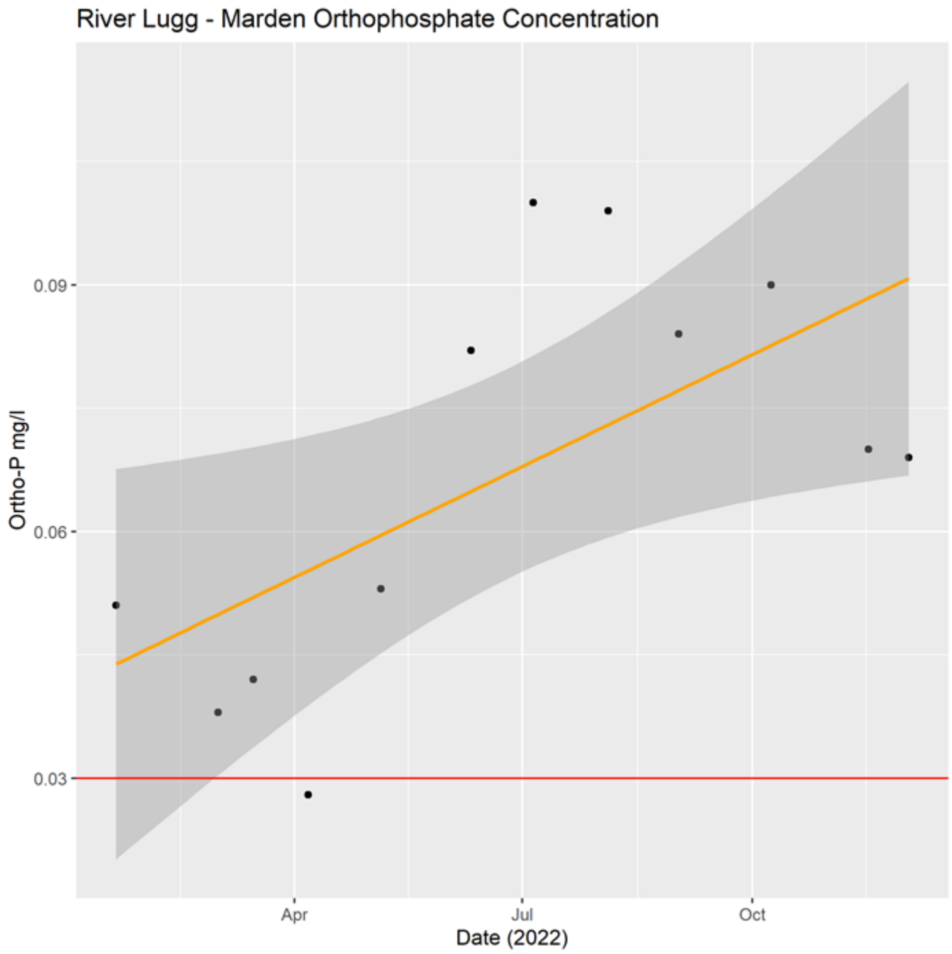

River Lugg - Eaton Bridge Orthophosphate Concentration
Ortho-P mg/l
0.2
0.1
0.0
2000
2005
2010
2015
2020
Date


River Lugg - Mortimer Cross Orthophosphate Concentration
Ortho-P mg/l
1.00
0.75
0.50
0.25
0.00
2000
2005
2010
2015
2020
Date


River Lugg - Ford Bridge Orthophosphate Concentration
Ortho-P mg/l
0.25
0.20
0.15
0.10
0.05
0.00
2000
2005
2010
2015
2020
Date

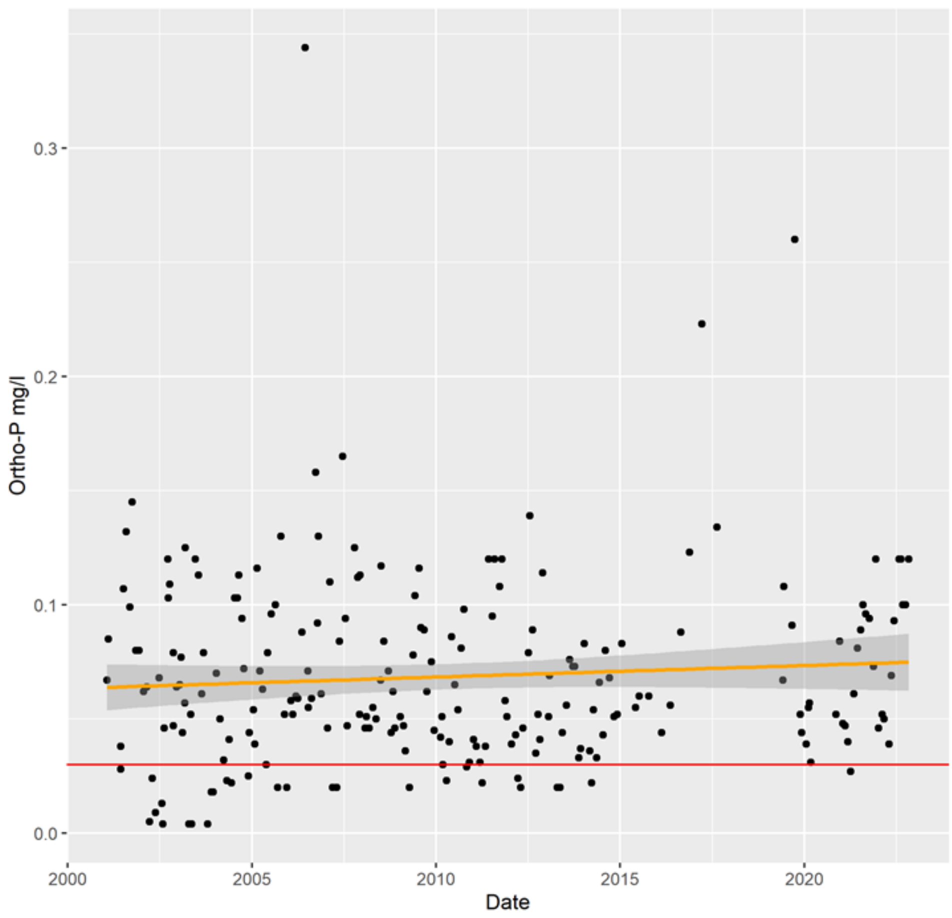


River Lugg - Hampton Orthophosphate Concentration
Ortho-P mg/l
0.00
0.05
0.10
0.15
0.20
2000
2005
2010
2015
2020
Date

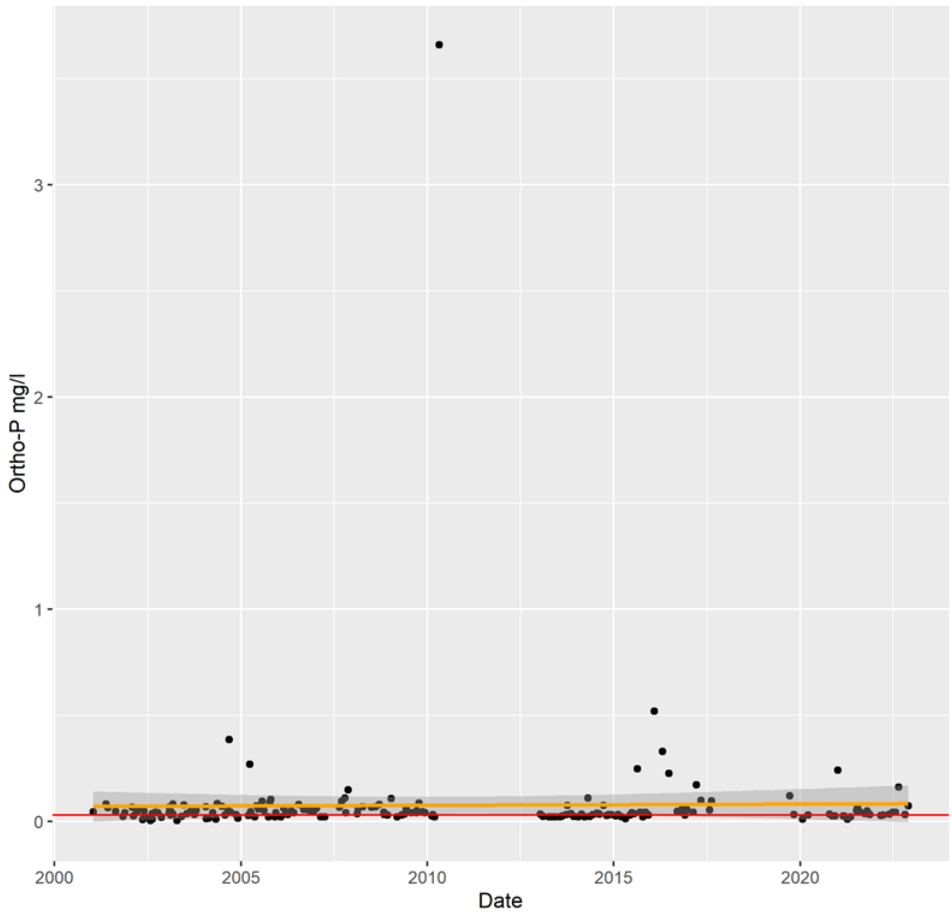


River Lugg - Marden Orthophosphate Concentration
Ortho-P mg/l
0.03
0.06
0.09
Apr
Jul
Oct
Date (2022)

River Lugg - Wergins Bridge Orthophosphate Concentration

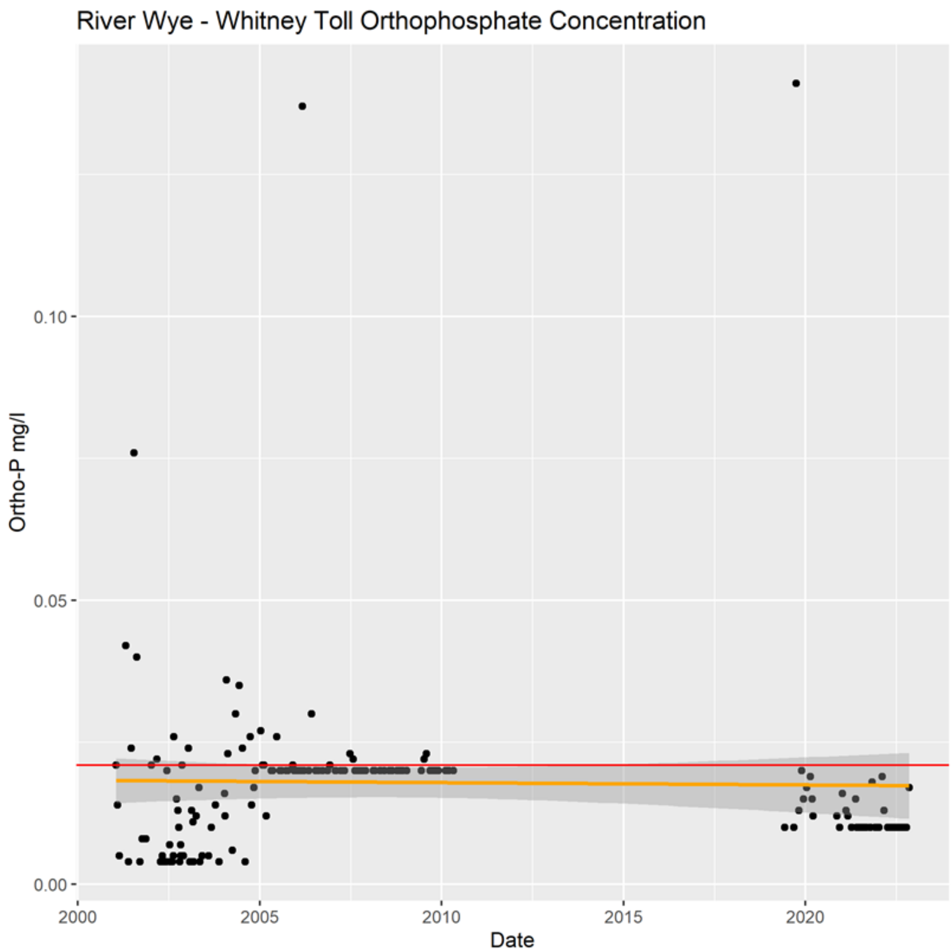


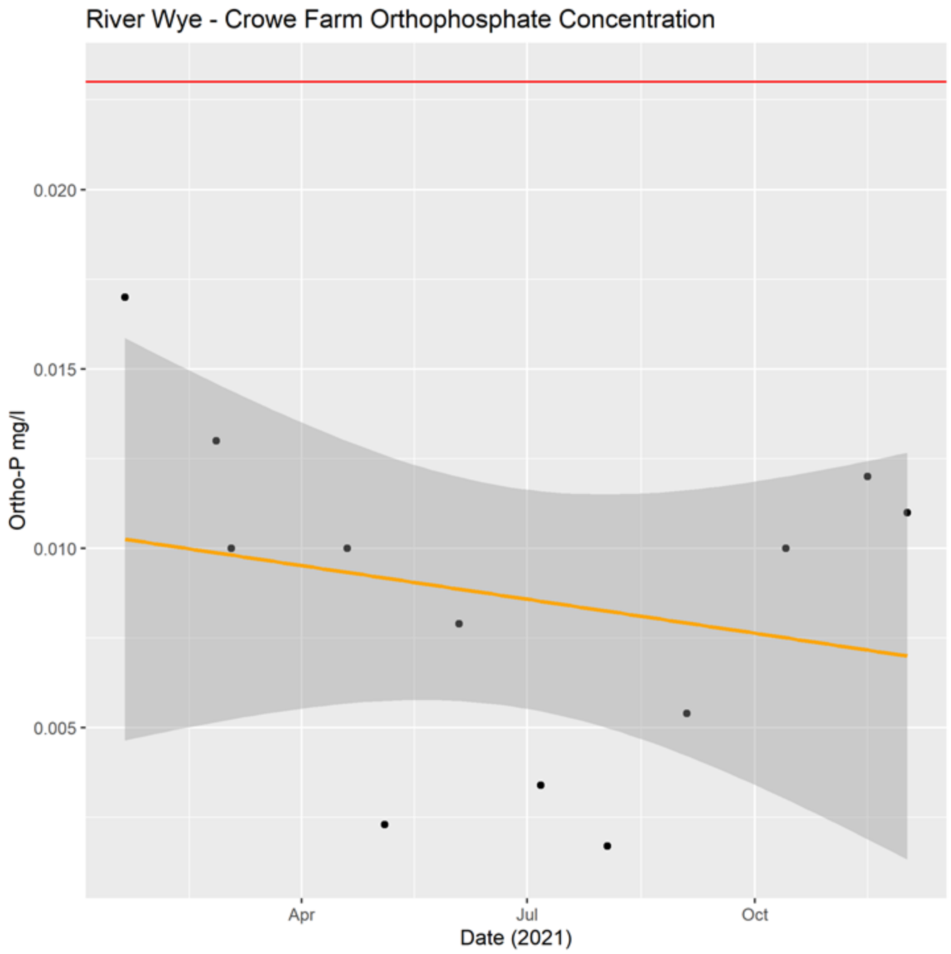
River Lugg - c.w. River Arrow Orthophosphate Concentration

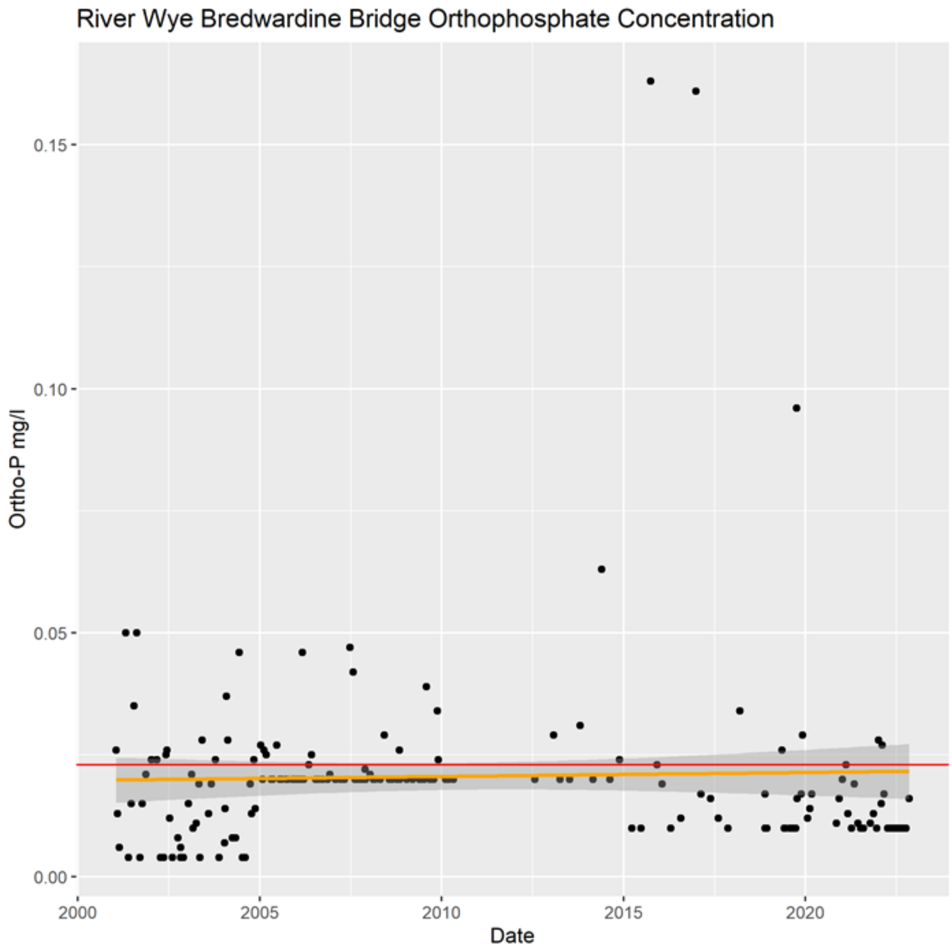


River Wye

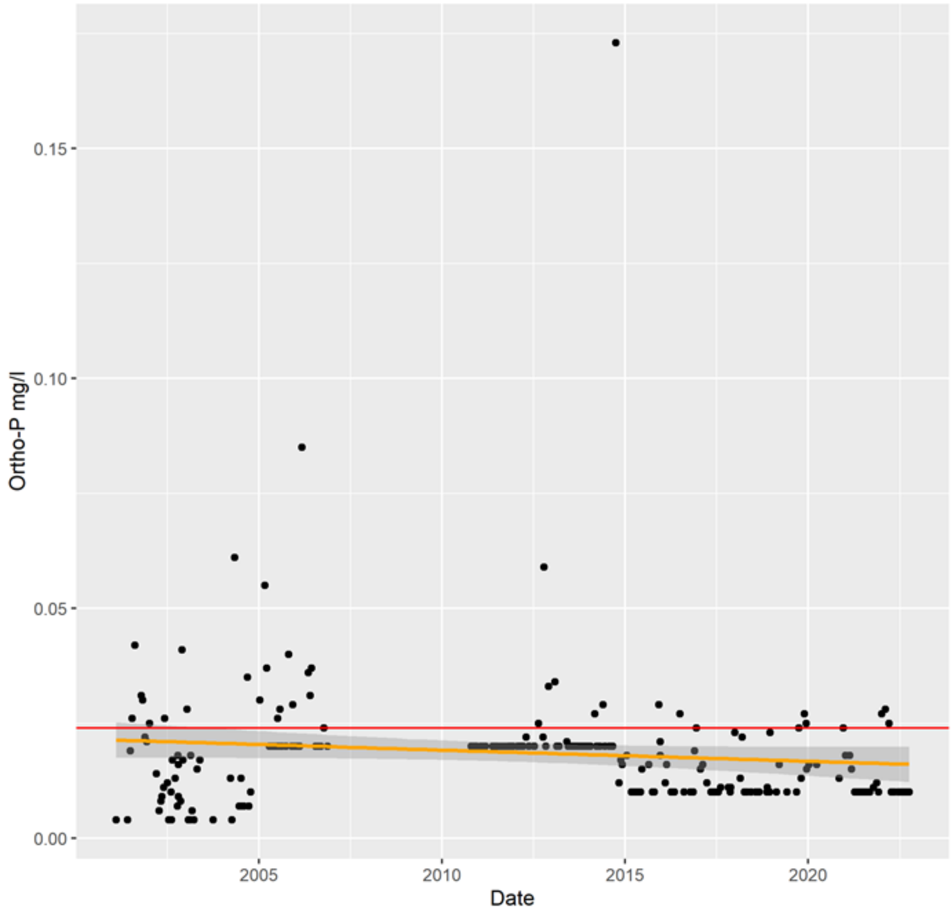
Each of the plots for the monitoring locations along the River Wye (u/s à d/s) show Ortho-P concentrations generally either stable or slightly declining over the past 20+ years – demonstrated by the neutral or negative linear regression lines.



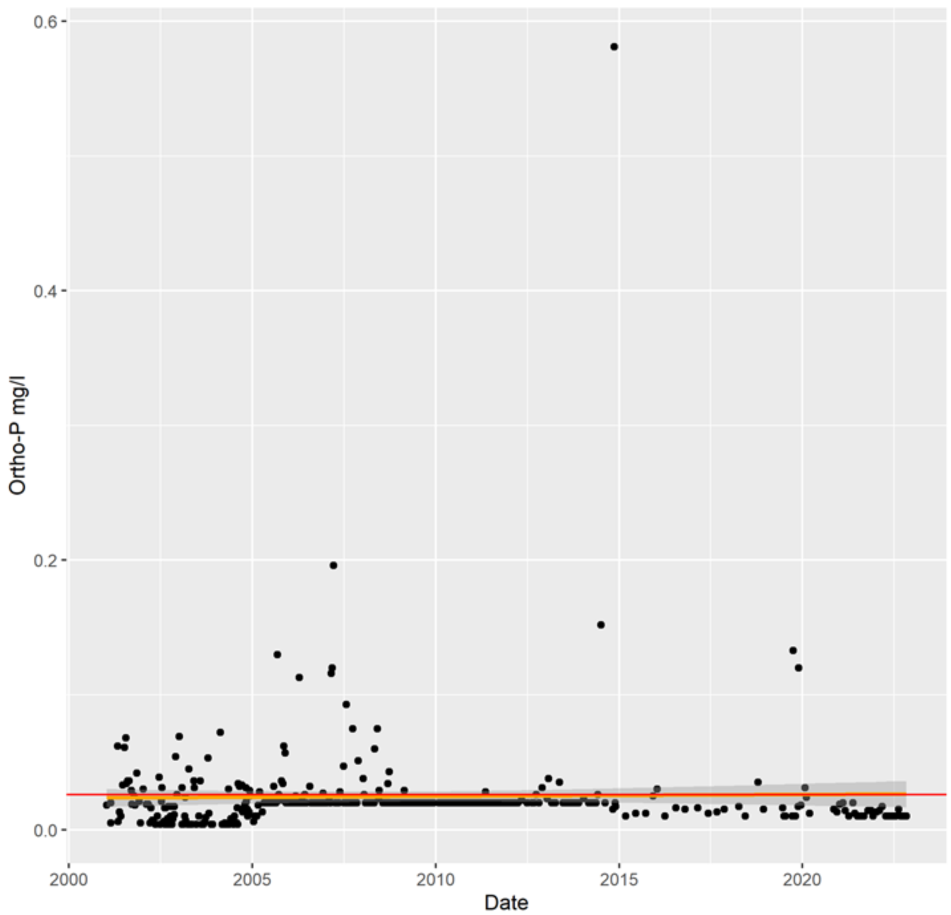

River Wye - Crowe Farm Orthophosphate Concentration
Ortho-P mg/l
0.020
0.015
0.010
0.005
Apr
Jul
Oct
Date (2021)

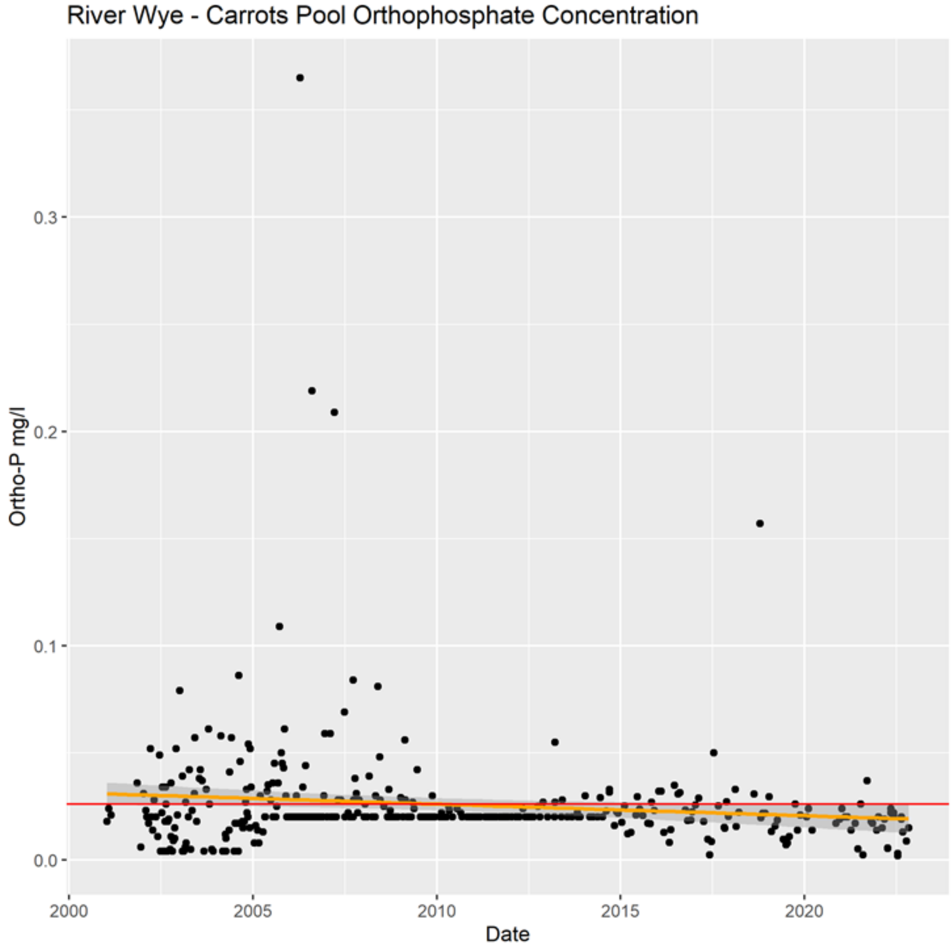

River Wye Bredwardine Bridge Orthophosphate Concentration
Ortho-P mg/l
0.15
0.10
0.05
0.00
2000
2005
2010
2015
2020
Date

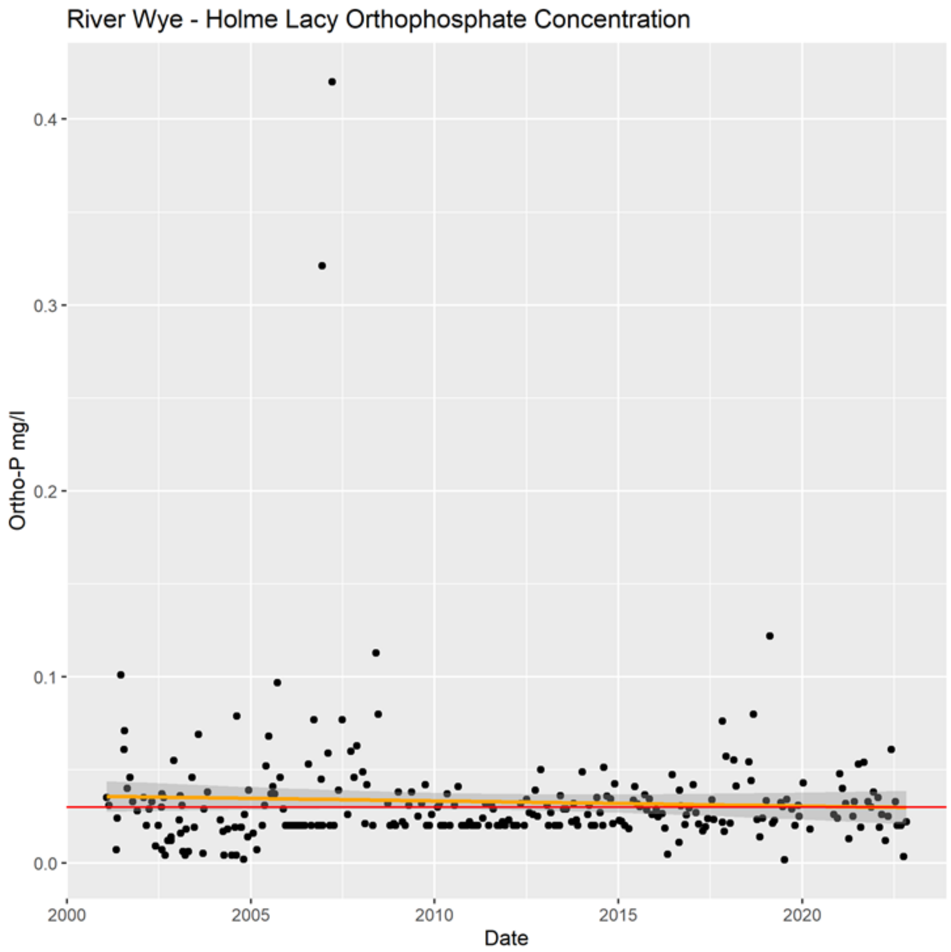
River Wye - Sollars Bridge Orthophosphate Concentration

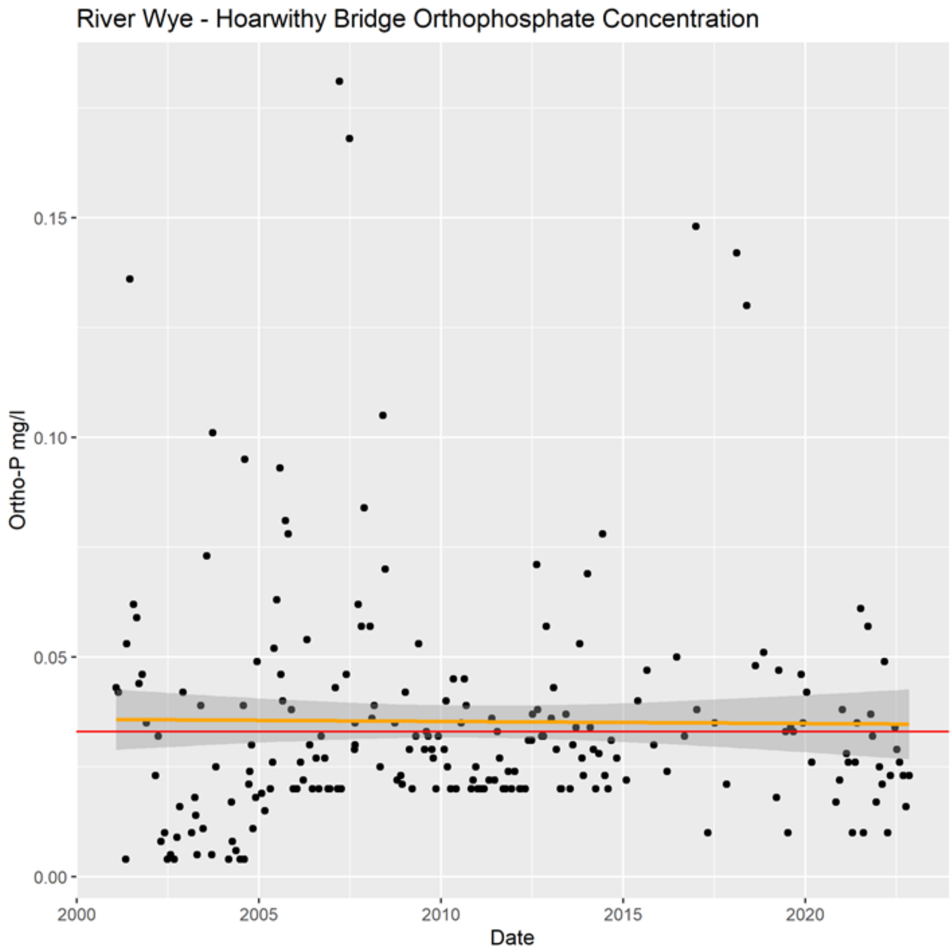


River Wye Victoria Bridge Orthophosphate Concentration

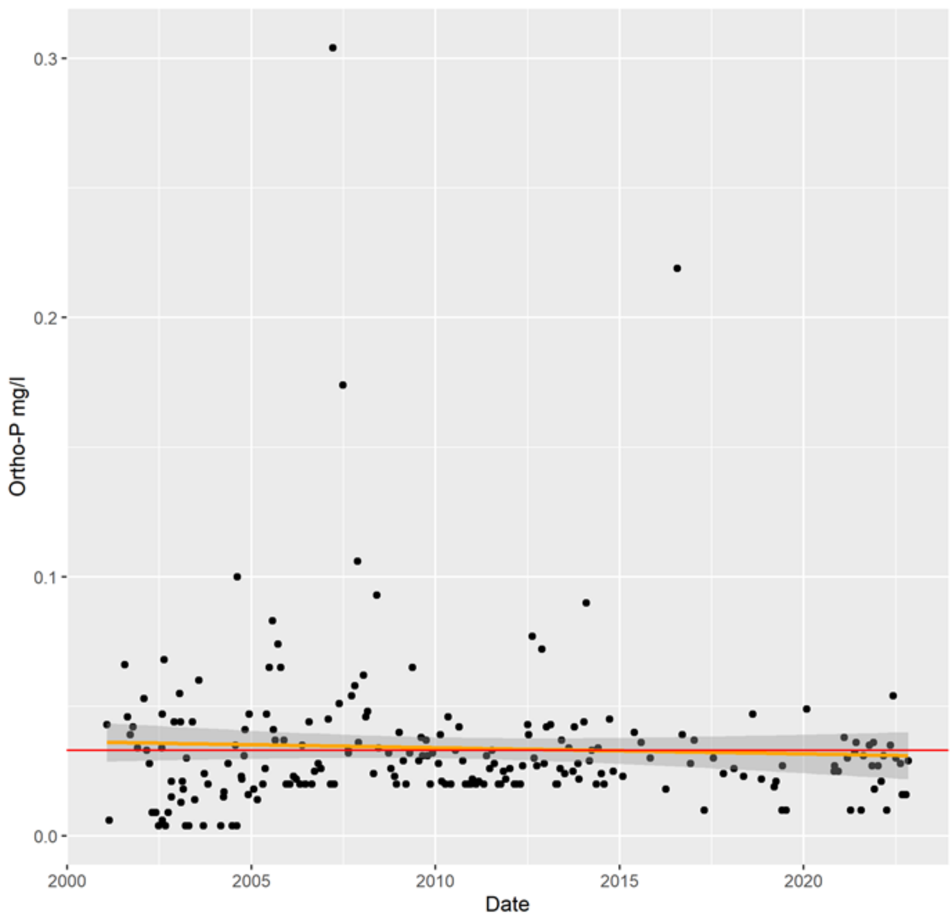



River Wye - Carrots Pool Orthophosphate Concentration
Ortho-P mg/l
0.3
0.2
0.1
0.0
2000
2005
2010
2015
2020
Date

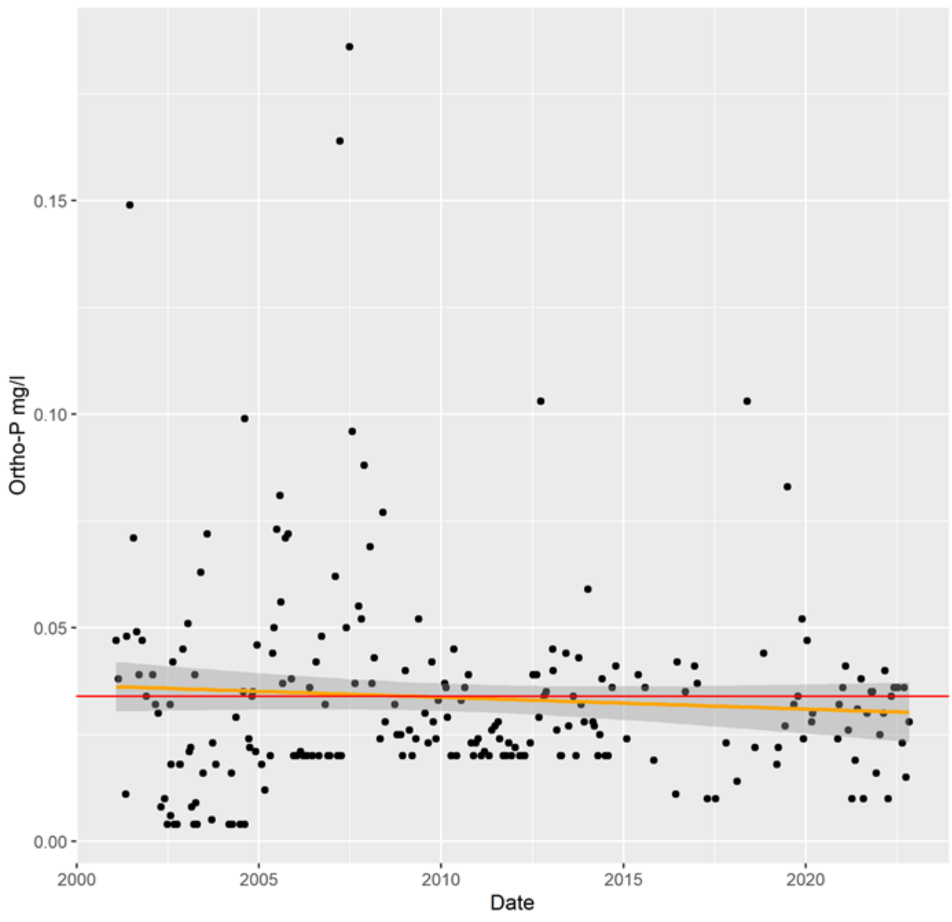

River Wye - Holme Lacy Orthophosphate Concentration
Ortho-P mg/l
0.4
0.3
0.2
0.1
0.0
2000
2005
2010
2015
2020
Date

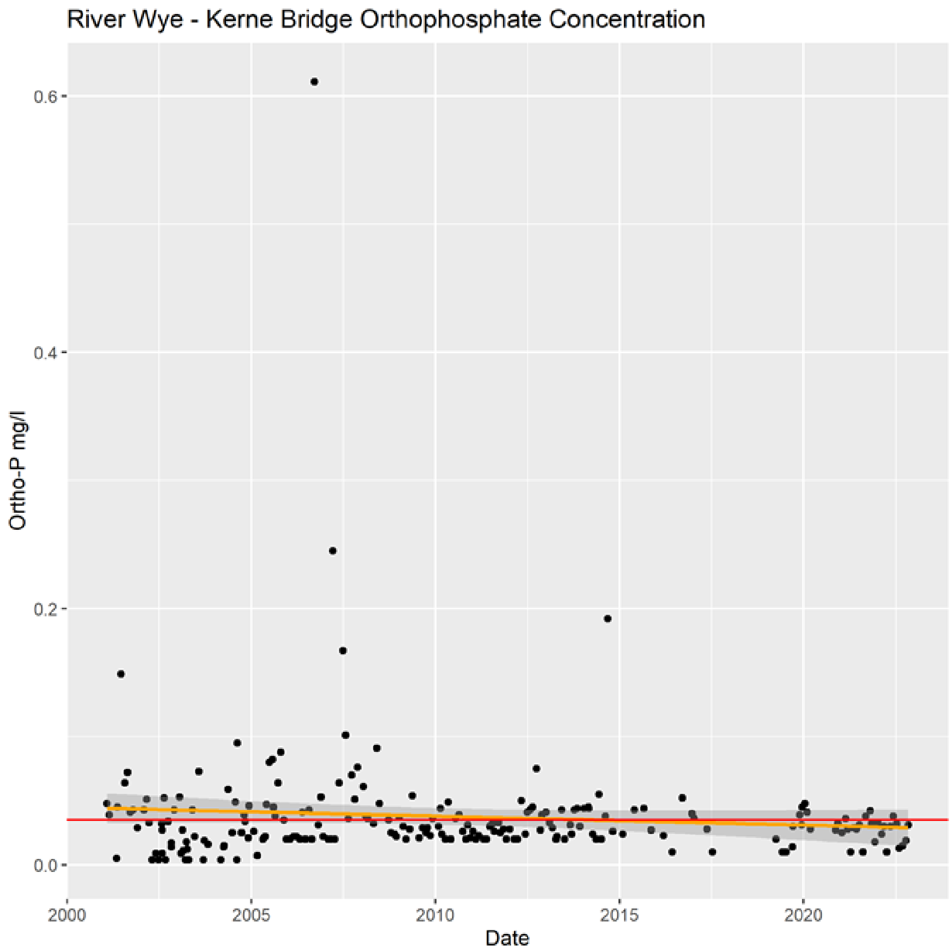

River Wye - Hoarwithy Bridge Orthophosphate Concentration
Ortho-P mg/l
0.15
0.10
0.05
0.00
2000
2005
2010
2015
2020
Date

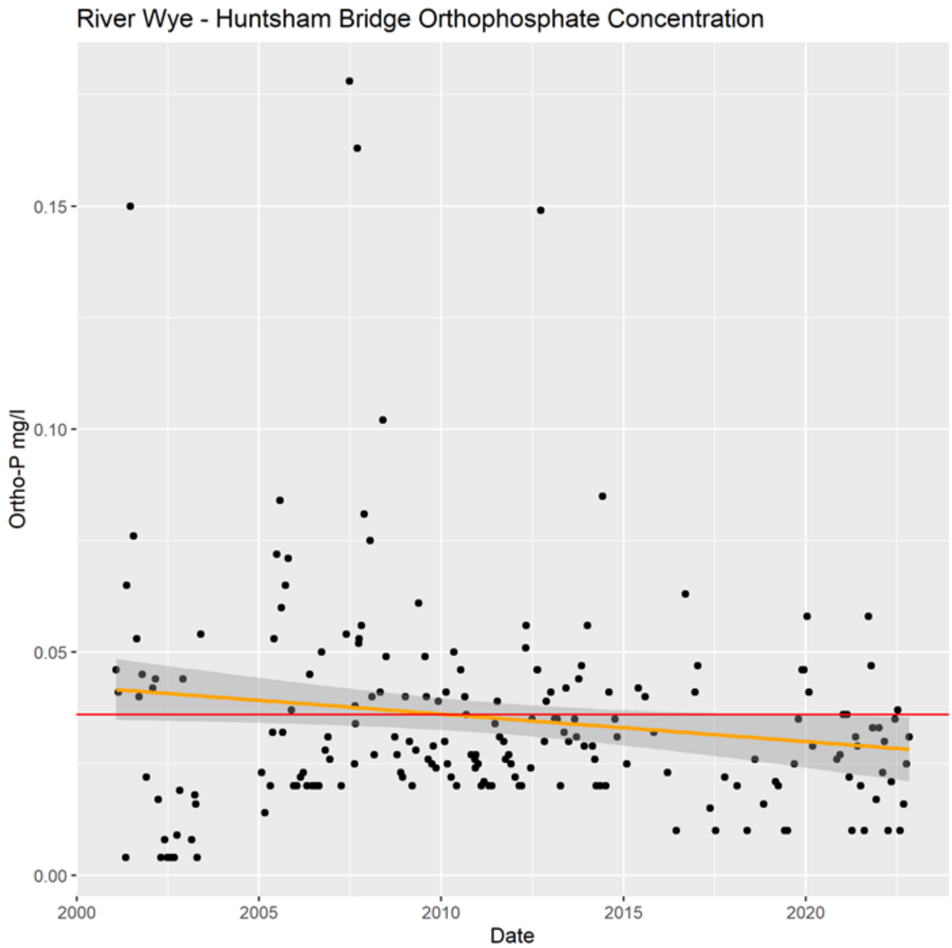
River Wye - Hole in the wall Orthophosphate Concentration

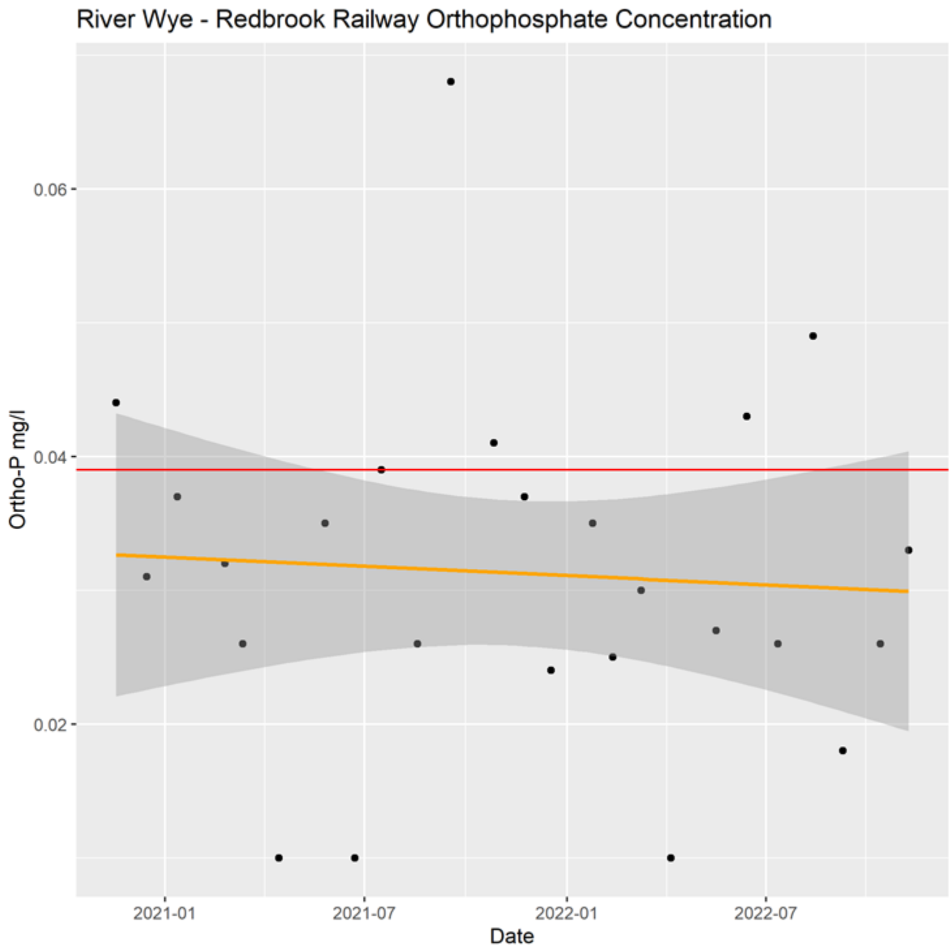


River Wye - Wilton Bridge Orthophosphate Concentration




River Wye - Kerne Bridge Orthophosphate Concentration
Ortho-P mg/l
0.6
0.4
0.2
0.0
2000
2005
2010
2015
2020
Date


River Wye - Huntsham Bridge Orthophosphate Concentration
Ortho-P mg/l
0.15
0.10
0.05
0.00
2000
2005
2010
2015
2020
Date



Consideration of changes to site condition.

There is evidence of failing condition on every unit of the River Wye and River Lugg (see table 4 and 5 below). Phosphate targets are exceeded on every unit of the river Lugg and the evidence shows phosphate levels to be increasing, demonstrating declining water quality. The River Wye is meeting its phosphate targets but is showing clear symptoms of eutrophication, despite stable phosphate levels, exacerbated by elevated water temperatures. This is supported by the moderate status of macrophytes & phytobenthos (this also encompasses algae trends).

White Clawed Crayfish have declined in both the Wye and Lugg.

The evidence from the assessment of Wye catchment salmon stocks (including the Lugg) suggests the number of Atlantic salmon returning to the catchment is in decline such that they are below the Conservation Limit and as a result Bylaws have been introduced.

Although there is much being done to try and address declines in both salmon and white clawed crayfish, there remains some uncertainty around the causes of the declines and therefore we cannot be assured that all necessary management is currently in place to deem the site to be recovering.

Regarding the decline in water quality on the Lugg, again despite significant efforts to address the issue by multiple stakeholders, given the continued declines we cannot be certain that the current measures in place will reverse this decline and further investigation is required.

Based on the evidence above, the site condition has been changed from Unfavourable Recovering to Unfavourable Declining based on CSMG as per the table below:

Table 5: Change in Condition for River Wye and River Lugg SSSIs monitoring units

Unit	SSSI	Reach	Condition prior to 30 May 2023	Updated condition from May 2023
1	River Wye	Tidal river - Estuary to Brockweir Bridge	Favourable	Unfavourable - Declining
2	River Wye	Brockweir Bridge to Monmouth	Unfavourable - Recovering	Unfavourable - Declining
3	River Wye	Monmouth to Ross	Unfavourable - Recovering	Unfavourable - Declining
4	River Wye	Ross to Hereford	Unfavourable - Recovering	Unfavourable - Declining
5	River Wye	Hereford to Bredwardine Bridge	Unfavourable - Recovering	Unfavourable - Declining
6	River Wye	Bredwardine Bridge to Whitney Toll	Unfavourable - Recovering	Unfavourable - Declining
7	River Wye	Whitney Toll to Hay	Unfavourable - Recovering	Unfavourable - Declining
1	River Lugg	Bodenham Weir to Confluence with Wye	Unfavourable - Recovering	Unfavourable - Declining
2	River Lugg	Bodenham Weir to Leominster	Unfavourable - Recovering	Unfavourable - Declining
3	River Lugg	Leominster to Mortimers Cross	Unfavourable - Declining	Unfavourable - Declining
4	River Lugg	Mortimers Cross to Presteigne	Unfavourable - Recovering	Unfavourable - Declining

Table 6. Summary of evidence and changes to condition by feature for the Wye SSSI

The following tables show a summary of the features assessed, condition and evidence used.

SSSI Notified Feature [#]	Monitored (Reportable) Feature	Designation (SSSI/SAC)	Unit No							Evidence
			1	2	3	4	5	6	7	
Atlantic stream crayfish	S1092 White-clawed (or Atlantic stream) crayfish Austropotamobius pallipes	SSSI, SAC								Crayfish survey (2013).
Sea lamprey	S1095 Sea lamprey, Petromyzon marinus	SSSI, SAC	*	*	*	*	*	*	*	
Brook lamprey	S1096 Brook lamprey, Lampetra planeri	SSSI, SAC	*	*	*	*	*	*	*	
River lamprey	S1099 River lamprey, Lampetra fluviatilis	SSSI, SAC	*	*	*	*	*	*	*	
Allis shad	S1102 Allis shad, Alosa alosa	SSSI, SAC	*	*	*	*	*	*	*	
Twaite shad	S1103 Twaite shad, Alosa fallax	SSSI, SAC	*	*	*	*	*	*	*	
Atlantic salmon	S1106 Atlantic salmon, Salmo salar	SSSI, SAC								Not achieving conservation limits, 2019 showed declining figures & overall declining trend.
Bullhead	S1163 Bullhead, Cottus gobio	SSSI, SAC		*		*	*	*	*	
Common otter	S1355 Otter, Lutra lutra	SSSI, SAC		*	*	*	*	*	*	
Invertebrates associated with riffles, river shingles and saltmarsh	Invert. assemblage W111 shingle bank	SSSI	*	*	*	*	*	*	*	
Invertebrates associated with river deadwood	Invert. assemblage W114 stream & river margin	SSSI	*	*	*	*	*	*	*	
Invertebrates associated with bankside vegetation.	Invert. assemblage W122 riparian sand	SSSI	*	*	*	*	*	*	*	

Aquatic plant communities - rivers on sandstone, mudstone and hard limestone Aquatic plant communities - clay rivers Aquatic plant communities - lowland rivers with minimal gradient Certain flowering plants and bryophytes Beds of water crowfoot (Ranunculus spp.)	Rivers and Streams	SSSI	*							Evidence base used WFD macrophyte, phytobenthos & invertebrate classification data
	H3260 Water courses of plain to montane levels with R. fluitantis	SAC			*	*	*	*	*	

Table 7. Summary of evidence and changes to condition by feature for the Lugg SSSI

SSSI Notified Feature [#]	Monitored (Reportable) Feature	Designation (SSSI/SAC)	Unit No				Evidence
			1	2	3	4	
Clay river displaying a transition from nutrient poor to naturally nutrient rich water chemistry River plant communities	Rivers and streams	SSSI					Evidence base used EA water quality monitoring data (reactive phosphorus – WFD no deterioration – failure report) & WFD macrophyte reporting.
	H3260 Water courses of plain to montane levels with Ranunculion fluitantis and Callitricho-Batrachion vegetation	SAC					Evidence base used EA water quality monitoring data (reactive phosphorus – WFD no deterioration – failure report). & WFD macrophyte reporting
Clay river displaying a transition from nutrient poor to naturally nutrient rich water chemistry	River Lamprey	SAC	*				
	Sea Lamprey	SAC	*				
	Brook Lamprey	SAC	*	*	*	*	
	Allis Shad	SAC	*				

	Twaite Shad	SAC	*	*	*	*	
	Atlantic Salmon	SAC					Not achieving conservation limits, 2019 showed declining figures & overall declining trend.
	Bullhead	SAC	*	*	*	*	
	Invertebrate assemblage W1 flowing water	SAC	*	*	*	*	
	White Clawed Crayfish	SAC					[Crayfish survey (2013).]()
Common otter	Otter	SSSI/SAC	*	*	*	*	

[#] List of notified features as confirmed by Natural England's Citation Review project in May 2023. This project establishes a robust and consistent approach to interpreting the notified features described on every SSSI Citation. Work is ongoing to update Monitoring Specifications (formerly SSSI Favourable Condition Tables) and the information on Designated Site Viewer to reflect the refined list of notified features and how these relate to what is monitored 'in the field' (monitored (reportable) features). These changes do not impact the evidence and conclusions reached in November 2022 and captured in this document.

* Not assessed

= Declining condition

When undertaking a condition assessment, the unit status should reflect the status of the feature with the lowest condition score.

Vicki Howden - West Midlands Senior Freshwater advisor (June 2022)

Daisy Burris - West Midlands Freshwater Adviser (November 2022)

Claire Minett – Operations Manager (November 2022)

Jonathan Blowers – Operations Manager (updated May 2023) to reflect Natural England's revised approach to interpreting and naming notified features resulting from an ongoing review of SSSI Citations.

Appendix 2: Understanding the terminology of the condition of a SAC river- using the example of the River Wye and Lugg SAC

Appendix 2: Understanding the terminology of the condition of a SAC river- using the example of the River Wye and Lugg SAC

Natural England May 2023

The terminology and meaning of describing and understanding the condition of a river and what certain phrases mean can be very confusing, especially when discussing alongside Nutrient Neutrality, which is itself complex. This note is a simple guide to understanding the current condition of a river using the Wye and Lugg as an example.

The different designations involved

The River Wye and the River Lugg are designated as two separate Sites of Special Scientific Interest (SSSI). They are the two component SSSIs that underpin the River Wye Special Area of Conservation (SAC) in England. Although only the stretch of the River Lugg SSSI between Leominster and its confluence with the Wye is part of the River Wye SAC. The biological features that make the River Wye SAC important, also form part of the underpinning SSSI designations. The River Wye SAC, also known as the Afon Gwy SAC, extends into Wales. Natural Resources Wales provide advice for the Welsh stretch.

SSSI monitoring specifications

When assessing the condition of a SAC, it is the biological features of the underpinning SSSIs that Natural England assess and record. Condition is 'judged' against each SSSI's monitoring specification, known as the site's Monitoring Specification. Monitoring Specifications are based on UK Common Standards Monitoring guidance published by the Joint Nature Conservation Committee. To request a copy of the monitoring specification please e-mail west.midlands.enquiries@naturalengland.org.uk.

SAC Conservation Objectives

Every SAC has Conservation Objectives identifying the site's designated features. This is supported by detailed Supplementary Advice on conserving and restoring site's features. Together these documents, and any case specific advice given by Natural England, should be used when developing, proposing, or assessing an activity, plan or project that may affect the site.

The SAC documents capture what is necessary to ensure the integrity of the site is maintained or restored so that it contributes to achieving the Favourable Conservation Status of its designated (qualifying) features. Specific targets or characteristics to achieve this, such as targets for phosphate levels for the River Wye SAC, are described in the underpinning SSSI's FCT as well as the SAC's Conservation Objective. This cross referencing provides a link between assessing the condition of SSSI features and the favourable conservation status of the SAC features.

Phosphate targets and levels in the Lugg and Wye

The River Lugg section of the SAC is currently exceeding the phosphate target for the river habitat feature identified in both the Wye SAC's Conservation Objectives and the underpinning River Lugg SSSI's FCT. This means the river habitat feature in this stretch is in unfavourable condition and failing its Conservation Objectives. This also means that this stretch is not contributing to achieving Favourable Conservation Status for this river habitat, and that other designated (qualifying) features in the SAC dependent on the river habitat are also unlikely to contribute to their Favourable Conservation Status.

The River Wye (between Hay -on -Wye and the River Lugg confluence) is currently just meeting its phosphate target in some monitoring locations and is, therefore, at risk of also failing the SAC's Conservation Objectives if phosphate levels increase.

The Phosphate target is just one element of the River Wye SAC's Conservation Objectives, but a very important one in terms of health of the river. In relation to Nutrient Neutrality the fact the Lugg stretch is exceeding the water quality targets has specific implications with regards how the Habitat Regulations are applied due to the Dutch Judgement.

River Lugg and River Wye SSSI Condition

The River Wye and Lugg designated site has a relatively complex set of interest features (those features for which the river is designated) and as such undertaking a full condition assessment is a significant undertaking. Natural England is seeking to undertake a full assessment in 2023/4 In the interim, the Area Team has reviewed a number of specific components of the interest features using Common Standard Monitoring Guidance (CSMG) to review the current condition stat. us. For full details of the features assessed please see Appendix 1.

Natural England's assessment is that the River Wye SSSI and the River Lugg SSSI are in unfavourable declining condition. Our interim assessment focused on Macrophytes, , Salmon and White-Clawed Crayfish.

SSSIs are divided into monitoring units (as per Table 1). A unit's condition reflects the lowest condition category of any designated feature present in that unit. If a unit is in unfavourable condition, then at least one feature present in that unit is assessed as unfavourable.

The recent assessment demonstrated that in every unit at least one of the assessed components of the interest features (Macrophytes, Salmon and White-Clawed Crayfish) was in unfavourable condition and was declining. Therefore the current condition is detailed below. This does not impact on the water quality target, and therefore makes no change to the "Nutrient Neutrality" status of both rivers, as this is based solely on water quality. The Lugg is failing its water quality targets, the Wye is not failing its water quality targets.

Table 1. Revised condition of River Wye and Lugg SSSI/SAC

Unit	River	Reach	Designation	Suggested Condition on CMSi
1	River Wye	Tidal river - Estuary to Brockweir Bridge	SSSI/SAC	Unfavourable - Declining
2	River Wye	Brockweir Bridge to Monmouth	SSSI/SAC	Unfavourable - Declining
3	River Wye	Monmouth to Ross	SSSI/SAC	Unfavourable - Declining
4a	River Wye	Ross to Lugg Confluence	SSSI/SAC	Unfavourable - Declining
4b	River Wye	Lugg Confluence to Hereford	SSSI/SAC	Unfavourable - Declining
5	River Wye	Hereford to Bredwardine Bridge	SSSI/SAC	Unfavourable - Declining
6	River Wye	Bredwardine Bridge to Whitney Toll	SSSI/SAC	Unfavourable - Declining
7	River Wye	Whitney Toll to Hay	SSSI/SAC	Unfavourable - Declining
1	River Lugg	Bodenham Weir to Confluence with Wye	SSSI/SAC	Unfavourable - Declining
2	River Lugg	Bodenham Weir to Leominster	SSSI	Unfavourable - Declining
3	River Lugg	Leominster to Mortimers Cross	SSSI	Unfavourable - Declining
4	River Lugg	Mortimers Cross to Presteigne	SSSI	Unfavourable - Declining

Table 2: The following table explains the condition categories.

SSSI Condition categories	
Condition status	**Explanation**
Favourable condition	The designated feature is being adequately conserved and the results from monitoring demonstrate that the feature is meeting all the mandatory site-specific monitoring targets set out in the Favourable Condition Tables (FCT). The FCT sets the minimum standard for favourable condition for the designated feature and there may be scope for the further (voluntary) enhancement of the feature.
Unfavourable recovering condition	Often known simply as 'recovering'. The Feature is not yet fully conserved, but all the necessary management measures are in place. Provided that the recovery work is sustained, the feature will reach favourable condition in time. At least one of the designated features mandatory attributes is not meeting their targets (as set out in the site specific FCT).

Unfavourable no-change condition	The feature is not being conserved, and will not reach favourable condition, unless there are changes to the management or external pressures and this is reflected in the results of monitoring over time; with at least one of the mandatory attributes not meeting its target (as set out in the site specific FCT) with the results not moving towards the desired state. The longer the feature remains in this poor condition, the more difficult it will be, in general, to achieve recovery.
Unfavourable declining condition	The feature is not being conserved and will not reach favourable condition unless there are changes to management or external pressures. The feature condition is becoming progressively worse, and this is reflected in the results of monitoring over time, with at least one of the designated features mandatory attributes not meeting its target (as set out in the site specific FCT) with the results moving further away from the desired state. The longer the feature remains in this poor condition, the more difficult it will be, in general, to achieve recovery.
Part destroyed condition	Lasting damage has occurred to part of a designated feature, such that it has been irretrievably lost and will never recover (no amount of management will allow the feature to ever reach favourable condition).
Destroyed condition	Lasting damage has occurred to an entire designated feature such that the feature has been irretrievably lost (no amount of management will bring this feature back). This feature will never recover e.g., a finite mineralogical feature has been totally removed from its surroundings without consent and is therefore lost forever.

What does Unfavourable-declining condition mean on the Wye & Lugg?

Where a feature/unit is recorded as unfavourable-declining, it is Natural England's judgement that there is evidence of continued decline against the feature's monitoring targets, and the management measures in place are insufficient to allow the feature to attain its monitoring targets in the future. Changes in site management and/or changes to external pressures are required to achieve favourable condition.

There is a significant amount of effort on both the Wye and Lugg to improve this situation, including a Nutrient Management Plan which outlines the actions required with regard to phosphates. Some of the reasons for decline may be outside the catchment, and further work is required to fully understand the reasons.

For details of pressures affecting the condition of the Wye and Lugg SSSis (River Wye) please visit the Designated Site Viewer. search for the site.

Herefordshire Council

Title of Report: Executive response to recommendations from the Environment and Sustainability Scrutiny Committee on the Local Flood Risk Management Strategy Action Plan

Meeting: **Environment and Sustainability Committee**

Meeting date: **25 September 2023**

Report by: **Democratic Services**

Classification

Open

Decision type

Non-key

Wards affected

(All Wards);

Purpose:

To note the Executive response to the 10 recommendations on the Local Flood Risk Management Strategy Action Plan made by the Environment and Sustainability Committee during its meeting on 18 November 2022.

Recommendations

a) **The response to the Environment and Sustainability Scrutiny Committee recommendations regarding the Local Flood Risk Management Strategy Action Plan, as attached appendix 1 is noted.**

Alternative options

None proposed.

Further information on the subject of this report is available from
Simon Cann, Tel: 01432260667, email: simon.cann@herefordshire.gov.uk

Key considerations

1. On 18 November 2022, the Council's Directorate Services Team Leader presented a report to the Environment and Sustainability Scrutiny Committee regarding the Local Flood Risk Management Strategy Action Plan. The report can be seen in appendix 2.

2. At the Environment and Sustainability Scrutiny Committee meeting held on 18 November 2022, the Committee agreed that the recommendations in appendix 1 were to be reported to Cabinet.

3. The responses to the Environment and Sustainability Scrutiny Committee recommendations regarding the Local Flood Risk Management Strategy Action Plan, as detailed in appendix 1 were approved 16 August 2023.

Community Impact

4. The resulting improvements from these recommendations will contribute towards the 'Environment' ambition of our County Plan (2020 – 2024) and the 'Increase flood resilience and reduce levels of phosphate pollution in the county's river' success measure.

Environmental Impact

5. This decision seeks to deliver the council's environmental policy commitments and aligns to the following success measure in the County Plan – 'Increase flood resilience and reduce levels of phosphate pollution in the county's river'.

6. The Council provides and purchases a wide range of services for the people of Herefordshire. Together with partner organisations in the private, public and voluntary sectors we share a strong commitment to improving our environmental sustainability, achieving carbon neutrality and to protect and enhance Herefordshire's outstanding natural environment.

Equality Duty

7. Under section 149 of the Equality Act 2010, the 'general duty' on public authorities is set out as follows:

8. A public authority must, in the exercise of its functions, have due regard to the need to –

   a) eliminate discrimination, harassment, victimisation and any other conduct that is prohibited by or under this Act;

   b) advance equality of opportunity between persons who share a relevant protected characteristic and persons who do not share it;

   c) foster good relations between persons who share a relevant protected characteristic and persons who do not share it.

9. The public sector equality duty (specific duty) requires us to consider how we can positively contribute to the advancement of equality and good relations, and demonstrate that we are

paying ‘due regard’ in our decision making in the design of policies and in the delivery of services.

Resource Implications

10. There are no resource implications associated with noting the content of this report as the Executive response provides information and indicates how the work is being taken forward. Where further decisions are required upon completion of the recommendations, any resource requirements will be considered in future reports.

Legal Implications

11. This Council operates executive arrangements under the Local Government Act 2000. This enables overview and scrutiny committees to raise issues and recommendations for the Cabinet to consider.

12. Paragraphs 4.5.50 of the Constitution reflects this arrangement and this report includes the views of Cabinet to the Committee’s recommendations.

Risk management

13. There are no risks associated with noting the content of this report as the Executive response provides information and indicates how the work is being taken forward.

Consultees

None

<u>Appendices</u>

Appendix 1: Executive response to the Environment and Sustainability Scrutiny Committee Local Flood Risk Management Strategy Action Plan

Appendix 2: Report to the Environment and Sustainability Scrutiny Committee regarding the Local Flood Risk Management Strategy Action Plan

Background papers

None identified

Appendix 1: Executive response to the Herefordshire Local Flood Risk Management Strategy by Environment and Sustainability Scrutiny Committee

<table>
<tr><td colspan="5">On 18 November 2022, the Environment and Sustainability Scrutiny committee considered the Herefordshire Local Flood Risk Management Strategy. The committee resolved ‘That the following be recommended to the executive:’</td></tr>
<tr><td>Recommendation 1.</td><td colspan="4">• That the Council's Local Flood Risk Management Strategy Action Plan include flood risk measures and mitigations that are identified as needed even if not resourced.</td></tr>
<tr><td>Executive response</td><td colspan="4">Accepted

HC is currently reviewing and refreshing the Herefordshire Local Flood Risk Management Strategy and associated Action Plan, prior to them being finalised and published during 2023/24.</td></tr>
<tr><td>Action</td><td>Owner</td><td>By when</td><td>Target/success criteria</td><td>Progress</td></tr>
<tr><td>Herefordshire Local Flood Risk Management Strategy Action Plan to be published</td><td>SH</td><td>March 2024</td><td>Action Plan published</td><td>Draft documents currently being prepared prior to consultation in summer 2023.</td></tr>
<tr><td>Recommendation 2.</td><td colspan="4">• That the Cabinet consider areas where there may be opportunities to “invest to save” (eg investment in drainage and drainage maintenance may save money on road maintenance).</td></tr>
<tr><td>Executive response</td><td colspan="4">This will be considered in line with the Highways Maintenance Plan (HMP), Transport Asset Management Plan (TAMP) and Annexes 3 and 7 of the annual plan for the public realm services contract with BBLP.</td></tr>
<tr><td>Action</td><td>Owner</td><td>By when</td><td>Target/success criteria</td><td>Progress</td></tr>
<tr><td>Consideration to be given to any such “invest to save” drainage opportunities.</td><td>SH</td><td>December 2023</td><td>Review completed</td><td></td></tr>
<tr><td>Recommendation 3.</td><td colspan="4">• That the Council work with parish councils and community groups to engage local communities and neighbourhoods in further initiatives they can do to mitigate and manage flood risk (eg proving local signage, flood risk mapping, local projects etc).</td></tr>
<tr><td>Executive response</td><td colspan="4">Accepted

HC recognises the importance of working with communities on flooding and is currently considering the best way in which to do this.</td></tr>
<tr><td>Action</td><td>Owner</td><td>By when</td><td>Target/success criteria</td><td>Progress</td></tr>
<tr><td>Set out how Herefordshire communities can work together to manage the risk of flooding in the county</td><td>SH</td><td>December 2023</td><td>Arrangements in place</td><td></td></tr>
</table>

Recommendation 4.	• That the Cabinet ensure that flood risk modelling information work carried out by the Environment Agency and flood risk mapping information held by the Hereford and Worcestershire Fire and Rescue services is used in the Council's flood risk mapping.			
Executive response	Accepted The flood data we collect comes from a number of sources, including the Environment Agency and Hereford & Worcester Fire and Rescue Service. We will continue to compare predicted flooding against historic flooding in order to improve the accuracy and reliability of predicted flood models.			
Action	**Owner**	**By when**	**Target/success criteria**	**Progress**
Continue to collate and analyse flood data	BBLP	Ongoing		
Recommendation 5.	• That the Cabinet make sure that the Local Plan is integrated and informed by new flood risk management strategy and up to date flood risk mapping data and analysis.			
Executive response	Partially accepted The Department for Levelling Up, Housing & Communities has recently consulted on the Levelling-up and Regeneration Bill: reforms to national planning policy. Whilst the timings of the outcome of this consultation are presently unknown, the documentation published to date suggests they will include development and flood-risk management as a national issue – applying a policy across England and as such there would not be scope for a similar policy to be included within the Local Plan. The Local Plan will still define the up-to-date extent of the land at risk of flooding which may well include sources of flooding other than just the Environment Agency Flood Zones, and this is the area where the national policy will apply. Strategic Flood Risk Assessments both at county and site level will be important in this process. As set out in the response to Recommendation 8, the Herefordshire Local Flood Risk Management Strategy will provide part of the evidence base for the preparation of the policies of the local plan.			
Action	**Owner**	**By when**	**Target/success criteria**	**Progress**
Ensure that the evidence base supporting the preparation of the Local Plan is comprehensive and complete prior to the submission of the Local Plan to the Secretary of State for Examination in Public.	Strategic Planning Manager	December 2024	Adopted Local Plan incorporating a sound set of planning policies and proposals.	Draft Local Plan currently being prepared for consultation in Autumn 2023.
Recommendation 6.	• That the Council carry out habitat risk assessments for landscape mitigation measures being undertaken to protect wildlife environments and ecosystems.			
Executive response	Partially accepted Arrangements are in place around the production of HRAs and we will consider in conjunction with BBLP and the Ecology Team whether any amendments to these processes are required.			
Action	**Owner**	**By when**	**Target/success criteria**	**Progress**

Consider whether amendments required to processes around HRAs for flood works.	SH	Summer 2023	Options considered	
Recommendation 7.	• That the Council introduce a forum for people who want to get involved in flood risk management and mitigation and need to know where to go to get involved.			
Executive Response	Accepted – links to recommendation (3) and responses as above.			
Action	**Owner**	**By when**	**Target/success criteria**	**Progress**
Link to recommendation (3) above.	SH	December 2023	Arrangements in place	
Recommendation 8.	• That the Cabinet clarify how the Flood Risk Management Strategy will fit in with the new Local Plan.			
Executive response	Accepted The Herefordshire Local Flood Risk Management Strategy sets out how we intend to work with partners to manage the risk of flooding. Whilst it is currently being reviewed and refreshed, before being finalised and published during 2023/24, it will seek to promote sustainable development and infrastructure that is resilient to flood risk, supports environmental improvement and responds to a changing climate. The Local Flood Risk Management Strategy will form an element of the evidence base which will be drawn upon in the preparation of the Local Plan, together with other key evidence base studies, such as the Strategic Flood Risk Assessment and Water Cycle Study.			
Action	**Owner**	**By when**	**Target/success criteria**	**Progress**
Consider relevant land use implications set out in the Local Flood Risk Management Strategy and include suitable references and development requirements within the policies and proposals of the Local Plan (subject to compliance with the scope and content of national planning policy).	Strategic Planning Manager	December 2024	Adopted Local Plan incorporating a sound set of planning policies and proposals.	
Recommendation 9.	• That the Council's Local Flood Risk Management Strategy Action Plan include any relevant actions being taken by our partners in this area.			
Executive Response	Accepted – links to recommendation (1) and responses as above.			
Action	**Owner**	**By when**	**Target/success criteria**	**Progress**

Herefordshire Local Flood Risk Management Strategy Action Plan to be published.	SH	March 2024	Action Plan published	Draft documents currently being prepared prior to consultation in summer 2023.

Recommendation 10.	• Herefordshire Council reviews the water course consent form and involves the ecology team and looks at the connections and linkages between the flood risk management and the nature strategy and the Habitats Regulation Assessment (HRA).
Executive response	Partially accepted Applications for Ordinary Watercourse Flood Defence Consent are processed on our behalf by BBLP. The Guidance Notes were last updated in September 2022 and we will consider in conjunction with BBLP and the Ecology Team whether any further updates to the process are required.

Action	**Owner**	**By When**	**Target/success criteria**	**Progress**
Consider whether further updates required to processes around Ordinary Watercourse Flood Defence Consent.	SH	Summer 2023	Options considered	

Herefordshire Council

Title of report: Local Flood Risk Management Strategy Action Plan

Meeting: Environment and Sustainability Scrutiny Committee

Meeting date: Friday 18 November 2022

Report by: Directorate services team leader

Classification

Open

Decision type

This is not an executive decision

Wards affected

(All Wards);

Purpose

To present the action plan which identifies a programme of work for reducing local flood risk within Herefordshire. Under the Flood & Water Management Act 2010, Herefordshire Council as the Lead Local Flood Authority is required to have a Local Flood Risk Management Strategy (LFRMS). The Environment and Sustainability Scrutiny Committee is allocated statutory flood risk management scrutiny powers.

Recommendation(s)

That:

a) **The Committee reviews the updated action plan and provides comments to help inform the development of a new action plan**

b) **The Committee receives an update in one year's time on progress.**

Alternative options

1. There are no alternatives to the recommendations; Environment and Sustainability Scrutiny Committee is allocated statutory flood risk management scrutiny powers.

Further information on the subject of this report is available from
Steve Hodges, Tel: 01432 261923, email: sthodges@herefordshire.gov.ukl

Key considerations

Background

2. As Lead Local Flood Authority (LLFA) as set out in the Flood & Water Management Act 2010, it is Herefordshire Council's responsibility to lead in managing local flood risks (i.e. risks of flooding from surface water, groundwater and ordinary (smaller) watercourses). This includes ensuring cooperation between Risk Management Authorities (RMAs) in their area.

3. RMAs are organisations with responsibilities for water management and therefore flooding. Such organisations are many other authorities also responsible for the management of flood risk within the county and include:

    a) The Environment Agency which has a strategic overview of all sources of flooding and is the authority responsible for managing flood risk from rivers designated as 'main rivers', reservoirs and the sea;

    b) Welsh Water which is the authority responsible for managing flood risk from the public sewerage network in the majority of Herefordshire;

    c) Severn Trent Water which is the authority responsible for managing flood risk from the public sewerage network in the north and east of Herefordshire;

    d) The River Lugg Internal Drainage Board who are responsible for water level management with its operational areas, which encompass the low-lying land within the catchments of the Rivers Lugg, Arrow, Frome and Monnow (in England).

    e) Lower Severn Internal Drainage Board who are responsible for the maintenance of the land drainage assets within the low-lying land within the catchment of the River Leadon; and

    f) National Highways and Network Rail who are responsible for managing flood risks within their trunk road, motorway and railway networks respectively.

4. See Appendix 1 for a diagram setting out who the LLFA interacts with, internally and externally.

5. As LLFA, the council has limited powers under the Land Drainage Act 1991 to regulate ordinary watercourses (outside of internal drainage districts) to maintain a proper flow by:

    a) issuing consents for altering, removing or replacing certain structures or features on ordinary watercourses; and

    b) enforcing obligations to maintain flow in a watercourse and repair watercourses, bridges and other structures in a watercourse

6. Note that as LLFA, the council does not have responsibility or powers to:

    a) implement a solution to a flooding incident;

    b) make other RMAs implement a solution; or

    c) maintain ordinary watercourses.

Recent flood events

7. Herefordshire experienced severe flooding events in October 2019 and February 2020, with several flooding incidents passing the 'significant event' threshold as set out within the LFRMS. The October 2019 event comprised a succession of heavy rainfall events that fell across England and Wales, and towards the end of the month led to flooding across Herefordshire. This was

followed by a series of heavy successive rainfall events in February 2020 that led to record breaking flows and significant flooding across Herefordshire. The three named storms, Ciara, Dennis and Jorge, along with other rainfall in the month resulted in the new UK maximum for February monthly rainfall total since records started in 1862. The rainfall for the nine months leading up to the end of February 2020 resulted in saturated catchments and enhanced flood risk. The Soil Moisture Deficits for the UK were near-zero for five consecutive months from October 2019 to February 2020. The consequence of the Soil Moisture Deficits being near zero is that river flows were very responsive to the rainfall, resulting in some peak flow records being established across the UK.

8. The council plays a key role in flood recovery and after the February 2020 floods, Talk Community helped coordinate council staff and other partner agencies going out to areas impacted by flooding, providing advice, completing applications for grants and helping directly in the clean-up.

9. Following the February 2020 floods the council:

    a) Arranged over 700 recovery grant payments for residents and businesses;

    b) Applied council tax and business rate discounts; and

    c) Administered a Property Flood Resilience (PFR) scheme on behalf of Defra between May 2020 and July 2022. Through this scheme we have supported 212 property owners in accessing a total of over £966,000 of funding to make their properties more resilient to future flood events.

10. The predicted impact of climate change on future weather patterns across the UK make it likely that Herefordshire will experience flooding events with increasing frequency in years to come. This may lead to areas being at risk of flooding that were not previously susceptible to such events. The risk of flooding is becoming more of an issue for communities across the county and is likely to further increase demand on limited resources.

Section 19 reports

11. The council investigates instances of flooding where three or more residential properties have been flooded internally, and other instances that meet its threshold of investigation (known as a Section 19 report – this is a public statement of the circumstances of a flood event and what parties have a role in managing the risks).

12. During 2021/22 the council completed its Section 19 reports which analysed flood events in October 2019 and February 2020 that were attributable to local sources of flooding. An overall Section 19 report, event analysis and 28 location summary documents have been published on our flooding webpages. See Appendix 2 for a summary of this work.

13. The council continues to work closely with the Environment Agency in order to identify opportunities to reduce flood risk in a collaborative manner. Consequently Herefordshire has a number of flood risk management projects within the government's 6-year flood and coastal erosion risk management (FCERM) programme, from 2021 to 2027. These locations will be investigated and, if viable, implemented to reduce flood risk. Alongside locations highlighted within its Section 19 reports, the council isare also delivering the Herefordshire Natural Flood Management (NFM) project which has received funding to deliver a wide variety of NFM measures within seven priority sub-catchments until 31 March 2027.

Community engagement

14. The council recognises the benefits of working in partnership with communities and flood groups whose local knowledge and understanding of particular problem areas is invaluable. Their ability to help in providing information and advice to communities and to help them better prepare for

flooding incidents is also acknowledged. Whilst funding is allocated within the annual plan for the public realm services contract with BBLP for supporting local flood groups and communities, more can be done to enable them to mitigate the potential impact of flooding and increase their resilience. Not least as investing in flood management schemes would be unlikely to remove all risk, especially considering the impact of climate change on all areas which was only increasing.

15. The council keeps its webpages up to date with flooding advice and guidance to help raise awareness of those organisations with responsibilities in relation to flooding, what people can do to prevent flooding, and what to do in the event of flooding.

Local Flood Risk Management Strategy

16. The council as LLFA, has a statutory responsibility to publish a Local Flood Risk Management Strategy (LFRMS). The LFRMS provides a framework to enable the LLFA to lead and co-ordinate flood risk management across Herefordshire and was adopted by Cabinet in September 2017. The associated Action Plan is updated annually and was reviewed by General Scrutiny Committee in March 2021.

17. The LFRMS contains:

    a) An overview of what it aims to achieve, why it needs to be prepared, the relevant legislation and the roles and responsibilities of key flood risk management authorities;

    b) A brief summary of flood risk throughout Herefordshire to provide the context from which the proposed actions and measures have been developed;

    c) The objectives that the council has selected to improve the management of flood risk;

    d) A summary of the key sources of funding that may be available to the council, other relevant authorities and the general public to help with the delivery of schemes and reduction of flood risk within Herefordshire; and

    e) An Action Plan that sets out how the council will deliver the LFRMS.

18. The LFRMS's five key objectives for flood risk management are:

    Objective 1: Understand flood risks throughout Herefordshire.

    Objective 2: Manage the likelihood and impacts of flooding.

    Objective 3: Help the community help themselves.

    Objective 4: Manage flood warning, response and recovery.

    Objective 5: Promote sustainable and appropriate development.

19. The specific measures are contained in Appendix A-1 of the LFRMS, which has been reviewed annually. Updated progress against priority measures is included in Appendix 3 to this report.

20. As part of the 2022/23 annual plan for the public realm services contract with BBLP, the LFRMS is being reviewed and refreshed. The council envisages that a new action plan will be developed and will seek to prioritise these actions against appropriate agreed criteria.

Drainage / flooding asset data

21. BBLP maintains the drainage asset database on behalf of the council. Given that drainage infrastructure has been developed historically and as much is hidden under the ground, the information held is not as comprehensive compared to a more visible asset such as street lights.

Whilst BBLP holds limited data on historic pipes and systems, much more comprehensive records are available for modern developments, as adoption records are recorded in the database. Detailed records are also available for problematic and risky flooding assets such as culverts – these are categorised by risk and inspected cyclically with any problems prioritised for maintenance works. If drainage issues arise on the highway for which BBLP don't hold details, the system would be investigated in order to resolve. When this occurs, any information gained about the asset is added to the database for future use.

22. The asset database is quite comprehensive in terms of road gullies with approximately 18,000 gullies currently recorded against cleansing routes. BBLP continue to find and record gullies as they go about running the service – note that when the public realm services contract with BBLP started, around 9,300 gullies were recorded. As gully cleansing is a revenue service and revenue funding is extremely tight, a limited, proactive cyclical emptying programme is carried out across the county, programmed using the network hierarchy and carried out by a single gully cleansing team. The remaining gullies are emptied reactively when they are identified as in need via routine highway inspection or through reports from members of the public.

23. BBLP manages the risk to roads of being undermined by watercourses or land movement through the proactive identification of all potential watercourse incursion points across the county and the inspection and risk scoring of them. The sites that are at risk are then further assessed and monitored by BBLP's engineers. Measures to repair and reinforce the highest risk sites are proposed as part of the annual plan for the public realm services contract with BBLP. When land movement occurs this is dealt with in the same manner.

Community impact

24. The LFRMS supports the strategic objectives that are described in our County Plan (2020-24) and which sets out how the council will ensure we make the best use of resources and deliver services that make a difference to people in Herefordshire. Specifically, the LFRMS contributes towards the 'Protect and enhance our environment and keep Herefordshire a great place to live' ambition. The council appreciates the distress that flooding has had and continues to have upon communities.

Environmental Impact

25. Herefordshire is already vulnerable to flooding and given that climate change is projected to increase the frequency and intensity of weather events, further impacts from heavy rainfall and river levels are likely. The LFRMS contributes towards the 'Environment' ambition of our County Plan (2020-24) and increasing flood resilience.

Equality duty

26. Under section 149 of the Equality Act 2010, the 'general duty' on public authorities is set out as follows:

    A public authority must, in the exercise of its functions, have due regard to the need to –

    a) eliminate discrimination, harassment, victimisation and any other conduct that is prohibited by or under this Act;

    b) advance equality of opportunity between persons who share a relevant protected characteristic and persons who do not share it;

    c) foster good relations between persons who share a relevant protected characteristic and persons who do not share it.

27. The public sector equality duty (specific duty) requires us to consider how the council can positively contribute to the advancement of equality and good relations, and demonstrate that it is paying 'due regard' in its decision making in the design of policies and in the delivery of services. This decision will have a positive impact on communities which have been impacted by flooding.

Resource implications

28. There are no specific resource implications contained within this report and implementation of the action plan will be delivered from within existing budgets. Local flood risk management forms part of the annual plan for the public realm services contract with Balfour Beatty Living Places. The costs of delivering flood management schemes are typically funded through Regional Flood and Coastal Committee Levy funds, Flood Defence Grant in Aid or the council's capital programmes. Note that any emergent schemes will be subject to any relevant funding and business case/governance requirements.

Legal implications

29. Herefordshire Council is the LLFA for the purposes of the Flood & Water Management Act 2010. The council has the statutory responsibility for managing the risks of flooding from surface water, groundwater and ordinary watercourses (which excludes main rivers managed by the Environment Agency within their area.

Risk management

30. The council does acknowledge the risk of flooding and this is reflected in a directorate level risk. The action plan identifies a programme of work for reducing local flood risk within Herefordshire.

Consultees

31. The council as LLFA continues to co-operate extensively with other risk management authorities (RMAs).

Appendices

Appendix 1 – diagram setting out who the LLFA interacts with, internally and externally
Appendix 2 – summary of Section 19 reports
Appendix 3 – updated progress against Action Plan priority measures

Background papers

None identified

Environment and Sustainability Scrutiny Committee draft work programme

25 September 2023 report deadline 15 September 23

Topic and Objectives	Evidence required	Attendees*
River water pollution - Understand the factors contributing to the pollution of rivers and watercourse. - Examine the council's duties and powers to address river pollution. - Scrutinise how the council fulfils its duties and exercises its powers. - Identify key partners and their roles and responsibilities	Map of rivers and watercourses in Herefordshire Appraisal of nature and extent of pollution in rivers and watercourses Outline of council powers and duties RePhokus report on River Wye Cabinet commission on phosphates reporting	• Service Director, Economy and Growth • Service Director, Environment and Highways • Head of Environment Climate Emergency and Waste Services • Wye and Usk Foundation • Farm Herefordshire

27 November 2023 report deadline 17 November 23

Topic and Objectives	Evidence required	Attendees*
Implementing the Environment Act 2021 - Understand the targets, duties and powers conferred to the council and its partners by the Environment Act 2021. - Scrutinise how Herefordshire Council is implementing the duties of the act - Further scrutinise partnership working relating to the act.	LGA briefing – Environment Act 2021 Analysis of consequences for the council in implementing the Act.	• Head of Environment Climate Emergency and Waste Services • Sustainability and Climate Change Manager

22 January 2024 report deadline 12 January 2024

Topic and Objectives	Evidence required	Attendees*

Meeting net zero-carbon in Herefordshire - Appraise current carbon emissions in Herefordshire and the work required to achieve the goal of net-zero carbon by 2030. - Scrutinise how the council contributes to the work of the Herefordshire Climate and Nature Partnership Board - Assess the partnership's achievement to date	Herefordshire Climate and Nature Partnership Board Terms of Reference Herefordshire Council net zero strategy and delivery plan	• Head of Environment Climate Emergency and Waste Services • Sustainability and Climate Change Manager

25 March 2024 report deadline 15 March 2024

Topic and Objectives	Evidence required	Attendees*

Nutrient Management Board
- Scrutinise the effectiveness and achievements of the Nutrient Management Board, to include:
  ○ governance arrangements
  ○ terms of reference
  ○ agreed objectives and
  ○ its role as river champion
  ○ agreed targets and key performance indicators
	Nutrient Management Board terms of reference
	Minutes from previous meetings
	Board action plan
		• Chair of Nutrient Management Board
		• Other members of the board

*The Corporate Director, Economy and Environment, and Portfolio Holder, Environment, both have a standing invitation to the meeting. It is assumed that the portfolio holder will attend each meeting.