Wye Salmon Association
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River Phosphate Aspects of Poultry Farming in Powys

Gordon Green, a member of Wye Salmon Association Water Quality Monitoring Team, sitting out the Third Covid-19 lockdown and unable to visit the river Wye to continue his citizens science monitoring activities decided to put the time to other uses.
An article in the Guardian had caught his eye. It described a recent Powys planning application for a poultry unit next to the river Teme at Knighton which has been successfully referred to judicial review by a local pressure group. He decided to try to understand what was so bad about poultry farming.
Not many, himself included, had any clue what the industry looked like, or what it was doing to cause a problem. His aim, to provide some factual resources, for anglers and other river users, to use in gaining a better understand on what was going on with the poultry industry in Powys.

Why does poultry farming appear to increase river phosphate levels? If they are so polluting, why are these schemes still being approved?

What his study found was rather shocking.

His two-part report is attached

River Phosphate Aspects of Poultry Farming in Powys – a Case Study

The recent Guardian Article relating to the referral to judicial review of an approved planning application for poultry units on a farm in Powys has prompted me to look a little closer in order to better understand the issues around this topic. Two questions spring to mind:

1. Why does poultry farming appear to increase river phosphate levels?
(an assertion not universally accepted in some circles)

2. If they are so polluting, then why are these schemes still being approved?

Using this specific planning application as an example, I have performed a rough order of magnitude calculation in order to estimate the impact that such projects could have on our rivers.

What I've found is rather shocking.

Gordon Green

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About the author

I am not a biologist, or a farmer and I have no particular knowledge of agriculture. So, if some of the agricultural details in this report are incorrect, then I apologise in advance. However, I believe the broad thrust of the calculations and of the conclusions does not depend upon such details.

My background is in physics and engineering. I have a degree in Pure and Applied Physics and subsequently obtained a PhD. I have followed a career in semiconductor process technology and more recently in 3D printing.

I am a lifelong angler who has spent many happy days fishing the rivers of Wales and the Welsh borders, over several decades now. Like most other river lovers, I have been alarmed by a progressive decline in water quality and biodiversity in recent years. This was reinforced last year by the release by the Environment Agency of the 2019 Water Framework Directive classification results for rivers in England. Shocking to say the least, but not really a surprise to anyone who spends time by the river.

Prompted by recent claims and counterclaims in the media, I have attempted to understand what is going on with the poultry industry in Powys.

Introduction to Llanshay Farm

Llanshay Farm happens to be the location of the planning application subject to judicial review. For no other reason, I've chosen to use it as my case study here. All of the following information about Llanshay Farm is taken from application documents placed within the public domain on the Powys CC Planning Portal. I have augmented this with information taken from OS mapping and similar public sources.

Llanshay farm occupies 160ha of land (400 acres in old money) near the market town of Knighton in the Welsh Borders. The farmer also rents 26ha from an adjacent property, taking the total to 186ha. The farm sits on elevated land (grid ref. SO 30150 71630) approximately 1km south of the upper River Teme and the land clearly drains into this river. Note that the River Teme, like the Wye, has SSSI status as a protected habitat.

The farm is almost exclusively set to pasture, with 900 breeding ewes and 175 cattle. The cattle comprise 2 bulls and 100 suckler cows plus progeny – the latter being sold at 16-22 months of age. The only arable activity is 4ha of forage crops for the stock. Some silage is taken off the pastures, presumably for winter feed.

In 2019, Mr. Thomas Price, the owner of Llanshay Farm submitted a planning application (19/0743/FUL) to add a substantial poultry operation on site. This was approved by Powys CC in September 2020 but has recently been referred to judicial review, following legal challenge by a local pressure group - Sustainable Food Knighton.

The Planning Application

The submitted application was for the construction of two poultry buildings, plus associated infrastructure. Each building was to be 104m x 25m and would house 55,000 birds – 110,000 in total. The plan is to put young chicks in there, grow them for six weeks, sell them for meat and repeat the process eight times per year. Because the number of birds was to be over 40,000 the project required an Environmental Permit from NRW (the Welsh EA), prior to submission (an Environmental Permit allows a person to carry on an activity subject to condition to protect the environment). This had been granted in September 2017. Note that this was well before the 2020 furore over algal blooms on the Wye.

I note in passing that this is a high-intensity, factory farming operation; it is an Intensive Poultry Unit (IPU). This is not agriculture as most people would understand it. It is an industrial activity that just happens to be located on a farm. Another recent Guardian Article claimed that the majority of poultry projects in Powys are IPUs. Apparently, there are estimated to be around 8.5 million birds in IPUs across Powys (a number I will return to later).

Mr. Price's planning application was prepared for him by a firm of agricultural consultants and was fairly comprehensive. As well as the obvious plans, it included (of relevance to us) a Drainage Plan, a Pollution Prevention Plan and a Manure Management Plan (MMP).

Powys CC turn to Natural Resources Wales (NRW) for consultation on environmental matters (just as they would consult the County Highways Department on matters of road safety). Nevertheless, Powys CC do still have a duty to take a view on environmental matters outside NRW's planning remit. One would reasonably expect though that NRW would be the organisation protecting the river Teme, not least because In Wales, they are responsible for SSSI administration. Certainly, NRW were responsible for approval of the MMP.

NRW initially criticised the as-submitted MMP and insisted on some re-calculation. Following this, NRW were happy with the proposal, provided that two conditions were added to the Decision Notice. One required a more detailed survey of great crested newts; the second required strict adherence to the submitted Drainage Plan, Pollution Prevention Plan and Manure Management Plan (not unreasonably)[1]. The MMP did not concern itself with phosphate emissions. Nor is there evidence within the NRW response of any consideration of the amount of phosphate potentially reaching the river Teme. In fact, there is no evidence in the available documents of any consideration of phosphate loads, either by the applicant, by NRW, by the Powys CC Ecologist or by the Powys CC Case Officer. This, in spite of the NRW guidance note *GN 021* [1] which states that a phosphate assessment is required.

Having read these documents, the Drainage Plan and the Pollution Prevention Plan look sensible and taken together mean that there would be a reasonably low risk of a point pollution event, for example a foul water spillage to surface water. The Manure Management Plan is where it gets interesting, not least because this directly impacts diffuse pollution from nutrients – phosphate especially.

I will return to the MMP after a detour around the principles.

[1] A potential issue here is that having requested the condition on MMP compliance, NRW are not responsible for monitoring and enforcement of it; this falls to Powys CC. There is reason to doubt that Powys CC have the technical capability to do this. The Campaign for the Protection of Rural Wales have established via a freedom of information request that Powys CC have never prosecuted for MMP non-compliance (private communication, Feb-21).

Nutrient Management on Farmland

Without getting down to trace minerals, there are three key nutrients required for crop growth: nitrogen (N), phosphorus (usually applied as P_2O_5) and potassium (usually applied as potash, K_2O). Of these, nitrogen and phosphorus (phosphate) are the only ones relevant to this discussion. Note that both can be applied either as manufactured chemicals (e.g., NH_3-N & P_2O_5), or combined together within organic fertilisers such as farmyard manure (FYM), slurry, digestate, etc. For organics, the ratio of nitrogen to phosphorus is what it is.

Soil has limited capacity to store nitrate beyond what is dissolved in the soil's moisture content. 'Mineral nitrogen' NH_3-N and similar do bind to soil particles but convert to nitrate fairly rapidly. Consequently, nitrogen additions to soil are relatively short lived and must be done frequently, generally being applied before each crop. Crop utilisation of nitrate is generally high (50-70%). It is prone to run-off [2], but is not considered to be a major driver of algal blooms in rivers (lakes are another matter).

Phosphate is different. In addition to the 'available', dissolved phosphate, phosphate also forms complex compounds which bind to soil particles. This bound phosphate will release back into solution as the available, dissolved phosphate is depleted by plant growth and run-off. The upshot is that soil behaves like a sponge for phosphate; crop utilisation of applied phosphate is typically low (10%). For these reasons, the management of phosphate is a long-term activity, taking several years to build up and several years to deplete. As we know, run-off of phosphate is a primary driver of algal blooms in rivers.

The decision of how much nitrate and phosphate to apply is guided by a DEFRA publication called *RB209 – Nutrient Management Guide* [5]. There are associated phone apps to help farmers through this stuff. It is important to realise that *RB209* is primarily about farm economics and is not greatly concerned with environmental impact. In *Section 1 - General Principles*, which comprises 48 pages, there is one tiny paragraph referring to the risk of algal blooms due to over-application of phosphate; it really is only mentioned in passing. *Section 2 – Organic Material* and *Section 3 – Grass and Forage Crops* complete the parts of *RB209* relevant to this study. Here is roughly how it works.

Soil can be laboratory analysed to determine nutrient levels. It can then be graded for each nutrient as follows. Index 0 and Index 1 represent degrees of impoverished soil. Index 2 represents (approximately) the economic optimum nutrient level, balancing the cost of additional fertiliser against improved crop yield. For a small number of crops, mainly vegetables, Index 3 might be appropriate; however, Index 2 is appropriate for all grass and forage crops (e.g., Llanshay).

Assuming land has been well-managed and is already at Index 2, the farmer's task is simply to apply sufficient nutrient each year to compensate for 'off-take' – that is the amount removed by the previous crop, which can be calculated from the crop tonnage or via simple approximations using *RB209*. This is called the 'maintenance level'. Periodically, soil analysis might indicate the need for further top-up, to compensate for other losses; in the case of phosphate this primarily means run-off to ground or surface water, depending on local geology.

According to *RB209*, maintaining Index 2 for phosphate essentially equates to optimum yield for arable, grassland and foliage crops. Going beyond this level and taking land into Index 3 is known to increase the rate of run-off according to *RB209*. There is no nutritional rationale for doing this on

[2] Throughout this document I will use the term 'run-off' to include both immediate surface run-off (during excess rainfall) and slower percolation through the soil; this is discussed further in Appendix 1

pasture. The relationship between phosphate levels and run-off rate is discussed in more detail in Appendix 1.

For Index 2 pasture, the maintenance amount of phosphate is $20kgP_2O_5/ha$. If the farmer takes a cut of silage before the animals go in, then this increases to $40kgP_2O_5/ha$. For a second silage cut, add a further 25kg/ha (*RB209 Table 3.3*). So, the appropriate amount of maintenance phosphate at Llanshay is likely to be in the region of $50kgP_2O_5/ha$, assuming not all fields produce silage.

A broadly similar logic applies to nitrogen. Pasture-only with three grazing rotations per year would require 80kgN/ha (*RB209 Table 3.9*); this increases to 130 kgN/ha (*RB209 Table 3.8*) for two silage cuts. So, we would expect to see N application in the region of 100kgN/ha at Llanshay.

The nutritional importance of nitrogen is reflected in the fact that kgN is the 'unit of currency' for organic fertilisers. The amount of N and P_2O_5 in different types of organic material is found in *Section 2 of RB209 (tables 2.2, 2.4, 2.5 & 2.7)*. Note the much higher values for poultry.

	KgN/tonne	**KgP2O5/tonne**
Sheep manure	7.0	3.2
Cattle manure	6.0	3.2
Pig manure	7.0	6.0
Poultry manure (60%)	28.0	17.0

Table 1: nutrient content of different manure types; for poultry, I use the data for 60% dry matter because this is what is used in the Llanshay MMP

The final point on Nitrogen comes from another DEFRA publication, *Guidance: Use of Organic Manures & Manufactured Fertilisers on Farmland* [4]. This is underpinned in England by a Statutory Instrument [2]. It states that organic fertiliser application must not exceed 250kgN/ha in any 12-month period. The same limit currently applies in Wales, although this has recently been superseded by a new Statutory Instrument [3].

Included within the above regulations and guidance are the rules regarding when and where you can and cannot spread organic fertilisers: not within 10m of a watercourse, not close to dwellings, not during rainfall, not on steeply sloping land, etc. Subject to these rules, the 'spreadable area' at Llanshey is reduced to 119ha.

Importantly, none of the above regulations explicitly control phosphate application rates.

We've covered a lot of stuff in this section, so here is a summary of the key points.

- *Nutrient requirements for Index 2 pasture, with some silage cropping, is in the region of 100kgN/ha and $50kgP_2O_5/ha$.*
- *Applying more P than this will increase the rate of run-off.*
- *Different animals produce manure with differing amounts of N & P.*
    - *<u>Poultry manure is 4-5 times more concentrated than cattle & sheep manure</u>.*
- *Organic fertilisers shouldn't be spread in circumstances where immediate run-off is likely.*
- *The maximum annual application rate for organic fertilisers is 250kgN/ha.*
- *<u>There is no maximum annual application rate for other nutrients – including P</u>.*

Llanshay Manure Management Plan

Current Practice

Within the Llanshay MMP is a table, based largely on *RB209*, showing the nitrogen-equivalent amount of manure produced each year on the farm. Clearly much of this is deposited in-situ during grazing by the animals, with only a fraction being collected from the barns and mechanically spread as FYM. But this doesn't change the calculation – a key point which we learn from the NRA review of the MMP.

In passing, we can also note that the 900 breeding ewes described in the MMP text has mysteriously dropped to 300 in the calculation table. For my purposes here, I will stick with the 300 for consistency - but it's a bit odd (there must be 600 very constipated ewes at Llanshay).

		Nitrogen	
	Number	**kgN/yr (ea)**	**kgN/yr**
Sheep	300	11.9	3,570
Suckler Cows	80	83.0	6,640
Bulls	2	48.0	96
Cattle 2-12mth	75	28.0	2,100
Cattle 12-24mth	20	50.0	1,000
		Total	**13,406**

Table 2: N emissions from existing Llanshay livestock

By using the ratio of N to P for each manure type (Table 1 above), I have then estimated the associated amount of P:

	kgP_2O_5/yr
Sheep	1,632
Suckler Cows	3,541
Bulls	51
Cattle 2-12mth	1,120
Cattle 12-24mth	533
Total	**6,877**

Table 3: P_2O_5 emissions from existing Llanshay livestock

If we take these two totals and apply them to the 119ha spreadable area, we find the application rates are as follow: nitrogen 113kgN/ha and phosphate 58 kgP_2O_5/ha. These rates are remarkably close to my estimates of 100 kgN/ha and 50 kgP_2O_5/ha. The consistency with *RB209* suggests a farm operating with reasonable environmental sustainability. There will undoubtedly be some additional fertiliser top-up occurring - to compensate for losses, mainly run-off - but it's unlikely to be a major amount.

So far so good.

Including the Poultry Project

Somewhat shockingly, the proposal for the poultry manure is simply to apply this in addition to the sheep & cow manure over the 119ha of spreadable area on Llanshay Farm. So how much is there? Below is the key bit of information from the MMP, plus my corresponding phosphate estimate.

		Nitrogen		
	Number	**kgN/yr (ea)**	**kgN/yr**	**kgP_2O_5/yr**
1000 broilers	110	330.0	36,300	22,039

Table 4

This is 1300 tonnes of chicken shit per year and represents a x4 increase in both nitrogen and phosphate emissions from this farm. All of this is coming from two sheds occupying approximately 1ha of 186ha of farmland and it is entirely additional to the current cattle and sheep activity.

But Mr. Price has a problem. This amount of nitrogen would take him well over the 250kgN/ha limit. So, the proposal is to dose Llanshay right up to this limit and then 'export' the excess poultry manure to his father-in-law's farm up the road (another cattle farm, similar but smaller). This has the effect of pushing two farms well above the 'maintenance level' for nutrient additions.

In Poultry manure, the phosphate associated with 250kgN/ha is 152kgP_2O_5/ha; three times the maintenance level currently being applied. This is off the scale for phosphate application to pasture as advised in *RB209*. I can't even determine what soil index this would correspond to. As outlined in Appendix 1, it is inevitable that in the fulness of time, 100% of the poultry phosphate will run off into the river. The fact that Mr. Price has exported some of it matters not one jot. His father-in-law's farm drains into the River Teme as well. Phosphate doesn't evaporate and there is relatively little crop 'offtake' on pasture. So once the soil has increased to its new phosphate level (on both farms), conservation of mass requires that the ongoing flow of phosphate goes somewhere. Whilst on some land there would be a valid question regarding the run-off split between groundwater and surface water, for Llanshay I suspect there is little uncertainty. The local geology is such that there are no significant aquifers beneath the land; the whole of the upper Teme catchment lies over impermeable bedrock. Moreover, the average soil depth near Llanshay is around 1m [6],[7].

One kilometre from the River Teme and with a relative elevation of some 70m, there is only one place this phosphate is going.

This MMP has been approved by NRW, apparently purely on the basis that it complies with the 250kgN/ha nitrogen limit. There has obviously been no consideration of phosphate issues, not least I suspect because there is no applicable regulation for phosphate. Appendix 2 illustrates the estimated phosphate flow paths in graphical form.

Finally, having reviewed the MMPs for the 25 most recent poultry units approved by Powys CC, I can confirm that all bar one spread poultry manure exactly as per the Llanshay MMP. This really is typical of Powys IPUs.

So, what does 22 tonnes per annum of P_2O_5-equivalent mean for the River Teme? First, we convert this from P_2O_5-equivalent to our familiar mgP measure (as used in water quality data). The fiddle factor is 44%, to throw away the mass of the five oxygen atoms. We then re-scale it to 'rate per second' rather than 'per year'. 22 tonnes per annum of P_2O_5 is the same as 305mgP/s.

The next thing we need is the flowrate of the River Teme in order to determine the dilution. The river up here is small, no more than 10m wide. I've estimated the depth at 1.5m and the surface flow speed at 1m/s, so averaging 0.5m/s across the water column. This gives a volumetric flow of 7.5m^3/s. This may be a bit out, but we're concerned here with the order of magnitude (number of zeros) in the answer. Nevertheless, we can crosscheck this against the flowrate downstream at Tenbury where there is an EA flow measuring station [6]. Here we have a mean flowrate of 14.5 m^3/s. Given that there are three major tributaries joining the Teme between Knighton and Tenbury, I'm happy to go with the 7.5m^3/s estimate for Knighton.

Dividing the first number by the second gives us a total phosphate concentration of 0.04mgP/litre. Meaning that the output from this one single poultry unit has the potential to make the River Teme fail its chemical purity targets (the 'good' classification requires less than 0.03mgP/l).

So how does this look at a regional level, with 8.5 million birds? The northern part of Powys drains eastwards into the Severn catchment. Further south, the land predominantly drains into the Wye catchment. So ultimately, all the excess phosphate from 8.5M birds will head for these two rivers. We already know that 1000 birds produce 200kg of P_2O_5 per year. So, let us assume 50% of the birds are in the Wye catchment. That leaves us with **850 tonnes of P_2O_5 getting into the middle Wye each year**. My estimate for the flowrate on the middle Wye below Hereford is 58m^3/s, based on NRFA data [6]. Doing the same calculation as above gives a total phosphate concentration of 0.20mgP/litre, over six times the 'good' classification level .

I am not claiming that this is the quantity we would measure as free phosphate, using typical Hanna or Hach measuring equipment. Phosphate flow in rivers, and the measurement of them, is more complex than that. Furthermore, I am not claiming that these two calculations are in any sense precise - but they are perfectly reasonable order-of-magnitude estimates. They show quite clearly that this quantity of additional phosphate arising from IPUs is significant and has the potential to disturb an entire regional ecosystem.

Here is a summary of the key points from this section:

- *The original farming model at Llanshay was reasonably environmentally friendly with the livestock well balanced to the land area and minimal need for phosphate top-up.*
- *The plan for the poultry unit entails <u>spreading all the resulting manure over the land</u>, up to the legal limit for nitrogen; this cynical action takes the phosphate additions to three times the reasonable maintenance level for pasture plus some silage.*
- *This MMP was approved by NRW; the only criterion seemed to be compliance with the nitrogen limit; there was no obvious concern regarding phosphorus.*
- *Essentially all recently approved poultry units are doing exactly the same.*
- *This will inevitably cause a huge increase in phosphate run-off to surface water; conservation of mass (in this case phosphorus atoms) requires it; in the absence of infinite storage capacity, what goes in must ultimately come out at the same rate.*
- *<u>The quantities of additional phosphate arising purely from poultry are significant both locally and regionally</u>.*

What do EA / NRW know?

The Environment Agency (and NRW in Wales) monitor water quality in rivers routinely, in line with Water Framework Directive requirements. Rivers are then classified against each metric and also receive an overall classification. The results have been reported annually up to 2016 and three-yearly thereafter. The 2019 reporting cycle was the one that got the headlines last year for "80% of English rivers failing to achieve 'good' status". All of this reporting is available on the EA website.

Looking at the results for the stretch of the River Teme near Knighton, we see that the river has achieved a consistent, overall 'Moderate' since 2013. However, drilling down to the 'Phosphate' category reveals a progressive decline over the past six years. This data is reproduced in the table below. I've added the description of each classification, as well as the numerical range for each class (the latter taken from *The Water Framework Directive (Standards & Classification) Directions (England and Wales) 2015*) [8]. The EA target for the Phosphate category on this water body is 'Good'.

Year	Class	Meaning	Approx. range (mgP/l)
2013	Good	Slight effect from human activity; no impact on fisheries and wildlife	0.01 to 0.03
2014	High	Near natural condition	Below 0.01
2015	Good	Slight effect from human activity; no impact on fisheries and wildlife	0.01 to 0.03
2016	Moderate	Moderate change due to human activity; some impact on fisheries and wildlife	0.03 to 0.09
2019	Poor	Major change from natural condition; moderate impact on fisheries and wildlife	0.09 to 0.750

'Phosphate' classification for the River Teme near Knighton

Clearly there has been a dramatic increase in phosphate pollution over the period 2014-19. To emphasise the numbers – it's gone from below 0.01 to over 0.09. That's roughly a 10x increase.

We can also see on the EA website a list of 'Reasons for not achieving good status and reasons for deterioration'. In here is cited 'Diffuse source / Agricultural & rural land management / Poor nutrient management' as an acknowledged contributor to the phosphate problem. Admittedly there are several other potential contributors cited, but it's hard to see how any of them would account for a 10x increase. We've got to be looking for a sudden and significant change in land use to explain this.

So, EA / NRW know all about the increasing phosphate problem on the Teme and they have identified poor nutrient management as a key factor. Furthermore, since they see all the planning applications, including associated Manure Management Plans, they know exactly what is going on in terms of changing land usage. In short, they could do these calculations as well as I can.

So why do they not join the dots? Why have they continued to sign off on these schemes over the years? That's for them to justify; I can only guess. The consistent lack of action is totally at variance with their stated purpose 'to protect or enhance the environment'; with 'protect' in this context specifically including threats such as pollution of rivers.

One observation is that they do appear to rigorously enforce the nitrogen limit in MMPs. This leads to the obvious conclusion that, if there was a regulation limiting phosphate, then this too might be enforced at planning stage.

But it gets worse. In 1995, the year before the Environment Agency was established, the National Rivers Authority (NRA), Severn & Trent Region[3] published a report on the river Teme. *The River Teme Catchment Management Plan Consultation Report 1995* [9] is an extensive and very detailed description of the river Teme. It was clearly compiled by people who cared and described "a top-quality river suitable for drinking water supply and capable of supporting game and other high-class fisheries". There were nevertheless multiple pressures on the river even then, but one stands out. The high concentration of poultry units already operating at that time, coupled with the practice of spreading manure on the land, was identified as a non-sustainable practice. It asserted that such spreading should only be done for the benefit of crops and not as a means of waste disposal. It stated that planning authorities need to take this aspect into careful consideration when approving new schemes. Clearly this didn't happen.

The upshot is that NRA / EA / NRW, which are all essentially restructurings of the same organisation, have understood the threat to river water quality posed by poultry manure spreading for at least 25 years.

Key points from this section are:

- *The hazard to water quality posed by IPUs in the Teme catchment has been known for at least 25 years.*
- *In 1995 the NRA identified a need to tighten planning requirements, particularly in respect of the practice of spreading as a means of waste disposal.*
- *Over recent years, the EA identify poor nutrient management as a 'reason for deterioration' for phosphate levels on the Teme.*
- *Nevertheless, EA and (since 2013) NRW continue to approve MMPs which blatantly over-apply nutrients*

[3] NRA were one of the bodies assimilated into the EA at its formation in 1996

Conclusions

Taking the questions posed in the abstract:

1. Reasons that poultry farming has a high impact on phosphate levels (and it unequivocally does):
    a. Poultry manure is much higher in nutrient concentration than that from grazing animals (x4-5).
    b. Factory farming style poultry operations occupy little space and are generally additional to existing operations.
    c. All resulting poultry manure is spread on the farm, or on nearby farms; this is in addition to existing cattle & sheep manure.
    d. The maximum nitrogen limit is cynically exploited, with complete disregard to the concomitant increase in phosphate load; best-practice nutrient management is being thrown out of the window.
    e. Manure spreading as a means of waste disposal appears to be the norm for Powys IPUs.
2. Reasons these projects have been approved:
    a. There has clearly been no assessment of the collective, regional impact of dozens of these projects; the environmental aspects of this clearly represent a gross omission by both NRW and Powys CC. This much is already known.
    b. Manure Management Plans appear to be approved purely on the basis of compliance with the maximum organic nitrogen guidance; there is no similar regulation or guidance for phosphate additions to land. Planners always find it difficult to refuse permission where there is no breach of a regulation. Their decisions need to be objective and transparent. There is clearly a pressing need for a regulatory limit on the amount of phosphate which can be applied to land in any one year.
    c. Unless I've missed something, the fact that Llanshay drains into an SSSI appears to have not been a consideration in the planning process, at least in the context of water quality. It makes you wonder what the point of it is.

Beyond these questions, the calculations show in a simple way how significant these quantities of phosphate are, both at a local and regional level. We should at least be adopting a precautionary approach to the risks.

For the farming sector or NRW to claim that there is no proven causal link between the Wye/Ithon algal blooms and poultry units within the Ithon valley is looking to be an unsustainable position. The above aggregated numbers adequately demonstrate the problem. There is no need to prove individual causal links.

Moreover NRA / EA / NRW have regularly documented their understanding of the threat to river water quality posed by the practice of spreading manure as a means of waste disposal for at least 25 years. Sadly, this has not prevented them from approving such schemes.

Given all of this, one has to ask the question: are our environmental agencies fit for purpose?

Furthermore, the planning process seems to suffer from overlapping and ill-defined responsibilities, with no one taking responsibility for the application of basic agricultural best practice.

The most obvious and pressing need is for a regulatory limit on phosphate application. This could be formulated in a similar fashion to the nitrogen limit: a maximum per annum application rate. However, this might limit a farmer's ability to improve impoverished land. A better alternative, because run-off is proportional to soil concentration, might be to state that no pasture or arable land is to be taken to more than 25mgP/litre (that is, Soil Index 2 top limit according to *RB209*). This has the advantage of being something that can be objectively measured at will, rather than relying on potentially questionable farm record keeping. Such a rule would have no impact on normal land usage but would prevent the routine dumping of poultry manure in the manner intended for Llanshay.

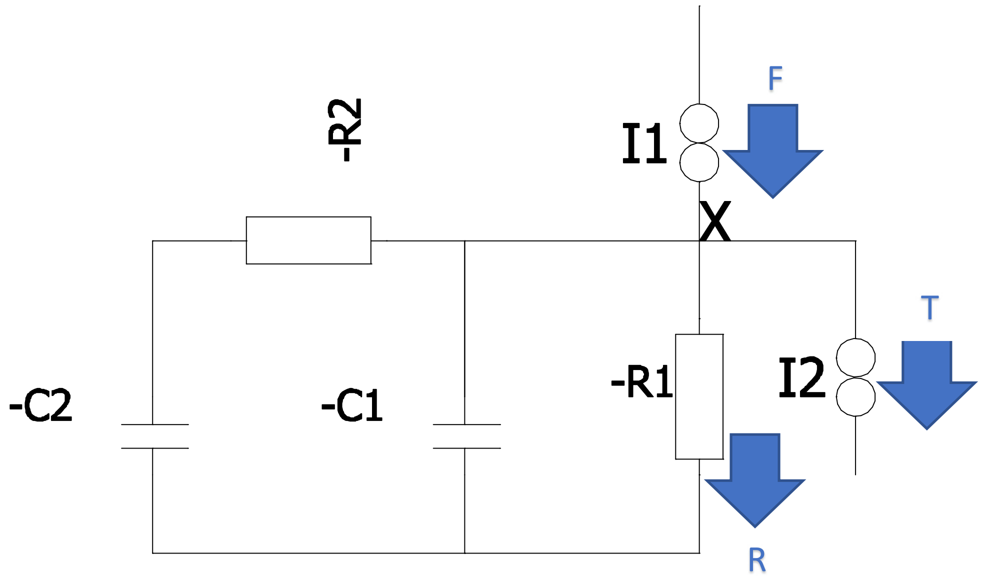
Appendix 1: modelling phosphate flow

The purpose of this appendix is to clarify my approach to the physical reality of phosphate movement in fields.

To recap the basics: free, water-soluble, available phosphorus occurs in the form of the orthophosphate radical $(PO_4)^{3-}$. This is the stuff that plants use and the stuff we measure in rivers. However, within soil, phosphorus can also form organic complexes which bind onto soil particles. This does not run off (at least in the absence of bulk soil erosion) and is not immediately available to crops. There is clearly an equilibrium between the amount of soil-bound phosphorus and the amount of free phosphorus. If the farmer adds phosphorus to a field, initially increasing the free phosphorus, this increased concentration will, over time, drive an increase in the amount of bound phosphorus. Likewise, if the free phosphorus becomes depleted by run-off during rainfall, bound phosphorus is progressively released to compensate. The key point is that this takes time. Generally, it seems that changes in free phosphate (like free nitrate) can occur over a timescale of months. Changes to bound phosphate on the other hand occur on a timescale of a few years.

This type of 'percolation' phosphate run-off occurs primarily when rain falls on the land and soaks into the soil, displacing water already in the soil. The displaced water percolates under the influence of gravity to drainage ditches and streams. This displaced water must inevitably carry the prevailing concentration of free phosphate within the soil. In other words, the rate of phosphate run-off is proportional to the soil concentration. The speed with which this occurs depends on many local factors: soil type, gradient, proximity to ditches, rainfall, etc.

These two 'components', a storage component connected to a linear conductance component belong to a class of problem familiar to all engineers and scientists. They are described by a first order differential equation, the solution to which is the classic exponential decay. Here is the equivalent electrical circuit to a field in Powys.



The voltage at point X is the analogue of soil phosphate concentration. Currents flowing in this circuit are the equivalent of phosphate flows. The capacitor C1 represents the storage capacity of the soil for free phosphate. R1 defines the run-off conductance from this. Similarly, C2 is the bound phosphate storage and R2 the conductance between bound and free storage (a chemical pathway, not physical movement). The time constant R2C2 is much larger than the run-off time constant R1C1 and hence determines the overall response of the system to changes in phosphate flow. Without C2, phosphate in soil would behave like nitrate – short lived.

The blue arrows indicate the phosphate flows. F represents the feed rate which the farmer chooses to apply. T is the off-take, meaning the phosphate consumed by the crop – in this case grass. Since F and T are defined by the farmer (as opposed to by the phosphate concentration), I've represented them by constant current sources, I1 & I2 respectively. R is the run-off flow.

One could solve the resulting mathematics, analytically or numerically, but this is not necessary to underpin the logic of the main text. It suffices to understand that C1 and C2 – together the total capacity of the soil to store phosphate – determine only the transient response of the system. I'll repeat this because it's important. The storage capacity of the land only affects the transient response of the system – the time taken to form a new equilibrium if the feed-rate changes. Once the system settles into equilibrium, there is no nett flow into or out of the soil storage, averaged over a year. In this condition the average flows must sum to zero at point X.

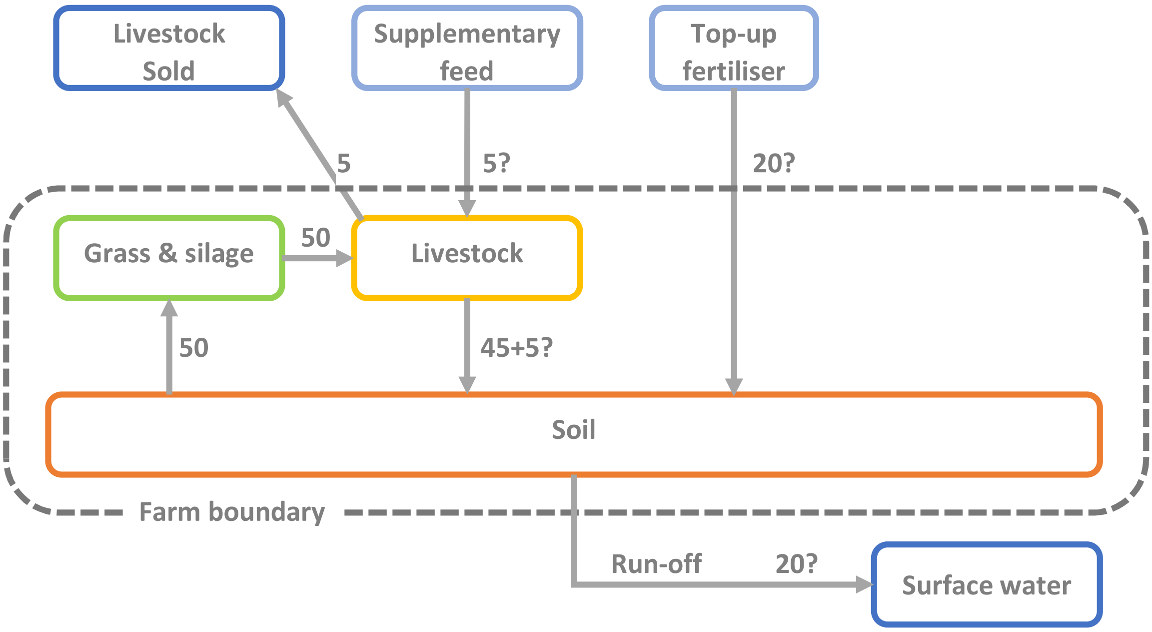
Stated mathematically, F = T + R.

So, using some typical numbers from *RB209* for a field established and stable at Index 2, if the farmer is applying 50kgP/ha per year, and the take-off is 20kgP/ha, then the run-off must be 30kgP/ha per year. It's that simple. If now, the farmer increases the feed rate (F) to 150kgP/ha per year, then both the soil concentration and the run-off rate will increase progressively over a few years to a new equilibrium level. At that point, the above equation holds once more. Take-off (T) is still 20kgP/ha, so run-off (R) must now be 130kgP/ha.

100% of the increase in feed goes into run-off – once the new equilibrium has been established. It may take a few years to get there, but this is the inevitable endpoint (unless we think there is a magic, infinite phosphate store somewhere).

Appendix 2: phosphate flow streams

We can expand on the principles of Appendix 1 to develop a more detailed phosphate flow chart for a farm such as Llanshay. The numbers are based on the Llanshay MMP, but with a bit of rounding to make the arithmetic more obvious. Here is the situation without poultry:



Phosphate flow streams for a typical livestock farm without poultry; number represent phosphate flow as kgP_2O_5/ha

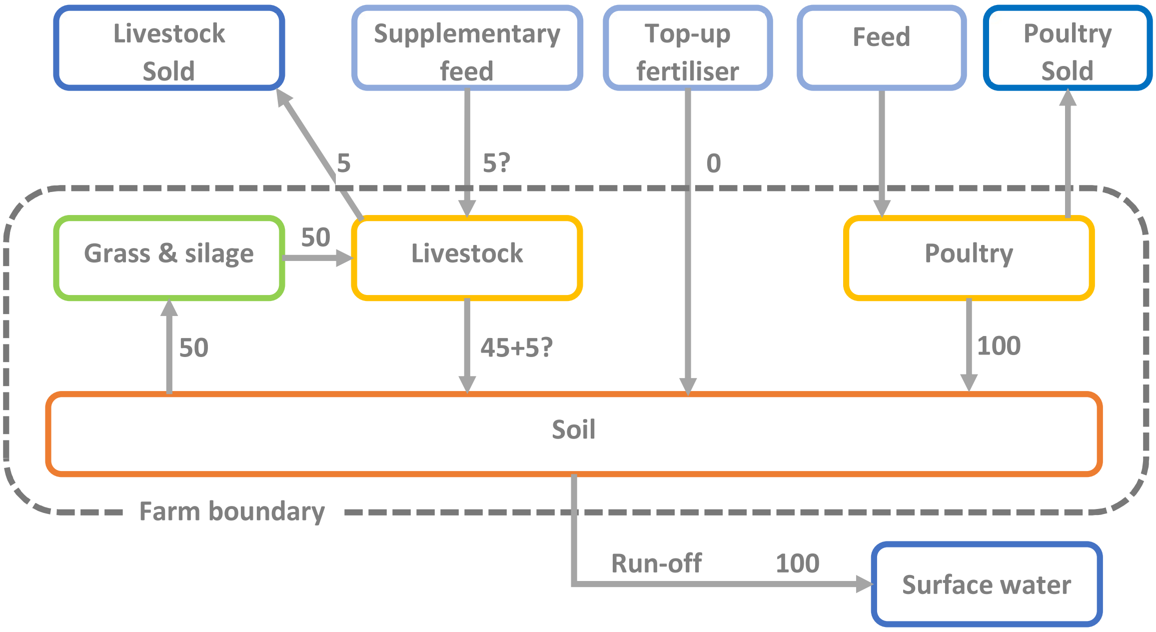
A key point here is that the phosphate run-off balances the nett flow into the farm from outside, exactly as per the 'F = T + R' equation in Appendix 1.

There is also an internal circular flow of approximately 50 kgP_2O_5/ha which is split between the 'grazing scenario' of *soil > grass > livestock > soil* and the 'housed scenario' of *soil > grass > silage > livestock > mechanical spread > soil*. Mature livestock will output as much phosphate as they consume, whereas young livestock will accumulate phosphate in order to grow. Therefore, the flow back to soil ($45kgP_2O_5/ha$) is less than the grass and silage off-take ($50kgP_2O_5/ha$). Since these animals are all sold, we can estimate this phosphate flow based on 0.8% of the body mass of the animals sold.

There could also be some supplementary winter feed for stock, which would represent a further phosphate input to the farm; since this isn't declared in the MMP, I've guessed at 10% of the grass & silage value. Similarly, the top-up fertiliser quantity isn't declared in the MMP, so once again I've put in an illustrative number, based on the national average application rate for grassland [10].

Note that run-off here is the sum of the percolation run-off described in appendix A and any surface run-off. whereby there is a bulk movement of recently applied organic material directly into surface water. In a perfect world the latter would never happen if manure has been spread strictly in accordance with the regulations but, in reality, it does happen. This phosphate effectively bypasses the soil and flows directly to surface water.

Finally, we can adapt the flow stream diagram to include the poultry unit:



Phosphate flow streams for a typical livestock farm with an IPU; number represent phosphate flow as kgP_2O_5/ha

Having added the poultry and spreading at the maximum limit for N, we can apply a total of 150kgP_2O_5/ha – far more than the crop off-take which remains 50kgP_2O_5/ha. Admittedly the top-up fertiliser flow goes down to zero but is massively outweighed by the additional poultry contribution. The upshot is that the balancing run-off increases from 20 to 100kgP_2O_5/ha.

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River Phosphate Aspects of Poultry Farming in Powys – Part 2

Following on from my earlier article, I have looked in more depth at approved planning applications for poultry units in Powys over the period 2000 - 2019. By doing this, I have been able to determine:

- *the total number of projects involved*
- *the number and type of birds by project*
- *the timing and location of each project*

From this, I have been able to calculate the phosphate output for each project.

I have then been able to place each project within a river catchment to determine the potential phosphate run-off to each river.

By making use of the time dependency of phosphate emissions within specific river catchments, I have been able to estimate the time dependency of the resulting phosphate run-off rates.

The results clearly demonstrate that phosphate emissions from poultry operations are of exactly the right magnitude to explain the increasing impact of phosphates in our rivers. It is clear that there is only one way out of this mess.

Gordon Green

March 2021

Contents

Introduction

In the previous article I studied a recent Planning Application (PA) for a new broiler poultry unit near Knighton on the river Teme. By making use of the Manure Management Plan (MMP) within the PA, I was able to demonstrate that the phosphate emissions from this one project would constitute a significant contribution to pollution of the river Teme. By extrapolating to the claimed 8.5 million birds in Powys, I then showed that the poultry industry is a significant pollution source for the entire Wye and Severn catchments.

In the first article, I introduced a key conservation concept. All the phosphate spread onto the land is ultimately carried away in surface water (or groundwater, where local geology permits). Storage of phosphate within the soil only affects the transient response of the system. If the phosphate application increases, the soil absorbs additional phosphate only until it comes into equilibrium with the new application rate. It might take a few years to reach equilibrium, but when it does, the phosphate going in must equal the phosphate coming out. There are only two output streams: run-off to the rivers and phosphate exported within the crop. For livestock businesses, the latter is relatively low.

A weakness of the first calculation was scaling up from a broiler unit (broilers are taken as day old chicks and are sold at 6 weeks). It turns out that many poultry units in Powys are for egg production, obviously with more mature birds; this unsurprisingly has an impact on the amount of N and P emitted. There are also breeder units and pullet rearing units, all with different emission figures. In this study I have made use of applicable N emission rates for each project, resulting in more robust P emission numbers.

An unanswered question in the first study was how much phosphate goes into each river. In this work, I have located each project and determined the river which it drains into. Of particular interest is the question regarding Wye algal blooms and their origin on the river Ithon. I have also been able to analyse the temporal development of poultry numbers and thus estimate the resulting development of phosphate concentration.

Geography

Powys does not possess high-grade soil; the vast bulk of the land being used for grazing. The majority of farms associated with poultry projects keep sheep and/or cattle. There is relatively little dairy activity and virtually no arable farming. It is easy to see why poultry is a logical add-on for these businesses.

The geology in the area is such that all rainwater, allowing for evaporation and transpiration losses, drains to the rivers; as far as I can tell, there are no major underground aquifers. By the same token, we can thus assume that any phosphate spread on the land ultimately goes into the rivers. An inspection of the OS mapping for the area shows that Powys is a mass of valleys, each with a river or stream at the bottom. There can hardly be a farm in Powys without a stream running through it.

Most of Powys is drained by the Severn catchment to the north and the Wye catchment south of this. Around the edges we also have the Dee in the extreme north, the Usk in the extreme south and a few westerly flowing rivers such as the Dovey on the western edge. None of these latter rivers will feature significantly in what follows.

The data

Overview

Searching for Powys CC planning applications for all poultry related applications is a slow and laborious job. The only option is to search the *Title* field for likely key words. However, part way through this research, I was introduced to the Campaign for the Protection of Rural Wales (CPRW), who have been monitoring the Powys poultry industry for many years. Unlike Powys CC and NRW, they do maintain a comprehensive database of relevant planning applications. Their data underpins the analysis which follows – and I am very grateful for being given access to it.

In total, I have been able to include a total of 290 approved projects spanning the period 2000 – 2019. The total number of birds involved is 8.8 million. Data before 2005 is a little sketchy, but from 2005 onwards it is pretty solid.

Planning applications submitted since 2015 have all documents, including MMPs, available online. For about half of these (69 in total) I have downloaded the MMP in order to (a) understand the size and nature of existing operations, and (b) to check the details of the nutrient calculations.

Farm activities

This table shows the breakdown of other farm activities described in the downloaded MMPs.

Non-poultry activity	*Number*
Cattle (inc. dairy) and/or sheep	59
None (i.e. poultry only)	7
Not declared	3
Total	69

Table 1: farm activities

Very little arable activity was declared beyond silage and other feed crops. As per the case study in my first report [3], the new poultry operation is always additional to existing sheep & cattle activities.

The size of farms varies enormously from less than 50ha up to 500ha; the average though is 150ha.

Disposal of poultry waste

The size of the farm is a key driver in determining whether there is a need to export some of the poultry manure. The larger farms generally have no need to export and can spread without exceeding the 250kgN/ha limit. Of the 69 MMPs examined, 63 are spreading the poultry manure on their own land. Six are 'exporting' some or all, but almost certainly to other farms in the area. None of the MMPs examined had any convincing evidence of any poultry manure not being spread directly on land, for example going to Anaerobic Digestion (AD) plants. A very few said that an AD plant would take excess manure, but this was never quantified or committed to.

All the 69 MMPs examined contained calculations to prove compliance with the 250kgN/ha limit. NRW approved every one of them on this basis alone. None of them considered phosphate loading or even acknowledged where the excess phosphate would go.

To underline the cynicism involved, there is a standard calculation often used in MMPs. This is to calculate the area of land required to support the stated number of livestock at 250kgN/ha. If the farm is bigger than that, then fine. The need to balance nutrients to crop requirements, as required by *RB209* [1] and *CoGAP* [2], is simply not addressed in any of the MMPs and clearly is not enforced within the planning process by NRW or by Powys CC.

Farmers are taking advantage of the 250kgN/ha limit, as if it's akin to a business tax allowance.

An aspect worth clarifying at this point regards silage. Most farms in Powys will produce some silage, which has a higher nutrient requirement than pasture. The first point to make is that silage is grown on only a small part of the farm – depending on farm size and stock density, but maybe 20%. The second point is that this silage is not exported: it feeds the stock in winter. This means that the phosphate in the silage is recycled each year: soil to silage to cattle to manure and back to soil. It is not an output stream unless it is exported from the farm. MMPs frequently cite silage as a justification for additional fertiliser, but spookily there are never any numbers to back this up. It is all smoke and mirrors.

Project types

Poultry operations fall into one of four types. *Breeders* produce chicks, generally sold as day-old chicks. *Broiler rearers* take these day-old chicks and fatten them for 6 weeks, selling them for meat at around 2.2kg weight; this process typically repeats 8 times per year. *Pullet rearers* take day-old chicks and grow them for 16 weeks, at which point they are able to lay eggs; this process typically repeats 3 times per year. *Egg producers* take 16-week-old pullets and produce eggs until yields fall after 12-18 months. Almost all egg producers in Powys are free-range, including a handful of organic free-range.

All of the above project types have the birds housed in large industrial sheds. Free-range units merely have *pop-holes* in the walls to allow birds daytime access to a field. All these activities are classified as Intensive Poultry Units (IPUs).

Project sizes vary by type. The majority of egg production units are in multiples of 16,000 birds (organic units are smaller), with most such projects in Powys being for 16,000 or 32,000 birds. Breeders and pullet rearers are generally in the 20,000 to 60,000 range. Broiler units can be huge, with projects in excess of 100,000 birds not uncommon. In all types, multiple projects are often executed cumulatively over time on the same farm.

The breakdown within the full dataset is as follows:

Project type	*Number of projects*	*Number of birds*
Breeders	9	220,500
Broiler rearers	63	4,483,700
Egg producer	195	3,242,800
Pullet rearers	23	874,000
Totals	*290*	*8,822,000*

Table 2: project types in the full dataset

That's fairly straightforward.

Phosphate analysis

Calculation of emissions

Nitrogen emissions from poultry are well documented and can be found for example in *Table 3* of the *NVZ guidance for farmers* [3]. These are the numbers which underpin all of the MMPs examined. From this value for N, we can use *Tables 2.5 & 2.7* from *RB209* [1] to derive the corresponding P_2O_5 value. These numbers are shown in the following table:

Project type	*kgN/year per 1000 birds*	*kgP_2O_5/year per 1000 birds*
Breeders	700	425
Broiler rearers	330	200
Egg producer	530	322
Pullet rearers	210	128

Table 3: N & P emissions from different types of poultry

Knowing the number and type of birds for each planning application, it is then a simple matter to apply the appropriate numbers to calculate the relevant N and P_2O_5 emissions. Within the 69 downloaded MMPs, I've also verified consistency with submitted numbers.

Free range aspects

Our basis for calculation has been of birds housed in IPUs, with all of the manure spread on the land by the farmer. Since a significant number of birds are free range layers, it is worth considering what happens while the birds are outside depositing manure and urine directly on the range area. In the UK, free range means that birds have access to the outside during daylight hours, at a stock density of 2,000 birds per hectare. If we apply this stock density, with the 'egg producer' numbers from Table 3, for 50% of the time, we get manure application rates of 530kgN/ha and 322kgP_2O_5/ha. This is over twice the permitted application rate for organic manure.

Clearly, we don't know what proportion of birds choose to avail themselves of fresh air each day, so these numbers may be a slight overestimate. But it does show that such a range area represents a phosphate hot spot. If this happened to be located too close to surface water, it could cause some significant point pollution. But from the farm boundary point of view, there is no change. The total amount of nutrients applied to the land of any one farm is the same, irrespective of whether the hens deposit it, or the farmer spreads it. On this basis, I will not consider free range to be a special case.

Project locations

It is a straightforward process to take the postcode of each project and locate it on a map. It is then possible to track down the local streams and determine which river the farm drains into. I have categorised this firstly by major river catchment (I've called this *Catchment*; to NRW it is a *Management Catchment*) and secondly by significant tributaries (which I've called *River*; to NRW an *Operational Catchment*).

This is how things break down by major catchment:

Catchment	*Number of projects*	*Number of birds*	*kgP_2O_5/year*
Dee	1	-	-
Dovey	1	36,600	4,658
Severn	146	5,281,000	1,263,413
Wye	142	3,504,400	875,399
Totals	*290*	*8,822,000*	*2,143,470*

Table 4: allocation of projects, birds and phosphate emissions by major catchment

Within the dataset, there are no poultry projects draining into the Usk catchment. The Dee project is not operational and the single Dovey project is small. Therefore, for the remainder of this document I will discuss the 288 projects spread over the Severn and Wye catchments.

Incidentally, it is worth pointing out that my estimate of 850 tonnes p.a. of P_2O_5 in the Wye catchment, as used in my first report [3], was not too far off the mark.

Wye catchment

The next table shows how the Wye catchment projects break down by river:

River	*Number of projects*	*Number of birds*	*kgP_2O_5/year*
Arrow	6	107,500	36,952
Bachawy	1	16,000	5,139
Duhonw	1	100,000	20,000
Edw	4	60,000	19,273
Irfon	3	86,600	13,349
Ithon	96	2,078,700	546,595
Lugg	8	451,600	94,446
Marteg	3	28,000	8,994
Wye	20	576,000	130,652
Totals	*142*	*3,504,400*	*875,399*

Table 5: allocation of projects, birds & phosphate emissions by river for the Wye catchment

It is immediately apparent how the Ithon alone accounts for two thirds of the Wye catchment projects and two thirds of the Wye phosphate emissions. To emphasise the point: that is over 546 tonnes of P_2O_5 being spread within the Ithon catchment every year. Geographically these IPUs are located throughout the valley.

The IPUs allocated to the Wye on the other hand, are predominantly clustered around three areas: Rhayader, Builth Wells and Glasbury.

Severn catchment

Table 5 shows how the Severn catchment projects break down by river:

River	*Number of projects*	*Number of birds*	*kgP_2O_5/year*
Banwy	13	565,600	132,325
Bechan	4	84,000	20,000
Caebitra	2	128,000	22,836
Cain	1	38,000	4,836
Camlad	1	90,000	18,000
Miwl	5	293,800	65,402
Rhyw	8	199,000	47,291
Severn	54	1,290,500	381,982
Teme	19	959,500	193,694
Trannon	1	32,000	10,279
Vyrnwy	38	1,600,600	366,767
Totals	*146*	*5,281,000*	*1,263,413*

Table 6: allocation of projects, birds and phosphate emissions by river for the Severn catchment

With the exception of the river Teme, all of these smaller rivers lie within the area known as the Severn Uplands and combine with the main stem of the Severn upstream of Shrewsbury. The Vyrnwy and Upper Severn together account for around two thirds of the projects.

The river Teme is notable in that all of the projects are clustered in the vicinity of Knighton.

Phosphate concentrations

What remains is to convert the agricultural metric kgP_2O_5/year to the scientific metric mgP/s. First, we multiply by 44% to remove the mass of the five oxygen atoms, then we convert from years to seconds. Finally, we can divide by the flowrate of the respective river to determine its total phosphate concentration[1]. River flowrates are annual mean flows taken from the UK National River Flow Archive. These are dependent upon the presence of EA flow measuring stations, which are not always present on smaller streams – hence the blanks in the table below. For the upper Teme I have used my estimate from the first report.

Catchment	*River*	*Phosphate flow (mgP/s)*	*River flow (m^3/s)*	*Phosphate concentration (mgP/litre)*
Wye	Arrow	512	2.4	0.22
	Bachawy	71		
	Duhonw	277		
	Edw	267		
	Irfon	185	10.2	0.02
	Ithon	7,568	8.1	0.93
	Lugg	1,308	5.9	0.22
	Marteg	125		
	Wye	1,809	37.0	0.28
Severn	Banwy	1,893		
	Bechan	277		
	Caebita	316		
	Cain	67		
	Camlad	249		
	Miwl	906		
	Rhyw	655		
	Severn	5,289	14.7	0.36
	Teme	2,682	7.5	0.36
	Trannon	142		
	Vyrnwy	5078	21.5	0.24

Table 7: calculated total phosphate concentrations for rivers where flowrate is known

The difficulty with this data is that it takes no account of confluences, for example where the phosphate load from the Arrow contributes to the total load in the lower Lugg. It is more informative to view this data graphically as follows.

[1] Within this report, phosphate concentration always refers to *total phosphate*. A discussion of the complexities of phosphate transport in rivers and phosphate measurement is beyond the scope of this document. It suffices to point out that EA & NRW measure *active phosphate*, which will always be less or equal to *total phosphate*.

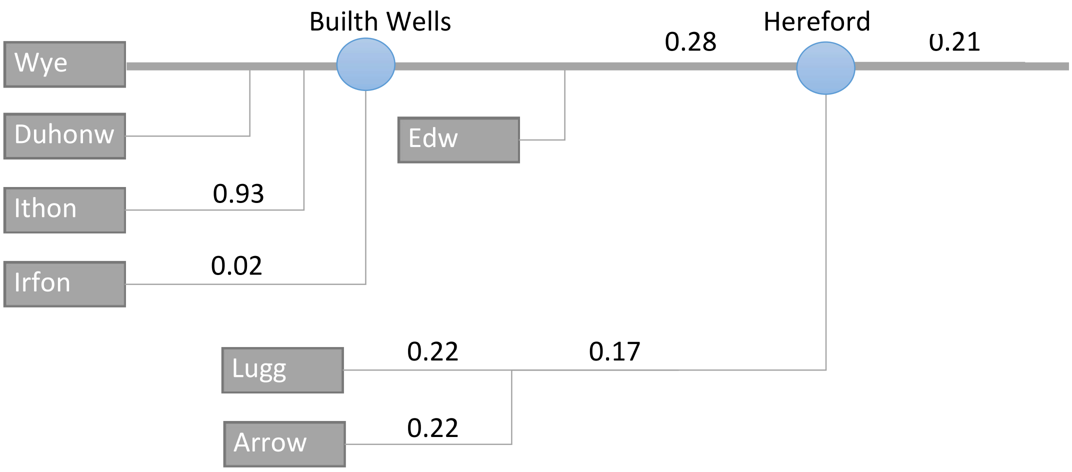

Figure 1: schematic flow-map of Wye catchment showing phosphate loads as mgP/litre

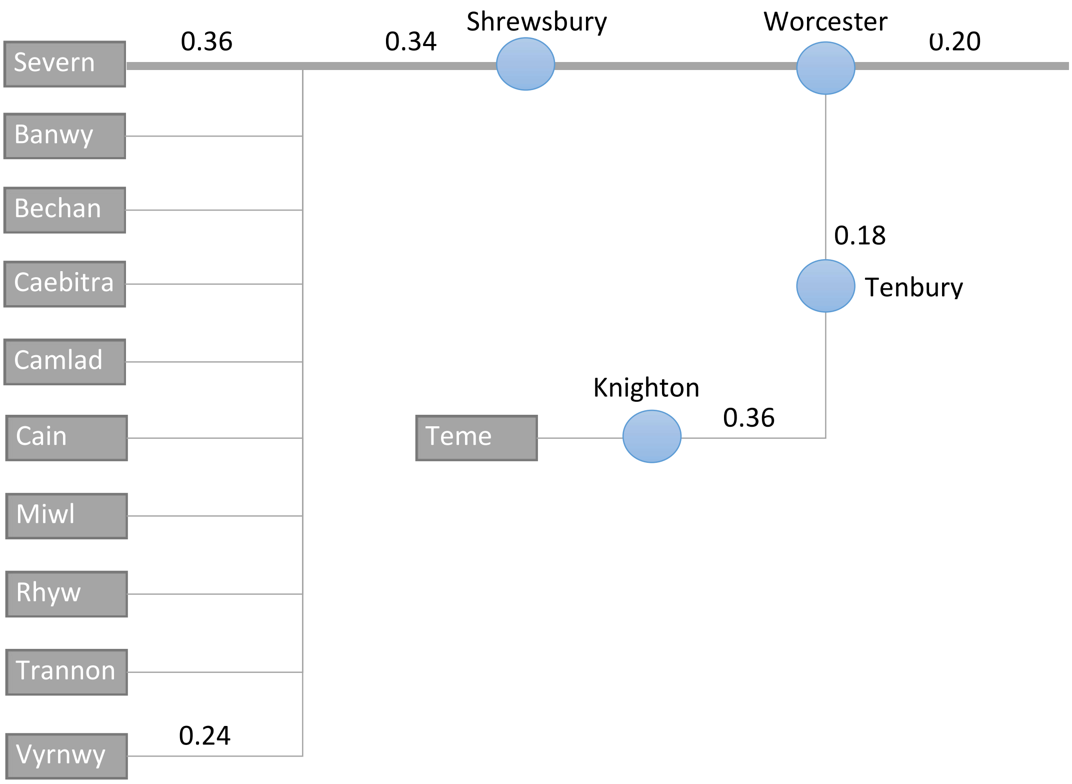

Figure 2: schematic flow-map of Severn catchment showing total phosphate loads as mgP/litre

What these figures show is the predicted total phosphate concentration at different points on the rivers taking account of phosphate load flowing in from their respective tributaries. Where there are no concentrations shown, this is generally because there is no flowrate data available to perform the calculation with.

To interpret these numbers, we first need to make use of the *Water Framework Directive (Standards and Classification) Directions (England and Wales) 2015*; this is the classification system used by EA and NRW. There are some river-dependent subtleties to this, but the classification is approximately as per the following table:

Class	*Min*	*Max*	*Description*
High	-	0.01	Near natural condition
Good	0.01	0.03	Slight change due to human activities; no impact on fisheries and wildlife
Moderate	0.03	0.09	Moderate change due to human activity; some impact on fisheries and wildlife
Poor	0.09	0.75	Major changes from natural condition; moderate impact on fisheries and wildlife
Bad	0.75	-	Severe changes from natural condition; major impact on fisheries and wildlife; many species absent

Table 11: WFD phosphate classification; units are mgP/litre of reactive phosphate

The stated national target for rivers is *good* – which requires phosphate to be below 0.03mgP/litre, on an annual average basis. Sadly, with the exception of the Irfon, all the rivers for which I have been able to show concentrations in figures 1 & 2 fall within the *poor* classification. The Ithon is particularly badly afflicted with a calculated concentration of 0.93 mgP/litre. Within the Severn catchment, the Upper Severn is also notable with a concentration of 0.36 mgP/litre.

Finally, I would emphasise two points.

Firstly, the phosphate concentrations calculated above are purely the additional phosphate resulting from poultry operations. They do not include the baseline phosphate loading from the 'business as usual' cattle and sheep rearing activities prevalent in these areas.

Secondly, they are equilibrium values, not necessarily current values. They represent where things are heading if we do nothing. It is important to understand that there is a time element to all of this – a topic which I will explore in the final section.

Here is a summary of the key points from this section:

- *From 2005 up to 2019, around 8.8 million additional birds have been housed in Powys.*
- *The Wye catchment accommodates 3.5 million birds, which emit 875 tonnes of P_2O_5 equivalent per year.*
    - *Of this, the Ithon accommodates 2.0 million birds, which emit 547 tonnes of P_2O_5 equivalent per year; this is a truly huge number on such a small river.*
- *The Severn catchment accommodates 5.3 million birds, which emit 1,263 tonnes of P_2O_5 equivalent per year.*
    - *The upper Severn and Vyrnwy together account for 749 tonnes of P_2O_5.*
- *This amount of phosphate is sufficient to take the majority of affected rivers into Water Framework Directive **poor** classification.*

Time dependency of river phosphate level

In my first report [3], I discussed how soil stores phosphate. The concept of phosphate storage in soil is well accepted and is described, for example, in *RB209* [1]. The time required to fill and empty this storage varies with local conditions but is long – maybe ten years or more. In Appendix 1 of my first report, I explained how we can model this situation mathematically. Here I will do just that, in order to understand how much of the phosphate that has already been spread on the land is getting into the rivers today.

Essentially, the phosphate 'emissions' which I calculated in the previous section represent the current amount of phosphate being spread on the land. What currently goes into the river is different because it has had to get past the soil storage system first. This storage system puts a significant 'lag' into the system, as we shall see.

The model works like this. For each year in turn, we add the calculated phosphate emissions into the storage, thus increasing the soil concentration. But we also allow a quantity of phosphate to run off to the river, the amount of run-off is not fixed, but varies in proportion to the soil concentration that year[2]. By cycling through each year in turn, this becomes a numerical solution to the first order differential equation which I referred to in Appendix 1 of my first report.

For the next section I will focus on two specific rivers: (a) the Teme at Knighton, because it exhibits a worrying trend on EA phosphate measurements, and (b) the Ithon, because it exhibits algal blooms.

The Teme

The first step in considering time dependency is to understand how the poultry phosphate emissions has varied over time. The following graph shows the number of approved projects submitted in each year in the vicinity of Knighton:

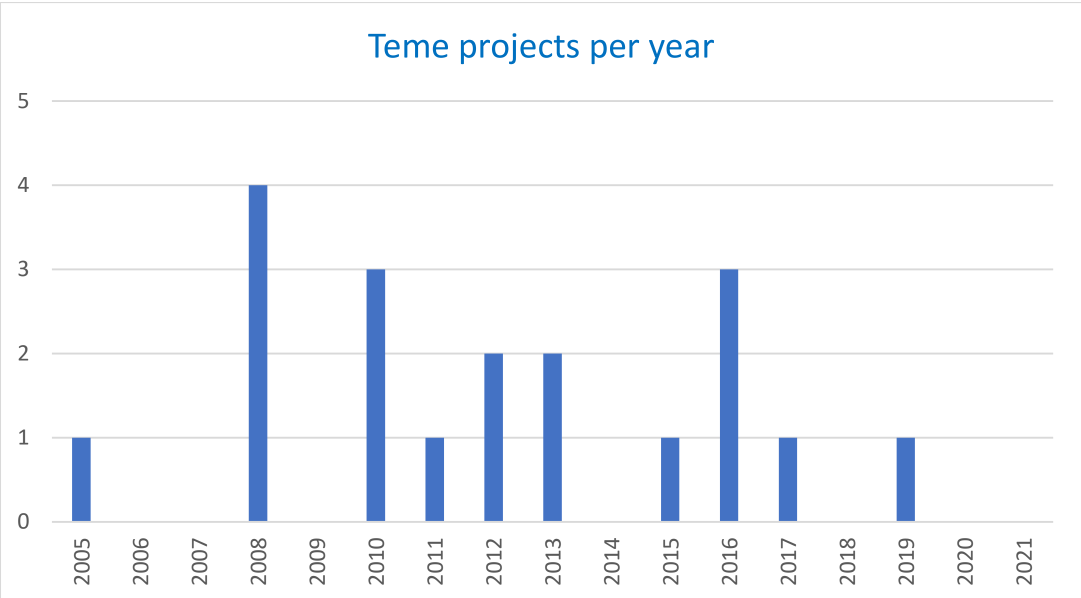

Figure 1: year of planning submission for IPUs on the river Teme

[2] The ratio of the capacity of the storage to the rate of run-off defines the 'time constant' of the system. For the following analysis, I have used a time constant of 10 years but in reality, this parameter will vary according to local conditions. 10 years will suffice for an order of magnitude calculation.

The next step is to look at the evolution of the resulting P_2O_5 emission. Although we know the date of approval, we have virtually no view of when projects come onstream. So, in the spirit of order of magnitude calculation, I have assumed a two-year lag between the year of submission and the year of commencing manure spreading. The result is the next graph:

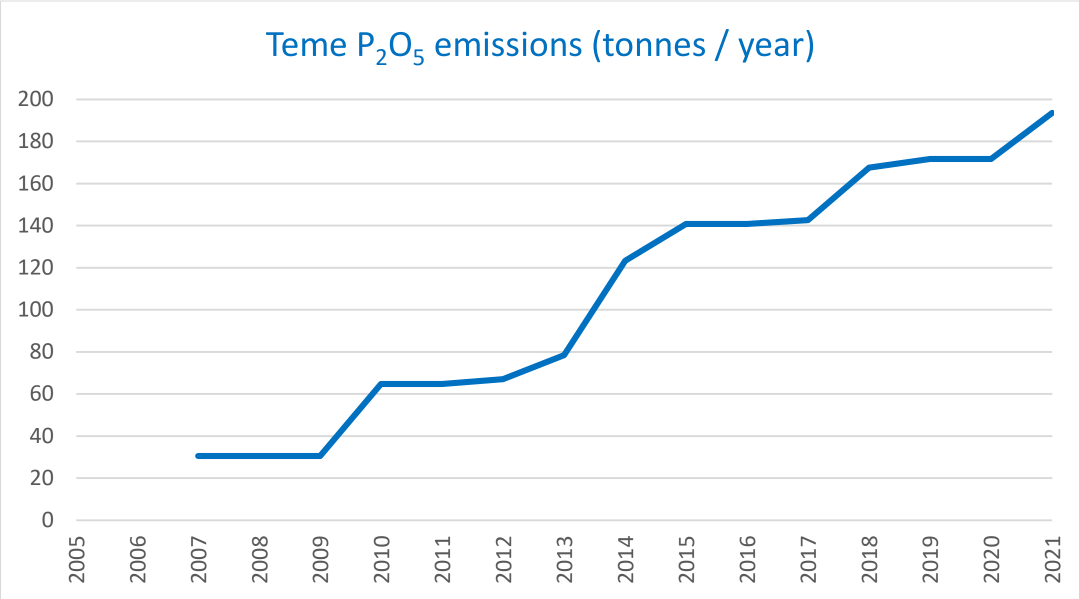

Figure 2: P_2O_5 emissions for IPUs on the river Teme

Note how the ramp-up commences in 2009 as a result of projects submitted in 2007. By 2021, P_2O_5 emissions have risen to 194 tonnes per annum. But as I pointed out above, this is not the same as the quantity of run-off to the river; this is what is being spread on the land. So now we apply the mathematical procedure described above to include the effect of soil storage and estimate the rate of run-off. The next graph is the result:

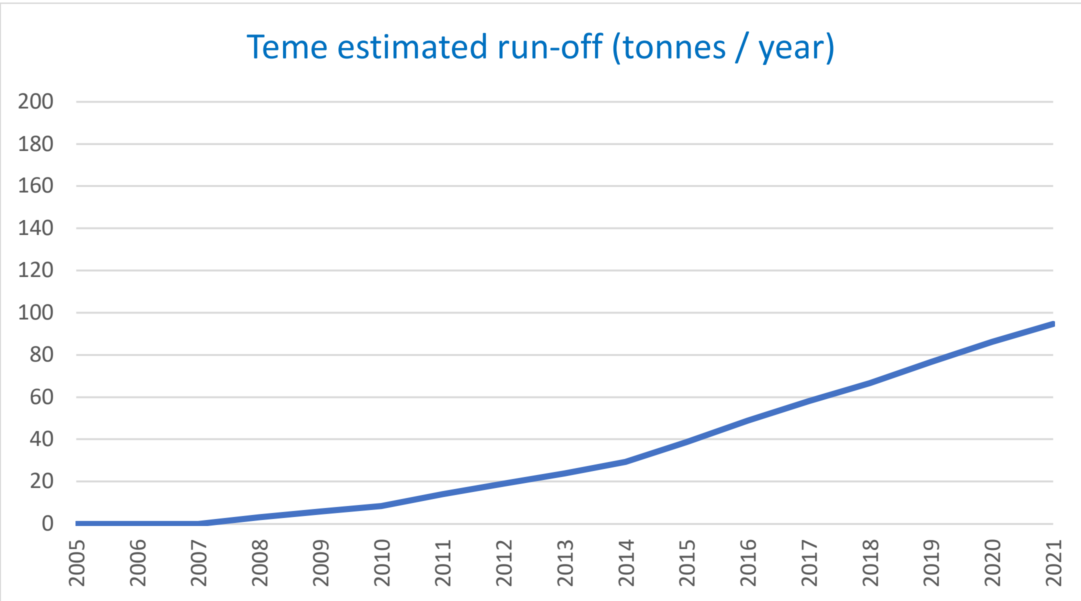

Figure 3: estimated P_2O_5 run-off due to IPUs on the river Teme

What the soil storage has done is to put a huge lag in the system. Looking again at Figure 2, we see that we reached 50% of the current emissions level around 2013-14. But 50% of peak run-off is predicted to occur in 2021 – seven or eight years later. Make no mistake, this curve is on the way up to 194 tonnes per annum, but it will not get there for another twenty years – assuming we don't build any more IPUs.

Finally, we can translate these P2O5 run-off quantities into river P concentrations. This results in the following graph:

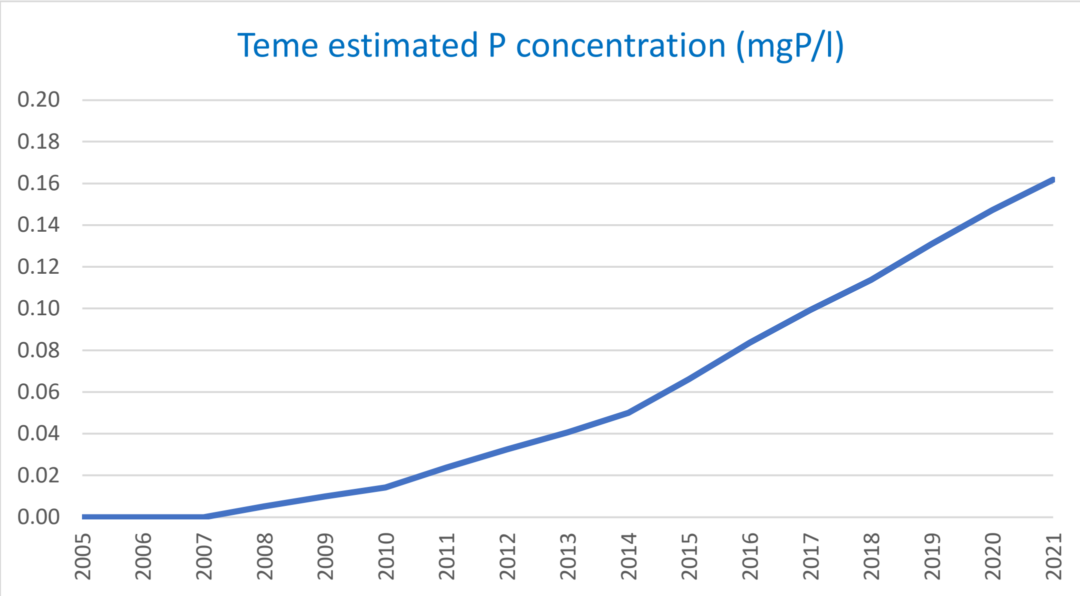

Figure 4: estimated total phosphate concentration due to IPUs on the river Teme at Knighton

Interestingly, this is a passably good fit for what the EA have reported for the Teme at Knighton: degrading from *good* to *poor* classification for phosphate over the period 2014-19.

The Ithon

Applying the same procedure for the river Ithon results in the following graphs:

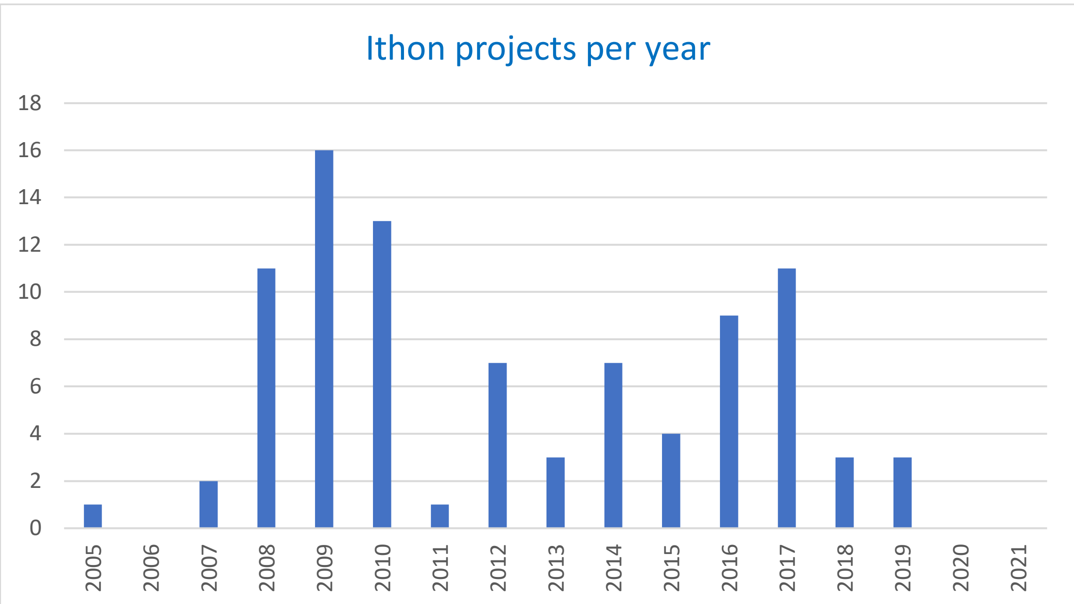

Figure 5: year of planning submission for IPUs on the river Ithon

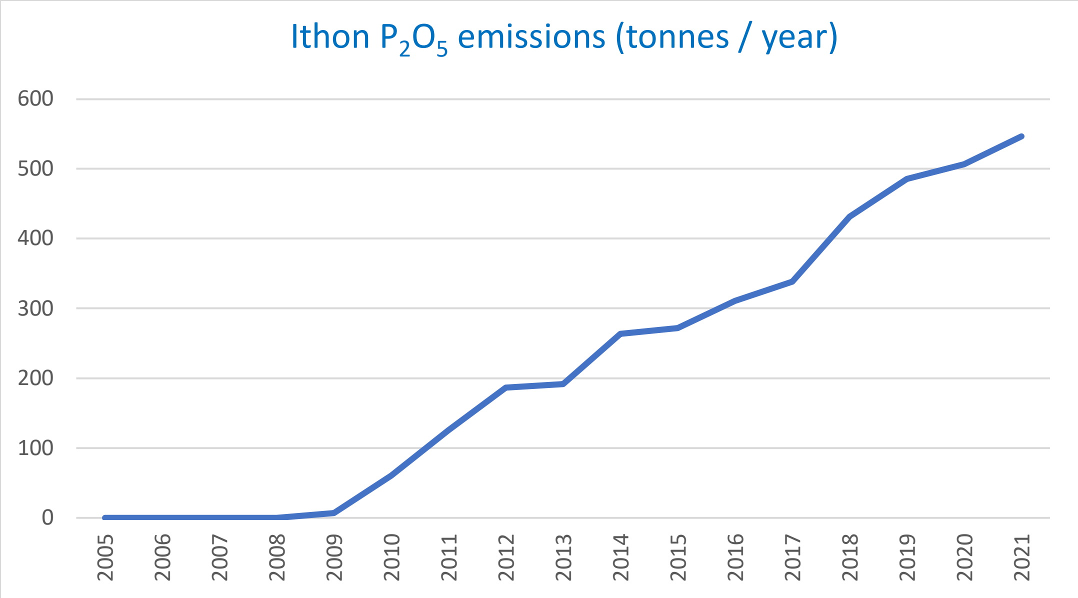

Figure 6: P_2O_5 emissions for IPUs on the river Ithon

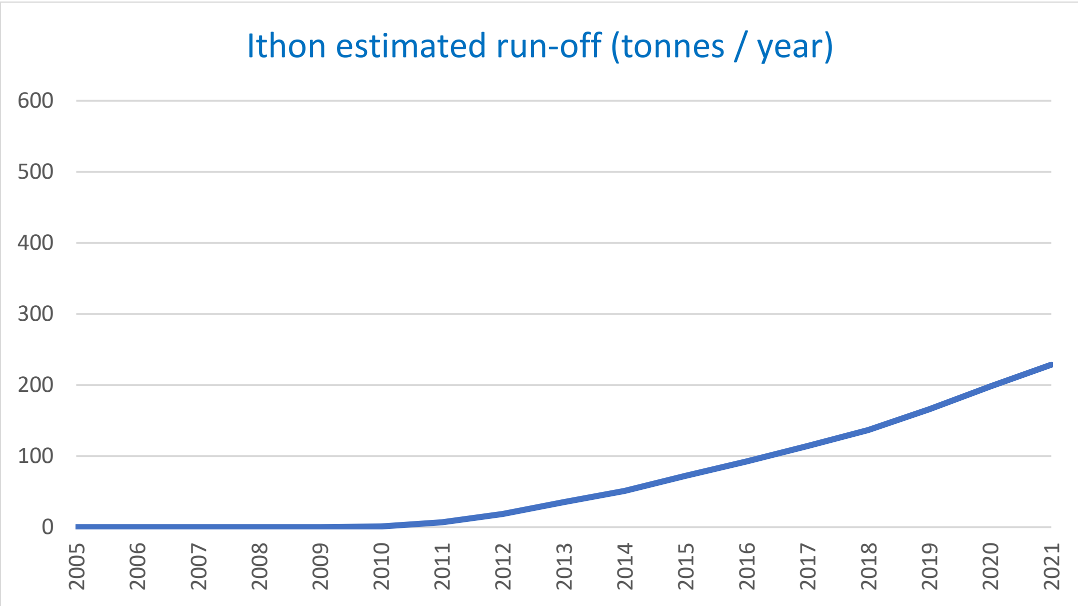

Figure 7: estimated P_2O_5 run-off due to IPUs on the river Ithon

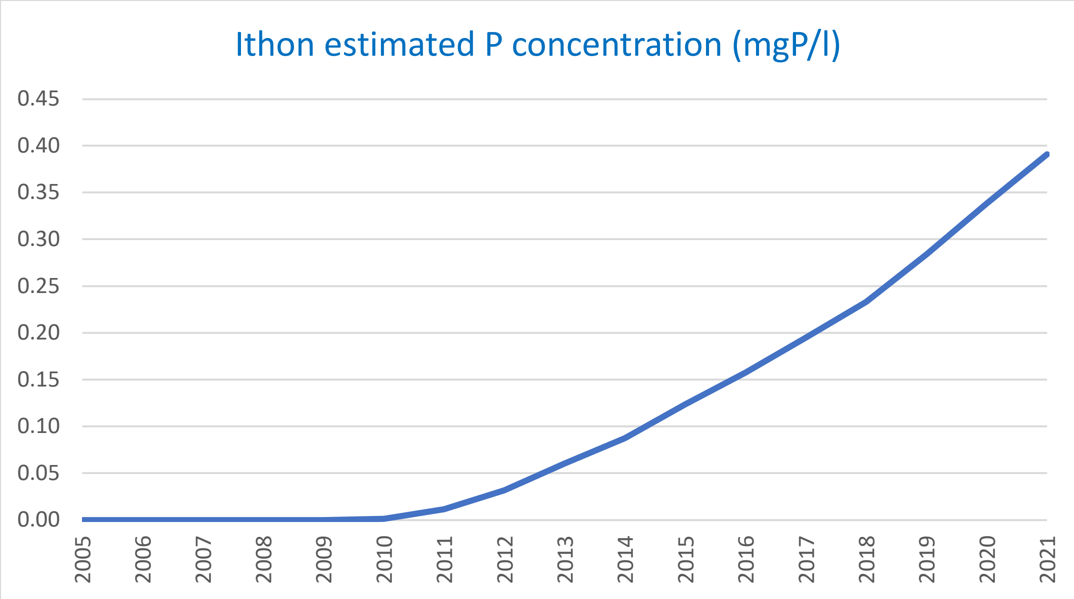

Figure 8: estimated total phosphate concentration due to IPUs on the lower river Ithon

Once again in Figure 7, we see the lag caused by soil storage. Once again in Figure 8, we see a plausible explanation for recent observations f the state of the river. In this case, the propensity for algal blooms over the last few years (as reported by WUF) is entirely consistent with the phosphate concentrations shown in Figure 8.

These two examples, the Teme and the Ithon, are typical of rivers across the two catchments in terms of their time evolution.

Summary

This has been a rather technical section, so here is a summary of the key points:

- *Equating phosphate run-off to IPU phosphate emission is overly simplistic, although it is certainly the long-term destination.*
- *We need to consider the time evolution – in particular, taking account of soil storage.*
- *It is widely known that changes to phosphate levels in soil take decades to stabilise.*
- *Soil storage introduces a huge lag between the application of phosphate to land and the resulting run-off to surface water.*
- *Current P concentrations in rivers are at maybe half the level they will achieve in another 10-15 year's time (even if we build no more IPUs).*

Conclusions

Location and nature of IPUs

- In the period 2000-2019, Powys CC have approved 290 intensive poultry units to accommodate around 8.8 million birds.
- About half of IPUs are free range egg producers, the rest are split between broilers, pullets and breeders. There is no significant regional segregation; all areas possess all types of IPU.

Manure disposal

- Near enough all of these IPUs dispose of their poultry manure by spreading it on the land; predominantly their own or, where necessary, their neighbours' as well.
- Spreading manure as a form of waste disposal is the norm in Powys. Manure application rates are generally many times the nutrient levels required for pasture.

Planning process

- All Manure Management Plans have been approved by EA / NRW - the only requirement appearing to be compliance with the 250kgN/ha annual limit for organic fertiliser application.
- The regulators have turned a blind eye to poor nutrient management practice.
- There has been no consideration of phosphate within the planning process.

River Ithon

- The Ithon is a disaster. It carries 547 tonnes of P_2O_5 equivalent per annum, approximately 60% of the total for the Wye catchment. It is a small river, so the result is an eye-watering mean flow phosphate concentration of 0.9 mgP/litre. Here is the smoking gun with respect to the Wye algal blooms.

Time dependency of phosphate run-off

- Accumulation of phosphate in the soil is a major factor determining the timing of phosphate run-off to surface water.
- There is several year's delay between the application of phosphate and the resulting run-off.
- Today's river phosphate readings are still climbing to their equilibrium level. It is likely that today we are only half-way up the curve.
- This is still true, even if we build no more IPUs.

What can we do?

- Irrespective of any change to NRW planning guidance going forwards, we have a massive legacy problem which can only be addressed by more robust regulation of the existing poultry industry.
- The recently announced reduction of the maximum application rate for organic fertiliser from 250kgN/ha to 170hgN/ha will have minimal impact on phosphate pollution.
- **There is only one solution which addresses the legacy problem:**

> - *We must completely ban the practice of spreading poultry manure as a form of waste disposal and rigorously enforce best practice nutrient management.*
> - *IPU operators must be forced to responsibly dispose of their hazardous waste – just like all other sectors of industry must.*

References

[1] RB209: Nutrient Management Guide link

[2] DEFRA guidance: July 2018,
Code of good agricultural practice (COGAP) for reducing ammonia emissions link

[3] G. Green report, March 2021,
River phosphate aspects of poultry farming in Powys: a case study