Phosphorus and Freshwater Eutrophication Pressure Narrative

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Contents

Background

This summary document is one of a series of pressure focused evidence narratives. A pressure is defined as a factor affecting the water environment. These narratives, or stories, have been produced to support the 2019 challenges and choices consultation as these pressures affect, or are affected by, the challenges described in the consultation. These pressure narratives cover chemicals, phosphorus, nitrates, fine sediment, physical modification, abstraction and flow, faecal contamination, invasive non-native species and drinking water protected areas.

The pressure narratives support engagement at national level and help build a common understanding of the issues. They also provide the national context for discussions at the local level during the consultation period from October 2019 for six months.

The introduction of revised river standards for phosphorus is referenced in appropriate sections, as are recent changes to measures to tackle diffuse agricultural pollution.

Relevance and accuracy of data

This document has been produced by bringing together the readily available information on the topic. Quality assurance of the information included so far is not complete. As a result the document may contain some errors or inaccuracies. Please let us know of any other relevant evidence or if you are aware of any issues with the information. This will help us to build a comprehensive and robust evidence base to underpin decision-making in river basin management planning. Contact details are given in Section 5 of the document.

Executive summary

What is eutrophication?

This is when there is too much nutrient in rivers, lakes/reservoirs, estuaries or the sea, causing excessive growth of algae and plants. This adversely affects the quality of the water and our uses of it, as well as damaging the local ecology.

Which nutrients are involved?

Phosphorus (P) and nitrogen (N) are the main nutrients involved in eutrophication, with phosphorus the main cause of eutrophication in freshwaters. Standards for phosphorus in UK rivers and lakes were introduced under the Water Framework Directive (WFD) in 2009 and the river standards were updated in 2015. These aim to prevent/limit eutrophication.

Nitrogen can contribute to freshwater eutrophication in some situations, particularly in lakes. Under the Nitrates Directive, some affected lakes in England already have control measures to reduce nitrogen pollution caused by agriculture. The UK Technical Advisory Group (UKTAG) for the WFD is consulting in 2019 on proposed lake N standards, for use alongside the current P standards for eutrophication control.

In saline waters, nitrogen is usually the key nutrient involved in eutrophication, but phosphorus may also be important in some estuarine situations.

In considering ways of controlling phosphorus pollution, particularly from agriculture, we should also consider current and future measures for tackling nitrogen pollution (which are often driven by drinking water resource protection rather than eutrophication) as the measures for P and N are related.

What are the problems?

For more than two decades, the Environment Agency and other interested groups have identified the risks and impacts of freshwater eutrophication in England as a significant concern. Eutrophication increases the cost of drinking water abstraction and treatment, adversely affects angling, water sports and other recreational activities, and causes the loss of sensitive plants and animals in rivers and lakes.

P concentrations in our rivers increased significantly between 1950 and the 1980s due to the introduction of P-based detergents, population growth and the growing use of artificial P fertilisers. Despite good progress in tackling phosphorus pollution since 1990, 55% of assessed river water bodies and 73% of assessed lake water bodies in England fail the current WFD phosphorus standards for good ecological status which aim to prevent eutrophication. In fact, phosphorus is the most common cause of water quality failures under the WFD in England because it is the number one reason for water bodies not achieving good ecological status.

Some waters are formally designated as affected by freshwater eutrophication[1] (5164 km of rivers, 96 lakes and reservoirs in England) and the Environment Agency

1 These are waters formally identified by Defra/Welsh Government as Sensitive Areas or Polluted Waters affected by eutrophication under the Urban Waste Water Treatment or Nitrates Directives.

has also reviewed the extent of eutrophication impacts in river and lakes more generally - see 1.2.

The ecological risks from phosphorus in rivers and lakes that have been designated for their conservation interest are also a concern (Natura 2000 (N2K) sites). Around 50% of N2K rivers and 60% of N2K lakes currently fail their long-term target for P.

Sources of phosphorus in freshwaters

The main sources of phosphorus in rivers and lakes are sewage effluent (primarily from water industry sewage treatment works) and losses from agricultural land. Food waste, food and drink additives and P dosing of drinking waters all contribute to sewage P loadings. Septic tanks and package sewage treatment plants are small sources nationally but can be important sources locally, particularly in the headwaters of catchments. Leaking water mains are a newly identified P source entering ground and surface waters.

Phosphorus loadings to English rivers from water industry sewage treatment works (STWs) have reduced dramatically since 1995. Almost 60% of England drains to rivers designated as sensitive to eutrophication with P reduction in place or planned at the major STWs. By 2020 the STW P load will have been cut by 66% (to 7.2kt/year), at a cost of £2.1bn capital, with further reductions planned for PR19 (2019 water industry price review). There have been significant reductions in agricultural fertiliser P inputs to land over recent decades (since the 1980s). This is related to improved manure use, plateauing of yields and economic pressure, including the cost of fertiliser. However, there has been a surplus of P applied to agricultural land over the last 70 years that has created large 'legacy' reserves of P in the soil which contribute to the risks of pollution. Agriculture and rural land management has now overtaken water industry STWs as the most common cause of water bodies not achieving good status for P. This is a significant change from second cycle of the river basin management plans when water industry sewage works were the most common cause.

The heavy reliance on phosphorus rock - a non-renewable resource - for supplies of phosphorus in the UK and Europe more generally, added to insufficient attention given to recovering and recycling phosphorus, is a further concern. We need to consider this when assessing ways of controlling phosphorus pollution in the future.

Why this is a nationally important water management issue

Despite significant progress in reducing river P over the last 30 years, the level of non-compliance with good ecological status for P remains high. Current and planned measures to control eutrophication will not achieve good ecological status in densely populated areas. Given what we know about the scale and location of population growth, they may also not prevent waters deteriorating. While the risks are difficult to quantify, the evidence suggests that climate change is likely to exacerbate the risks and impacts of freshwater eutrophication. Lower summer river flows will reduce the dilution for effluents and, with higher temperatures, increase the potential for algal/plant growth. Wetter winters are predicted to lead to increased runoff and erosion which will increase P losses to water from agricultural land. In the coming decades, agricultural intensification to meet an increasing population may give rise to greater livestock densities and loss of permanent pasture for increased fodder crop production, increasing nutrient losses to water.

Therefore we need to consider further national and catchment-level measures to control phosphorus. The costs and benefits of these extra measures are considered when agreeing priority actions for the WFD river basin management plans (RBMPs). The need to set less stringent objectives may need to be considered in places where P pressures are particularly high.

What appear to be the most cost effective and affordable solutions?

A mix of national measures and catchment-based planning to target water industry and agricultural measures has been demonstrated to be the most effective way to reduce P.[i]

It is important to recognise that timescales for improving eutrophic water bodies can be lengthy - several decades. This is particularly the case if diffuse agricultural sources are significant (the 'legacy' soil P issue), or if internal loadings of P are present (for example in lake or river sediments). Ecological recovery (from eutrophication) can be lengthy and uncertain [ii] [iii] [iv] [v]. This supports the need to prevent deterioration of our best rivers and lakes, alongside restoration measures.

A programme of P reduction trials at STWs has been undertaken by the water companies, through investigations in the National Environment Programme of the 2014 Periodic Review. These trials and the follow-up experience with the new/improved techniques are helping to determine which technologies, suited to UK conditions, can reliably reduce P at STWs to very low levels. As a result of the trials, the Technically Achievable Limit (TAL) for P reduction at STWs has been tightened from 0.5 mgP/l to 0.25 mgP/l for PR19 (the 2019 water industry price review). This improves the prospects of achieving river P standards.

Further to the P trials and in response to the challenges with river P compliance, a large programme of P reduction at STWs is proposed as part of PR19, the latest water industry price review. Capital expenditure of around £1.65bn on P reduction is planned, with schemes at around 900 STWs, serving 15 million people, aimed at protecting or improving 5500km of river. It is predicted that this will reduce the P loading from STWs to rivers by 88% by 2027, relative to loadings in 1995. This is primarily to progress towards good status for P and to meet Urban Waste Water Treatment Regulations.

With major P reductions by 2027 planned by the water industry, the contribution of agriculture to total P loads in freshwaters is increasingly significant. Our latest analysis suggests that, without further agricultural P load reductions, the agricultural contribution to national river P loadings will increase from around 25-30% at present to over 50% by 2027. Major reductions of agricultural P losses (in the order of 50%) are needed, alongside further point source reductions, in order to achieve good ecological status. Water industry STWs will be around 70% compliant with their 'fair share' of the reductions to achieve good status for P in 2027. Agriculture is currently about 48% compliant with 'fair share' and this constrains the overall progress that can be made with P compliance. PR19 STW measures are predicted to achieve only a 2% improvement in river P compliance unless agricultural contributions are reduced. Reductions of around 50% are at the upper extremes in terms of estimates of the load reductions that agricultural measures might realistically achieve. The issue of legacy soil P reserves also needs to be considered. Over 40% of UK soils are over-fertilised, with soil P levels above the agronomic optimum. A key challenge for the third cycle of the river basin management plans is how to achieve greater reductions in agricultural P losses, particularly given the risks from climate change.

The Farming Rules for Water (2018) provide a statutory countrywide baseline for reducing agricultural P pollution. Advice-based voluntary schemes such Catchment Sensitive Farming (CSF), together with incentive-based approaches such as agri-environment schemes are also helping. The Catchment-Based Approach is maturing and is also contributing to improvements. Through its project on water quality and agriculture Defra has been reviewing future measures and mechanisms for controlling diffuse water pollution from agriculture, based on the latest evidence available. The new environmental land management scheme (ELMS), now proposed, will be an important future mechanism for reducing diffuse pollution from agriculture.

Further attention should be given to tackling small rural sewage sources, particularly in the headwaters of catchments.[vi] [vii] [viii] Since 2015, a regime involving general binding rules for most septic tank and small package treatment plants has been in place, with permits required for higher risk situations. In urban areas, leaking water mains and sewers, and misconnections are sources of P entering rivers and lakes that deserve more attention.

The Environment Agency supports the increasing attention being given by the EU and UK governments to sustainability as an issue in the terms of the supply, uses and disposal of phosphorus. The potential for wider adoption of source control, recovery and recycling of phosphorus is something we wish to explore further with government, sector groups and other stakeholders in managing P for the future.

1. Current and potential future problems with phosphorus in freshwaters

1.1 Phosphorus and eutrophication

Phosphorus (P) is an essential element for life on earth; a nutrient required for plants and animals to grow. Modern society has radically altered the natural cycling and supply of P in the environment by mining P-rich rock and processing it to produce fertilisers, animal feed, our food and drink, detergents and other industrial applications (see Figure 1). Readily recoverable supplies of P-rich rock are found only in a few countries globally. Those resources are being depleted with implications for global food security. Reliance on mined P rock can be reduced by source control, waste reduction, recovery and recycling [ix] [x]. (The European Commission published a Communication on this issue in July 2013). Some of this P, as soluble phosphates or bound to particulate matter, is discharged or lost to the water environment in sewage effluents or land drainage.

The main issue of concern with phosphorus in the water environment is freshwater eutrophication.[2] This is the adverse effects on water uses and ecology of excess algal/plant growth caused by excessive nutrient enrichment. Eutrophication is an international concern and has been recognised as an issue in England and Wales, particularly in fresh waters, since the 1990s.[xi] [xii]

Nitrogen can contribute to freshwater eutrophication in some situations, particularly in lakes (see 1.6). The UK Technical Advisory Group for the WFD is consulting in 2019 on proposed lake N standards, for use alongside the current P standards for eutrophication control.

In saline waters, nitrogen is usually the key nutrient involved in eutrophication, but phosphorus may also be important in some estuarine situations.

Eutrophication can adversely impact on a range of water uses and societal benefits. These include drinking water abstraction and treatment, water contact sports, angling, wildlife and conservation interest, livestock watering, navigation, general amenity, tourism and waterside property values[xiii].

The adverse ecological effects include excessive growth of algae/plants, increased prevalence of toxic algal blooms, loss of sensitive plants which are replaced by nutrient tolerant species, a shift from plant to algal dominated lakes, reduced oxygen levels and associated impacts on invertebrates and fish. The effects in lakes and rivers are more fully characterised in the scientific literature. [xiv] [xv] [xvi] [xvii]

An absence of eutrophication problems is part of achieving good ecological status under the Water Framework Directive (WFD).

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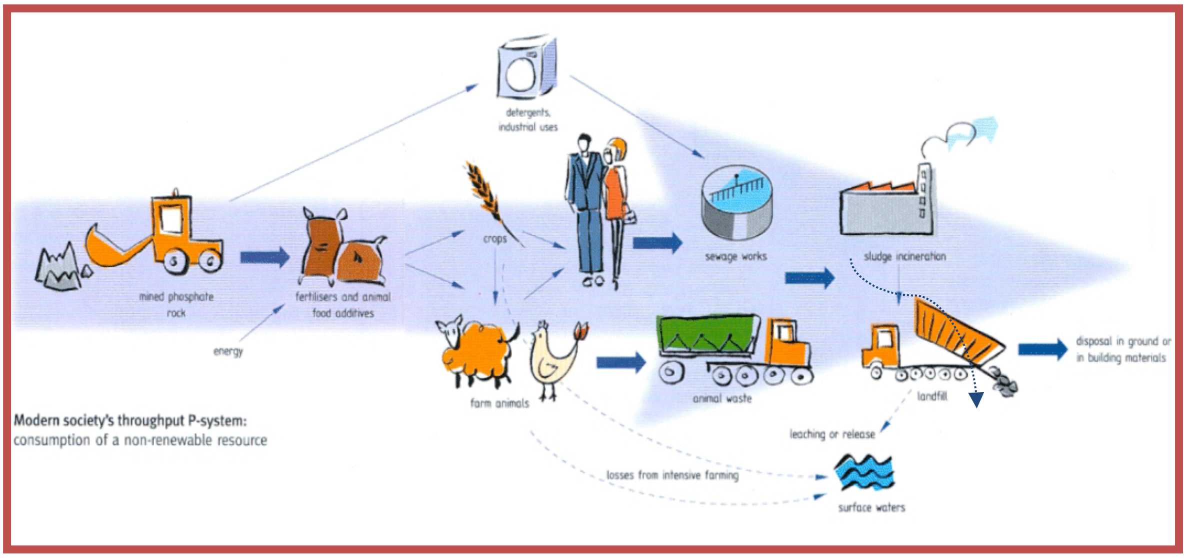
[2] Phosphorus can also play a supporting role alongside nitrogen in eutrophication in estuaries and marine waters.

Figure 1: Modern society's phosphorus through-put system



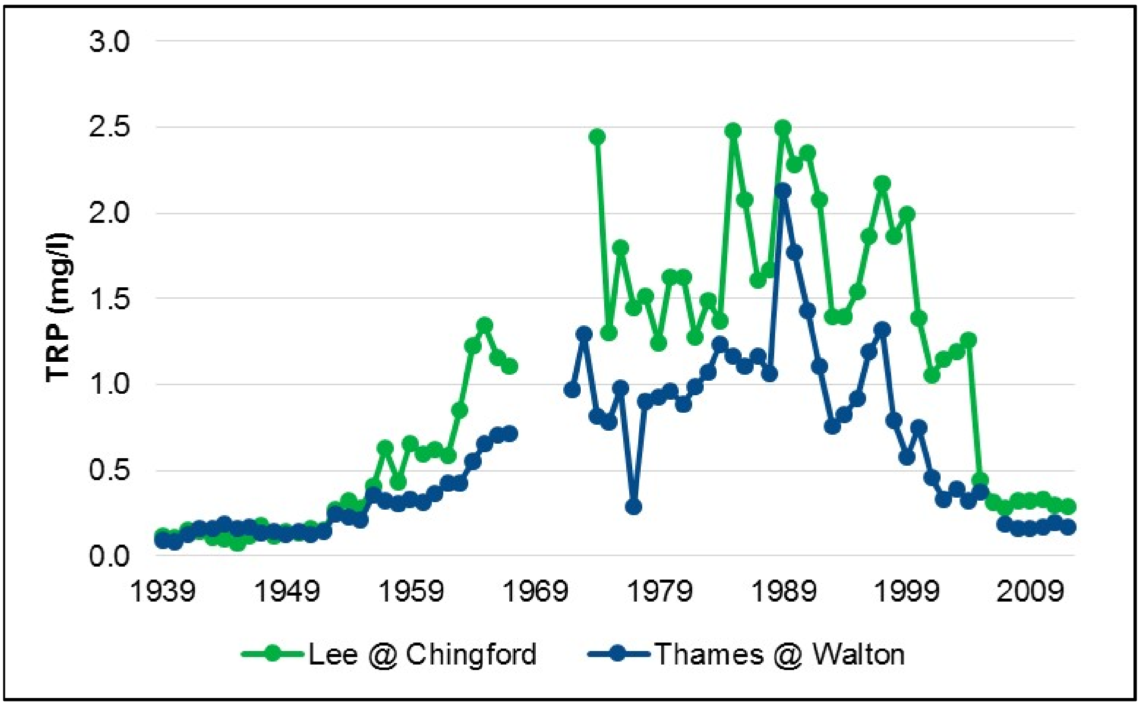
Source: CEEP with addition

1.2 The current situation

P concentrations in our rivers increased significantly between 1950 and the 1980s due to the introduction of P-based detergents, population growth and the growing use of artificial P fertilisers [xviii], [xix]. Sewage treatment and other measures have reduced P significantly since 1990. The P loadings to rivers in England and Wales from water company sewage treatment works were reduced by more than half between 1995 and 2010[xx] and will be reduced by 66% to 2020 through the introduction of P reduction treatment. In addition, the contribution of detergents to sewage P loadings has fallen from around 50% in the 1970s to minimal levels[xxi],[xxii]. Reductions in fertiliser use and animal numbers over the last 30 years will have helped to control P loadings to water from agricultural sources. However there is still a P surplus in UK agriculture with greater P inputs (in fertilisers and manures) than removed via crop and fodder production, so P continues to accumulate in our soils.

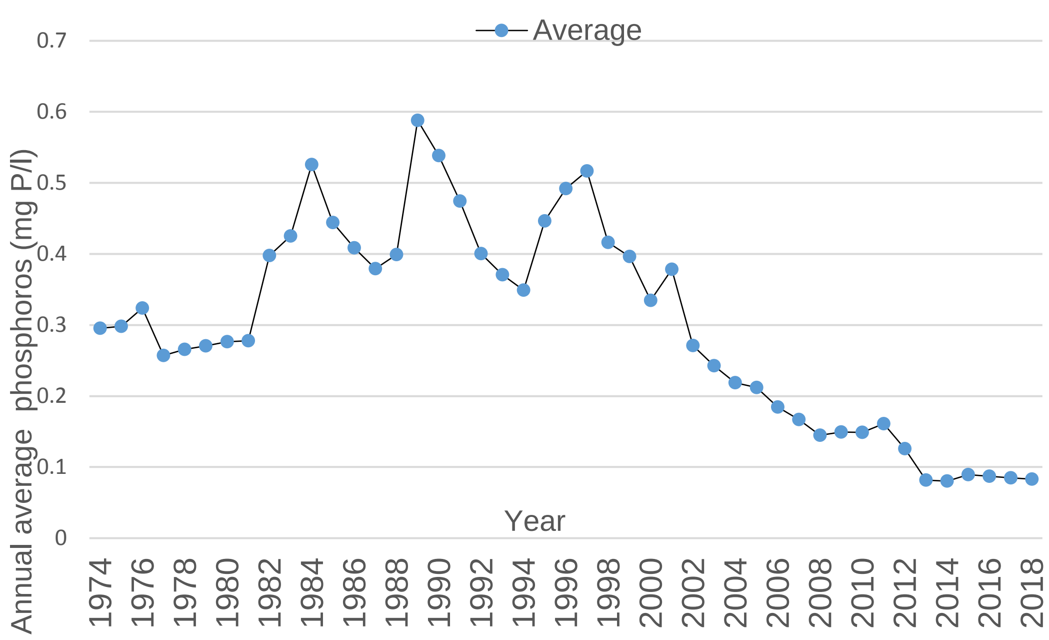
Figure 2 is a good illustration of the rise of river P concentrations after World War II and their decline in recent decades, using the River Thames and the River Lee, a tributary of the River Thames, as examples.

Figure 2. Total reactive phosphorus concentrations in the rivers Thames and Lee 1932-2012



The very significant improvements since about 1990 in the River Thames are reflected in other rivers throughout England (see Figure 3). This shows the annual average P concentration from pooling P data for all Harmonised Monitoring Scheme points in English rivers. These points are mostly located at the lower end of rivers. Major reductions in river P have been achieved since the late 1990s when P reduction measures at sewage treatment works first began to be introduced.

Figure 3. Annual average concentration of total reactive phosphorus in rivers, 1974 to 2018. Courtesy of Professor Fred Worrall, Durham University.



However, despite this significant progress, much of our river length still has P levels which are too high[xxiii]

55% of river water bodies assessed for P in England fail the revised P standards for good ecological status. 73% of assessed lake water bodies in England also fail the good status standard for P. Compliance with the P standards is worst in lowland high alkalinity rivers - the dominant river type in England. 24 groundwater bodies also fail due to eutrophication impacts on surface waters.

More water bodies in England fail good status due to phosphorus than any other WFD water quality pressure. Some fresh water bodies are formally designated as affected by eutrophication[3] and the Environment Agency has also now reviewed the extent of eutrophication impacts in river and lakes more generally based on recent WFD monitoring and investigations – see below.

WFD assessments of eutrophication in rivers and lakes/reservoirs

In the run-up to 2015 river basin management plans, the Environment Agency assessed the certainty of eutrophication impacts in rivers and lakes/reservoirs at risk from phosphorus. These assessments are used in applying Defra and UKTAG guidance on WFD nutrient standards, whereby expensive regulatory measures to control nutrients are targeted to water bodies with firm evidence of eutrophication. This confirmation is necessary because exceeding the WFD nutrient standard alone is considered insufficient to judge the risk of impacts on the biology. An approach has been developed which combines the latest WFD classification results with wider evidence in a structured way, to make best use of all evidence in identifying whether there is a problem to solve in a given water body. The assessments were made available as part of the supporting information to the proposed updated 2015 river basin management plans. Results from these assessments of certainty of eutrophication impacts in English water bodies are as follows.

Lakes and reservoirs – assessments were undertaken for 587 WFD water bodies, with around three quarters failing the good status phosphorus standard, 16% categorised as 'very certain' and 9% being 'quite certain' of a eutrophication problem.

Rivers –assessments were undertaken for 3769 WFD water bodies, of which around 55% fail the phosphorus standard for good status, around 25% were categorised as 'very certain' and 17% as 'quite certain' of a eutrophication problem.

The results confirm that eutrophication is a significant issue in freshwaters in England. Many of the affected water bodies will be those designated under the UWWT/Nitrates Directives.

[3] These are waters formally identified by Defra/WG as Sensitive Areas or Polluted Waters affected by eutrophication under UWWTD or Nitrates Directives. 96 lakes/reservoirs and 5164km river length in England.

The risks and eutrophication impacts of P in designated N2K/SSSI rivers and lakes also remain a concern[xxiv] . Around 50% of N2K rivers and 60% of N2K lakes currently fail their long-term target for P.

Problems associated with algae/eutrophication are also one of the reasons for Drinking Water Protected Areas (DrWPAs) being designated 'at risk'. Of the 485 surface DrWPAs in England, 266 (55%) are currently assessed as at risk with eutrophication a causal factor in 44 cases (mostly reservoir sites). Algal can block filters in water treatment works, make abstraction from reservoirs problematic, and give rise to taste or odour problems in water.

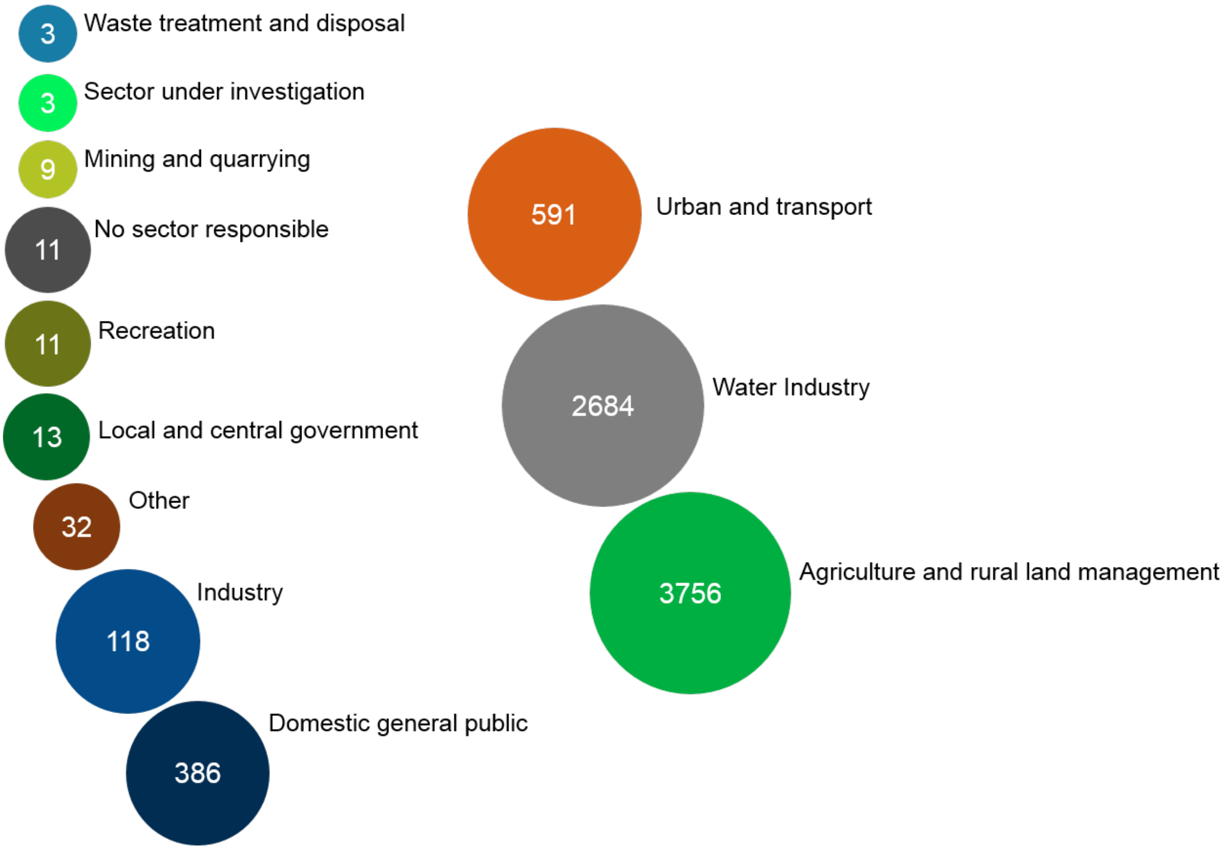
A small number of groundwater bodies were at poor status for phosphate in the 2015 river basin plans. This was because elevated concentrations of phosphate in groundwater were causing impacts in associated surface water bodies. Generally P does not cause widespread pollution problems in groundwater. This is because P in the subsurface often becomes attached to clay or iron minerals. However, once this sorption capacity in the subsurface is used up it is possible for P to move through groundwater to reach surface water receptors. Some aquifers also have naturally elevated concentrations of P. In the 2015 river basin plans less than 4% of the groundwater bodies in England were at poor status due to P.

1.3 Sources of phosphorus and reasons for not achieving good status

The largest source of P to rivers is sewage effluent (about 60-80% of the total for England). However, for lakes agricultural practices are the major cause, contributing around 25% of the total P load to waters in England. The proportions from different sources vary between and within river basins/ catchments [xxv] [xxvi] [xxvii] [xxviii].

Sewage effluent and agriculture (losses from fertilisers and feed/ manures) are the largest P sources [xxix] [xxx] [xxxi] [xxxii] [xxxiii] and the most common reasons for water bodies not achieving good status for P. Of the 7617 reasons for not achieving good status for phosphate agriculture and rural land management is the main sector responsible in 3756 cases and the water industry in 2684 cases (March 2019). This is a change from the second cycle of river basin plans when water industry sewage works were the most common cause.

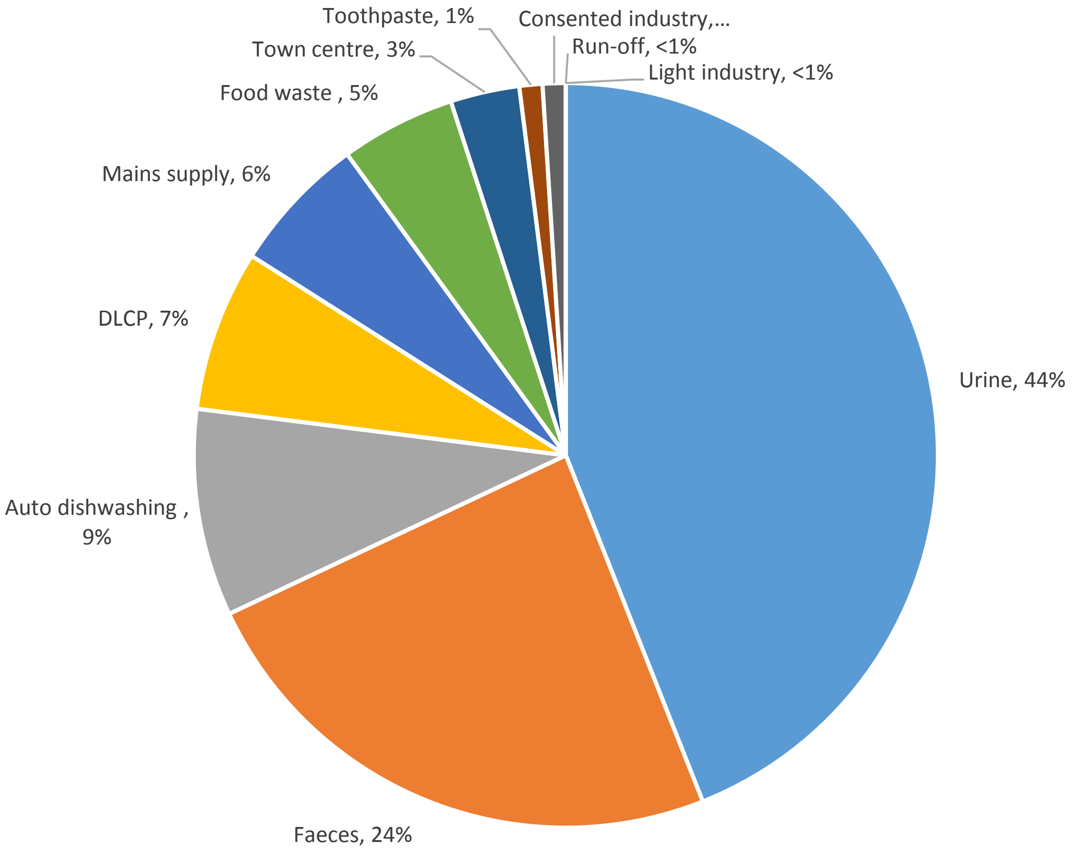
Figure 4 Counts of numbers of Reasons for Not Achieving Good Status (RNAG) (not numbers of water bodies). Data source: Environment Agency March 2019



Within sewage, detergents are now a minor source since EU and UK restrictions were introduced in recent years[4], food waste (5%), food and drink additives (around 5-10%[xxxiv]), and P dosing of drinking water supplies (6%) are all relatively significant sources of P [xxxv] [xxxvi] (see Figure 5).

[4] Domestic laundry detergents and dishwasher detergent comprised 7% and 9% respectively but became subject to EU regulation from 2013 and 2017.

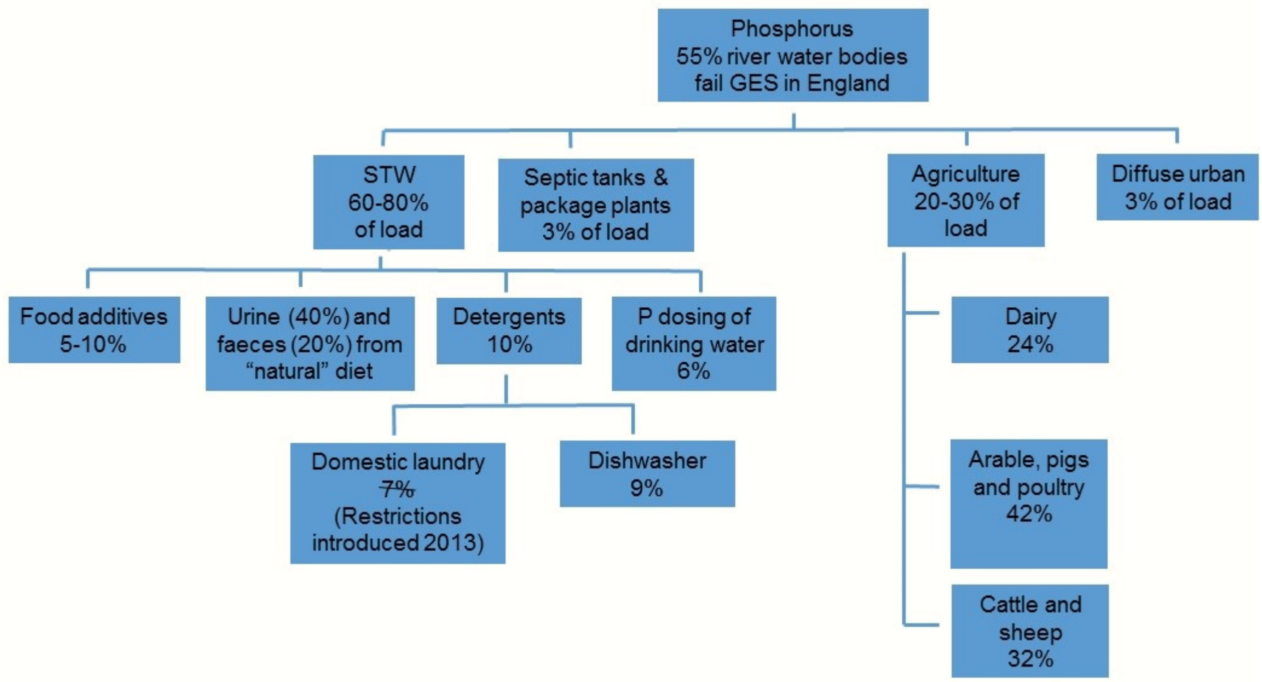
Figure 5. Summary of sources of phosphorus to sewer from domestic sources



Other minor contributors to P levels in water include industry, misconnections, urban drainage, leaking sewers, combined sewer overflows, septic tanks and small package plants [xxxvii] [xxxviii] [xxxix] [xl] However, these sources can be locally significant such as in the headwaters of catchments[xli] [xlii]. Leaking water mains are a further source as the large UK water companies lose about 25% of mains water to ground and surface waters through leakage. Since tap water is dosed with P, this adds significant amounts of P (around 1200 tonnes per annum) to our ground and surface waters (equivalent to up to 25% of the STW P input to rivers in some urban areas). Figure 6 is an approximate national apportionment for the sources of phosphorus in English rivers.

Phosphorus loadings to English rivers from water industry sewage treatment works (STWs) have been reduced dramatically since 1995. By 2020 the STW P load will have been cut by 66% (to 7.2kt/year), at a cost of £2.1bn capital, with further reductions planned for PR19 (the 2019 water industry periodic price review). For agriculture there have been reductions in fertiliser P inputs to land over recent decades, related to improved manure use, plateauing of yields and economic pressure, including the cost of fertiliser. The input to arable land in England and Wales in 1983 was 26 kgP/ha, falling to 7 kg/ha by 2017. Input to grassland was 39 kgP/ha falling to 15 kgP/ha. However, there has been a surplus of P applied to agricultural land for many decades. There is still an annual surplus and there are now "legacy" reserves of P in the soil which could take decades to run down.

Figure 6 National apportionment for sources of phosphorus in English rivers



The input of P from sewage treatment works to rivers and lakes is generally relatively constant through the year and are mostly easily used by algae and plants (except where chemical P reduction treatment is in place). Agricultural inputs are much more closely linked to rainfall events and are more seasonal, with greater inputs to water in the autumn and winter when algae and plant growth is limited. They are more variable in terms of their forms and immediate bioavailability. However, most forms of P can become bioavailable to algae and plants over time, contributing to ongoing eutrophication risks. [xliii],[xliv],[xlv],[xlvi]

1.4 Failure of phosphorus standards in combination with other pressures

P standard failures in rivers commonly occur alongside sediment (and morphology) failures, particularly in relation to the losses from land. For all water bodies where a where the pressures is known to be from agriculture and rural land management, phosphate accounts for the greatest proportion of failures (55%), followed by fine sediment (16%) and physical modification (15%). P failures also often coincide with high nitrate (e.g. in Nitrate Vulnerable Zones). It is difficult to distinguish between the enrichment effects of elevated P and nitrogen, but in freshwaters it is generally assumed that P is the main causal nutrient [xlvii] and the prime focus for control action. Nitrogen can contribute to freshwater eutrophication in some situations, particularly in lakes.

1.5 Future risks of eutrophication and phosphorus failures

There are a number of issues that could pose a risk of future deterioration and additional eutrophication problems or in some cases reduce P pressures on water and hence eutrophication risks:

Climate change is likely to exacerbate the likelihood of eutrophication, through warmer summers, changes in precipitation and reduced summer river flows. A recent study by the Environment Agency indicated that reduced future river flows were projected to result in small, but variable increases in annual average P concentrations in rivers. At most sites, these changes would not by themselves be expected to result in deterioration in WFD P status classification.

Greater storm runoff may also lead to increased nutrient loads from land to water, particularly in winter. A recent study of 3 rural English catchments suggests that average winter P losses to water from agricultural land may increase by up to 30% by the 2050s. Increased temperatures and sunlight are likely to encourage more algal/plant growth and reduced summer river flows would lead to increased nutrient concentrations and longer water residence times during the algal growing season. However, more frequent storms may reduce eutrophication impacts.[xlviii] [xlix] [l] [li] [lii] [liii] [liv]

Increased population pressure, leading to new housing and sewage treatment infrastructure (particularly in southern and south east England) will increase P loadings. Many of the locations desirable for new housing are areas where P already exceeds WFD standards. In the near term this pressure presents the most likely risk of deterioration in rivers and has been estimated to pose a risk to 2% of rivers water bodies in England.

Increases in the P dosing of water supplies, to meet tighter Drinking Water Directive standards for lead, would increase P loadings to water where the receiving sewage works have no P reduction treatment, and P loadings to STWs generally.

The withdrawal from the Common Agricultural Policy following EU exit and future economic fluctuations with higher commodity prices are likely to drive P fertiliser applications.[lv]

Agricultural intensification to meet an increasing population may give rise to greater livestock densities and loss of permanent pasture for increased fodder crop production, with increased nutrient losses to water. Although the annual P surplus has been reducing, it applied for many decades and has given rise to a major "legacy" issue with P having accumulated in soils. It may take several more decades and the adoption of more efficient nutrient management methods in agriculture if we are to run down these reserves and reduce the risks of pollution. This needs to be factored into thinking on agricultural P measures and timescales for reducing P losses to water.

1.6 Evidence gaps and uncertainties around the problem

There are significant uncertainties in assessing and managing the risks associated with P and eutrophication [lvi] [lvii] [lviii] [lix] [lx]. Key areas of uncertainty are outlined below.

Links between P (in its different forms) and ecological responses, which are complex and influenced by a range of factors. This leads to uncertainty in deriving standards and underlines the need for a weight of evidence approach to confirming eutrophication.

Ecological recovery times are long and can vary considerably between catchments. In lakes the role of internal sediment P loading can be important and delay recovery by several decades.

Recent science suggests that nitrogen can contribute to freshwater eutrophication in some situations, particularly in lakes. The UK Technical Advisory Group (UKTAG) for the WFD is consulting on proposed freshwater nitrogen standards for lakes, for use alongside those for P, in controlling eutrophication.[lxi]. This development would build on the use of lake N thresholds for Nitrates Directive and N2K/SSSI purposes.

The importance of in-stream cycling of P in rivers including timing, forms and the relative importance of P inputs from different sources[lxii] [lxiii]. This is complex and not easily accounted for in models, leading to uncertainty in assessing options to meet standards and in recovery times.

The extent and nature of climate changes influences on nutrient delivery to waters and eutrophication is a further area of uncertainty. Further research and development work is needed to improve our understanding of the most effective management interventions. An increased population will have greater food and energy needs which is likely to lead to further intensification of farming practices and increased growth of bio crops. Currently the UK loses 2.9 tonnes of topsoil per annum to erosion; this could increase due to the influence of climate change.

Contributions from septic tanks and small package plants can be locally important. Assessing the risks relies on good information on locations, construction, maintenance etc. There is a lack of quantitative studies.

The importance of P alongside N in estuarine and coastal eutrophication.

In order to confirm whether targeted regulatory measures may be needed at water body level, we require firm evidence of ecological impacts. We must also understand causes of failure. Since the start of the river basin management plans the evidence base has since been greatly improved through a large programme of investigations and monitoring, informing decisions on measures. For some water bodies, uncertainty over eutrophication and its causes will remain, requiring further investigation if expensive regulatory measures may be required.

Appendices 4 and 5 show the range of Joint Water Evidence Programme (JWEP) projects aimed at resolving some of the above identified gaps.

1.7 Stakeholders involved in P and eutrophication

The main stakeholders contributing to and/or affected by or interested in P and eutrophication nationally are listed in Annex 1.

2. Current solutions and the extent of the challenge

2.1 Evidence for improvements resulting from control measures

Ecological recovery from eutrophication can be lengthy and uncertain. Despite reducing P concentrations in rivers, the control measures to date have generally produced minimal ecological benefit. This is considered to be mainly because the actions have not reduced P enough to improve the biology. It will in part be due to legacy issues such as P release from river bed sediments. However, there are examples of long term success. Some of the Norfolk Broads have improved markedly following from measures to control P, but it has taken 30 years indicating that long recovery times, particularly for lakes, are an important consideration in managing eutrophication.

2.2 Solutions for Point Source P inputs

The regulatory mechanisms to control P at sewage treatment works (STWs) are tried and tested. There are two main technical control options - chemical dosing or biological nutrient removal (BNR). Effectiveness of chemical dosing is high, with costs dependent on the size of the STW.[lxiv] BNR has not been widely used in the UK, with only around 20 STWs using this approach at present. It appears expensive in terms of cost, energy and carbon but is becoming more common and can enable recovery of the phosphorus which is not possible with chemical dosing methods.

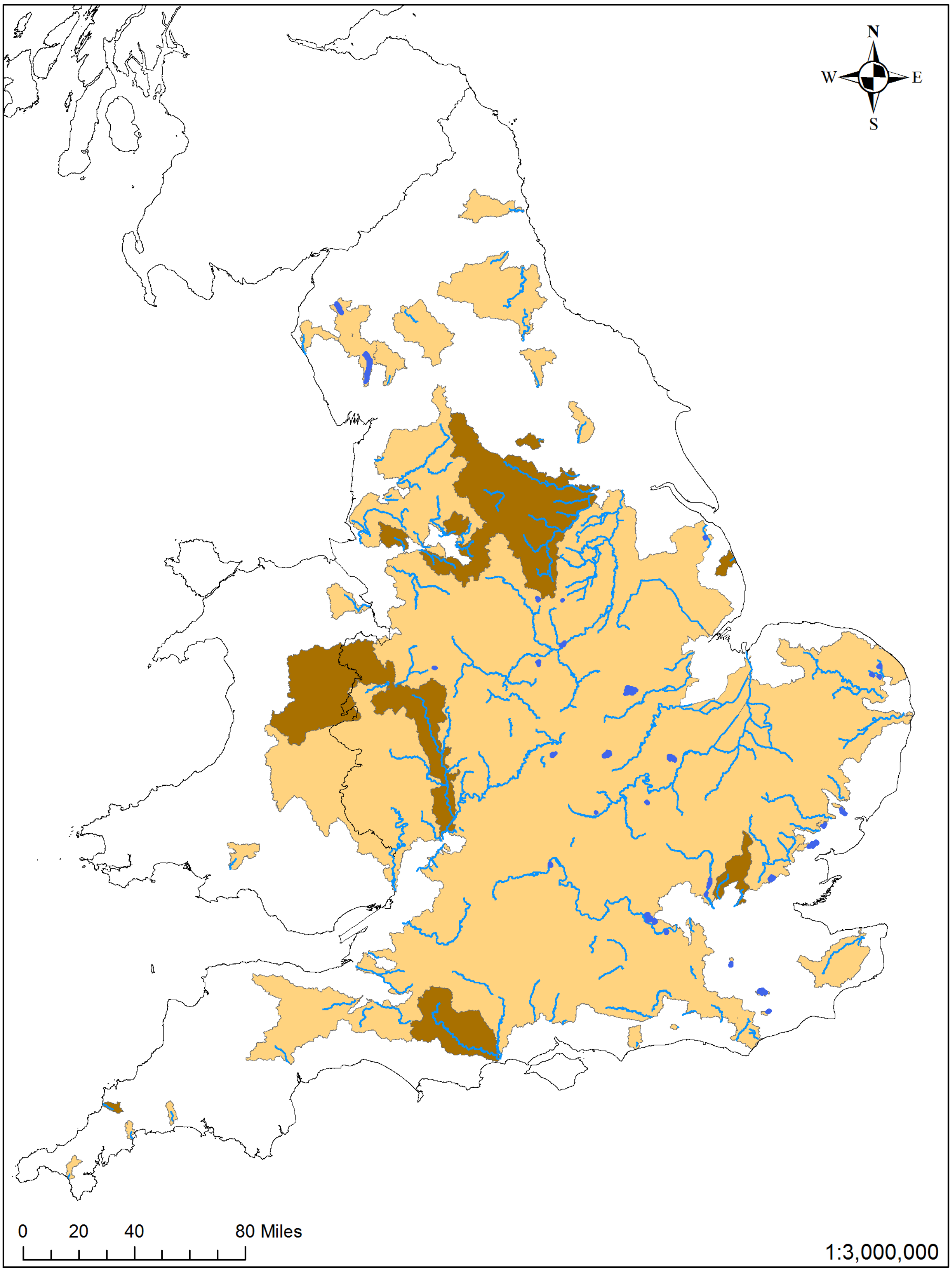
By 2015, 650 STWs serving 24 million people (60% of those served by STWs discharging to freshwaters) will have P removal in place, for the Urban Waste Water Treatment Directive (UWWTD) and conservation policies.

By 2027, with the addition of the large programme of P reduction for WFD, around 95% of the population served by STWs discharging to freshwaters will be connected to a STW with P removal. This is based on populations in 1995. The measures are mainly to improve P status, but in some places are to prevent deterioration from population growth causing an increase in P loadings to STWs.

Annex 6 summarises the progress made in reducing STW P loadings, also indicating capital expenditure, numbers of P reduction schemes, km of river protected or improved, and populations served.

As shown in Figure 7 below, the rivers and their catchments associated with UWWTD Sensitive Areas (Eutrophic), where P reduction is required at large STWs, now cover 59% of England following the latest review of designations which was completed in May 2019.

Figure 7 Urban Waste Water Treatment Directive (UWWTD) freshwater sensitive areas (eutrophic) and their catchments



Legend

Freshwater SA eutrophic

2014 Existing freshwater SAe catchments

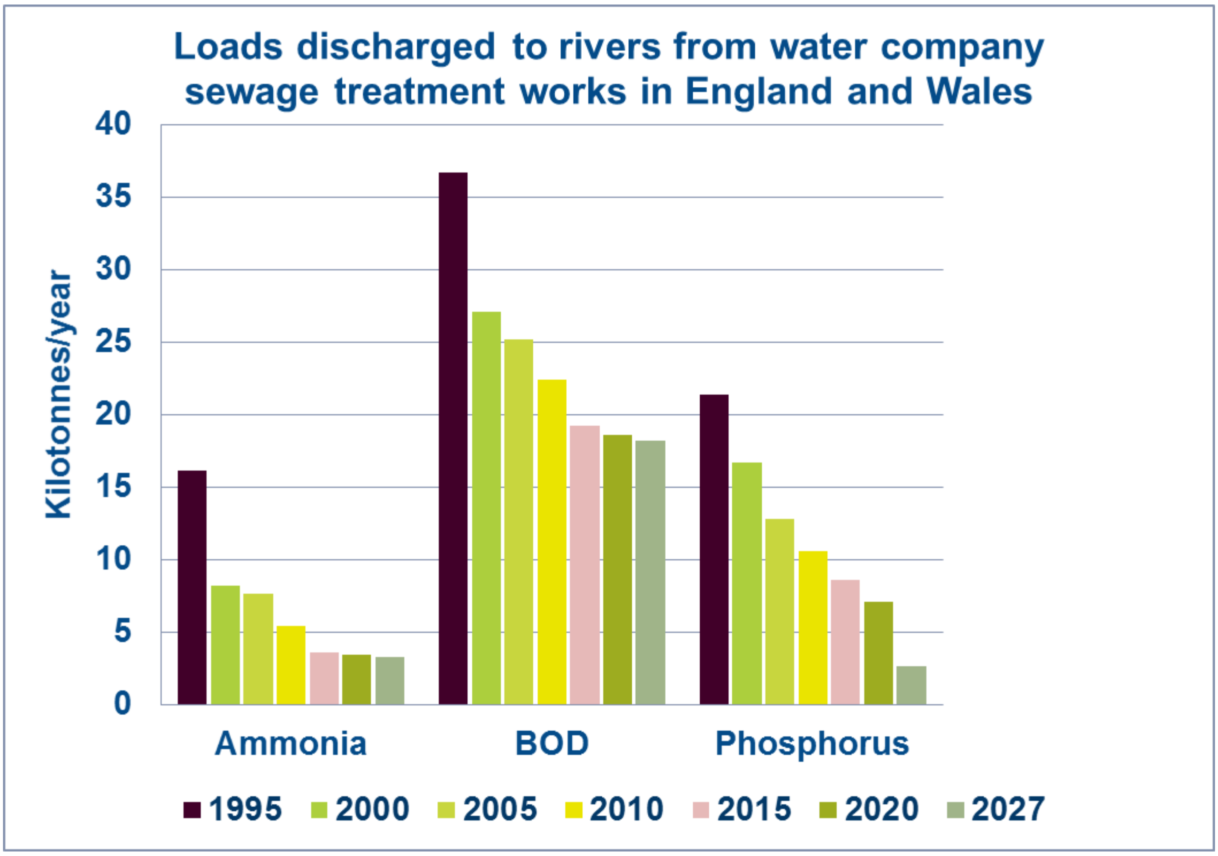
Additional area from 2019 proposed SAe catchments

Environment Agency

Map produced 29/07/2019

The new UWWTD measures are part of a large programme of further STW P reduction measures proposed for PR19 (2020-27). These measures are mainly targeted at progress towards the water industry's fair share of WFD good ecological status for P and will improve some 5,500km of river at a capital cost of around £1.65bn. Under this programme, around 900 STWs serving 15 million population equivalent will have new or tighter P reduction by 2027. This will result in a reduction of 88% in the STW P loading to rivers compared to the position in 1995. See Figure 8 below.

Figure 8 Reductions in national loads of pollutants from STWs to rivers



Despite this action to reduce this major source of P, we predict from our latest SAGIS-SIMCAT modelling that river P compliance will improve by only 2% nationally, on a river length or water body basis, as a result of the PR19 water industry investment to 2027. This is because although the water industry is 70% compliant with its 'fair share' of the P reductions needed to meet good status for river P, agriculture is 48% compliant and this constrains the extent of progress towards the good status objective.

Approximately 70% of sewage sludge produced nationally is currently recycled to land as biosolids, which means that around 43% of the P load entering waste water treatment works is recycled to land[lxv].

2.3 Solutions for diffuse agricultural pollution

There are limited controls currently over the use of agricultural land e.g. the types of farming practised. In addition there were until recently no direct regulatory controls on agricultural P inputs (to limit the accumulation of surplus P in soils) or the prevention of P losses to water from agricultural activities[lxvi]. However, the Reduction and Prevention of Agricultural Diffuse Pollution (England) Regulation - commonly known as the Farming Rules for Water - came into force from April 2018. These provide a baseline of good practice measures that will reduce P (and nitrate) losses by typically 8%. They embed in law various recommended good practices such as nutrient planning, and soil and manure management. They provide a step-by-step checklist aimed at ensuring that fertilisers are spread to meet crop and soil needs. Other rules safeguard water quality by requiring farmers to judge when it is best to apply fertilisers, where to store manures and how to avoid pollution from soil erosion.

Cross-compliance contains some measures such as those that protect soils which will indirectly control P losses. These may not be part of the future approach depending what happens with EU Exit. However the Farming Rules for water cover soil management to prevent erosion. The NVZ measures, which currently apply across 55% of England, while aimed at nitrate, will also indirectly reduce P losses by 1-2%[lxvii]. Analysis of existing CSF measures and of the entry level (agri-environment) scheme suggests that reductions of 4-8% in P load are typically achieved at a catchment level although greater reductions may be achieved in individual catchments or at the farm scale [lxviii],[lxix].

However, P fertiliser use, livestock numbers and manure P inputs to land have all been reducing nationally in recent years mainly due to economic factors.[lxx] Agricultural 'business as usual' predictions suggest P load reductions of 5-9% by 2020 (from a 2004 baseline), mainly due to reducing livestock numbers caused by economic drivers[lxxi].

CSF, which started in 2006, is an important voluntary initiative. Initially targeted at priority catchments for water quality, CSF advice has been aligned with the priorities for water in the Countryside Stewardship scheme since 2015. This helps to put in place measures where they can make most difference and effectively links advice to funding measures on farm for public benefits. CSF advice had been provided to 23,512 farmers. 43% of this advice has focused on nutrient and manure management, 16% infrastructure and 25% on soil management, all of which help reduce P losses. Latest assessments of CSF suggest a 4-10% reduction in dissolved P (and 6-14% total P) load will be achieved at a sub-catchment scale. Countryside Stewardship high priority areas cover 35-40% of the agricultural land in England.

The Catchment Based Approach is maturing into a further initiative that is particularly important in the context of reducing diffuse pollution from agriculture and other sources. This collaborative local approach, backed by Defra and the Environment Agency, has led to 87 catchments across England being covered by 111 different catchment partnerships. There are several examples emerging of local initiatives to tackle P. One such example is the Welland Valley Partnership where the group has set up a 'working with farmers' scheme offering advice on reducing pollution, free soil nutrient testing and capital grants. The group has also promoted advice on good practice to septic tank owners and use of P-free detergents in selected villages.

Defra’s CSF policy work examined economic, supportive/voluntary and regulatory mechanisms for controlling diffuse pollution. The Defra analysis indicated that agriculture needs to reduce P loss by an average of 48% nationally to achieve the WFD standards for its share of the load. [lxxii]

Preliminary findings of the latest (2019) Environment Agency modelling[lxxiii], using the Source Apportionment Geographical Information System-SIMulation of Catchment

(SAGIS-SIMCAT) model, indicate that an average agricultural load reduction of 47% is needed to achieve agriculture's 'fair share' of good status for river P. This assumes that the burden of reductions is proportionate to the contributions from water company discharges and agriculture.

Anthony *et al*[lxxiv] predicted the maximum potential phosphorus reduction achievable as a national average across England and Wales by the implementation of all available mitigation methods (69 in total) by the year 2020 to be 55%, relative to 2004 losses. This analysis suggests the required WFD reduction could be achieved, but only through widespread adoption of the full range of mitigation methods, including land use change. The implementation of all the methods resulted in a net cost to the agricultural sector of £2010 m/yr, and were estimated to result in a society benefit of up to £705 m/yr based on use value and treatment costs avoided for emissions to water, and the human health and climate change impacts of gaseous emissions.

Implementation of only those mitigation methods which saved the farmer money or where there was a net benefit to society in the year 2020 (20 methods in total) made it possible to achieve a 34 to 42% reduction in phosphorus, sediment and ammonia emissions for a net saving of £774 m/yr relative to 2004. It is important to caution that the calculations of method effect assumed that mitigation methods were implemented across 100% of the applicable land area. Farm economics, farmer attitude and the level of government support will determine the actual level of uptake.

Cost effectiveness of measures to tackle diffuse P pollution, for agriculture, is better when parallel reductions in other pressures (sediment, nitrate, Faecal Indicator Organisms) are considered. [lxxv] The benefits, in terms of P and N loss reduction, of nutrient management planning (including avoidance of incidental losses from poor timing and placement of applications), manure storage and separation of clean and dirty water in farmyards, are widely recognised.

2.4 Modelled national scenarios for river P based on point and diffuse source reductions

The SAGIS-SIMCAT catchment modelling system has been used to assess compliance for phosphorus under a range of theoretical diffuse and currently planned point source P reduction scenarios[lxxvi] (Table 1). Compliance was estimated in terms of percentage river length compliance with the P standards for good status. Modelled compliance in 2020, after the 6th water industry Asset Management Plan (AMP6) is completed, is 46% which compares well to the 2016 classification results (45% compliant river water bodies). This is predicted to improve to 48% compliance in 2027 after AMP7. If agricultural P loadings to rivers were reduced by 30%, or by 47% to a 'fair share' of good status, this would further improve compliance to 59% or 68% of river length respectively. These are improvements of 13% or 16% compared to compliance in 2020.

Table 1 National phosphorus compliance predictions for rivers under currently planned point source and theoretical diffuse source reduction scenarios

Discharges	AMP7 (2027)	48%	50%	59%	76%	68%
	AMP6 (2020)	46%	48%	55%	70%	62%
		0 %	10%	30%	60%	Fair Share (average 47%)
		Diffuse reduction (0%, 10%, 30%, 60%, fair share)				

2.5 Solutions for non-agricultural diffuse pollution

EU measures for restricting P content of both domestic laundry (from June 2013) and dishwasher detergents (from 2017) were agreed in March 2012[lxxvii]. While reductions in P loadings will be quite small, these national source controls will complement targeted measures for STWs and agriculture, reducing P inputs from combined sewer overflows, septic tanks and small treatment plants and reducing P removal costs and chemical usage at STWs [lxxviii, lxxix, lxxx].

Other mechanisms for non-agricultural diffuse pollution may also reduce P losses, for example general binding rules for site management, washing activities and misuse of drainage systems (e.g. misconnections), and the use of sustainable urban drainage systems (SUDS). However, data on costs and effectiveness are currently limited. [lxxxi] Since 2015, a regime involving general binding rules for discharges from most septic tank and small package treatment plants has been in place, with permits required for higher risk situations.

Defra consulted in 2012 on the wider issue of non-agricultural diffuse pollution and published a summary of the responses to the consultation in summer 2013.

2.6 Evidence gaps and uncertainties around the solutions

Technologies to achieve very low levels of P in STW effluent have only recently been widely tested in UK conditions and experience in using them on an operational basis is still developing. See section 3.3 for details of trials of innovative and ambitious methods.

Recycling of P in rivers is complex and not easily accounted for in models, leading to uncertainty in assessing options of measures to meet standards and predict recovery times[lxxxii]. There is uncertainty over timescales and the effectiveness of measures to tackle diffuse agricultural P pollution. Much of this uncertainty stems from the challenges of scaling up from small (e.g. field) scale studies to larger (e.g. catchment) scale[lxxxiii].

The effects of climate change on nutrient losses to water and our ability to mitigate those losses is another area of uncertainty needing further research.

There is limited information on costs and effectiveness of control measures for non-agricultural diffuse pollution in terms of P reduction (other than for detergents).[lxxxiv]

In order to review the potential for more sustainable practices in relation to P use, treatment, recovery, recycling and impacts, further life cycle analysis/assessment of the options could usefully be undertaken.[lxxxv]

Appendices 4 and 5 show the current Joint Water Evidence Programme (JWEP) projects aimed at resolving some of the above identified gaps.

3. Potential future solutions

3.1 Overview

Predictive analysis in the first round of river basin management plans suggested that there are major challenges in achieving P standards nationally. Preliminary results from our latest river P modelling (see 2.4) suggest that, even with the proposed PR19 measures for sewage treatment works and if major reductions in agricultural P losses were achieved, some 30% of national river length may still exceed the P standards. Progress towards good status is currently largely dependent on the reductions that can be achieved by agriculture. More detailed analysis for individual river basin districts will confirm the extent of the challenge and how it varies across river basins and catchments in England.

Taking into account the extent of challenges and uncertainties, the original cost-effectiveness analysis for the 2009 river basin management plans suggested that the way forward would require a mix of national measures, catchment-based planning to target water industry and agricultural measures in the most effective way, and a likely need for alternative objectives (both extended deadlines and less stringent objectives) in some areas.[lxxxvi] Our latest modelling, of the effectiveness of potential further measures, supports these conclusions.

Ecological recovery (from eutrophication) can be lengthy and uncertain [lxxxvii] [lxxxviii] [lxxxix] [xc]. This supports the need to prevent deterioration of our best rivers and lakes, alongside restoration measures. Further, the potential to rationalise P standards and targets across WFD and Natura/SSSI policies needs additional consideration[xci].

The WFD provides a good framework for managing eutrophication. In line with EU guidance we advocate a harmonised approach, across the key directives, to assessing eutrophication problems[xcii]. We also suggest that multi-sectoral and partnership approaches are needed in considering measures[xciii].

We assume retention of the current approach whereby expensive targeted regulatory measures require evidence of a local eutrophication problem (due to the uncertainty in nutrient standards). This does not preclude 'no regrets' measures based on P failure without biological corroboration.[xciv] [xcv] Our current planning assumptions with respect to dealing with P and the problems of eutrophication are shown in Annex 2. A consolidated list of possible control measures is shown in Annex 3.

3.2 Scenarios

In considering potential strategies for managing P at river catchment level it may be useful to distinguish and consider the relative priority for action of the following two scenarios:

- High P concentrations, often in high alkalinity lowland rivers, due to sewage and agricultural sources, with good local evidence of ecological harm (eutrophication), high confidence that some reduction in concentration/load will be achieved but low likelihood it will be sufficient to achieve P standards and thus uncertainty over ecological improvement. Tackling P from sewage treatment works is an essential starting point in these situations but agricultural sources are increasingly important.

- Low P concentrations, often in sensitive low alkalinity or headwater river reaches, where local evidence of eutrophication is likely to be weaker, but deterioration needs to be prevented and measures for agriculture, small STWs and rural sewage sources might reduce P concentrations from just failing to levels that will deliver ecological improvement.

3.3 Point sources – innovation

A programme of P reduction trials at sewage treatment works (STWs) was recently undertaken by the water companies through investigations in the National Environment Programme of the 2014 Periodic Review. These trials and the follow-up application of new improved techniques are helping to determine which technologies (suited to UK conditions) can reliably reduce P at STWs to very low levels. The focus is on new technologies and innovation, as well as making best use of existing technology and assets. As a result of the trials, the Technically Achievable Limit (TAL) for P reduction at STWs was tightened by the Environment Agency from 0.5 mgP/l to 0.25 mgP/l for PR19. This has significantly improved the prospects of achieving river P standards and reducing the risks and impacts of eutrophication, in terms of water industry contribution to river P.

P recovery at sewage treatment works is not widely practised in the UK, but following trials at Slough and Derby, a full scale biological nutrient removal plant with P recovery (producing high grade fertiliser pellets) was opened at Slough STW in 2013 and a further plant is under construction in Nottingham. We suggest that further consideration is given to the potential wider adoption of P recovery practices at UK STWs. Recovery of P is only possible where biological P removal is used and this is only feasible in certain situations. Wider use in the UK would require a shift away from chemical dosing and require major rebuilding of assets in some cases. Incentives such as more flexible, catchment-based permitting are being trialled and could facilitate the adoption of more sustainable approaches.

3.4 Point Sources - designations

In May 2019 Defra designated 20 new river stretches as Sensitive Areas under the Urban Waste Water Treatment Directive (UWWTD) requiring P reduction at 82 STWs - the measures are part of the PR19 water industry price review.

Some waters are designated for conservation purposes under the Habitats and Birds Directives or national Sites of Special Scientific Interest (SSSI) legislation. For these, Natural England (NE) targets for P in designated Natura 2000 and SSSI rivers and lakes are currently considered to be long term management objectives. The targets for P in rivers were tightened through the release of revised Common Standards Monitoring Guidance. Interim goals for P in Natura 2000 rivers are included in the 2015 RBMPs. A programme of water company investigations into the feasibility and costs of meeting the more stringent targets is an important part of the 2019 price review (PR19) proposals. In addition, options for further measures to tackle diffuse pollution in these rivers are also being assessed through joint working between the Environment Agency, Natural England and stakeholders.

3.5 Diffuse pollution approaches

As discussed in sections 2.3 - 2.4, major reductions of agricultural P losses (in the order of 50%) would be needed alongside point source reductions, in areas affected by agricultural sources of P, to achieve good ecological status.

A key challenge is to determine the best mix of measures and mechanisms to encourage adoption of good practice in tackling the range of related diffuse agricultural pressures - P, nitrate, sediment and faecal indicator organisms. In recent years Defra has taken forward a project to review the evidence of diffuse water pollution from agriculture and the policy options for addressing such pollution. This informed recent policy proposals.

In 2018, Defra released its 25 Year Environment Plan (25 YEP) and a Command Paper "Health and Harmony: the future of food, farming and the environment in a Green Brexit." These recognise that, in order to secure the required water quality improvements, more farmers and rural land managers will need to take significant steps towards adopting good practices. The 25 YEP sets clear targets including 'clean and plentiful' water. A new environmental land management scheme (ELMS) is proposed, that will encourage land managers to use fertilisers and organic manures efficiently, protect crops whilst reducing the environmental impact of fertilisers and improve soil health. Under the transition to ELMS, direct payments to farmers will be phased out over a seven year period, bringing a new era for farming based on public money for public goods.

Currently there is uncertainty over how this will be implemented in practice, however, Defra seeks to deliver the government's aspiration for a thriving farming industry and land management which leaves the environment in a better state than we found it. The vision is for a changed regulatory culture to underpin this new domestic policy which focusses less on rules and more on greater partnership and support for compliance.

There is also an aspiration is for a strong regulatory baseline and increased 'earned recognition'. The government has signalled that farm assurance could play a role in delivering government policy on regulation and other mechanisms that generate environmental outcomes. It has also signalled that increased data sharing between assurance schemes and regulators will be necessary to target poor performers effectively and reward good performers.

For diffuse nutrient pollution, learning from ongoing pilot and research studies should influence our future approach, for example:

A joint Environment Agency and NFU project on P in East Anglia, to review national and local evidence of agricultural P contributions and promote voluntary measures in selected pilot sub-catchments[xcvi];

The Defra-Environment Agency Demonstration Test Catchment programme is providing underpinning research, from farm to catchment scale, to inform policy and practical approaches for the reduction of agricultural diffuse pollution and the improvement of ecological status in freshwaters, whilst maintaining economically viable food production[xcvii].

In designing improved measures to reduce agricultural P losses to water, it will be important to take into account the legacy P issue and ongoing surplus described earlier (and in 3.6 below) and the likelihood that climate change will increase P losses.

For lakes where external nutrient inputs have been controlled, in-lake measures (e.g. sediment capping or bio-manipulation) continue to warrant consideration[xcviii].

Further attention should be given to tackling small rural sewage sources, particularly in the headwaters of catchments.[xcix] [c] [ci] These can be either 'diffuse' or 'point' sources. In 2015 Defra introduced a new regime for controlling pollution from small sewage discharges, based on general binding rules in the main, with permits still required for sensitive locations[cii].

3.6 Improving sustainability

The sustainability of P supply, use and disposal appear to deserve more attention.[ciii] [civ] [cv] [cvi] The Environment Agency supports the increasing attention being given by the EU and UK governments to sustainability as an issue in the terms of the supply, uses and disposal of phosphorus. Wider adoption of source control, recovery and recycling of phosphorus is something we wish to explore with government, sector groups and other stakeholders in managing P for the future.

Consideration should be given to the potential for further national source control measures for P. The issue of P dosing of water supplies, including losses to the water environment from leaking water mains is one example. Fertiliser and animal feed (through use of phytase enzymes to increase efficiency of P uptake by livestock) may be further potential candidates.

In common with other developed countries, UK agriculture has for decades been heavily reliant on imported (mined) P fertiliser. Farmers were encouraged to feed the soil (rather than the crop), which has led to the 'legacy P' issue described in section 1.3. Nutrient use efficiency in agriculture remains poor. More sustainable approaches to agricultural nutrient management need to be developed and promoted in order to reduce P losses to water. The large stores of 'legacy P' need to be recognised and utilised, to reduce the risks of water pollution and reliance on artificial fertiliser. Over 40% of UK soils are over-fertilised, having Olsen-P (soil test) levels above the agronomic optimum. Reducing soil P through nutrient management planning in these areas will reduce dissolved P concentrations in drain-flow and surface run-off and thus water pollution. Making greater use of recycled and recovered P would also fulfil this aim. Crop P demand could be reduced as current levels are generally unnecessary for human and animal growth. Plant breeding programmes could also help with these objectives. More efficient forms of fertiliser and methods for their application should be increasingly employed. Finally education and societal awareness raising and debate are needed to make the public more aware of the links between dietary choices (e.g. meat consumption is a major driver of P fertiliser use), food production, waste management and sustainability.

The Environment Agency has encouraged the water companies to view and manage P as a resource for potential recycling and/or recovery (for agricultural or other uses) as well as a pollutant to remove from sewage. This includes use of research, innovation and trials associated with the development and adoption of wastewater treatment processes to reduce effluent P to low levels whilst also facilitating effective P recycling and/or recovery. Options for sewage treatment including carbon and energy costs could usefully be reviewed. The main UK method, chemical dosing with iron or aluminium, precludes subsequent P recovery.

The potential scope to increase land recycling of sewage biosolids in the UK could be explored with the aim to reduce reliance on inorganic fertilisers. The P in the stabilised biosolids that are now more widely applied in the UK is only slowly water-soluble. Biosolids act as a slow-release source of P that can be more efficiently utilised by crops on certain soil types, and release less P to runoff than fertilisers and manures.[cvii] Recent changes in farming practice have meant that more organic materials (e.g. digestate from anaerobic digestion) are now being spread on land; the nutrients should be accounted for in farm nutrient management planning and the risks of water pollution must be considered.

Addressing inefficiencies in the food chain could also significantly improve wider P sustainability. Around 55% of phosphorus in food is lost between ‘farm and fork’[cviii]. Thinking more radically, more sustainable human diets e.g. reducing the amount of meat consumed could reduce the main source of P in sewage. Reducing food waste and increasing recycling, with less disposal to landfill, could also significantly improve the sustainable management of phosphorus.[cix]

3.7 Valuing nature

The concepts of “nutrient neutrality” and “payments for ecosystem services” (PES) deserve consideration as future approaches to controlling nutrient loads, particularly for new development, at a catchment level.

There are examples of these approaches in the USA and elsewhere[cx].

The Loch Leven example in relation to small rural P sources (replacing septic tanks with package plants)[cxi].

The 'EnTrade' scheme operated by Wessex Water catchment team in the Poole Harbour catchment is a promising recent initiative. This takes a reverse auction approach where farmers are encourage to bid for funding to introduce measures such as cover crops to reduce winter nitrogen losses to water courses. This saved Wessex Water 30% on its nitrogen costs compared to its previous methods of interacting with farmers. This type of approach could be potentially also be used for phosphorus.

4. Contacts

If you have any feedback or comments on the evidence contained in the summary then please contact: enquiries@environment-agency.gov.uk

Annex 1 Main national stakeholders for phosphorus

Stakeholders contributing to phosphorus pressure and eutrophication

These stem from the main uses of P in society – in agriculture, food/drink and animal feed supplements, detergents and other industrial applications – and the routes by which P enters the water environment (sewerage, sewage treatment, land runoff). The list may not be exhaustive.

- Phosphorus industry (e.g. Rhodia/Solvay)
- Water industry – sewage treatment and sewerage – includes companies and Water UK
- Water industry – water treatment (P dosing of drinking waters)
- Agriculture fertiliser manufacturers and retailers e.g. Agricultural Industries Confederation, International Fertiliser Society
- Animal feed manufacturers and retailers
- Agrochemicals
- Horticulture e.g. Agriculture and Horticulture Development Board
- National Farmers Union for England
- Farmers – livestock (dairy, beef, sheep, pigs & poultry), arable
- Forestry sector e.g. Forestry Commission
- Country Land & Business Association & large land owners e.g. National Trust, Crown Estate
- Food and drink sector e.g. Food & Drink Federation
- Retail (supermarket) sector
- Paper and pulp industry
- Detergents industry – laundry and dishwasher – e.g. UK Cleaning Products Industry Association
- SMEs
- Waste management sector
- Other industry e.g. toothpaste, lighting, flame retardants, metal finishing
- Developers, local authorities and home owners
- Manufacturers, suppliers and owners of package plants and septic tanks

Stakeholders affected by P or interested in P & eutrophication in our rivers/lakes

- European Commission
- Defra, Welsh Government, other UK Administrations
- Environment Agency and NRW including the water leaders group
- WFD UK Technical Advisory Group
- Ofwat
- Natural England
- Catchment groups
- NGOs - Rivers Trusts, Angling Trust, RSPB, WWF, Pond Conservation, Plantlife, Wildlife Trusts, Salmon & Trout Conservation, Wildlife & Countryside Link
- Water sports and outdoor amenity groups
- National Trust, CL&BA and other land owners
- National park authorities
- Local authorities

- Tourism interests
- CC Water
- Abstractors – water companies, farmers, industry
- Internal Drainage Boards
- Angling groups
- Canal & River Trust
- Water body owners including water companies
- General public
- Academic and research organisations and consultancies providing services in this area.

Annex 2 Consolidated list of planning assumptions for phosphorus from the 2015 river basin management plans

This is a list of the technical and policy assumptions which underpinned action to tackle the risks and impacts from phosphorus in rivers and lakes in England and Wales in the 2015 river basin management plans. These assumptions will be reviewed and potentially updated as part of updating the plans for 2021, particularly those assumptions where there have been changes in policy and advances in technology and understanding.

P standards/targets and their application:

- The aim is to achieve the WFD Good Ecological Status standards for P in rivers and lakes by 2021 except where alternative objectives apply.
- Deterioration of status under WFD must be prevented and the "no deterioration" approach applies to P standards under the WFD, at least in the context of Water Industry sewage treatment works measures (to control growth).
- The original WFD P standards were changed through the ongoing UKTAG/Admins review. The revised river P standards should be used alongside the original standards for planning purposes.
- The Natural England (NE) targets for P in SAC and SSSI rivers and lakes are currently, in planning terms, considered to be long term management objectives. Interim goals for Natura 2000 sites in WFD will be agreed with NE following agreement of the process with Defra.
- For expensive targeted regulatory measures for P to be in considered under WFD and UWWTD, firm evidence of a local eutrophication problem is required (in addition to P failure). This is in line with Defra River Basin Planning guidance and Defra/UKTAG standards reports, reflecting the uncertainty in nutrient standards.
- Softer targeted 'no regrets' measures or national measures (eg source control) under the WFD may be progressed based on extent of P failure (sometimes in combination with other agricultural pressure failures) without confirming eutrophication at a local level.
- Ecological recovery when P measures are put in place can take many years, for example, typically 10-15 years for shallow lakes.

Water Industry measures:

- Urban Waste Water Treatment Directive Sensitive Areas are required where water bodies are found to be affected by eutrophication and there are qualifying discharges (STWs >10,000pe) involved. There is no assessment of disproportionate costs in these cases, although there is some flexibility as to which indirect qualifying discharges (in the upstream catchment) require treatment.
- Defra is currently applying a targeted approach rather than a 'whole territory' approach in relation to Sensitive Areas under the UWWTD.
- The water industry has historically assumed that chemical dosing to UWWTD emission limit values for P (1-2 mg/l or 80% reduction) is the norm, with biological nutrient removal, other methods (eg membrane technologies) or more stringent treatment being exceptions to that norm due to perceptions

about cost, reliability and lack of UK experience. More ambitious performance to achieve effluent P levels as low as 0.1mgP/l is now being trialled in PR14. Pending the outcome of the trials we will include improvement to 0.5 mg/l effluent P in PR14 and set less stringent objectives where more stringent levels are needed. Following the outcome of the trials, objectives will be reviewed based on improved information on performance, and cost-benefit.

- Planned measures for P reduction at STWs by the water industry are predicted to reduce river reach length failure for P to about 36% by 2015.
- P recovery at STWs has been considered, in the main, uneconomic in the UK. This is beginning to change with trials and in some cases full scale P recovery at some UK STWs now commencing.
- Sewage sludge recycling to land remains a viable option in the majority of cases. Sewage biosolids are considered a useful, slow-release alternative to artificial agricultural P fertiliser.
- Replacing lead pipes as an alternative to P dosing of drinking waters is assumed to be prohibitively expensive in general. Pipe lining technology may have some promise as an alternative to P dosing.

Detergents:

- P in domestic laundry detergents in the EU was restricted from 1 June 2013 and has been controlled in dishwasher detergent from 2017 (New EU measures published in March 2012 brought forward the UK laundry detergent ban which had been intended to come into effect from 2015). In accordance with the Defra Impact Assessment, the restrictions for laundry detergents can be assumed to reduce the total P loading to freshwaters nationally by 3% and the P content of crude sewage by 7.5%.

Agriculture:

- There are currently limited controls over the use of agricultural land eg the types of farming practised.
- Water Protection Zones WPZs are currently considered a measure for consideration only if the evidence shows that voluntary and supportive measures are proving unsuccessful.
- Economic instruments (including tradable permits and a fertiliser tax) for the control of nutrients from agriculture are not currently favoured by the Government (included in 'measures ruled out' in the Defra WFD Preliminary Cost Effectiveness report in relation to nutrients).
- Catchment Sensitive Farming (CSF) in England is extended for 2015 and is being reviewed to ensure any new scheme is aligned to the new elements of the Rural Development Programme. The control measures are likely to achieve around 4-8% reductions in P losses in the targeted catchments.
- It is assumed that decisions on affordability of existing advisory schemes (e.g. CSF) and incentives (e.g. agri-environment) have been made by Ministers as part of the Impact Assessment for the relevant mechanism (for example the Rural Development Programme for England).
- At a farm level a package of the best available measures might reduce P losses by 20-40%. This assumes similar levels of effort and efficiency in relation to current measures and mechanisms (for example existing advisory schemes, incentives and regulation).

- At a sub-catchment or water body level, reductions in agricultural P losses of 11-24% might be achieved if all mechanisms such as agri-environment, CSF, regulation and so on were applied and with unconstrained resourcescxii.
- Defra is currently applying a targeted approach rather than a 'whole territory' approach to Nitrate Vulnerable Zones (which indirectly reduce agricultural P losses a little) in England and Wales.
- Business As Usual predictions for agriculture suggest P loss reductions of 5-9% by 2020, from a 2004 baseline, mainly due to reducing livestock numbers caused by economic factors.
- Agriculture needs, on average, to reduce P loss by 48% to achieve the WFD standards for its share of the load in England (statement in the Defra WFD Preliminary Cost Effectiveness Analysis, from Defra CSF policy work). This is not accepted by the NFU.

Annex 3 Possible control measures for the main sources of phosphorus in water

This outlines some the main control measures available for reducing P losses to water. It is not exhaustive and does not attempt to set out all the detailed options. It focuses mainly on control measures rather than mechanisms (policies/approaches) for their uptake. The headings relate to the sources of phosphorus for potential control.

Key: [C] denotes a current measure in the UK; [F] denotes a possible future measure, little or not yet used in the UK

Water company sewage treatment works:

- Chemical (iron or aluminium) dosing – the current UK norm (using iron) [C]
- Biological phosphorus removal – not much used in UK [C/F]
- As 1st two bullets with effluent polishing to achieve very low P (e.g. 0.1 mg/l) [F]
- Getting the best we can from current treatment plants [F]
- Membrane filtration, reverse osmosis and other novel technologies [F]
- Reed beds with adsorption media for tertiary P polishing at rural STWs [F]
- Sludge recycling to agricultural land, or sludge to landfill, or to incineration [C]
- Phosphorus recovery from sludge or effluent e.g. to produce fertiliser pellets [F]
- Trade effluent control [C]

Agriculture:

- Source control and P mobilisation measures
- Nutrient management planning – matching inputs from manure and fertiliser to crop needs, and including routine testing of soils and equipment [C]
- Avoiding incidental losses (due to poor placement or timing of manure/fertiliser applications) particularly in high risk areas [C]
- Provision of adequate and appropriate manure and fertiliser storage [C]
- Clean and dirty water separation in farm yards [C]
- Reduction/control of stocking rates on livestock farms [C/F]
- Cover crops and incorporation of crop residues into the soil [C]
- Conversion to grass [C]
- Tillage practices to reduce erosion and alleviate compaction [C]
- Precision-targeted application of fertilisers and manures with soil and manure testing and fertiliser spreader calibration [C/F]
- Restricting stock access to watercourses and livestock feeding station locations [C]
- Reduction of dietary P intake by livestock and optimisation of livestock and poultry feed conversion to reduce nutrient in manures [F]
- Land use change in high risk areas [F]
- Crop research for better use of nitrate and phosphorus [C]
- Pathway control measures
- Buffer strips, wetlands, field drain management, track/gateway management, rural Sustainable Urban Drainage systems (SuDs) [C/F]

Dosing of drinking water supplies with phosphorus (to meet lead standards):

- Removal of lead pipes as an alternative to P dosing [C/F]
- Use of pipe lining technology as an alternative to P dosing [F]
- Optimisation of dosing to minimise residual P [C/F]

Food and drink additives:

- Restrictions or voluntary reductions on P content of additives leading to less P in food and drink. [F]

Septic tanks & package plants (nationally small but can be locally important):

- Environment Agency campaigns in high risk areas [C]
- Planning controls eg general binding rules on siting and operation/maintenance [C/F]
- Planning measures in high risk areas eg require mitigation (Loch Leven example) [F]

Detergents (measures coming in):

- Restrictions on P content of domestic laundry detergent (coming in 1.1.2015 in the UK, with an EU Regulation now adopted which will bring this forward to 1.6.2013). [C/F]
- Restrictions on P content of domestic dishwasher detergents (proposed for control from 2017 via the EU Regulation subject to EU impact assessment). [C/F]
- Local initiatives targeted at householders (and retailers?) in high risk areas. [F]

Misconnections (a small source nationally)

- Range of control measures/mechanisms – e.g. awareness raising, plumbing control measures, transfer of powers between authorities, incentives, general binding rules [C/F]

Urban drainage (a small source nationally):

- Sustainable urban drainage systems (SuDs) in high risk areas [C]
- General binding rules to require good practice [F]
- Local action to tackle unsatisfactory combined sewer overflows [C]

Industrial discharges to water (a small source nationally):

- Local solutions involving treatment plants to meet the requirements of UK and EU legislation. [C]
- In-lake/river control measures for P and eutrophication
- Sediment capping or sediment removal [F]
- Biomanipulation [C/F]
- Mixing/de-stratification [C]
- Barley straw [C]
- Continued risk-based response to toxic/nuisance algal incidents [C]
- Controlled production of algae for commercial uses (algal farming) [F]

Annex 4 Environment Agency current projects to address the evidence gaps in relation to management of nutrients and eutrophication.

Organ-isation	Ref.	Summary
EA	SC140013	Climate Change and Eutrophication. To understand the potential impacts of climate change on phosphorus concentrations and eutrophication at the national scale and can plan appropriate adaptation action. The 1st Phase will look at developing an approach to assessing and mapping future eutrophication risk for rivers in England. The 2nd Phase will aim to produce a more comprehensive risk map of eutrophication taking into account of biological responses.
EA	SC170006	Phosphorus Stewardship in Waste Water Management. A literature and desk based review of approaches to encouraging or requiring improved P stewardship in the water industry being used or trialled in other developed countries. The approaches considered should include regulatory and softer options and include novel approaches to the economics such as payments for environmental services (PES) and natural capital accounting.
EA/JWEP	SC180008	Relationships between nutrients and biology in rivers – confounding factors and implications for management – Workshop. 1 day academic workshop, early 2019, following up recent work undertaken in collaboration with Stirling University. Aim: to review the current state of knowledge on river nutrient/biology interactions and the influence of other stressors.

JWEP – Joint Water Evidence Programme

Other projects are in also place that provide cross pressure benefits, these are summarised in Annex 5

Annex 5 Environment Agency and Joint Water Evidence Programme (JWEP) projects that are ongoing to address the evidence gaps - cross pressure projects

Organ-isation	Ref.	Summary
EA	SC160001	UKCP18 Project. To shape the next set of UK Climate Change projections (UKCP18) to ensure they meet user needs.
EA	SC160020	Assessing the Statistical Significance of Changes: OOG Monitoring. The overall aim is that we should have a proportionate approach to environmental monitoring requirements for OOG. The project aims to identify techniques for statistical analysis for the design of monitoring programmes and the assessment of data. It should give early information on changes and their causes, in order to discriminate local environmental or seasonal conditions so that OOG impacts can be addressed.
EA	SC170019	Mapping residence time in English rivers for water quality risk screening. The aim of this project is to produce a map of 'at risk' river locations using a modification of an approach developed and used by CEH in previous investigations of climate change impacts. This will consist of two primary tasks: 1. Adapt, test and automate the existing approach to deriving residence time 2. Apply this to the river network of England to identify areas of potential risk to water quality.
EA/JWEP	SC180006	Future resilience (SRoC funded) Peer review. To explore how catchment resilience can be measured and managed for the benefit of communities, business and wildlife, given pressures including climate change, population growth and changing landuse. Catchment resilience has many definitions and concepts, including resisting change, recovering after change, and recovering to perform a similar function after change. We will commission approximately 13 small expert reviews on catchment resilience to understand the current state of knowledge and perspectives from different disciplines.

JWEP – Joint Water Evidence Programme

Annex 6 Progress with sewage treatment works phosphorus reduction through water industry periodic price reviews

Period of Spend	Capex on installing P reduction at water industry STWs in England	Population equivalent served	P reduction in place for what proportion of population served by STWs discharging to freshwaters? (N.B. P standards apply on to freshwaters)	Number of STWs with P reduction in place	Km of river protected or improved for P (not fully additive as some STWs have been improved more than once over time)	Kilotonnes of P per annum discharged to rivers from water industry STWs	Percentage reduction in STW P load to rivers in England relative to 1995.
1995 to 2015 (actual) AMP2,3,4 and 5	£1.3bn comprising AMP3 £220m AMP4 £710m AMP5 £370m	24 million	60% relative to 1995 population	650 by 2015	4,500km	21.4 in 1995 16.7 in 2000 12.8 in 2005 10.6 in 2010 8.6 in 2015	0% 22% 40% 50% 60%
2015 to 2020 (current) PR14/AMP 6	£800m (£0.8 bn)	4 million	70% relative to 1995 population	400	2000km	7.2 in 2020	66%
2020 to 2027 (PR19/AMP7)	£1.65bn in draft water company business plans (for final determination Dec 2019).	10 million with 1st time P limits. 5 million with tighter P limits.	95% relative to 1995 population	650 with 1st time P limits. 250 with tightened P limits.	5500km	2.7 in 2027	88%

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