PHOSPHORUS STANDARDS FOR RIVERS

Consultation on Draft Proposals

UK Technical Advisory Group

December 2012

Executive Summary

The UK Technical Advisory Group on the Water Framework Directive (UKTAG) develops and makes technical recommendations to the UK government administrations on the environmental standards for implementing the Water Framework Directive. The UKTAG is a working group of experts drawn from environment agencies and conservation agencies[1]. It also includes representatives from the Republic of Ireland.

Proposals for standards were first published in 2007 [1] and 2008 [2]. These were adopted by the government administrations for the first cycle of the Directive's river basin management plans. The plans were published in 2009. The standards help focus efforts to improve and protect the water environment.

Between April and June 2012, the UKTAG consulted on proposals for new and revised standards to help with the development of second cycle of plans. Recommendations arising from this review were sent to government administrations in December 2012 [3]. Ministers will now decide whether to adopt these standards and to instruct the UK environment agencies and conservation agencies accordingly on their use.

At the time of making the recommendations, proposals for revised phosphorus standards for rivers were not sufficiently developed. Work on these has continued and UKTAG is now in a position to consult on proposed revisions to these standards.

This document sets out those proposals in two parts. Firstly, UKTAG presents a new approach to setting phosphorus standards on a site-specific basis, taking account of alkalinity and altitude. The implications for WFD status classification across the UK are presented. The standards are derived from an improved relationship between phosphorus concentrations and biology compared to the existing standards.

Principle 1: The UKTAG recommends that new site-specific phosphorus standards for rivers are adopted based on a new model of the relationship between biology and phosphorus concentrations

The new standards have the effect of reducing the mismatch between classifications based on biology and phosphorus. However, the relationship is not perfect. There is still a large amount of unexplained error in the model which leads to a substantial chance of misclassifying sites. This is believed to be as a result of other environmental factors such as sunlight and nitrogen for example, which are not taken into account in the modelled relationship between biology and phosphorus.

[1] Countryside Council for Wales (CCW), Natural England (NE), Environment Agency (England and Wales), Northern Ireland Environment Agency (NIEA), Joint Nature Conservation Committee (JNCC), Scottish Environment Protection Agency (SEPA), Scottish Natural Heritage (SNH), Republic of Ireland's Department of Environment, Community and Local Government (DECLG).

As a result of variation in the model, the default standards may be overly stringent or overly lax in some cases, underestimating or overestimating the capacity for additional phosphorus to be accommodated in the environment without adverse ecological impact. Overly stringent standards may lead to unnecessary restrictions on new discharges arising from development or it may lead to unnecessary investment in treatment of existing discharges. Overly lax standards may allow additional phosphorus to be discharged to the detriment of the ecology.

The UKTAG is considering a second proposal and seeks views from stakeholders on how the default standards (predicted by the new modelled relationship between phosphorus and biology) may be modified at a site level by taking account of the observed biology. Where we are confident that the biology is better or worse than suggested by the phosphorus results, the default phosphorus standards could be made less stringent and visa versa. This approach would further reduce the mismatch between biology and phosphorus classifications and provide a firmer basis for taking decisions on whether actions to improve water quality are necessary.

UKTAG is undertaking further work to establish the rules by which the adjustment of standards could be made.

Principle 2: The UKTAG suggests that the proposed new default phosphorus standards for rivers are adjusted to take account of observed local biology (referred to below as adjusted standards).

The UKTAG seeks your views on the two principles presented above and invites you to consider the following consultation questions;

1. Should the recommended new default standards be adopted as the basis for assessing status, decisions on whether or not to allow new discharges and identifying the likely scale of improvements that may be needed at existing discharges?

2. Should adjusted standards be used to assess status and take decisions relating to discharge control?

3. Should default standards be adopted as the basis for assessing status and decisions relating to new discharges and adjusted standards used, where applicable, when planning improvements at existing discharges?

Because of the noise in the relationship between phosphorus and biological response, UKTAG continues to recommend that expensive action to reduce phosphorus concentrations at a site should be considered only where there is supporting evidence of adverse biological impacts.

The UKTAG seeks your views on these three questions.
Once the UKTAG has considered your comments and taken them into account, a final report will be sent as advice to the government administrations. It is for the UK’s

government administrations to decide whether to adopt the recommendations for revised standards. The approach to the adoption and implementation of proposals can vary for each country within the UK, depending on present and proposed legislation, and on policy in each country. Assessment of the implications arising from the implementation of new standards is the responsibility of the UK government administrations and will be for Ministers to decide.

1. Introduction

1.1 UKTAG is preparing recommendations on phosphorus standards for rivers for consideration by the UK Government administrations. Prior to making any recommendations, UKTAG is seeking your views on the standards and the methodology it used to derive them. This paper describes that methodology and the standards. An accompanying technical paper [4] provides further details.

1.2 Phosphorus is a plant nutrient and elevated concentrations in rivers can lead to accelerated growth of algae and other plants. The impact on the composition and abundance of plant species can have adverse implications for other aspects of water quality, such as oxygen levels, and for the characteristics of river habitats. These various changes can cause undesirable disturbances to populations of water animals, such as invertebrates and fish.

1.3 Phosphorus standards are used in managing the risk of these adverse ecological impacts. Where rivers are already adversely affected, phosphorus standards can indicate the likely degree to which phosphorus concentrations would need to be reduced (eg by reducing concentrations in discharges) to improve ecological quality. Where a new discharge is proposed, phosphorus standards can indicate whether or not the river is likely to be able to accommodate the additional inputs without significant risk of adverse ecological effects. The Water Framework Directive also requires that relevant standards for nutrients are met for a river to be classed as being at good or high ecological status.

1.4 UKTAG first made recommendations on phosphorus standards for rivers in 2006 [1]. UKTAG has undertaken a review of these earlier recommendations because:

(a) the existing standards for algae and other plants that the phosphorus standards aimed to protect are changing[2]; and
(b) the existing phosphorus standards were producing a high number of mismatches between phosphorus and biology classifications.

1.5 The review has led to draft recommendations for revised standards for phosphorus. The revised standards were identified using a larger dataset than was available when the existing standards were developed and a new methodology. These developments have improved scientific understanding and enabled UKTAG to identify revised standards that are matched to the average biological response to phosphorus. This contrasts with the existing phosphorus standards, which the review found are on average overly lax. The existing standards have a strong tendency to place phosphorus in a better class than biology and this bias remains when the new standards for algae and other plants are taken into account.

1.6 UKTAG assessed the effect of the revised standards on 804 sites across the UK with matched biology and chemistry data. The combination of the new standards for algae and other river plants and the revised phosphorus standards would increase the proportion of sites classed as high or good status for both biology and phosphorus from 34% to 47%.

1.7 In general, the revised standards represent lower concentrations of phosphorus than the

[2] Biological standards are changing as a result of intercalibration

corresponding existing standards. Because the revised standards are site-specific, the degree to which they are more stringent than the existing, type-specific standards varies considerably from site-to-site. At some sites, there is little or no difference between the revised standards and the existing standards. At others, the difference is large.

1.8 The general increased stringency of the revised standards means that the phosphorus concentrations needed for good ecological status (the Directive's default restoration target) would typically be lower than under the existing standards. An important context for this is that, for a significant proportion of sites, the existing standards for good are not providing any indication of the likely reduction in phosphorus concentrations needed to restore good ecological quality. Of the sites assessed by UKTAG, about 44% are classed as worse than good status under the combination of the existing phosphorus standards and the new biology standards. For 54% of these (24% of all the sites), phosphorus is classed as good or high. For around 10% (5% of all sites), biology is classed as good or better.

1.9 The increased stringency also means generally narrower class widths. The narrower the class width, the smaller the change in concentration (eg as a result of a new inputs) that would result in a breach of a standard. However, narrower class widths do not mean that all sites would have less capacity than they do under the existing standards to accommodate new inputs of phosphorus before a standard is breached. This is because another effect of more stringent standards is to place a significant proportion of sites in a lower phosphorus class than their class under the existing phosphorus standards. For example, for the sites assessed by UKTAG, the proportion at high status for phosphorus would decrease by 16%. Because phosphorus class widths increase from high to poor, a site previously in high and re-classified as good or moderate may be in a wider class than it is under the existing standards.

1.10 Of the sites assessed by UKTAG, the proportion very close (within 1 µg/l) to a class boundary (i.e. a phosphorus standard) under the revised standards would remain at around 2%. The proportion within 1 to 5 µg/ would increase from 5% under the existing standards to 14% and the proportion more than10 µg/ from a class boundary would decrease from 82% to 67%.

1.11 Whilst the revised phosphorus standards are well matched to the average biological response to phosphorus, there remains considerable site-to-site variation around the average response. Some sites appear more responsive than average and others less so. Some of this variation is a product of the inevitable statistical errors in monitoring results for phosphorus and biology. It is impossible to monitor everywhere and all the time so monitoring results are never perfect. However, a significant proportion of the variation results form real differences between sites in their biological response to phosphorus concentrations. This is caused by factors that UKTAG was unable to identify and account for in the methodology it used to derive the standards. The variation means that at some sites the revised standards may be more stringent than necessary and at others they may be insufficiently stringent.

1.12 Because of the noise in the relationship between phosphorus and biological response, UKTAG continues to recommend that expensive action to reduce phosphorus concentrations at a site should be considered only where there is supporting evidence of adverse biological impacts. UKTAG is also investigating potential methodologies for using biological information to further refine the phosphorus standards themselves.

1.13 One way of identifying sites where the revised standards may be too lax or too stringent and, hence, where the standards might need further refinement is to look at biological and phosphorus monitoring results. For sites that are particularly unresponsive to phosphorus, the biology would be expected to be in a much better condition than predicted by the new phosphorus standards. For example, suppose the biology is measured as being at the top of the good status class (i.e. almost high status) and the phosphorus is measured as right at the bottom of its good status class. This might indicate the biology at the monitoring site is less responsive than average to phosphorus concentrations. In such a case, prohibiting further inputs of phosphorus may be unnecessary to protect the biology. The consultation outlines a potential methodology for adjusting the revised phosphorus standards to reflect information from biological monitoring.

2. Method used to derive new standards

2.1 The standards for phosphorus recommended by UKTAG for the first river basin management plans [1] were derived by assembling a set of sites whose ecology was measured as being at good status. The approach looked at the values for the annual mean reactive phosphorus concentration across all the sites of the same river type. The types were defined by particular ranges of altitudes and alkalinities. For example, the lowland, high alkalinity river type included all rivers with altitudes of no more than 80 metres above sea level and with alkalinities of 50 mg/l or more of calcium carbonate.

2.2 UKTAG's review [4] involved a thorough mathematical analysis of a large set of biological and chemical data. It also involved a review of the scientific literature on eutrophication in rivers and collation of the sparse information available on the standards used in other EU countries. The review led to the development of a revised approach to identifying phosphorus standards.

2.3 The revised approach first predicts the concentration of phosphorus expected if a site were at what are called “reference conditions” – an estimate of the natural condition of the site. The prediction uses values of alkalinity and altitude to represent key geological and geographic factors that determine a site's natural phosphorus concentrations. Details of the calculations involved are provided in Box 1 below.

Box 1: Equation used to predict a site's reference condition phosphorus concentration

$$RP(reference) = 10^{(0.454 (\log_{10} alk) - 0.0018 (altitude) + 0.476)}$$

Where:

- "RP(reference)" is the annual mean concentration of reactive phosphorus in µg/l estimated for the site under reference conditions. If the value of RP(reference) predicted by the equation above is < 7 µg/l, RP(reference) is set to 7 µg/l.
- "Log_{10}alk" means $\log_{10}$(alkalinity), where alkalinity is the concentration of $CaCO_3$ in mg/l. For sites with an alkalinity greater than 250, alkalinity is set to 250. For sites with an alkalinity less than 2, it is set to 2.
- "Altitude" means the site's altitude above mean sea level in metres. For sites with an altitude greater than 355 metres, altitude is set to 355 metres.
- “Reactive phosphorus" means the concentration of phosphorus as determined using the

phosphomolybdenum blue colorimetric method. Where necessary to ensure the accuracy of the method, samples are recommended to be filtered using a filter not smaller than 0.45 µm pore size to remove gross particulate matter[3].

2.4 The approach calculated the ratio between the estimated “natural” phosphorus concentration and the concentration actually measured at the site. It then developed a second regression equation representing the link between the biological data (the worst classed of macrophytes and diatoms) and these phosphorus ratios. Provided a site's alkalinity and altitude are known, the equation can be used to estimate the likely ranges of phosphorus concentrations at the site associated with each biological status class.

2.5 The regression equation was re-arranged and used to calculate the most likely phosphorus concentration at the midpoint[4] of each biological class. As an example the most likely concentrations for the midpoints of the five biological classes for a particular pair of values of alkalinity and altitude are shown in Figure 1 as small shapes at the centre of coloured horizontal lines. The lines represent ranges in the estimates of the mid-point phosphorus concentrations predicted by the regression model. The "EQR" values on the Y axis represent the degree of disturbance to the biology compared with near undisturbed conditions. The results are for a lowland, high alkalinity river.

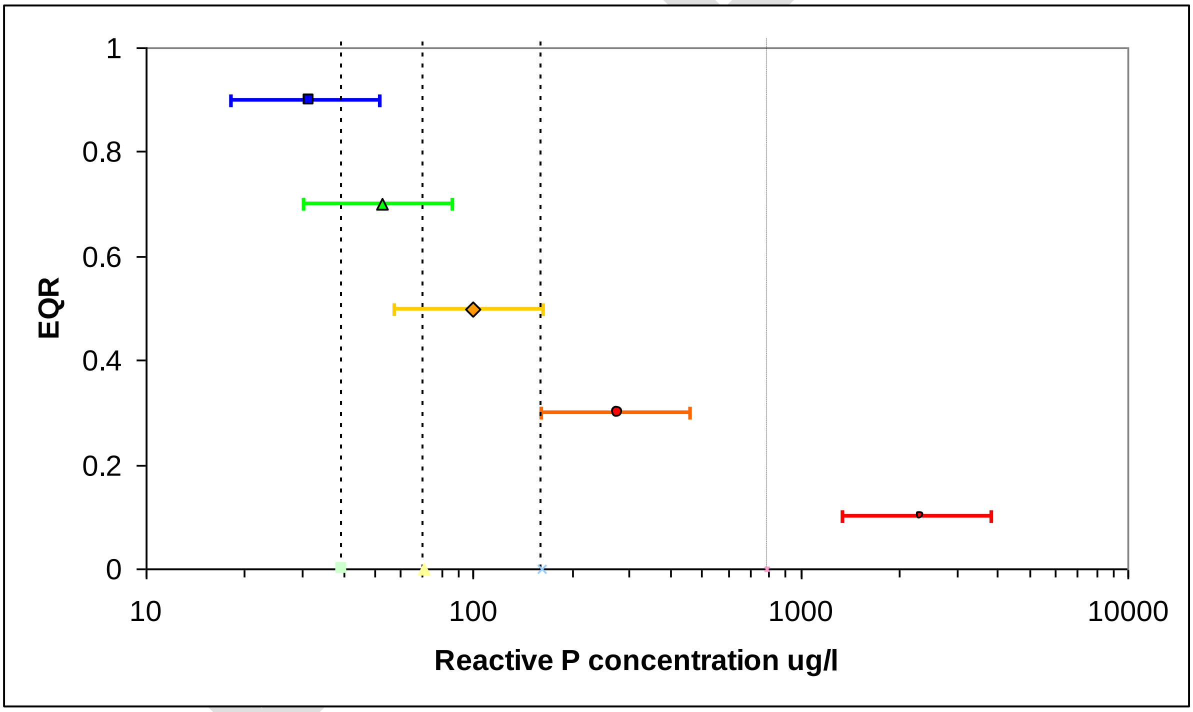

Figure 1: Links between phosphorus and biological quality

2.6 Like all environmental standards, phosphorus standards are intended to help in managing environmental risks. They are designed to describe the likely tolerance limits to phosphorus of each biological status class. Identifying the recommended standards involved seeking a best match with the boundaries of the parallel biological status classes.

[3] Previous UKTAG standards were referred to as soluble reactive phosphorus (SRP). Most analyses by UK agencies are of molybdate reactive phosphorus in unfiltered samples from which large particles have been allowed to settle and referred to here as “reactive phosphorus” (RP). In practice, the difference between RP and SRP is usually minor.
[4] The value for the biological data is put into in the equation and the resulting concentration of phosphorus is expressed as a single value with a range associated with the mathematical “goodness of fit” for the regression equation.

2.7 The proposed default phosphorus standards are set at a position midway between the estimated mid-point phosphorus concentrations. The midway position represents a concentration at which there is equal statistical confidence of the biology being in adjacent classes. The class boundaries are the vertical dotted lines in the example illustrated in Figure 1. For any site, the phosphorus concentrations at these boundaries are calculated using the equation and biological EQR values shown in Box 2

Box 2: Standards equation used to calculate site-specific phosphorus standards

$$RP(standard) = 10^{((1.0497 \times \log_{10}(EQR)+1.066) \times (\log_{10}(\text{reference condition RP}) - \log_{10}(3{,}500)) + \log_{10}(3{,}500))}$$

Where:

- "RP(standard)" is the annual mean concentration of reactive phosphorus in µg/l estimated for the lower class boundary of high, good, moderate and poor ecological status, depending on the value of "EQR" used.
- "EQR" means the ecological quality ratio at the status class boundary for the most sensitive of the new diatom and macrophyte assessment methods[5] (i.e. the high, good, moderate or poor biological class boundaries). This is normally the diatom method at low alkalinities and the macrophyte method at high alkalinities. The values for EQR in the standard equation are: High, 0.702; good, 0.532; moderate, 0.356; poor, 0.166.

2.8 A benefit of the approach is that it does not rely on dividing rivers up into types. By using the alkalinity and altitude of the site concerned, the method identifies phosphorus standards that are, in principle, specific to each point in a river. In contrast, the existing method specifies a single standard applicable to the continuum of waters within a type.

2.9 The proposed approach produces phosphorus standards that are more likely on average than the existing standards to classify phosphorus in the same status class as the biology.

[5] Information on the new diatom and macrophyte methods is available in UKTAG's parallel consultation on biological standards. The biological standards defined for high and good have been checked for comparability with the corresponding standards established by other Member States as part of the EU intercalibration exercise.

3. Peer review

3.1 The proposed method for deriving the default standards has been reviewed by four independent experts. Two are river ecologists (Steve Ormerod and David Harper); one is a general expert in nutrient flux (Louise Heathwaite), and one an expert on statistical approaches (Steve Juggins). Given the available data and the need to revise the current standards for phosphorus, Harper and Ormerod supported the work and said that the resulting standards were better than the current standards.

3.2 All agreed that with current knowledge, the link between phosphorus and biology will come through as a fuzzy equation. Harper concluded that with this starting point, the analysis behind the proposed standards was sound. Ormerod and Juggins suggested further work to increase precision. This will not produce different standards, but could trim the uncertainty about them, and so justify decisions on actions that would otherwise be borderline.

3.3 Heathwaite thought that the approach was pragmatic given the available data and the assumptions made about key explanatory variables. She also thought the statistical approaches were appropriate. Heathwaite and Ormerod suggested that the literature review was limited. Nevertheless, Heathwaite considered that the knowledge used was adequate. She also suggested that alternative analyses such as fuzzy-rules based approaches may allow further insight given the nature of the available data and its uncertainties. Such an analysis may be beyond the scope of the report but ought to be included in future work.

4. Dealing with uncertainty in the regression model

4.1 The relationship between phosphorus and biological quality in the data used to develop the regression model is highly variable - there is a lot of scatter in the data. As a result, a regression model cannot produce standards that perfectly correspond to every site's biological status class boundaries. The biology at a significant proportion of sites will be more affected by phosphorus than indicated by the standards. At others, it will be significantly less affected.

4.2 Part of the reason for this is the inevitable statistical errors in the summary statistics of phosphorus and biology used in setting up the regression equation used to derive the standards. However, UKTAG considers the major reason to be that biological response to phosphorus is affected by other factors as well as those represented by a site's alkalinity and altitude. For example, shade, river flow, river bed composition, grazing and the effects of other plant nutrients, such as nitrates, or the presence of other pressures could all influence the biological response to phosphorus.

4.3 In the longer term, it may be possible to produce better models of the relationship between phosphorus concentrations and accelerated plant growth by incorporating information about such additional factors. UKTAG s will ensure that support for the development of such models is part of its on-going work programme.

4.4 In the short-term, if we can identify which sites are likely to be significantly more responsive to phosphorus than the average site and which significantly less so, the existing regression relationship could be used to identify different phosphorus standards for these sites. An outline of how such an approach could be used to adjust standards is given in Annex 1. It involves adjusting the standards for sites at which monitoring data indicate that the biology is in a significantly better or a significantly worse condition than predicted by the default, revised phosphorus standards. There are a number of considerations that affect how such an approach could be used in practice. UKTAG is currently evaluating these. For example:

(i) The approach requires biological and chemical monitoring results for a site. Monitoring programmes across the UK are targeted on water bodies at risk. Many water bodies do not fall into this category. This means the approach cannot be applied to a significant number of water bodies using current data sets.

(ii) Because the approach provides no information on what is causing differences in responsiveness, it is unclear whether the monitoring sites are representative of the responsiveness of the water body as a whole. One way to take this into account would be to check whether adjacent monitoring sites are indicating similar responses before adjusting the phosphorus standards.

(iii) Biology may appear to be worse than indicated by the proposed default phosphorus standards because it is being adversely affected by other pressures. This makes the identification of sites where the biology appears worse than indicated by the proposed default phosphorus standards more vulnerable to error than the identification of unresponsive sites. UKTAG is considering how this risk could be managed.

4.5 If these issues can be addressed, UKTAG believes that the approach could be used to
(a) reduce mismatches between chemical and biological classifications; and
(b) reduce the risk that the phosphorus standards for a site are overly stringent or lax.

4.6 UKTAG would welcome views on the principle of, and approaches to, adjusting the revised phosphorus standards based on chemical and biological monitoring data. During the consultation period, UKTAG will continue to further develop the approach, taking account of the issues listed above.

5. Comparison of the revised standards with existing standards

5.1 Comparing the revised standards with the existing phosphorus standards is not straightforward because the revised standards are site-specific standards rather than type-specific. In principle, there are as many new standards as there are unique combinations of altitude and alkalinity.

5.2 Table 1 shows the median of the revised phosphorus standards for a set of 819 sites with relevant chemistry monitoring data. The theoretical ranges of standards across all rivers are also shown. In the great majority of cases, the revised standards are lower concentrations of phosphorus than the existing standards.

Table 1: Comparison of existing and revised standards for phosphorus

Type (for existing standards)	Annual mean of reactive phosphorus (µg per litre)							
	High		Good		Moderate		Poor	
	Existing	New	Existing	New	Existing	New	Existing	New
Lowland, low alkalinity	30	19 (13-26)	50	40 (28-52)	150	114 (87-140)	500	842 (752-918)
Upland, low alkalinity	20	13 (13-20)	40	28 (28-41)	150	87 (87-117)	500	752 (752-851)
Lowland, high alkalinity	50	36 (27-50)	120	69 (52-91)	250	173 (141-215)	1000	1003 (921-1098)
Upland, high alkalinity	50	24 (18-37)	120	48 (28-70)	250	132 (109-177)	1000	898 (829-1012)

Notes:

The revised standards illustrated are the medians from, respectively, 456 lowland, high alkalinity sites; 129 upland high alkalinity sites; 137, lowland, low alkalinity sites; and 97 upland, low alkalinity sites.
The numbers in parentheses are the upper and lower 5th and 95th percentiles of the standards for the sites in each type.
"Lowland" means less than or equal to 80 metres above mean sea level.
"Upland" means more than 80 metres above mean sea level.
"Low alkalinity" with a concentration $CaCO_3$ of less than 50 mg per litre.
"High alkalinity" with a concentration $CaCO_3$ of greater than or equal to 50 mg per litre.

5.3 In general, the revised standards produce narrower the class widths than the existing standards. This is illustrated in Table 2. The median class widths at high status under the revised standards are typically around half to a quarter of those under the existing standards. The median widths at good status in high alkalinity rivers are around half to one third those under the existing standards. For low alkalinity rivers, the effect at good status is a quarter narrower class widths for upland sites. For lowland sites, the median width under the revised standards is slightly greater than under the existing standards.

Table 2: Comparison of the class widths of the existing and revised standards for phosphorus

Type (for existing standards)	Annual mean of reactive phosphorus (µg per litre)					
	High		Good		Moderate	
	Existing	Default	Existing	Default	Existing	Default
Lowland, low alkalinity	21 (13 - 29)	9 (6 - 26)	20	21 (15 - 27)	100	74 (59 - 91)
Upland, low alkalinity	14 (8 - 19)	8 (6 - 20)	20	15 (15 - 22)	110	59 (59 - 77)
Lowland, high alkalinity	28 (14 - 49)	15 (9 - 54)	70	32 (23 - 44)	100	105 (81 - 131)
Upland, high alkalinity	37 (25 - 49)	10 (6 - 34)	70	24 (15 - 35)	100	84 (59 - 111)

Notes:
The class widths illustrated are the medians from, respectively, 456 lowland, high alkalinity sites; 129 upland high alkalinity sites; 137, lowland, low alkalinity sites; and 97 upland, low alkalinity sites. The figures in parentheses are the minimum and maximum class widths for these sites.
"Lowland" means less than or equal to 80 metres above mean sea level.
"Upland" means more than 80 metres above mean sea level.
"Low alkalinity" with a concentration $CaCO_3$ of less than 50 mg per litre.
"High alkalinity" with a concentration $CaCO_3$ of greater than or equal to 50 mg per litre.

5.4 Comparison with standards set by other countries is also complicated because of the wide variety of river types; different approaches to setting standards; and the use of different of phosphorus and summary statistics. According to a recent review by one of the European Working Groups on the implementation of the Water Framework Directive[6], there is a large range in the values of the standards established by different countries. The report suggests that standards for good for annual mean total phosphorus concentration may range from less than 10 µg per litre to up to around 1,000 µg per litre. However, no general conclusions could be reached about the reasons for the apparent differences. The lowest concentration standards for good being proposed by UKTAG are higher than the standards for some countries but of a similar magnitude to those in countries such as The Netherlands, allowing for the differences in the determinand and in the summary statistics used to define the standards.

6. Effect of the proposed standards on status classifications

6.1 The proposed new standards would affect phosphorus status classifications. The changes are illustrated in Table 3. There would be a decrease in the proportion of sites classed as good or high for phosphorus from around 80% to 65%. Using as an example the approach set out in Annex 1, applying standards adjusted to biological response could potentially reduce the proportion at high or good by a further 5%. In Scotland, this latter effect is reversed, with the adjusted standards increasing the proportion of sites at good or better by about 3% compared with the proposed default standards.

[6] WFD CIS ECOSTAT WG A Report (2012); Comparison of Environmental Quality Objectives, Threshold Values or Water Quality Targets Set for the Demands of the European Water Framework Directive. 29 February 2012.

Table 3: Phosphorus classifications under the existing and proposed new phosphorus standards

Phosphorus class	Proportion of sites (%)											
	England/Wales (283 sites)			Northern Ireland (300 sites)			Scotland (221 sites)			All UK (804 sites)		
	E	N	A	E	N	A	E	N	A	E	N	A
High	51	39	35	51	33	26	61	43	38	54	38	30
Good	17	21	18	33	32	32	28	27	36	26	27	30
Moderate	13	16	24	14	28	36	10	26	24	13	23	30
Poor or bad	18	24	23	2	7	7	1	4	2	7	11	10

Note
"E" means existing phosphorus standards
"N" means new phosphorus standards
"A" means adjusted phosphorus standards as proposed in the example in Annex 1

6.2 Status classification requires the results for phosphorus and the biology to be combined. The changes in combined class are illustrated in Table 4. The proposed new phosphorus standards are only partly responsible for the changes. The application of the new biology standards is also responsible for the general improvement in combined class compared to classifications made using the existing phosphorus and biology standards.

Table 4: Combined status class of phosphorus and biology (diatoms & macrophytes) as proportion of sites (%)

Combined class	England/Wales (283 sites)				Northern Ireland (300 sites)				Scotland (221 sites)				UK (804 sites)			
	B	E	N	A	**B**	E	N	A	**B**	E	N	A	**B**	E	N	A
High	**13**	7	11	10	**9**	9	8	6	**32**	19	21	23	**17**	11	12	13
Good	**32**	18	28	28	**51**	24	40	42	**50**	27	40	45	**44**	23	35	38
Moderate	**44**	32	34	34	**35**	53	40	37	**18**	52	35	30	**33**	45	37	35
Poor	**11**	37	28	28	**6**	15	13	14	**0**	1	4	2	**6**	19	14	14
Bad	**0**	5	0	0	**0**	0	0	0	**0**	0	0	0	**0**	2	1	0

Note
"B" means the biology class based on the proposed new macrophyte and diatom standards
"E" means combined class based on the existing phosphorus & the existing biology standards
"N" means combined class based on the proposed default new phosphorus & the new biology standards
"A" means combined class based on the adjusted phosphorus standards (as proposed in the example in Annex 1) and the new biology standards

6.3 The impact of the proposed new phosphorus standards on classification mismatches is illustrated in Table 5. The application of the new biological standards for diatoms and macrophytes leads to an appreciable reduction in classification mismatches, from 75% of sites to 67% of sites. Application of the new phosphorus standards results in a further reduction of about 5%. However, mismatched classifications still dominate over aligned classifications with 62% of the assessed sites still having mismatched classifications. Application of phosphorus standards adjusted as set out in the example in Annex 1 could potentially reduce mismatches by an additional 16%, giving 54% of sites with biology and phosphorus classifications aligned. There would remain a substantial number of cases (46%

of sites) where the new standards are overly stringent and a substantial number of cases where they would be overly lax.

Table 5: Implications of the revised phosphorus standards for classification mismatches

	Proportion of classification mismatches (%)							
Standards	Existing & existing biology		Existing & new biology		Default & new biology		Adjusted & new biology	
Bias: biology cf RP class	Biology better	Biology worse	Biology better	Biology worse	Biology better	Biology worse	Biology better	Biology worse
England/Wales (283 sites)	79		70		69		59	
	19	60	17	53	24	45	23	36
Northern Ireland (300 sites)	79		69		60		50	
	6	73	8	62	18	42	18	31
Scotland (221 sites)	66		60		56		44	
	7	58	14	46	28	28	23	21
UK - combined (804 sites)	75		67		62		46	
	11	65	13	54	23	39	20	26

Notes:
"Existing" means the existing phosphorus standards, as previously recommended by UKTAG
"Default" means the proposed default phosphorus standards.
"Adjusted" means the proposed standards adjusted as proposed in the example in Annex 1
"Existing biology" means the existing biology standards for macrophytes and diatoms, as previously recommended by UKTAG.
"New biology" means the proposed new biology standards for macrophytes and diatoms.

6.4 Under the existing standards, the bias in classification mismatches is high, with biology being in a worse class than phosphorus in 65% of sites compared with 11% where biology is in a better class.

6.5 The proposed default phosphorus standards would reduce but not eliminate this bias. The number of overly stringent and overly lax cases would be more balanced than under the existing standards. Application of the adjusted phosphorus standards could almost eliminate bias.

7. Implications of the proposed standards for water management

General implications

7.1 Environmental standards are used to make risk-based judgements about the steps needed to protect and, where necessary, improve ecological quality. Where standards are not perfectly matched to the biology, they can overestimate risk, underestimate risk or provide no useful guide to assessing risk. The greater the mismatch, the less help standards provide.

7.2 The potential implications of overly lax and overly stringent phosphorus standards are summarised in Table 6 below. UKTAG's review and the bias evident in the classifications indicate that the existing phosphorus standards tend to be overly lax. A high proportion of water bodies have a biology class that is worse than the phosphorus class. Because of this, the issues described in points (b) and (d) of Column 3 of the Table would be expected to dominate.

Table 6: Potential implications of overly stringent and overly lax phosphorus standards

Column 1	Column 2	Column 3
Match to biology standards	Overly stringent	Overly lax
Characteristics of mismatches with biology classification	(a) Bias towards phosphorus being in a worse class than biology	(a) Bias towards phosphorus being in a better class than biology
Improvement planning	(b) Phosphorus standards are likely to overestimate the scale of phosphorus reduction needed	(b) Where phosphorus is classed as high or good and biology classed as moderate, poor or bad, phosphorus standards provide no useful guide to the scale of phosphorus reduction needed; (c) Where phosphorus is also classed as worse than good, phosphorus standards are likely to underestimate the scale of phosphorus reduction needed.
Managing risk of deterioration	(c) Where phosphorus is classed as worse than biology, the effect is variable but, if taken at face value, the phosphorus standards would tend to overestimate the additional phosphorus concentration that can be accommodated without deterioration of biological status. This is because phosphorus class widths increase from high to poor. (d) Where phosphorus and biology are classed the same, phosphorus standards are likely to underestimate the additional phosphorus concentration that can be accommodated without deterioration of biological status.	(d) Where phosphorus is classed as better than biology, the effect is variable but, if taken at face value, the phosphorus standards would tend to underestimate the additional phosphorus concentration that can be accommodated without deterioration of biological status. This is because phosphorus class widths decrease from poor to high. (e) Where phosphorus and biology are classed the same, phosphorus standards are likely to overestimate the additional phosphorus concentration that can be accommodated without deterioration of biological status.

Implications for improvement planning

7.3 For planning at a national or regional scale, the proposed new standards would offer a potential advantage over the existing standards. At these large scales, the much lower bias in the new standards is likely to mean that errors for individual sites would start to cancel out. Because of this, the standards would provide for a reasonably reliable assessment of the scale of action needed on phosphorus at a national or regional level. Assessments based on the standards could help inform decisions about actions designed to be applied evenly across wide areas.

7.4 For risk assessments at individual sites, the reduced bias means that the issues listed in Columns 2 of Table 6 are likely to occur more frequently than under the existing standards. However, for management purposes, a significant advantage of the proposed new standards is that the risk of error is understood and quantified. This allows scope for it to be factored into decision-making. For example, when planning improvements at an individual site, the potential for error could be mitigated at least in part by planning improvements as a series of iteratively evaluated steps, depending on the biological effect achieved. The regression model provides a means of defining sensible steps.

7.5 UKTAG continues to recommend that costly action to reduce phosphorus concentrations should be considered only where there is high confidence of associated adverse biological impacts. Where there is such evidence, the norm in terms of improvement planning might be an initial step aimed at achieving the phosphorus standard indicated by the regression model to be appropriate for sites relatively unresponsive to phosphorus (See Annex I). Where there is already good evidence that the biology in the water body concerned is more responsive to phosphorus than this, the initial step might instead aim, as appropriate, at the default standard or an adjusted standard for sites with very responsive to biology.

Implications for new development

7.6 When considering proposed new developments, standards are used to estimate the capacity within the current status class for accommodating further discharges without deterioration to a worse class.

7.7 In principle, four factors affect the capacity of water bodies to accommodate additional phosphorus inputs before a standard is breached:

(i) The ratio of the magnitude of a proposed discharge and the flow in the receiving river determines the extent to which phosphorus concentrations in the discharge will be diluted. The larger the discharge as a proportion of river flow, the less the dilution;

(ii) The concentration of phosphorus in the discharge. Sewage is the main point source of phosphorus and the concentration of phosphorus in sewage discharges is in part controlled by the level of treatment installed at the treatment works. Many works with tertiary treatment to remove phosphorus achieve concentrations in the discharge of less than 1000 µg/l. Some of the most advanced works can achieve effluent concentrations as low as 100 to 500 µg/l.

(iii) The biological tolerance to phosphorus at the particular ecological status class of the water body. The phosphorus standards are used to estimate this tolerance. At many but not all sites, the proposed new phosphorus standards produce narrower class widths (i.e. lower tolerance) for high, good and moderate status than the existing phosphorus standards [See Table 2].

(iv) The existing concentration of phosphorus in the river.

7.8 Table 7 illustrates the face value effect of the proposed new standards with respect to the last two factors above. These factors affect the available capacity of a site (in terms of µg/l) to accommodate additional phosphorus inputs. The proposed new standards (including those adjusted as proposed in the example in Annex 1) increase the proportion of sites with a remaining capacity of less than 5 µg /l and decrease the proportion with more than 10 µg/l remaining.

Table 7: Capacity remaining in status classes before phosphorus class boundary is reached

Distance to class boundary (µg per litre)	Proportion of sites (%)											
	England/Wales (283 sites)			Northern Ireland (300 sites)			Scotland (221 sites)			UK (804 sites)		
	E	N	A	E	N	A	E	N	A	E	N	A
≤ 1	2	2	5	1	3	4	2	2	5	2	2	5
> 1 & ≤ 5	6	17	24	4	12	18	5	12	18	5	14	20
> 5 & ≤ 10	16	11	11	9	19	18	9	21	15	11	17	12
>10	77	70	60	85	67	60	84	65	62	82	67	63

Note:
"E" means existing phosphorus & existing biology standards
"N" means new, default phosphorus standards & new biology standards
"A" means adjusted phosphorus standards as proposed in the example in Annex 1& new biology standards
1 µg per litre is 5% of a class width of 20 µg per litre; 5 µg per litre is 25% of a class width of 20 µg per litre; and 10 µg per litre is 50% of a class width of 20 µg. For all low alkalinity rivers, the good status class width under the existing phosphorus standards is 20 µg per litre.

7.9 The high rate of mismatches between phosphorus class and the biology class (see Table 6) indicates that the existing phosphorus standards are not reliably estimating the tolerance of the biology to phosphorus. The proposed new standards reduce the proportion of mismatches but do not perfectly describe the tolerance to phosphorus of every site. Particularly where biology and phosphorus class are mismatched, the phosphorus standards do not provide a reliable guide to the capacity of the river to accommodate additional phosphorus inputs.

Overestimates of capacity

7.10 The environment agencies avoid allocating all the estimated capacity to developments as this could push waters right to a class boundary, putting them at significant risk of deterioration. This regulatory practice partially mitigates the effect of overestimated capacity. Knowledge of the risk of deterioration can also be factored into the development decision and into treatment system upgrade planning by, for example, considering the measures needed to restore the condition of the water body should deterioration occur.

Underestimates of capacity

7.11 Significant underestimates of capacity can place extra costs on development. Proposed discharges may be subject to greater levels of treatment to reduce their phosphorus concentration or may be re-directed to more distant waters where the estimated capacity is sufficient to accommodate them.

7.12 Adjusting the phosphorus standards according to information on the biological sensitivity of a site could be expected to reduce the likelihood of standards being overly lax or overly stringent. Such adjustments would not eliminate the risk of error and the consequences listed in Table 6. However, the frequency and severity of the errors would be reduced.

7.13 To minimise additional monitoring and assessment costs in cases where appropriate information on biology is not been collected through normal monitoring programmes, UKTAG would recommend that the proposed default phosphorus standard is applied initially. If the proposed development cannot be accommodated without a breach of these standards, further evidence on the biological response could be collected to assess whether or not an adjusted phosphorus standard would be applicable.

Practical application of adjusted standards

7.14 The use of adjusted standards would require the agencies to undertake combined biological and chemical monitoring at least at all sites planned for improvement (This is already normal practice) and at all sites where future development is likely. The latter monitoring could increase upfront regulatory costs. These would likely be more than offset because of the potential of the approach to reduce environmental damage costs and unnecessary phosphorus control costs.

7.15 The upfront assessments would also need to check that monitoring information is representative of the waters. This might involve checking at more than one monitoring location. It would also involve checking whether or not the apparent biology response could be due to the effects of other pressures. This latter check would be particularly important where the biology appeared to be more responsive to phosphorus than indicated by the unadjusted phosphorus standards.

Annex I: Illustrative example of adjustment of the revised standards

1.1 This Annex describes an illustrative example of how adjustments to the revised standards might be made. UKTAG is continuing to assess and develop this and other options.

1.2 The option described here is based on the principle that, if we can identify which sites are likely to be biologically significantly more responsive to phosphorus than the average site and which significantly less so, the regression relationship from which the default standards are derived could be used to identify different phosphorus standards for these sites.

1.3 This would be done by taking account of the information on sensitivity when estimating the phosphorus concentrations corresponding to the biological class boundaries rather than taking the regression model estimate of the value at the midpoint of the biological class. In Figure 1 in Section 2, for biologically unresponsive sites, the default, revised standards (dotted lines) would be adjusted rightwards along the horizontal lines. For responsive sites, they would be adjusted leftwards. This would produce phosphorus standards for these sites that were more likely to correspond to the biological class boundaries than the standards derived for sites of "average" responsiveness.

1.4 One way to identify sites that may be more responsive or less responsive to phosphorus is to look at their biological and phosphorus monitoring results. For sites that are particularly unresponsive to phosphorus, the biology would be expected to be in a much better condition than predicted by the unadjusted (default) revised phosphorus standards. For example, suppose the biology is measured as being at the top end of the good status class and the phosphorus is measured as being in the moderate status class. This might indicate the biology at the monitoring site is not as responsive to phosphorus concentrations - it is less sensitive - than average.

1.5 UKTAG is currently exploring the potential to use such information to adjust the default phosphorus standards produced by the regression model according to the likely responsiveness of the biology of the site. For the initial analysis, moderately less responsive sites are defined as sites where the biology is between half a class width and four fifths of a class width better and than the corresponding classification for phosphorus under the default standards. Very unresponsive waters are defined as sites where the biology is more than four fifths of a class width better. Very responsive waters are defined as sites where the biology is more than four fifths of a class worse than the corresponding phosphorus classification. Early indications are that these criteria identify sites where the reason for the difference between the biology and chemistry monitoring results is likely to be due to the sensitivity of the biology to phosphorus rather to errors in measurement.

1.6 Initial testing also shows that adjusting the standards in the appropriate direction along the horizontal lines in Figure 1[7] achieves a significant reduction in the number of sites where biology and chemistry are in different status classes. The approach appears to better match the phosphorus standards to the biology. Details of the adjustments so far considered are described in Box 3. Other adjustments are being worked on and compared.

[7] Up to the ± 12.5th percentile of the regression model residuals (i.e. 87.5% of the predicted phosphorus values for the biological class midpoint)

Box 3: Adjustment of phosphorus standards based on biological sensitivity

Initial testing of biologically adjusted standards used standards calculated using the following modifications to the standard equation described in Box 2:

$$\text{Adjusted standard} = 10^{((1.0497 \times \log_{10}(\text{Adjusted EQR}) + 1.066) \times (\log_{10}(\text{reference condition RP}) - \log_{10}(3{,}500)) + \log_{10}(3{,}500))}$$

Where "Adjusted EQR" has the following values:

Difference biology vs. phosphorus results	High	Good	Moderate	Poor
Biology half a class width better	0.655	0.513	0.356	0.166
Biology four fifths of a class width better	0.515	0.402	0.296	0.106
Biology four fifths of a class width worse	0.952	0.701	0.427	0.166

1.7 Table A1 shows the median of the proposed default phosphorus standards and the median of the adjusted phosphorus standards after adjustments for sites identified as likely to be biologically more or less responsive than average to phosphorus. The range of standards is also shown. The range increases when the adjusted standards are included. In most cases, the median standards are similar under the default standards and when adjusted standards are included. However, for lowland, low alkalinity sites, the median of the adjusted standards is less than three quarters the concentration of that of the default standards.

Table A1: Comparison of the default revised standards for phosphorus and those adjusted based on site-specific information on biological sensitivity

Type (used for existing standards)	Annual mean of reactive phosphorus (µg per litre)					
	High		Good		Moderate	
	Default	Adjust	Default	Adjust	Default	Adjust
Lowland, low alkalinity	19 (13-26)	17 (11-31)	40 (28-52)	28 (14-62)	114 (87-140)	90 (56-148)
Upland, low alkalinity	13 (13-20)	13 (10-21)	28 (28-41)	28 (13-42)	87 (87-117)	87 (52-117)
Lowland, high alkalinity	36 (27-50)	35 (20-50)	69 (52-91)	63 (28-143)	173 (141-215)	161 (94-250)
Upland, high alkalinity	24 (18-37)	23 (15-49)	48 (38-70)	46 (21-95)	132 (109-177)	124 (76-206)

Notes:

"Default" means the proposed default phosphorus standards.
"Adjust" means the proposed standards adjusted to take account of information on the biological sensitivity of the sites.
The standards illustrated are the medians from, respectively, 456 lowland, high alkalinity sites; 129 upland high alkalinity sites; 137, lowland, low alkalinity sites; and 97 upland, low alkalinity sites.
The numbers in parentheses are the upper and lower 5th and 95th percentiles of the standards for the sites in each type.
"Lowland" means less than or equal to 80 metres above mean sea level.
"Upland" means more than 80 metres above mean sea level.
"Low alkalinity" with a concentration $CaCO_3$ of less than 50 mg per litre.
"High alkalinity" with a concentration $CaCO_3$ of greater than or equal to 50 mg per litre.

1.8 Table A1 shows the median of the proposed default phosphorus standards and the median of the adjusted phosphorus standards after adjustments for sites identified as likely to be biologically more or less responsive than average to phosphorus. The range of standards is also shown. The range increases when the adjusted standards are included. In most cases, the median standards are similar under the default standards and when adjusted standards are included. However, for lowland, low alkalinity sites, the median of the adjusted standards is less than three quarters the concentration of that of the default standards.

REFERENCES

GENERAL

[1] UKTAG (2008); UK Environmental Standards and Conditions; (Phase 1); Final report (SR1 – 2006), April 2008. http://www.wfduk.org/sites/default/files/Media/Environmental%20standards/Environmental%20standards%20phase%201_Finalv2_010408.pdf

[2] UKTAG (2008); UK Environmental Standards and Conditions (Phase 2); Final (SR1 – 2007); March 2008. http://www.wfduk.org/sites/default/files/Media/Environmental%20standards/Environmental%20standards%20phase%202_Final_110309.pdf

[3] UKTAG (2012); Updated Recommendations on Environmental Standards; (Phase 3); River Basin Management (2015-21); Final; November 2012. http://www.wfduk.org/stakeholders/stakeholder-review-2012-response-submissions

PHOSPHORUS

[4] A revised approach to setting Water Framework Directive phosphorus standards. UKTAG; October 2012. http://www.wfduk.org/stakeholders/stakeholder-review-phosphorus-and-biological-standards