WINEP: phosphorous removal

Prepared for Yorkshire Water

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1 Summary

The water industry is undertaking a large phosphorous removals (P-removals) programme over AMP7, accounting for 53% of all planned enhancement expenditure. This is driven by the Urban Wastewater Treatment Directive (UWWTD) and the Water Framework Directive (WFD). These two directives account for the vast majority of phosphorous consents (P-consents).

This P-removals programme affects water companies' base and enhancement expenditure in a number of ways—companies may need to build new assets, upgrade existing ones, incur the associated ongoing operating expenditure to meet tighter P-consents, or develop alternative solutions such as water catchment solutions.

Within the industry, Yorkshire Water (YKY) is in a unique position with regard to the need for its P-removals programme. YKY has *both* UWWTD and WFD drivers at *all* of its major works. A total of 86% of its load is affected by UWWTD obligations (the second highest figure is 40% and the industry average is only 21%). The UWWTD requires specific solutions, which results in higher costs than would be the case if no UWWTD obligations were in place or if WFD obligations were in place instead. It also has the second lowest number of existing obligations. So, compared with the rest of the industry, YKY is facing the most significant step up in expenditure requirements.

While Ofwat's approach to assessing P-removals in its draft determinations is an improvement over its IAP approach, its new approach is still not able to adequately estimate YKY's efficient level of spend on P-removals over AMP7.

- First, Ofwat does not account for the fact that different P-removal directives require different solutions that incur different enhancement expenditure levels.

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- Second, Ofwat's WINEP[1] enhancement cost assessment includes a calculation error regarding the upper quartile (UQ) efficiency challenge, and its models are not accurate enough with respect to YKY's cost prediction to justify the use of a challenging benchmark for YKY, given the unique nature of YKY's P-removals programme.
- Third, Ofwat has not allowed for the ongoing costs of complex P-removals treatments in its base models.

We have previously[2] proposed several adjustments to Ofwat's approach that can be used to capture the above factors for YKY. These have the overall impact of increasing YKY's TOTEX allowance by £234m.[3] Table 1.1 provides a high-level breakdown of this figure.

Table 1.1 Summary of impact of modelling changes on YKY's WINEP allowance

Models	Allowance (£m)
Ofwat's view of base and enhancement costs	2,216
Enhancement modelling changes (section 3)	+191
Re-allocation of YKY's costs (section 3.1)	+25
Accounting for UWWTD obligations (section 3.2)	+91
Moving from a UQ to an average benchmark (section 3.3)	+76
Accounting for phosphorus treatment complexity in base expenditure (section 4)	+43
Overall impact	+234
Revised YKY allowance across base and enhancement expenditure	**2,449**

Source: Oxera analysis.

2 Yorkshire Water's unique position on phosphorous removals

2.1 Industry context and drivers of P-removals costs

Over AMP7, the industry needs to meet higher environmental standards. In particular, the industry has a significant P-removals programme to meet tighter consent levels.

The drivers of the base and enhancement costs relating to these tighter consents are: the degree of tightness of consents required by the end of AMP7; the change in the required level of consents from their current level to the level required by the end of AMP7; and the volume of sewage (or population equivalent) that requires a higher level of treatment.

In addition, these costs are significantly affected by the type of obligation—mainly UWWTD and the WFD.[4] These two directives account for 88% and 8.5%[5] of P-consents at the industry level, respectively.[6]

[1] Water Industry National Environment Programme.
[2] Oxera (2019), 'Ofwat's enhancement modelling approaches at the IAP: a review', March.
[3] This also accounts for the £137m of base expenditure that YKY has reallocated to enhancement expenditure.
[4] Yorkshire Water (2019), 'Price Review 2019 Business Plan Submission Document', p. 142.
[5] Oxera analysis of Environmental Agency dataset.
[6] The remainder are accounted for by other obligations such as those relating to Bathing Waters, Drinking Water Protected Areas, Shellfish Waters, Environmental Permitting Regulations, Local Drivers, Habitat Directives, SSSIs, NERC Biodiversity Priority, INNS, Marine Conservation Zone and Eels.

Critically, the UWWTD is very specific about the solution required, specifying that:

> Member States shall ensure that urban waste water entering collecting systems shall before discharge be subject to **secondary treatment** or **an equivalent treatment**.[7] [emphasis added]

That is, where a UWWTD designation is present, a particular treatment solution is mandated. In contrast, with WFD obligations, although the consents are lower than UWWTD consents, there is an opportunity to consider a number of alternative solutions, including catchment management solutions if appropriate.

In addition, WFD designations are subject to a cost–benefit analysis, whereas UWWTD designations are not. Therefore, some more expensive WFD treatment solutions from other companies may have been rejected before designation, resulting in a tendency for cheaper solution to be accepted by the Environment Agency. In contrast, for sites where both UWWTD and WFD drivers are present, only the incremental cost is subject to a cost–benefit analysis, resulting in more WFD obligations that would otherwise have been rejected on cost benefit grounds.

It is, therefore, potentially much more costly to address P-consents driven by UWWTD designations than those driven by WFD ones.

2.2 What costs are affected?

This programme of new P-consents affects base and enhancement expenditure, due to the following:

- expenditure to build *new* assets/treatment works to accommodate the tighter consents (enhancement CAPEX);
- associated ongoing operating expenditure—e.g. on chemicals, power and staff (enhancement OPEX). In the long term this will become base expenditure (for this reason, these ongoing costs for existing assets are currently included within base expenditure);
- ‘enabling’ expenditure to modify *existing* treatment works to accommodate the tighter consents—i.e. resizing and/or upgrading existing assets (base or enhancement expenditure);
- ongoing capital maintenance costs of the new assets—i.e. to maintain them once they are built assets (base expenditure).

Following discussions with, and further guidance from, Ofwat, YKY has reallocated some expenditure that was within base expenditure—with regard to upgrading existing assets due to enhancement activity (see section 3.1)—to enhancement expenditure.

2.3 Yorkshire Water’s unique position

The WINEP drives 36% of YKY’s TOTEX over AMP9.[8] This expenditure is heavily weighted towards wastewater network plus (75%). Within this, a majority (67%) is to address 80[9] new consents for P-removal.

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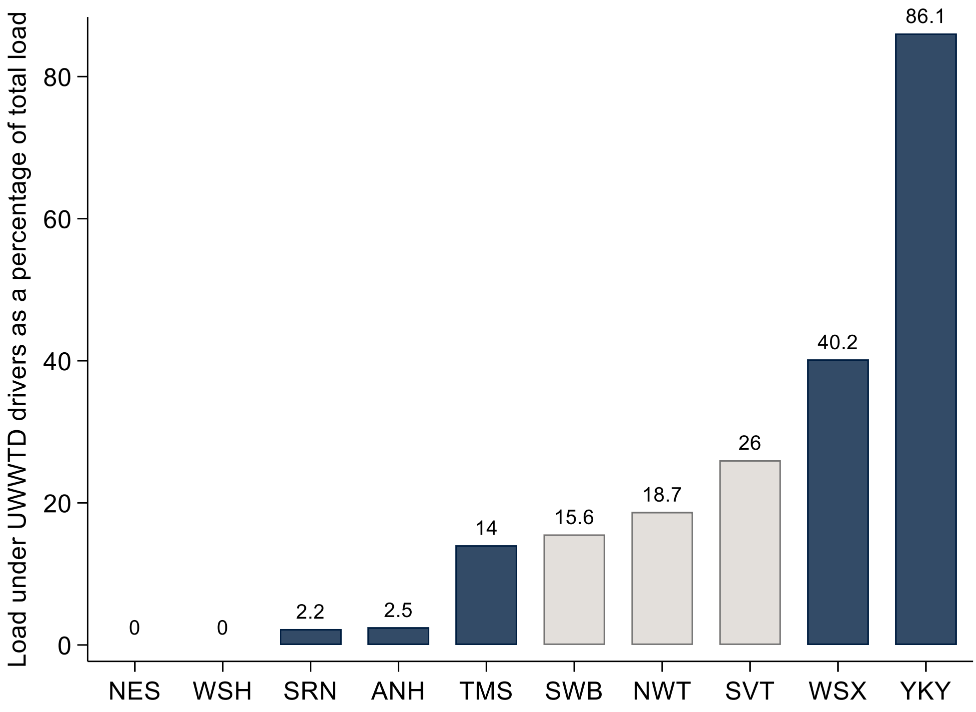
[7] European Commission (1991), ‘Council Directive of 21 May 1991 concerning urban waste water treatment’, 91/271/EEC, section 4, para. 1.
[8] Yorkshire Water (2019), ‘Price Review 2019 Business Plan Submission Document’, p. 143.
[9] The figure is 81 including one tightened consent.

While some companies have a comparable number of WINEP obligations to YKY, YKY is unique in having *both* UWWTD and WFD drivers at *all* of its major works. As Figure 2.1 below shows, 86% of YKY's load is affected by UWWTD obligations[10] (the UQ companies[11] are shown in grey).

Figure 2.1 The proportion of total load under UWWTD obligations over AMP7 (%)

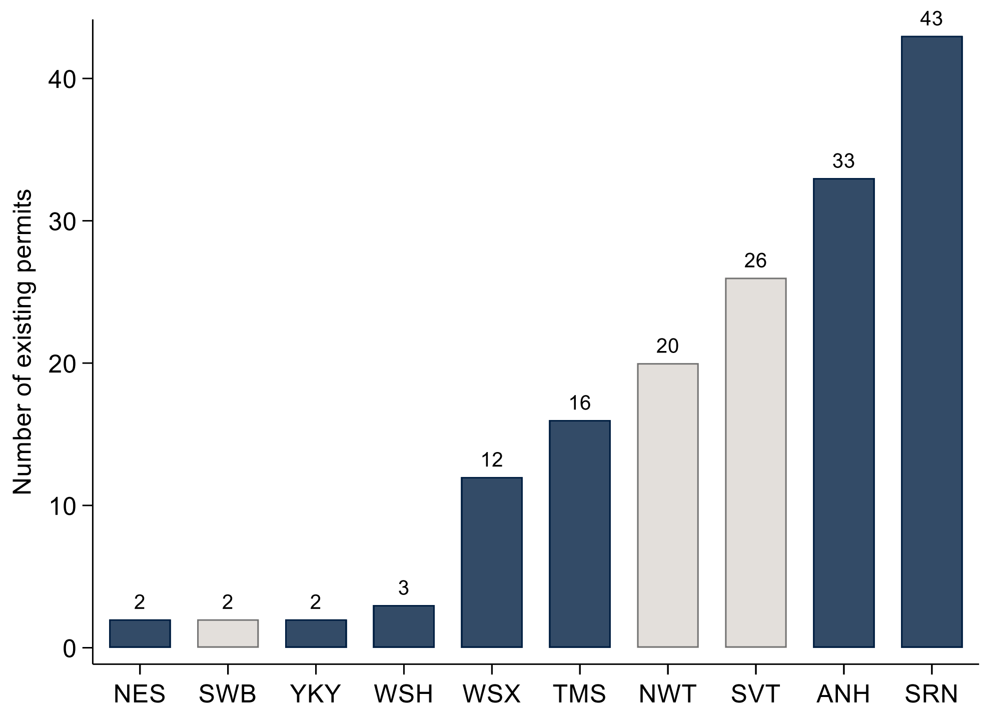


Source: Oxera analysis. UQ companies are highlighted in grey.

In addition, we understand from YKY that many of the other companies in the industry will have previously had these designations and will have been allowed enhancement expenditure to achieve the UWWTD-based consent limit (typically 1mg/l or 2mg/l) in previous AMPs. Therefore, the required investment for these companies to achieve the WFD-based consent limit in AMP7 will be the amount needed to move from the UWWTD consent limit down to the WFD consent limit. In contrast, as YKY's large works are receiving UWWTD and WFD designations for the first time, YKY's AMP7 investment is required to achieve the UWWTD limit and then to go further to achieve the WFD consent limit. That is, YKY is facing a much bigger step change than the other companies in terms of required expenditure. This is apparent when examining the number of existing obligations—as Figure 2.2 below shows, YKY has the equal lowest number of current obligations. (Of the other companies with the lowest number of current obligations, Northumbrian Water and Welsh Water have no load affected by UWWTD designations over AMP7, while South West Water has 16% of its load under UWWTD designations).

[10] This is based on the Environment Agency's dataset of WINEP obligations over AMP7, https://data.gov.uk/dataset/a1b25bcb-9d42-4227-9b3a-34782763f0c0/water-industry-national-environment-programme, accessed 27/08/2019.
[11] Based on Ofwat's P-removals model at DD with a corrected UQ calculation and HDD and SVE combined into a single company.

Figure 2.2 Number of existing obligations



Source: Oxera analysis. UQ companies are highlighted in grey.

Of the two issues discussed above, we understand from YKY that the UWWTD has the greater cost impact. In section 3, we examine the impact of UWWTD designations on P-removal enhancement expenditure. Ideally, the extent to which consents have been tightened would also be captured in the modelling. However, while this factor is likely to have an impact on costs, we have not captured it in the analysis below because it is difficult to establish a numeric value of moving from having no prior consents to a tightened consent over AMP7, as the former is not defined.

3 P-removals enhancement expenditure[12]

Limitations of Ofwat's modelling in the draft determinations: the need for adjustments for YKY

In its draft determinations, Ofwat has made a number of changes to the way it has estimated efficient costs compared with its approach at the IAP. This affects the relevance of some elements of our previous estimation of the impact of P-removal, although the analysis below remains consistent with the principles underlying our previous work.[13]

In particular, Ofwat has amended its model specification when modelling P-removal enhancement expenditure compared with its approach at the IAP. Ofwat now has two models of enhancement TOTEX and has averaged the outcomes from these. One model accounts for the current population equivalent for sites with tightened consents[14] and the change in the number of

[12] The analysis in this section is based on data that is available at the Draft Determinations. Therefore, it does not account for any potential changes in company input costs.
[13] Oxera (2019), 'Ofwat's enhancement modelling approaches at the IAP: a review', March.
[14] Current population equivalent served by activated sludge STWs with tightened/new P consents and current population equivalent served by filter bed STWs with tightened/new P consents.

sites with stringent P-consents.[15] The second model accounts for the number of sites and current population equivalent for sites with tightened consents.

Combined with modelling enhancement CAPEX and OPEX together, this better accounts for the impact of the stringency of P-removal on enhancement costs than Ofwat's IAP models do. However, Ofwat's approach does not account for all the issues discussed above.

In this section we examine how the models can be extended to better account for the enhancement cost impact for YKY of the issues discussed above and in section 2. But first we examine the impact of YKY's revised cost allocation, as mentioned in section 2.1.

3.1 Reallocation of base expenditure to enhancement expenditure

As stated above, since the draft determinations, and following Ofwat guidance that enabling work should be split appropriately between enhancement and base expenditure, YKY has reallocated a total of £137m of expenditure associated with P-removals from base to enhancement, as set out in the table below.

Table 3.1 YKY's reallocation of expenditure from base to enhancement (£m)

	2020/21	2021/22	2022/23	2023/24	2024/25	Total
Expenditure moved from base to enhancement (£m)	48.9	49.6	26.6	9.6	2.3	**137.1**

Source: YKY.

This reallocation will affect YKY's estimated efficient cost level for enhancement expenditure.[16]

Table 3.2 shows the impact of this reallocation on Ofwat's P-removals enhancement expenditure model and the overall WINEP outcome and, in particular, on YKY's estimated efficient cost level (after the WINEP UQ challenge).

Table 3.2 Impact on P-removals of reallocating base spend to P-removals enhancement: efficient enhancement cost level after the WINEP UQ challenge (£m)

Model	P-removals	WINEP
Ofwat model (1)	460	658
With enhancement spend reallocated (2)	498	683
Impact (2) - (1)	38	**25**

Source: Oxera analysis.

Note: Ofwat's P-removal models were re-estimated, and the UQ challenge was calculated at the WINEP level before applying it to P-removals spend. The UQ challenge has been calculated after correcting for Ofwat's calculation error, discussed in section 3.3.

This represents our base case against which all our subsequent analysis should be assessed.

[15] The change in the total number of sewage treatment works with P consents ≤0.5mg/l from the end of 2020 to the end of 2024.
[16] However, there will not be an impact on Ofwat's base expenditure allowances from this reallocation, because Ofwat's base expenditure approach uses only forecast cost drivers and not forecast costs.

3.2 The impact of UWWTD designations

Below, we examine the impact of accounting for the UWWTD within Ofwat's approach to enhancement expenditure at the draft determinations.

3.2.1 An illustrative example of the impact of UWWTD designations on costs

As discussed in section 2, when sites do not have UWWTD designations, compliance can be achieved without building at the site—for example, by promoting catchment schemes (if feasible). This potentially leads to a significantly reduced cost per unit population equivalent.

For example, based on examining the three other WASCs that have large P-removals programmes (United Utilities, Southern Water and Anglian Water) and the UQ companies (Untied Utilities, Severn Trent Water and South West Water), it appears that:[17]

- United Utilities (NWT) is able to promote catchment schemes at its Davyhulme wastewater treatment works (WWTW), which has a population equivalent of over one million.[18] When these sites are very large, such as Davyhulme, failing to account for this in the enhancement cost model leads to biased results. In particular, NWT's unit costs, which are estimated by Ofwat to be within the UQ, will be far lower than if Davyhulme had a UWWTD designation. This can result in an overly challenging UQ benchmark for companies that have significant UWWTD designations, such as YKY;
- Southern Water has identified a number of sites where it can implement catchment solutions, saving it approximately £23m;[19]
- Anglian Water has a large number of obligations. However, it appears to have 34 catchment approaches ('natural capital solutions') out of its 160 new or upgraded P-removals plants, and only three UWWTD obligations;[20]
- Severn Trent Water describes in its plan how it has been able to use catchment solutions to reduce the number of treatment solutions and costs;[21]
- South West Water has very small P-removals programme, so their programme is not overly comparable to the companies with larger programmes.[22] In addition, South West Water plans to undertake catchment management for over 80% of the catchments within which it operates.[23]

In contrast, of YKY's 81[24] sites, 48 schemes cover 50 UWWTD obligations.[25]

[17] This is based on analysis of these companies' business plans, as publicly available, and, as such, would require checking for accuracy with the companies in question.
[18] United Utilities (2019), 'Enhancement expenditure: WINEP – Phosphorus and sanitary determinants. Chapter 7: Supplementary document', p. 12.
[19] Southern Water (2018), 'TA.12.WW06 Wastewater Environmental Programme Business Case', September, Appendix 3.
[20] Anglian Water (2019), 'PR19 Wastewater Data Tables Commentary', p. 22.
[21] It is unclear what PE is associated with these sites. Severn Trent Water (2018), 'A8: Securing cost efficiency and enhancement spend', March.
[22] Namely, their P-removals programme only covers a population equivalent of 59,000 with a TOTEX of £27.5m (excluding Hafren Dyfrdwy, this is the smallest P-removals programme in the industry).
[23] South West Water (2018), 'Environment Plan to 2050'.
[24] 80 new sites and one site with a tightened consent.
[25] As noted in section 2, the population equivalent affected is more important than the number of sites, but we provide the number of sites here for comparison with the above figures.

Illustrative impact

In order to illustrate the impact of companies being able to use cheaper options, we remove the population equivalent (but not its costs)[26] of Davyhulme from NWT's data. NWT has identified that it can achieve the required Phosphorus levels in the Manchester Ship Canal using catchment solutions rather than investing in an end-of-pipe treatment solution at Davyhulme WWTW. They have identified that this is over 20 times more beneficial (indicating of up to 20 times lower costs). However, from the EA database, it appears that this obligation contributes 29% of all of NWT's population equivalent with tightened or new P-consents.[27]

We then re-estimate Ofwat's P-removal models, recalculate the WINEP challenge, and apply this to P-removals and WINEP. The resulting allowances are shown in Table 3.3 below. Relative to the post-reallocation allowance, YKY's allowance rises by £103m on P-removals and £117m across WINEP. Furthermore, NWT is no longer efficient across WINEP, whereas it was efficient in Ofwat's original draft determination models. This suggests that Ofwat's modelling is very sensitive to the impact of UWWTD designations/catchment management solutions.

Table 3.3 The impact on YKY's costs of removing the Davyhulme catchment scheme from Ofwat's modelling of P-removals: efficient enhancement cost level after the WINEP UQ challenge (£m)

	P-removals allowance	WINEP allowance
Ofwat's view after YKY's reallocation (1)	498	683
With Davyhulme removed (2)	600	800
Impact (2) - (1)	103	117

Source: Oxera analysis.

Note: Ofwat's P-removal models were re-estimated, and the UQ challenge was calculated at the WINEP level before applying it to P-removals spend. The UQ challenge has been calculated after correcting for Ofwat's calculation error, discussed in section 3.3.

The analysis presented above is illustrative only, as many companies' sites do not have UWWTD designations, and will be able to adopt alternative cheaper solutions including catchment management. Also, we have not accounted for NWT's costs of its catchment solution. However, the analysis does illustrate that UWWTD designations can have a material impact on estimated efficient cost levels.

Below, we estimate the impact across the industry by accounting for UWWTD designations directly in Ofwat's models, rather than adjusting the dataset.

3.2.2 The impact of UWWTD designations on YKY's costs

As discussed above, given that 86% of YKY's load is affected by UWWTD obligations, YKY's unit costs will be higher than those of other companies, all else being equal. As such, we examine the impact of accounting for the directive driving the obligation within Ofwat's modelling framework.

By extending Ofwat's enhancement model to include population equivalent driven by UWWTD obligations, the relative cost impact of these obligations can

[26] As these are not identifiable from NWT's Business Plan.
[27] The EA database states that Davyhulme has a population equivalent of 1,044 ('000s), while Ofwat's P-removals model 'FM_E_WWW_p-removal' shows that NWT has a population equivalent of 3,601.

be picked up.[28] The coefficients have the expected sign, and are statistically significant (see Appendix A1). With the cost allocations made in section 3.1, the P-removals (WINEP) cost allowance is £87m (**£91m**) higher than Ofwat's estimates post-allocation, and £125m[29] (£116m) higher than Ofwat's estimate pre-reallocation. Furthermore, YKY moves from being considered an inefficient company in Ofwat's model to an efficient company in this model.

Table 3.4 Impact of UWWTD on enhancement expenditure: efficient enhancement cost level after the WINEP UQ challenge (£m)

	P-removals	WINEP
Ofwat's view after YKY's reallocation (1)	498	683
With PE UWWTD included	585	774
Difference	**87**	**91**

Source: Oxera analysis.

Note: Ofwat's P-removal models were re-estimated, and the UQ challenge was calculated at the WINEP level before applying it to P-removals spend. The UQ challenge has been calculated after correcting for Ofwat's calculation error, discussed in section 3.3.

3.3 Choice of benchmark

In the draft determinations, Ofwat has applied a UQ efficiency challenge, calculated across the aggregate WINEP position rather than at the enhancement activity level (as undertaken at the IAP).

Ofwat's calculation error of the upper quartile challenge

In the draft determinations, Ofwat has made a calculation error when implementing the efficiency challenge across WINEP programmes. Instead of applying a UQ challenge, it has applied a challenge based on the gap at the other end of the efficiency rankings. In addition, Hafren Dyfrdwy's WINEP outperformance of submitted spend of £2.7m compared with the predicted £9m is clearly not comparable to the other WASCs. If Hafren Dyfrdwy's data is merged with that of Severn Trent, as per Ofwat's approach at the IAP for all enhancement areas where it applied a UQ challenge (i.e. P-removals and flow to full), and the calculation error corrected, the UQ challenge becomes 5% and YKY's position across WINEP TOTEX improves by £26m.

We have used calculated the corrected UQ calculation throughout this paper, although the size of the UQ challenge will depend on the changes that have been made to Ofwat's modelling.

The accuracy of models suggests that an average benchmark should be used for YKY

Ofwat's enhancement models are inherently more inaccurate than its BOTEX models. Ofwat's enhancement cost models have fewer cost drivers than its BOTEX models and are based on forecast data (which itself is inherently uncertain) rather than outturn data (which its BOTEX models are based on). In

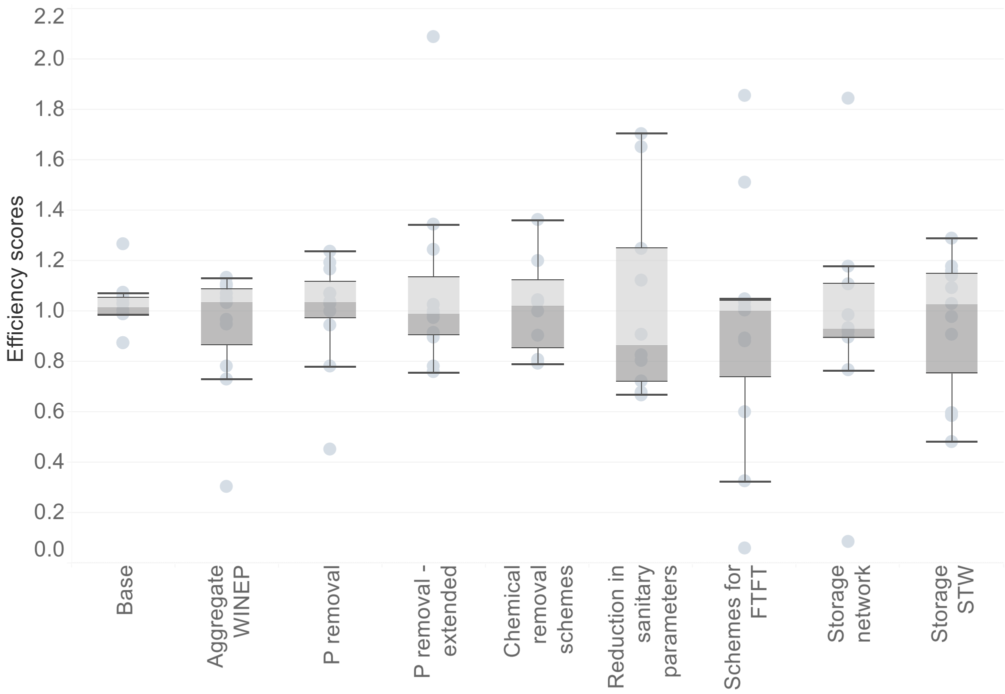
[28] The population equivalent driven by UWWTD obligations is generated from the Environmental Agency dataset. Schemes with exact duplicate names were removed, and only sites with new or tightened P-consents are considered. We have not been able to reconcile the population equivalent data in the Environment Agency dataset with the PE data in Ofwat's dataset. This may be because Ofwat's PE variable includes schemes with catchment solutions, which do display new or tightened P-consents in the Environment Agency dataset.
[29] This is calculated by summing the initial impact of reallocation on P-removals of £38m, and the incremental impact of UWWTD of £85m.

addition, Ofwat's P-removals model is based on only ten observations (as the expenditure is averaged over the period).

Below, we show how the broad range of efficiency scores implies that the UQ benchmark may be too challenging. In particular, we note that BOTEX still has a much tighter range of efficiency scores than enhancement expenditure, and is even tighter under the new cost definition than at the IAP (see Figure 3.1). This is also evident when comparing the fit of the models—the R^2 for Ofwat's wastewater models ranges from 0.846 to 0.946, while for the WINEP models that use regression the R^2 ranges from 0.673 to 0.979.

To the extent that the range within which the cost estimates/efficiency scores lie provides an indication of model accuracy (as per the view of Ofwat's consultants),[30] and Ofwat can be more challenging for more accurate models (as Ofwat itself has previously argued),[31] more accurate models should have the more challenging efficiency target. However, the efficiency challenge for WINEP is 8.6% (5% when corrected for an error—see below), compared with 1.4% in wastewater network plus BOTEX. It is counter-intuitive that less robust models, which have a wider range of efficiency scores, have larger efficiency challenges.

Figure 3.1 Range of efficiency scores by model: Ofwat's base expenditure models compared to Ofwat's WINEP models



Note: The UQ challenge for each model is given by the gap between 100% and the lower 'whisker'.

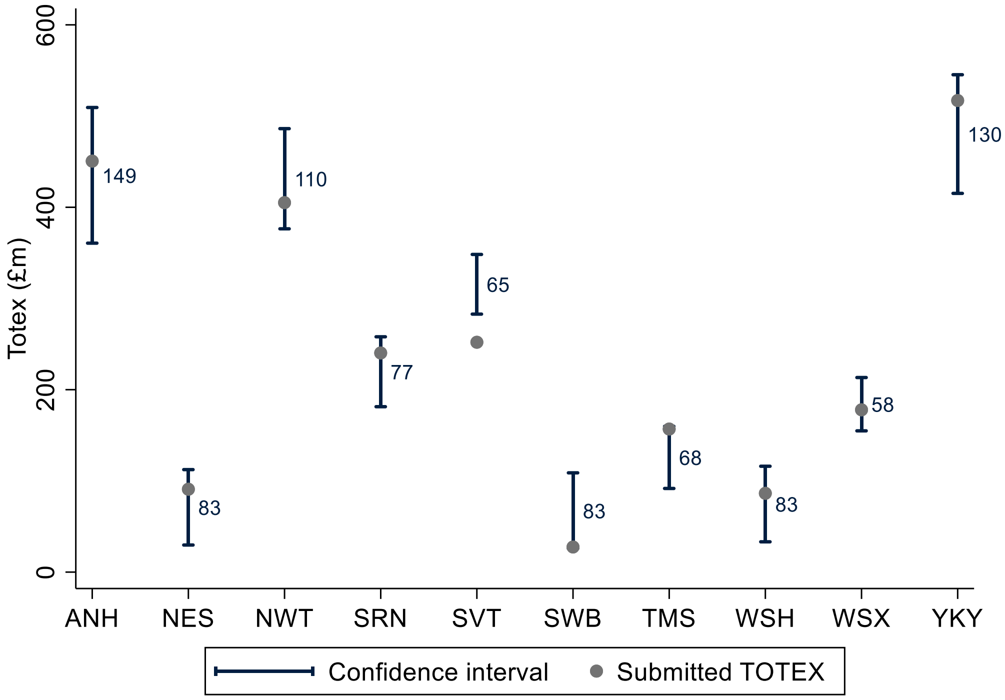
Source: Oxera analysis.

Below we examine the confidence intervals around the cost predictions from Ofwat's model of P-removals (Figure 3.2) and Ofwat's model of P-removals after reallocations and accounting for UWWTD obligations (Figure 3.3). We can see that these are wider, in £m terms, for YKY, AWS and NWT, which all have very large P-removals programmes. This is because the further a cost

[30] CEPA (2018), 'PR19 Econometric Benchmarking Models Ofwat', March, p. 47.
[31] Ofwat (2015), 'Ofwat's initial submission to the Competition and Markets Authority following the acquisition of Bournemouth Water Investments Limited by Pennon Group plc', June, Appendix A4.

driver is from the industry average, the less accurate the model prediction becomes, all else being equal. We also note that YKY is an outlier in both Ofwat's P-removal models and the extended models discussed in section **Error! Reference source not found.**.[32] This is not unsurprising, because as well as having one of the largest P-removals programmes, YKY is extreme on some of the cost drivers in the models, including the population equivalent driven by UWWTD[33] (see Figure 2.1) and the total amount of load with new or tightened P-consents.[34,35] Therefore, even if a model is sufficiently precise for a UQ challenge to be applied to some companies, it may not be appropriate for all companies.

Figure 3.2 Accuracy of model predictions from the Ofwat P-removals model (confidence intervals)

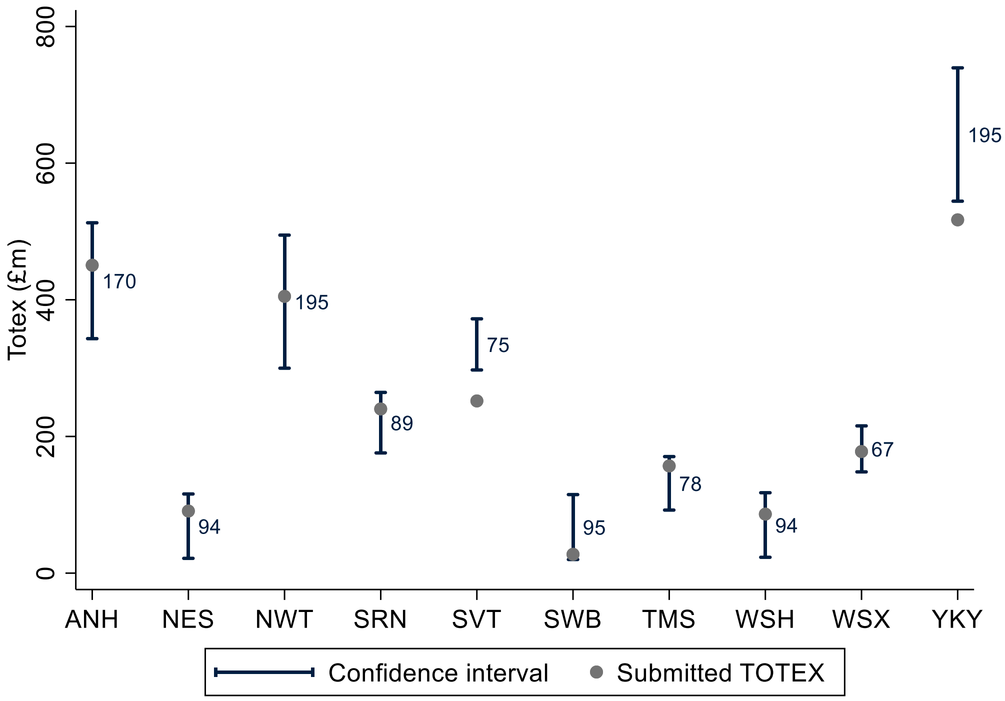


Note: The numbers indicate the range of the confidence interval.

Source: Oxera analysis.

[32] We carried out five outlier tests based on leverage, dffits, Welsch distance, Cook's distance and the standardised residual. YKY is considered an outlier in three out of five tests in Ofwat's models (and in four out of five tests in the extended models). AWS is also considered an outlier in Ofwat's models, and SVT in Ofwat's second model.
[33] As included in the extended models.
[34] As included in Ofwat's models and the extended models.
[35] In addition, as shown in Figure 2.2, YKY is extreme in variables not included in the models, such as the number of existing obligations, for which it has the second lowest value.

Figure 3.3 Accuracy of model predictions from the extended Ofwat P-removals model (confidence intervals)



Note: The numbers indicate the range of the confidence interval.

Source: Oxera analysis.

Given the greater uncertainty around YKY's prediction relative to those of most other companies, a less challenging benchmark may be appropriate for YKY. If an average benchmark were to be used for YKY, YKY's estimated efficient cost level would increase by approximately **£57m** in P-removals and **£76m** across all WINEP categories.

It is also noticeable that under the extended model YKY is only one of two companies whose costs are below the confidence interval of the model prediction, indicating relatively efficient costs (Figure 3.3). In contrast, under Ofwat's model, YKY's costs are within the confidence interval of the cost prediction (Figure 3.2).

4 Base expenditure[36]

P-removal solutions can involve building additional complex treatment processes, which has an ongoing operational and capital maintenance component that is not currently captured in the modelling. Therefore, P-removals also affect base expenditure.[37]

On the base expenditure models, Ofwat has not changed the model specification, but has made a number of other changes.[38] However, Ofwat's BOTEX approach still does not account for the impact of P-removal on the ongoing costs of maintaining sewage treatment works, as we had previously

[36] The analysis in this section is based on data that is available at the Draft Determinations. Therefore, it does not account for any potential changes in company input costs.
[37] Expenditure to modify *existing* treatment works to accommodate the tighter consents—i.e. resizing and/or upgrading existing assets—has now been allocated to enhancement expenditure. See above.
[38] The cost base included in the econometric models now includes income treated as negative expenditure, new development and connections enhancement, growth at sewage treatment works enhancement, and reduced flooding risks for properties enhancement. Ofwat has also changed its forecast methodology for many companies, in particular using ONS data on population where available.

provided evidence on.[39] Below we examine the impact of accounting for P-consents.

4.1.1 Phosphorous removals base expenditure

Below, we update the impact on base expenditure, taking into account Ofwat's changes to its econometric modelling framework, modelling the impact of increased treatment complexity on ongoing operational and capital maintenance component.

To capture P-removal treatment complexity costs, we create a composite variable combining the stringency of ammonia and P-consents.[40] The coefficients have the expected sign, and are statistically significant.[41]

Table 4.1 Impact of tight consents on base expenditure after a UQ challenge is applied

Model	YKY's estimated efficient cost level (£m)
Ofwat (1)	1,558
Replacing Ofwat's ammonia consent variable with a composite ammonia and P-consents ≤ 0.5mg/l variable (2)	1,601
Impact (2) - (1)	**43**

Note: Had costs not been reallocated as described in section 3.1, Ofwat's base models would also have needed to be modified to account for the cost of upgrading. In Oxera's earlier work, this was captured by including the percentage of PE with new or tightened P-consents.

Source: Oxera analysis.

This suggests that there should be a positive adjustment of **£43m** on YKY's BOTEX allowance.

5 Estimating the overall impact on YKY's total expenditure

In this report we have examined the cost adjustments required for YKY to account for its unique position with regard to P-removals. In order to quantify the impact, we examined a number of amendments to Ofwat's modelling of P-removals enhancement and base expenditure. This improves the robustness of the modelling with regard to estimating YKY's efficient cost level. We also consider that the WINEP models are not sufficiently accurate to justify using a UQ over an average benchmark, particularly for YKY, which has a very large P-removals programme and a significant majority of this is driven by UWWTD obligations.

The table below summarises the impact on enhancement expenditure.

[39] Oxera (2019), 'Ofwat's enhancement modelling approaches at the IAP: a review', March.
[40] When estimating a model with P-consents and ammonia consents included separately over a dataset combining both the historical and forecast periods, we find some evidence that their coefficients are similar in size.
[41] Details are provided in Appendix **Error! Reference source not found.**.

Table 5.1 Summary of impact improvements to Ofwat's enhancement modelling

Changes to enhancement modelling	WINEP allowance (£m)
Ofwat's view (1)	658
Reallocations (section 3.1)	+25
UWWTD (section 3.2.2)	+91
All enhancement modelling changes modelled together (2)	+116
Ofwat's view, with all modelling changes included (3) = (1) + (2)	**774**
Moving from a UQ to the average benchmark (section 0) (4)	+76
Ofwat's view, with all modelling changes included and an average benchmark across WINEP (5) = (3) + (4)	**848**

Source: Oxera analysis.

In addition, we augment Ofwat's base expenditure model to account for the complexity of P-removals treatment.

Table 5.2 Impact of tight consents on base expenditure

Model (relative to Ofwat base)	YKY's estimated efficiency cost level (£m)
Ofwat's view (1)	1,558
Accounting for phosphorus treatment complexity (section 3.3.1) (2)	+43
Ofwat's view, accounting for phosphorus treatment complexity (1) + (2)	**1,601**

Source: Oxera analysis.

In summary, YKY's overall enhancement and base allowance rises from £2,216m to £2,449m, an impact of **£234m** (including an implicit enhancement OPEX allowance).

Table 5.3 Combined impacts of enhancement and base modelling changes

Changes to P-removals modelling	WINEP allowance (£m)
Ofwat's view (1)	2,216
Enhancement modelling changes (2)	+116
Moving from a UQ to an average benchmark (3)	+76
Accounting for phosphorus treatment complexity in base (4)	+43
Overall impact (5) = (2) + (3) + (4)	+234
Revised YKY allowance (1) + (5)	**2,451**

Source: Oxera analysis.

A1 Ofwat's enhancement models including UWWTD drivers

We have split the population equivalent into two variables—population equivalent at sites with UWWTD obligations, and population equivalent at sites without a UWWTD obligation. We can see that UWWTD obligations are more costly to meet than non-UWWTD obligations, although both are highly statistically significant. A test of whether the coefficient of PE driven by UWWTD obligations is equal to the coefficient of PE driven by non-UWWTD obligations is rejected at the 5% significance level, implying that the incremental costs from UWWTD are statistically significant.

Figure A1.1 Ofwat's P-removals enhancement models, accounting for UWWTD obligations

	Model 1	Model 2
Total population equivalent not driven by UWWTD obligations (1)	0.0612**	0.0618**
	(0.0149)	(0.0242)
Total population equivalent that is driven by UWWTD obligations (2)	0.132***	0.123***
	(5.24e-05)	(0.000167)
Number of sites	1.624***	
	(0.00409)	
Change in total number of STWs with P-consents ≤ 0.5mg/l		3.010***
		(0.00870)
Constant	14.43	19.26
	(0.592)	(0.524)
Observations	10	10
R-squared	0.969	0.961
P-value: test that the coefficient of (1) is equal to the coefficient of (2)	0.0192	0.0444

Source: Oxera analysis.

A2 Ofwat's base expenditure models including P-consents

Figure A2.1 Sewage treatment models

Dependent variable	**Log of real sewage treatment BOTEX**					
log(Load)	0.849***	0.842***	0.843***	0.835***	0.836***	0.829***
Percentage of load treated at STWs between size bands 1 and 3	0.058**		0.057**		0.0574**	
Percentage of load with ammonia consents less than 3mg/l			0.004***	0.004***		
Percentage of load treated at STWs of size band 6		-0.012**		-0.015*		-0.015*
Composite ammonia and phosphorus variable	0.004***	0.004***			0.004***	0.004***
Percentage of PE under new/ tightened consents			0.005***	0.004***	0.005***	0.004087***
Constant	-6.190***	-4.689***	-6.114***	-4.642***	-6.028***	-4.564***
Observations	70	70	70	70	70	70

Source: Oxera analysis.

Figure A2.2 Bioresources plus models

Dependent variable	**Log of real bioresources plus BOTEX**					
log(Load)	0. 836***	0.805***	0.825***	0.788***	0.821***	0.785***
Percentage of load treated at STWs between size bands 1 and 3	0.051***		0.050***		0.050***	
Percentage of load with ammonia consents less than 3mg/l			0.005***	0.005***		
Percentage of load treated at STWs of size band 6		-0.011**		-0.011**		-0.011**
Composite ammonia and phosphorus variable	0.005***	0.005***			0.005***	0.005***
Percentage of PE under new/ tightened consents			0.006***	0.005***	0.006***	0.005***
Constant	-5.723***	-4.244***	-5.594***	-4.107***	-5.542***	-4.056***
Observations	70	70	70	70	70	70

Source: Oxera analysis.