Update to claim: Combination of exogenous factors impacting surface water runoff

Cost assessment representations: Appendix

Document Reference: D003a

This is our more comprehensive response to the short note provided in UUW.CE.A1 of “I001 - United Utilities Actions Response Document” and addresses the feedback received in the assessment of the cost adjustment claim for the Wastewater Network+ baseline due to the “combination of exogenous factors impacting surface water runoff”.

United Utilities Water Limited

Contents

1. Introduction

This is our more comprehensive response to the short note provided in UUW.CE.A1 of "*I001 - United Utilities Actions Response Document*" and addresses the feedback received in the assessment of the cost adjustment claim for the Wastewater Network+ baseline due to the "*combination of exogenous factors impacting surface water runoff*". In reviewing the comments for each of the assessment gates, we believe that key aspects have not been fully accounted for which when coupled with inaccurate data (on our part, from PR14) have led Ofwat to its conclusion. We remain confident that the need for an adjustment is justified from both an econometric and engineering perspective and that there are "*regional operating circumstances with significant impact on costs*" which support the need for a cost adjustment claim.

This supplements the information previously supplied within the May and September 2018 submissions and does not seek to repeat information contained within these other than for where it directly relates to an issue raised. For clarity, although we now have visibility of Ofwat's models, we are not changing the valuation of the claim and therefore the £87.7m is still applicable. We address each of the assessment gates separately, responding to the issues raised in turn and providing clarity and further validation where necessary.

1.1. Feedback from the IAP

The results of the assessment of the claim is contained within FM_CAC_NWT_IAP under NWT-WWN801001 and summarised in Table 1 below. Overall, Ofwat assessed the claim as having a "*lack of evidence to demonstrate the need for adjustment. Costs estimates are not robust. Although United Utilities Water demonstrates that it is an outlier regarding surface water runoff, it has not presented convincing evidence that this results in a more expensive suite of assets and thus higher costs*."

Table 1 IAP gate results for cost adjustment claim WWN801001 - Combination of exogenous factors impacting surface water runoff

Test area	Assessment
Need for investment	N/A
Need for adjustment	Fail
Management control	Pass
Best option for customers	N/A
Robustness and efficiency of costs	Fail
Customer protection	N/A
Affordability	N/A
Board assurance	N/A

This results in an IAP assessment for overall quality as a fail, reducing United Utilities score for IAP test question CE4 from a B to a C (with a fail receiving -5 'points'). We respond to the comments made in each of these failed assessment gates in the following sections.

We structure the remainder of this document according to the test gateways, responding in turn to each of the issues that Ofwat highlight, providing additional evidence in support of our claim where necessary.

2. Need for adjustment

Ofwat note

> *“there are **two factors that suggest that United Utilities Water does not incur higher costs** to manage this regional runoff than from other companies: natural drainage through rivers, and its own asset characteristics”.*

- “United Utilities Water fails to evidence that it actually receives higher levels of runoff in its sewers, as opposed to these being drained naturally”
- “United Utilities Water **does not have larger sewer assets** or an above-average number of the largest sewers in terms of diameter”

We address each of these factors in turn in sections 2.1 and 2.2 below.

2.1. Evidencing that UUW actually receives higher levels of runoff in its sewers, as opposed to these being drained naturally.

> *“Using regional figures for rainfall and urban density to calculate runoff masks that, in United Utilities Water's catchment area, the areas with the highest rainfall are not urban. In fact the highest rainfall occurs on unsewered areas – notably the Lake District – and this will flow into rivers, not sewers. Figure 13 in their WwNI_M report shows that most of the large built-up areas (including Manchester and Liverpool) lie in the drier parts of United Utilities Water's region.”*

Whilst we accept that Arup’s use of aggregated data in the construction of the drainage variable for use in modelling does have its limitations, Ofwat uses this approach to constructing variables extensively elsewhere within cost assessment, notably in the derivation of proxy density variables e.g. using numbers of properties and sewer lengths. Additionally, this criticism is in stark contrast to Ofwat rejecting sub-regional disaggregation of model variables at PR14, when United Utilities made representations to disaggregate density variables to represent the extremes of high and low density in the urban south and rural north of its region. We do not believe that it is correct to dismiss this construct on this basis given the precedent already set. Furthermore, whilst the statement that the highest rainfall occurs within the Lake District when compared to built-up areas (Greater Manchester) is true, comparative assessments solely within the North West neglect the underlying basis of the claim which is that these built-up areas still receive higher average levels of rainfall experienced by other companies and regions. The interactive tool provided by the Met Office (which uses the same base data as the Arup variable) on their website[1], as captured in Figure 1 and summarised in Table 2 below, enables a granular desktop comparison between cities and regions throughout the UK. This unequivocally demonstrates that **average annual rainfall within our major urban conurbations (Greater Manchester etc) is significantly higher than average**, particularly those cities within the East and South East of England. Figure 8 within the Appendix also demonstrates this by ranking the rainfall within the largest 100 cities in England & Wales by rainfall, of which 17 out of the top 26 cities fall within our region.

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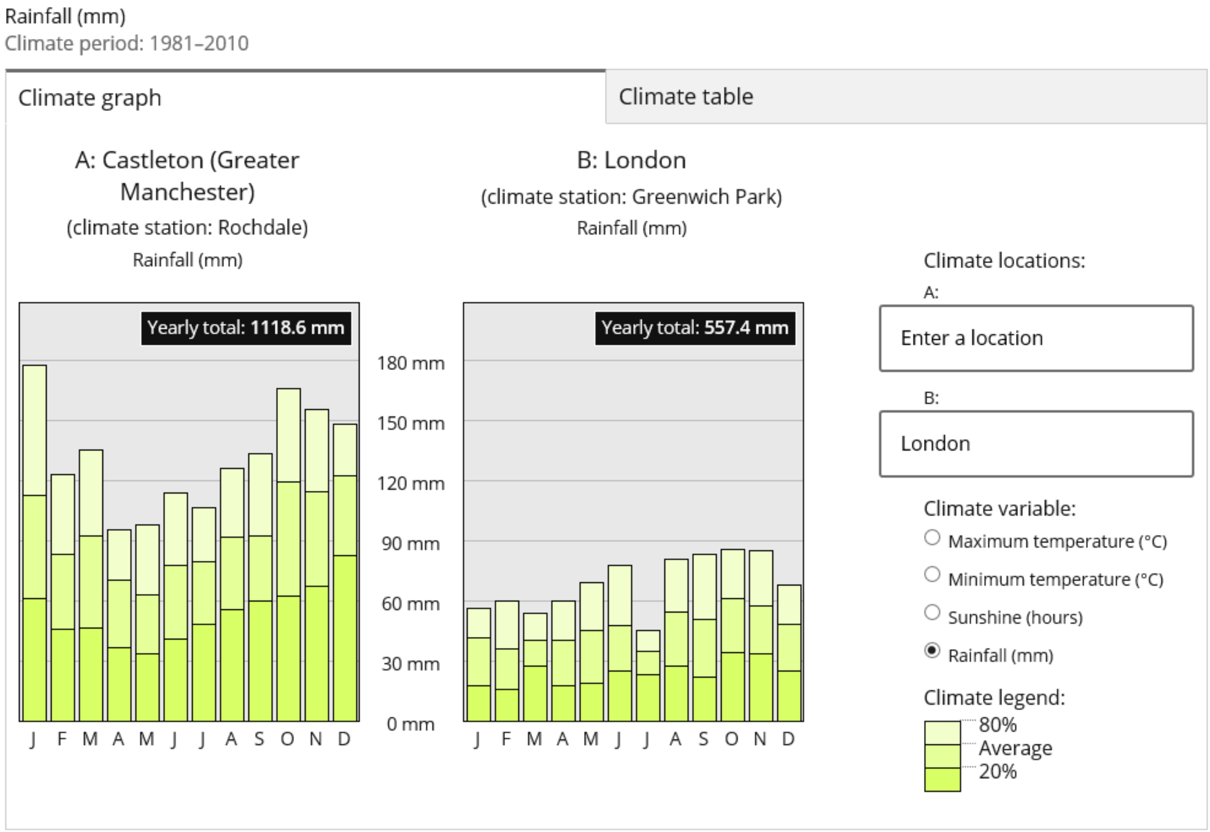
[1] https://www.metoffice.gov.uk/public/weather/climate/gcw2ys6fr

Table 2 Met Office rainfall comparisons between major cities [https://www.metoffice.gov.uk/public/weather/climate/gcw2ymd6s]

Company	City/Climate location	Climate Station	Average rainfall (mm)	Variance (mm)
Anglian	Norwich	Coltishall	674.2	-155.3
Dŵr Cymru	Cardiff	Cardiff	1,151.9	322.4
Northumbrian	Newcastle	Tynemouth	597.2	-232.3
United Utilities	Greater Manchester	Rochdale	1,118.6	289.1
Southern	Southampton	Southampton W.C.	779.4	-50.1
Severn Trent	Birmingham	Winterbourne	804.9	-24.6
South West	Exeter	Exeter Airport	784.9	-44.6
Thames	London	Greenwich Park	557.4	-272.1
Wessex	Bristol	Filton	802.1	-27.4
Yorkshire	Leeds	Bingley SAMOS[2]	1,024.1	194.6
Average			**829.5**	

Figure 1 Rainfall location comparison tool [https://www.metoffice.gov.uk/public/weather/climate/gcw2ymd6s]



Climate locations:

A: Enter a location

B: London

Climate variable:

○ Maximum temperature (°C)

○ Minimum temperature (°C)

○ Sunshine (hours)

● Rainfall (mm)

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[2] Leeds is located east of Bingley SAMOS and west of Church Fenton, which only receives 603.2mm of rainfall on average, and therefore the actual annual rainfall within the Leeds urban area is likely to be significantly lower than what we have stated within Table 2 but we have maintained the Met Office mapping for completeness.

The Met Office state that “we would expect, on average, once every five years to be lower than the 20% value and once every five years higher than the 80% value”. This further compounds the fact that on average for the same stations, **Greater Manchester has the highest number of days rainfall >1mm each year of all cities** (as shown in Table 3 below). The result of this is that the potential total exposure is significantly higher and that our assets are required more frequently to deal with the additional rainfall experienced within our major urban areas (increasing ongoing maintenance requirements thus cost).

Table 3 Average days of rainfall >= 1 mm per year (days) comparisons between major cities [1981-2010]

Company	City/Climate location	Climate Station	Days of rainfall[3] >= 1 mm (days)	Variance (days)
Anglian	Norwich	Coltishall	122.8	-6.9
Dŵr Cymru	Cardiff	Cardiff	148.6	18.9
Northumbrian	Newcastle	Tynemouth	109.5	-20.2
United Utilities	Greater Manchester	Rochdale	161.7	32.0
Southern	Southampton	Southampton W.C.	114.7	-15.0
Severn Trent	Birmingham	Winterbourne	131.1	1.4
South West	Exeter	Exeter Airport	121.1	-8.6
Thames	London	Greenwich Park	109.4	-20.3
Wessex	Bristol	Filton	125.9	-3.8
Yorkshire	Leeds	Bingley SAMOS	152.3	22.6
Average			**129.7**	

An important difference between our region and others that experience higher than average levels of rainfall in a year (such as Welsh Water and South West Water) is that many of our urbanised areas lie inland rather than on the coast (with Liverpool being the exception). A significant proportion of customers live within the Greater Manchester and surrounding areas of central Lancashire that simultaneously experience the higher than average levels of rainfall each year. With major conurbations being located inland rather than coastal, it means that there are less opportunities for surface water to runoff naturally (i.e. into the sea or rivers/estuaries) and instead more surface water runoff needs to be transported through the network or stored in tanks if sewer capacity is strained. All of this adds to both the base requirements of a network and the ongoing maintenance of that network.

> *“This is corroborated by the fact that although the company operating area is relatively urbanised, the proportion that is sewered is in line with industry average. Our data also suggests that United Utilities Water's proportion of surface water received at treatment works is in line with the average, (66% vs. 62%).” Ofwat.*

Our attempts to replicate Ofwat’s figure 2 within the cost adjustment response have raised two issues with the above statement. Firstly, we have been unable to replicate the same information but given the factors mentioned, believe that this graph must have been extrapolated by using APR data contained within tables 4E (‘Volume collected’ lines 4E.25) and 4R (line 4R.13). A quick analysis of the 2018 APR is within Table 4 below which shows that United Utilities’ proportion of surface water

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[3] For 'Days of' elements, 0.1 equates to one day every ten years, 0.5 to one day every two years, 2.5 to five days every two years, and so on.

received at sewage treatment works is significantly higher than the average (62% vs 44%) which is not in line with Ofwat's findings.

Table 4 Replication of Ofwat figure 2 using 2018 APR datashare

	4E Volume collected (surface water) [Ml]	4E Volume collected (highway) [Ml]	4R Volume of wastewater receiving treatment at sewage treatment works	Proportion of wastewater treated that is surface water
Anglian	211,305	95,744	582,806	53%
Dŵr Cymru	50,502	27,720	551,701	14%
Northumbrian	98,440	53,006	315,276	48%
Southern	41,181	41,181	421,781	20%
Severn Trent	291,094	193,136	1,011,903	48%
South West	72,295	63,854	221,281	62%
Thames	325,097	179,348	1,613,153	31%
United Utilities	526,322	209,876	1,175,529	63%
Wessex	68,380	68,380	318,334	43%
Yorkshire	317,487	94,834	659,205	63%
Average	**2,002,102**	**1,027,078**	**6,870,970**	**44%**

However, our analysis of this information has raised another issue that should preclude the use of this data without further validation. Companies have clearly adopted significantly different methodologies to populating these lines within the APR, seen by looking at the difference in the sum totals of the volumes between tables highlighted in Table 5 below.

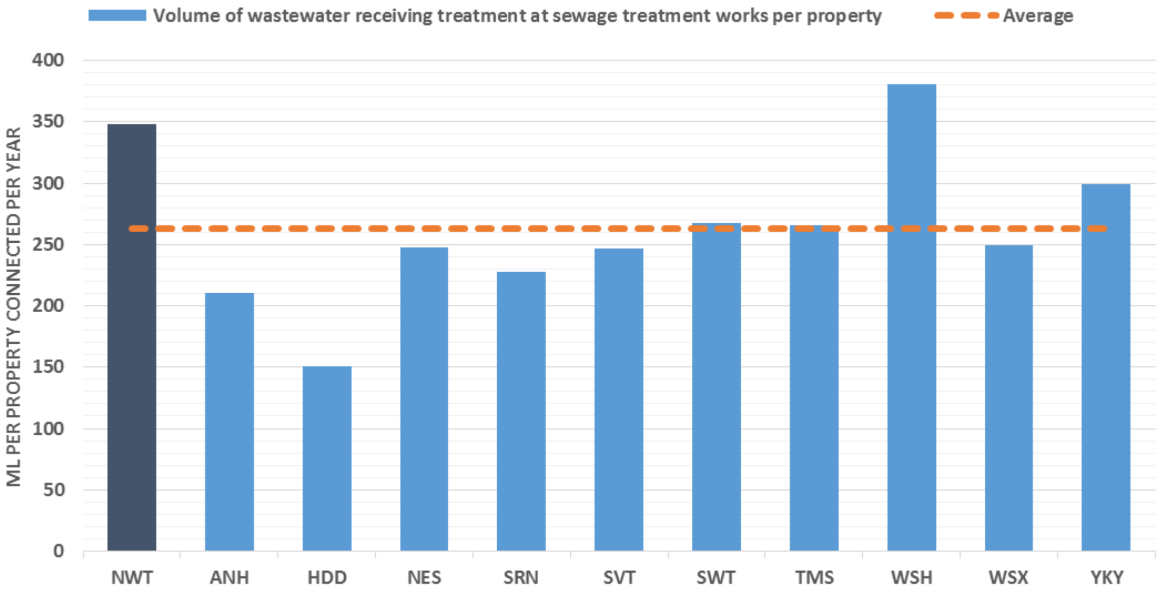
Table 5 Comparative industry analysis of sewage volumes [2018 APR]

	Volume collect (foul)	Volume collected (surface water)	Volume collected (highway)	Total volume collected	Volume of wastewater receiving treatment at sewage treatment works	Variance (should be zero)
Anglian	495,747	211,305	95,744	802,796	582,806	219,990
Dŵr Cymru	209,613	50,502	27,720	287,835	551,701	-263,867
Northumbrian	163,830	98,440	53,006	315,276	315,276	0
Southern	188,922	41,181	41,181	271,284	421,781	-150,497
Severn Trent	1,011,903	291,094	193,136	1,496,133	1,011,903	484,230
South West	85,114	72,295	63,854	221,263	221,281	-18
Thames	702,658	325,097	179,348	1,207,102	1,613,153	-406,051
United Utilities	439,331	526,322	209,876	1,175,529	1,175,529	0
Wessex	176,953	68,380	68,380	313,713	318,334	-4,620
Yorkshire	298,445	317,487	94,834	710,765	659,205	51,560

United Utilities, along with Northumbrian and South West (the minor variance assumed in error), apply the logic in that the volume collected must equate to the volume received at a sewage treatment works (as spills are not 'collected' and treatment returns would quantify a double count). Anglian, Severn Trent and Yorkshire all receive less volume at their works than is collected by their network whilst Southern, Thames, Welsh and Wessex all receive more volume at their works than is collected. These clear discrepancies mean that we cannot credibly support the use of this information in comparative assessments even if the analysis within Table 4 would validate that we are significant outliers when it comes to the proportion of surface water received. We also query the use of percentages as a method by which to assess company exposure to cost because of drainage requirements. The physical volume transported drives the required costs rather than the proportion of the total and so a percentage does not capture this impact. Additionally, these factors are not directly related to size and will therefore cannot be assumed to be predicted by the scale variable within an econometric model.

We have analysed at the volume data provided by companies at PR19 in isolation, as we may still be able to make some reliable comparisons if companies have provided credible justification for the variances above. Comparing the normalised (by connected property) volumes of wastewater receiving treatment at sewage treatment works (PR19 submission table WWn3, line 13, ref CPMS2015) would support the evidence highlighted by the Met Office dataset that higher levels of rainfall are required to be dealt with by United Utilities, Welsh, South West and Yorkshire Water as shown in Figure 2 below.

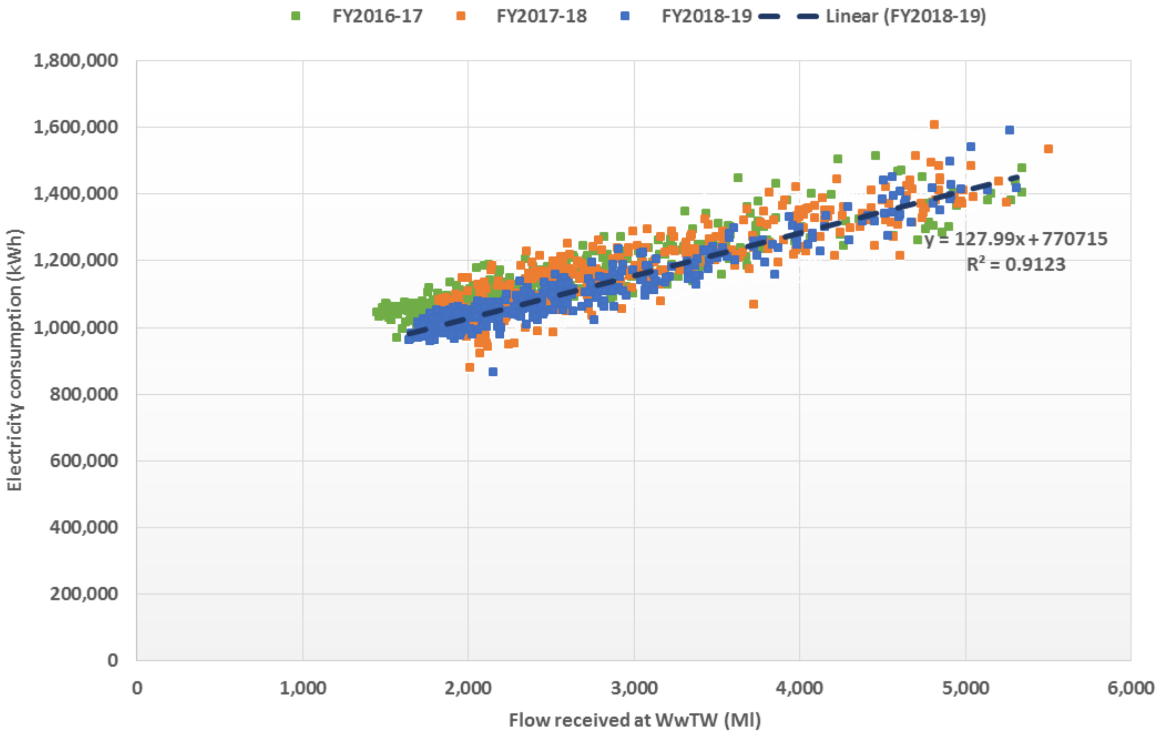
Figure 2 Average annual volume of wastewater received at sewage treatment works per capita [2020-21 to 2024-25]



This supports the need for the claim and that we do indeed accommodate higher levels of runoff (inferred by total volume as household volumes should be broadly comparable between companies) within our system rather than it returning to the environment naturally.

It is important to note that the total cost associated with managing these additional volumes is not solely limited to the assets and operations contained within the sewage network. Indirectly, having additional flows at a treatment works will require either increases to the maximum capacity (the flow to full treatment) of the works or the addition of storage within the boundaries of the site (volumes that are not accounted for within network storage). Whilst the construction of these assets would clearly be enhancement expenditure, once constructed, they further add to the on-going maintenance requirements of the company in addition to the operational requirement to pump larger volumes out of storage and/or through the treatment process. From an operational viewpoint, we have a significant amount of internal data that we can use to analyse this relationship as around 90% of our total electricity use is on assets that are half-hourly metered, allowing us to support our future operational planning as well as the identification of potential efficiencies. Figure 3 below shows the last three years of data for these operational impacts and illustrates the strong relationship that you would expect to find between volume and energy consumption.

Figure 3 United Utilities Wastewater Treatment: total daily electricity consumption and flow received



Although from an engineering point of view the legitimacy of higher cost requirements is undoubtable, the potential issues highlighted above with the industry wide data meant that in the interest of fairness and balance, we did not seek to include any additional costs of treatment within the cost adjustment claim. We have calculated the additional power costs in an AMP due to higher volumes using the marginal electricity consumption (the gradient) illustrated above. This **results in a range of £7.58m-£8.92m (per AMP) for average rainfall with the upper range of £28.93m-£33.28m based on maximum annual rainfall using our measured data or £17.10m using the industry average volume data** (depending on the approach adopted as set out in *Calculation methods for additional treatment costs associated with higher runoff/volume* in the Appendix). Clearly, this is not an insignificant amount to have accepted as another efficiency within our business plan. Whilst these approaches may have their limitations, they do offer quantifiable approaches to valuing the additional cost pressures faced by our treatment operations by using actual power data. If we had more confidence that the supporting industry data would have not devalued the quality of our claim, then we would have included this at the outset rather than only seeking additional expenditure related to network assets and activities.

This information set out above provides clear evidence that United Utilities does actually receive higher levels of runoff in its sewers, as opposed to these being drained naturally and therefore Ofwat should instead accept the need for the claim and proceed to the next stage gate.

2.2. Confirmation that UUW has larger sewer assets or an above-average number of the largest sewers in terms of diameter.

Ofwat refers to the fact that United Utilities' asset characteristics for the sewer stock includes lower than average proportion of pipes above 626mm diameter. We have replicated this analysis and believe that the last time this information was explicitly reported was within the 'Asset information for wastewater service' table submitted at PR14 (table S5). We still collect and maintain this information within our corporate systems. We use it to calculate the total volume of network storage as reported in PR19 table WWS4 and so we have been able to validate the information using current data. Comparing the PR14 lengths with our current internal data, PR14 has a significant reduction in the length of large diameter sewers that was due to an error in reporting rather than a change in the assets that we operate and maintain. Comparing this information over time (for PR09, PR14 and with our latest APR data), our current data is consistent with that previously reported before PR14. We are confident that the error is an isolated occurrence to PR14 where the lengths had been (incorrectly) reallocated to band three (321mm – 625mm) from the higher categories as illustrated in Figure 4 below.

Figure 4 UUW Asset information for wastewater service: band 3 and above over time

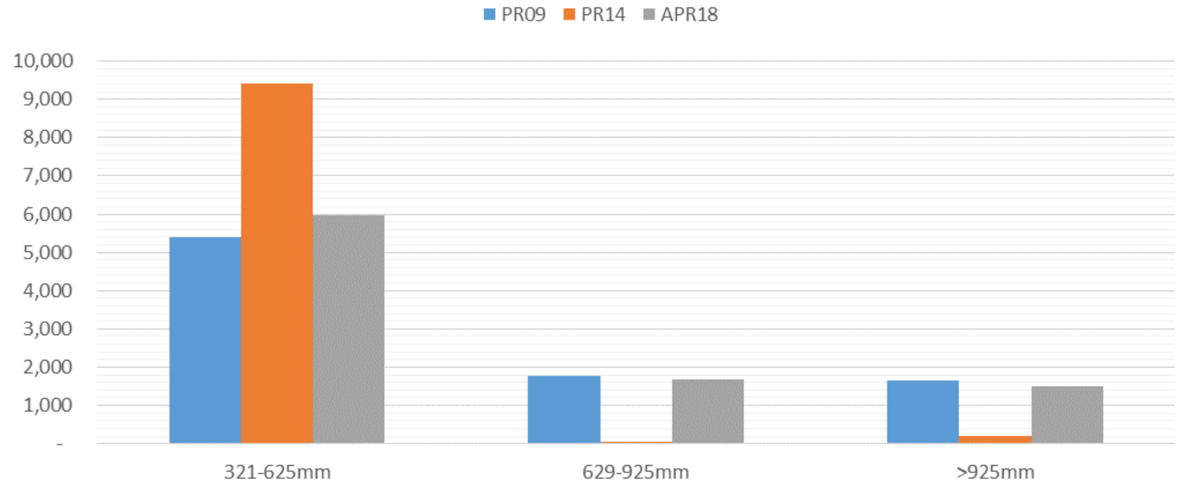
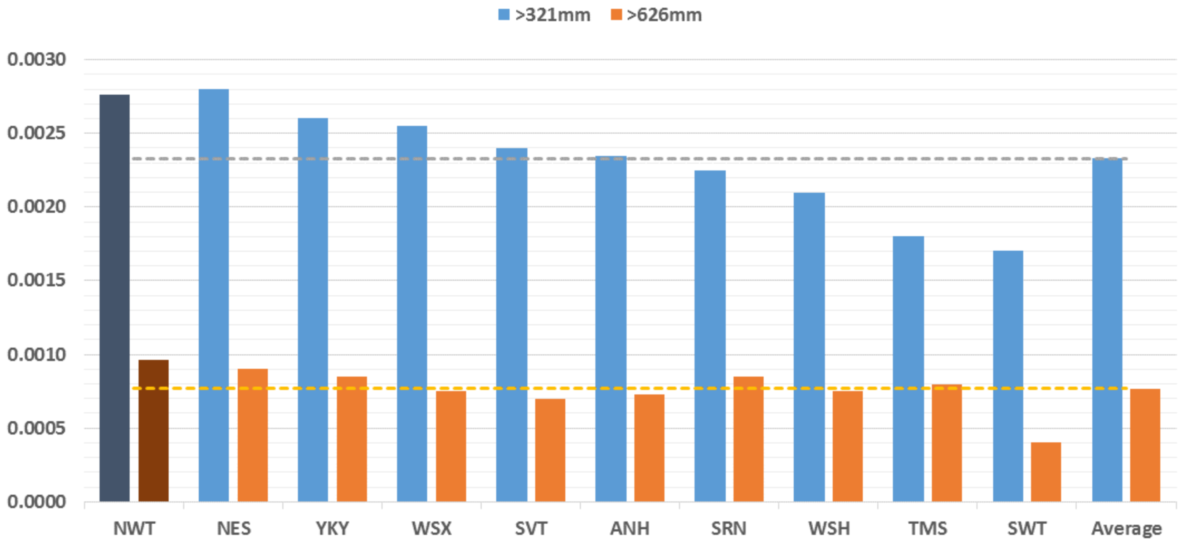


Figure 5 below replicates the information provided by Ofwat and illustrates that when correcting for this error (holding other companies constant) United Utilities is above industry average for both sewers larger than 321mm and 626mm, which is in line with expectations. This reasserts the fact that we do own and operate larger assets that given the engineering evidence, result in the higher than average maintenance requirements and support the necessity for a cost adjustment claim to account for this not being reflected within cost assessment.

Figure 5 Updated asset characteristics: length per sewer connection



Appreciating that whilst it does not solely represent Wastewater collection assets, we can further illustrate the larger asset base that we are required to maintain by comparing the relative sizes of each Wastewater network plus RCV to the efficient base expenditure predicted by Ofwat within the IAP. As Figure 6 demonstrates, for the majority of companies, botex predictions in the IAP correlate well with scale of the RCV and so (ceteris paribus) base cost 'allowances' *should* provide sufficient expenditure to maintain their respective assets/RCVs[4]. The relationship between maintenance requirements and the size of a company asset base is logical and has precedent in regulatory cost assessment, for example Scottish Water's Asset Stewardship Modelling[5]. Whilst this approach does not form part of Ofwat's derivation of botex baselines, it should at the very least be used as a sense check that modelled predictions are reflective of the asset base a company is required to maintain. Within this comparison, United Utilities are once again significant outliers, demonstrating that we must operate and maintain the largest asset base within the sector but for a fraction of the base expenditure predicted by econometric models. It is clearly not possible to capture every single specific factor within an econometric model for the industry, but Ofwat should not overlook this this skew in the predictions in favour of blind reliance on model results.

Figure 6 Wastewater network plus opening RCV in relation to efficient modelled base expenditure allowances

Finally, we note that Ofwat states;

> *"United Utilities Water also claims that their current allowance is too low in order to meet an upper quartile performance target, and that the upward cost adjustment of £87.717m is to support the resilience improvements needed to improve their performance on flooding (p.32 in WwNI_M).* ***This seems to imply***

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[4] We illustrate this relationship using the RCV for each company but the same relationship holds if the (natural) RCV run off is used

[5] 'Scottish Water's approach to capital maintenance', Report by the Independent Assuror, 2013

> ***an enhancement rather than an adjustment to baselines which is inconsistent with United Utilities Water's claim of consistently higher baseline costs**."*

This comment is inconsistent with the approach taken by Ofwat to assessing other claims whereby,

> *"we consider that base allowance provides expenditure sufficient for companies to achieve an upper quartile level of performance by 2024-25" (Anglian leakage cost adjustment claim).*

If botex baselines are intended to provide sufficient expenditure for companies to achieve upper quartile performance, then our need for a claim against this baseline in its current form is applicable and should not be rejected. If however Ofwat now deem that the botex allowance does not provide sufficient allowance for upper quartile performance, we believe that it is appropriate for Ofwat to make an enhancement allowance in order to enable companies to 'catch up'.

3. Robustness and efficiency of costs

Within the comments for this test, Ofwat notes

> *"The engineering quantification of costs is not robust…To show how the run off affects costs, United Utilities Water commissioned Arup to create a financial model of an average efficient wastewater company using market costs for different assets and activities. There are two key issues with the model."*
>
> - ***"The model seems to only consider sewer sizes up to 600mm****. While United Utilities Water is an outlier in having more sewers of medium sizes (above 321mm), it is not an outlier in sewers of the largest bands (above 626mm). United Utilities Water's own data submitted shows that unit costs increase in diameter size above 321mm. Therefore, the engineering model omits some of the (arguably) most costly assets, which would drive up modelled costs for other companies, but not United Utilities Water itself."*
> - ***"The modelled costs may not be efficient****. While (potentially) efficient costs are calculated for an average company, actual company asset profiles are used for actual companies - it is not clear whether the asset profiles would be efficient for each company (e.g. companies could build larger sewers unnecessarily)."*

Furthermore, on a separate issue Ofwat

> *"note also that the econometric evidence for the relevance of runoff as a cost driver is not compelling."*

We address these three issues in sections 3.1, 3.2 and 3.3 below.

3.1. The model considers catchments that have an average sewer size of up to 600mm.

The model developed by Arup theorises the **average sewer size** within a catchment rather than diameter of all sewers within each catchment. Engineering logic informs the average diameter assumptions, which is then applied consistently to each of the ranges. This assumption reflects both the fact that within more heavily populated catchments, larger diameter sewers are required but also that there will still be a proportion of smaller sewers within the catchment and that not all will be the same size. This means that while the maximum diameter used within the modelling may only be 600mm, this permutation will reflect a range of different sewer sizes, a proportion of which will be larger than 600mm (by the laws of averaging) and so the model does indeed capture the effects of having these larger assets.

As evidenced within section 2.2, the perception that United Utilities operates a smaller (diameter) asset base is due solely to a reporting error. Once corrected, this data and the resulting comparison across the industry then supports the weightings to the catchments in the modelling of United Utilities within the Arup model.

3.2. Confirmation that credible/independent assessments derive the predictions of modelled costs.

We agree that including the use of actual company data does increase the potential to bias the results if there had been inefficient investment by firms. While the Arup model does utilise actual company data for the length of sewer (in order to derive a company cost assumption), it **does not use actual company volumes**. We do not consider that there is a significant risk around using the length of sewers reported by companies as this is used often used within cost assessment as a scale driver and therefore there must be a reasonable degree of certainty over its accuracy. Therefore, as the model uses the theorised/required average asset characteristics (given the specific urban runoff requirements) actual investment decisions have no impact on the results and the costs predicted can be taken be to efficient both from a unit cost perspective (as they have been provided by the market) and from a scale perspective.

3.3. Evidence supporting the relevance of runoff as a cost driver

> *"The econometric evidence is insufficient to demonstrate the need for adjustment. United Utilities Water provides evidence that the variable is statistically significant and positive in some models…Moreover, we have tested a runoff variable combining urbanisation and rainfall. While this variable was significant,* ***it was highly collinear with our scale driver. Therefore, a large portion of this claim will be captured by the implicit allowance.****" Ofwat.*

Ofwat's assertion that collinearity with the scale driver precludes the need for a cost adjustment for United Utilities appears to be based on a simple aggregate correlation result rather than an assessment of the company specific distributions between the variables. As evidenced in Figure 7 below (using the scale variable proposed in the collection models), whilst for many companies the relationship between scale and drainage is highly correlated (although not causal), United Utilities is a clear and significant outlier, receiving a considerably higher average annual urban runoff for a company of its size than the rest of the industry. Indeed, the average annual urban runoff is comparable to that of the size of Thames that operates a significantly larger asset base but, importantly, is remunerated for this through the inclusion of the scale variable. **Using the corresponding scale value for the levels of drainage experienced by United Utilities within Ofwat's model suite would add almost £500m[6] of post-efficiency expenditure to the Wastewater baseline**.

Figure 7 Company relationships between different scale variables and annual urban runoff

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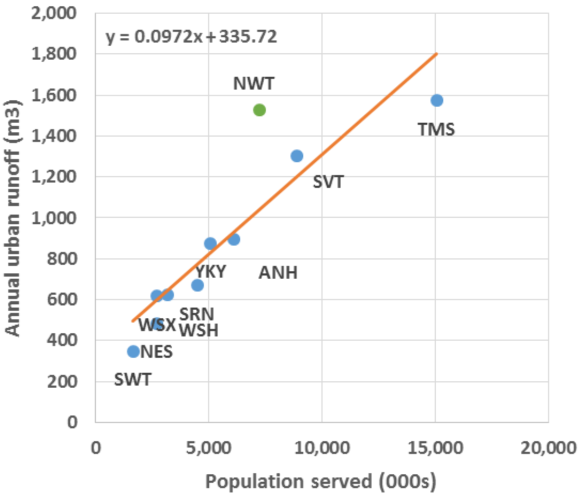
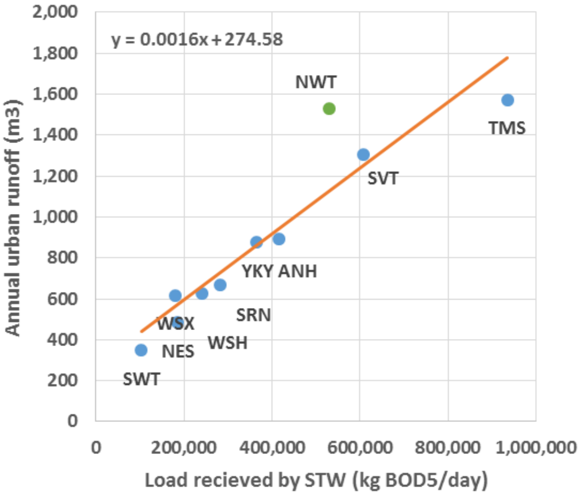
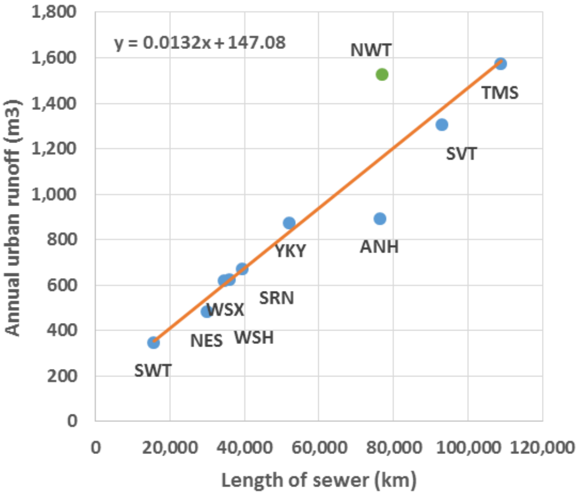
[6] Updating the forecast number of properties, sewer length and load only. Population served is not used as a scale driver within Ofwat's econometric models. £491m addition through deriving the corresponding scale value by rearranging the formula of the trend line in each and then overlaying any growth over the period from FY2021 as per Ofwat assumptions. We leave all other variables remain unchanged including those related to scale variables e.g. density, for simplicity although we note that this would also increase the predicted value.







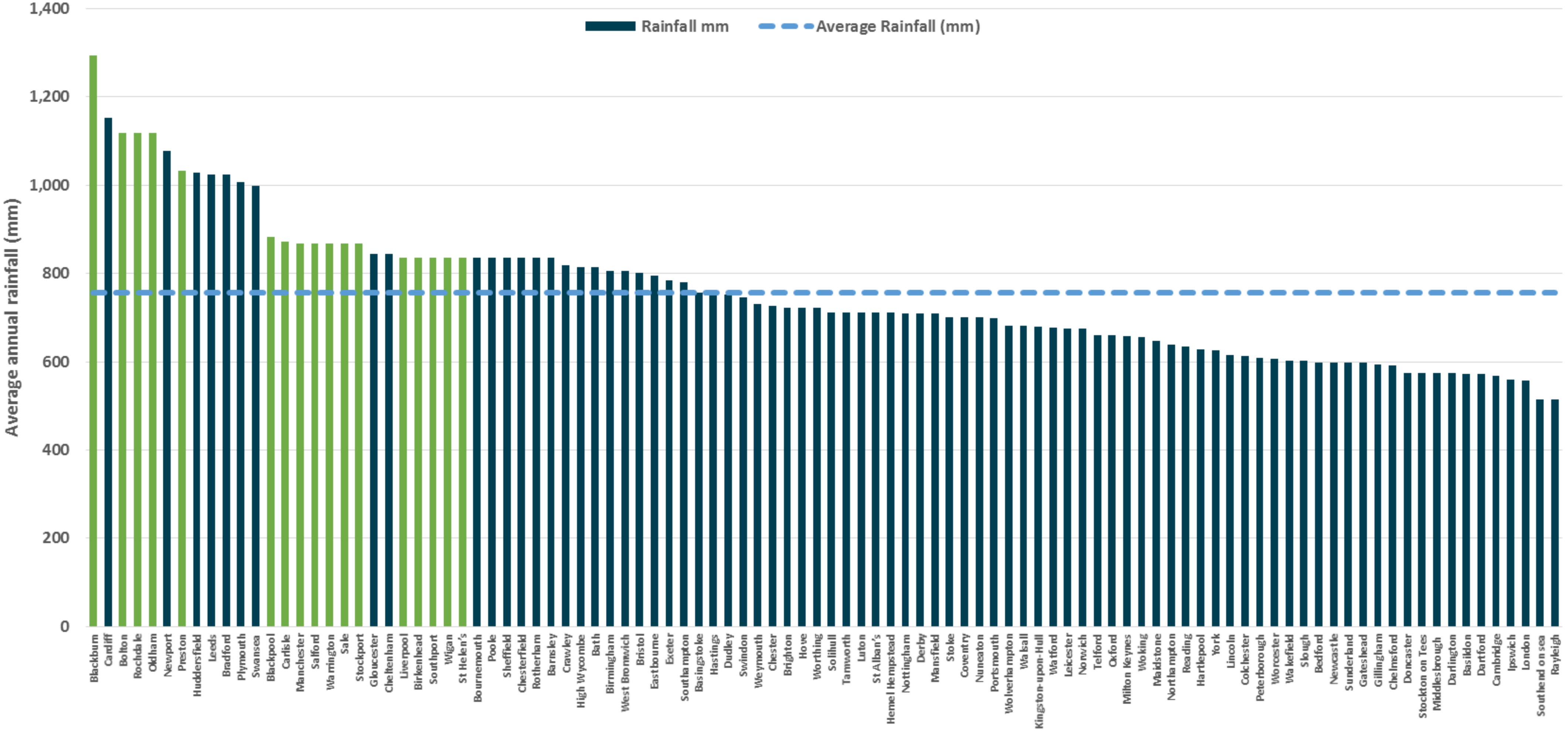
The other benefit of including the variable within models (accepting the need for an appropriate sign and magnitude) is that it enables models to better reflect the fact that drainage varies year on year, whereas scale remains largely constant. This improves the ability of models to explain annual differences in botex, hence the inclusion of drainage as an explanatory variable within our cost assessment proposal (S6002). The majority of variables that are typically proposed (as are those used within the PR19 models) are naturally static over time as they are asset focussed which mean that they are incapable of explaining intra year variations in expenditure for a company. The inclusion of an appropriate drainage variable, which both varies between companies and over time, offers a significantly greater opportunity to capture these variances rather than simply assessing them as differences in (in)efficiency over time and its use in models should not be discounted solely on the basis of high degrees of correlation with a (static) scale variable.

We are confident that the information provided, taken alongside that originally supplied within our submission, provides sufficient evidence in respect of each of the issues raised within the assessment to be explained fully, enabling Ofwat to have greater certainty in the underlying requirement and valuation of the claim and thereby accept the adjustment in its entirety. We would welcome further discussion on any aspect if it were required.

4. Appendix

4.1. Annual average rainfall across the top 100 cities within England and Wales.

Figure 8 Additional rainfall station data: Top 100 cities in England & Wales (green cities are those within United Utilities region).



4.2. Calculation methods for additional treatment costs associated with higher runoff/volume

We are able to analyse highly detailed data due to recording half-hourly metered electricity consumption (kWh) and flow (Ml/d) across 90% of total consumption for the previous three financial years as illustrated in Figure 3 above.

This relationship between the two variables is simply explained by the following formula;

$$Total\ electricity\ consumption\ = \alpha\ \times Volume\ recieved\ at\ WwTW +\ constant$$

To solve, we can quickly calculate the gradient and constant for each of the years, as well as the total in Excel, which we have summarised below in Table 6.

Table 6 Summarised flow data for UUW Wastewater treatment sites 2016-17 to 2018-19

Year	Min flow (Ml/d)	Ave flow (Ml/d)	Max flow (Ml/d)	Gradient (α)	Constant	R^2
FY2016-17	1,448	2,629	5,338	106.28	873,358	0.82
FY2017-18	1,786	3,000	5,502	124.29	808,729	0.80
FY2018-19	1,642	2,644	5,308	127.99	770,715	0.91
Average/total	**1,625**	**2,758**	**5,383**	**119.92**	**817,140**	**0.82**

From this aggregated data, we can see that over the three years our;

- Dry weather flow is on average 1,625 Ml per day (the minimum flow received)
- Average flow to treatment is on average 2,758 Ml per day (the average flow received)
- Flow to full treatment is on average 5,383 Ml per day (the maximum flow received)

Combining this with the rainfall data collected by Arup in their investigation into the exogenous drivers of wastewater costs; as set out within Table 7 below, we can value the additional costs of accommodating the higher volumes received compared to the 'average' company.

Table 7 Arup annual rainfall (mm) data 2011-12 to 2016-17

Company	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17	Average (6yr)	Variance (6yr)
ANH	448.97	932.73	670.43	672.98	710.52	639.26	679.15	-27.5%
NES	670.74	1,243.24	858.80	768.97	1,066.16	812.75	903.44	-3.6%
NWT	944.89	1,365.50	1,136.49	978.19	1,325.89	1,003.40	1,125.73	20.2%
SRN	537.36	1,024.28	957.39	837.11	790.74	640.27	797.86	-14.8%
SVT	536.83	1,045.47	761.97	728.33	832.12	714.92	769.94	-17.8%
SWT	814.50	1,520.50	1,289.70	1,028.90	1,208.60	937.40	1,133.27	21.0%
TMS	546.28	1,045.23	954.59	835.61	808.13	656.83	807.78	-13.8%
WSH	850.80	1,466.68	1,235.82	1,009.43	1,239.54	954.69	1,126.16	20.2%
WSX	805.94	1,505.17	1,279.43	1,022.97	1,195.69	928.22	1,122.90	19.9%
YKY	670.82	1,232.99	859.19	771.79	1,059.44	812.33	901.09	-3.8%
Ave	682.71	1,238.18	1,000.38	865.43	1,023.68	810.01	936.73	

We do this by taking the difference between the minimum and average flow for each year to calculate the amount of additional flow received at our sites that can be attributed to rainfall (labelled 'Additional volume' in the tables below). As we are only interested in the *additional* volumes that we need to accommodate, we multiply this additional volume by the (percentage) variance of United Utilities to the average rainfall received in the industry. This resulting value is then the comparative additional volume that we have to accommodate compared to the average company, which will not be reflected in models that only use a variable to account for scale. We multiply this net additional volume by the gradient derived in Table 6 to give the additional daily power consumption compared to the average company, which is then scaled to account for the additional power consumption expected in an AMP. We have used a unit rate for power of 14.6p/kWh in line with the assumptions set out for our AMP7 business plan. As we measure approximately 90% of power and flows, the calculated value is scaled up to derive a total wastewater expenditure value to account for the missing 10%. **This results in a range of £7.58m-£8.92m for average rainfall in a year with the upper range of £28.93m-£33.28m based on maximum flow**. We have summarised the results of these calculations below in Table 8.

Table 8 Estimates of net additional power expenditure due to average and maximum rainfall for United Utilities

Assumptions		
Time	1825	days
Power unit rate	14.6	p/kWh

FY2016-17 rates	**Unit**	**Ave - Min**	**Max-Min**
Additional volume	*Ml/d*	*1,181*	*3,890*
Additional power consumption	*kWh*	*54,691,412*	*180,130,646*
Additional AMP expenditure (100%)	**£m**	**8.78**	**28.93**
FY2017-18 rates			
Additional volume	*Ml/d*	*1,214*	*3,716*
Additional power consumption	*kWh*	*55,550,820*	*201,244,238*
Additional AMP expenditure (100%)	**£m**	**8.92**	**32.32**
FY2018-19 rates			
Additional volume	*Ml/d*	*1,002*	*3,716*
Additional power consumption	*kWh*	*47,225,808*	*207,233,759*
Additional AMP expenditure (100%)	**£m**	**7.58**	**33.28**
Total/average rates			
Additional volume	*Ml/d*	*1,132*	*3,757*
Additional power consumption	*kWh*	*49,997,170*	*196,318,588*
Additional AMP expenditure (100%)	**£m**	**8.03**	**31.53**

An alternative approach would have been to use volume data available through the Information Request. This involves normalising the '*Volume of wastewater receiving treatment at sewage treatment works*' to account for scale (population being the most appropriate) and then following the same approach of valuing the difference to the average using the same unit cost of 14.6p/kWh for power and the average gradient calculated above to convert the volumes into units of power. **This approach predicts that on average United Utilities would be required to spend an additional £3.42m p.a. or £17.10m in an AMP to accommodate the additional volumes because of higher levels of rainfall** as shown below in Table 9.

Table 9 Alternative approach to valuing additional power expenditure requirements using Ofwat Information Request [average 2012-2017]

	Volume of wastewater receiving treatment at sewage treatment works	Total population	Volume treated per capita	Difference to average	Annual additional volume treated	Additional power used (1Ml = 120kW)	Additional cost per year
Company	Ml/y	000s	Ml/y/000s	%	Ml/y	kW/y	£m/y
ANH	617,805	6,109	101.13	-18.5%	-140,010	-16,801,219	-2.45
NES	324,276	2,723	119.08	-4.0%	-13,535	-1,624,223	-0.24
NWT	1,099,843	7,293	150.82	21.6%	195,217	23,426,013	3.42
SRN	449,929	4,493	100.14	-19.3%	-107,416	-12,889,931	-1.88
SVT	993,297	8,915	111.42	-10.2%	-112,579	-13,509,504	-1.97
SWT	208,411	1,661	125.45	1.1%	2,338	280,538	0.04
TMS	1,667,213	15,064	110.68	-10.8%	-201,398	-24,167,790	-3.53
WSH	513,080	3,206	160.02	29.0%	115,341	13,840,948	2.02
WSX	326,784	2,716	120.33	-3.0%	-10,096	-1,211,485	-0.18
YKY	714,941	5,056	141.41	14.0%	87,780	10,533,581	1.54