SRB-DDR-015: Coastal Population

Cost Adjustment Claim

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from
Southern
Water

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1. Summary and purpose

1.1. Background

A coastal environment has a number of factors that exert unique cost pressures on wastewater treatment, and these are not currently captured in Ofwat's econometric models. As part of our PR24 business plan we submitted a well evidenced cost adjustment claim (CAC) to Ofwat providing engineering rationale and empirical evidence on the impact of coastal population on wastewater treatment costs.

We set out multiple reasons for higher wastewater treatment costs associated with coastal population. These include: space constraints and planning restrictions which result in either double pumping to inland works for treatment before coastal discharge, or confined (and often underground) treatment works on the coast which incur atypical costs; maintenance of sea outfall infrastructure; enhanced corrosion due to salinity; stricter ultraviolet / total nitrogen consents for coastal discharge; high load variability due to summer tourism; and stricter spill frequency constraints on coastal discharge. We developed an exogenous variable that captures these multitude of factors—the proportion of coastal population in the area—and showed that it is statistically significant and of the expected sign in an econometric model.

1.2. Feedback on the proposed cost adjustment

Two companies commented on the early submission of our claim: Severn Trent and United Utilities. We were pleased that both companies agreed that the claim had validity.

Within their business plan, United Utilities stated that the evidence provided in the cost adjustment claim addressed previous concerns and that they considered that Southern Water had provided a compelling engineering and operational rationale as to why coastal location drives higher costs. They further stated "we support Southern's claim. The variable is transparent, replicable and calculated using robust third-party data. It is clear that omitting the variable will lead to material bias within cost assessment." [1]

Severn Trent also agreed that coastal population impacts costs, stating that "it is uncontentious that some of these factors will be drivers of additional base cost, and we are sympathetic to the need to better account for complexity cost drivers in the base econometric models." [2] However, they also commented that they are less convinced of the materiality of some of the cost pressures, or that coastal proximity is the causal determinant.

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[1] United Utilities business plan "UUW46 Cost Assessment Proposal" pg 79 (United Utilities, 2023)

[2] Severn Trent business plan "sve13-appendix-4a-1-cost-adjustment-claims (Severn Trent Water, 2023)

Ofwat rejected this cost adjustment claim in the Draft Determination stating that it failed the need for adjustment gate owing to lack of evidence that the issue is material for Southern Water using actual Southern Water cost information. However, Ofwat has suggested that Southern Water derives an alternative bottom-up estimate of its cost adjustment claim to provide further evidence to support the need for the claim.

1.3. Purpose

In this paper we provide further evidence of the bottom-up costs associated with the engineering factors and respond to the issues raised by Severn Trent and highlighted in the Ofwat assessment.

Our bottom-up estimate, based on actual Southern Water cost data, provides evidence that the additional cost for Southern Water to operate in a coastal environment is approximately £78m. This provides a broader weight of evidence to support the case for our cost adjustment claim of £65.490m (net of implicit allowance) as submitted within our business plan.

A key point in Ofwat's and Severn Trent's challenge was an econometric one – that the statistical significance of the coastal variable is sensitive to whether Southern Water is included in the sample. Specifically, if Southern Water is excluded, the variable becomes statistically insignificant. Indeed, Southern Water is a statistical outlier because it is uniquely affected by the impact of coastal population. This only provides further evidence that this claim is necessary. Without the coastal population cost driver, the models omit a material driver of our efficient costs and hence insufficiently compensates Southern Water. In this paper we show that there is sufficient statistical evidence to further support the coastal variable as a cost driver, and therefore for the application of a cost adjustment for Southern Water, which is disproportionately affected by its absence from the models.

Southern Water is the company with the highest coastal population, although Ofwat noted that South West Water also has a significant proportion. However, Frontier Economics' assurance of Severn Trent's challenge (appended to Severn Trent's claim)[3] noted that including 'coastal population' as a cost driver is capturing a Southern Water specific impact. This only further highlights that the issue is unique and specific to Southern Water, which is a key requirement for a cost adjustment claim. It also infers that, given that Southern Water is an outlier, the claim should be asymmetrical with no adjustment applied to other companies.

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[3] Severn Trent business plan "sve13-appendix-4a-1-cost-adjustment-claims" (Severn Trent Water, 2023)

2. Evidence of Engineering Factors

As discussed above, we provide an engineering rationale as to why operating in a coastal location incurs higher operational and maintenance costs. In Ofwat's assessment of the claim it states that "it is not clear if the issues identified are material for Southern Water as they have not been quantified using actual Southern Water cost information"[4] and specifically comments that it has seen no quantitative evidence to support the case that UV consents, saline corrosion or load variability are a significant cost driver.

Severn Trent reviewed the engineering rationale of the claim and generally agreed that the cost factors were reasonable, stating that "it is uncontentious that some of these factors will be drivers of additional base cost."[5] However, they did question the materiality of the cost pressure and extent to which coastal proximity is the causal driver.

Whilst we are not stating that each cost driver is significant in its own right, the overall cost pressure of all these factors combined is material, as demonstrated by the econometric evidence. To further support the claim, we have provided additional bottom-up quantitative evidence to demonstrate the materiality of the coastal cost drivers and address the concerns raised by Ofwat and Severn Trent on the causal link.

2.1. Supporting Cost Evidence

To demonstrate the cost pressures associated with coastal treatment works, we have undertaken analysis of Southern Water cost information to quantify the additional costs of operating in a coastal environment and provide evidence that the higher costs are material.

We have taken externally assured and publicly available Southern Water cost data for our large wastewater treatment works from APR Table 7B to understand the variation in costs between our inland and coastal treatment works. We averaged four years of data from 2020-21 to 2023-24 and used total costs for each site against load (kg BOD_5 per day) to obtain a unit cost (£/load) for each site (see Appendix A). Because APR costs are in prices of the year, we inflated all the costs to 2022/23 prices.

The average unit cost (£/load) across all sites was £368/kg BOD_5. Coastal sites had a higher unit cost of £441, whilst inland treatment works had lower unit costs of £294. The results demonstrate that our coastal sites have a significantly higher cost to operate, with on average 50% higher unit costs compared to inland works, as illustrated in Table 1 below.

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[4] Ofwat draft determination "PR24-DD-SRN_Cost-adjustment-claims" (Ofwat, July 2024)

[5] Severn Trent business plan "sve13-appendix-4a-1-cost-adjustment-claims" (Severn Trent Water, 2023)

Table 1: Average Unit Costs of Southern Water Wastewater Treatment Works

Unit Cost	Average Unit Cost (£/kg BOD_5)	As a % of all sites	As a % of inland sites
All Sites	368	-	-
Coastal Sites	441	120%	150%
Inland Sites	294	80%	-
UV Sites	521	142%	-
Total N Sites	442	120%	-

Note: All costs are in 2022/23 prices.

Our total cost for coastal works is £238.9m over an AMP (2022/23 prices). The unit cost of operating inland sites is 67% than the unit cost of coastal sites. Therefore, the counterfactual should coastal sites be operated inland is £159.2m. This equates to an additional £79.7m premium for operation in a coastal environment (see Table 2 below). This bottom-up derived cost premium for coastal operation corroborates our adjustment claim of £65.5m and demonstrates the materiality of the coastal cost drivers quantified using actual Southern Water cost information.

Table 2: Premium cost of operating in a coastal environment

		Unit cost (£/kg BOD_5)	Total costs ove AMP (£m)*
Inland sites		294	
Coastal sites		441	
Inland/Coastal	(a)	294/441=67%	
Coastal sites operating costs	(b)		238.9
Coastal site cost if operated inland	(c) = b x (a)		159.2
Coastal premium	(d) = (c) - (b)		**79.7**

Note: Based on operating costs of the 4 years ending in 2023-24 and factored for the 5 years of an AMP. All costs are in 2022/23 prices.

This provides quantifiable evidence that coastal location is a material driver of cost for Southern Water.

We present evidence (below) of the cost pressures for each of the engineering factors, which provides further compelling evidence that the costs are both material and linked to coastal location.

Stricter Ultraviolet (UV) and Total Nitrogen Consents

Both UV and Nitrate are other drivers of cost associated with effluent quality at coastal works. However, Ofwat did not find the UV variable in the sewage a significant cost driver. UV treatment is only one of multiple factors impacting coastal treatment and may not be significant on its own. However, it should be noted that UV consents are much stricter for coastal discharge, with operational outages of UV treatment limited to a maximum of four hours before consent failure. This level of operation requires a higher degree of maintenance, energy, and out-of-hours support to ensure treatment works do not fail compliance compared with UV at inland sites and, is one of the many factors impacting the increase in energy usage and operational costs at coastal sites.

From analysis of APR Table 7 data (see Appendix A), our large wastewater treatment works with UV have a unit cost of 42% above the average cost to operate of all our works, as illustrated in Table 1.

Southern Water also has 8 coastal WWTW with Total Nitrogen permits, with six at or below the Technical Achievable Limit (TAL). The operational processes to achieve consent below the TAL of 10mg/l requires additional chemicals and power usage. These sites, which require Total Nitrogen removal at coastal works, equates to 17.5% of the population served by Southern Water and is not included in Ofwat's load cost allowance.

As shown in Table 1, sites with Total N consents have an 20% higher unit cost to operate than average sites.

It should be noted that ammonia consents are captured within Ofwat's PR24 proposed models for inland waters through the complexity bands, unlike Total N consents and UV treatment for coastal sites which are not considered within the econometric models.

Space Constraints and Planning Restrictions

Severn Trent acknowledges that proximity to the coast can drive additional costs due to space constraints and planning restrictions but argue that specific circumstances of space constraints and design may also impact inland sites. We must distinguish between anecdotal and systematic arguments or evidence. No doubt it is true that space constraints may be triggered by factors other than proximity to coast. We expect all companies to be exposed to such factors. Our point is that **all** coastal sites are severely impacted by space and planning constraints. By their very nature, all coastal sites are limited to only 180 degrees of land for potential growth, and planning restrictions on coastal land near urban centres are acute and often require atypical treatment works built underground or on a small footprint which incur significant additional chemical, energy and maintenance costs.

An example of the atypical nature of coastal sites is our Eastbourne Wastewater Treatment Works, which operates below sea level and requires significant additional resource to carry out maintenance activity below ground due to health & safety and logistical issues.

Figure 1: Eastbourne Wastewater Treatment Works predominantly located underground

Furthermore, treatment works which pump to sea and were built prior to the Urban Waste Water Treatment Directive (UWWTD) require either atypical solutions (as discussed above) or double pumping inland for treatment. In contrast, new inland works have less constraints and can be located in a variety of locations downstream of population centres before discharge into rivers.

In cases where new wastewater treatment works are required to be located inland due to coastal space and planning constraints, we are subject to additional pumping from the original point of collection, to inland treatment, before further pumping back to the coast for sea discharge. This double pumping incurs additional energy usage. We undertook analysis of our internal power costs across sites and found a 70% uplift in energy cost per unit of load for coastal works compared to inland sites, on average over 2020/21 to 2023/24.

This clearly demonstrates that Southern Water, which has the highest proportion of coastal population (See Graph 1), is systematically exposed to costs of atypical works and double pumping related to coastal planning and space constraints.

Enhanced Corrosion due to salinity

Severn Trent concurs that the adverse effects of corrosion relate to saline infiltration into sewers is a significant issue for coastal locations. Severn Trent suggest that urban areas with high levels of air pollution can also generate corrosion and that sites with potential corrosion issues should be built with this in mind. We do not disagree that urban sites can be affected by single sources of pollution. However, all companies are exposed to such sources of pollution, arguably in a broadly similar way. In contrast, Southern Water is exposed to the saline effect at coastal locations. What is more, the level of saline corrosion is far more prevalent for coastal sites. All assets within 1.5 miles of coastal locations are potentially impacted by saline corrosion and therefore proximity to the sea is a specific cost driver for Southern Water that operates in a coastal environment.

The impact of saline environments can be mitigated by the use of corrosive resistant products, such as using stainless steel, rather than chemical dosing to reduce the production of hydrogen sulphide. However, the widespread use of such assets in all our coastal locations would be exceptionally expensive, further justifying the high total costs of operating in a coastal environment.

Wastewater Treatment Load Variability (Peakiness)

In the draft determination, Ofwat state that there is no quantitative evidence that tourism drives additional cost and argues that tourism is not unique to companies that operate near the coast. Similarly, Severn Trent argues peakiness, whilst evident in coastal resorts, can be experienced in other areas with high tourist demand.

As suggested by Severn Trent, we have reviewed external data to evidence the level of seasonal tourism. Our analysis of ONS data[6] found that coastal areas had a higher proportion of seasonal tourism. Specifically, coastal areas have both more people employed in tourism as a % of employment (16% more than non-coastal areas) and more businesses involved in tourism (11.7% compared with 9.6% for non-coastal areas). The ONS data also showed that holiday stays (represented by total nights stayed by visitors while on holiday as a % of all nights by all visitors) are much higher for coastal areas (26% compared with 19% for non-coastal areas excluding London). This demonstrates that the impact of *seasonal* tourism (as opposed to all visits, which includes business trips which are spread through-out the year) is greater in coastal areas than non-coastal areas.

Coastal discharge has stricter spill frequency

We explained that treatment works that discharge to seawaters have stricter spill frequency constraints due to shellfish and bathing water requirements. As a result, more storm tanks, storm screening and storm pumping capacity is required with additional pumping to store and then treat the extra flow, resulting in additional maintenance costs over time. We do not see the relevance of Severn Trent's challenge for two reasons:

- We do not argue that costs associated with CSOs are uniquely driven by proximity to the coast, as Severn Trent suggests. We recognise that there are other drivers which all companies are exposed to. The key is that proximity to the coast increases spill frequency compliance costs other things equal, and that Southern Water is uniquely exposed to this factor. The fact that there are other drivers is irrelevant, unless they systematically impact a single company (or a small group of companies).

- Ongoing costs to ensure no deterioration in spill frequency are higher in coastal works, other things being equal, due to additional storm tanks, screening and pumping - precisely as we set out in our claim and ignored by Severn Trent.

Sea-outfall Infrastructure

Severn Trent acknowledges that sea outfalls will have atypical maintenance requirements. Wastewater works that discharge to sea have long (>1km) and multiple outfalls compared to inland works. These long outfalls require expensive maintenance in a marine environment. They also require expensive pumping of the full load, rather than rely on gravity as inland outfalls often do. Pumping requirements are significant (as acknowledged by Severn Trent) and the high capital maintenance costs of sea-outfalls add to the many factors that increase the cost of operating coastal WWTWs which are not captured in wastewater treatment models.

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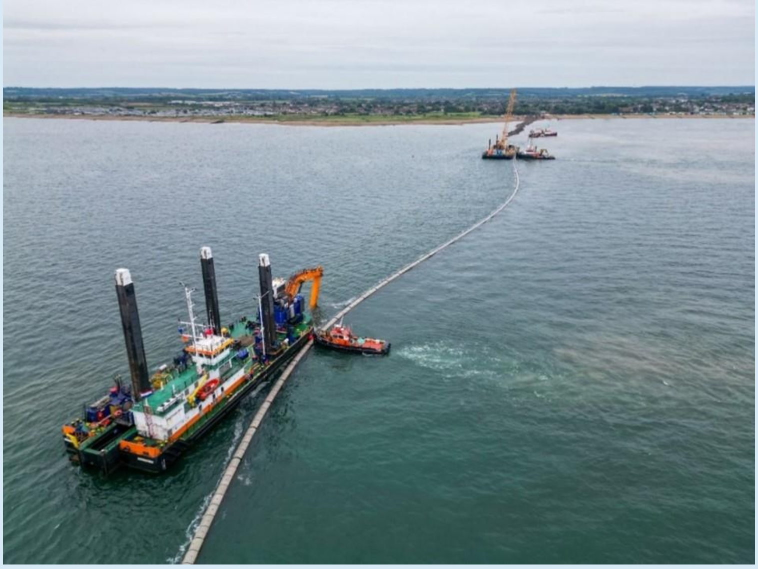
[6] "Estimates of the economic value of tourism within UK regions, sub-regions and local areas" (Office for National Statistics, 2015)

Case Study: Swalecliffe Replacement Sea-outfall

One example of significant atypical costs for sea outfalls is at Swalecliffe that requires a replacement sea-outfall under our capital maintenance programme at a cost of £23m. The new sea outfall replaces a sea damaged outfall pipe and has involved digging a trench that runs from Swalecliffe Wastewater Treatment Works out into the North Sea. The project has involved the controlled sinking using a specialist dredger of a new outfall pipe nearly 1km long. The pipe was manufactured in Norway and towed across the North Sea.

Figure 2: Sea-outfall replacement at Swalecliffe



This case study alone provides evidence that atypical costs associated with operating in a coastal environment are material (the sea outfall replacement at Swalecilffe represents over one third of the total value of this claim on its own) and that these costs are inherently driven by coastal factors, so demonstrating a causal link.

In addition, Southern Water has incurred other sea outfall maintenance schemes and an additional £2.5m over AMP7 for rent to the Crown Estate for sea-outfalls.

Resilience

Severn Trent argues that additional costs of coastal works, to ensure resilience to external stresses (such as sea level rise), should be considered as enhancement. This is a question of definition of whether these costs fall under resilience enhancement. We do not think so – these are ‘routine’ costs of addressing risks related to our unique operating environment. For example, additional capital maintenance costs are required to remedy treatment assets following regular storm events, such as from cliff erosion at our Portabello treatment works, or repair of causeway infrastructure as seen at Ventnor following a recent storm event and which necessitated substantial capital maintenance.

Case Study: Ventnor sea-wall collapse

In November 2022, storms caused a catastrophic failure of the seawall and promenade at Eastern Esplanade. A 35m section of seawall collapsed that supports Eastern Undercliff Esplanade and protects the cliffs. The defence also protects an 825mm foul sewer which if ruptured would have caused a category 1 pollution incident into an internationally designated site. Had the defence not been stabilised there would have been risk to life, with 1400 properties in that landslide unit. The emergency works cost £4.7m and required a multi-disciplinary team to address the challenges. Southern Water had to undertake emergency works and develop alternate overflow options for the duration of the 20 month stabilisation works.

Figure 3: Eastern Esplanade, Ventnor – Emergency Work (December 2022)

Existing coastal defences are at the end of their life. Asset grades in some locations are very poor with significant to severe defects. More recent surveys show that the speed of deterioration is greater than normal and that the extent of frontage where work is needed has increased from about 900m to 2,700m.

In addition to the extra costs incurred in AMP7, the investment planned in AMP8 for Southern Water delivered coastal erosion schemes at Ventnor and Portobello total £13.86m alone, a significant and material cost to Southern Water.

We do not report these additional costs as enhancement in our APRs and, therefore, they are part of our base costs and are captured within this claim.

We note that, Severn Trent does not challenge this cost driver, just as it doesn't fundamentally challenge the other factors we have put forward.

3. Econometric Evidence

3.1 A brief reminder of our econometric evidence

As we set out above, we provide multiple engineering factors that uniquely exert cost pressures on wastewater treatment in coastal areas. We recognise that individually, each factor in isolation has some impact but only through a driver that captures all the effects is the magnitude sufficient to be statistically significant in Ofwat’s small sample models.

It is precisely for these reasons that we developed the exogenous variable below. The variable that we have developed is reliably and consistently measured based on ONS data, and it encapsulates all the engineering factors we have set out in our claim and briefly summarised above.

Specifically, to provide econometric evidence for our cost claim we obtained data on coastal population by town and city from the ONS.[7] This allowed us to construct a variable that measures the proportion of coastal population within a company service area:

$$\%\ coastal\ population\ in\ company\ i = (coastal\ population\ in\ company\ i)/(total\ population\ in\ company\ i)$$

Table 3 provides econometric results. It shows that the models with coastal population as a driver meet all of Ofwat desirable statistical properties. The coefficient of the coastal population driver is of a plausible magnitude and is statistically significant. The models with coastal population have a better (higher) R-squared and improved (lower) range of efficiency scores, as compared to the models without coastal population as a driver.

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[7] We provide further detail on the data and method of constructing a company specific metric in Appendix A of the Coast Adjustment Claim submission

Table 3: impact of the coastal variable on wastewater treatment models

	without coastal variable			with coastline variable		
	SWT1	**SWT2**	**SWT3**	**SWT1**	**SWT2**	**SWT3**
Load (log)	0.653***	0.723***	0.788***	0.833***	0.892***	0.873***
Load treated in size bands 1-3 (%)	0.029			0.032*		
Load treated in WWTW >100k (%)	0.006***	0.006***	0.006***	0.006***	0.006***	0.006***
WATS (ln)			-0.242***			-0.220***
Load with ammonia consent below 3mg/l (%)	0.004***		0.004***	0.003***		0.004***
Coastline population (%)				0.009**	0.009**	0.006**
Constant	-3.734***	-4.072***	-3.001***	-6.198***	-6.367***	-4.389***
Number of observations	110	110	110	110	110	110
R squared	0.854	0.869	0.911	0.887	0.897	0.922
RESET test (P value)	0.056	0.272	0.849	0	0.25	0.887
Range of efficiency scores	0.684	0.535	0.331	0.437	0.323	0.259

Notes:

Three/two/one stars indicate 1% / 5% / 10% significance level respectively.

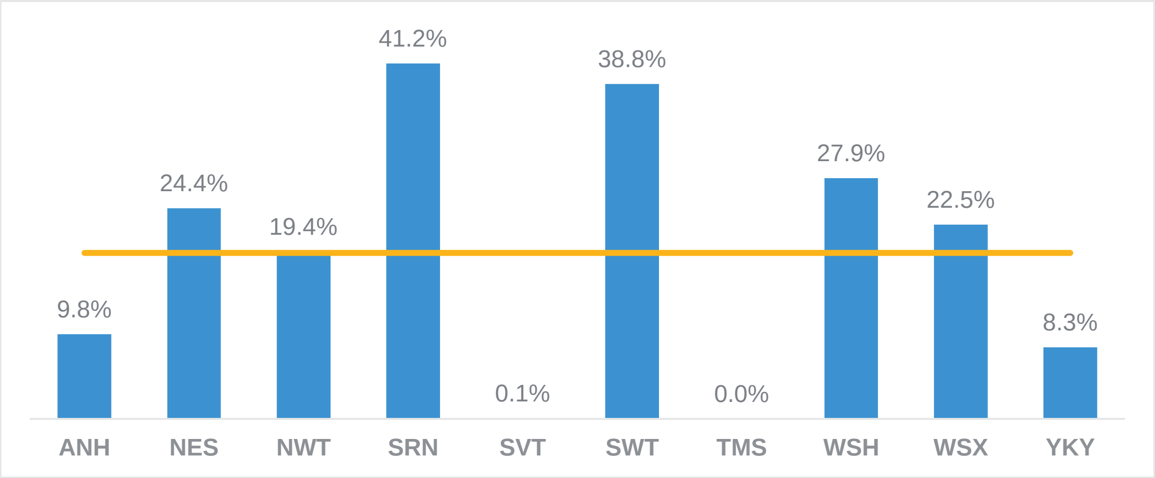
Random effects estimation using panel data from 2011-12 to 2021-22.

This table replicates the results we presented in our cost adjustment claim submission.

3.2 Impact on efficiency scores

As the figure below shows, Southern Water has the highest percentage of coastal population, whilst Severn Trent and Thames Water have nearly zero coastal population.

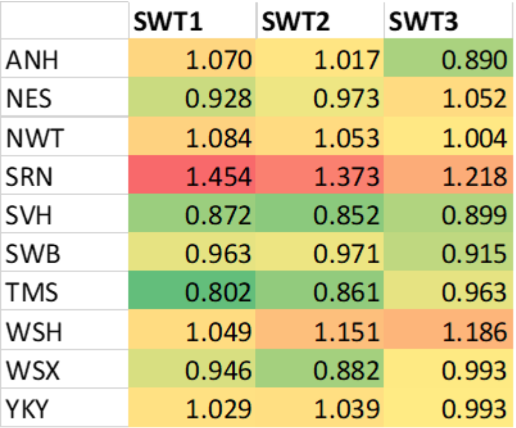
Figure 2: Percent coastal population by wastewater company



It is interesting to note that the efficiency scores for the wastewater treatment models without coastal variable, show Southern Water to be inefficient, with scores ranging from 1.218 to 1.454, whilst the two companies with almost zero coastal population (Severn Trent and Thames Water) rank as the most efficient companies, with scores significantly below 1.

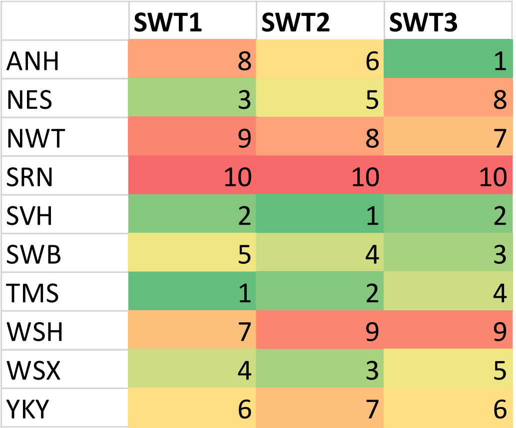
Table 4: Efficiency scores from wastewater treatment models without coastal variable

Efficiency scores



	SWT1	SWT2	SWT3
ANH	1.070	1.017	0.890
NES	0.928	0.973	1.052
NWT	1.084	1.053	1.004
SRN	1.454	1.373	1.218
SVH	0.872	0.852	0.899
SWB	0.963	0.971	0.915
TMS	0.802	0.861	0.963
WSH	1.049	1.151	1.186
WSX	0.946	0.882	0.993
YKY	1.029	1.039	0.993

Ranking



	SWT1	SWT2	SWT3
ANH	8	6	1
NES	3	5	8
NWT	9	8	7
SRN	10	10	10
SVH	2	1	2
SWB	5	4	3
TMS	1	2	4
WSH	7	9	9
WSX	4	3	5
YKY	6	7	6

3.3 Econometric challenge

Ofwat and Severn Trent argue that the statistical performance of the coastal variable is highly influenced and sensitive to the inclusion of Southern Water. When Southern Water is excluded from the sample, the variable loses significance.

Severn Trent claims that Southern Water's Cook's distance is above 3 across the Sewage Wastewater Treatment (SWT) models, which means it is deemed a statistical outlier, with a potential undue influence on the model.

3.4 Our response

We accept that the variable loses significance when Southern is excluded from the models based on current data. Ofwat and Severn Trent claim that Southern is a statistical outlier, with an influential impact on the coefficient of the coastal variable. Southern Water is a statistical outlier because it is uniquely affected by the impact of coastal population on base costs, which only reinforces the need for this claim. It also reinforces the point that this claim should be asymmetrical because Southern Water is a statistical outlier, uniquely and specifically affected by the absence of a costal population cost driver.

We undertook sensitivity analysis of our model specification to further assess the impact of coastal population on base costs. Specifically, we investigated the case for using the coastal population variable in log form, as using variables in log form is a common practice to mitigate undue influence of statistical outliers.

The use of log-transformed variables in econometric modelling

Log-transforming variables in econometric modelling is very common. It offers a number of advantages:

- A log transformation often makes the variables and the error terms normally distributed. While this is not crucial in large samples, it is essential in small samples, which is the case in Ofwat models.
- The log helps mitigate the influence of outlier/influential data points by 'bringing them in'.
- A log-log models provides a useful interpretation of the coefficients as elasticities: the coefficient on variable X is the percentage increase in Y from a one percent increase in X.

Indeed, the variables in Ofwat's econometric models are generally log-transformed, consistent with a Cobb-Douglas specification.

At PR19 Ofwat made a decision in principle not to log transform percentage variables. This was in light of the CMA's approach in the PR14 redeterminations for Bristol Water, where it chose not to log transform percentage variables, arguing that it made the interpretation of their coefficients less intuitive.

However, percentage variables can be log transformed, and in many cases have been log transformed in academic studies.

For example, Wooldridge's popular textbook suggests some rules of thumb for using logs in econometric models:

"There are some standard rules of thumb for taking logs, although none is written in stone. When a variable is a positive dollar amount, the log is often taken. We have seen this for variables such as wages, salaries … Variables such as population, total number of employees, and school enrolment often appear in logarithmic form; these have the common feature of being large integer values. Variables that are measured in years—such as education, experience, tenure, age, and so on—usually appear in their original form. A variable that is a proportion or a percent … can appear in either original or logarithmic form, although there is a tendency to use them in level forms. This is because any regression coefficients involving the original variables—whether it is the dependent or independent variable—will have a percentage point change interpretation." 8

The takeaways from this are two:

- Rules for taking logs are not written in stone. A percentage variable can be used in logs.
- The tendency to use percentage variables in level form is related to the interpretation of the coefficient. In fact, this is also how the CMA justified its decision not to log transform a percentage

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[8] Introductory Econometrics, Jeffrey M. Wooldridge, 2nd edition, page 189.

variable in the PR14 redeterminations, even though Ofwat's models had been academically reviewed and endorsed.

In light of the above, it is appropriate to consider log transforming a percentage variable, in particular if there are fundamental issue that the log can mitigate.

Why is it appropriate to log-transform the coastal variable?

The simple answer is that log transforming the coastal variable addresses the issue of Southern being a statistical outlier – with a log transformed coastal variable it is no longer an outlier. Furthermore, the statistical significance of the coastal variable in log form is robust to the exclusion of Southern from the sample. Finally, log transform slightly improves other model diagnostics.

We provide evidence on each of the above in turn.

Log transforming the coastal variable improves outlier issues

The Cook's Distance is a common measure for identifying influential observations (or, outliers). The Cook's Distance for an observation is calculated as the sum of (standardised) deviations of a model's predictions with and without the observation. A large number suggests the observation may be 'influential'. A threshold of 1 is often used to identify an influential observation.

It is important to note that an influential observation (e.g., with a high Cook's Distance) is not necessarily 'unduly' influential. Undue influence of an outlier is typically a result of data reporting errors or infrequently occurring events. In such instances removing the observation may be the appropriate mitigation. This is not the case here. In our case the presence of an outlier is more likely due to a mis-specified model. The mitigation in this case should seek to address the specification of the model, which, we argue, the log transformation achieves.

Table 5 provides the Cook's Distance for the three SWT models. The SWT models include the coastal variable – the first three columns include the coastal variable in percentage term, without a log transformation. The last three columns include the coastal variable in log.

First, we note, that the issue of outlier arises only in one of the three models, namely in SWT1. In our view – and indeed in other companies' view [9] – this model is clearly inferior to SWT3. This is because SWT3 uses a more appropriate variable to account for economies of scale at treatment (WATS) compared to the variable in SWT1 (% load in bands 1-3).

Second, Southern Water ceases to be an influential observation once the log of the coastal variable is used. Using the log of the coastal variable mitigates the issue of influential observations more widely than Southern. With the log transformed coastal variable the average Cook's Distance is reducing across all

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[9] ANH, HDD, SVE, SWB, SRN, UUW, WSX support this position regarding their responses to other company CAC submissions and Ofwat's consultation on econometric models.

models, although, we acknowledge that there are still two companies that are ‘influential’ (i.e. with a Cook’s Distance above 1) when the coastal variable is log transformed.

Table 5: Cook’s Distance

	% coastal population			ln % coastal population		
	SWT1	**SWT2**	**SWT3**	**SWT1**	**SWT2**	**SWT3**
ANH	0.17	0.15	0.52	0.29	0.27	0.59
NES	0.16	0.14	0.08	0.15	0.16	0.15
NWT	0.23	0.11	0.22	0.01	0.03	0.01
SRN	3.49	0.40	0.97	0.31	0.35	0.13
SVH	0.01	0.05	0.02	1.72	0.67	0.85
SWB	0.88	0.17	0.46	0.67	0.40	0.16
TMS	1.42	1.21	1.16	2.46	1.00	0.60
WSH	0.24	0.19	0.20	0.11	0.17	0.31
WSX	0.24	0.20	0.15	0.27	0.23	0.17
YKY	0.12	0.18	0.11	0.05	0.07	0.15

Log transforming the coastal variable provides results that are robust to the exclusion of Southern Water

Table 6 provides econometric results for SWT models. The objective of the table is to compare the statistical significance of the coastal variable with and without Southern Water. The table provides this comparison for two specifications of the coastal variable: in percentage terms (i.e. original variable) and log transformed.

The results show that the coastal population variable measured as a % loses statistical significance when Southern is excluded. However, with the log transformed variable the coastal population remains robust and does not lose statistical significance when Southern is excluded.

Table 6: Sensitivity of the coastal variable to the exclusion of Southern Water

	Southern included						Southern excluded					
	% coastal population			ln % coastal population			% coastal population			ln % coastal population		
	SWT1	SWT2	SWT3	SWT1	SWT2	SWT3	SWT1	SWT2	SWT3	SWT1	SWT2	SWT3
Load (ln)	0.868***	0.950***	0.895***	1.024***	1.015***	0.907***	0.653***	0.904***	0.967***	0.965***	0.980***	0.887***
	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.009}	{0.001}	{0.000}	{0.000}	{0.000}	{0.000}
Band 1-3 (%)	0.032**			0.047***			0.044*			0.052***		
	{0.042}			{0.000}			{0.069}			{0.000}		
STWs >100k (%)		-0.010***			-0.010***			-0.011***			-0.011***	
		{0.000}			{0.000}			{0.000}			{0.000}	
WATS (ln)			-0.216***			-0.199***			-0.225***			-0.209***
			{0.000}			{0.000}			{0.000}			{0.000}
NH3 below 3mg (%)	0.006***	0.006***	0.006***	0.006***	0.006***	0.007***	0.006***	0.006***	0.006***	0.006***	0.006***	0.006***
	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}
Coastal population	0.011***	0.010***	0.007***	0.188***	0.159***	0.104***	-0.003	0.007	0.011	0.141***	0.125***	0.085**
	{0.003}	{0.003}	{0.005}	{0.001}	{0.000}	{0.002}	{0.838}	{0.610}	{0.195}	{0.007}	{0.004}	{0.038}
Constant	-6.653***	-7.051***	-4.730***	-8.970***	-8.085***	-5.185***	-3.767	-6.328*	-5.613**	-8.137***	-7.495***	-4.788***
	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.258}	{0.076}	{0.011}	{0.000}	{0.000}	{0.000}

Note: *** indicates 1% significance level; ** indicates 5% significance level; * indicates 10% significance level. Absence of stars indicates a lower level of statistical significance.
Results are based on a ‘random effects’ estimation using panel data from 2011-12 to 2022-23. The numbers with Southern included (% coastal population) differ slightly from Table 1 due to the additional year of data used in the sensitivity analysis.

Log transforming the coastal variable slightly improves other model diagnostics

Table 7 compares three model diagnostics for three specifications: SWT models without the coastal variable, with the original coastal variable, and with the log-transformed coastal variable. The findings are:

- The **R-squared** improves with the introduction of the coastal variable to SWT models. It improves even further with the log-transformed coastal variable.
- The **RESET test** (for model specification) performs poorly in SWT1 in all specifications, and performs well in SWT2 and SWT3 in all specifications. The RESET test does not support any specification more than any other. However, it raises a broader concern with the validity of SWT1 model, which we have consistently flagged with Ofwat throughout the base cost modelling consultation process.
- The **range of efficiency scores** reduces significantly with the introduction of the coastal variable, whether it is in percentage or log-transformed.

Overall, the diagnostics favour the inclusion of the coastal variable. Across the board they are also better for SWT2 and SWT3. The R-squared specifically favours the log-transformed coastal variable.

Table 7: Sensitivity of the coastal variable to the exclusion of Southern Water

	R-squared			RESET			Efficiency range		
	SWT1	SWT2	SWT3	SWT1	SWT2	SWT3	SWT1	SWT2	SWT3
no coastal	0.846	0.862	0.906	0.050	0.363	0.782	0.770	0.641	0.367
coastal (%)	0.885	0.896	0.920	0.001	0.487	0.896	0.463	0.321	0.222
coastal (ln%)	0.913	0.910	0.923	0.010	0.598	0.967	0.415	0.378	0.299

Log transforming the coastal variable improves normality tests relative to models without the coastal variable

A common rationale to log-transform a variable, as noted above, is to improve the normality of distribution of the residuals.

An underlying assumption in econometric modelling is that the residuals are normally distributed. Whereas in large samples we can rely on the Central Limit Theorem (CLT) which says that the residuals would be converging to a normal distribution, in a small sample we cannot rely on the CLT. Normality must be tested and addressed. Violations of normality often arise because the distribution of the dependent or independent variables are themselves significantly non-normal.

Table 8 provides results from three normality tests. The table provides the p-values of the respective tests. Generally, higher p-values values indicates stronger confidence that the residuals are normal. Cases marked in red or amber are weaker – red results denote cases where the normality assumption is rejected with 95% confidence and amber results denote rejection with 90% confidence.

The clear evidence from the table is that normality tests improve with the inclusion of the coastal variable.

There isn't strong evidence, however, that the normality test improves with the log coastal variable over the non-logged variable.

Table 8: Normality tests (p-values)

	SK test			Shapiro-Wilk			Shapiro-Francia		
	SWT1	SWT2	SWT3	SWT1	SWT2	SWT3	SWT1	SWT2	SWT3
no coastal	0.00	0.05	0.02	0.00	0.12	0.01	0.00	0.08	0.02
coastal (%)	0.27	0.70	0.41	0.08	0.46	0.31	0.11	0.50	0.39
coastal (ln%)	0.06	0.46	0.36	0.12	0.60	0.64	0.10	0.38	0.56

4. Conclusions

A coastal environment has a number of factors that exert unique cost pressures on wastewater treatment, and these are not currently captured in Ofwat's econometric models.

We have provided quantifiable cost evidence to support the engineering rationale. This includes clear evidence that costs for coastal works are significantly (50%) higher than inland works. Our analysis, using actual Southern Water cost information, shows a cost premium for coastal operation of £79.7m, which corroborates our adjustment claim of £65.5m and demonstrates the materiality of the coastal cost drivers. We also provide clear case study evidence of atypical costs associated with operating in a coastal environment, such as Total Nitrogen consents, that are not incurred by inland works. This is exemplified by the £23m sea outfall capital maintenance expenditure at Swalecliffe, which is material to the value of this claim alone and demonstrates the causal link.

Furthermore, the econometric evidence provided above is robust and supports an adjustment in respect of our exposure to coastal operating environment. Our coastal variable is intuitive, beyond management control and based on exogenous data from the ONS – a recognised independent source. Our approach satisfies all Ofwat's model selection criteria as follows:

- High quality data
- Engineering rationale
- Exogenous cost driver
- Estimated coefficient is statistically significant
- Estimated coefficient has a stable, plausible magnitude and correct sign
- Robust cost model

We performed sensitive analysis of our model specification to assess the Ofwat and Severn Trent challenge that the coastal population models are skewed by Southern Water being an outlier. Our sensitivity analysis shows that the models with a log transform of coastal population are robust even when Southern Water is excluded.

Given the additional engineering cost evidence, demonstrating that the costs are material and driven by coastal factors; the robustness of our econometric results (using two versions of the coastal variable); and the fact that Southern is uniquely impacted by coastal population (as demonstrated by being an outlier), we consider that an asymmetric adjustment for this claim is appropriate, efficient, and justified.

APPENDIX A

Table 9: Total Unit Cost for each WWTWs derived from Table 7B 2020/21 to 2023/24

Site	Load received kg BOD$_5$	Total expenditure £m/year	Unit cos £/kg BOD$_5$	Treatment Type	Category	UV	TN
ASHFORD	7,176	1,505	210	Tertiary B2	Inland		
AYLESFORD	8,180	579	71	Secondary biological	Inland		
BROOMFIELD BANK	6,912	2,488	360	Secondary activated sludge	Coastal		
BUDDS FARM HAVANT	22,822	3,752	164	Tertiary A2	Coastal		TN
CANTERBURY	4,343	487	112	Tertiary A2	Inland		
CHICHESTER	2,768	2,327	841	Tertiary A2	Coastal	UV	TN
CHICKENHALL EASTLEIGH	6,288	2,137	340	Tertiary B2	Inland		
EAST WORTHING	8,443	1,794	212	Secondary activated sludge	Coastal		
EASTBOURNE	6,931	4,026	581	Secondary activated sludge	Coastal		
FAVERSHAM	1,747	331	190	Secondary biological	Inland		
FORD	8,327	1,182	142	Secondary activated sludge	Coastal		
FULLERTON	3,889	1,808	465	Tertiary B2	Inland		
GODDARDS GREEN	3,791	837	221	Tertiary A2	Inland		
GRAVESEND	3,828	706	184	Secondary activated sludge	Inland		
HAILSHAM SOUTH	1,836	1,038	565	Tertiary A2	Inland		
HAM HILL	4,176	551	132	Tertiary A1	Inland		
HASTINGS BEXHILL	8,472	696	82	Secondary activated sludge	Coastal		
HORSHAM NEW	4,450	1,402	315	Tertiary B2	Inland		
MAY STREET HERNE BAY	2,549	2,288	898	Tertiary A2	Coastal		
MILLBROOK	8,846	3,724	421	Tertiary A2	Coastal		
MORESTEAD ROAD WINCHESTER	2,719	736	271	Tertiary A2	Inland		

Site	Load received kg BOD$_5$	Total expenditure £m/year	Unit cos £/kg BOD$_5$	Treatment Type	Category	UV	TN
MOTNEY HILL	16,341	1,889	116	Secondary activated sludge	Inland		
NEWHAVEN EAST	3,712	1,007	271	Secondary activated sludge	Coastal		
NORTHFLEET	3,523	941	267	Secondary activated sludge	Inland		
PEACEHAVEN	18,180	3,216	177	Secondary activated sludge	Coastal		
PEEL COMMON	16,546	2,929	177	Tertiary A2	Coastal	UV	TN
PENNINGTON	3,311	781	236	Tertiary A2	Coastal	UV	TN
PORTSWOOD	4,853	2,681	552	Secondary activated sludge	Inland		
QUEENBOROUGH	2,462	1,807	734	Secondary activated sludge	Coastal		
SANDOWN	8,102	2,910	359	Secondary activated sludge	Coastal		
SCAYNES HILL	2,507	688	274	Tertiary B2	Inland		
SHOREHAM	3,464	1,281	370	Secondary activated sludge	Coastal		
SITTINGBOURNE	4,685	2,167	462	Secondary activated sludge	Inland		
SLOWHILL COPSE MARCHWOOD	4,376	3,383	773	Tertiary A2	Coastal		
SWALECLIFFE	2,160	2,753	1,275	Tertiary A2	Coastal	UV	
TONBRIDGE	3,091	974	315	Tertiary B2	Inland		
TUNBRIDGE WELLS NORTH	1,975	1,016	514	Tertiary B2	Inland		
TUNBRIDGE WELLS SOUTH	1,823	711	390	Tertiary A2	Inland		
WEATHERLEES HILL A	5,489	1,810	330	Secondary activated sludge	Coastal		
WEATHERLEES HILL B	5,893	451	77	Tertiary A2	Coastal	UV	
WHITEWALL CREEK	2,271	475	209	Secondary biological	Inland		
WOOLSTON	4,024	3,181	790	Tertiary A2	Coastal		TN

Note: the costs have been inflated from prices of the year to 2022/23 prices.