April 2018
Economic Insight Ltd

MEASURES OF SERVICE: COST BENEFIT ANALYSIS

Report for Welsh Water

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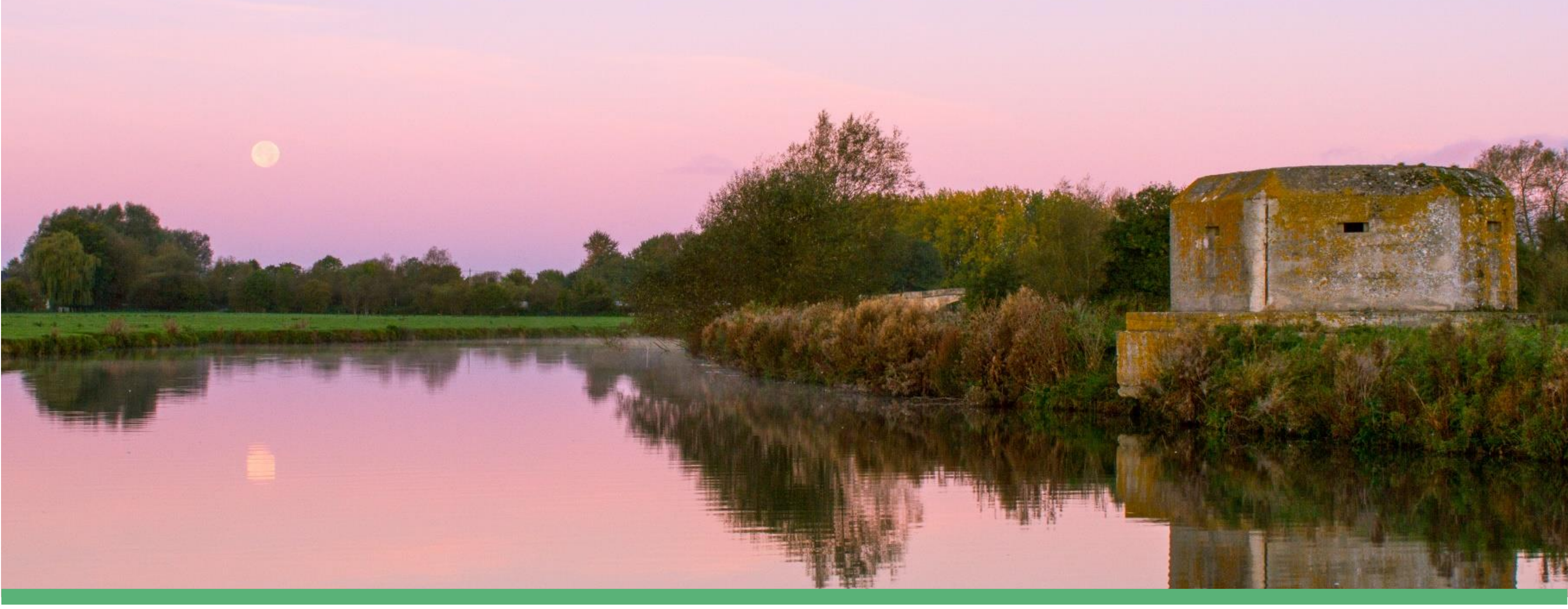


1. Introduction and Executive Summary

This report sets out our advice to Welsh Water (Welsh) on cost benefit analysis (CBA) for the company's PR19 measures of service (MoS). We first provide background information, before going on to set out the issues around the conceptual approach to CBA, and our recommended method. Finally, we apply this method to 12 measures: water supply interruptions; leakage; wastewater pollution incidents; internal sewer flooding; external sewer flooding; river water quality; rainscape; water acceptability; renewable energy; worst served customers – low pressure; worst served customers – supply interruptions; and worst served customers – sewer flooding. This report is further accompanied by spreadsheets that implement our method for these measures. Our method reflects Ofwat's guidance on CBA and incorporates both multi-input and systematic judgement approaches.

1.1 Background – Ofwat's approach to PCs and ODIs

At PR14, companies were required to specify performance commitments (PCs) for certain Outcome Delivery Incentives (ODIs), using a CBA approach. PC targets were set at the level at which the marginal benefits of increased performance (specifically, marginal willingness to pay) equalled marginal costs – although some allowance was made for lower performance, where performance improvements beyond that point were considered unaffordable. After reviewing companies' business plans, Ofwat was concerned by the very wide variations in proposed PCs for similar outcomes. It therefore intervened and set common PCs using 'comparative assessments', based on 2011/13-2013/14 upper quartile performance for: water quality compliance; water quality contacts; water supply interruptions; wastewater pollution incidents; and internal sewer flooding performance.

In its PR19 methodology, Ofwat proposes a mixture of common and bespoke ODIs and associated PCs. Specifically, the regulator has mandated 14 common ODIs / PCs (i.e. PCs that all companies must have). These will address:

- customer measure of experience (C-MeX);
- developer services measure of experience (D-MeX);
- water quality compliance;
- water supply interruptions;
- leakage;
- per capita consumption;
- internal sewer flooding;
- pollution incidents;
- risk of severe restrictions in a drought;
- risk of sewer flooding in a storm;
- mains bursts;
- unplanned outage;
- sewer collapses; and
- treatment works compliance.

In addition to these common areas, companies are free to propose additional bespoke ODIs and PCs.

Ofwat has further suggested that some firms' strong performance against the PR14 PCs could indicate that the levels were insufficiently challenging.[1] It has, therefore, put further emphasis on the need to select demanding levels for PCs at PR19. In order to achieve this, Ofwat's proposals are as follows:

- Of the above 14 common PCs, Ofwat has specified that three will be set on a 'comparative basis'. These are: (i) water supply interruptions; (ii) internal sewer flooding; and (iii) pollution incidents. Here, Ofwat requires companies to set PCs targeted on *at least* forecast upper quartile. Here, Ofwat stated that: *"we see little reason why companies should not be achieving the same level of stretching performance for these metrics."*[2]

- In relation to leakage specifically, Ofwat has stated that a stretching PC would be: (i) achieving at least upper quartile; (ii) achieving at least a 15% reduction; and / or (iii) achieving the largest actual percentage reduction since PR14.[3]

- In relation to **bespoke PCs** (i.e. the 10 PCs that are a subset of the 14 common PCs above, but which are not among the four set on a comparative basis; or any PCs that are themselves company specific), Ofwat has said that 'stretching' PCs should reflect a range of evidence. This should include:

  - **CBA** (as addressed in this report);
  - comparative information (where available);
  - historical information;
  - minimum improvement;
  - maximum level attainable; and
  - expert knowledge.[4]

[1] *'Delivering Water 2020: Our methodology for the 2019 price review. Appendix 2: Delivering outcomes for customers.' Ofwat (December 2017), p44.*
[2] *'Delivering Water 2020: Our methodology for the 2019 price review. Appendix 2: Delivering outcomes for customers.' Ofwat (December 2017), p61.*
[3] *'Delivering Water 2020: Our methodology for the 2019 price review. Appendix 2: Delivering outcomes for customers.' Ofwat (December 2017), p65.*
[4] *'Delivering Water 2020: Our methodology for the 2019 price review. Appendix 2: Delivering outcomes for customers.' Ofwat (December 2017), p51.*

1.2 Ofwat's guidelines relating to CBA

Under Ofwat's PR19 methodology, CBA is one input into companies' evidence base for setting bespoke PCs. Specifically in relation to CBA at PR19, Ofwat's methodology provides guidance as to how companies should implement this in practice. This includes:

- That, in general terms, the purpose of CBA is to identify a PC level based on the intersection of marginal cost and marginal benefits (primarily, willingness to pay).
- That in assessing marginal benefits, companies should consider wider impacts, such as those on the environment.
- That it might be appropriate to set a PC service level below the 'economic level' as identified using CBA, for reasons of affordability.

The above is consistent with the approach at PR14. In addition, Ofwat has proposed two improvements to CBA at PR19 – as follows:

IN ITS GUIDANCE ON CBA AT PR19, OFWAT EMPHASISES THE NEED TO DRAW ON MULTIPLE SOURCES OF EVIDENCE AND TO APPLY FORECAST EFFICIENT COSTS.

- **Companies should use multiple sources of evidence** on customer preferences, *"where it is proportionate to do so"*.[5] Ofwat has stressed that stated preference willingness to pay (WTP) is *not* the 'default' approach to assessing benefits. Companies are, therefore, expected to use a range of methods, where feasible or appropriate (for instance, when there is a large associated ODI incentive payment). As this may lead to multiple, and conflicting, sources of evidence, Ofwat emphasised the need to test the sensitivity of their PCs to changes in customer valuations – and to apply suitable triangulation frameworks.[6]
- Ofwat will challenge companies on their marginal cost estimates; and will expect companies to **use forecast efficient cost levels.**[7] This includes *explaining how they have calculated their marginal cost estimates* and *explaining how they have treated common costs*.

5 *'Delivering Water 2020: Our methodology for the 2019 price review. Appendix 2: Delivering outcomes for customers.' Ofwat (December 2017), p52.*
6 *'Delivering Water 2020: Our methodology for the 2019 price review. Appendix 2: Delivering outcomes for customers.' Ofwat (December 2017), p52.*
6 *'Delivering Water 2020: Our methodology for the 2019 price review. Appendix 2: Delivering outcomes for customers.' Ofwat (December 2017), p52.*
7 *'Delivering Water 2020: Our methodology for the 2019 price review. Appendix 2: Delivering outcomes for customers.' Ofwat (December 2017), p52.*

1.3 Scope of this report

In the above context, Welsh commissioned Economic Insight to:

(i) **Develop a conceptual approach and method for CBA at PR19**, consistent with Ofwat's guidelines, but also best practice on CBA – including HM Treasury's Green Book and the wider literature on CBA.

(ii) To **apply that method** in practice across 12 specific measures.

(iii) To **inform the setting of Welsh's PCs at PR19, by identifying the service level ranges indicated by the CBA.** Here, it is important to stress that, as described above, under Ofwat's method for bespoke PCs, CBA is considered to be only one source of evidence that companies should rely on. Consequently, the analysis set out in this report should be considered alongside a range of other information, when selecting PC levels for PR19.

The scope of our work includes constructing CBAs for 12 specific measures:

- water supply interruptions;
- leakage;
- wastewater pollution incidents;
- internal sewer flooding;
- external sewer flooding;
- river water quality;
- rainscape;
- water acceptability;
- renewable energy;
- worst served customers – low pressure;
- worst served customers – supply interruptions; and
- worst served customers – flooding.

This report should be read alongside the accompanying spreadsheets, which provide the full calculations that were used to generate the CBAs.

1.4 Key findings

1.4.1 Approach to CBA

Our research suggests that Welsh's approach to CBA for the PR19 PCs should include the following features.

- **Benefits estimates should be based on a multi-input CBA approach,** which draws on both Welsh's WTP and MoS evidence, utilising the 'range' of benefits values implied within each piece of research.

- **Benefits should further take into account broader impacts, using a subjective judgement approach with robust evaluation criteria.** Specifically, consideration should be given as to whether: (a) there are any environmental or social benefits that the research does not reflect; or (b) benefits accrue to people who are not Welsh customers. We address this separately for each measure we have analysed in the following chapter.

- For consistency with Ofwat's methodology, CBAs should **use estimates of efficient costs.**
- Costs and benefits should be **estimated across the whole lifetime of the assets** that generate them.
- **Costs and benefits should be discounted using the social rate of time preference** (which the Treasury estimates to be 3.5%, declining after 30 years), with capital costs annualised at an estimate of the cost of capital.

OUR CBA ANALYSIS PROVIDES GUIDLINE RANGES FOR PC LEVELS AT PR19. HOWEVER, AS PER OFWAT'S GUIDELINES, STRETCHING PC LEVELS SHOULD REFLECT A BROADER RANGE OF EVIDENCE THAN CBA ALONE.

1.4.2 Summary results

The following table presents indicative ranges for socially optimal PC levels for the 12 measures set out above, based on the CBA evidence. Again, we should highlight that Welsh's proposed PC levels should reflect a broader range of evidence than CBA alone. Consequently, it might be entirely appropriate for Welsh to set PCs that are outside of these ranges, depending on the nature of the additional evidence relied upon.

Table 1: Indicative ranges for socially optimal PC levels

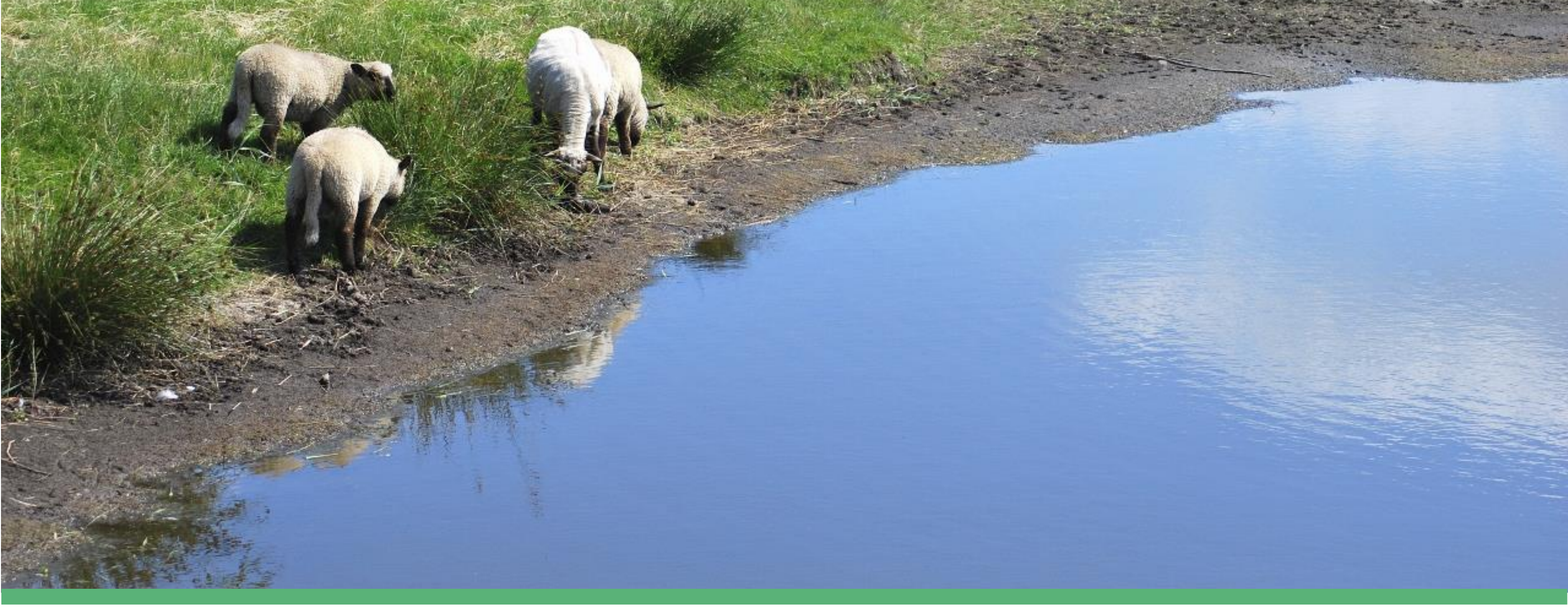
Measure	Indicative range for PC level
Water supply interruptions	5.0 minutes to 12.0 minutes
Leakage	163 to 169 Ml per day
Wastewater pollution incidents	74 to 88 incidents
Internal sewer flooding	166 to 220 incidents
External sewer flooding	3,650 to 4,000 incidents
River water quality	0km to more than 600km
Rainscape	25,000 to more than 60,000 roof equivalents
Water acceptability	1.95 to 2.4 per 1,000 population
Renewable energy	30% to more than 40%
Worst served customers – low pressure	No socially optimal improvement
Worst served customers – supply interruptions	Below 500 affected properties
Worst served customers – sewer flooding	Below 320 properties

Source: Economic Insight

1.5 Report structure

The report is structured as follows:

- We discuss conceptual issues around the approach to CBA and present our recommendations as to the approach to CBA for PR19 PCs in Chapter 2.
- We apply this approach to the 12 MoS described above in Chapter 3.
- We provide more detail of our review of relevant literature in Annex A.
- We give further details on our approach to the inclusion of environmental, social and health benefits in Annex B.



2. Conceptual Approach to CBA

This chapter sets out the theoretical and conceptual underpinnings of CBA, and examines evidence on good practice in performing such analysis. It then considers the key practical issues encountered in conducting a CBA, and how they can be addressed, before concluding with our recommendations on the approach to, and method for, CBA at PR19.

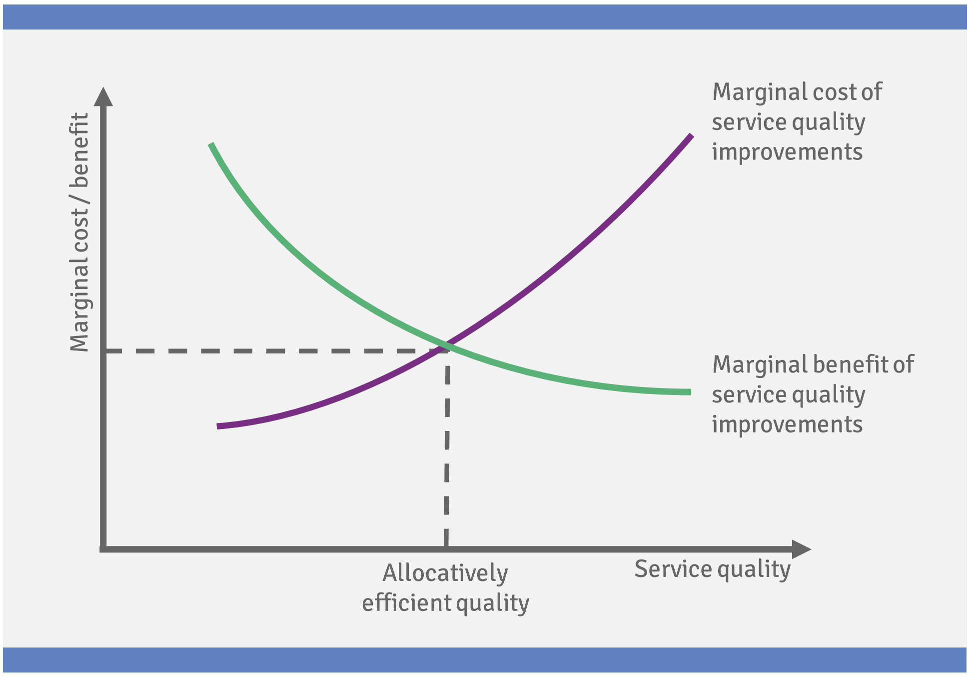
2.1 The purpose of CBA in a price control

'In a perfectly competitive market … service quality levels are allocatively efficient.'

In a perfectly competitive industry, firms have incentives to provide the products that customers want at service quality levels that maximise value to society. Service quality levels are **allocatively efficient**, in that it would be impossible to increase service quality without the additional costs of doing so exceeding the additional benefits. We illustrate this in the figure overleaf. Marginal benefits generally fall as service quality increases, with allocatively efficient quality being at the intersection with marginal cost. For service quality, the benefits of quality improvements are generally considered in terms of 'willingness to pay' – that is, the maximum additional amount that consumers would be willing to pay to gain the service improvement.

Monopoly suppliers, however, lacking incentives to provide allocatively efficient service quality, supply lower quality than the social optimum. Indeed, while the focus of the negative effects of monopoly is often on high prices, price-capped monopolies have incentives to cost minimise, but still lack incentives to be allocatively efficient.

Figure 1: Allocative efficiency for service quality



Source: Economic Insight

THE PURPOSE OF COST BENEFIT ANALYSIS WITHIN THE PRICE CONTROL PROCESS IS TO PROVIDE EVIDENCE TO INFORM THE SOCIALLY OPTIMAL COMBINATION OF SERVICE PERFORMANCE.

The purpose of CBA within the price control process for water companies is, therefore, to provide evidence to help inform the **socially optimal combination of service performance levels** across the various measures of water company service quality, by analysing the marginal costs and benefits of service quality improvements. Firms can then receive appropriate incentives – such as ODI payments – that give rewards for providing the required service level, or punishments for not doing so.

2.2 Key practical issues

In principle, CBA simply involves a comparison of the marginal costs and benefits of achieving different levels of service quality. In practice, CBA for water and wastewater service quality improvements is complicated by several issues.

- There is no directly observable evidence as to how much value people place on improvements in service quality.
- Some costs and benefits may accrue more widely than water industry billpayers (e.g. environmental and / or social impacts).
- CBAs need to combine multiple sources of possibly conflicting evidence.
- Actual costs may diverge from efficient costs for monopoly suppliers, so there is a question as to which it is appropriate to use.
- Costs and benefits will occur at different points over time; so, some account will need to be taken of the fact that having something now is worth more than having it in the future.

We discuss each of these issues in turn.

2.2.1 Unobservable benefits

CBAs usually use market prices to infer the value of different goods and services to consumers. As this is clearly impossible for water industry service quality (due to the monopoly supply nature of the industry), other sources of evidence must be used. In principle, a range of methods can be applied to value benefits, including: (i) stated preference WTP surveys; (ii) economic experiments; and / or (iii) revealed preference techniques.

WELSH HAS DEVELOPED THREE MAIN SOURCES FOR BENEFITS ESTIMATES: WTP SURVEY, MoS AND COST OF CONSEQUENCE ANALYSIS.

In Welsh's case, the primary source of evidence that can be used to inform the benefits of improvements to service performance is its own **WTP customer research.** This provided estimates of customers' WTP for service improvements, by asking consumers about 'packages' of incremental improvements to service quality (each with different levels of supply interruptions, internal sewer flooding etc.); and decomposing this into separate WTP estimates for individual aspects of service. In addition to this, Welsh has benefits evidence derived from:

- a separate online survey, referred to as **'MoS estimates';** and
- **cost of consequence** analysis (which captures benefits by measuring the costs incurred of rectifying service quality issues).

The Treasury Green Book states that all relevant benefits (and costs) should be included within a CBA (and that even when they cannot be valued, they should be appraised). Basing an assessment of benefits on research into Welsh's own customers leaves the possibility that some benefits are not accounted for. As such, the CBA will also need to consider: (i) whether there are any benefits (particularly environmental and social benefits) that would not be detected by Welsh's research; and (ii) whether any benefits accrue to people who are not customers of Welsh, such as tourists or visitors. If so, attempts should be made at quantification, although this may not always be possible in practice.

2.2.2 Combining multiple evidence sources

As noted previously, a key part of the PR19 methodology relating to CBA includes Ofwat's requirement that firms use multiple sources of evidence (where this is appropriate) including a range of methods. This raises the question as to how potentially conflicting evidence of benefits (and costs) from different sources should be combined into a single estimate. In a report for Ofwat, Frontier Economics[8] identified three options for combining multiple sources of evidence on customer valuations:

- **Option 1:** using a pre-defined mechanistic rule (e.g. average or weighted average with pre-defined weights).
- **Option 2:** using a 'systematic judgement' approach, with a pre-defined system or set of criteria.
- **Option 3:** a 'multi-input CBA'.

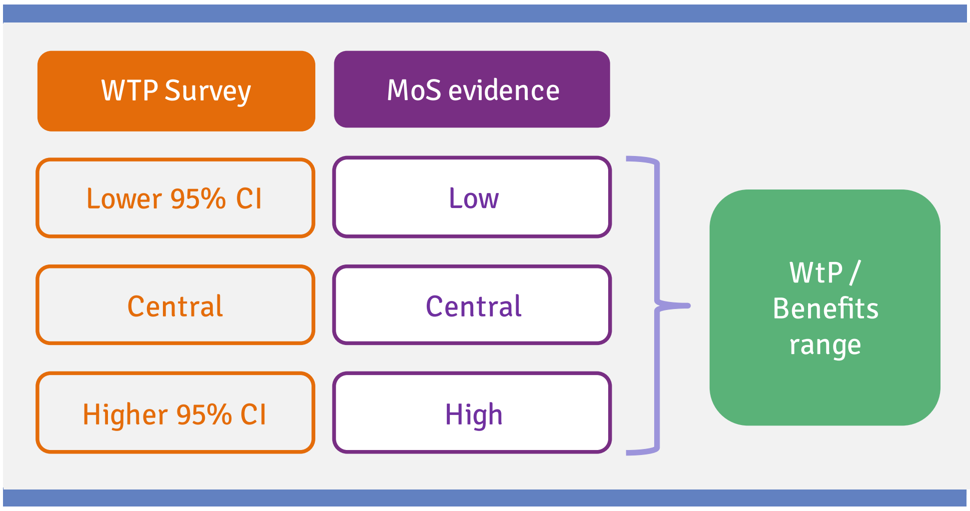
[8] *'Performance commitments and outcome delivery incentives at PR19: a report for Ofwat.' Frontier Economics (March 2017).*

The latter would use a range of evidence on customer valuations to generate upper and lower bound WTP estimates, and develop PC ranges based on these different levels.

THE METHOD WE HAVE DEVELOPED COMBINES A 'MULTI-INPUT' CBA APPROACH WITH A 'SYSTEMATIC JUDGEMENT' APPROACH.

In identifying the economic level of service for the 12 measures analysed in our analysis, we have, in effect, used a combination of Options 2 and 3 from the Frontier Economics report. Namely, **we have used a multi-input CBA approach** by drawing on both the WTP and MoS evidence (and the ranges within this evidence) to identify an overall 'benefits range' for Welsh, as shown in the figure below.

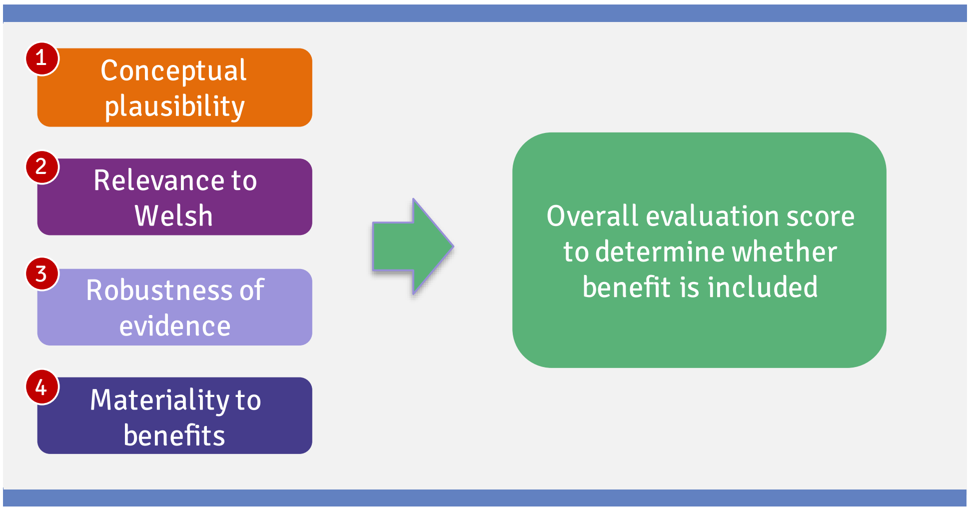
Figure 2: Multi-input CBA approach



Source: Economic Insight

In addition, **we also applied a systematic judgement approach to determine where environmental and social benefits should be included.** Here, we developed a robust set of evaluation criteria for each wider impact considered, as summarised below.

Figure 3: Systematic judgement approach: evaluation criteria for environmental and social impacts



Source: Economic Insight

2.2.3 Efficient versus actual costs

'We recommend basing CBAs on estimates of efficient costs.'

For consistency with Ofwat's methodology, we recommend basing CBAs on estimates of *efficient costs*. Companies' actual costs may be different to their efficient levels, and so CBAs could suggest different conclusions, depending on which costs are used (i.e. with **efficient** costs suggesting that **higher** performance levels are optimal). In its PR19 methodology, Ofwat has required that CBAs use forecast efficient costs (and firms will have to explain how they have calculated marginal cost estimates and their treatment of common costs).

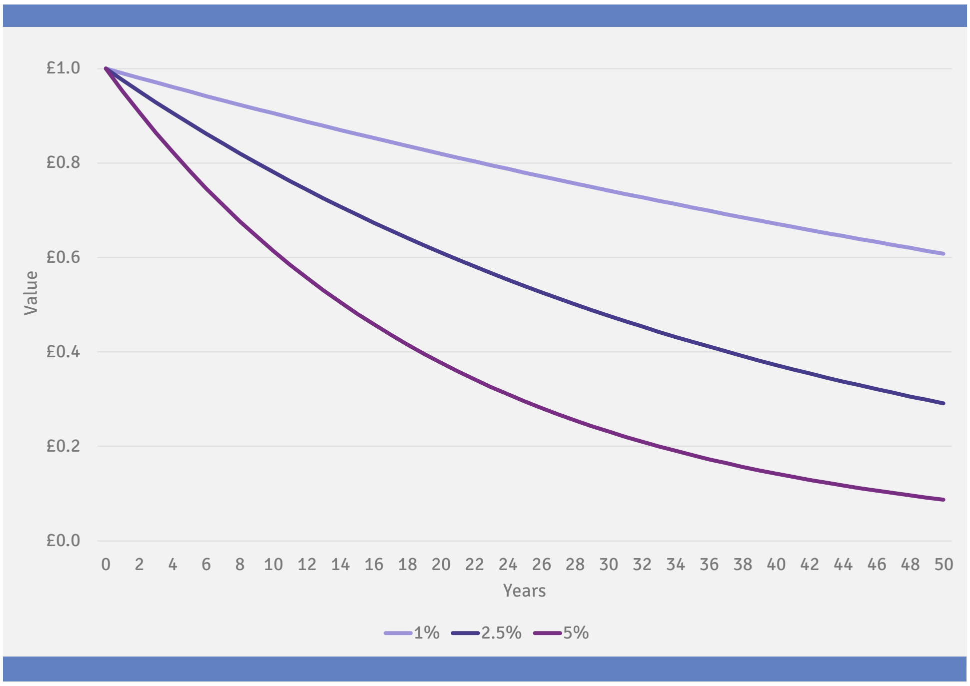
In practice when applying our CBA, we have relied on the marginal cost information provided Welsh, which the company informed us was arrived at in a way such as to ensure they are 'efficient' measures. Welsh told use that their approach was to build up their investment plan using current cost information, and then apply a percentage adjustment to reflect the extent of efficiencies that can be made in delivery, reflecting engineering judgement. The scope of our work has not included verifying the efficiency deductions.

2.2.4 Accounting for time

The costs and benefits of any service improvement will occur across different points in time. In practice, this means that decisions need to be taken over the timeframe over which costs and benefits are assessed. According to the HM Treasury Green Book, this should cover the useful lifetime of the asset (and should account for any residual value of the asset at the end of its life). Costs and benefits also need to be discounted to reflect the fact that people prefer to have things *"now"*, rather than in the future. The appropriate choice of discount rate is uncertain and can make a very large difference to cost and benefit estimates. For example, the figure below shows the impact of different discount rates on the value of £1 in the future, with very large differences between figures.

In practice, the Green Book recommends that costs and benefits to society as a whole should be discounted using the **social time preference rate**. It suggests a rate of 3.5%, declining after 30 years, which reflects a combination of the rate at which individuals discount future consumption over present consumption – and expected growth in future consumption.

Figure 4: Example of the impact of different discount rates



Source: Economic Insight

IN TERMS OF DISCOUNTING, REGULATORS FAVOUR THE 'SPACKMAN APPRPOACH'. THIS INVOLVES ANNUALISING CAPITAL COSTS USING THE WACC, THEN DISCOUNTING BACK ALL COSTS AND BENEFITS AT THE SOCIAL TIME PREFERENCE RATE.

There is, however, a remaining question as to how to treat costs that are generated by private investment, but which generate public benefit. **Regulators favour a method known as the 'Spackman' approach.** This involves discounting all costs and benefits at the social time preference rate. Before discounting at this rate, however, capital costs are annualised, using the cost of capital.[9]

2.3 Our recommended approach

In summary, our favoured approach to CBA is as follows:

- **Benefits estimates should be based on a multi-input CBA approach,** which draws on both Welsh's WTP and MoS evidence, utilising the 'range' of benefits values implied within each piece of research.

- **Benefits should further take into account broader impacts, using a subjective judgement approach with robust evaluation criteria.** Specifically, consideration should be given as to whether: (a) there are any environmental or social benefits that the research does not reflect; or (b) benefits accrue to people who are not Welsh customers. We address this separately for each measure we have analysed in the following chapter.

- To be consistent with Ofwat's methodology, **CBAs should use estimates of efficient costs,** consistent with the 'theoretically optimal' level of service performance.

- Costs and benefits should be **estimated across the whole lifetime of the assets** that generate them.

[9] *'Discounting for CBAs involving private investment, but public benefit.' Joint Regulators Group. 2011.*

- **Costs and benefits should be discounted over time.** We recommend discounting costs and benefits by the social rate of time preference (which the Treasury estimates to be 3.5%, declining after 30 years), with capital costs annualised at an estimate of the cost of capital (Ofwat's latest estimate being 2.4%).

3. Results

This chapter presents the results of our CBAs for 12 measures: water supply interruptions; leakage; wastewater pollution incidents; internal sewer flooding; external sewer flooding; river water quality; rainscape; water acceptability; renewable energy; worst served customers – low pressure; worst served customers – supply interruptions; and worst served customers – flooding.

3.1 Water supply interruptions

This measures the duration of interruptions to customers' water supply – which includes having no water and having intermittent supply. It can include short-term interruptions of a few hours, or longer interruptions lasting several days. It is expressed as the average duration (in minutes) of supply interruptions, across Welsh's customer base. At present, the average duration of supply interruptions for Welsh is approximately 12 minutes.

3.1.1 Costs

Welsh provided us with estimates of total up-front costs for improvements in water supply interruptions. Welsh told us that the standard approach to reducing supply interruptions is to replace mains, as modern plastic mains have a much lower rate of bursts, but this is expensive. It expects, however, that it can reduce the duration of supply interruptions to 8 minutes, on average, at lower cost by minimising response times. Further reductions would be materially more expensive.

The table below shows Welsh's estimates of the efficient costs associated with performance improvements (on a total cost basis). They further estimate that these improvements would lead to on-going costs equal to 1% of the initial up-front cost.

Table 2: Cost estimates for water supply interruption performance improvements

Average duration of supply interruption (minutes)	One-off costs (millions)	On-going costs (millions)
12	£0	£0.0
8	£95	£1.0
6	£250	£2.5
4	£505	£5.1
2	£1,010	£10.1

Source: Welsh Water

3.1.2 Benefits

3.1.2.1 Customer research

The main source of evidence on the benefits of improvements in Welsh's water supply interruption performance comes from Welsh's PR19 WTP research.[10] This research gave separate valuations for short-term supply interruptions (giving 3-6 hours as an example) and long-term interruptions (i.e. those lasting more than 24 hours). It also made clear in asking questions that Welsh provides mitigation, in the form of mobile water tanks or bottled water for vulnerable consumers, in the case of long-term supply interruptions.

The table below shows WTP levels associated with the performance levels set out above. These show central estimates of customer WTP for the associated reductions, alongside outer bounds for the 95% confidence interval around this estimate.

Table 3: WTP for water supply interruption performance improvements

Estimate	Short-term interruptions		Long-term interruptions	
Service level	12 to 7 min.	7 to 5 min.	12 to 7 min.	7 to 5 min.
Lower 95%	£8,006,266	£967,687	£1,674,221	£148,488
Central	£9,534,368	£1,625,913	£2,004,314	£260,607
Upper 95%	£11,031,971	£2,282,892	£2,328,181	£372,578

Source: Welsh Water

The MoS estimates provide WTP estimates for a different set of supply interruption durations, as we show in the following table.

[10] *'Dŵr Cymru Welsh Water PR19 Willingness to Pay Research: Final Report.' Accent & PJM Economics (December 2017).*

Table 4: MoS WTP for water supply interruption performance improvements

Version	12 to 10 min.	10 to 7 min.
Main	£1,261,903	£480,172
Pilot	£2,181,618	£710,837

Source: Welsh Water

3.1.2.2 Consequential costs

In addition to direct benefits to customers, service improvements can have benefits as a result of avoiding costs that would otherwise be incurred. Welsh estimates that costs of £37 per affected property would be avoided in the case of short-term supply interruptions, and £219 per affected property would be avoided in the case of long-term interruptions.

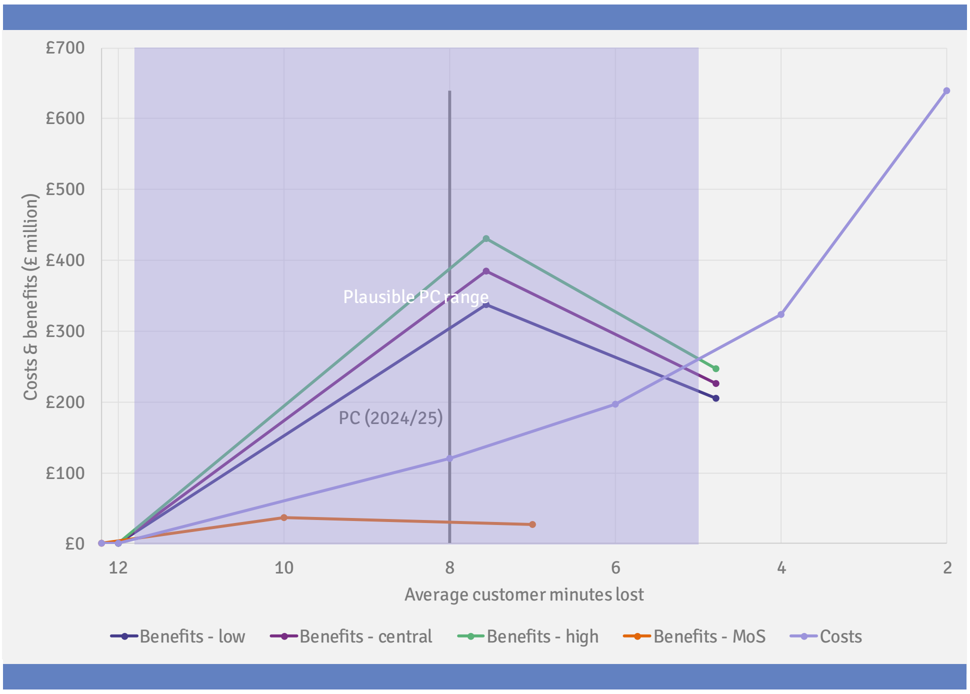
3.1.2.3 Environmental and social benefits

The benefits of reduced duration of water supply interruptions accrue primarily to Welsh's customers. There are also no obvious 'spill-overs' with respect to supply interruptions. For instance, there seems no obvious reason why a customer would experience disutility from their neighbour experiencing a supply interruption. As such, we do not expect that there are wider social and environmental benefits associated with reduced supply interruptions.

3.1.3 Economic level of service

We used the above information to calculate present discounted values of the marginal costs and benefits associated with the service improvements set out above. We then plotted these to identify the economic level of service, at the point at which the marginal cost and benefit lines cross. As we show in the chart overleaf, this implies an optimal average service interruption in the range of 5 to slightly less than 12 minutes.

Figure 5: Marginal costs and benefits of water supply interruption service improvements



Source: Economic Insight

3.2 Leakage

This measure relates to leakage in Ml per day. The status quo level of leakage is 169 Ml per day.

3.2.1 Costs

The table below shows Welsh's estimates of efficient total costs associated with leakage service improvements. On-going costs are estimated to be 1% of initial up-front costs.

Table 5: Cost estimates for leakage reductions

Leakage (Ml/day)	One-off costs (millions)	On-going costs (millions)
169	£0.0	£0.0
143	£73.0	£0.7
120	£250.0	£2.5

Source: Welsh Water

3.2.2 Benefits

3.2.2.1 Customer research

Welsh's MoS evidence provides WTP estimates for different reductions in leakage, as we show in the table below.

Table 6: MoS WTP for leakage performance improvements

Version	121 to 117	117 to 114
Main	£317,368	£86,792
Pilot	£589,273	£168,364

Source: Welsh Water

3.2.2.2 Consequential costs

In addition to direct benefits to customers, service improvements can have benefits as a result of avoiding costs that would otherwise be incurred. In the case of leakage, Welsh estimates that costs of £55,970 per Ml per day could be avoided (over the course of a year).

3.2.2.3 Environmental, social and health benefits

We considered whether there could be wider environmental, social and health benefits as a result of improved performance. In this case, benefits relate to reductions in eutrophication.[11] Our research indicates that these benefits could range between £0.0018 m per Ml per day and £0.0031 per Ml per day, as we set out in the

[11] *See, for instance, 'Mains water leakage: Implications for phosphorus source apportionment and policy responses in catchments.' D.C. Gooddy, M.J. Ascott, D.J. Lapworth, R.S. Ward, H.P. Jarvie, M.J. Bowes, E. Tipping, R. Dils, B.W.J Surridge. Science of the Total Environment 579 (2017) 702–708.*

table below. Note, a fuller description of environmental / social benefits – and all related evidence and sources used – is contained in Annex B.

Table 7: Environmental, social and health benefits associated with leakage service improvements

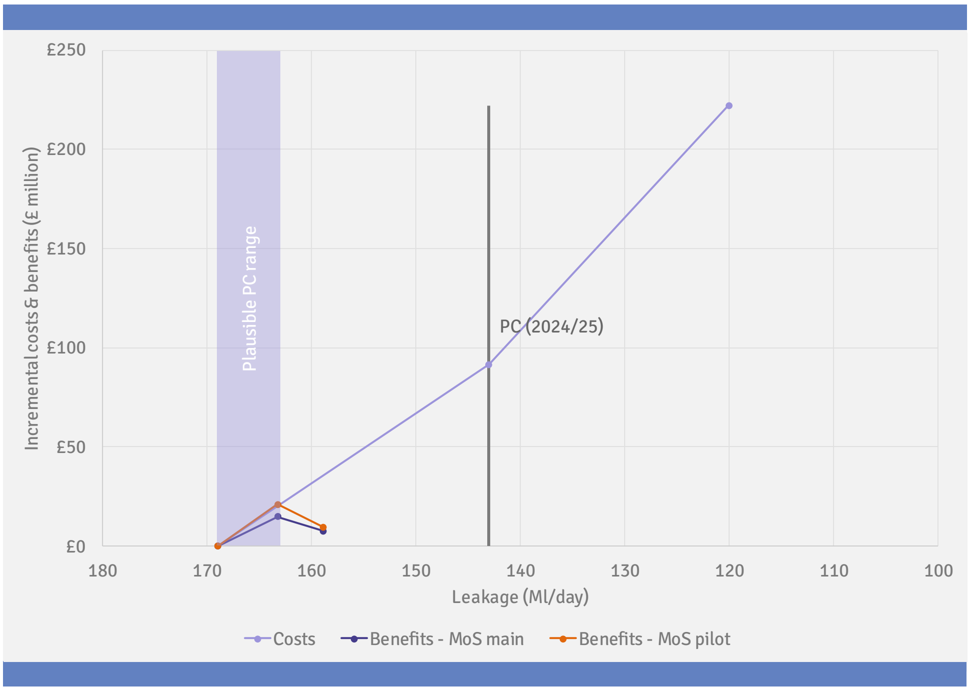
Scenario	Benefits (£ m per Ml per day)
Low	£0.0018
Medium	£0.0024
High	£0.0031

Source: Welsh Water

3.2.2.4 Economic level of service

We used the above information to calculate present discounted values of the marginal costs and benefits associated with the service improvements set out above. We then plotted these to identify the economic level of service, at the point at which the marginal cost and benefit lines cross. As we show in the chart below, this suggests an optimal level of service of between 163 and 169 Ml per day.

Figure 6: Incremental costs and benefits of leakage service improvements



Source: Economic Insight

3.3 Wastewater pollution incidents

This measures the number of cases in which Welsh's operations lead wastewater to pollute on water or land. This ranges from minor incidents, with localised effects, to major incidents that could have significant impacts on commercial and agricultural activities.

3.3.1 Costs

Welsh provided us with estimates of total up-front costs for improvements in the number of wastewater pollution incidents. Again, Welsh told us that their estimates are of efficient costs. They further estimate that these improvements would lead to on-going costs equal to 1% of the initial up-front cost. These estimates (on a total cost basis) are shown in the table below.

Table 8: Cost estimates for wastewater pollution incidents performance improvements

Number of incidents per year	One-off costs (millions)	On-going costs (millions)
120	£0	£0
90	£5	£0.05
75	£100	£1.0
50	£505	£5.0

Source: Welsh Water

3.3.2 Benefits

3.3.2.1 Customer research

The primary source of WTP evidence on wastewater pollution incidents again comes from Welsh's customer research. This distinguished between minor and significant pollution events. Minor pollution was defined as pollution that would cause fewer than ten fish to die, or would affect agricultural or commercial activities in some way. Significant pollution was defined as leading to the death of between 10 and 99 fish, or having significant effects on agricultural or commercial activities.

The table below shows WTP levels associated with the performance levels set out above. These show central estimates of customer WTP for the associated reductions, alongside outer bounds for the 95% confidence interval around this estimate.

Table 9: WTP for wastewater pollution incident service improvements

Estimate	Minor incidents		Significant incidents	
Service level	110 to 80	80 to 50	2 to 1	1 to 0
Lower 95%	£125, 822	£31,816	£325,624	£89,750
Central	£150,459	£45,834	£397,225	£128,622
Upper 95%	£175,906	£59,788	£473,678	£167,321

Source: Welsh Water

The MoS evidence provides WTP estimates for different reductions in the number of pollution incidents, as we show in the table below.

Table 10: MoS WTP for wastewater pollution incident performance improvements

Version	103 to 90	90 to 70
Main	£1,349,631	£823,984
Pilot	£2,110,963	£1,490,150

Source: Welsh Water

3.3.2.2 Consequential costs

In addition to direct benefits to customers, service improvements can have benefits associated with avoiding costs that would otherwise be incurred. Welsh's estimates of avoided costs across the various categories of pollution incident are set out in the table below.

Table 11: Consequential costs associated with wastewater pollution incidents

Severity	Cost
Category 4: Has no potential to have an environmental impact	£659
Category 3: Has the potential to have a minor environmental impact e.g. small spills with little visual impact	£6,934
Category 2: Has the potential to have a significant environmental impact e.g. cancellation of a local water sport event due to discharge of sewage	£31,268
Category 1: Has the potential to have a major environmental impact e.g. >100 dead fish	£54,135

Source: Welsh Water

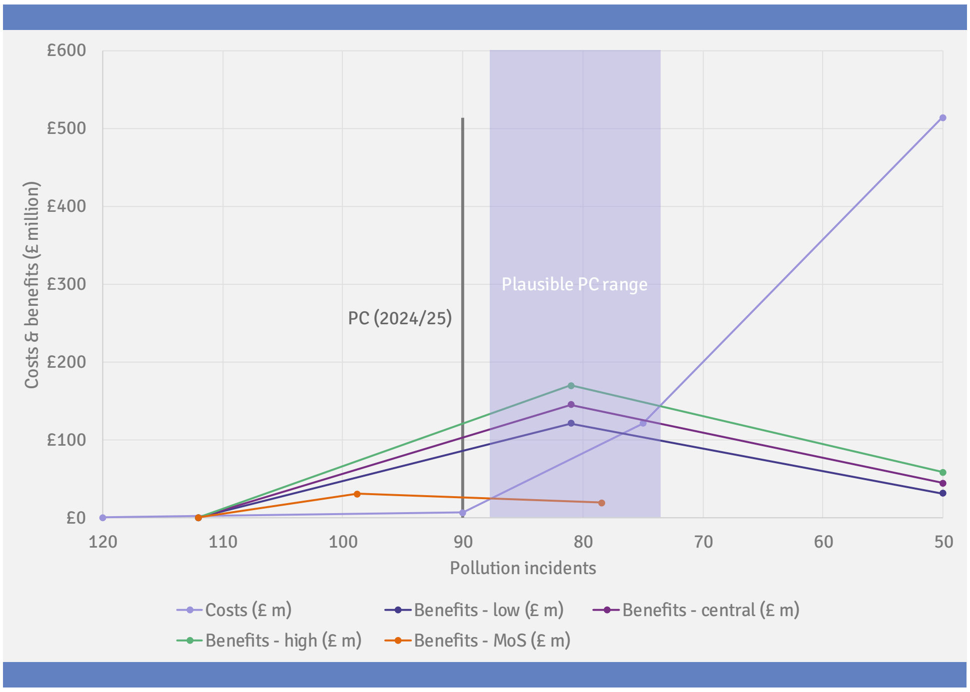
3.3.2.3 Environmental and social benefits

We expect that reductions in wastewater pollution incidents have the potential to give rise to wider benefits to customers outside of Welsh's supply area. Pollution incidents occur outside the home; and so one does not need to be one of Welsh's customers to be affected by them. As such, WTP estimates from customer research are likely to reflect only a proportion of the benefits of service improvements for wastewater pollution incidents – and so we used WTP data to estimate benefits to visitors to Wales. We note that, for the lower bound using the MoS data, we did not include these wider benefits. More detail on our approach is provided in Annex B.

3.3.3 Economic level of service

We used the above information to calculate present discounted values of the marginal costs and benefits associated with the service improvements set out above. We then plotted these to identify the economic level of service, at the point at which the marginal cost and benefit lines cross. As we show in the chart overleaf, this suggests that net benefits are maximised between 74 and 88 pollution incidents.

Figure 7: Incremental costs and benefits of wastewater pollution service improvements



Source: Economic Insight

3.4 Internal sewer flooding

This measures the number of incidents in which there is flooding from sewers within customers' properties – including homes, garages and outbuildings. This ranges from minor flooding incidents, in which there is no lasting damage to properties, to serious flooding incidents, in which extensive flooding makes the property uninhabitable. Welsh pays customers compensation equal to annual wastewater bills in such cases.

3.4.1 Costs

Welsh provided us with estimates of total up-front costs for improvements in the number of internal sewer flooding incidents. Again, Welsh told us that their estimates are of efficient costs. They estimate that these improvements would lead to on-going costs equal to 1% of the initial up-front cost. These estimates (on a total cost basis) are shown in the table below.

Table 12: Cost estimates for internal sewer flooding performance improvements

Number of incidents	One-off costs (millions)	On-going costs (millions)
225	£0	£0
203	£11	£0.1
150	£100	£1
100	£400	£4

Source: Welsh Water

3.4.2 Benefits

3.4.2.1 Customer research

Again, the main source of evidence on the benefits of improvements to Welsh's internal sewer flooding performance comes from the PR19 WTP research. In this case, separate WTP estimates were generated for minor incidents, in which sewer flooding does not lead to lasting damage to the property, and major incidents, which make the property uninhabitable. The research also made clear that Welsh provides compensation, equal to wastewater bill amounts.

The table below shows WTP levels associated with internal sewer flooding service improvements. These show central estimates of customer WTP for the associated reductions, alongside outer bounds for the 95% confidence interval around this estimate.

Table 13: WTP for internal sewer flooding performance improvements

Estimate	Minor incidents		Major incidents	
Service level	122 to 97	97 to 83	98 to 78	78 to 67
Lower 95%	£255,838	£38,161	£341,921	£57,848
Central	£325,894	£59,337	£448,905	£88,637
Upper 95%	£402,723	£80,465	£569,596	£119,356

Source: Welsh Water

The MoS evidence provides WTP for different reductions in the number of internal sewer flooding incidents, as we show in the table below.

Table 14: MoS WTP for internal sewer flooding performance improvements

Version	225 to 200	200 to 180
Main	£98,647	£28,931
Pilot	£234,599	£110,502

Source: Welsh Water

3.4.2.2 Consequential costs

In addition to direct benefits to customers, service improvements can have benefits as a result of avoiding costs that would otherwise be incurred. In the case of internal sewer flooding, Welsh's estimates of avoided costs are set out in the table below.

Table 15: Consequential cost estimates for internal sewer flooding

Severity	Cost
No permanent damage	£1,416
Fittings - Repairable damage caused	£10,385
Fixtures - Irreparable damage caused	£24,738
House destruction	£344,159

Source: Welsh Water

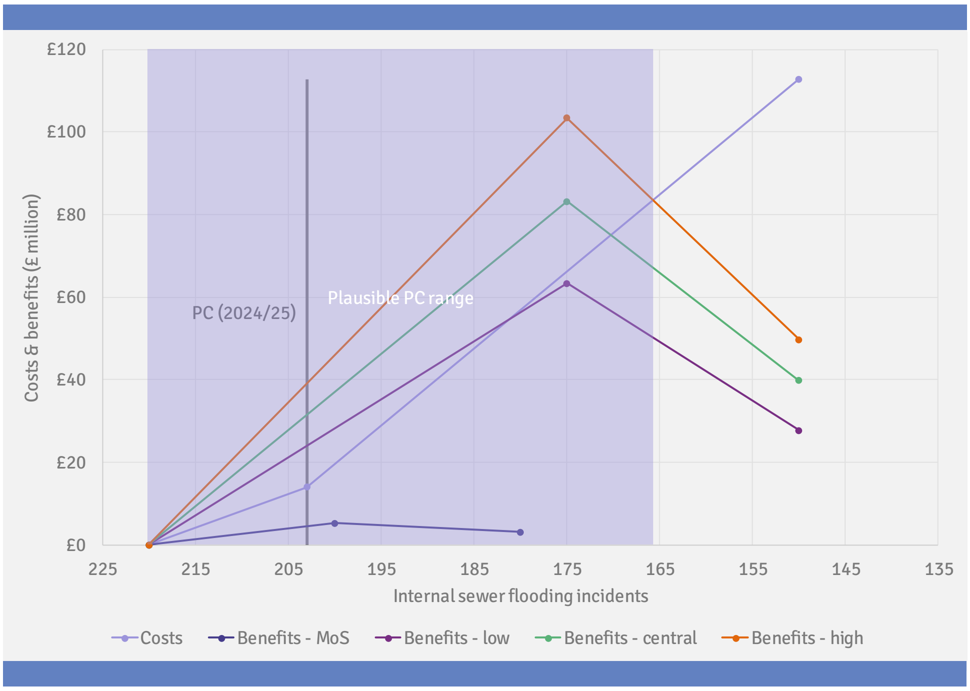
3.4.2.3 Environmental and social benefits

We considered whether there could be wider environmental, social and health benefits as a result of improved internal sewer flooding performance. In this case, benefits could occur through reduced incidents of gastroenteritis. Our research indicates that these benefits could range between £0.04 million per incident and £0.07 million, with a central estimate of £0.06 million per incident. Details of our analysis and evidence pertaining to this are set out in Annex B.

3.4.3 Economic level of service

We used the above information to calculate present discounted values of the marginal costs and benefits associated with the service improvements set out above. We then plotted these to identify the economic level of service, at the point at which the marginal cost and benefit lines cross. As we show in the chart below, this suggests that a plausible range for the economic level of service is between 166 and 220 incidents (the latter representing no reduction, relative to the status quo).

Figure 8: Marginal costs and benefits of internal sewer flooding service improvements



Source: Economic Insight

3.5 External sewer flooding

This measures incidents in which sewer flooding occurs within the curtilage of Welsh's customers' properties.

3.5.1 Costs

The table below shows estimates of efficient total costs associated with external sewer flooding service improvements. On-going costs are estimated to be 1% of initial up-front costs.

Table 16: Cost estimates for external sewer flooding performance improvements

Incidents	One-off costs (millions)	On-going costs (millions)
4,184	£0.0	£0.0
3,800	£15.0	£0.0
3,500	£150.0	£1.0
2,500	£200.0	£2.0

Source: Welsh Water

3.5.2 Benefits

3.5.2.1 Customer research

Evidence on benefits to Welsh's customers comes from the PR19 WTP research and the online MoS estimates. The table below shows estimated WTP from the WTP research, for the specified service increments.

Table 17: WTP estimates for service improvements in external sewer flooding performance

Estimate	Outside property	
Service level	SQ to SQ+1	SQ+1 to SQ+2
Lower 95%	£2,420,446	£647,946
Central	£3,044,064	£988,497
Upper 95%	£3,722,447	£1,328,117

Source: Welsh Water

The MoS estimates provide WTP per customer for different reductions in the number of external sewer flooding incidents, as we show in the table below.

Table 18: MoS WTP for external sewer flooding incident performance improvements

Version	SQ to SQ+1	SQ+1 to SQ+2
Main	£225,184	£102,804
Pilot	£162,673	£192,106

Source: Welsh Water

3.5.2.2 Consequential costs

In addition to direct benefits to customers, service improvements can have benefits as a result of avoiding costs that would otherwise be incurred. Welsh's estimates for consequential costs for external sewer flooding incidents at various levels of severity are set out in the table below.

Table 19: Consequential cost estimates for external sewer flooding

Severity	Consequential cost per incident (£)
Public amenity	£1,955
Roads or public access / Footpath	£528
Non- curtilage private	£890
Curtilage not inhibiting access	£2,182
Curtilage inhibiting access	£7,791

Source: Welsh Water

3.5.2.3 Environmental, social and health benefits

We considered whether there could be wider environmental, social and health benefits as a result of improved performance. In the case of external sewer flooding, we expect that benefits could arise relating both to recreational activity and eutrophication. These estimates are shown in the table below (and are further explained in Annex B).

Table 20: Environmental, social and health benefits – per external sewer flooding incident

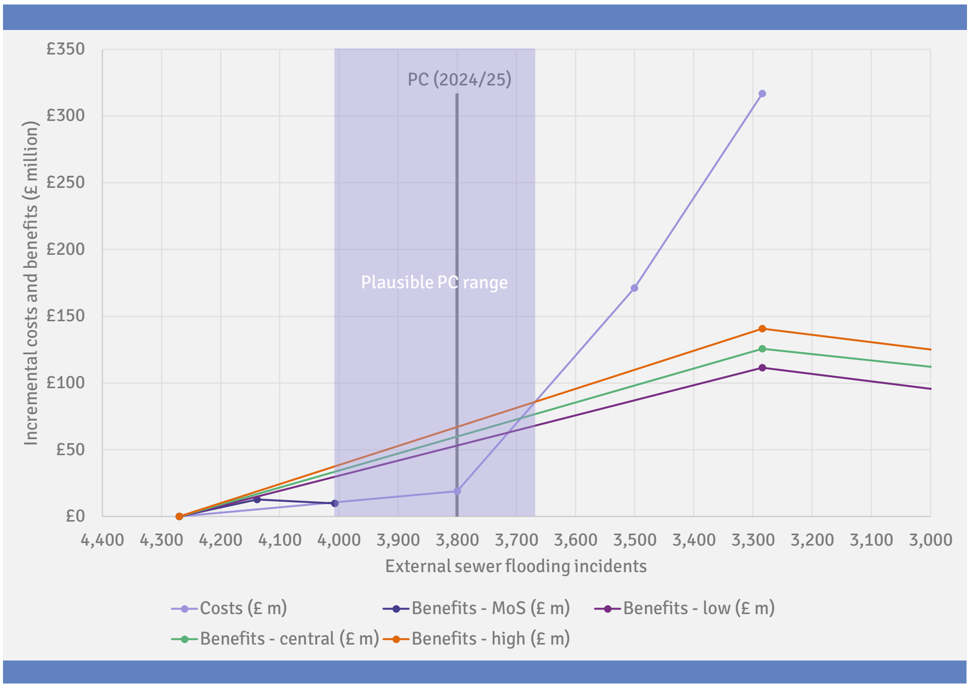
Scenario	**Recreation** Benefits (£ m)	**Eutrophication** Benefits (£m)
Low	£0.000145	£0.000006
Medium	£0.000320	£0.000008
High	£0.000408	£0.000010

Source: Economic Insight

3.5.2.4 Economic level of service

We used the above information to calculate present discounted values of the marginal costs and benefits associated with the service improvements set out above. We then plotted these to identify the economic level of service, at the point at which the marginal cost and benefit lines cross. Overall, this suggests an optimum level of service in the region of 3,650 to 4,000 incidents.

Figure 9: Incremental costs and benefits of external sewer flooding service improvements



Source: Economic Insight

3.6 River water quality

This measures km of river improved, which is achieved by altering the volume and/or quality of treated waste that is put back into rivers. The status quo level is 0km, as this measures km improved from the start of the AMP.

3.6.1 Costs

The table below shows estimates of efficient total costs associated with river water quality service improvements. On-going costs are estimated to be 1% of initial up-front costs.

Table 21: Cost estimates for river water quality improvement

Km improved	One-off costs (millions)	On-going costs (millions)
0	£0.0	£0.00
293	£264.7	£2.7
659	£587.9	£5.9

Source: Welsh Water

3.6.2 Benefits

3.6.2.1 Customer research

Evidence on benefits to Welsh's customers comes from the PR19 WTP research and the online MoS estimates. The table below shows estimated WTP from the WTP research, for the specified service increments.

Table 22: WTP estimates for river water quality improvement

Estimate	WTP estimate	
Service level	0 to 299	299 to 666
Lower 95%	£12,380,007	£4,590,581
Central	£21,497,064	£8,951,378
Upper 95%	£47,966,270	£21,360,510

Source: Welsh Water

The MoS estimates provide WTP estimates for km of river improved, as we show in the table below.

Table 23: MoS WTP for river water quality performance improvements

Version	SQ to SQ+1	SQ+1 to SQ+2
Main	£1,082,724	£164,883
Pilot	£2,183,937	£382,406

Source: Welsh Water

3.6.2.2 Consequential costs

In addition to direct benefits to customers, service improvements can have benefits as a result of avoiding costs that would otherwise be incurred. In the case of river water quality, there are no such avoided costs.

3.6.2.3 Environmental, social and health benefits

We considered whether there could be wider environmental, social and health benefits as a result of improved performance. In this case, benefits could occur through increases in property values generated by improved river quality, and through health benefits. The table below summarises our estimates of the associated benefits. Annex B provides further evidence and details of our approach to calculating these.

Table 24: Environmental, social and health benefits associated with river water quality improvements

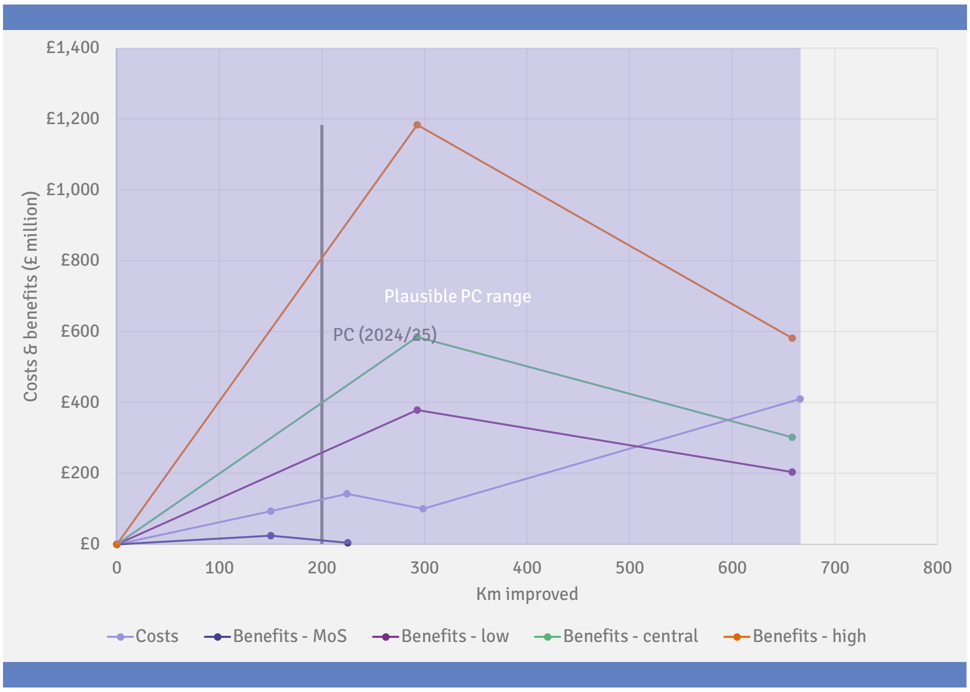
Scenario	Property values (£ m)	Health (£ m)
Low	£0.0002	£0.0149
Medium	£0.0002	£0.0210
High	£0.0002	£0.0271

Source: Economic Insight

3.6.2.4 Economic level of service

We used the above information to calculate present discounted values of the marginal costs and benefits associated with the service improvements set out above. We then plotted these to identify the economic level of service, at the point at which the marginal cost and benefit lines cross, as shown in the figure overleaf. The MoS and WTP data are highly contradictory, with MoS data suggesting that no level of service improvement would be net beneficial, while the upper bound of the WTP data suggest that welfare would potentially be maximised at values in excess of 600 improved river km.

Figure 10: Incremental costs and benefits of river water quality service improvements



Source: Economic Insight

3.7 Rainscape

This measure relates to the removal of surface water, associated with the resilience of the wastewater network to storms, and is expressed in roof equivalents. The status quo level is 25,000 roof equivalents.

3.7.1 Costs

The table below shows estimates of efficient total costs associated with rainscape service improvements. As there is some uncertainty over costs, we present both low and high cost cases. On-going costs are estimated to be 1% of initial up-front costs.

Table 25: Cost estimates for rainscape

Roof equivalents	Low		High	
	One-off costs (millions)	On-going costs (millions)	One-off costs (millions)	On-going costs (millions)
25,000	£0	£0.00	£0.0	£0.0
40,000	£15	£0.15	£95.7	£1.0
60,000	£20	£0.20	£127.6	£1.3

Source: Welsh Water

3.7.2 Benefits

3.7.2.1 Customer research

Benefits evidence for rainscape are available only from the MoS research. These estimates of WTP are shown in the table below.

Table 26: MoS WTP (per customer) for rainscape performance improvements

Version	25,000 to 40,000	40,000 to 60,000
Main	£1,472,858	£479,098
Pilot	£1,907,905	£669,431

Source: Welsh Water

3.7.2.2 Consequential costs

In addition to direct benefits to customers, service improvements can have benefits by avoiding costs that would otherwise be incurred. We have not quantified these benefits in this case.

3.7.2.3 Environmental, social and health benefits

We considered whether there could be wider environmental, social and health benefits as a result of improved performance. In this case, benefits could occur through reduced eutrophication. Our research indicates that these benefits could range between £22 and £39 per roof equivalent, as set out in the following table (for further details and sources, see Annex B).

Table 27: Environmental, social and health benefits for rainscape

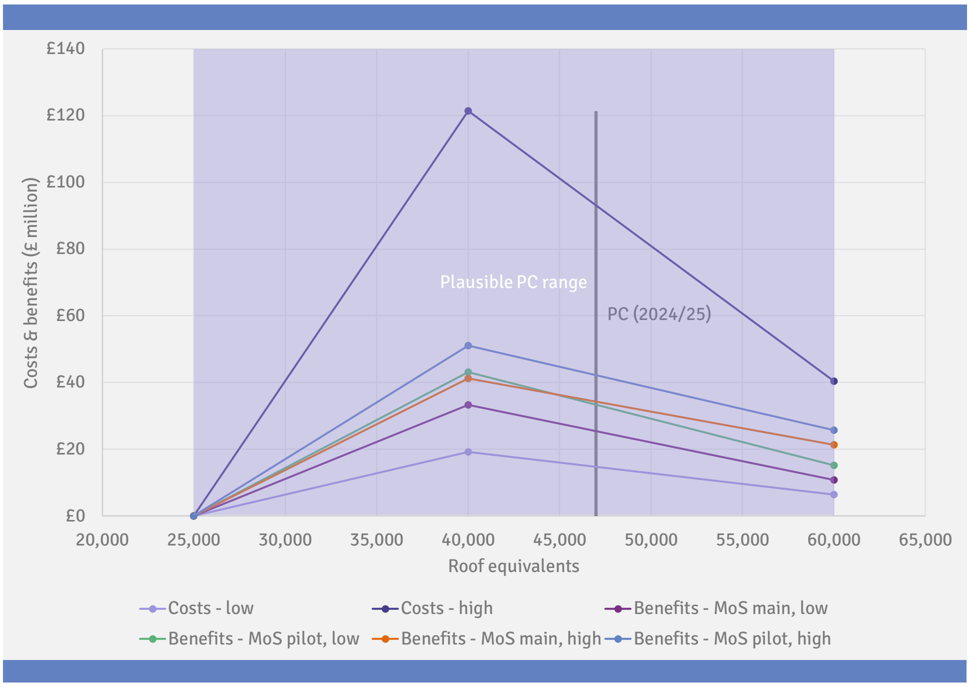
Scenario	Benefits per roof equivalent (£)
Low	£22
Medium	£30
High	£39

Source: Economic Insight

3.7.2.4 Economic level of service

We used the above information to calculate present discounted values of the marginal costs and benefits associated with the service improvements set out above. We then plotted these to identify the economic level of service, at the point at which the marginal cost and benefit lines cross. In this case, uncertainty over costs is very high, meaning that a very wide range of possible service levels represent plausible PCs – ranging from 25,000 to more than 60,000.

Figure 11: Incremental costs and benefits of rainscape service improvements



Source: Economic Insight

3.8 Water acceptability

This measures the number of customer contacts per 1,000 of population, relating to issues such as water discolouration and water taste and smell. The status quo level is 2.4.

3.8.1 Costs

The table below shows estimates of efficient total costs associated with water acceptability service improvements. On-going costs are estimated to be 1% of initial up-front costs.

Table 28: Cost estimates for water acceptability improvements

Contacts per 1,000 population	One-off costs (millions)	On-going costs (millions)
2.40	£0	£0.0
2.00	£30	£0.3
1.50	£200	£2.0

Source: Welsh Water

3.8.2 Benefits

3.8.2.1 Customer research

Evidence on benefits to Welsh's customers comes from the PR19 WTP research and the online MoS estimates. The table below shows estimated WTP from the WTP research, for the specified service increments.

Table 29: WTP estimates for service improvements in water acceptability

Estimate	Discoloured water	
Service level	SQ to SQ+1	SQ+1 to SQ+2
Lower 95%	£1,971,280	£514,491
Central	£2,295,622	£743,042
Upper 95%	£2,611,702	£970,465

Source: Welsh Water

The MoS estimates provide WTP for different water acceptability service improvements, as we show in the table below.

Table 30: MoS WTP for water acceptability performance improvements

Version	SQ to SQ+1	SQ+1 to SQ+2
Main	£1,836,006	£1,032,242
Pilot	£2,436,886	£762,459

Source: Welsh Water

3.8.2.2 Consequential costs

In addition to direct benefits to customers, service improvements can have benefits as a result of avoiding costs that would otherwise be incurred. In the case of water acceptability, Welsh expects costs per contact as set out in the following table.

Table 31: Consequential costs associated with water acceptability

Type of contact	Cost per contact
Taste & Odour Complaints	£24.59
Discolouration Complaints	£26.13
Significant Acceptability Complaints	£60.34

Source: Welsh Water

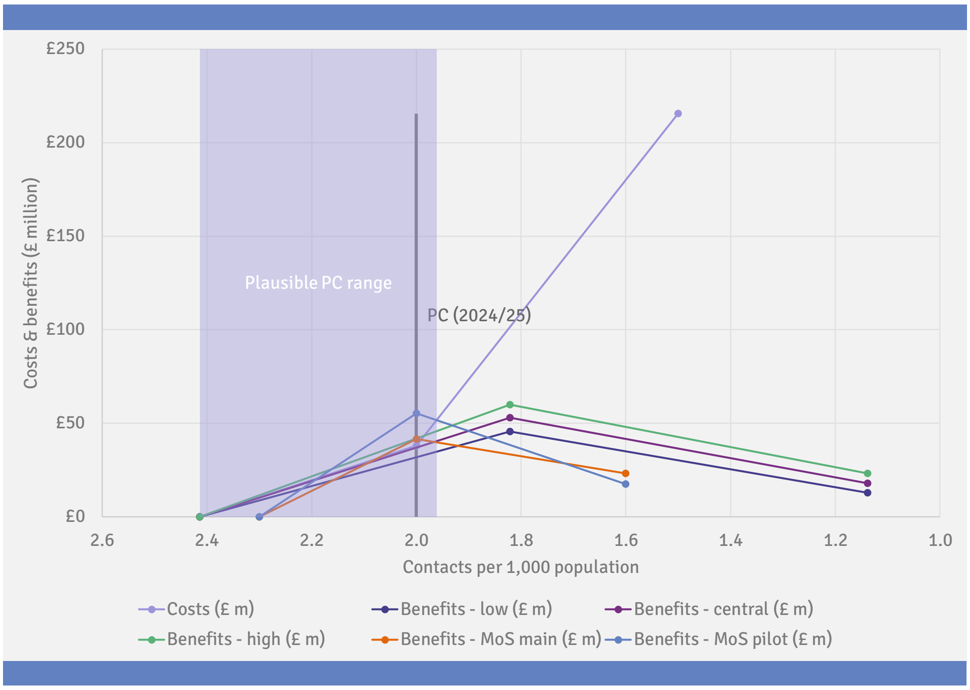
3.8.2.3 Environmental, social and health benefits

We considered whether there could be wider environmental, social and health benefits as a result of improved performance. In this case, we do not expect there to be such wider benefits.

3.8.2.4 Economic level of service

We used the above information to calculate present discounted values of the marginal costs and benefits associated with the service improvements set out above. We then plotted these to identify the economic level of service, at the point at which the marginal cost and benefit lines cross. As we show in the chart below, this suggests a range of 1.95 to 2.4.

Figure 12: Incremental costs and benefits of water acceptability service improvements



Source: Economic Insight

3.9 Renewable energy

This measures Welsh's renewable energy use as a proportion of its total energy use. The status quo level is 30%.

3.9.1 Costs

The table below shows estimates of efficient total costs associated with renewable energy service improvements. On-going costs are estimated to be 1% of initial up-front costs.

Table 32: Cost estimates for renewable energy improvements

Renewable energy as % of total	One-off costs (millions)	On-going costs (millions)
30%	£0.0	£0.0
33%	£22.0	£0.2
43%	£67.0	£0.7
50%	£100.0	£1.0

Source: Welsh Water

3.9.2 Benefits

3.9.2.1 Customer research

Evidence on Welsh's customers' WTP for improvements in its renewable energy performance is only available from the MoS research. This is shown in the table below.

Table 33: MoS WTP for renewable energy performance improvements

Version	30% to 35%	35% to 40%
Main	£694,338	£1,170,171
Pilot	£231,446	£748,064

Source: Welsh Water

3.9.2.2 Consequential costs

We have not identified any consequential costs associated with improvements in renewable energy performance.

3.9.2.3 Environmental, social and health benefits

We considered whether there could be wider environmental, social and health benefits as a result of improved performance. In this case, we expect the main benefits to occur through health improvements associated with reduced fossil fuel use. These benefits are set out in the table overleaf. Further details of the evidence and sources used are contained in Annex B.

Table 34: Environmental, social and health benefits

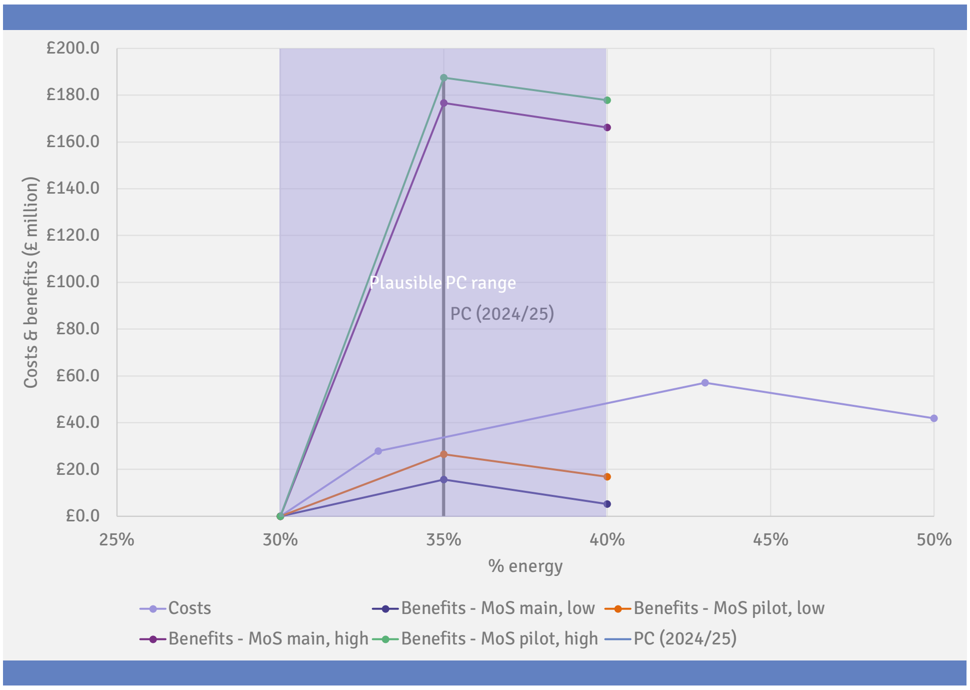
Scenario	Benefits (£ per kWh)
Low	£0.00000012
Medium	£0.00000022
High	£0.00000031

Source: Economic Insight

3.9.2.4 Economic level of service

We used the above information to calculate present discounted values of the marginal costs and benefits associated with the service improvements described above. We then plotted these to identify the economic level of service (i.e. where the marginal cost and benefit lines cross). As this measure is very sensitive to levels of environmental benefits, we have shown benefits both including and excluding these (i.e. the low and high versions). When excluding wider benefits, no level of increase would be net beneficial. When wider benefits are included, the whole range of service levels for which we have data would be net beneficial.

Figure 13: Incremental costs and benefits of renewable energy service improvements



Source: Economic Insight

3.10 Worst served customers – low pressure

This measures the number of properties affected by persistent low pressure. The status quo level is 100 properties.

3.10.1 Costs

The table below shows estimates of efficient total costs associated with worst served customers – low pressure service improvements. On-going costs are estimated to be 1% of initial up-front costs.

Table 35: Cost estimates for worst served customers – low pressure

Affected properties	One-off costs (millions)	On-going costs (millions)
100	£0.0	£0.0
50	£14.5	£0.1
0	£45.2	£0.5

Source: Welsh Water

3.10.2 Benefits

3.10.2.1 Customer research

The MoS evidence provide WTP estimates for reductions in the number of customers experiencing persistent low pressure, as set out below.

Table 36: MoS WTP for worst served customers – low pressure

Version	35 to 10	10 to 0
Main	£129,318	£156,509
Pilot	£14,465	£28,061

Source: Welsh Water

3.10.2.2 Consequential costs

In addition to direct benefits to customers, service improvements can have benefits as a result of avoiding costs that would otherwise be incurred. The following table shows Welsh's estimates of avoidable costs relating to low pressure.

Table 37: Consequential costs associated with low pressure

Severity	Cost per incident
Low pressure noticed by customer but above or at acceptable level	£180
High Pressure (customer complaints)	£215
Pressure below acceptable level	£249

Source: Welsh Water

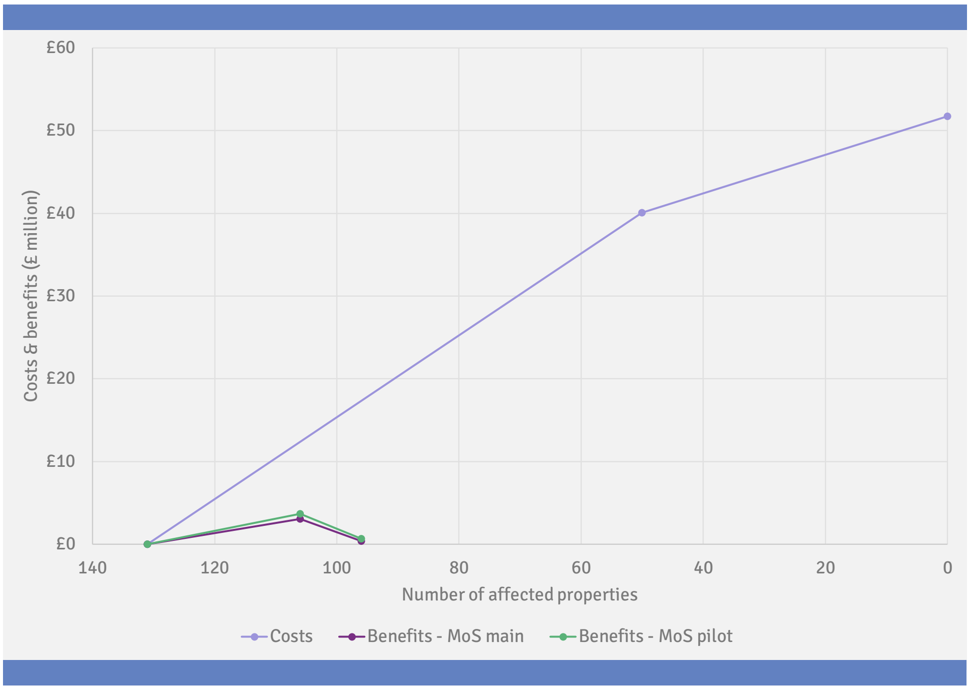
3.10.2.3 Environmental, social and health benefits

We have not estimated any wider environmental, social or health benefits associated with worst served customers – low pressure.

3.10.2.4 Economic level of service

We used the above information to calculate present discounted values of the marginal costs and benefits associated with the service improvements set out above. We then plotted these to identify the economic level of service. However, as we show in the next chart, this suggests that no level of improvement in this measure would be welfare enhancing.

Figure 14: Incremental costs and benefits of service improvements for worst served customers – low pressure



Source: Economic Insight

3.11 Worst served customers – supply interruptions

This measures the number of properties affected by repeat supply interruptions. The status quo level is 1,000 properties affected.

3.11.1 Costs

The table below shows estimates of efficient total costs associated with reducing repeat supply interruptions. On-going costs are estimated to be 1% of initial up-front costs.

Table 38: Cost estimates for worst served customers – supply interruptions

Number of properties affected	One-off costs (millions)	On-going costs (millions)
1,000	£0.0	£0.0
750	£9.9	£0.1
500	£19.7	£0.2

Source: Welsh Water

3.11.2 Benefits

3.11.2.1 Customer research

The MoS evidence provides a separate estimate of WTP per customer, specifically with reference to worst served customers. These estimates are set out in the table below.

Table 39: MoS WTP for worst served customers – supply interruptions performance improvements

Version	1,400 to 1,000	1,000 to 800
Main	£1,382,280	£1,860,531
Pilot	£219,458	£219,458

Source: Welsh Water

3.11.2.2 Consequential costs

In addition to direct benefits to customers, service improvements can have benefits as a result of avoiding costs that would otherwise be incurred. In this case, we have assumed consequential costs consistent with those set out above, for water supply interruptions.

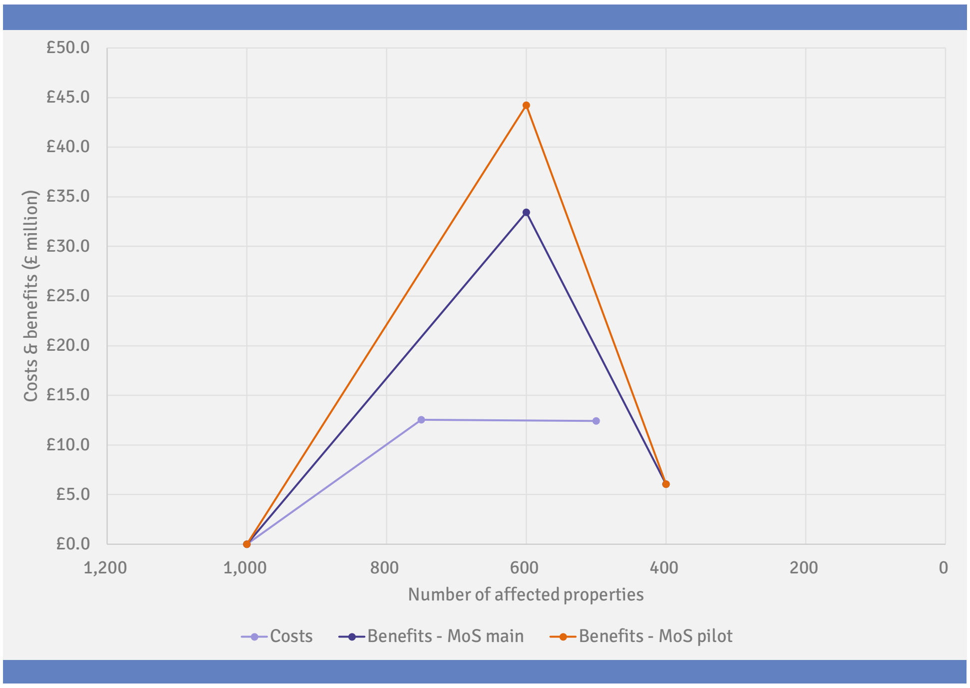
3.11.2.3 Environmental, social and health benefits

We have not estimated any wider environmental, social or health benefits for reductions in supply interruptions for worst served customers.

3.11.2.4 Economic level of service

We calculated the present discounted values of the marginal costs and benefits associated with the service improvements described in the preceding sections. We then plotted these in order to identify the economic level of service (where the marginal cost and benefit lines intersect). As we show in the chart below, this suggests that net benefits will be maximised *at some level below 500 properties.*

Figure 15: Incremental costs and benefits of worst served customers – water supply interruption service improvements



Source: Economic Insight

3.12 Worst served customers – flooding (internal & external)

This measures the number of customers affected by repeat sewer flooding incidents (internal and external). The status quo level is 368 incidents.

3.12.1 Costs

The table below shows estimates of efficient total costs associated with worst served customers – flooding service improvements. On-going costs are estimated to be 1% of initial up-front costs.

Table 40: Cost estimates for worst served customers – sewer flooding

Number of incidents	One-off costs (millions)	On-going costs (millions)
368	£0.0	£0.0
359	£13.0	£0.1
276	£23.0	£0.2

Source: Welsh Water

3.12.2 Benefits

3.12.2.1 Customer research

Evidence on benefits to Welsh's customers comes from Welsh's MoS research, as shown in the table below.

Table 41: MoS WTP for worst served customers – sewer flooding performance improvements

Version	368 to 359	359 to 276
Main	£35,871	£323,257
Pilot	£58,928	£530,606

Source: Welsh Water

3.12.2.2 Consequential costs

In addition to direct benefits to customers, service improvements can have benefits by avoiding costs that would otherwise be incurred. In the case worst served customers – sewer flooding, consequential cost estimates are consistent with those set out above for internal and external sewer flooding.

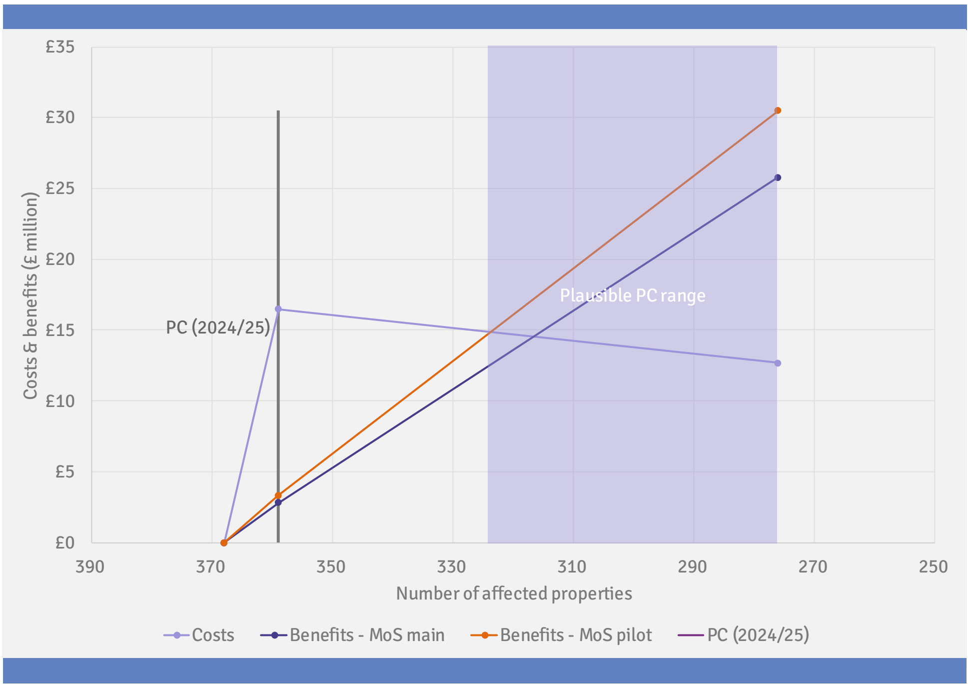
3.12.2.3 Environmental, social and health benefits

We have not included wider benefits in our assessment of this measure.

3.12.2.4 Economic level of service

We used the above information to calculate present discounted values of the marginal costs and benefits associated with the service improvements set out above. We then plotted these to identify the economic level of service, at the point at which the marginal cost and benefit lines cross. As we show in the chart below, this suggests that net benefits are maximised at a level below 320 affected properties.

Figure 16: Incremental costs and benefits of worst served customers – sewer flooding service improvements



Source: Economic Insight

4. Annex A - Background

4.1 Frontier Economics report

- In its March 2017 report for Ofwat, Frontier identified several potential improvements to the CBA methodology. These focused on: using multiple data sources on customer valuation/triangulation approaches; improvements to the quality of cost data; affordability; and distributional concerns.[12]

- Frontier note that there are three options as to how different sources of data on valuations can be combined for CBA purposes. A mechanistic rule would involve either simple averages or weighted averages, with weights defined in advance. Alternatively, a systematic judgement approach would use reasoned judgement, based on a pre-defined system or criteria – for example treating revealed preference as a lower bound because it does not account for 'inconvenience'.[13] Frontier also set out a third option, a 'multi-input CBA':

  - First use a range of valuation sources to develop an upper and lower bound for customer valuations (or use confidence intervals if only using stated preference WTP). Where there are a range of available data sources, companies should develop criteria to set upper and lower bounds (statistical validity, track record etc.).
  - Run CBAs with low and high consumer valuations, and then calculate associated PCs to generate a range of PC levels. This could be generated for each PC separately or done simultaneously. This will identify the parts of the business plan that are sensitive to consumer valuation.
  - Having identified the sensitive parts, companies could: develop two or three versions of the plan and explicitly test with customers/CCGs; review and refine the most important customer valuations; or use qualitative information and prioritisation to inform final PCs.
  - Companies should take account of how differences in approaches use drive differences between results.
  - A Monte Carlo simulation of customer valuations could provide a probability distribution for CBA outcomes.[14]

- Frontier also set out potential improvements to the quality of cost data.

  - They suggested that Ofwat set clearer expectations as to how companies should deal with common costs, to improve consistency of allocation. This would ideally be based on engineering analysis of the way that costs relate to measures.
  - They suggested Ofwat set explicit expectations that companies use proportionate sensitivity analysis of how CBAs change in response to

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[12] *'Performance Commitments and Outcome Delivery Incentives at PR19: A report prepared for Ofwat.' Frontier Economics (2017), p28.*
[13] *Ibid., p28-31.*
[14] *Ibid., p31-33.*

alternative cost assumptions. Where CBAs are sensitive to cost data, this would suggest more resources should be allotted to cost estimates.[15]

- Frontier noted that overall WTP may not equal the sum of individual WTP across the PCs. To meet the affordability constraint in the most allocatively efficient manner, Frontier suggest that commitment levels should be set such that the difference between marginal WTP and marginal cost is equal across PCs. As this is likely to be challenging in practice, they recommend re-scaling WTP used in each CBA by a common factor, and then re-calculating CBAs until the affordability constraint is reached.[16]

- Frontier identified two ways in which distributional concerns could be addressed within the framework:
  - In the multi-input CBA framework, companies could test how targets would change if the lowest customer valuation (rather than the average) was used in each case.
  - Companies could explore how incentive rates and maximum rewards vary with customer variations, for instance whether ODIs would differ materially using low income group valuations rather than average valuations.[17]

4.2 HM Treasury Green Book

4.2.1 General considerations

- To achieve identified objectives, a range of objectives should be developed. This should include a 'do minimum' option, involving the least amount of action necessary.[18] If a shortlist of options is created, this should always include the 'do minimum' option.[19]

- In assessing options, the relevant costs and benefits to government and society of all options should be valued, and their net benefits or costs calculated. This should avoid spurious accuracy, but confidence in the estimates will need to increase for larger scale decisions.[20]

- Costs and benefits should usually cover the useful lifetime of the asset – though this may be different in the case of purchasing contracts for the delivery of particular outputs or outcomes.[21]

- Costs and benefits should normally be based on market prices and reflect opportunity costs, i.e. best alternative uses – though market prices may need to be adjusted for tax differences between options.

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15 *Ibid., p33-34.*
16 *Ibid., p34-37.*
17 *Ibid., p37.*
18 *'The Green Book: Appraisal and Evaluation in Central Government.' H.M. Treasury. 2011. P17.*
19 *Ibid., p19.*
20 *Ibid., p19.*
21 *Ibid., p19.*

- Social and environmental costs need to be considered. As there is usually no market price, they may be difficult to value, but should not be ignored. Cashflows and resource costs are important, as they inform affordability considerations. [22]

4.2.2 Costs

- Costs should be expressed as relevant opportunity costs, and it is therefore necessary to explore what other opportunities exist. Sunk costs, i.e. those that have already occurred and are irrevocable, should be ignored.[23]

- It is useful to distinguish between fixed, variable, semi-variable and step costs, though this should be considered carefully as costs fixed related to one factor may vary with another.[24]

    » Fixed costs are constant over activities, for a specified time.
    » Variable costs change with the volume of activity.
    » Semi-variable costs have a fixed and variable component.
    » Semi-fixed or step costs are fixed at a given level of activity but eventually increase at a critical point.

- The full costs of an option include direct and indirect costs and attributable overheads.[25]

- Depreciation and capital charges should not be included when assessing asset costs. Depreciation is an accounting device which spreads expenditure on a capital asset over its lifetime. Capital charges reflect opportunity costs of capital assets once they have been purchased. This means that they should be used to assess the value for money of retaining an asset, not whether to purchase it in the first place.[26]

- Assets may have residual value, which should be included in the assessment and tested for sensitivity.[27]

4.2.3 Benefits

- Benefits should be valued unless it is not practicable to do so. In principle, all benefits to the UK should be accounted for, including direct effects and wider impacts on other areas of the economy.[28]

- Real or estimated market prices are the primary source of evidence on the value of benefits – but there are exceptions where this is not suitable, including if the market is distorted by monopolies, taxes or subsidies.[29]

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[22] *Ibid., p19.*
[23] *Ibid., p20.*
[24] *Ibid., p20.*
[25] *Ibid., p20.*
[26] *Ibid., p21.*
[27] *Ibid., p21.*
[28] *Ibid., p21.*
[29] *Ibid., p21.*

- Where there is no market value, alternative techniques are available, though they may be subjective. WTP determined by revealed preferences (i.e. consumer behaviour) is preferred, though if this is not possible stated preferences can be used (for example asking consumers how much they would be willing to pay for a particular benefit, or in the case of a cost asking how much they would demand to accept it).[30]

4.2.4 Adjustments

- Adjustments may be required to reflect distributional considerations and relative price changes. All such adjustments should be shown clearly.[31]

- Values should be expressed in real terms/constant prices, rather than nominal terms/current prices. If necessary, future inflation should be removed by deflating future cash flows – the Bank of England inflation target being the appropriate measure over very long-term periods. If prices are expected to increase at a different rate to general inflation, the relative price change should be calculated.[32]

4.2.5 Discounting

- Discounting reflects the fact that people prefer goods and services now, rather than later, and is used to compare costs and benefits in different time periods. For individuals, this can be measured by the real interest rate. For society as a whole, the recommended social time preference rate is 3.5%. For projects with impacts over 30 years, a declining schedule of discount rates should be used.[33]

4.2.6 Risk and uncertainty

- Adjustments should be made for biases and uncertainty. Biases include optimism bias, for which should be explicit, empirically evidenced adjustments should be made.[34] It is good practice to add a risk premium. Expected values can be calculated to provide a single value for the impact of all risks, in cases in which likelihoods and outcomes can reasonably be estimated.[35]

- To deal with uncertainty, sensitivity analysis should be used to test options' vulnerability to unavoidable uncertainties. Calculating switching values shows how much benefits would have to fall (or costs rise) to stop an option being beneficial. This should be a prominent part of any appraisal.[36] Scenario analysis may also be useful when considering how uncertainty affects different options.[37]

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[30] *Ibid., p22-3.*
[31] *Ibid., p24.*
[32] *Ibid., p25.*
[33] *bid., p26-7.*
[34] *Ibid., p28-30.*
[35] *Ibid., p30.*
[36] *Ibid., p32.*
[37] *Ibid., p33.*

4.2.7 Unvalued costs and benefits

- Even if they have not been valued, costs and benefits should be appraised. Comparisons can be made by weighing and scoring techniques (multi-criteria analysis). Alternatively, one can assess options by listing required performance criteria ('critical success factors').[38]

4.2.8 Selecting the best option

- In the case of a full CBA, the best option is likely to have the highest risk-adjusted net present value. If there is a budget ceiling, the combination of options that maximises the value of benefits should be chosen – in which case the ratio of net present value to expenditure is a useful guide. Where risk is material, the 'maximin', i.e. the project that provides the least worst option in the worst possible conditions, may be appropriate.[39]

- In practice, unvalued costs and benefits will affect the choice of option. Weighting and scoring techniques may be useful in this case.[40]

- 'Pay back periods' should be avoided as they ignore differences in values over time and ignore wider impacts. Further, internal rate of return should be avoided as it will, in some cases, suggest different, incorrect answers from the NPV.[41]

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38 *Ibid., p34-5.*
39 *Ibid., p37-38.*
40 *Ibid., p38.*
41 *Ibid., p39.*

5. Annex B: Environmental Benefits

This annex provides further details of the methodology and sources used to estimate environmental benefits included in our CBA, as set out in the main body of our report. We also provide a summary of our evaluation of environmental benefits considered, and included, in our report against our 'systematic judgement' criteria.

5.1 Further details of environmental benefits calculations and sources

In this section, we describe each of the externalities used in the CBA analysis, how these benefits were quantified and then calibrated for Welsh Water. In total, we examine seven benefits. Note that all figures have been adjusted to 2017 prices.

5.1.1 Visitor benefits

To generate an estimate of the wider benefits of reductions in the number of wastewater pollution incidents, we used the WTP estimates in Welsh's customer research, and divided these by 365.25 to generate 'day estimates' of WTP for reduced risk of encountering sewer flooding incidents. We then applied these estimates to figures for the number of visitor days to Wales, using 2016 data.

5.1.2 Gastroenteritis

Gastroenteritis occurs when people are exposed to sewer water or water that is of very poor quality. The symptoms may include diarrhoea, vomiting and abdominal pain.

Machado and Mourato (1999)[42] estimate the WTP to avoid gastroenteritis per person to be between £9 to £29. Further, a paper by Dwight et al (2005)[43] estimate that the economic burden of gastroenteritis per illness to be £27. This includes medical costs and foregone wages. The sum of the above two benefits gives us the total benefit per person.

To obtain the annual benefit, we multiplied the total benefit as calculated above with the population served by Welsh Water. This was then multiplied by the probability of contracting gastroenteritis due to direct contact with polluted water.

5.1.3 Eutrophication

Eutrophication occurs when a body of water becomes overly enriched, due to excess nutrients. This is largely an outcome of human activity, as farms, golf courses, lawns and other fields tend to be heavily fertilised. When there is heavy rainfall or flooding, fertilisers tend to runoff into water bodies generating an oversupply of phosphate and nitrate nutrients. This in turn can lead to enhanced growth of aquatic vegetation and algal blooms, which can disrupt the normal functioning of the ecosystem, causing a variety of problems such as a lack of oxygen, needed for fish and shellfish to survive.

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42 *Evaluating the multiple benefits of marine water quality improvements: how important are health risk reductions? Journal of environmental management, Machado and Mourato, 1999.*

43 *Estimating the economic burden from illnesses associated with recreational coastal water pollution – a case study in Orange County, California, Journal of environmental management, Dwight et al (2005).*

Health problems can also occur when eutrophic conditions interfere with drinking water.

Survey analysis by Nocker et al (2014)[44], shows that the average household is willing to pay between £17 and £30 to limit algae blooms and eutrophication. This figure is then multiplied by the number of households that Welsh water serves to obtain the total benefit value.

5.1.4 Recreational usage

Water quality across recreational sites can have an impact on whether users are able to undertake certain activities. Research by Curtis and Hynes[45] examine whether water quality levels at recreational sites affects the length of the trip. Their premise is that recreational users undertake trips of longer duration at sites with better quality water. In their analysis of trip durations, they examine four categories of users: angler, boater; those engaged in other water sports (e.g. canoeing, water skiing, rowing); and, those engaged in activities for which access to water is not essential, such as walking and cycling.

They find that there is a strong statistical evidence that recreational users in fact do spend more time engaged in their activities at sites with higher water quality levels. (as measured by chemical status). Their research shows that the value per recreational trip (in excess of expenses) is roughly £50 per person. This figure was then multiplied by the number of people that visit Welsh beaches to obtain the approximate annual benefit for Welsh Water.

5.1.5 House prices

Many studies have shown that river water quality can affect the value of property adjacent to or in the immediate vicinity of a water body or water course. Water quality generally has a positive relationship with property prices. Study by Pretty, Nedwell and Bragg (2002)[46] find that the annual cost of reduced value of waterside dwelling in the UK due to low water quality to be £14m. This is multiplied by the ratio of Wales waterways to UK waterways to obtain an annual estimate for Welsh Water.

5.1.6 Health benefits of using renewable energy

The use of fossil fuels can have adverse health impacts and cause environmental damage which are not accounted for in the retail price,

Research by Machol and Rizk (2013)[47] find that the economic value of health impacts associated with fossil fuel usage is £0.12 to £0.31 per kWh. To obtain a Welsh Water estimate we multiply this unit cost to the kWh energy that will be saved with a 30% renewable energy target.

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[44] *Information system on the eutrophication of our coastal seas, Chapter 4, ISECA, 2015.*

[45] *Demand for Water-Based Leisure Activity: The Benefits of Good Water Quality, EPA research, Curtis and Haynes, 2015.*

[46] *A preliminary assessment of the environmental costs of the eutrophication of fresh water in England and Wales, Environmental science and technology, Pretty, Nedwell and Bragg, 2002.*

[47] *Economic value of US fossil fuel electricity health impacts, Environmental International, Machol and Rizk (2013).*

5.1.7 Social cost of using bottled water

According to Ofwat, water companies are obliged to provide at least 10 litres of water per person per day when water supply is interrupted. This is usually done either through water bowsers or bottled water. Both these modes of supply have negative environmental impact due to the energy used in the transportation.

In our calculations, we have estimated the total social cost of the use of bottled water. Research by the Beverage Industry Environmental Roundtable[48], estimates that a 500ml plastic bottle of water has a carbon footprint of 82.8 grams. This incorporates both the production and transportation of plastic bottles.

The Interagency Working Group[49] in the US estimate the social cost of carbon pollution to be between £7 to £36 per unit of carbon footprint. This figure together with the carbon footprint per bottle gave us an estimate of the social cost associated with a bottle of water. To obtain a figure commensurate with Welsh Water, we multiplied the total social cost with an approximate estimate of the number of bottles of water that Welsh Water customers are likely to need in an event where supply interruption occurs.

5.2 Evaluation of environmental benefits against criteria for inclusion

The following table sets out our assessment of the various potential environmental benefits for inclusion in the CBA, based on the framework set out in the main body of our report.

48 *What is the carbon footprint of a plastic bottle*, Sciencing, 2018.
49 *The cost of carbon pollution*, 2007.

Table 42: Summary of evaluation of environmental benefits

Benefit	Conceptual plausibility	Relevance to Welsh	Robustness of evidence	Materiality of benefits	Include in CBA?
Eutrophication (leakage)	High	High	High	Medium	Yes
Pollution incident spill-overs	High	High	Medium	Medium	Yes
Gastroenteritis (internal sewer flooding)	High	Medium	High	Low	Yes
Recreational activity & eutrophication (external sewer flooding)	Medium	High	Medium	Medium	Yes
Property value spill-overs (water quality)	Medium	High	Medium	High	Yes
Eutrophication (rainscape)	High	High	High	Medium	Yes
Health improvements (renewable energy)	High	Medium	Medium	Low	Yes
Bottled water use (water supply interruptions)	High	High	Medium	Medium	Yes
Reduced waste of water by customers (water supply interruptions)	Low	Medium	Low	Low	No
Environmental benefits of less replacement of household fixtures and fittings (internal & external sewer flooding)	Medium	Medium	Low	Low	No
Reduced water consumption from switching from baths to showers (worst served customers – low pressure)	Medium	Medium	Low	Low	No
Generation of additional tourist visits due to more pleasant surroundings (pollution incidents, river water quality)	Medium	Medium	Low	Low	No
Benefits to local hoteliers and traders of providing services to victims of sewer flooding (internal & external sewer flooding)	Low	Low	Low	Low	No
Reduced insurance premiums due to lower incident risk	Medium	Low	Low	Low	No
Lost earnings of customers recovering from material flooding incidents (internal sewer flooding)	Medium	Medium	Low	Medium	No
Environmental impact cleaning products (internal & external sewer flooding; wastewater pollution incidents)	Medium	Medium	Low	Low	No

Source: Economic Insight

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