Storm overflow evidence for Wales (SOEfW)

An investigation into the costs and benefits of different storm overflow control policies for Wales

Stantec

Prepared for:
Welsh Government

Prepared by:
Elliot Gill, Sophie Stable,
Gurjit Ghuman

September 15, 2023

Revision	**Description**	**Author**	**Quality Check**
1	Draft	SS / GG / EJG	EJG
2	Provisional	SS / GG / EJG	EJG
3	FINAL	SS / GG / EJG	CD

Sign-off Sheet

This document entitled Storm overflow evidence for Wales (SOEfW) was prepared by Stantec Limited (“Stantec”) for the account of Welsh Government (the “Client”). Any reliance on this document by any third party is strictly prohibited. The material in it reflects Stantec’s professional judgment in light of the scope, schedule and other limitations stated in the document and in the contract between Stantec and the Client. The opinions in the document are based on conditions and information existing at the time the document was published and do not take into account any subsequent changes. In preparing the document, Stantec did not verify information supplied to it by others. Any use which a third party makes of this document is the responsibility of such third party. Such third party agrees that Stantec shall not be responsible for costs or damages of any kind, if any, suffered by it or any other third party as a result of decisions made or actions taken based on this document.

Prepared by ______________________________

Elliot Gill

Approved by ______________________________

Chris Digman

Table of Contents

List of Tables

List of Figures

Executive Summary

This research has used data from water companies and a Wales-wide simplified water quality model to explore a set of policies related to the control of storm overflows in Wales. It is independent analysis undertaken by Stantec on behalf of the Welsh Government. The policies examined compare different environmental or asset performance outcomes and engineering approaches to deliver them. Legislative change and novel funding approaches are not considered.

Although uncertainties make any such nationwide analysis challenging, the range of results generated are a good resource through which to compare costs and benefits of different policies and engineering approaches.

The focus of this work is on overflow spills due to rainfall. A spill due to other causes are a matter for sewer system asset management, operations and maintenance. Data indicate that overflows are possibly operating more than might be expected if rainfall was the only influence, but this is uncertain because neither overflow monitoring nor sewer hydraulic models are highly accurate and reliable.

Nine policy options have been explored. One option is to pursue a science-first approach, focused on removing the harmful environmental impacts of storm overflows rather than reducing spill frequency for its own sake or to address societal concerns. The capital costs of following this approach (policy E) are estimated to be between £1.5 billion and £2.7 billion depending on whether a conventional ‘grey’ or hybrid ‘grey-blue-green’ approach is taken respectively. This would permanently add between £50 and £90 to a typical Dŵr Cymru Welsh Water (DCWW) household water bill (depending on how it was achieved) and between £30 and £60 to a typical Hafren Dyfrdwy (HD) household water bill. Bill increases would apply throughout an assumed 80 year asset life. The net result of these changes would be to avoid environmental harm to 47 waterbodies with a monetized benefit of £8.6m per year. The reduction in spills would deliver a social impact evaluated at £5.0m per year and if blue-green approaches were adopted a further £23.1m per year of benefit would be delivered.

To adopt a policy similar to that being followed in England (policy H) would cost between £2.5 billion (grey) and £6.5 billion (grey-blue-green). The policy eliminates environmental harm in rivers but also ensures that all overflows do not spill more than 10 times per year on average. This policy would permanently add between £80 and £220 to a typical DCWW household water bill (depending on how it was achieved) and between £50 and £140 to a typical HD household water bill. The costs of adopting a policy akin to the proposed revision to the EU’s Urban Wastewater treatment directive are approximately twice this amount and would require spill frequencies to be reduced

to approximately 5 per year to ensure that annual spill volumes did not exceed 1% of treated dry weather flows.

To adopt a policy which respects Natural Resources Wales' (NRW) definition of 'heavy rain' and focusses improvements to limit spills to those occasions whilst also addressing residual environmental harms is similar to policy G (20 spills) tested in this research. This would cost between £2.1 billion and £5.6 billion (depending on approach). This would permanently add between £70 and £190 to a typical DCWW household water bill (depending on how it was achieved) and between £45 and £120 to a typical HD household water bill.

To eliminate all spills due to rain in a typical year (policy D) would cost between £7 billion and £11.9 billion depending on approach. This would permanently add between £215 and £390 to a typical DCWW household water bill (depending on how it was achieved) and between £140 and £250 to a typical HD household water bill.

The benefit cost appraisal shows that benefits never outweigh costs, although it is acknowledged that benefit assessment methods are highly uncertain. The most economical advantageous policies are to do the least investment, either limiting environmental improvements to priority waterbodies or simply limiting spills to 40 times per year on average (policy A). Blue-green approaches introduce significant additional benefits but at additional cost. The policy favoured in Wales (E) (NPV £-1.1bn) is more economically advantageous than the policy adopted in England (H) (NPV £-1.8bn). If blue-green technologies are widely used then the differences widen to NPV £-1.9bn and NPV £-4.5bn.

All cost estimates exclude the provision of new or upgraded screening on storm overflows.

All results by policy are summarized in the table below:

Policy	Spill frequ control		No harm	CAPEX		OPEX		BILL IMPACT (Grey)		BILL IMPACT (GBG)	
	Coast	River		Grey	GBG	Grey	GBG	DCWW	HD	DCWW	HD
				£m	£m	£m/yr	£m/yr	£/yr	£/yr	£/yr	£/yr
A	10	40		1,343	3,641	7	22	45	30	125	80
B	10	20		1,796	5,134	8	30	60	40	175	110
C	10	10		2,274	6,205	9	36	75	50	210	135
D	0	0		7,009	11,932	12	50	215	140	390	250
F	10	40	✓	1,809	4,288	8	24	60	40	145	95
G	10	20	✓	2,126	5,588	9	32	70	45	190	120
H	10	10	✓	2,511	6,518	9	36	80	50	220	140
E	10	none	✓	1,481	2,678	5	14	50	30	90	60
I	10	none	üSAC	846	1,609	3	9	25	20	55	35

Policy	Spill frequ control		No harm	BENEFITS		NPV		EMBODIED CO2		OPERATIONAL CO2	
	Coast	River		Grey	GBG	Grey	GBG	Grey	GBG	Grey	GBG
				£m/yr	£m/yr	£m/yr	£m/yr	T CO2e	T CO2e	T CO2e/y	T CO2e/y
A	10	40		18	58	- 965	- 2,515	100,773	327,284	122	110
B	10	20		25	82	- 1,266	- 3,523	145,571	473,059	143	129
C	10	10		30	98	- 1,621	- 4,272	198,122	582,087	156	141
D	0	0		36	136	- 5,745	- 8,891	774,020	1,229,989	185	167
F	10	40	✓	27	71	- 1,235	- 2,892	152,766	395,113	133	120
G	10	20	✓	31	91	- 1,457	- 3,787	184,118	522,325	148	133
H	10	10	✓	33	103	- 1,765	- 4,458	226,513	616,701	159	143
E	10	none	✓	14	37	- 1,144	- 1,920	131,499	247,311	97	88
I	10	none	üSAC	5	19	- 713	- 1,211	74,715	148,670	56	51

GBG = grey-blue-green | SAC = Special Areas of Conservation

1.0 Introduction

Storm overflows (also ‘combined sewer overflows’) are at the forefront of the public discourse on river and bathing water quality and the role of water companies in providing a properly managed and planned-for sewerage system in line with legislation. Attention on this topic in the media and through the campaigns of environmental NGOs and activists has seized the attention of politicians and governments across the UK.

In 2021 Defra (for England) published a Storm Overflows Evidence Project (SOEP)[1], authored by Stantec. The Welsh Government has commissioned a similar programme of evidence gathering and research from the same Stantec team and is reported here. Analysis for Wales and England has been undertaken in a similar way with a common set of assumptions, making the conclusions broadly comparable.

The objectives of the Storm Overflow Evidence for Wales (SOEfW) project were to:

1. Characterise the operation of, and environmental harm caused by, storm overflows (in rivers) today and forecast for 2050.
2. Estimate the costs and benefits of different policy options concerning the control of storm overflow discharges.
3. Estimate the carbon emissions associated with each policy option.
4. Estimate the impact on customer bills of adopting each policy option.
5. Reflect on the potential for co-creation and co-financing of solutions.

1.1 Policy options considered in SOEfW

The analysis tests policies controlling the frequency of allowed storm overflow activations (or ‘spills’) and policies directed at avoiding environmental harm in rivers. The control and impact of illegal discharges during dry weather, as a result of poor asset health, or non-compliance with permits, is excluded from this analysis.

Policies were tested for a future 2050 scenario, with allowances made for the impacts of climate change and population growth for that planning horizon. The full matrix of policies tested is described in Table 1-1. The policies described approximate the range of interventions open to Government and Regulators. They are differentiated in a way appropriate to a national-scale policy assessment.

---

[1] https://www.gov.uk/government/publications/storm-overflows-evidence-project

Common to every policy (with the exception of D) is the control of storm overflows spills to the coastal environment of 10 per year on average, this being broadly equivalent to 3 spills per bathing season. This standardized approach is included to provide protection to meet Bathing Water and Shellfish Water bacteriological standards. Policy D reduces all overflows, including at the coast, to zero spills in a typical year due to rainfall. The overflow remains and could still operate to alleviate flood risk if the sewer were blocked, there was a mechanical-electrical failure of a pumping station or other apparatus, or there was an extreme rain event.

Policies A, B and C apply spill frequency control to storm overflows discharging to rivers starting at 40 spills per year on average but then reducing to 20 and 10. This limits storm overflow operation to periods of moderate to heavy rainfall.

Table 1-1 SOEfW policies

Policy	Spill frequency control to coastal waters (annual average)	Spill frequency control to rivers (annual average)	Elimination of environmental harm risk to all rivers	Elimination of environmental harm risk to protected rivers (SAC) only
A	10	40		
B	10	20		
C	10	10		
D	0	0		
F	10	40	Yes	
G	10	20	Yes	
H	10	10	Yes	
E	10	None	Yes	
I	10	None		Yes

Policies F, G and H introduce the concept of eliminating environmental harm due to storm overflows. This is when each overflow is managed to ensure that the impact of the spills is consistent with the river still achieving Good Ecological Status, notionally assumed to be evidenced through modelled or measured compliance with Urban Pollution Management (UPM) Fundamental Intermittent Standards (FIS) limits for dissolved oxygen and unionized ammonia[2]. Many storm overflows currently have little or no environmental impact because either discharges are low in volume or river flows (and hence dilution) is high. But some storm overflows will cause environmental harm

---

[2] Review of Urban Pollution Management standards against WFD requirements

locally and this harm can be managed by reducing the frequency and volume of spills. It is possible to treat storm overflow discharges to mitigate environmental harm but these technologies are not included in this analysis.

For the purposes of this study, it is assumed that other pollution sources potentially compromising WFD status are controlled, hence the methodology addresses the impact that storm overflows have on their own. The assessments made here are not substitutes for proper investigations of local water quality impact and solutions but serve to demonstrate when a high pollution risk is present and how to reduce this.

In policies F, G and H the storage required to achieve spill frequency control is 'topped up' by further storage judged necessary to eliminate any residual risk of environmental harm. Policy E imposes no limits on spill frequency to rivers and only adjusts overflow performance where this is deemed necessary to eliminate the risk of environmental harm. Under policy E, storm overflows may still operate in light rainfall, and hence at high frequencies, if there is no risk of harm.

For reference, the policy adopted in England[3] by Defra through the Environment Act is equivalent to H, a limit of 10 spills at all overflows and a requirement to also eliminate harm due to overflows, which might require reducing spill frequency to less than 10 in some locations.

Policy I is the same as E but restricts the elimination of risk of harm to a subset of priority waterbodies with Special Areas of Conservation (SAC) status[4].

1.1.1 Other policy considerations linked to Wastewater Treatment Regulations

A storm overflow classification approach under development by Natural Resources Wales (NRW) deems a storm overflow activation 'unsatisfactory' if it occurs in anything other than 'heavy rainfall'. This is defined as a period of 1 hour with greater that 4mm of rain in the preceding 24 hours period. An analysis of historical rainfall timeseries in Wales undertaken for this project demonstrate that such conditions might occur between 15 and 25 times per year depending on location and local 'wetness'. Hence, this policy, for practical purposes, is similar in effect to policy G tested in this research.

The European Commission has published a proposal for a new Urban Wastewater Treatment Directive[5] that may be considered should Wales' Wastewater Treatment Regulations be revised in the future. The proposal references new indicative targets for storm overflows such that their discharges (on a catchment level) do not represent more

---

[3] https://www.gov.uk/government/publications/storm-overflows-discharge-reduction-plan
[4] https://sac.jncc.gov.uk/site/wales
[5] New Wastewater Treatment Directive Proposal

than 1% of the annual volume and load collected of urban wastewater, to be calculated in dry weather conditions. Of volume and load, the most exacting requirement will be for volume, because concentrations pollutants in overflow discharges are highly dilute compared to dry weather flow. Results taken from analysis undertaken for the England SOEP show that controls to limit spill frequency to approximately 10 spills per year results in percentage spill volumes of between 1.62% (lower quartile) and 4.68% (upper quartile) of the dry weather flow volume for the catchment. A spill frequency control of 5 per year is required to bring the lower quartile value below 1%. An equivalent analysis has not yet been completed for Wales although it would be expected that the analysis would be similar in its preliminary conclusions which are that to meet the requirement to spill an annual volume (through overflows) equivalent to less than 1% of treated dry weather flow annual volume would require a spill frequency control of at least 5 per year in many catchments. This option is more costly than C, potentially 100% more expensive, though this will be highly catchment specific.

1.2 Engineering options considered in SOEfW

Two principal methods for engineering spill reductions are considered. The first is an entirely 'grey' option which uses conventional sewerage options (tanks, large diameter sewers) to retain more flow within water company infrastructure prior to its eventual treatment. The second combines the 'grey' option with interventions that remove or slow stormwater (also, 'surface water') entering combined sewers. This reduces the requirement for 'grey' infrastructure but introduces a new requirement for 'blue-green' infrastructure (also, 'SuDS', is termed 'RainScape' by DCWW[6]) to be retrofitted within the public realm or on private property.in accordance with SuDS hierarchy principles as outlined in The SuDS Manual[7]. Throughout SOEfW a RainScape approach has been adopted that is consistent with that tested and modelled by DCWW in its DWMP. That is that 10% of impermeable area connected to combined sewer will be managed with retrofitted 'blue-green' infrastructure. The costs and benefits of delivering each policy is tested with both conventional 'grey' and hybrid 'grey-blue-green' engineering options.

An alternative approach, full separation of foul and surface water sewerage, is not considered, as this is deemed impractical and prohibitively expensive.

---

[6] https://corporate.dwrcymru.com/en/community/environment/our-projects/rainscap

[7] https://www.susdrain.org/resources/SuDS_Manual.html

2.0 Data sources & uncertainties

Storm overflows in Wales are in sewerage systems operated by Dŵr Cymru Welsh Water (DCWW) and Hafren Dyfrdwy (HD).

Table 2-1 shows how the overflows divide across the two water companies, and whether hydraulic modelling results are available. Take note, that the table below excludes emergency overflows, as they are not designed to spill in wet weather.

Table 2-1 Number of storm overflows in Wales and included in SOEfW analysis

Water Company	Number of overflows	Number of overflows with hydraulic modelling results	Percentage overflows with hydraulic modelling results	Storm overflows with EDM
DCWW	2113	1882	89%	2,094
HD	52	48	92 %	48
TOTAL	**2165**	**1930**	**89 %**	**2142**

There are 2,165 storm overflows in Wales. Most overflows (>97%) are operated by DCWW and there is 99% coverage with Event Duration Monitoring (EDM). 89% of overflows are hydraulically modelled.

Although EDM data are available to characterize the current-day frequency and duration of spills for 2,142 overflows, the SOEfW project has necessarily relied on the outputs of water company generated sewer hydraulic modelling data to characterise spill-volume today and in the future. Spill volume is required to both dimension sewerage solutions to control spills and estimate the environmental impact of spills.

Sewer hydraulic modelling information is available for 1,930 overflows (89%) and results generated for Drainage and Wastewater Management Plan (DWMP) studies were made available for further analysis. Because the number of overflows modelled is less than the total number of overflows in Wales, computed costs have been uplifted by a factor of 1.124 to account for this unknown investment requirement. This is an uncertainly that could be reduced should water companies improve their coverage of overflows in hydraulic models.

2.1.1 Event Duration Monitoring data vs. sewer hydraulic modelling data

Table 2-2 summarizes differences in the average number of spills per storm overflow measured and modelled using these different data sources. Figure 2-1 shows a comparison of a selection of storm overflows for which there are both EDM (year 2020) and hydraulic modelling data.

Table 2-2 Differences in average number of spills per overflow for EDM and hydraulic modelling data

Spill frequency method	Number of overflows	Average number of spills per overflow
EDM[8]	2142	40.9 (2021 and 2022)
Hydraulic model	1930	24.0 (timeseries average)

An important observation is that the number of measured spills (EDM) varies year-on-year because of the weather. For example, 2020 was an exceptional wet year throughout Wales. A recorded reduction in 2022 compared to 2021 is partly attributable to the driest January to August period since 1976[9]. Annual rainfall was 10% lower in 2022 than the long-term average. Hydraulic modelling results are generated using an historical time-series of rainfall input data of approximately 10 years in length, that includes wetter and drier years.

However, the lower average number of spills predicted by hydraulic modelling is also reflective of the multiple potential cause of spills. Hydraulic models can only represent spills due to rainfall and not spills from causes such as blockages or mechanical-electrical breakdown. This point is exemplified in Figure 2-1 which illustrates three broad categories of spills. Sometimes the hydraulic models predict a pattern of spills which is not reflected through EDM data. In [A] the models predict a greater number of spills than measured in any one year. This might be due to untypical rainfall patterns for that location, insufficiently calibrated hydraulic models or malfunctioning EDM equipment. In [B] the opposite occurs, where the EDM is recording spills that are not represented in hydraulic models. This might be indicative of uncertainties or error in measurement or models (as in A) but equally might be due to overflows spilling when it’s not raining or under conditions not representable in a hydraulic model. A final subset [C] is where

---

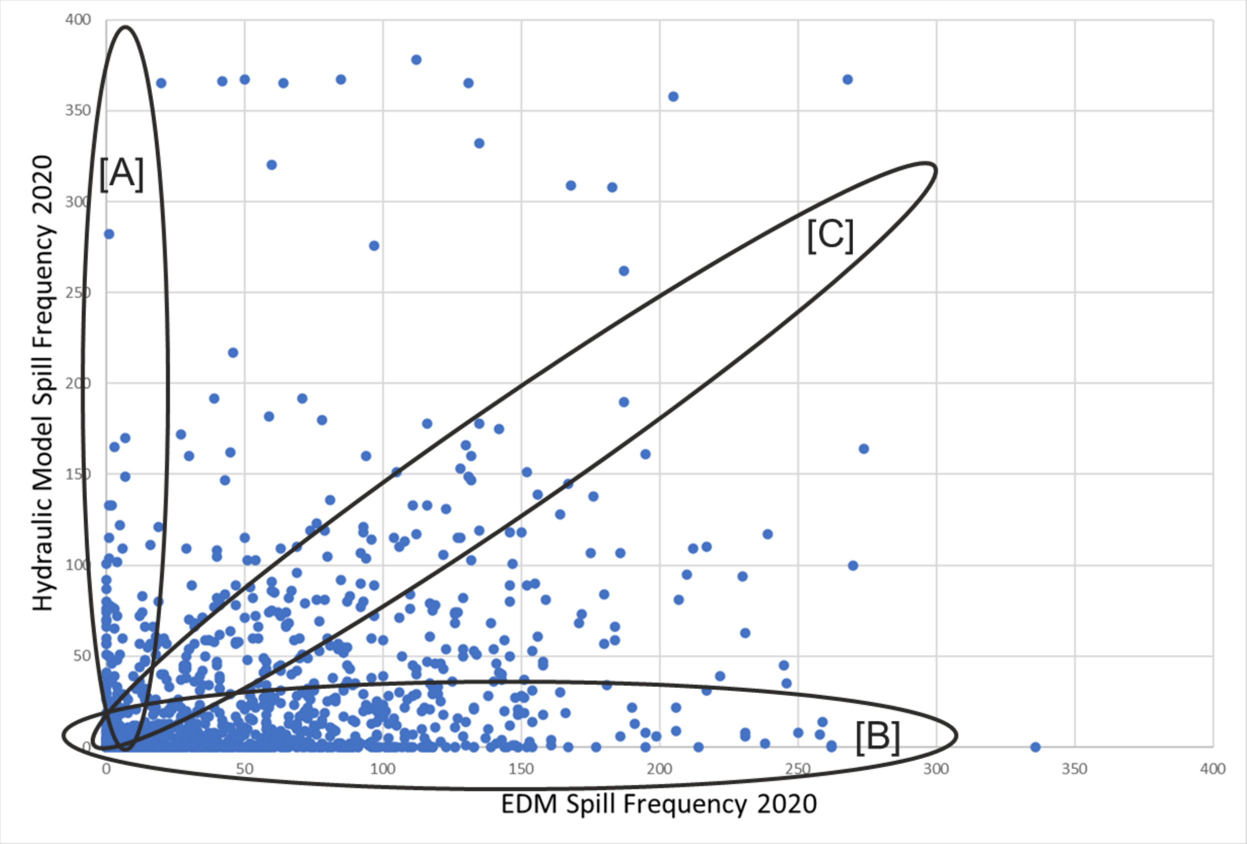
[8] Welsh Water data only https://corporate.dwrcymru.com/-/media/Project/Files/Page-Documents/Corporate/Environment/Combined-Storm-Overflows/Annual-Storm-Overflow-EDM-return---DCWW-2022.ashx

[9] https://corporate.dwrcymru.com/en/community/environment/combined-storm-overflows

there is broad agreement between the two spill counting methods. Here it is possible that hydraulic models capture the exact mechanism of spills but chance might also play a part. This figure serves to illustrate uncertainties in EDM data and hydraulic modelling results and is a reminder that precision at this level of analysis and planning is challenging.

While it is plausible to interpret these data by suggesting that EDMs are measuring a large number of spills that are not due to rainfall the uncertainties outlined above must strongly caveat any such assertion. Water Company led investigations under the Storm Overflow Assessment Framework (SOAF[10]) have undertaken detailed analysis at individual overflows and these data should be used to develop any generalized argument attributing spills to rainfall or other causes.

Figure 2-1 EDM spill frequency (2020) vs. hydraulic modelling average spills frequency



---

[10] https://www.water.org.uk/wp-content/uploads/2018/12/SOAF.pdf

3.0 Methodology

This section describes the methodology applied in the analysis, stating key assumptions and reflecting on significant uncertainties. The approach is a refinement of that developed for Defra for a similar analysis in England. Where relevant this earlier work is reference for further information.

The methodology is divided into subsections addressing different elements of the analysis:

- Estimating sewer storage requirements to achieve spill frequency targets.
- Substituting storage with blue-green infrastructure for grey-blue-green policies
- Estimating the environmental impact of spills
- Estimating CAPEX, OPEX, carbon and bill impacts
- Estimating benefits

Each sub-section addresses key assumptions and uncertainties.

3.1 Estimating sewer storage requirements to achieve spill frequency targets.

3.1.1 Approach

For DCWW storm overflows, hydraulic modelling results data were made available that identified the spill volumes for all events in a 10-year timeseries, representative of the 2050s and inclusive of the impacts of population and climate change. This enabled the extraction of annual spill volumes and frequencies representative of an average (or typical) year. Storage volumes to achieve ‘n’ spills were estimated by evaluating the spill volume of the ‘n+1’ ranked event in the typical year. For example, the storage volume to achieve 10 annual spills is the spill volume of the 11th ranked (largest) individual spill.

For HD overflows annual spill volume and frequency data were available for an equivalent 2050s epoch. Here, an algorithm was applied that estimates the annual spill volume and storage requirements to achieve ‘n’ spills. The algorithm was developed through analysis of 600 overflows and applied throughout the SOEP project for Defra’s Storm Overflow Task Force in England. It is described in Appendix B of that report[11].

---

[11] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1030980/storm-overflows-evidence-project.pdf

3.1.2 Assumptions and uncertainties

These approaches are acceptable for strategic planning and policy assessment purposes. They are limited by the adequacy (and availability) of hydraulic models and can be used to represent an infrastructure response to the type of storm overflow spill that is caused by rain. Causes due to inflow and infiltration are less well represented and causes due to operational reasons (blockages, mechanical/electrical failure) are not represented at all.

All storage is conceptually provided ‘off-line’ and it is assumed that stored sewage will be emptied and returned to the sewer for treatment. The engineering and hydraulic practicalities of this are not addressed and, in some cases, it will be infeasible to make these improvements without substantially increasing conveyance capacity through the sewer system to treatment at substantial cost. In practice, an equivalent storage might be delivered through distributed storage at more than one location and/or the mobilization of unused storage within existing assets (although this would increase costs). For costing purposes an allowance is made for enhancing treatment facilities to receive additional flows over prolonged periods but this is done without prior knowledge of existing capacity or treatment type.

3.2 Substituting storage with blue-green infrastructure for grey-blue-green policies

3.2.1 Approach

Grey-blue-green solutions retain sewer storage elements but ‘replace’ a component of this with above-ground surface water management measures, retrofitted into public and private space. In this analysis we have adopted a standard applied by DCWW in its DWMP to manage 10% of impermeable area contributing to combined sewers in this way. The effect is to reduce the need for conventional ‘grey’ solutions though not eliminate it. This hybrid approach is typical of that used by wastewater planners across the UK.

Making overflow and catchment specific assessments of the effect on storage needs of managing surface water flows is complex and demanding and beyond the needs of a strategic assessment of this type. Therefore, an assumed relationship has been applied which reduces storage needs to 78.2% of the initial assessment when 10% of impermeable area is managed. The derivation of this factor is described in Appendix B of the SOEP report[11], it was based on analysis of a series of detailed hydraulic model assessments.

For most sewer catchments included in the analysis there was an estimate of total impermeable area draining to the combined sewer. 10% of this value was used to define the area requiring blue-green measures to manage its runoff. Where total catchment impermeable area was not available a DCWW-data derived linear model linking population with impermeable area was applied. Catchment impermeable areas were disaggregated to improved overflows on a *pro-rata* basis.

3.2.2 Assumptions and uncertainties

This means of describing a grey-blue-green solution type is appropriate for strategic planning purposes. Its limitations include no consideration of where the blue-green infrastructure might be situated or the feasibility of doing this. Local hydraulic dynamics are important and surface water removal might need to be linked to measures that control flows underground. The approach to estimating is unreliable at the overflow level where detailed local analysis is always required.

3.3 Estimating the environmental impact of spills

3.3.1 Approach

A simple approach is applied to indicate where there is a high risk that overflows in a river waterbody might be causing environmental harm and the failure to achieve and maintain good ecological status. The approach is a development of that undertaken for the SOEP project in England, where it was validated against some SOAF and Urban Pollution Management (UPM) modelling results and with reference to Water Framework Directive Reasons for Not Achieving Good (RNAG) assessments. The approach is described in detail in Section 3.3 of the SOEP report.

In summary, the approach combines all the overflows discharging within the boundary of a waterbody catchment, summing their annual spill volume and comparing this to a diluting river water volume. The diluting river water volume is estimated from the 70th percentile river flow (exceed for 30% of the time) at a typical spill duration (4 hours) multiplied by a representation of the number of spills per year into the waterbody. The number of spills is calculated from the individual spill frequencies and volumes of all discharges to the waterbody and is described as the Volume Weighted Spill Frequency (VWSF[12]).

The ratio of annual storm overflow spill volume to annual diluting river flow volume is assessed for each waterbody. Where the ratio is greater than 0.1 the risk of harm due to storm overflows is considered high. The ratio has been calibrated, to a degree, with reference to DCWW's completed SOAF water quality impact studies so that known areas of poor riverine biology (due to storm overflows) are recognized in the simplified SOEfW model. However, the limitations of the simplified model are such that it is never

---

[12] Where VWSF = Σ (spill volumes * frequencies) / Σ spills volumes.

likely to capture all known cases where environmental harm risks are present or replicate exactly the harms evidenced through biological sampling.

The advantage of this approach is that it allows for a rapid assessment of current and future environmental harm risks and the testing of policies which limit the maximum number of spills at each overflow. Similarly, the spill volume reduction required to avoid harm is readily calculated. These two methods can be applied in combination to see the residual level of harm remaining when applying a spill frequency standard and to then reduce spills further to eliminate the harm risk. Or the approach can be used to determine the necessary improvements to avoid harm risk with no generalized control on spill frequencies.

The river impact model also identifies waterbodies with SAC status so that policies can be limited to these alone as required.

3.3.2 Assumptions and uncertainties

The approach only considers the impact of overflows and assumes that other sources of pollution are managed.

River flows are reduced for the 2050s epoch to represent the effect of climate change. The adjustment is crude[13] and significant local variations will occur heightening or reducing risks.

In the SOEP analysis, different dilutions were associated with progressive WFD ecological statuses between bad and good, assigning a so-called ‘Equivalent Ecological Status’. On reflection, this implied accuracy is possibly misleading, so the language used here is different and assigns a threshold at which the risk of harm is considered high. The threshold is within the range used in SOEP but calibrated against DCWW assessments of harm through riverine biological sampling, whilst recognising that linkages between modelled (or measured) water chemistry and observations of river biology can be weak.

Waterbodies are either at high risk or not and mitigations are aimed at avoiding high risk. This approach is more consistent with the limitations of the analysis and suited to the strategic planning context. Full water quality modelling is required to assess true impacts and necessary mitigations and this can include sensitivities to slope, local natural water chemistry and local impacts around the clustering of overflows within waterbodies and on small tributary streams.

The environmental assessment is for rivers only. There is no equivalent assessment in estuaries, transitional or coastal waters. There is also no assessment of health risks

---

[13] 3.5% reduction in flows for 2050s, consistent with SOEP

associated with faecal coliform indicators. Aesthetic pollution risk is also not assessed and the presence or otherwise of screens (to manage this) is not included.

3.4 Estimating CAPEX, OPEX, carbon and bill impacts

3.4.1 Approach

The approach is to dimension solutions (storage volume, blue-green infrastructure area) and apply unit capital and operating costs. Carbon costs are included too, covering embodied elements associated with construction and materials. Storage provides additional sewerage capacity and reduces the frequency and volume of storm overflow spills. Blue-green solutions intercept storm runoff from paved areas or roofs attenuating or preventing it entering combined sewers. Types of blue-green solutions are rain planters on drainpipes, swales in roadside verges and road-side rain gardens. These approaches are also termed sustainable drainage systems (SuDS). DCWW apply the term Rainscape[14].

Whole life costs are computed applying a Net Present Cost approach, where Net Present Cost = Capital Cost + 18.9 x Annual Opex change. This assumes a 30-year assessment period and 3.3% discount rate.

Cost estimates are either consistent with DCWW assumptions used for DWMP planning or adopted from the SOEP analysis. Estimates are mid-range assumptions with large associated uncertainty of ± 50% but are suitable for planning purposes and especially for the comparison of policies.

3.4.2 Assumptions and uncertainties

Table 3-1 provides the costing assumptions applied in this analysis with the data sources and units indicated. Construction cost inflation is currently high and these costs reflect the most likely position in 2020/21.

The blue-green costs (and also benefits) have been developed based on a ‘typical’ basket of measures commonly used in blue-green infrastructure retrofit. The solution manages 4 hectares of impermeable area, and effectively separates this from the combined sewer system. The solution assumes 24 tree pits, 480m of road-side swales and rain gardens including connecting pipework, and 480m^3 of attenuation storage. At the property level it includes 100 water butts, 100 rain gardens and 100 planters.

---

[14] https://corporate.dwrcymru.com/en/community/environment/our-projects/rainscape

When network or storm tank storage is emptied there may need to be enhancements to treatment capacity to maintain effective wastewater treatment. The needs are locally specific but this analysis has assumed a capital expenditure of £18.50 for every additional annual cubic meter of wastewater treated because of emptying storage.

Embodied carbon calculations use unit rates taken from the SOEP[15] analysis in England. These are simplified average values that make assumptions about carbon associated with construction and materials for unit volume of storage and unit area of blue green infrastructure.

CAPEX and OPEX estimates are factored by 1.124 to account for overflows excluded from the analysis because they are not modelled and hence no spill volume information is available to estimate storage needs.

CAPEX and OPEX estimates are used to estimate the impact on customer bills using this relationship:

Bill impact (£/household/year) = OPEX (£/year) + CAPEX / life of asset + X% CAPEX

Where X% is the Weighted Average Cost of Capital (we assume 2.96%), the number of households is 1,400,000 (DCWW) and 22,000 (HD) and asset life is 80 years. We assume for the purposes of indicating bill impacts that CAPEX and OPEX costs are split 99.9% to DCWW and 0.1% to HD. HD's much lower costs are, of course, borne by far fewer customers. Overall, HD customers' bill impacts are 35%-40% less than DCWW customers.

It is assumed here that the entire overflow improvement cost is met through the bills of water company customers throughout the asset life (80 years). In practice there may be opportunities for co-funding with partners (especially blue-green elements) and this will lessen the burden on bill payers but possibly not the community more generally. Water companies might also be able to finance such investment at lower costs than indicated here.

---

[15] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1030980/storm-overflows-evidence-project.pdf

Table 3-1 Key costing assumptions

	CAPEX (£)	OPEX (£/year)	Embodied Carbon (Kg CO2e)	Operational Carbon (Kg CO2e /year)
Storage	An average of £2,000 / m^3 (A)	£2,150 / new storage tank/year (C)	250 Kg CO2e /m^3 (C)	N/A
Blue-Green Infrastructure	1,000,000 /Ha (B)	£6,214 /Ha/year (C)	98,300 Kg CO2e /Ha (C)	N/A
Additional treatment (per annual m3)	£18.50 /annual additionally treated m^3 (C)	£ 0.20 /m^3/year (C)	N/A	0.0042 (D)

Data sources and assumptions

(A) Averaged from DCWW costing approach across small, medium and large tanks

(B) Midrange SOEP estimate and also consistent with DCWW assumptions in DWMP and cited as typical for the Llanelli Raincape

(C) SOEP approach values

(D) Stantec calculation

For WLC, carbon is priced at £270 / tonne (embodied) and £316 /tonne (operational)

For estimating programme costs CAPEX is factored by 1.5 to account for unmodelled overflows and their unknowable cost of improvement. Net present costs and benefits are not factored.

3.5 Estimating benefits

3.5.1 Approach

A simplified approach is taken to benefits assessment with elements for improved water quality (through reduction in spills), reduced social concern (through reduction in waterbody VWSF) and new ecosystem services benefits through the provision, where relevant, of blue-green infrastructure. The data are consistent with those developed for SOEP, although the water quality approach is changed to recognize the different concept of 'risk of environmental harm'.

3.5.2 Assumptions and uncertainties

Table 3-2 provides the benefits assumptions applied in this analysis with the data sources and further information.

Table 3-2 Key benefits assumptions

	Benefit	Details
Water quality	£38,445 per km waterbody with removed risk of environmental harm	It is assumed that when a water body is removed from risk of environmental harm the classification changes from Bad to Good. The mid-range SOEP[16] estimate for the benefit of improving river heath through these categorizations is £38,445 per km. It is assumed that 50% of the waterbody length is improved.
Social concern	£1,573 /reduced total VWSF	It is assumed that benefit is derived from reduced social concerns when spill frequencies are reduced. The assessment is concerned with rivers only and relates reductions in VWSF per waterbody to a SOEP[17] derived midrange and factored willingness to pay value for the reduction of pollution incidents.
Blue-green infrastructure	£17,630 /Ha/ year	It is assumed that the midrange SOEP[18] benefits per hectare of blue-green infrastructure are generated with each hectare of area managed through SuDS. The categories of benefit are: air quality, amenity, biodiversity, carbon sequestration, education, health, groundwater and

---

[16] See Section 3.5.2.1 (page 3.35) of https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1030980/storm-overflows-evidence-project.pdf for derivation of these benefits from NWEBs data.

[17] See Section 3.5.2.3 (page 3.38) of https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1030980/storm-overflows-evidence-project.pdf

[18] See Section 3.5.2.4 (page 3.39) of https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1030980/storm-overflows-evidence-project.pdf

	Benefit	**Details**
		flood risk. The dominant benefits are flood risk, health and amenity (96% of total).

4.0 Results

In this section results are presented for the range of policy alternative assessed. Table 4-1 repeats these for reference. The policies are tested with a conventional ‘grey’ and hybrid ‘grey-blue-green’ engineering approach.

Table 4-1 SOEfW policies

Policy	Spill frequency control to coastal waters (annual average)	Spill frequency control to rivers (annual average)	Elimination of environmental harm risk to all rivers	Elimination of environmental harm risk to protected rivers (SAC) only
A	10	40		
B	10	20		
C	10	10		
D	0	0		
F	10	40	Yes	
G	10	20	Yes	
H	10	10	Yes	
E	10	None	Yes	
I	10	None		Yes

4.1 Estimated requirements for engineering solutions

Figure 4-1 presents the estimate of storage and blue-green infrastructure required to meet policies A to D for the ‘grey’ engineering approach (top) and ‘grey-blue-green’ (lower) policies. This is only for overflows with hydraulic modelling results available, which is approximately 89% of the total in Wales. Uplifts (to costs) to account for the underestimation are applied later in the analysis.

The chart also indicates the number of inland river waterbodies where the risk of environmental harm remains high once this policy is implemented. As the storage required increases to reduce the frequency and volume of spills, the number of affected waterbodies is reduced until the ‘no spill’ policy eliminates the risk of harm to all waterbodies. The default assessment for no control (in 2050) is that there will be 47 inland river waterbodies at risk of environmental harm due to storm overflows. If spill frequency is limited to 40 times per year on average the number of waterbodies at risk immediately reduces to 38. At 20 spills the equivalent number of at risk waterbodies is 29 and at 10 spills it is 22.

DCWW's SOAF assessments to identify where current storm overflow spills are linked to observed biological harm, identifies 40 waterbodies containing overflows where the impact is high/very high or severe+. This indicates that the SOEfW approach is indicating a level of environmental risk from storm overflows broadly commensurate with DCWW's own observed biology-based assessments.

Figure 4-2 continues by presenting equivalent results for policies F, G, H, E and I. It shows how the spill-frequency based solutions are 'topped up' so that the risk of harm is eliminated. Policy E has no spill frequency requirement so presents a harm reduction only approach. This is refined in policy I which limits this approach to waterbodies with SAC designations.

Estimated improvements to water quality

Figure 4-3 maps the changing number of waterbodies at risk of environmental harm for 2050 (with no control policies) and then policy A, B and C. Policies D, F, G, H, E and I all result in no waterbodies at risk of environmental harm.

4.2 Estimated CAPEX

Figure 4-4 shows the total estimated CAPEX for each policy inclusive of a 1.124 uncertainty factor to account for overflows where there is no knowledge of spill volumes.

Figure 4-5 shows the breakdown of each estimate by category, separately identifying storage costs, blue-green infrastructure costs, the cost of additional treatment facilities and the uncertainty factor.

4.3 Estimated OPEX

Figure 4-6 shows the total estimated change in OPEX for each policy inclusive of a 1.124 uncertainty factor to account for overflows where there is no knowledge of spill volumes.

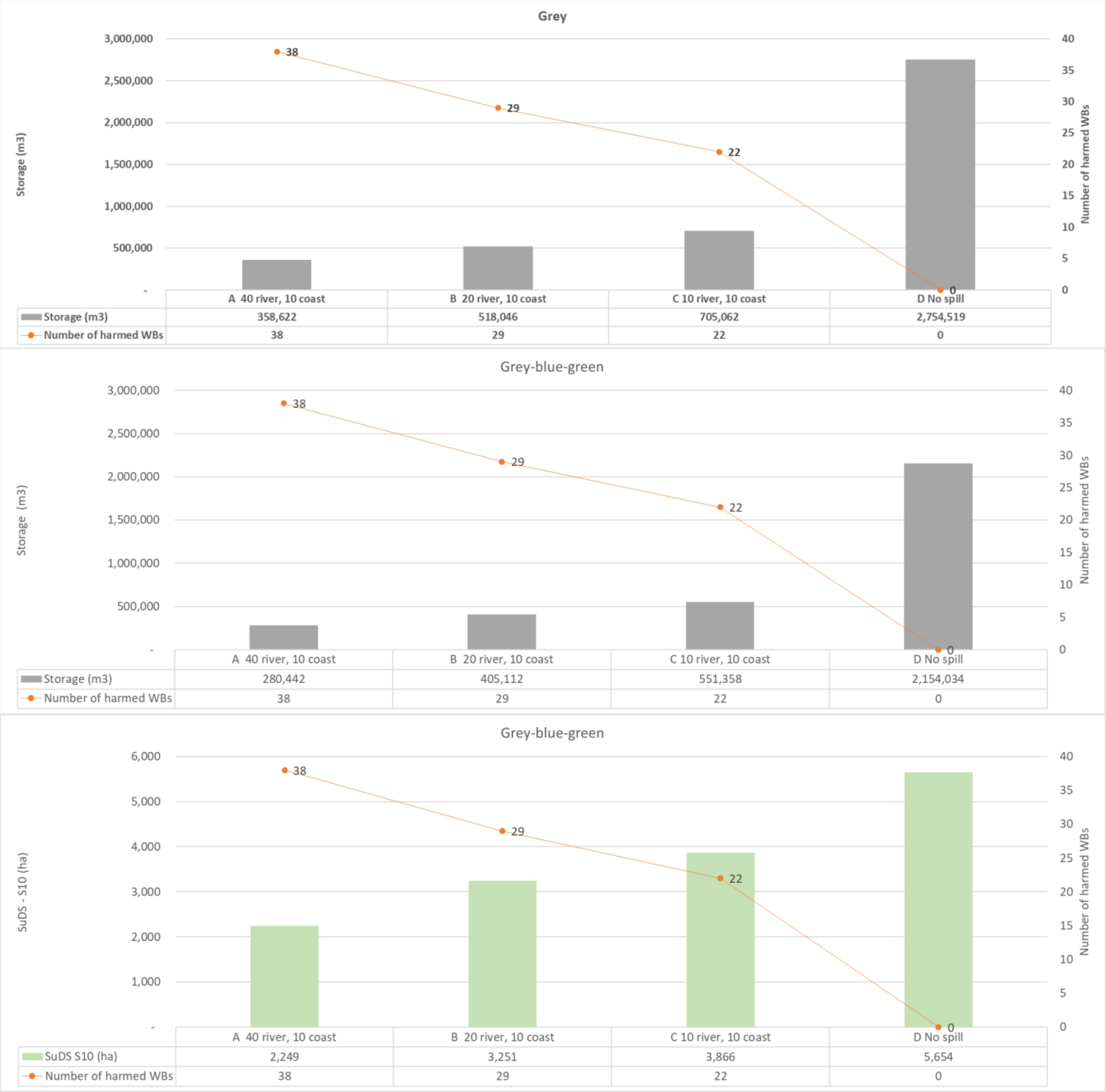
4.4 Estimated impact on bills

Figure 4-7 shows the estimated impact on bills from the levels of CAPEX and OPEX anticipated. The values are rounded to the nearest multiple of £5. More sophisticated and accurate bill impact methods are available and in use by Regulators and water companies. These values are indicative of the broad differences in the bill impacts of different policy.

4.5 Estimated carbon

Figure 4-8 shows the estimated operational and embodied carbon associated with each policy, inclusive of a 1.124 uncertainty factor to account for overflows where there is no knowledge of spill volumes These values (less the uncertainty factor) are monetised and included in the benefit-cost appraisal. There is no account for how the carbon estimate may change in the future, e.g. through different methods of construction compared with today.

Figure 4-1 Storage and blue-green infrastructure for policies A, B, C, D

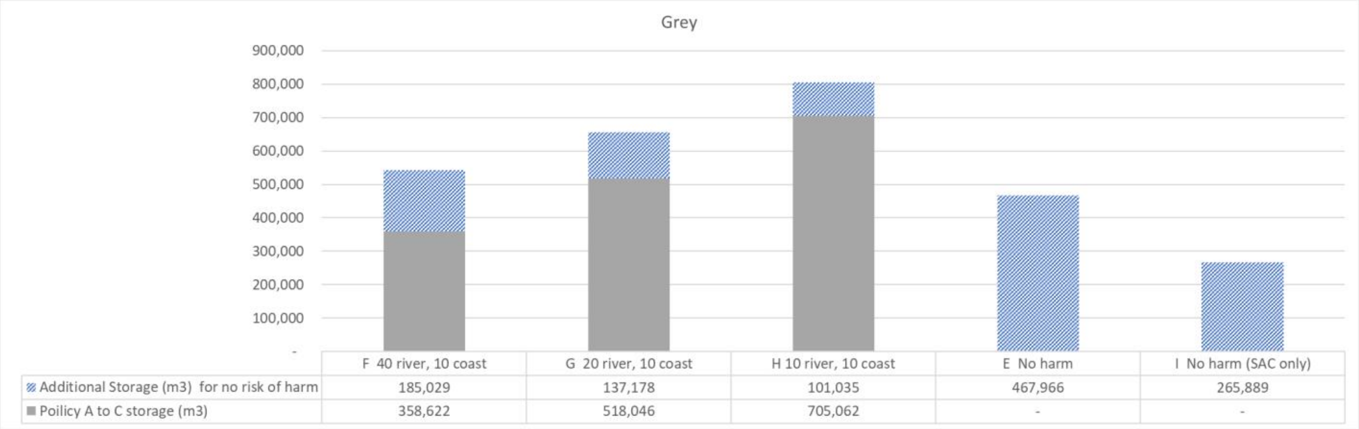


	A 40 river, 10 coast	B 20 river, 10 coast	C 10 river, 10 coast	D No spill
Storage (m3)	358,622	518,046	705,062	2,754,519
Number of harmed WBs	38	29	22	0

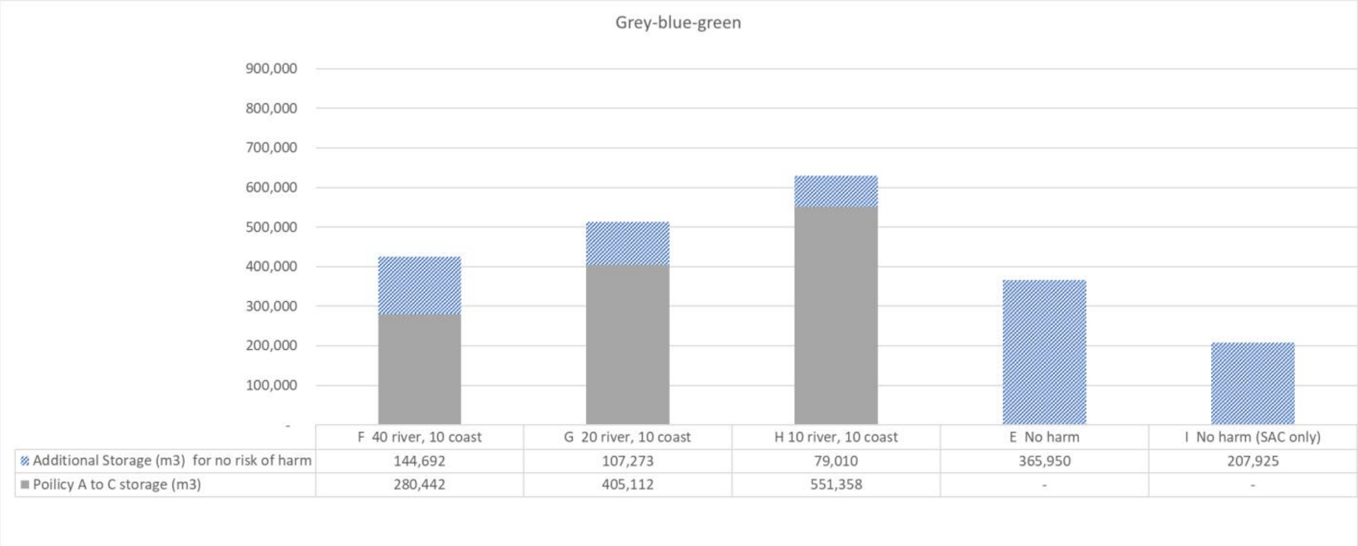
	A 40 river, 10 coast	B 20 river, 10 coast	C 10 river, 10 coast	D No spill
Storage (m3)	280,442	405,112	551,358	2,154,034
Number of harmed WBs	38	29	22	0

	A 40 river, 10 coast	B 20 river, 10 coast	C 10 river, 10 coast	D No spill
SuDS S10 (ha)	2,249	3,251	3,866	5,654
Number of harmed WBs	38	29	22	0

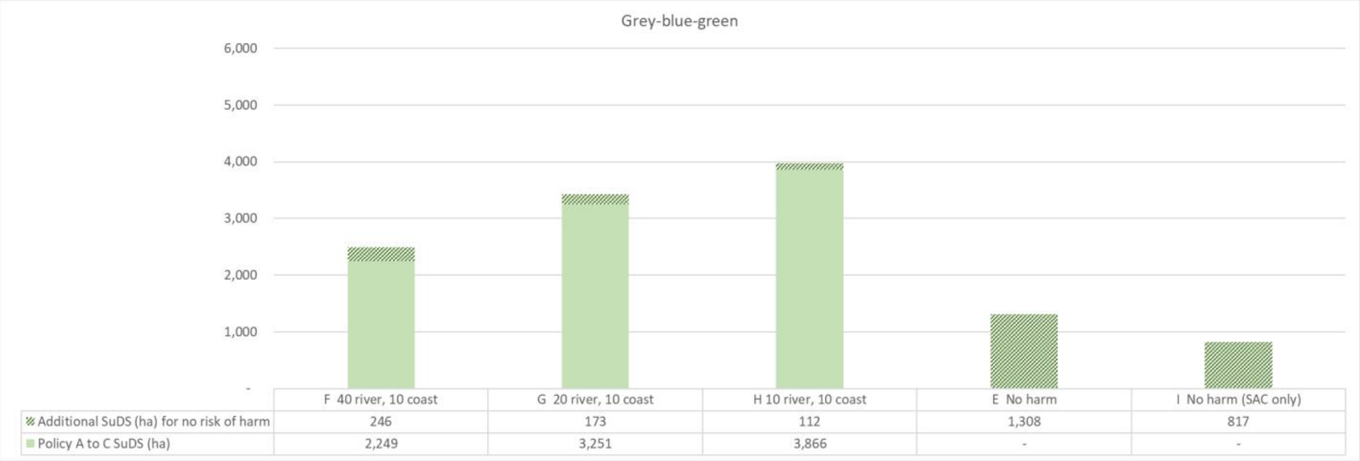
Figure 4-2 Storage and blue-green infrastructure for policies F, G, H, E, I



	F 40 river, 10 coast	G 20 river, 10 coast	H 10 river, 10 coast	E No harm	I No harm (SAC only)
▨ Additional Storage (m3) for no risk of harm	185,029	137,178	101,035	467,966	265,889
■ Poilicy A to C storage (m3)	358,622	518,046	705,062	-	-



	F 40 river, 10 coast	G 20 river, 10 coast	H 10 river, 10 coast	E No harm	I No harm (SAC only)
▨ Additional Storage (m3) for no risk of harm	144,692	107,273	79,010	365,950	207,925
■ Poilicy A to C storage (m3)	280,442	405,112	551,358	-	-



	F 40 river, 10 coast	G 20 river, 10 coast	H 10 river, 10 coast	E No harm	I No harm (SAC only)
▨ Additional SuDS (ha) for no risk of harm	246	173	112	1,308	817
■ Policy A to C SuDS (ha)	2,249	3,251	3,866	-	-

Figure 4-3 Predictions of inland waterbodies at high risk of environmental harm

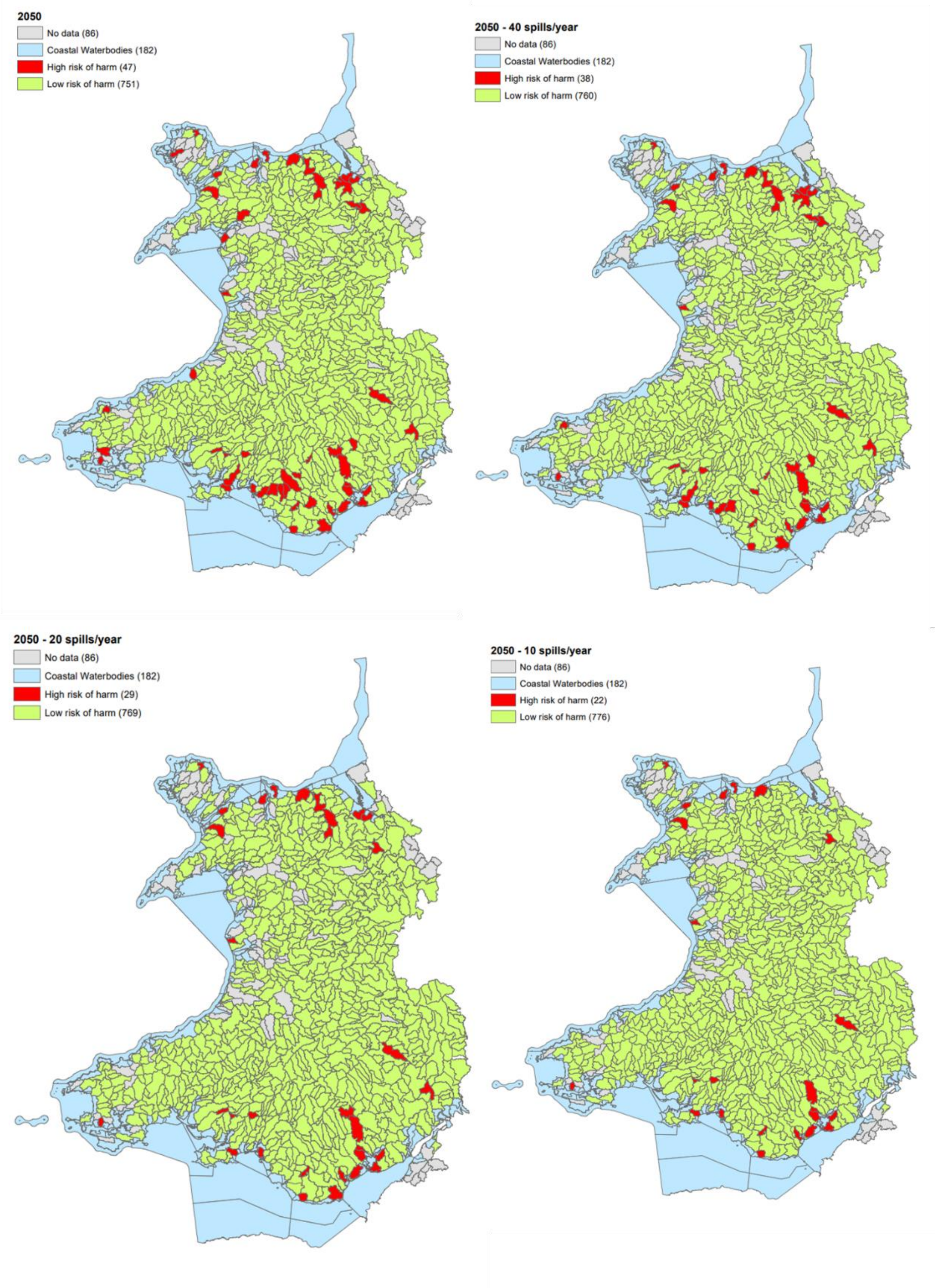
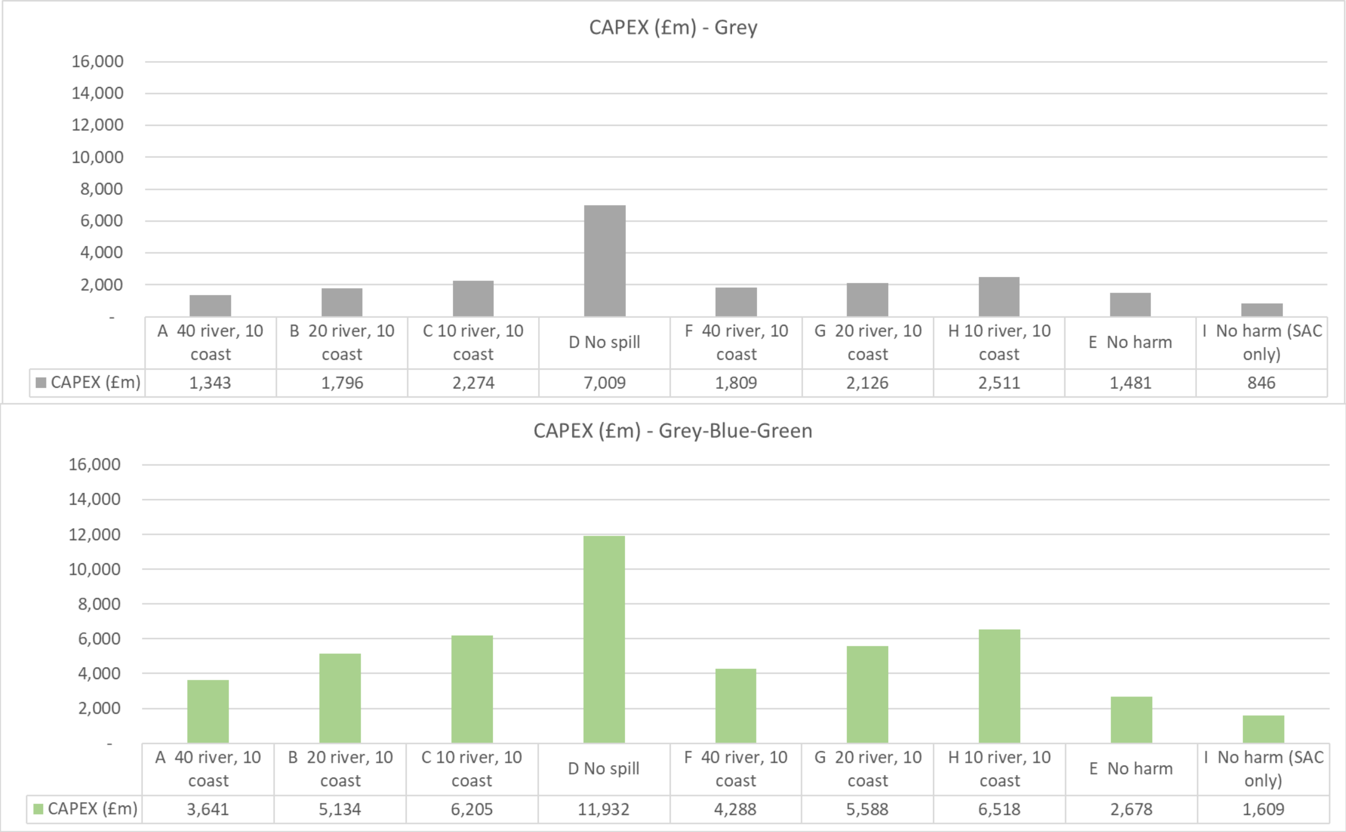


Figure 4-4 SOEfW CAPEX estimates by policy



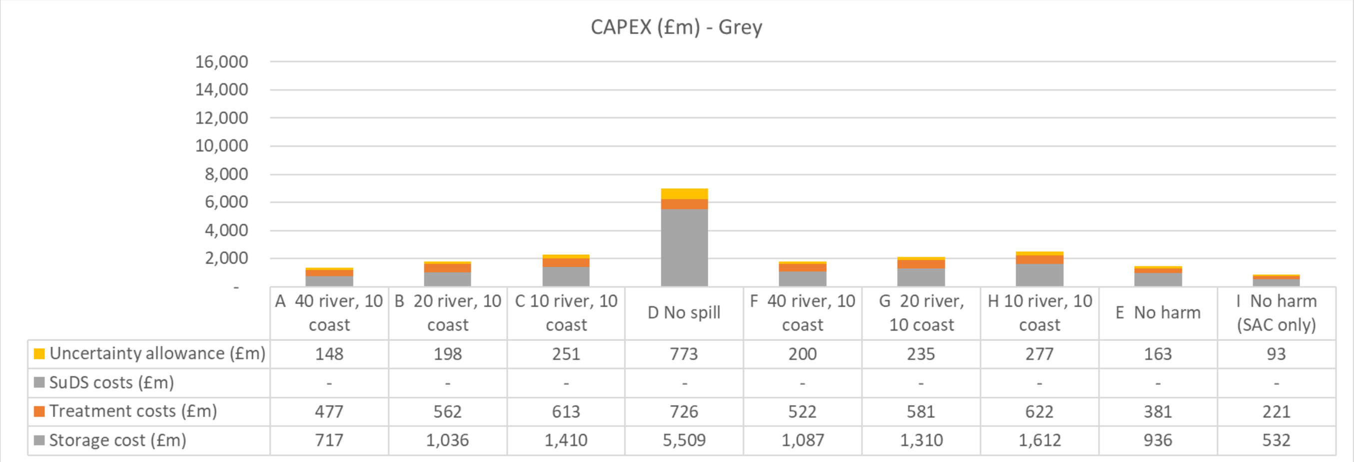
CAPEX (£m) - Grey

	A 40 river, 10 coast	B 20 river, 10 coast	C 10 river, 10 coast	D No spill	F 40 river, 10 coast	G 20 river, 10 coast	H 10 river, 10 coast	E No harm	I No harm (SAC only)
▨ CAPEX (£m)	1,343	1,796	2,274	7,009	1,809	2,126	2,511	1,481	846

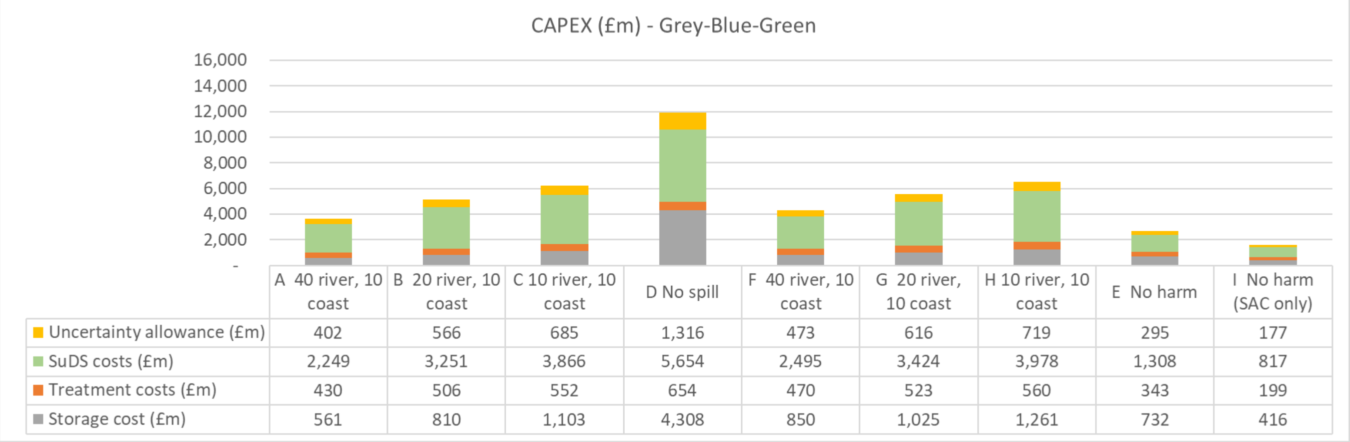
CAPEX (£m) - Grey-Blue-Green

	A 40 river, 10 coast	B 20 river, 10 coast	C 10 river, 10 coast	D No spill	F 40 river, 10 coast	G 20 river, 10 coast	H 10 river, 10 coast	E No harm	I No harm (SAC only)
🟩 CAPEX (£m)	3,641	5,134	6,205	11,932	4,288	5,588	6,518	2,678	1,609

Figure 4-5 SOEfW CAPEX estimates by category and policy



	A 40 river, 10 coast	B 20 river, 10 coast	C 10 river, 10 coast	D No spill	F 40 river, 10 coast	G 20 river, 10 coast	H 10 river, 10 coast	E No harm	I No harm (SAC only)
🟨 Uncertainty allowance (£m)	148	198	251	773	200	235	277	163	93
■ SuDS costs (£m)	-	-	-	-	-	-	-	-	-
🟧 Treatment costs (£m)	477	562	613	726	522	581	622	381	221
■ Storage cost (£m)	717	1,036	1,410	5,509	1,087	1,310	1,612	936	532



	A 40 river, 10 coast	B 20 river, 10 coast	C 10 river, 10 coast	D No spill	F 40 river, 10 coast	G 20 river, 10 coast	H 10 river, 10 coast	E No harm	I No harm (SAC only)
🟨 Uncertainty allowance (£m)	402	566	685	1,316	473	616	719	295	177
🟩 SuDS costs (£m)	2,249	3,251	3,866	5,654	2,495	3,424	3,978	1,308	817
🟧 Treatment costs (£m)	430	506	552	654	470	523	560	343	199
■ Storage cost (£m)	561	810	1,103	4,308	850	1,025	1,261	732	416

Figure 4-6 SOEfW OPEX change estimates by policy

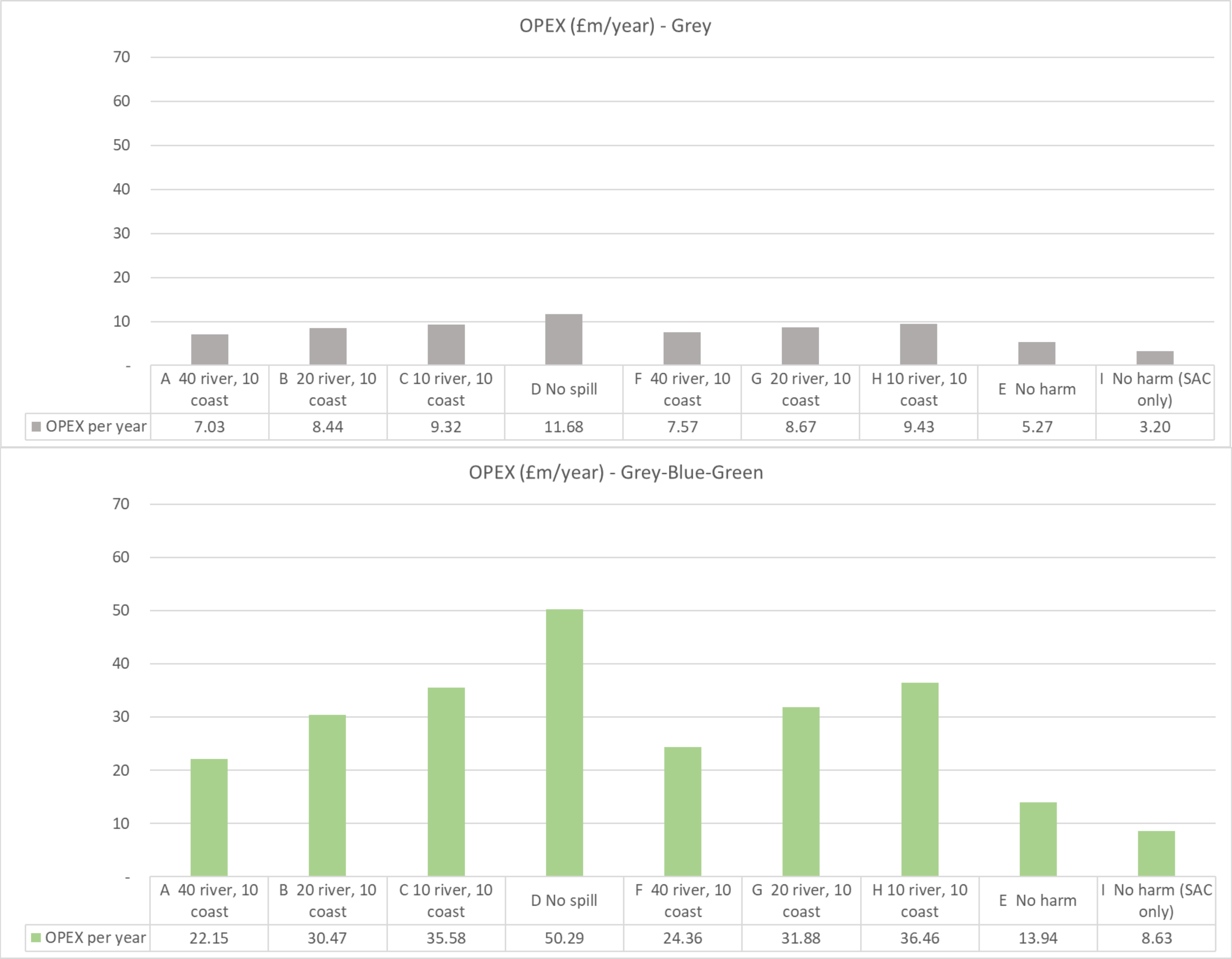
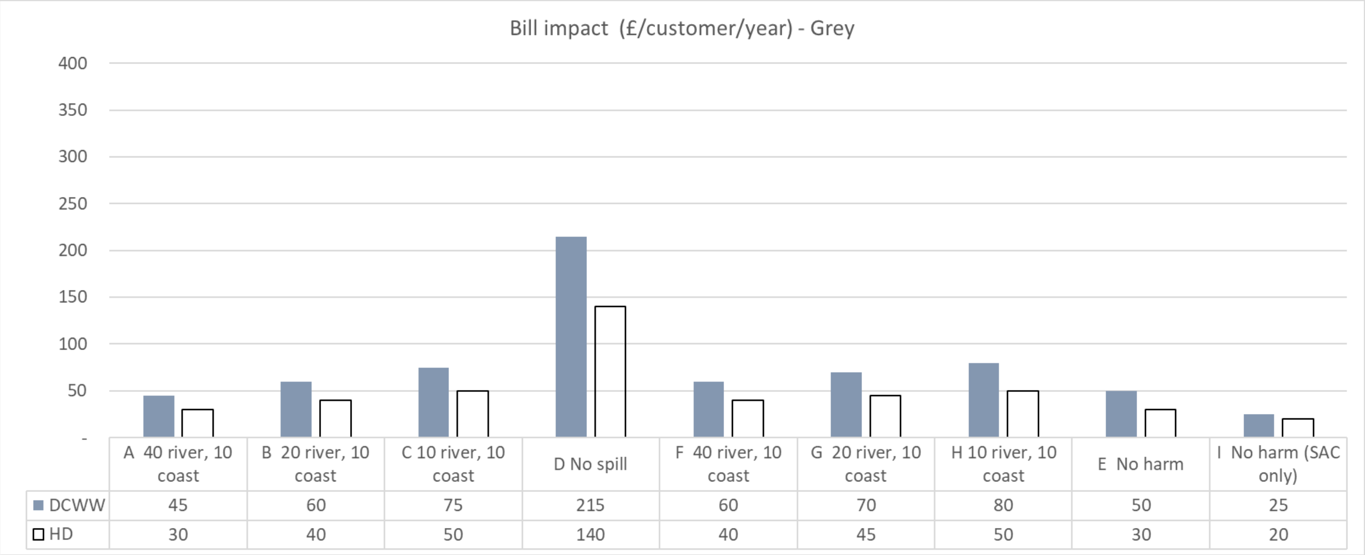
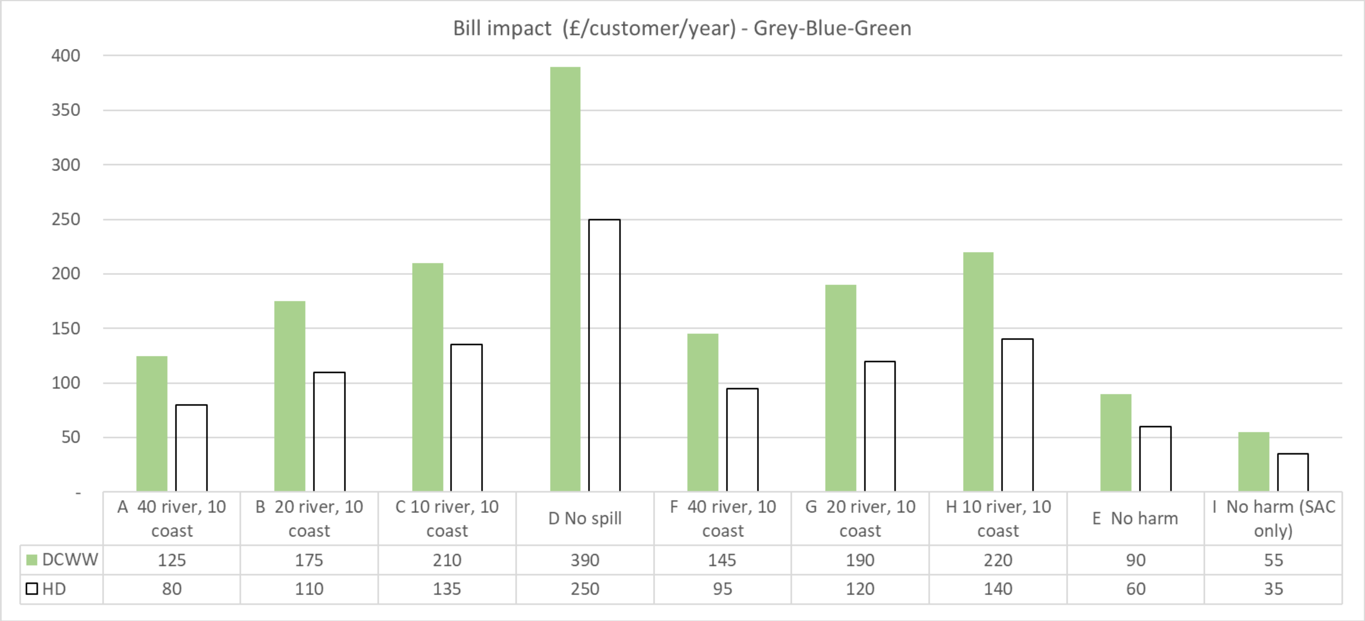


Figure 4-7 SOEfW household bill impact estimates by policy



	A 40 river, 10 coast	B 20 river, 10 coast	C 10 river, 10 coast	D No spill	F 40 river, 10 coast	G 20 river, 10 coast	H 10 river, 10 coast	E No harm	I No harm (SAC only)
■ DCWW	45	60	75	215	60	70	80	50	25
☐ HD	30	40	50	140	40	45	50	30	20



	A 40 river, 10 coast	B 20 river, 10 coast	C 10 river, 10 coast	D No spill	F 40 river, 10 coast	G 20 river, 10 coast	H 10 river, 10 coast	E No harm	I No harm (SAC only)
🟩 DCWW	125	175	210	390	145	190	220	90	55
☐ HD	80	110	135	250	95	120	140	60	35

Figure 4-8 SOEfW carbon estimates by policy

	A 40 river, 10 coast	B 20 river, 10 coast	C 10 river, 10 coast	D No spill	F 40 river, 10 coast	G 20 river, 10 coast	H 10 river, 10 coast	E No harm	I No harm (SAC only)
■ Tonnes CO2e - Grey	100,773	145,571	198,122	774,020	152,766	184,118	226,513	131,499	74,715
🟩 Tonnes CO2e - Grey Blue Green	327,284	473,059	582,087	1,229,989	395,113	522,325	616,701	247,311	148,670

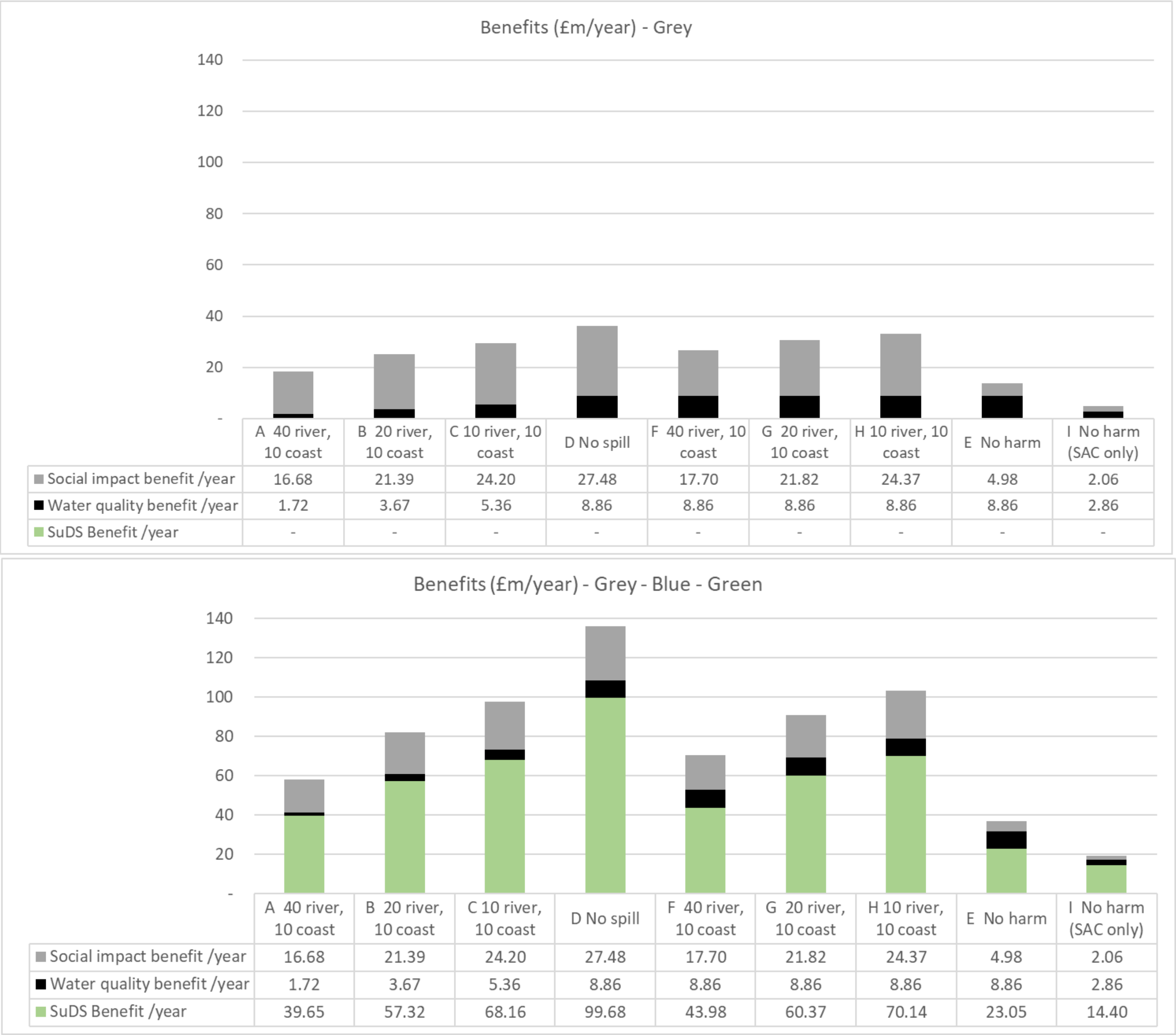
	A 40 river, 10 coast	B 20 river, 10 coast	C 10 river, 10 coast	D No spill	F 40 river, 10 coast	G 20 river, 10 coast	H 10 river, 10 coast	E No harm	I No harm (SAC only)
■ Tonnes CO2e - Grey	122	143	156	185	133	148	159	97	56
🟩 Tonnes CO2e - Grey Blue Green	110	129	141	167	120	133	143	88	51

4.6 Estimated benefits

Figure 4-9 shows the annual benefits associated with each policy, broken down by category: river health, social impact and blue-green benefits. These benefits are not factored by an uncertainty allowance and are combined with unfactored costs (in Section 4.7 for a benefits-cost appraisal.

The data illustrate that benefits arise mainly through blue-green infrastructure and reduced social concern, rather than water quality improvements.

Figure 4-9 SOEfW benefit estimates by policy



	A 40 river, 10 coast	B 20 river, 10 coast	C 10 river, 10 coast	D No spill	F 40 river, 10 coast	G 20 river, 10 coast	H 10 river, 10 coast	E No harm	I No harm (SAC only)
▨ Social impact benefit /year	16.68	21.39	24.20	27.48	17.70	21.82	24.37	4.98	2.06
■ Water quality benefit /year	1.72	3.67	5.36	8.86	8.86	8.86	8.86	8.86	2.86
🟩 SuDS Benefit /year	-	-	-	-	-	-	-	-	-

	A 40 river, 10 coast	B 20 river, 10 coast	C 10 river, 10 coast	D No spill	F 40 river, 10 coast	G 20 river, 10 coast	H 10 river, 10 coast	E No harm	I No harm (SAC only)
▨ Social impact benefit /year	16.68	21.39	24.20	27.48	17.70	21.82	24.37	4.98	2.06
■ Water quality benefit /year	1.72	3.67	5.36	8.86	8.86	8.86	8.86	8.86	2.86
🟩 SuDS Benefit /year	39.65	57.32	68.16	99.68	43.98	60.37	70.14	23.05	14.40

4.7 Benefit – cost appraisal

Figure 4-10 combines costs and benefits (excluding uncertainty factors and including monetised carbon costs) to compare policies through a net present value and benefit cost ratio methodology.

As costs outweigh benefits the NPV is always negative (least negative policies are more economically attractive) and BCR is always less then one (higher ratio policies are more economically attractive).

Figure 4-10 SOEfW benefit cost appraisal

Net Present Value (£m)

	A 40 river, 10 coast	B 20 river, 10 coast	C 10 river, 10 coast	D No spill	F 40 river, 10 coast	G 20 river, 10 coast	H 10 river, 10 coast	E No harm	I No harm (SAC only)
GREY	-965	-1,266	-1,621	-5,745	-1,235	-1,457	-1,765	-1,144	-713
BLUE GREY GREEN	-2,515	-3,523	-4,272	-8,891	-2,892	-3,787	-4,458	-1,920	-1,211

Benefit-cost ratio (BCR)

	A 40 river, 10 coast	B 20 river, 10 coast	C 10 river, 10 coast	D No spill	F 40 river, 10 coast	G 20 river, 10 coast	H 10 river, 10 coast	E No harm	I No harm (SAC only)
GREY	0.265	0.272	0.256	0.107	0.289	0.285	0.262	0.186	0.115
BLUE GREY GREEN	0.304	0.307	0.302	0.224	0.316	0.312	0.305	0.266	0.232

5.0 Summary of results and discussion

Table 5-1 contains a summary of consolidated results by policy. It describes each policy and presents results for CAPEX, OPEX, bill impact, benefits, Net Present Value and embodied and operation carbon. Results for conventional grey and hybrid grey-blue-green (GBG) approaches are included.

Table 5-1 Consolidated results

Policy	Spill frequ control		No harm	CAPEX		OPEX		BILL IMPACT (Grey)		BILL IMPACT (GBG)	
				Grey	GBG	Grey	GBG	DCWW	HD	DCWW	HD
	Coast	River		£m	£m	£m/yr	£m/yr	£/yr	£/yr	£/yr	£/yr
A	10	40		1,343	3,641	7	22	45	30	125	80
B	10	20		1,796	5,134	8	30	60	40	175	110
C	10	10		2,274	6,205	9	36	75	50	210	135
D	0	0		7,009	11,932	12	50	215	140	390	250
F	10	40	✓	1,809	4,288	8	24	60	40	145	95
G	10	20	✓	2,126	5,588	9	32	70	45	190	120
H	10	10	✓	2,511	6,518	9	36	80	50	220	140
E	10	none	✓	1,481	2,678	5	14	50	30	90	60
I	10	none	üSAC	846	1,609	3	9	25	20	55	35

Policy	Spill frequ control		No harm	BENEFITS		NPV		EMBODIED CO2		OPERATIONAL CO2	
				Grey	GBG	Grey	GBG	Grey	GBG	Grey	GBG
	Coast	River		£m/yr	£m/yr	£m/yr	£m/yr	T CO2e	T CO2e	T CO2e/y	T CO2e/y
A	10	40		18	58	- 965	- 2,515	100,773	327,284	122	110
B	10	20		25	82	- 1,266	- 3,523	145,571	473,059	143	129
C	10	10		30	98	- 1,621	- 4,272	198,122	582,087	156	141
D	0	0		36	136	- 5,745	- 8,891	774,020	1,229,989	185	167
F	10	40	✓	27	71	- 1,235	- 2,892	152,766	395,113	133	120
G	10	20	✓	31	91	- 1,457	- 3,787	184,118	522,325	148	133
H	10	10	✓	33	103	- 1,765	- 4,458	226,513	616,701	159	143
E	10	none	✓	14	37	- 1,144	- 1,920	131,499	247,311	97	88
I	10	none	üSAC	5	19	- 713	- 1,211	74,715	148,670	56	51

GBG = grey-blue-green | SAC = Special Areas of Conservation

Headline results are as follows:

- The cost of implementing current policies, based on eliminating harm in rivers, but with no control on spill frequency other than at the coast (policy E) is between £1.5bn (grey) and £2.7bn (grey-blue-green). This is reduced by approximately 40% if improvements are made to priority waterbodies only. Total annual bill impacts would be £50 (DCWW) and £30 (HD) for grey and £90 (DCWW) and £60 (HD) for grey-blue-green.

- The cost of implementing an England-style policy (policy H) is between £2.6bn (grey) and £6.6bn (grey-blue-green). Overall annual bill impacts would be £80

(DCWW) and £50 (HD) for grey and £220 (DCWW) and £140 (HD) for grey-blue-green.

- The cost of limiting all spills to zero (policy D) is between £7.1bn (grey) and £12.0bn (grey-blue-green). Overall annual bill impacts would be £215 (DCWW) and £140 (HD) for grey and £390 (DCWW) and £250 (HD) for grey-blue-green.

- Policy H is associated with an additional 95,015 tonnes CO2e (embodied) compared to policy E for grey solutions and with an additional 369,390 tonnes CO2e (embodied) for grey-blue-green solutions. These are percentage increases of 72% and 149%. It should be noted that in all likelihood local opportunities for lower carbon blue-green solutions will arise, for example by seeking nature-based means to control rural runoff entering urban drainage. The carbon premium described here for grey-blue-green solutions is therefore not universal. Local decisions will always be informed by local carbon appraisals, including operational carbon too.

- Water quality benefits are modest (see Figure 4.9) and a maximum of £8.6m per year if environmental harm is avoided. Social impact benefits are higher when spill frequency is reduced significantly. For example, at 10 spills per year on average the social impact benefit is assessed to be £24.2m per year. Benefits from the ecosystem services gains of blue-green infrastructure can be as high as £70m/year when a 10 spills per year performance is targeted and 10% of impermeable area is managed in this way. The uncertainties around all benefit assessments are very high.

- The most economically advantageous policy (with the highest NPV) is policy I (high priority water quality improvements only) followed by policy A (40 spills). Policy E is superior to policy H but no policy has a positive NPV as costs are always greater than benefits.