River water quality and storm overflows

A systems approach to maximising improvement

Technical report

CIWEM Chartered Institution of Water and Environmental Management

Background

Scope of this report

This report presents the findings of research involving stakeholder engagement, systems mapping and policy and regulatory analysis around the issue of sewage pollution from storm overflows.

It considers the challenges in their widest context, understanding where certain action should be driven by significant actors in the system and factors which combine to create the current situation, but can be considerably enhanced though action in a range of other complementary areas. The report's focus is on England, but the principles discussed apply to greater or lesser extents to the devolved nations of the UK, as well as internationally.

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Executive Summary

The issue of sewage pollution of our rivers and coastal waters has become a high profile public issue in the past two years, with concerted demand for a clean-up leading to new legislation and policy proposals from government.

There are hundreds of thousands of kilometres of sewers in England, a large proportion of which are combined, collecting foul sewage from homes and businesses along with rain water which drains off rooftops, streets and yards. To prevent sewage backing up into properties, these combined networks have 'storm overflows' in them which are designed to discharge dilute but raw sewage into receiving waters during particularly heavy rain. Sewage treatment works also have storm overflows to prevent them being overwhelmed during such conditions.

Monitoring is now showing that storm overflows across England are discharging tens of thousands of times, for millions of hours, quite often outside of the weather events that they are designed for.

Fixing this problem may initially appear to be something which water and sewerage companies (WaSCs) should address directly. They own and manage the bulk of the infrastructure concerned and are regulated this effluent in accordance to permits, so that they don't cause harm. There has been considerable outrage at poor WaSC performance in delivering their responsibilities, set against the scale of shareholder profit they have delivered at the same time.

However the underlying causes for the progressive worsening of the situation are diverse. Whilst water companies do own and manage most of the infrastructure and have a leading role to play in rectifying the situation, they only have so much control over the factors which have increased the inflow of sewage and rainwater into these combined networks. A WaSC-only solutions-set risks investing water-bill payers' money in measures but leaving root causes to continue.

Additionally, there may be opportunities to take action elsewhere which could reduce the amount of costly investment needed by WaSCs. A more systematic approach is required which takes action more broadly and involves a wider range of organisations.

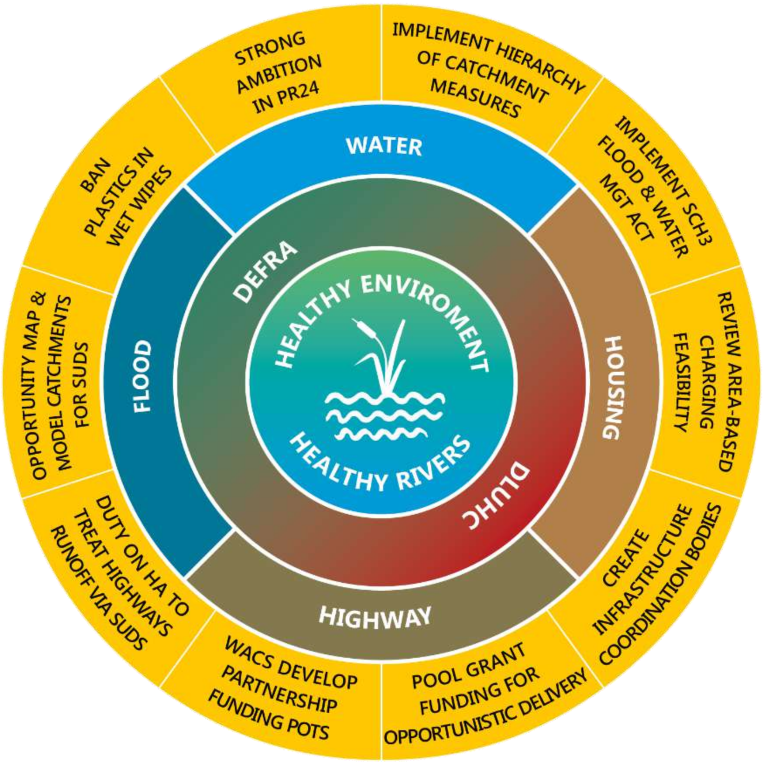
This work engaged a range of water experts, regulators and NGOs to understand the complexity of this picture through a series of workshops. Workshop findings were then used by systems experts to map the system of influences and drivers impacting on storm overflows pollution. This helped to identify where action should be taken over and above that which will need to be delivered by WaSCs.

It found that there is a need for stronger regulation, both by the environmental regulator the Environment Agency, and the economic regulator, Ofwat. This has been evident in recent months as both increased data on WaSC performance has become available, and pressure from the public and politicians has increased.

It also found that because of the strong influence of surface water runoff on storm overflow discharge frequency, those organisations who have a key role to play in managing surface water must be closely involved in delivering solutions to the problem. These include lead local flood authorities, highways agencies and local planning authorities due to their roles in flood risk management, and the development of roads and buildings, the hard surfaces of which run off so much of this water.

Solutions point strongly towards disconnecting much of this runoff from combined sewers in problem areas. This is possible and effective through the use of sustainable drainage systems (SuDS) which infiltrate, slow or store water mainly above ground. Ideally, these use landscaped or vegetated structures which also deliver wider benefits: They help clean pollutants from the water, are good for nature, human health and wellbeing, and provide resilience to climate change in terms of both flood and extreme heat. They will need to be retrofitted into our towns and cities widely, and supplemented by enhancements to more conventional engineered infrastructure in existing sewers and treatment works.

We make ten recommendations which build around this theme, but which point to enabling such solutions delivery as widely, cost-effectively and opportunistically as possible. These rely on government commitment beyond Defra; in particular from the housing and communities department, DLUHC and the Department for Transport. We recommend:



1. Water companies to deploy a hierarchy of catchment-wide measures to reduce storm overflows, prioritising nature-based solutions and active system management over underground storage.

2. Government to implement Schedule 3 of the Flood and Water Management Act 2010, including mandatory multifunctional SuDS standards, a conditional right to connect development to public sewers and a route to adoption and long-term maintenance.

3. Strong regulation by Ofwat and the Environment Agency for PR24 and beyond.

4. Government to ban plastic in wet wipes.

5. Government to review the barriers and feasibility to implementing area-based charging for surface water drainage.

6. WaSCs and lead local flood authorities to hydraulically model key catchments to identify optimal opportunities to retrofit distributed SuDS.

7. Government to review funding sources and rules to enable grant funding to be pooled and drawn down opportunistically over a period of time.

8. WaSCs to create partnership funding pots for use with local authorities on retrofit SuDS schemes where flood risk is not the primary driver.

9. Establish a legal duty on highways authorities to seek opportunities to manage highway runoff through SuDS when undertaking other infrastructure or renewal works.

10. Local authorities to develop infrastructure coordination services to enable synchronised and coordinated delivery, including of SuDS.

Context

There are more than 570,000km of sewers in the UK[1], draining a constantly changing volume and mixture of waste and surface water from our homes and businesses, villages, towns and cities to sewage treatment works, rivers and the sea.

These sewers have always discharged effluent into receiving waters. Since the dawn of 'modern' wastewater management following the 'Great Stink'[2] of 1858, the aim has been to ensure that sewage causes minimal harm both to public health and to the environment.

In the decades since, that has been achieved to greater or lesser extents. Yet in an age when technologically there is no reason why our rivers should be in failing health, something is clearly wrong: The frequency of discharges from storm overflows has become apparent in recent years as an 'event duration monitoring' (EDM) programme initiated by the Environment Agency in 2015 has started to produce data from the bulk of the 15,000 overflows in England. Citizens are also observing and frequently reporting sewage discharges and sewage-borne litter in rivers on a frequent basis.

This has led to increasing media coverage of the extent of the problem and, in-turn, growing public engagement and concern with a growing desire to "end sewage pollution"[3]. The debate became further amplified as Government introduced measures aimed at addressing some of the problem into its Environment Act 2021[4] as it passed through Parliament in the Autumn of 2021.

This development was initiated by the promotion of a Private Members' Bill – The Sewage (Inland Waters) Bill 2019-21[5] – by the MP for Ludlow, The Rt Hon. Philip Dunne who generated considerable support for his Bill's proposals. Government established a Storm Overflows Taskforce[6] in August 2020; a joint regulator – water sector group with the objective to *"recommend actions to achieve the long-term aim of eliminating harm from storm overflows in England."*

Responding to the challenge – keeping it affordable and unlocking wider benefits

This growing awareness and pressure from a range of different parties and interests spurred government to act and to convene the storm overflows taskforce. The focus of its work has been – at least initially – on what water and sewerage companies (WaSCs) might deliver through existing regulatory, and business investment and planning frameworks to reduce the frequency, duration and harm from the overflows on their networks. This is, undoubtedly, where a good amount of the attention must focus and has been reflected in legal requirements in the Environment Act.

However, to focus only what WaSCs can do to their sewer networks and their storage and treatment capacity over-simplifies the situation and risks a number of shortcomings. Because this is an 'end-of-pipe' approach, it misses the opportunity to tackle the problem at source, understanding and addressing the root causes of the problems that we see at overflows and in our rivers.

A WaSC-centric approach risks often being more about tackling the symptom, not the cause. We can build this extra capacity, but without addressing root causes they will continue, and eventually erode away the additional storage, drainage capacity and resilience that the customer and the taxpayer will have to invest in over coming years and decades. Simply, it won't deliver the best value for money or the best outcomes.

In addition to these risks, The way that parts of a system are organised (e.g. funding, governance, operators) influences how the organisations and humans within it interact and behave. Focussing too overtly on WaSCs limits consideration of better ways of organising the water system, or our human-centred constructs within it, to change interactions and behaviours that would lead to healthier rivers in England.

There are many other wider considerations bound up with these challenges, which if properly recognised and addressed could mean that interventions of the right kind, in the right place, could also deliver improved climate (e.g. flood, drought and heatwave) resilience, nature recovery, health and wellbeing, place-making, or other wider sustainability benefits.

Maximising the range of benefits achieved through investment in a variety of solutions means better long-term cost-effectiveness. And being clever about delivery, involving a range of partners, could unlock further cost efficiencies and funding sources. Fixing storm overflows pollution is not going to be cheap; we should do everything we can to make it as affordable *and* multi-beneficial as possible.

A systemic problem needs a systemic solution

To identify the range of contributary factors to the problem and the wider benefits that could be unlocked through tackling it in the optimum way, it is necessary to look beyond the immediately obvious.

Systems-thinking approaches help to understand complex and dynamic interactions and to then work out where and how it is likely to be most effective – and efficient – to intervene to drive the improvement we want to achieve.

Put simply, undesirable (or unacceptable) pollution of rivers from storm overflows is not occurring only because WaSCs have not maintained and expanded their infrastructure in line with development. This is, of course, a significant factor and the underlying reasons for that need to be understood and addressed.

But, public understanding of the problem has changed because we have a clearer picture of its scale and nature. Public expectations of what is acceptable practice has changed because public recreational interests and habits has changed.

Planning, policies and enforcement governing the growth of our towns and cities and our road networks have not properly considered the impact of this growth on the downstream water (and wider) environment.

Added to this, our climate is changing, putting more strain on drainage networks that were not designed for extreme rainfall we're likely to receive. 'Unflushable' products are cheaper and more widely used than ever before, but the way many people dispose of them through toilet flushing causes big problems through blockages.

These are all significant factors which, if not addressed as part of a system-wide package of solutions, will only undermine the effectiveness of an 'end of pipe' approach. The Defra

Minister has stated[7] that *"Everything we're doing on water, we're going to have to look at the really big picture on all of it"*. This is welcome but will need action across many different actors and government departments and it is not clear how big government is thinking.

Government's recent consultation on its Storm Overflows Discharge Reduction Plan[8] sets out various measures water companies should take, targets they should comply with, and wider enablers including legal changes to aid progress. However it remains almost entirely focused on actions water companies should take. Other actors in the wider system need to make changes and improvements too.

Systems thinking is not new to the water sector. There is extensive literature concerning the water cycle as a system, its interactions with other social, economic and environmental systems, and the importance of recognising this and understanding the relationships with these systems when managing water.

Systems thinking is recognised by the two major regulators in this context. The Environment Agency has published demonstration of a systems analysis framework for catchment scale processes[9], noting that: *"Systems thinking provides a structured approach to understand complex problems. It provides a shared view of the system that allows us to see the 'big picture', understand dependencies, consider different perspectives and ensure that components of a system work together to achieve the objectives of the whole."*

And economic regulator Ofwat, in its 2017 Resilience in the Round report noted[10]: *"Water and wastewater services are made up of a complex set of operational, corporate, and financial systems. They are also linked with a wide range of other systems. These include the broader natural environment, social systems, the economy and agriculture… Impacts on any of these related systems can impact water and wastewater service delivery. As future pressures converge and increase in intensity, they are likely to increase interactions between these different systems."*

Government, in its 25 Year Environment Plan[11], proposes that through various pioneer projects the environment should be *"mapped and managed more as a system"*. And the Department for Environment, Food and Rural Affairs (Defra's) Enabling a Natural Capital Approach[12] guidance aims to: *"support systems-based thinking, identify new lines of inquiry linking previously disconnected spheres of operation or data, and support identification of priority areas of investment."*

The engagement and research undertaken through this work has shown that understanding of the range of contributory factors to the challenge exists, understanding of the (in)adequacy of regulation and policy response over the past two decades exists, and understanding of the solutions options exists. It is now important that these are taken forward in an appropriately thorough and committed way.

Project overview and methodology

Importance of collaboration

This project sought to explore all dimensions of this challenge with a range of representative stakeholders, bringing knowledge and expertise to bear in understanding it from a systems perspective so that important considerations were not forgotten and the best opportunities for success were identified and not missed.

Collaboration and engagement of the right parties, involved with managing all aspects of an issue, as well as those who are impacted or have a stake in seeing improvement, is fundamental to identifying and implementing solutions which deliver the best and most enduring outcomes.

This is because such an approach develops a broader understanding of the problem and associated drivers, can engage the range of relevant actors who have control and influence over these drivers and can mobilise them and their resources around solutions and changes which are more widely owned and supported.

This is not a new concept in water. Integrated water management, which recognises that a broad range of factors have a bearing on what happens to water in the environment, and thus needs to be engaged in solutions delivery, has been understood by practitioners for decades. It is reflected in a range of water management approaches, from the Catchment Based Approach (CaBA)[13] and the Water Framework Directive, to regional water resources planning and, internationally, concepts such as Water Sensitive Urban Design[14].

Concepts of collaborative working and co-funding of solutions are being increasingly encouraged by policymakers in recognition of the complexity of how we interact with the water cycle. The issue of sewage pollution from storm overflows is a particular example of where this would be beneficial. However the system of factors which impact on river water quality is, by virtue of the extent of discharges, currently not well-geared to managing the problem and indeed appears to be perpetuating it.

This project recognised from the outset that understanding this full picture required the close involvement of a representative cohort of stakeholders spanning the range of relevant interests.

The individuals involved should be actively engaged with this subject in relevant areas and highly knowledgeable on the detail. This would ensure their input could be used to inform the mapping exercise which would help to identify nexus points within the system, and thus opportunities to intervene in it to drive change.

Broadly these stakeholders may be characterised as representatives from:

- **The water sector** including drainage and sewerage experts from both industry and academia, as well as water and sewerage companies;
- **Environmental and community groups** working to raise awareness on water quality both nationally and locally, and

- **Government and its agencies, regulators and advisors**, including national government, local government, environmental and economic regulators.

Individuals were engaged across two forums: A project steering group and a pool of workshop attendees. In addition, CIWEM's Urban Drainage Group and SuDS and Water Reuse Policy Leadership Group provided an extensive pool of technical expertise for the work.

The **Project Steering Group** contained representatives from the following organisations:

Imperial College London
University of Sheffield
University of Exeter
Consumer Council for Water (CCW)
Z-tech Control Systems
Anglian Water
Yorkshire Water
United Utilities
London Borough of Hillingdon
Kent County Council
Cardiff City Council
The Rivers Trust
Stormwater Shepherds
CIWEM Urban Drainage Group

Workshops

Facilitated stakeholder workshops were a fundamental part of understanding the perspectives, concerns, priorities and knowledge pertinent to the system as a whole. These were designed to explore the problem, its various components, their current management, the range of proposals and solutions and any system gaps or enhancements which may be identified.

To explore detail underpinning these factors, it was important to ensure consistency of participation in the workshops. Individuals were invited to attend the full series of workshops as far as possible and where this was not possible, organisational consistency was sought. The majority of participants maintained consistency right through the series, ensuring that workshop discussion effectively built on those from the prior session.

Participants drawn from representative interest groups and knowledge pools were also important to the discussions. We wanted to ensure that those with detailed knowledge, strong concerns and relevant responsibilities were all given the opportunity to engage. Invitations were sent out to a wide range of stakeholders and participants from the following organisations were engaged (Table 1).

Water sector practitioners	Community & NGO interest groups	Government, agencies & regulators
WRc	Ilkley Clean River Campaign	Defra
CIWEM	Windrush Against Sewage Pollution	Environment Agency
Stantec	The Rivers Trust	Ofwat
South West Water	British Canoeing	Department for Levelling Up, Housing and Communities
Thames Water	Wessex Rivers Trust	National Highways
Southern Water	Thames 21	National Infrastructure Commission
Water UK	Town & Country Planning Association	Greater Manchester Combined Authority

Table 1: Workshop participants by organisation

Workshops, which took place across Autumn 2021, were professionally designed and facilitated by Claire Vintiner. Claire is an independent consultant, facilitator and coach specialising in applying systems thinking and systemic practices to water management challenges, and with a background and expertise in water management, catchment management, resilience, treatment, water quality, environmental assessment, public health protection, and stakeholder engagement.

Workshops were designed and structured to answer a range of questions for inquiry:

1. What do we (or pressure groups) really mean by "End Sewage Pollution"?
2. What is on the table from Government at the moment? Is this enough?
3. What are the range of solutions available to tackle the problem?
4. How do we join these up in a systematic way?
5. Are the governance / regulatory frameworks set up right to deal with this problem effectively? If not, what should they look like?

The sequencing of these questions enabled a progressive unpacking of the problem of sewage pollution from storm overflows and its components; the consideration of where – from a systems perspective – challenges exist, and whether they are effectively managed in a balanced way.

A range of participatory tools, frameworks and methods were used throughout the workshops to help break down and explore the questions.

Literature review

There is considerable published literature and analysis in the public domain relating not only to the problem of pollution form storm overflows, but also on many aspects of the operation of the wider water management system. A desktop review and analysis of this information has been undertaken and informs the discussion throughout this report.

Systems mapping and why we need a systems approach to fixing the storm overflows problem

Systems thinking has long been an approach to understanding complex, 'wicked' environmental problems[15]. Its value is in providing a shared and comprehensive view of the system being analysed, which helps to better understand multiple system perspectives.

The systems approach is also beneficial when analysing options to solve the problem under consideration. These options are seen as 'leverage points' and include management, infrastructural, policy or behavioural changes that create the biggest positive impact in the system[16].

Systems thinking and mapping specialists from the Centre for Systems Engineering and Innovation at Imperial College London were invited to develop a visual map of the system of factors and actors influencing storm overflows discharges. This map identified the relationships and interactions between these and identified leverage points to enable positive change.

A systems approach to analysing water quality has been applied as part of the Systems Water Management for Catchment Scale Processes (CASYWat)[17]. The work has shown that environmental problems, such as an increase in water pollution, are a result of numerous interactions within multiple subsystems: development, water infrastructure, environmental and socio-economic.

This report puts storm overflows problems within a broader context of urban development and drainage and wastewater infrastructure planning, to understand the range of interventions that could be implemented, and how they must be coordinated.

The Storm Overflows Systems Map (SOSM) was developed broadly following the method proposed by CASYWat, with a key difference, namely that the preliminary mapping was developed based on the input provided via three participatory workshops organised by CIWEM. The mapping and its findings are discussed later in the report.

To provide a comprehensive cross-sectoral view of the problem, the workshop participants included representatives from multiple organisations. The purpose of the preliminary map was to incorporate information collected so that key components of the storm overflow management system could be integrated. In the fourth workshop, a preliminary systems map was shown to the participants for their comments and feedback; these have enabled refinement of the SOSM presented in this report.

The collected information from participants was processed as follows: Systems components (nodes) and interactions between them (links) were mapped for both current and potential future views of the storm overflow system and were integrated in a preliminary systems map.

The map was created around **Storm Overflows (SO)** as a key system variable, and components were assigned to one of **nine subsystems** identified in the workshops as factors (either positive or negative) influencing the spills, justifying the need to approach the storm overflows problem from a systems perspective.

No additional information has been added on the preliminary map, apart from assuming the causal (positive or negative) relationships based on the authors' technical understanding of these systems, if these were not clear from the information provided in the workshops.

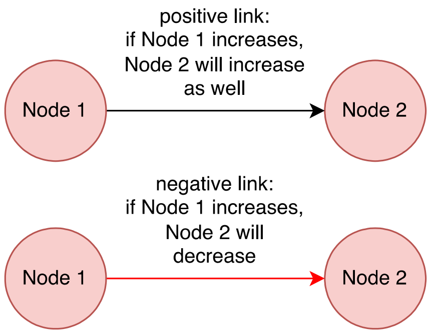


Fig. 1: An example of the notation used for the systems map nodes and positive (black) and negative (red) links

After the fourth workshop, the revisions were made to the preliminary systems map to account for:

(i) different time horizons (current vs future system), and

(ii) categorisation of types of causal relationships (physical, informational, and regulatory).

An example of the notation used for the nodes and links, and explanation of the interpretation is shown in Figure 1.

SOSM components, links, and subsystems

Analysis of the information collected from the first three workshops resulted in clustering the SOSM components into nine subsystems: four physical systems (water, transport, housing, and planning, and environmental) and five socio-economic perspectives (social, regulatory, implementation, design and innovation, and financing). Figure 2 shows the colouring scheme that was used to differentiate the nodes assigned to a specific subsystem.

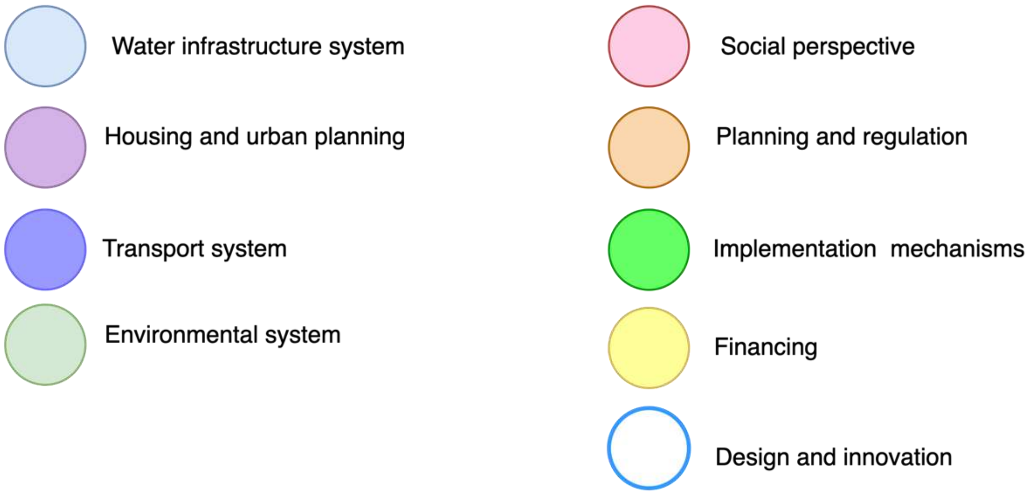


Fig. 2: SOSM nodes colouring scheme for nine subsystems

In addition, interactions between the nodes in a form of positive and negative links were further divided into three types of interdependences:

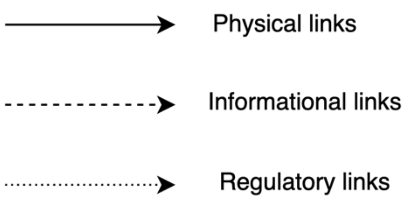


Fig. 3: SOSM links notation

(i) physical, which define interactions in the system due to physical changes, such as the increase of surface runoff due to increased urbanisation;

(ii) informational, which define the influence of the information propagation, such as increased awareness of storm overflows due to increased availability of water quality data; and

(iii) regulatory, which define influence of policy and regulation on system components, such as Ofwat influence of Water and Sewerage Companies (WaSCs) investments and planning (see Figure 3).

The problem – what condition are our rivers in and why?

Rivers in many parts of the UK are not in good health. Despite appearances that rivers have recovered considerably since the decline of heavy industry, with the return and / or recovery of certain species such as salmon and otters, this has been offset by a widely observed decline in quality because of other influences.

This situation means that 86% of river water bodies, classified under the EU Water Framework Directive, fail to meet good ecological status[18]. Good ecological status is defined by biological, hydrological and chemical quality considerations. On the latter consideration – chemical status, no surface water bodies achieve good – all fail.[19]

Reasons for not achieving good status (RNAG) are varied but if we look at pollution, the main sources are, in order of frequency, agriculture and rural land management (5159 cases), the water industry (3485 cases), urban transport (925 cases), domestic general public (571 cases), mining and quarrying (427 cases), and industry (275 cases)[20].

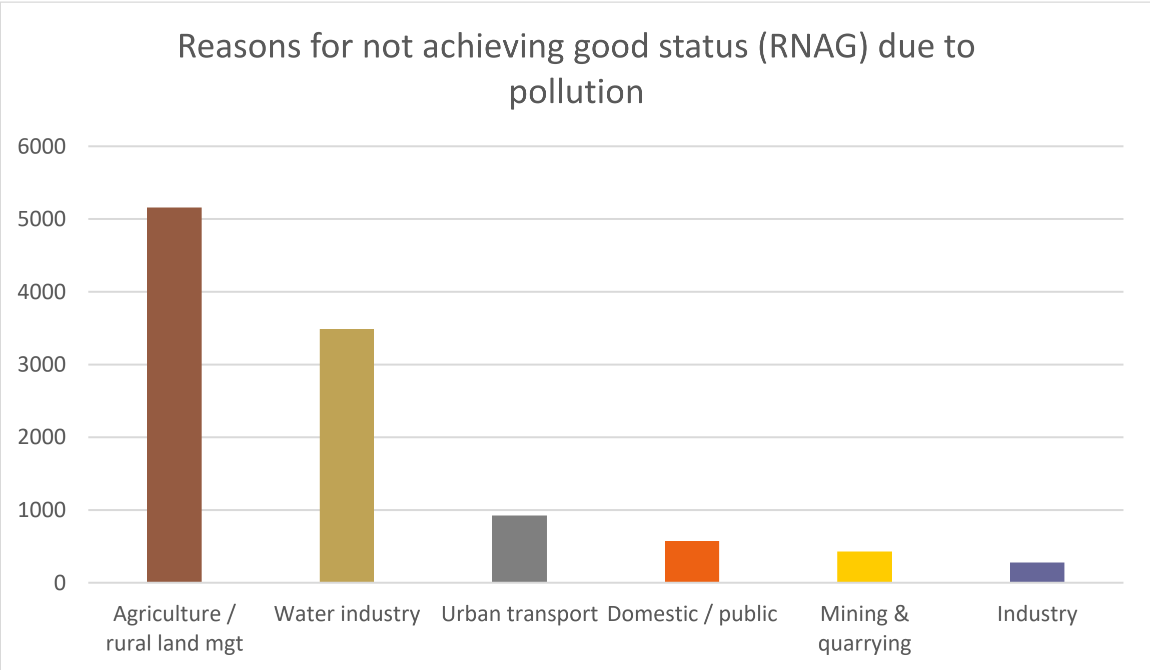


Fig. 4: Reasons for not achieving good status due to pollution

Considering this in other terms, the biggest causes of pollution of rivers and other inland waters are:

- Agricultural diffuse pollution from rural areas (40% of water bodies)
- Wastewater (36% of water bodies)
- Runoff from towns, cities and transport (18% of water bodies).[21]

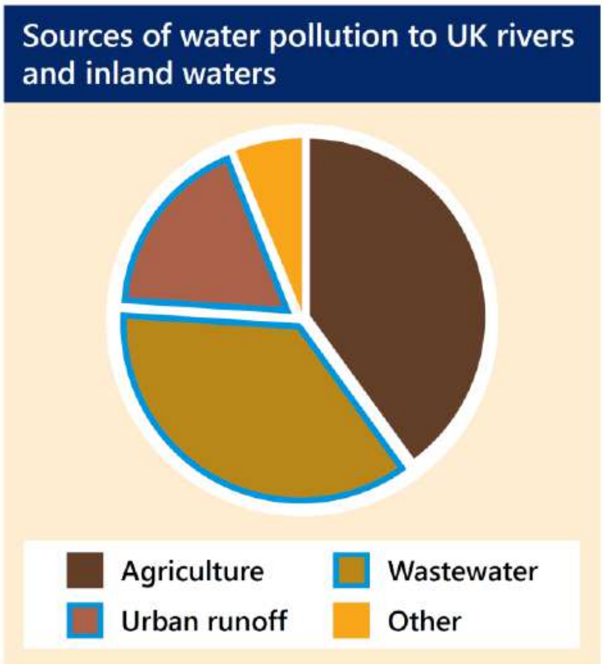


Fig. 5: Sources of water pollution to UK rivers and inland waters

If we consider that wastewater and urban runoff are the major source components of the discharges from storm overflows, by taking an integrated, systems approach to managing these sources of pollution at source, we can make effective inroads into addressing more than half of this water pollution picture (outlined in blue in Fig. 5).

It is important to emphasise that rivers are suffering from a chronic influx of pollution from a range of sources, often varying from their upper reaches and catchments where these are likely to be rural in origin and linked to agriculture or other rural land management, to their lower reaches where catchments may be more urbanised with more pollution from wastewater or transport sources.

Agricultural diffuse pollution has extensive and significant impact on the health of rivers. Pesticide and fertiliser use, intensive farming of livestock and, latterly, poultry, are resulting in considerable influxes of chemicals, excess nutrients, animal faecal matter as well as soil eroded off fields during rainfall. These cause pollution, nutrient enrichment and the clogging of river bed substrates with sediment with significant impacts on aquatic flora and fauna.

Because at least 62% of all land in England[22] is used for agriculture, there is a large area from which this pollution can originate if land management practice is not of sufficient standard.

Land which is considered to be developed, by contrast, covers around 8.3% of England. Pollution associated with urban runoff, as well as surface water which exacerbates the capacity challenges in combined sewer networks therefore originates from a far more condensed source. Improving water management practice in such areas could therefore yield considerable gains.

Pollutants associated with **urban runoff** include hydrocarbons, metals, plastics, suspended solids and faecal matter, as well as litter. Highway runoff can contain high levels of polycyclic aromatic hydrocarbons which are persistent and carcinogenic. These materials accumulate on surfaces and are then washed off them when it rains.

The pollutants can reach watercourses in one of two ways. Either directly via surface water drainage networks which receive roof runoff from downpipes, and drainage from highway outfalls (of which there are around 1 million in England[23]) which typically may have some passive water treatment, such as oil separators, associated with them. Unlike sewage works' discharges, highways outfalls are not permitted or regularly monitored.[24]

Highway runoff can be treated using SuDS techniques or treatment wetlands, and this is more commonly the case for newer or particularly problematic highways and outfalls but is not widespread.

Alternatively, runoff is discharged via combined sewers into which drains connect, in which case the effluent received is treated in a sewage treatment works initially before discharge to a receiving water unless a storm overflow is spilling.

The **water industry wastewater** components of RNAGs include the contribution which is made by storm overflows. It also includes pollution incidents typically associated with discharges above consented levels and failures at wastewater treatment works, pumping stations and other wastewater treatment and sewerage infrastructure, such as misconnections of foul sewerage into separate surface water drains.

Storm overflows use is discussed extensively elsewhere in this report. The environmental impact of storm overflow spills has been known about for decades and ultimately led to the implementation of the 'event duration monitoring' (EDM) programme.

Storm overflow discharges are permitted by the Environment Agency and their impact should be mitigated by the high flows in receiving waters during times of heavy rain. However, EDM data is now showing that storm overflows discharge frequently outside of these conditions.

There is a requirement on water companies to self-classify overflows as either unsatisfactory, substandard or satisfactory, but these have historically not been reported voluntarily.

The pollutant pressures associated with wastewater discharges are ammonia, dissolved oxygen (DO) and biochemical oxygen demand (BOD)[25], alongside pathogenic pollution, microplastics, pharmaceuticals and sewage-borne litter.

Pathogens can affect both human health when receiving waters are used recreationally, as well as the health of shellfish waters. Ammonia can be toxic to fish and macroinvertebrates and its breakdown reduces DO levels.

Phosphorus, found in high concentrations in sewage, is a leading cause of eutrophication and the single highest reason for waters failing to achieve good status. The high organic matter loading of sewage can cause low levels of oxygen in the river for aquatic organisms.

Sewage pollution from storm overflows

What are storm overflows?

For much pre-1960s development in our towns and cities, sewers remove the ‘foul’ sewage, or wastewater we put down our toilets and drains, along with rainwater from roofs, driveways and other hard surfaces in the same pipe – a ‘combined sewer’. This mixture of effluent is taken to wastewater treatment works and treated before being discharged – to a quality agreed and set under permit by the Environment Agency – back into rivers or the sea.

This approach brings with it a risk: When it rains, the volume of rainwater in the network of combined sewers and sewage treatment works increases. The volume of this sewage and rainwater effluent can exceed the designed capacity of the sewers (these are typically designed to be able to handle up to six times their usual dry weather flow) and treatment works (which commonly can handle three times the dry weather flow, above which around two hours’ of peak flow will be diverted into storm tanks, before overflows will spill into a receiving water).

This capacity has historically been sized to balance the financial cost of building very large sewers and treatment works, against the likelihood of pollution if capacity were exceeded during particularly heavy rain.

Exceedance of capacity is always a possibility during extreme rainfall, so when combined sewers were built there was a need to include an ability for excess effluent to escape the network. This prevents effluent backing up and causing flooding through peoples’ toilets and other drainage points into the network, once the sewer’s capacity is reached.

This is where storm overflows come into play, operating as ‘relief valves’. They exist either as overflows for sewage treatment works – used when the flow through the works exceeds the peak headroom capacity because of rainfall of a given intensity. Or, they exist within the sewer network itself as combined sewer overflows (CSOs) – possibly before a treatment works or pumping station or other bottleneck in the system – to prevent infrastructure being overwhelmed and / or sewers backing up into homes and businesses. There are approximately 15,000 in England, of which 13,350 discharge into rivers[26].

A function of how these overflows work is that they discharge untreated sewage into the environment. Whilst untreated, the principle associated with these being *storm* overflows is that at times when they are discharging, the sewage is diluted with large volumes of rainwater.

Normally in such storm situations the receiving watercourse would be also swollen with rain and at high flow, providing additional dilution and further reducing the impact on water quality and ecosystems.

There may also be a broad expectation that people would typically not be using such receiving waters recreationally in storm conditions so would not be exposed to this pollution (though recreational use is not a consideration for permits on rivers currently, but is a factor behind user groups seeking bathing water designations for inland waters).

It is, however, becoming evident that some overflows are discharging in dry weather – the negative impacts of which are significantly higher – and the degree to which others are discharging is having an unacceptably negative impact on the environment and river users.

Newer sewer networks have separate foul and surface water drains. This should stop sewage being discharged directly into rivers, though sometimes they can connect to combined networks downstream. In addition, and polluted urban runoff can still be discharged through surface water drains straight to watercourses with minimal treatment. Furthermore, development can be mis-connected so that foul sewage is connected into surface water drains (this is common following modifications to buildings). Separate sewer networks are therefore not a guarantee of zero pollution.

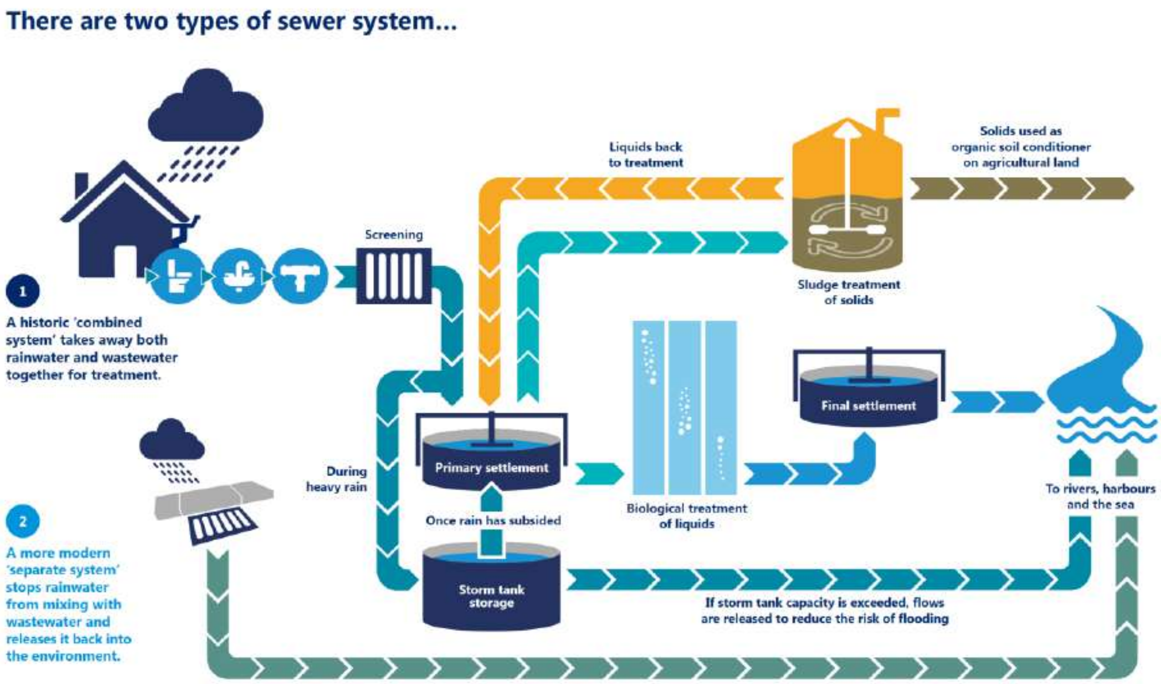


Fig. 6: Types of sewer system – combined and separate[27]

Impacts of storm overflow discharges

This frequency and duration is causing a range of issues:

Impact on wildlife

There is often an observable impact on wildlife. This is often most immediately evident in the presence of 'sewage fungus' which coats aquatic plants and the river bed. Changes in biodiversity have been recorded[28] and there is evidence of increased prevalence of microplastics around outfalls[29]. Reasons for water bodies not achieving 'good' status under the Water Framework Directive are ascribed to storm overflows in 402 cases[30].

Awareness of the poor state of England's nature is growing and Government has committed to drive forward its recovery through instruments such as its 25-Year Environment Plan[31], Nature Recovery Networks[32] and The Environment Act[33]. Public awareness of pollution from storm overflows is growing in-line with rising concerns about the poor health of rivers and nature and need to recover it, creating pressure for action.

Amenity value

Storm overflows discharges can impact on the amenity value of a watercourse. The ability of the public to access and enjoy local rivers was brought into particular focus during the Covid-19 pandemic when travel was restricted and awareness of the health and wellbeing benefits of recreational engagement with the natural environment rose.

More people either walked by, used watercraft on, or swam in rivers which may be receiving untreated sewage effluent discharges at a greater frequency than intended. This may or may not be immediately noticeable but issues of odour and sewage litter (such as wet wipes and sanitary products), as well as sewage fungus coating plants and surfaces, have a negative impact on amenity value.

Public awareness of the existence of storm overflows has been low in the past, but this growing interest in recreational use of rivers has raised it considerably. This is adding to that pressure for action.

Public health

There is a direct risk to human health from any immersion in or exposure to water polluted by untreated sewage effluent. Pathogens such as E. coli can make users sick and there are concerns over exposure to antibiotic resistant strains[34]. This has been a long-standing concern of recreational user groups such as surfers, canoeists and rowers and has seen the development of warnings such as the 'rower warnings' on the River Thames[35]. These warn users of the likelihood of storm overflow discharges during certain conditions, during which recreational use is advised against.

There is a growing expectation alongside increasing popularity of wild swimming, kayaking and paddleboarding that the public should be able to use rivers recreationally without fear of becoming ill. This expectation adds further to pressure for improvement.

Why is the problem getting worse?

As the population has grown and in turn our towns and cities have expanded and become more densely developed, two things have happened:

- Firstly, more people and more homes equals more toilets being connected to sewers that are already in the ground. This means more foul sewage in the sewer.
- Secondly, this expansion of development brings with it more hard surfaces. From rooftops to more roads, car parks, driveways[36], schoolyards, patios and so-on.

  This hard surface transforms the ground from a natural, absorbent surface that can soak up some rainfall before it gets saturated and the rain runs off the surface into a nearby drain or stream, into one which water cannot penetrate. On hard surfaces, rainfall will quickly run off into gutters and drains, then into the sewers. Intense rainfall under climate change exacerbates this picture.

WaSCs have limited influence over the location and type of development that will generate more inflow into their sewers. They are statutory consultees on local plans, strategic infrastructure plans and site allocation planning, but not planning applications themselves.

WaSCs have a statutory duty to maintain and extend the public sewer network to ensure that urban areas are “effectually drained”[37] and are expected to plan for maintenance and development of their networks to meet current and future demand. In doing so they consult with other interested parties and take account of local development plans.

WaSCs have ‘developer services’ functions which should be notified of new connections to their sewer networks and may stipulate certain requirements concerning how this should be done. However, within the legislation which established, at the time of privatisation, the water companies as we know them today, there is provision for new development to have a right to connect to (or “communicate” with) the sewer[38].

Most towns in England date back beyond the 1960s and are therefore likely to have at least some combined sewers serving them. Often these are at the bottom of what is called a ‘sewer catchment’, as this is often the oldest, topographically lowest part of the network feeding into a treatment works and near to a receiving water. Because of this, they are often the most likely to be at full capacity.

Newer developments at the outer peripheries of these catchments may feature the more modern approach of separated sewers but will often feed into the older, combined ones. So, when new development takes place on a sewer network which has some combined part to it, this has a direct impact on the ability of a WaSC to meet the requirements set out in its effluent discharge permits.

Other factors can play a part too. Sewers may be in poor condition and prone to groundwater entering through joints or brickwork. Changes in products and customer behaviour may exacerbate additional load with increased likelihood of blockages due to disposal of non-degradable wet wipes and fats, oils and greases down sewers. All such factors will increase the likelihood of CSOs discharging.

Provision has been made by the economic regulator Ofwat for WaSCs to maintain their sewerage infrastructure (typically referred to as “assets”) and upgrade them to deal with additional load from new development as part of the water industry investment rounds which occur every five years. These assets include the sewerage network as well as wastewater treatment works.

It is evident that insufficient use has been made of this provision to cope with the scale of development in some places, or indeed the pace of physical deterioration.

A review[39] in 2020 noted : “Much of our drainage infrastructure is ageing, and in need of significant maintenance or replacement" and government’s 2010 Water for Life[40] white paper noted that from 2000 it took 8 years to replace or rehabilitate just 1 percent of sewers in England and Wales, meaning a renewal rate of 800 years. Prior Defra policy documents including Directing the Flow (2002)[41] and Making Space for Water (2004)[42] also pointed to the challenge of drainage and sewerage capacity and condition, and the need for improvement and a more integrated approach to managing the various pressures associated with water in our towns and cities.

A 2011 study[43] for Ofwat indicated a likely 92% mean increase in sewer flood volumes by 2040 resulting from pressures of climate change, urban creep and growth, noting the role of storm overflows and the pollution they cause. It recommended preventing all new connections of rainwater drainage to combined or foul sewers, beginning to remove existing connections, increasing wastewater capacity and improving sewer condition.

Many storm overflows exist outside of the combined sewer network itself, and within wastewater treatment works. Treatment works' capacity is designed according to the size of population they serve. This population creates a typical 'flow' through the works (and sewage concentration) which are set out within its discharge permit.

Many such works will receive effluent from combined sewers so when it rains, the volume of water received can quickly increase. Works can handle a certain amount of this additional flow until they reach their full treatment capacity. This is the range known as 'flow to full treatment'[44] (FFT).

Once at full treatment capacity, works can store excess effluent in storm tanks for a period of time so that when it stops raining and the flow drops below the full treatment capacity, the stored water can be treated for safe discharge into the receiving watercourse. Should the capacity of storm tanks be exceeded then works may be allowed under their permit conditions to discharge effluent directly to the receiving water via a storm overflow.

Along with the EDM monitoring programme, there has been focus in recent water company investment rounds on improving understanding of how consistently treatment works are complying with their FFT conditions through increased flow monitoring. Evidence[45] has indicated that a considerable number of works may be prematurely discharging to their storm management system without treating the minimum FFT quantities. This and admissions by certain WaSCs that they may be illegally discharging in this way led to an investigation[46] by Ofwat and the Environment Agency into over 2200 treatment works.

The first major batch of FFT data has recently been provided to the Environment Agency and will be instructive in understanding how WaSCs have kept pace with the pressures population growth, development and climate change have placed on their assets. It is expected that this data will significantly worsen the picture of the extent of unpermitted discharges from the latest based on EDM data[47].

Solutions – technology and approaches

What are the options?

There are various ways to tackle this challenge. These involve:

- Re-engineering existing infrastructure and landscapes to reduce the amount of surface water which enters combined sewer networks (using SuDS);
- optimising ways in which water flows are managed within the existing network ('active system management' using telemetry and remotely controlled structures);
- reducing the amount of groundwater infiltration into drainage infrastructure through sewer repair;
- building additional storage tank capacity within the network and at treatment works;
- treating discharges from overflows in wetlands, which use natural processes to store and treat the effluent prior to onward discharge to the receiving water;
- preventing the problem of blockages from 'unflushable' products such as wet wipes and FOGs by tackling these problems at source is an obvious area for attention, and
- improving engagement and data sharing between WaSCs and local authorities on local planning and infrastructure modelling, delivery and maintenance.
- A further option – separating combined sewers into separate foul and surface water drains – is a particularly major and costly undertaking.

Various considerations will apply when assessing the most appropriate solution for any given location, sewer and overflow involving factors of topography, development, sewer condition and so-on. Levels of cost, disruption, carbon and the ability to achieve wider benefits including on climate resilience and amenity will inform decisions.

An assessment[48] of potential costs of a limited range of options scenarios has indicated remediation costs between £18bn and £600bn depending on extent of spill reduction and how targeted or blanket solutions were. This range was refined in Spring 2022 as part of the government's consultation on its Storm Overflows Discharge Reduction Plan[49] to an average capital cost of £51.5bn with a range of £40bn to £63bn and the public appetite for investing in improvements will need to be understood, set alongside other cost of living pressures.

There are limits to the scope of these cost assessments; they have not examined the cost to the environment or society of not doing anything, nor the wider economic benefits arising from tourism for example, in areas where there might be considerable improvement in storm overflows and bathing water quality.

There is scope within the proposals to both prioritise action on the worst performing overflows initially but also to achieve efficiencies through synchronising works with other utilities to assist with retrofitting the sewer network.

Additionally, combining funding streams where multiple benefits can be achieved for different stakeholders and risk management authorities (particularly flood risk management grant-in-aid for the management of surface water flood risk) could enable more cost-effective delivery at the local level.

Sustainable drainage systems (SuDS)

Sustainable drainage mimics natural processes and reduces flooding by managing rainfall close to its source and wherever possible at, or near the surface. By building in permeable paving, channels, green roofs, swales, soakaways or ponds, SuDS can slow, store and treat runoff that could cause damage.

Planning policy currently requires SuDS to be delivered in major developments, mitigating the impact of new development on storm overflows but with limited impact on urban infill. SuDS therefore also need to be retrofitted into streets, public open space and private properties by WaSCs, highways authorities and others to prevent surface water drainage to combined sewer networks.

Many SuDS techniques use landscapes and vegetation which achieve a wide range of benefits: Treating and improving highway runoff water quality, reducing local surface water flood risk, providing habitat for nature, reducing the impacts of heatwaves in urban areas, improving air quality and enhancing amenity value of their location.

Using available approaches such as CIRIA's Benefits Estimation Tool (B£ST)[50] enables WaSCs and other RMAs to understand where SuDS would most effectively deliver this range of benefits potentially enabling costs to be shared, e.g. between local authorities looking reduce surface water flood risk and WaSCs reducing storm overflow spills.

Treatment wetlands can be used specifically to treat water to a higher standard using natural processes and can be highly effective where there is space for them. Their use at storm overflow sites[51] is not unusual, particularly elsewhere in Europe[52] and they have a range of wider benefits; particularly their low energy use and ability to create habitats for nature.

Fig. 7: Yorkshire Water's Willow Lane, Wakefield detention basin. Nature has colonised this area providing habitat for a wide range of species.

SuDS as part of a blue-green infrastructure approach have been utilised internationally to reduce the challenges associated with storm overflows. For example, the Green City Clean Waters[53] approach in Philadelphia is a 25-year plan to reduce the volume of stormwater entering combined sewers using green infrastructure alongside expanded traditional stormwater treatment infrastructure. Similar approaches have been taken to manage stormwater effectively in urban settings in Copenhagen, Mälmo and Melbourne.

Active system management (ASM)

A combination of monitoring current and recent sewer conditions, forecasting rainfall and proactive manipulation of pumps, storm tanks, weirs and control gates within the sewer network can help to maximise the available capacity to store water before a storm overflow spills. It can also help to maintain self-cleansing flows in sewers during normal operating conditions.

Innovation is starting to enable modelling, machine learning and AI to create digital twins of networks to understand the impacts of different forecasts and inform the best management of the sewer system to minimise the risk of storm overflow spills. The approach relies on utilising the existing capacity of the network, rather than creating new storage. It can be used effectively alongside other approaches which create new capacity but its ability to achieve significant improvements within the network itself are ultimately limited by existing capacity.

New engineered storage

Historically the approach to managing peaks of stormwater within drainage networks and at treatment works has been to build storage tanks to temporarily hold back water to prevent flooding, releasing it gradually once a storm has eased.

The approach provides high certainty of performance, but depending on the required location and hydraulic characteristics of the network, can involve disruption associated with construction, ongoing energy and carbon costs associated with pumping, and does not deliver any of the wider benefits of SuDS. Additionally, if buried such solutions may be harder to adapt and expand in future than surface-based systems.

Fig. 8: Modular stormwater storage Photo: Hydro International

A hierarchy of solutions

It is likely that there will be scope to use various combinations of these approaches depending on context. However in view of the desirability of achieving wider climate resilience (including flood risk and water resource management), nature and amenity benefits alongside those to water quality, the use of retrofitted SuDS is recommended where possible. Broadly, a sustainable hierarchy of approaches would involve:

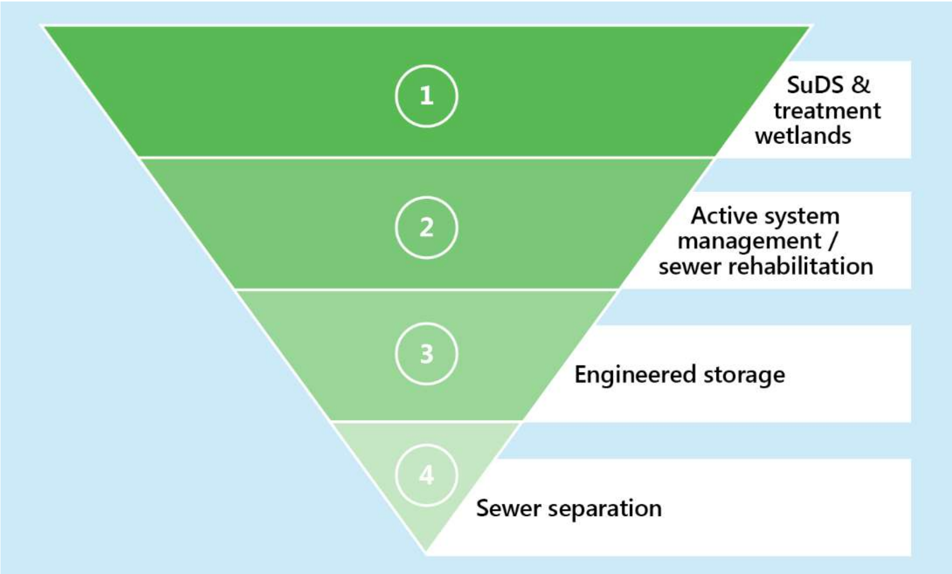


Fig. 9: A hierarchy of solutions to storm overflows

Beyond these solutions, which would be water company-led and require additional investment translating into higher water customer bills, other interventions reflecting wider integrated water management principles could support timely progress. Many of these require broader policy and regulatory changes.

Solutions – policy and regulatory

Drivers and mechanisms identified by government

Since the recent increased public awareness of sewage pollution from storm overflows, various policy and regulatory mechanisms have been developed or utilised to bring about greater action, these include:

- Storm Overflows Taskforce
- Environment Act provisions
- A stronger Strategic Priorities Statement
- A revised Water Industry Natural Environment Programme
- Statutory Drainage and Sewerage Management Plans
- The Office for Environmental Protection, and scrutiny

Storm Overflows Taskforce

In response to increasing media focus, local and national campaign group activity and growing public engagement with the issue of pollution from storm overflows, government established a Storm Overflows Taskforce in late 2020 to consider what might be done to tackle the problem.

The Taskforce[54] comprises government, its regulators and agencies, water companies and representatives of the NGO community. Its purpose is to consider technical, societal and economic factors including the scale of the problem, the public's position on the problem and solutions, and to make recommendations to Defra for inclusion in future regulatory guidance.

Some, but not all of these recommendations have been set out in Defra's consultation on its Storm Overflows Discharge Reduction Plan. The Taskforce's Legislative Task and Finish Group is considering how amendments to the Water Act 2014[55] to enable more sustainable management of surface, ground and foul water.

Environment Act provisions

The Environment Act became a key area for government attention around storm overflows, following the traction developed by Philip Dunne MP's Sewage (Inland Waters) private member's bill.

Under the Act, a number of requirements and duties were established to require:

- **The Secretary of State to prepare a Storm Overflow Discharge Reduction Plan, together with periodic progress reports.** This must set out how government intends to reduce both the frequency and extent of storm overflow discharges, as well as the adverse impact of these on the environment, and on public health.

  This plan is intended to consider how the need for anything to be discharged through overflows can be reduced, how anything that *is* discharged may be treated to reduce its impact, how the quality of water bodies into which discharges are made will be monitored, and how information on the operation of overflows will be obtained. This plan is to be published by September 2022 and laid before Parliament. Progress reports must be published by government in 2025 and then every five years subsequently.

The consultation published in March 2022 sets out three headline requirements which it proposes WaSCs should comply with fully by 2050, at a likely cost of £54bn. These would require that WaSCs may only discharge from a storm overflow where they can demonstrate no local adverse ecological impact; for them to significantly reduce pathogenic content at or near bathing water sites, and for discharges to only occur during an average of 10 rainfall events per year or less.

- **WaSCs to produce annual Storm Overflow Reports** detailing the extent and impact of discharges (location, frequency and, where possible, volume) in the preceding year, investigations and remediation works undertaken or planned. These should be readily understandable by a public audience.
- **The Environment Agency to produce an annual report** on storm overflows setting out its understanding and position on the factors which WaSCs are required to report against.
- **WaSCs to monitor water quality** (dissolved oxygen, temperature, pH, turbidity, ammonia, and anything additional specified by the Secretary of State) both upstream and downstream of storm overflow or sewage treatment works outfalls.
- **WaSCs to secure a progressive reduction in the impacts on the environment and public health of storm overflow discharges.** The Act does not prescribe any timescales or extent for this reduction which has been a cause for concern by campaigners who point out that regular but tiny reductions would class as "progressive".
- **The Secretary of State to produce a report – by September 2022 – on the actions needed to eliminate all discharges**, and the costs and benefits of those.

The Environment Act's storm overflows provisions represent a legal requirement on government, the Environment Agency and WaSCs to establish a far deeper, more granular understanding of sewerage infrastructure and the operation of storm overflows. It requires them to report publicly on this, as well as future management options and plans and as such, is a welcome step.

Stakeholders in our workshops observed that the legislation does not provide for any actual compliance, management or enforcement progress over and above that which already existed through pre-existing legislation and regulation, and that the problem has developed purely because this legislation was never adequately enforced. This is discussed under 'Existing provisions and their enforcement' later in this section.

It should be noted however, that the Environment Act considerably sharpens the focus and levels of expectation on what WaSCs will be required to deliver. Considering the impact that the publication of data from the EDM programme – which has only become available on a large scale over the past couple of years – has had on the level of scrutiny placed on the issue, the raft of reports will continue to shine a light on the scale of both the problem and progress to clean up rivers. The results of FFT programme are highly likely to add even greater intensity to this focus.

We welcome the production of the consultation on the Storm Overflows Discharge Reduction Plan and recognise the challenge of balancing ambition with protection of customers from bill increases (increases are proposed to occur from 2025, rising to around £20 per year increase by 2030).

Beyond these specific targets, there is recognition of activity elsewhere in relation to the water environment to improve quality and management. It points towards:

- requirements for quicker remedial action in areas of poor performance, outside of the rigid 5-yearly water company investment rounds;
- new monitoring requirements on WaSCs enabling increased levels of enforcement activity by the Environment Agency and Ofwat;
- reviews government is undertaking of legislation relating to SuDS delivery within new developments, on measures to help WaSCs and others improve management of rainwater, and on potential restrictions on the sale of 'un-flushable' wet wipes; and
- further protection for bathing and shellfish waters.

The outcomes of these reviews and recommendations will, government says, be taken forward in the final discharge reduction plan.

A stronger Strategic Priorities Statement

Government has been at pains to point out that there is a broad policy framework which informs the priorities and level of investment delivered through WaSC investment rounds[56]. Prior to Ofwat setting out its guidance for water companies in advance of the development of their 5-yearly investment plans, Defra sets out its strategic priorities for the regulator (known as the strategic priorities statement, or SPS) following a draft for consultation[57]. This provides the high level, strategic steer for the rest of this framework.

Knowledge of the problem of storm overflows and their impact on the environment has existed for decades. However the scale and extent has not been understood in detail and it was this reality – brought into focus by regulatory compliance challenges with the Urban Wastewater Treatment Directive and the Water Framework Directive – which prompted investment in understanding sewage treatment works compliance on their flow (treatment capacity) and on the frequency of storm overflow discharges (event duration monitoring) in successive investment rounds.

Nevertheless the level of priority attached to maintaining the capacity and integrity of sewers and treatment works, and their associated storm overflows, was low in previous SPS. The 2021 draft statement raised the bar significantly , noting under a heading of *"Getting the basics right"* that:

"We want to see far less reliance on storm overflows… We expect companies to significantly reduce the frequency and volume of sewage discharges from storm overflows, so they operate infrequently. We expect overflows that do the most harm or impact on the most sensitive and highest amenity sites to be prioritised first."

Whilst recent priorities have included reducing leakage, improving levels of service and keeping bills low, now the policy is focusing more squarely on environmental performance – particularly in relation to sewage.

The strategic direction from Defra to Ofwat does make clear an increased priority attached to rectifying sewage pollution. However, it does still leave significant discretion to Ofwat as to what may or may not be considered appropriate levels of investment in tackling this issue when it could be argued this is a more appropriate judgment for an environmental regulator or ministers to make. The range and urgency of issues and pressures that water companies are having to tackle and factor into their planning are growing and intensifying, pointing to a need for increased investment over coming years – something which may butt up against the historic steer to keep customer bills low.

Within the SPS, Defra reiterates the ambition government has placed within its 25 year environment plan to leave the environment in a better state for future generations and to improve at least three quarters of waters to be close to their natural state as soon as is practicable. It acknowledges increasing pressures on the environment and that the water industry impacts on this and states that *"water companies must change the way they plan, invest and operate their services"*.

There are however many priorities within the SPS, including those relating to both drought and flood resilience, continuing to bear down on leakage, improve service to customers and protecting vulnerable customers. It remains to be seen how strongly action on storm overflows will be prioritised alongside these.

A revised Water Industry Natural Environment Programme

A further component of this policy framework is the Water Industry Natural Environment Programme, or WINEP. It has been the primary vehicle through which the Environment Agency, as the environmental regulator, has prioritised investment by water companies to deliver improvements identified as necessary within the river basin management planning (RBMP) process – established under the EU Water Framework Directive.

For the period 2020-2025 it set out a £5.2 billion programme of monitoring, investigations, asset improvements and catchment measures[58]. These are incorporated within the asset management plan programmes established by water company business plans and delivered over the same timeframes.

In summer 2021 the Environment Agency consulted on a revised approach[59] to identifying the priorities for attention through the WINEP, recognising the *"increasingly complex environmental challenges"* and proposing a greater role for water companies in the development of priorities as part of a co-designed, co-developed and co-funded process. This is a step forward, towards a more systems-focused, cross-sector approach from one which was previously quite prescriptive in terms of the priorities it identified and tightly bound in terms of water company delivery.

As with the SPS, the WINEP review acknowledges the increasing pressures on the water environment, and on the water sector to manage them. It notes that these pressures are reducing the effectiveness of investments made to date through WINEP and its predecessor schemes.

The proposals place greater emphasis on the use of nature-based solutions, taking a longer-term approach (less tightly-bound to the 5-year water company business planning rounds) and focusing more on tackling issues at their source by involving a wider range of organisations within a catchment in the programme. This would be underpinned by a review of cost-benefit assessment within the programme.

The overall direction of travel is one in which there is increasing expectation for water companies to engage with a wider range of parties and to focus on multi-beneficial interventions. This is very welcome, although co-delivery will always be an area involving greater complexity and partner organisations will need time to become familiar with how each other work best together.

Statutory Drainage and Sewerage Management Plans

Under S. 79 of the Environment Act, WaSCs will be required to develop drainage and sewerage management plans (DSMPs – also commonly referred to as drainage and *wastewater* management plans or DWMPs).

These plans offer the opportunity for a longer-term, strategically planned approach to managing drainage and sewerage assets. In part DSMPs are a response to the imbalance between development and other pressures and appropriate levels of maintenance and upgrade of sewerage infrastructure. They should provide a long-term picture of drainage and sewerage investment needs and inform WaSC business plans.

The contribution of surface water storm overflow discharge frequency is significant. WaSCs developing their DSMPs have indicated that it is not unusual for between 30-50% of water in combined sewers to be highway runoff for example. The twin problems of storm overflows and urban flooding are so intertwined that they could be considered to be two different sides of one problem (the management of water in our urban environment) and need to be addressed in a properly integrated way that also delivers benefits in terms of water resource management and supply.

In maximising the effectiveness of DSMPs – especially in relation to surface water management – WaSCs will need cooperation from a range of other bodies. These will particularly include highways authorities (HAs), local planning authorities (LPAs) and lead local flood authorities (LLFAs) given the range of inter-related responsibilities which have a bearing on drainage and sewerage networks.

Strategic planning elsewhere in the water industry, e.g. with water resources management plans, has been effective in building resilience and this is being taken further through the regional water resources planning approach (also being made statutory under the Act).

DSMPs will undoubtedly help drive a better understanding of the nature and condition of sewers and therefore storm overflows and enable prioritisation of remedial action on those which are most problematic.

One option in the conceptual design of DSMPs through the 21st Century Drainage programme[60] could have been fully-integrated WaSC-LLFA plans that looked at water quality and surface water flooding together. A fundamental question within that programme was that despite legislation such as the Flood and Water Management Act 2010, the sector continued to be criticised for working in silos – how could collaborative working be delivered more quickly?

However, it was decided not to progress in this way, not least because WaSCs and LLFAs have completely different funding and investment approaches and horizons. In essence, it was too difficult to integrate planning in this way. Consequently there is a real risk the approach will remain siloed, with too few people with requisite knowledge spanning the different technical disciplines involved.

Nevertheless, the collaborative working need – and challenge – remains, despite collaboration being an increasingly common theme seen across water management policy. There is growing experience – through activities such as regional water resources planning and the Catchment Based Approach – of how to make it work although greater resource will be needed to mainstream such approaches and support collaboration at-scale.

There is a duty established under the Flood and Water Management Act 2010 for LLFAs to cooperate with other Risk Management Authorities. However, whilst duties to cooperate are not unusual within legislation, they are rarely enforced in practice. Experience amongst many who are working on the development of DSMPs is that there is a disparity in resource and capacity available to consider drainage issues within local authorities and other risk management authorities, compared to within WaSCs[61].

Local authorities face a range of challenges in funding and resourcing surface water management because budgets and resource are typically not ring-fenced for this purpose and are subject to competition with other front-line service funding needs.

This day-to-day reality can considerably constrain the ability for local authorities to collaborate at the level needed and maximise the benefits of doing so. This hampers the ability of democratic accountability – embedded within local government – to feed into planning and decision-making led by WaSCs. Whilst there are undoubtedly examples of positive collaborative relationships between WaSCs and local authorities there is a long way to go before this is widespread and consistently delivering the best outcomes.

Placing DSMPs on a statutory footing for all relevant stakeholders, alongside the legal need to report on storm overflow progress will undoubtedly result in more resource being invested in them, as well as the datasets and knowledge capacity (from guidance to competent practitioners) being built up over time to support their refinement. It should be recognised that DSMPs will be complex to develop, not least because whilst water companies producing WRMPs may each have to plan for a handful of water resource zones, each WaSC may have to understand and plan for hundreds of sewer catchments.

Increasing refinement of the DSMP approach over time may in turn bring other risk management authorities to the table more concertedly where they see opportunities to achieve wider benefits. They represent an opportunity for a wide range of stakeholders to engage with and inform strategic plans that look out to 2050 – something which may otherwise not be possible for these stakeholders. Nevertheless, wider and additional duties, such as a new duty on local authorities – and particularly Highway Authorities – to prevent water pollution would arguably help to drive this cooperation and should be retained as a potential additional driver should progress on reducing pollution not be sufficiently quick.

The Office for Environmental Protection, and scrutiny

Prior to the UK's exit from the European Union, scrutiny and enforcement of EU-derived regulation was ultimately delivered by the European Commission and the European Court of Justice. This independent structure had significant bearing on the priority attached to environmental compliance and led to considerable performance improvement in water quality, particularly in response to the Bathing Water Directive and the Urban Wastewater Treatment Directive.

The Brexit process necessitated the establishment of an alternative, and to the creation under the Environment Act 2021 of the Office for Environmental Protection (OEP)[62]. The OEP now has the role of independent scrutineer of government and public bodies' environmental performance and is able to enforce compliance where failures to comply are identified, including as a result of a public complaint.

During the design and establishment of the OEP, concern was widely expressed about the extent of its independence and whether this went far enough, with fears that it would be a regulator without real teeth. Nevertheless, its existence is already indicating a degree of influence over government and its regulators: One of the first complaints put to the OEP was by the NGO Salmon and Trout Conservation (STC)[63] in September 2021 concerning an alleged failure by Defra and OFWAT to properly enforce components of the Water Industry Act 1991, leading to the current scale of discharges from storm overflows.

Following the passing of the Environment Act in November and confirmation that the OEP would formally assume its legal powers from the start of 2022, Ofwat and the Environment Agency announced a joint investigation[64] into the performance of more than 2000 sewage treatment works. This followed admissions by WaSCs to the regulators that they could be making unpermitted discharges. Whilst the complaint by STC was referred back to Ofwat's own formal complaint process, the OEP expressed a desire for a "substantive response" by the water regulator[65].

A combination of concerted campaigning by NGOs and individuals, media coverage and the attention of a new independent enforcement body is not only resulting in greater scrutiny and attention on the performance of WaSCs, but also on that of government and its regulatory bodies. All are alive to the fact that they can be challenged, and that a mobilised community is prepared to challenge them to deliver against the law.

Stakeholder perspectives on the adequacy of proposed measures, current and future systems

So, are these measures – existing legislation and regulation, provisions within the Environment Act and the policy and scrutiny frameworks available to drive improved practice sufficient to tackle the challenge of sewage pollution from storm overflows as they are currently set out?

Participants in workshops undertaken as part of this project considered this question, having discussed the characteristics of the current (failing) system of storm overflows management and their aspirations for a future (effective) system. They pointed towards a current system in which WaSCs had historically exploited a regulatory landscape featuring insufficient commitment and resources for enforcement. A landscape in which companies could maximise profit over investment, with England's sewerage network infrastructure suffering from replacement rates approaching every 800 years[66].

Within the system, WaSCs have significant resources and capacity to deliver outcomes, but lack democratic accountability. Other actors in the system – particularly local authorities – have democratic accountability but a lack of resources and capacity to deliver outcomes.

Stakeholders considered that there was not so much a need for new legislation and policy to direct WaSCs towards improved environmental outcomes, though some considered that this may help to sharpen the focus of both regulators and other system actors. Rather, a stronger recognition by government on the need to invest properly in environmental leadership, regulation and enforcement given the extent of current and future pressures on the environment.

There was also concern about a lack of value attached to environmental goods by current economic models feeding through to a freedom to exploit the environment. Increased visibility of the problem and a transition towards capitals accounting approaches could help shift this value set and make water and wider environmental health a higher priority issue within society. This might be starting to happen as a result of increasing recreational use of local environments during the pandemic.

There was a general consensus that planning and funding mechanisms across the wider system of water management did not adequately consider and manage contributory factors such as housing development and the wider impacts of urbanisation. Datasets used to inform decision-making were patchy, disparate and under-utilised. Policy direction too often lacked compulsion, allowing both it, as well as investment to be discretionary and open to de-prioritisation in the face of other pressures.

Growing appreciation amongst the public of environmental value and the need to conserve and enhance it was recognised. But stakeholders broadly agreed that there remained a concern amongst decision-makers that weaving environmental stewardship into spatial and development-planning and funding mechanisms could hinder delivery of housing and infrastructure.

Participants considered that there was too much emphasis on costs and insufficient on benefits of good water management. Multi-capitals accounting and ecosystems services approaches were gradually gaining traction in changing such perceptions but too slowly to have averted the current situation. It was also recognised that implementing nature-based solutions could also deliver multiple benefits and help realise a number of different policy aspirations.

Whilst there was a clear desire for stronger enforcement against regulatory contravention, there was also caution expressed that regulatory approaches which point strongly to compliance could risk directing potential polluters to the safest or cheapest short-term compliance option, rather than the best multi-beneficial, long-term approaches and solutions. There will need to be appropriate balance and consideration within future regulatory systems to prevent such unintended consequences and drive the most beneficial, long-term outcomes for environment and society.

Workshop participants considered how they understood the current system – which has led to widespread, frequent storm overflow discharges – and what might need to happen as part of a future system which was managing pollution effectively.

	Current system	Future system
Events	**Change:** Climate change/ population growth/ increasing recreational use of rivers.	**Change:** Climate change/ population growth/ rivers becoming healthier.
Trends	**Lack of:** Urgency/ ambition, leadership, enforcement, investment, collaboration.	More: Monitoring, transparency, enforcement, informed decision-making, surface/ foul water separation. Less: Spill frequency.
Systems Infrastructure	**Piecemeal:** Historic/ legacy, fragmented, adversarial.	**Aligned & integrated:** with more accountability, longer-term planning and new financial & funding models.
Mental Models	**Assumptions:** WaSCs responsible for river health, we understand what public wants/ willing to pay for, consequences of failure are low, someone else will sort.	**Values:** Shift towards shared responsibility. Water is valued by society, sewage in seen as a resource. System is outcome-driven.

Fig. 10: Events, trends, systems structure and mental models associated with current and future systems relating to storm overflows

The iceberg model was used to identify the events, patterns or trends, structure and mental models (assumptions, values and beliefs) associated with both the current and future systems (with common findings summarised in Fig. 10). In focusing on the trends associated with the current, polluting system, stakeholders pointed to a lack of sufficient priority and action on a range of fronts. These included:

- A lack of recognition (until recently) of the scale of and urgency of the problem;
- A lack of ambition and leadership in terms of desire and commitment to deliver significant improvements;
- A lack of collaboration between the various parties who play a contributing part to the problem to manage it effectively;
- A lack of investment in existing assets so that they function as they should, and in delivering enhancement to keep pace with growing pressures on the sewerage system, and

- A lack of enforcement of existing regulation, such as the Water Industry Act 1991, which sets out in statute that sewage should be dealt with "effectually".

It became clear that there was a cycle operating within which data and understanding became a critical enabler for action, supported by other factors such as governance which could ensure that such action might result in desirable outcomes. This is set out in Fig. 11.

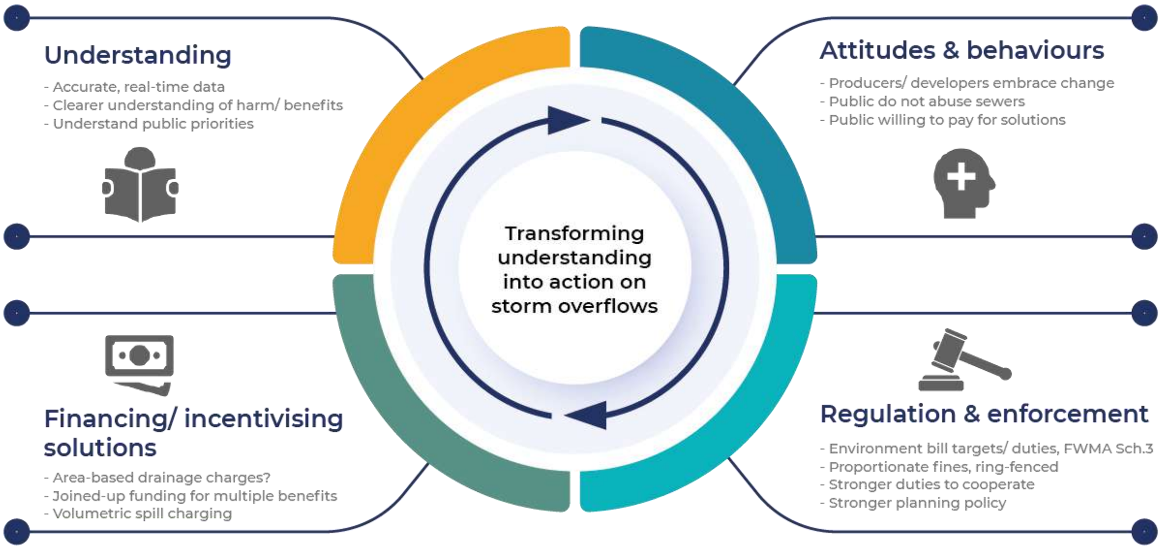


Fig. 11: Cycle of understanding, attitudes, behaviours, regulation and incentivisation

Data has enabled far greater understanding of the storm overflows situation recently (though the accuracy of that picture is not yet reliable whilst WaSCs finalise their EDM installations and rectify glitches with existing monitor installations).

This understanding is changing attitudes towards river water quality and its current status and is driving behaviours amongst campaigners, decision-makers and regulators, and WaSCs themselves. This is likely to spread to wider system actors over time providing this cycle continues.

Decision-maker response has informed updates to legislation, as well as regulator activity which is resulting in significant requirement for increased scale and pace of outcome delivery. The success of this will feed back into the data and the cycle should repeat. Each time – which may become evident in data reporting cycles, investment planning cycles and progress reporting cycles, it may be expected that the breadth of the cycle may draw in an increasing cohort of stakeholders – or actors within the system.

What that system might look like in future – in a scenario in which improved management was resulting in considerably reduced and harmful storm overflow discharges – was explored using the three horizons approach.

Through this approach, stakeholders identified challenges within the current system which were contributing to and /or exacerbating the problem, which needed to be rectified along with elements of the present system were worthy of retention and inclusion in the future. They identified their aspirations for the future system and considered where there were pockets of this already occurring in the present. They then considered which activities and conditions might be needed to make the transition from the present failing system to the future – in terms of both transformative and supportive changes. The results of this thinking are set out in Fig. 12.

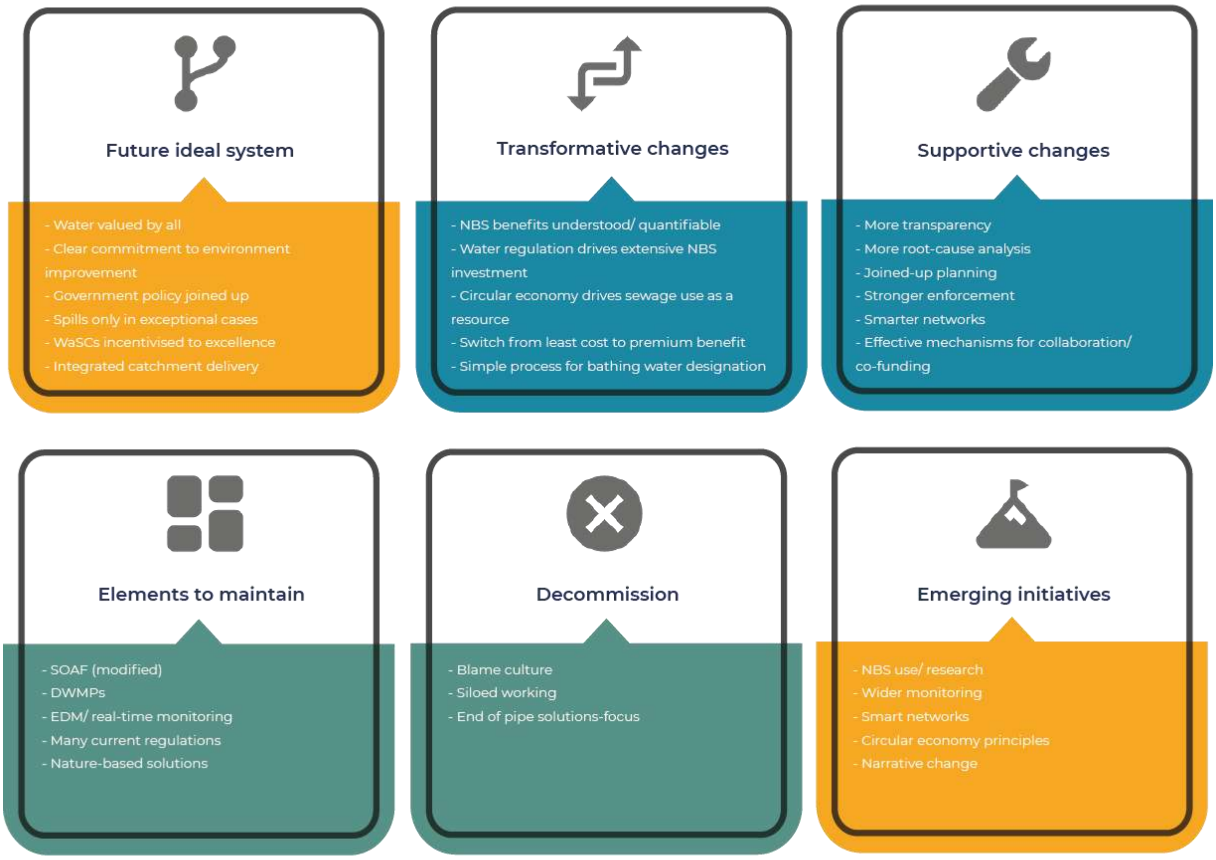


Fig. 12: Three horizons for storm overflows management

This exercise pointed towards a current system being fragmented and siloed, and adversarial in nature. There were mechanisms such as monitoring networks, more strategic planning in drainage and sewerage management plans, and the Storm Overflows Assessment Framework[67] alongside increasing deployment of nature-based solutions, which could be refined and built upon in a future system.

The future system was characterised by a far more integrated, whole-catchment approach involving consistent engagement by all key stakeholders. This would be underpinned by a far deeper societal value attached to water generally, and good water quality specifically and driven by stronger ambition driven by policy-makers. Circular economy and multi-capitals approaches would help to ensure that decisions drove the best outcomes building on far wider deployment of nature-based solutions, smart network operation, as well as monitoring and enforcement against illegal practice.

Change could be driven through focusing more explicitly on the delivery (and measurement) of beneficial outcomes, rather than on input costs. Greater transparency, stronger enforcement, more readily-accessible funding and investment mechanisms and improved collaboration and planning approaches were also considered to be supportive of beneficial change.

How storm overflows and pollution from them is regulated

Given the degree of discussion around enforcement and compliance amongst stakeholders, how much has this played a role in the current system and what might be required to drive significant improvements?

Storm overflows are regulated by two main bodies. The Environment Agency and Ofwat. Both regulators take their policy direction from Defra.

The **Environment Agency** is an executive non-departmental public body, and the environmental regulator as established under the Environment Act 1995[68]. Its aim is to protect or enhance the environment, contributing towards the objective of achieving sustainable development.

The EA has responsibility to control polluting discharges to controlled waters and ensure that they comply with conditions set via its Environmental Permitting mechanism.

Salmon & Trout Conservation (S&TC)[69] point to a history in which the issue of storm overflows and how they should be managed has been long-recognised, having been set out in the National Rivers Authority's Kinnersley Report[70] in 1989, which recommended strong enforcement as essential to maintaining (or achieving) good practice on the part of dischargers.

It also points to a more recent deregulatory agenda, put on a statutory footing by 2015's Deregulation Act[71] and prior reviews, which reduce the impact of enforcement visits and place duties on regulators to contribute to economic growth.

S&TC note that *"Since it was set up in 1995, the EA has been made progressively subject to constraints on its ability to deliver its principal statutory function – protecting and enhancing the environment"*.

S&TC and other campaigners argue that the pre-existing legislation book should have been adequate to ensure appropriate management and enforcement of storm overflows discharges, but has been eroded over time by a combination of deregulation (including operator self-monitoring) and austerity. This has ultimately been a reflection of prevailing government priorities and policies, played out over time.

Campaigners argue that without a change in such priorities, no amount of new legislation and plans will change the reality on the ground. Indeed, in response to concerns over the extent to which Environment Agency staff were not following up pollution complaints, Chief Executive James Bevan has been clear that regulation takes resourcing and it has needed to prioritise heavily in the face of funding constraints[72].

Ofwat is the water services regulation authority, and a non-ministerial government department. It was established in 1989 when the water and sewerage industry in England and Wales was privatised and its role is set out in sections 2 and 3 of the Water Industry Act 1991.

Its main statutory duties relate to protecting the interests of consumers and ensuring that water and sewerage undertakers can finance the proper carrying out of their statutory functions. Additionally, to secure the long-term resilience of undertakers' water and wastewater systems and ensure they take steps to meet the long-term needs for these services. Other regulatory drivers it deploys include performance commitments placed on companies. These include commitments on frequency of pollution incidents, sewer flooding and sewer collapse.

Ofwat set its priorities out in its 2019 strategy 'Time to act, together'[73]. This set out three goals for the next few years:

- To transform water company performance;
- to drive companies to meet long-term challenges through increased collaboration and partnerships, and
- to ensure they provide better public value and deliver more for customers, society and the environment.

These goals appear to align very closely with the concerns expressed by stakeholders within this work, and by the wider public and campaigners in response to the increasing public debate around storm overflows. They should have strong resonance in the lead-up to the PR24 development of water company business plans, alongside the headline strategic priorities set out by Defra. Crucially, Ofwat state: *"Ofwat will make the environment integral to all that we do."*

In a demonstration of this pledge, Ofwat'sChief Executive David Black wrote to chairs of remuneration committees of all regulated water companies[74] encouraging them to link performance-related executive pay with performance, *"most notably on the environment"*.

The priority placed within the Environment Act for government to develop a Storm Overflow Discharge Reduction Plan and for WaSCs as well as the Environment Agency to prepare annual Storm Overflow Reports puts the ball firmly in the WaSC court to reduce the frequency and impact of their overflows.

There has been considerable discussion[75,76] regarding how and why the problem was allowed to get as bad as it has, and particularly how the level of investment in sewerage infrastructure replacement and maintenance has compared with the scale of borrowing by companies and of dividend payments made to shareholders.

These questions become particularly pertinent when evidence on the costs of reducing spill frequency and harm as set out in the Storm Overflow Evidence Project (SOEP)[77] are considered and the follow-on questions of who *should* and who *could* pay these are asked.

Ofwat reviews the financial resilience[78] of companies annually, alongside service delivery[79]. It has identified – amongst other considerations – where companies have low credit ratings and where the health of their wastewater assets (measured in terms of sewer collapses and treatment works permit compliance) is below where they would expect it to be. This reflects information provided by the companies themselves, alongside publicly available information such as that produced by the Environment Agency as well as credit rating agencies.

Whilst Ofwat's identified deviation from the target 'performance commitment' level may be small in terms of percentage points, evidence[80] from analysis of 13 sewage treatment works operated in Oxfordshire by Thames Water indicates that discharge permit non-compliance reported by the Environment Agency may be a small fraction of the actual frequency that is occurring, or which was worked into the SOEP, based upon WaSC sewer modelling data.

Calls have been made by campaign groups[81] to use shareholder dividends to pay for storm overflows remediation. This is unlikely to be realistic for a range of reasons, from the uncertain state of financial resilience of many WaSCs to the potential costs of remediation eclipsing such dividends.

This means that it will be water customers who will be most likely to have to foot the majority of the bill, whether or not investigations by the Environment Agency and Ofwat and, potentially, the Office for Environmental Protection point towards a need for more stringent application of environmental compliance and changes to how far water companies are regulated to reinvest their profits. This has been reflected in suggest water bill increases included within Defra's consultation on its Storm Overflows Reduction Plan.

It is likely that whoever leads the way on delivering improvements (and this will undoubtedly – and rightly – be the WaSCs), without a comprehensive and wholesale review and improvement to how water is managed both in the rural and urban setting, the pace and scale of improvement to water quality will almost certainly not match the public appetite for it. To get the best return on investment, a systems-level approach that maximises the extent of benefits will be crucial.

The complexity of this is considerable. The range of regulation relating to land and water management which impacts on storm overflows discharges is extensive, wide-ranging and complex with different information, direction and reporting flows. Fig. 13 illustrates this, containing policy and regulation which stakeholders understood to be relevant.

Government has sought to inject clarity and impetus into the regulatory picture through putting in place requirements in the Environment Act and setting clearer strategic policy priorities. Others have proposed system operators[82] as a means of prioritising specific outcomes at the catchment scale in relation to water.

These measures will, and could achieve improvements to performance. However the web of regulation which relates to water is complex because water in all its elemental simplicity is complex, affecting and being affected by a myriad of factors. Stakeholders within this project considered that this complexity needs to be engaged with, and this engagement needs capacity and resource. This applies to both those tasked with delivery as well as regulation, and updating regulatory rules or models without adjusting capacity and resource to reflect enhanced priority will not engender lasting improvement.

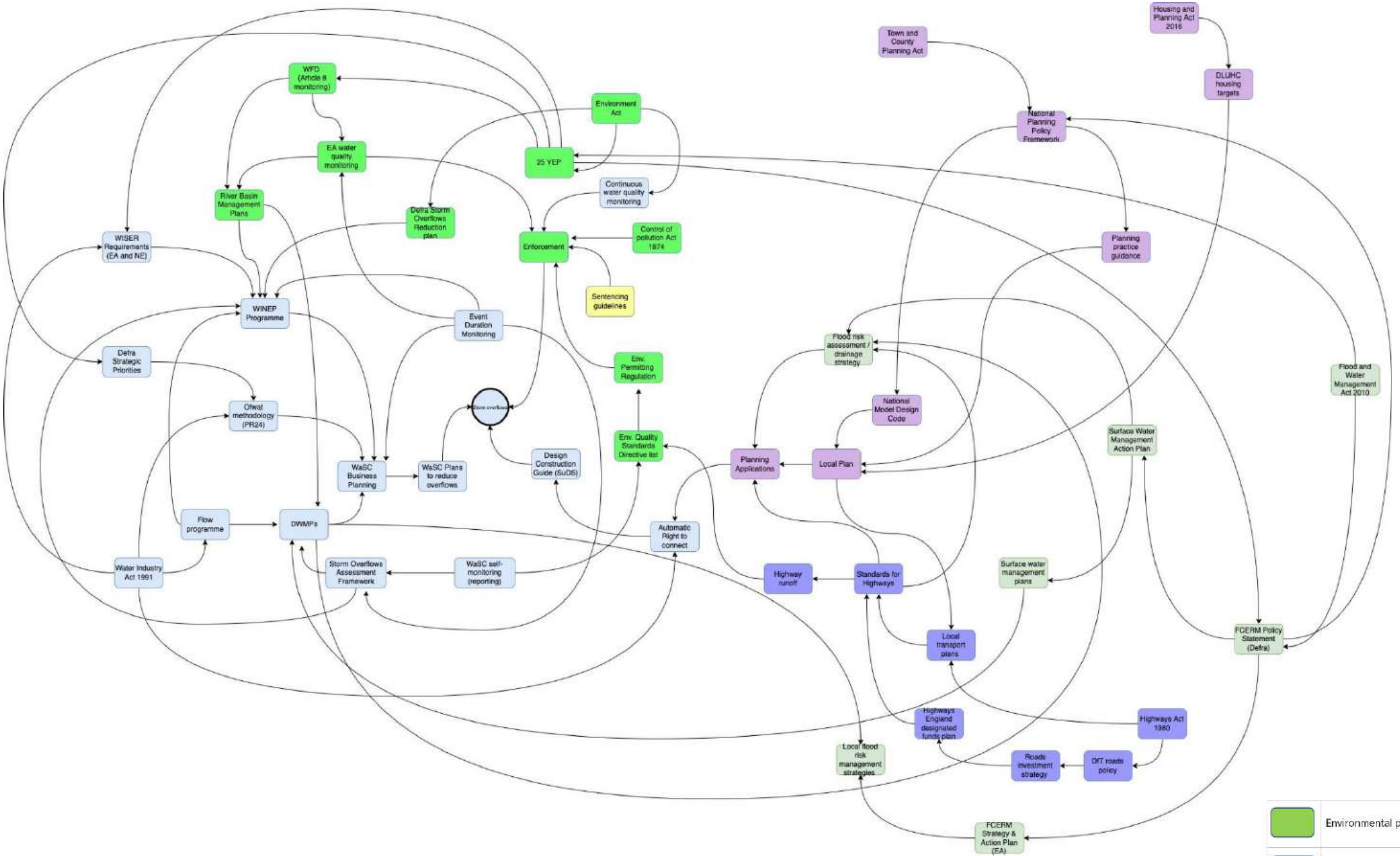


Fig. 13: A map of land and water management policy and regulation with a bearing on storm overflows discharge frequency

Surface water management

Storm overflows, by definition, are designed to overflow during storm events when surface water volume in combined sewers threatens to overwhelm their capacity. The source of this water is many-fold, and the risk of surface water flooding is both significant (with more than 3 million[83] properties at risk in the UK) and likely to increase with climate change[84].

Government recognises this risk and complexity in its 25 Year Environment Plan[85], stating: *"Surface water flooding poses a significant and increasing risk, which can lead to sewer flooding and environmental pollution. We will look at improving how Lead Local Flood Authorities, water and sewerage companies, highways authorities and other risk management authorities work together to manage it."*

Historic engineered solutions have focused on removing water from the surface rapidly, but drainage network capacity – particularly in older networks – is a problem. Solutions which manage water at or near the surface, including by slowing its rate of runoff, temporarily storing it or enabling it to infiltrate into the ground, are generally regarded as more sustainable than hard-engineered, below-ground solutions designed to remove surface water quickly. This is because they have the scope to be able to deliver a range of wider benefits.

The Environment Agency has a duty under the Flood and Water Management Act 2010 to exercise a supervisory and strategic role in relation to all sources of flood risk, though it only has direct responsibility to manage flooding from main rivers and the sea. Via this role it oversees the development of a range of management plans and funding streams which, may be utilised to pay for surface water management schemes subject to satisfaction of their criteria. It can strategically advise other relevant risk management authorities. The Environment Agency also has responsibility for regulating water quality so is, in theory at least, well-placed to strategically support an integrated approach to these outcomes.

There are a range of risk management authorities (RMAs) with a role to play in managing surface water, and thus with an influence on how much of it may end up in combined sewers. These include but are not limited to:

- Lead local flood authorities
- District and borough councils
- Highways authorities
- Water and sewerage companies

These authorities are required to co-operate with each other (under a legal duty established by the Flood and Water Management Act 2010[86]). In common with their title, Lead Local Flood Authorities (LLFAs) lead and advise on local flood risk. In doing so they should identify flood risks in their areas, potential interventions and develop a local flood risk management strategy to manage these risks and deliver the interventions.

LLFAs should work with partners including other RMAs and potentially stakeholder organisations from wider public and private sectors to build business cases for funding and delivery of risk management schemes. They have a statutory tole in advising other authorities – such as local planning authorities – on flood risk relating to activities such as land use and development.

LLFAs then, form a critical link between WaSCs and their role in maintaining sewerage networks and wider local government activities such as housing, highway and public realm development activities which may have an impact on the water entering these networks. As such, they are critical (if often resource-constrained) parties for involvement in the development of DSMPs. Their lead role does not preclude direct engagement between other RMAs such as highways authorities and WaSCs where appropriate however.

This complex range of roles and responsibilities was subject of a review[87] in 2019 (known as the Jenkins Review) given concerns expressed in consultation prior to the development of Defra's surface water management action plan[88].

Jenkins described fragmented, unclear ownership of surface water and drainage assets with unclear powers and duties to maintain them, alongside inadequate planning and building control focus on the best ways to manage surface water. Monitoring, reporting and data on ownership and condition of assets were considered to be limited and inconsistent and there was a far greater need for a *"common sense of purpose and public interest"* across authorities to enable constructive collaboration and partnerships. His report made a range of recommendations to government and the Environment Agency to make improvements to this landscape.

Whilst flood risk was the primary focus of Jenkins' review, the issues it shone a light on and the recommendations it made undoubtedly have a clear bearing on the ability to manage surface water effectively before it enters combined sewer networks. Government responded to the review and provided an update to its surface water action plan in 2021[89], accepting a number of the review's recommendations. But rejecting some.

Various recommendations[90,91] have been made in the past for updates to how responsibilities are handled and might be clarified or simplified. The Jenkins review notes however that whichever configuration may be deployed, without appropriate standards of drainage design, acknowledgement of climate change and regulation of development and utilities, failings will continue. He further noted that successes often exist despite rather than because of the current arrangements.

Sustainable drainage systems (SuDS)

SuDS represent one of the main approaches through which WaSCs will look to reduce the volume of surface water entering combined sewers. They do this by extensively disconnecting traditional surface water drains from the combined system.

It is commonly considered that SuDS should seek to manage water according to a hierarchy which prioritises the use of rainwater and the infiltration of water directly into the ground, before alternatively discharging any water which has not infiltrated directly to a surface water body. If this is not possible then they should discharge to a surface water sewer, highway drain or other drainage system, with only the final option being to discharge to a combined sewer[92].

SuDS should be delivered widely for a number of reasons. Two that primarily relate to storm overflows are:

1. to manage surface water associated with new development, to prevent a further increase in the volume of surface water directed to combined sewers on top of that which development has already created.

2. to proactively reduce existing surface water volume in the sewer, through extensive retrofit schemes.

As already discussed, SuDS can be multifunctional, achieving flood risk management benefit through managing the volume of water, as well as directly improving water quality through filtration and biological processes that take place within them, when they are planted.

In the context of storm overflows, the primary benefit comes from managing the volume (though the ancillary benefits to local communities of multifunctional SuDS will be significant). For this reason, there should be significant scope for WaSCs and LLFAs to work together in identifying opportunities for SuDS schemes and pooling resources where appropriate to aid delivery. This collaboration should be extended to other RMAs where their assets also impact on volumes of water, e.g. highways authorities.

A challenge in recent years has been encouraging developers to deploy a SuDS hierarchy within new developments even where there are sustainable drainage routes available. Jenkins pointed to this and noted that it left *"WaSCs with capacity challenges and increased sewer flood risk capacity"*.

Planning policy remains a challenge when it comes to influencing how much surface water enters the sewer. Policies within the National Planning Policy Framework[93] direct developers to utilise the sustainable drainage hierarchy. However since it was introduced the NPPF has contained various loopholes relating to the appropriateness of doing so, on various grounds such as cost or practicality.

Over time, these loopholes have been tightened somewhat, and policies are more prescriptive in terms of requiring sustainable drainage systems to deliver multiple benefits. However, these requirements are still limited by qualitative caveats around whether they are considered "possible", and they do relate to major developments, under a 2014 Ministerial statement[94]. The scope for developers to push the boundaries of these requirements remains and is, the Jenkins review found, still widely exploited. Good outcomes require strong local policies, and proactive engagement between the LPA, LLFA and developer.

This results in a picture where SuDS are commonly deployed on larger new developments – a finding set out in the government's review of the application and effectiveness of planning policy for SuDS[95]. But where development is not considered 'major', which applies to much of the development which may be described as 'urban infill' the problem of incremental addition to surface water and foul sewage load on sewers continues.

Government is in the process of reviewing whether or not it should commence Schedule 3 of the Flood and Water Management Act 2010. This would set in place a mandatory, far more robust approach to setting standards for SuDS, as well as approving and providing for their adoption and long-term maintenance. Through this it would minimise any connections by new developments to the public sewer, through making the automatic right for developers to connect (established under the Water Industry Act 1991[96]) conditional on the deployment of a robust sustainable drainage hierarchy.

This would also tackle another fundamental failure of the current planning-led approach, which is that too often within planning applications the sustainable drainage component is incorporated too late in the day to optimise its benefits. Developers too often comply with requirements after an initial application has been made and the site layout determined. If advice from the LLFA is obtained at pre-application stage or even earlier, drainage design can be fully incorporated into the site layout and multiple benefits – including maximising removal of surface water from the sewer – achieved.

Schedule 3 has been commenced in Wales from 2019. Further to bedding in it is beginning to demonstrate delivery of better, more multi-functional SuDS, cost-effectiveness, and in some instances an improvement in the pace of scheme delivery. It is also supporting the delivery of retrofit SuDS.

Whilst SuDS are generally being delivered (albeit not necessarily to a high standard) in new development, extensive delivery of retrofit SuDS remains comparatively rare. This will need to change significantly for WaSCs to make significant inroads into surface water removal from their networks in problem combined sewer catchments. Large-scale retrofit schemes which have been delivered in recent years include the Greener Grangetown[97] scheme in Cardiff and Sheffield's Grey to Green[98] projects. Forthcoming schemes include Severn Trent Water's green recovery programme in Mansfield[99].

Fig. 14: The Greener Grangetown scheme was delivered to remove surface water from combined sewer networks, to avoid needing to pump effluent 8km to a sewage treatment

works before discharge to the sea. A mixture of SuDS interventions within the scheme removed 40,000m^3 per year from the combined network (photo credit: Susdrain).

Fig. 15: Sheffield's Grey to Green scheme links regeneration objectives with a need to improve flood resilience in the Castlegate area of the city. SuDS enhance this resilience as well as increasing amenity value in the centre whilst also treating the quality of surface water running off hard surfaces before this reaches local watercourses (photo credit: George Warren)

Fig. 16: The Mansfield sustainable flood resilience scheme is a blueprint for how Severn Trent Water intends to manage surface water in future. Nearly 20,000 SuDS features will be built to store more than 58 million litres of water and reduce surface water flood risk to 90,000 people. In-line with Severn Trent's River Pledge[100], SuDS interventions will also be targeted to reduce combined sewer overflows in the catchment (photo credit: Severn Trent Water / Arup).

Funding

Funding and investment to deliver improvements to storm overflow discharge frequency will mainly be channelled through the water industry's 5-yearly investment planning cycle. Through this, and guided by the Government's strategic priorities, the Storm Overflows Reduction Plan and Ofwat's methodology, WaSCs will potentially invest £ billions into remediating overflows.

Achieving good value for money will be critical however. A significant means of achieving this should be through making best use of different funding streams to deliver schemes which achieve multiple benefit outcomes.

The obvious example here would be by identifying where surface water management schemes (most likely SuDS) could deliver surface water flood risk benefits (funded by some flood risk management grant), alongside storm overflows discharge reductions (funded by some water industry investment), potentially alongside wider climate resilience, water quality and nature recovery outcomes (funded by green finance or other mechanisms) in a diverse partnership approach. The Ignition[101] project in Greater Manchester is exploring how green finance can be mobilised to fund green-blue infrastructure delivery to achieve climate resilience outcomes.

Funding for many surface water flood risk management schemes typically comes from a variety of sources, including flood risk grant-in-aid and local levy (via Environment Agency Regional Flood and Coastal Committees[RFCCs]) as well as any funding which local authorities may be able to provide, WaSCs or other partners may contribute. Typically partnership funding originates from public rather than private streams (although WaSCs are private).

Funding was considered in the government's Surface Water Management Action Plan[102], which set out to review the sources available to assist surface water management, as well as whether or not they were appropriate.

The review emphasised that revenue funding for flood risk management by local authorities had increased by 29% in real terms since 2010/11, and that local authority funding is only one source of funds for managing surface water flood risk and that there were a range of other sources including government flood risk management grant in aid (GiA).

However, it noted that LLFAs commonly identified challenges in obtaining funding for capital schemes because of the requirements to be satisfied in order to access GiA, particularly for smaller schemes (which local authority surface water schemes often are) which may individually only protect a small number of properties.

Government committed to reviewing partnership funding requirements and GiA to ease such barriers, and to fully review funding sources for surface water management, including how spending by WaSCs, government and others could best be directed. Further to this commitment, in 2020, government amended partnership funding rules, adding an additional band between 'high' and 'medium' risk which should mean that more schemes which reduce surface water flood risk are able to receive funding in future.

It is hoped that DSMPs will form an effective instrument in forging links between RMAs and promoting partnerships which can secure funding from other sources to deliver improved surface water management, benefitting both flood risk and water quality outcomes by keeping more surface water out of combined sewer networks. Improved clarity is needed on how DSMPs will link in with local flood risk management strategies produced by LLFAs however.

Challenges remain in the ability to optimally bring together plans and programmes between WaSCs and local authorities given the differences in governance processes, funding quantum, organisational capacity, planning cycle synchronicity and budgeting timescales and certainty. The mandatory status of DWMPs following the Environment Act may help to encourage relevant RMAs to the table however this could be incentivised further were key bodies such as LLFAs made statutory consultees to this process.

Aside from the ability to harness GiA and partnership funding to deliver schemes, to make serious inroads into removing surface water from combined sewers, WaSCs will need to explore wider funding streams. The main mechanism will be the water industry's investment planning roundoverseen by Ofwat. Informed by the Government's Storm Overflows Reduction Plan and the WaSCs own annual plans, this is likely to see a considerable expansion of investment in this area.

RFCCs may have a significant role to play in linking up funding sources from various parties. A number have WaSCs involved with them and the Jenkins review recommended that RFCCs should always feature at least one WaSC as a means of enabling this. It also proposed that the EA should develop good practice guidance on the development and operation of effective partnerships across relevant risk management authorities.

It is likely that many surface water management schemes delivered by WaSCs to improve overflows over coming investment rounds will be large-scale. However achieving the most extensive improvement across the wider water management system means that smaller-scale opportunities should be taken too.

The London Strategic SuDS Pilot Scheme (LSSPS)[103] was developed to demonstrate whether retrofit SuDS of this kind i.e. individually small, distributed SuDS features installed at various points in a catchment could collectively demonstrate an effective surface water flood risk management solution. If so, whether such a scheme could qualify for government flood defence grant-in-aid funding (GiA) through the government's Partnership Funding process.

The challenge with small features such as tree pits or raingardens is that individually they will not demonstrate sufficient benefit to qualify for GiA (or other local authority funding – known as the Local Levy) and / or the evidence and modelling requirement is such that the process is simply too onerous to be worthwhile. This is despite the findings of surface water management plans across London that the only practical way to reduce surface water flood risk in such urban areas – with their space constraints – was through extensive retrofit of small-scale SuDS across whole catchments.

However, modelling deployment of such features at scale and calculating the value of their collective benefit using multi-capitals accounting tools (the CIRIA B£ST[104] tool) enabled demonstration of a case justifying long-term collaborative funding opportunities on account of their multiple benefits. These helped strengthen the funding case and make schemes attractive to funding partners. The scheme also sought to investigate opportunities to align construction with other public work programmes such as highways maintenance or upgrade.

The pilot found that by using hydraulic modelling of flood risk benefits of SuDS installation across a catchment, it was possible to readily satisfy the benefit-cost requirements for GiA. £35m of SuDS installation was found to return £190m in avoided flood damages, alongside £40m in wider natural capital benefits.

The LSSPS also tested an opportunistic delivery model for SuDS as part non-flood risk management works. Such non-optimised SuDS do not meet the requirement for GiA without a large partnership funding contribution (found in the study to be around 60% funding). However where there are other major drivers for SuDS retrofit, this could add a beneficial contribution from an extensive national FCERM capital budget. This could, in theory at least, help to bolster delivery of distributed SuDS in combined sewer catchments instigated by WaSCs to remove surface water from sewers to reduce storm overflow discharges, at the same time yielding surface water flood resilience not to mention the wider benefits.

Fig. 17: The London Strategic SuDS Pilot Study sought to bundle distributed SuDS into one grant funding bid (photo credit: George Warren).

The scheme noted that: *"Proactive flood risk management needs to find partners for delivery in order to capitalise on opportunities to collaborate"*; *"distributed SuDS free up significant capacity within the sewer network, helping to reduce spills from combined sewer overflows"*, and *"the capital investment can be shared amongst other interested stakeholders (with) the potential to draw on other sources of funding and create a 'win-win' for all stakeholders and beneficiaries involved"*.

In other words, where surface water flood risk (which is widespread) intersects with a need to reduce storm overflow spills (also widespread), distributed SuDS represent a widely beneficial solution for which funds could be shared, making the investment pot go further.

Many organisations make regular investment in maintenance or other activity in the proximity of where SuDS might be delivered, potentially offering efficiency savings associated with excavation or infill costs. These may be highways or local authorities undertaking work in streets, parks or in social housing. Such works may be planned or emergency, but commonly are undertaken with limited lead-in time to enable them to be synchronised with projects where GiA funding may need to be sought or investment programmes developed.

If it were possible to be more opportunistic with the use of either GIA or water company investment, it could be possible to deliver far more for the money. In essence, a different, more flexible approach is needed. This might, for example, secure an investment pot against a modelled distributed benefit demonstrating an average cost for SuDS delivery per m^2 and an agreed delivery timeframe (for example 5 years). This pot could then be drawn down opportunistically, achieving efficiencies associated with works synchronisation and co-delivery.

Infrastructure coordination teams, such as that run by the GLA in London[105], may offer potential to achieve such outcomes. A stated objective of the team is to *"help coordinate their activities across many layers of London's infrastructure, identifying interfaces and seeking alignment in shared outcomes towards the Mayor's priorities"* and includes SuDS amongst the types of infrastructure, alongside utility, transport, streets, public realm, parks, ecological corridors and others in a concept it describes as *"complete streets"*. It is developing data and innovation tools, an infrastructure coordination service and supporting policies.

Surface water drainage charge and site-area-based charging

Properties typically pay a proportion of their water bill to WaSCs for the water which drains off their roofs and other hard surfaces and into the public sewer, which the WaSCs are responsible for. The exception to this rule is if such water is dealt with in another way because it is disconnected from the sewer (because of use of a soakaway or other sustainable drainage which doesn't ultimately connect to the sewer).

The exact mechanism through which this charge is made can vary company to company, and depending on how customers are charged for their water (it may be linked to the volume of water consumed, or the rateable value of a property as an approximation of its size and therefore drainage area). Typically a WaSC will charge for 90% of the water it understands is used at a property. This 10% reduction is known as a Wastewater Abatement.

WaSCs may offer a rebate of more than 10% where customers have an accurate picture of their supply (by being on a meter) and are able to demonstrate that less than 90% of this volume is discharged to the sewer.

This arrangement represents a mild but largely inaccessible incentive to household customers to reduce their bills by removing a proportion of their surface water from the sewer given the evidence and calculations required. It can, theoretically, be more concertedly applied, in an approach known as 'area-based charging'.

Area-based charging applies to an approach through which bill payers are charged for drainage according to the area of impermeable surface on their property. For properties – such as commercial or retail units – with large roof spaces or areas of hardstanding there is a potentially significant incentive available to the use of SuDS and disconnection of at least a proportion of this surface from drainage to the public sewer. This is particularly feasible for organisations who pay a significant surface water drainage charge, for whom the capital investment in a SuDS solution would be paid back in reasonable time by the savings achieved.

Ofwat considers site area-based charging to be the fairest approach[106] for such non-household customers. Four WaSCs currently take this approach: Severn Trent Water, United Utilities, Yorkshire Water and Northumbrian Water, with each adopting a banded approach to charging depending on impermeable surface area. Customers near the lower end of a banding may readily easily access savings by implementing measures to drop them into the charging band below.

Ofwat's Wholesale Charging Rules require that charges made for sewerage services should separate out those made for the reception, treatment and disposal of foul water, trade effluent, surface water draining from Eligible Premises, and surface water draining from highways. Additionally, they should provide for an appropriate reduction in these charges where surface water does not drain to the public sewer from those premises.

There is therefore a mechanism through which site-area based charging may be delivered either as a mandatory approach for non-household customers, or as an incentive which might be more actively harnessed by companies (including retail companies who might specialise in being able to offer their customers the means to achieve reductions through disconnection and sustainable drainage).

There have been concerns in the past around the implications of such rules and charges for community groups, places of worship and schools who might be impacted beyond their means to pay high charges where they occupy or operate sites with large areas of surface water drainage. The Charging Rules prescribe for WaSCs to define classes of such groups and concessionary reductions which may be applied to them, with guidance[107] having been produced to support this.

Despite site area-based charging being considered by the regulator to be the *fairest* approach though, it is not yet a *required* approach.

The growing emphasis on significantly reducing the occurrence and harm resulting from storm overflow discharges, allied to the need to adapt and build resilience to climate change both within and beyond the water industry, mean there are increasingly strong drivers behind a review of what may be achieved through more concerted and widespread use of site area-based charging. This could also harness greater customer awareness of the impacts of their surface water drainage on downstream networks, alongside their ability to take action themselves. Given that the focus for this action would be within the curtilage of the property itself, barriers relating to adoption and maintenance of SuDS features by a body such as a local authority of WaSC would not apply, with the maintenance burden falling to the property owner.

Lessons are there to be learned from those companies who have introduced area-based charging in the past. Where introduction has meant that customers have been hit by significant increases in bills, this has been unpopular and a phased approach would help to enable customers to put in place measures and adjust over time. In addition, area-based charging should operate hand-in-hand with advice and schemes designed to help customers to reduce their surface water discharge as cost-effectively as possible. This could take a targeted approach, strategically focusing on buildings with the biggest surface water disconnection benefit in the most problematic catchments first.

In the most recent water company price review (PR19), Ofwat set out four overarching themes for companies to deliver against: great customer service, resilience in the round, affordability and innovation.

Resilience in the Round encouraged companies to take a long-term view on their planning, beyond the five-year business plan period. It called on companies to actively explore opportunities to deliver SuDS as a means to reduce the flow rate into the sewer system and the need for wastewater infrastructure. Additionally it proposed that companies should make greater use of innovative market-based mechanisms to achieve environmental resilience where they deliver best value for customers.[108]

Highway drainage and engagement with highway authorities

Significant volumes of highway drainage is connected to WaSC combined sewer networks – potentially contributing up to 50% of rainwater in these. Highway drainage is considered to be any water which drains from roads or footpaths into public drainage systems. Under s.146 of the Water Industry Act 1991[109], WaSCs are unable to directly charge a highway authority in respect of drainage from a highway, or disposal of the contents of any drain or sewer used for draining any highway.

Instead, WaSCs make a set charge to all customers who are connected to the public sewer on the basis that all customers benefit from use of a highway in some way, whether that be for personal or work-related journeys, and the delivery of goods and services. Many companies have now started to itemise the highway drainage component of the overall sewerage charge in order to make this visible to customers. The sum varies WaSC-to-WaSC with 'standard' (non-metered) charges typically in the range £10-£35 per household per year.

Whilst there is obvious scope to utilise site area-based charging to incentivise the removal of surface water drainage from combined sewer networks, because of the lack of a direct connection between the highway authority and the WaSC, there is no flexibility to leverage the use of more sustainable surfaces in the highway through charging.

It may be possible that some companies might choose to increase their highway drainage charges – particularly if these are at the lower end of the charging spectrum – in order to fund schemes to reduce highway runoff into their networks. However they have no control over decisions made by highway authorities on construction and materials choices which could help ameliorate runoff pressure on their networks. Strong partnerships between WaSCs and highways authorities, most likely driven through DSMPs, are likely to offer the most scope for improvements.

We would propose that consideration be given to the establishment within appropriate forthcoming legislation of a duty on local authorities and highways authorities to seek opportunities when they are maintaining, upgrading or building new infrastructure, to ensure that runoff from roads and other urban surfaces is not discharged into combined sewer networks unless a sustainable drainage hierarchy has first been followed.

Collaborative working

Because of the interconnectedness of the water cycle with both nature and human activity, and the wide range of organisations and responsibilities which impact on those, collaboration is critically important to effective, integrated water management.

Water management is an area where partnership working has been achieved with some success for a number of years. CaBA for example has developed and honed partnership amongst over 1500 organisations, working across more than 100 river catchments since 2013.

The participants in many catchment partnerships include many of those who have a stake in the wider system impacting on storm overflows: NGOs, water companies, local government, wider risk management authorities, central government and its agencies. The successes of CaBA show that partnership working can be done effectively. However it is almost always challenging.

Reasons why collaborative working is challenging typically relate to a range of different factors: Different remits, drivers, motivations and interests may be the most difficult to transcend. Often where motives may be common, challenges will still exist. Often they relate to capacity and different *modus operandi* of the collaborators. This can mean that because certain parties are resource-constrained they have minimal scope to focus on more strategic issues and simply don't have sufficient time to engage properly with potential delivery partners. Elsewhere, differences in quantum of resource to invest may make contributions seem out of balance. Funding and planning cycles may be prohibitive with one party able to plan and budget over longer timescales, with considerably more certainty than another.

David Jenkins, in his review noted that *"It is difficult to prescribe for constructive partnerships: they depend crucially on good local trust and working relationships, across organisational boundaries. The importance of these, in my view, cannot be overstated."* Often these effective partnerships develop because of individual level commitments and despite governance frameworks and systems, not because of them. Strong interpersonal relationships can compensate for weak institutional relationships up to a point, but consistently effective partnership working requires a system architecture which enables and supports it.

Government says in its 2021 Surface Water Management Update[110] that *"Water companies and other risk management authorities should work together to manage water in a more* *integrated way to improve flood resilience, enhance the natural environment and deliver value for customers."*

It confirms that the EA and Ofwat will set out how companies are expected to consider flood risk and coastal erosion in their duties and advises that these recommendations and those made by the National Infrastructure Assessment[111], relating to surface water (that water companies and local authorities should build on their existing plans to take joint action on local surface water flood risk) are taken forward through DSMPs.

The Jenkins review notes that the Environment Agency has powers to issue guidance on how risk management authorities should discharge their duty to cooperate. Given its strategic oversight role on flood risk management and its regulatory role for environmental water quality, the Agency is well-placed to work alongside Defra and Ofwat to promote partnership working amongst the various authorities impacting on storm overflows. It would need support from DLUHC and the Department for Transport to ensure that wider local government functions including local planning and highways authorities have the appreciation of the issues and the capacity to participate in a meaningful way.

Government further states that: *"Drainage and sewerage systems do need to be more robust to withstand the pressures on them and these plans will ensure water companies play their part, with others, in identifying investment and implementing the solutions needed."*

It acknowledges that whilst WaSCs are leading the development of DSMPs, a range of organisations have a role in them. It recognises that these organisations working effectively together is important to ensure that the plans identify actions to better manage flood risk and water quality.

Government research[112] examining how strategic surface water management may enhance coordination and collaboration on surface water made recommendations that improvement should be delivered in:

- Understanding the various roles and responsibilities of those involved with managing surface water;
- improving the alignment of those responsibilities, particularly those of WaSCs relating to surface water and other risk management authorities, and
- addressing resourcing issues of that undermine the ability of some of these actors to actively participate.

It is considered that this latter point is particularly pertinent.

The research further recommended (as did the Jenkins review) improved data sharing between these organisations, including on the part of WaSCs around the capacity of their drainage networks locally. It also pointed to the lack of engagement of highways authorities with surface water management, stating:

"So that highways authorities are better and more consistently engaged in surface water management… guidance should also specifically address their role in the system, including how their data can best be shared with and utilised by other risk management authorities".

Whilst there are many factors which obstruct effective partnership working, in the context of storm overflows and the parties with the biggest impact on the system it is suggested that the fundamental barriers relate to:

- The appreciation within an organisation of its role in the system and impact on it
- The capacity within that organisation – whether resource or intellectual – to engage with the issue effectively, and
- A clear driver and motivation to engage – or a meaningful consequence for failing to do so.

Presently there is insufficient understanding amongst the various organisations involved in the storm overflows system of their role and impact, insufficient capacity within some to engage effectively, and insufficient consequence attached to a failure to engage with the issue. For the system to improve in an effective and lasting way, this needs to change.

Systems mapping

Current system driving sewage pollution of rivers from storm overflows

From the information provided in the stakeholder workshops, the Storm Overflows Systems Map (SOSM) for current drivers influencing storm overflows was created (Fig. 18). The core of the map is the water infrastructure system representation *(subsystem 1)*, which captures the issues mentioned around lack of sewer and wastewater treatment works capacities, as well as problems with sewer blockages and the need for system maintenance and renewal.

Other subsystems have been mapped to account for impacts of urban expansion *(subsystem 2)* and diffuse pollution from transport infrastructure *(subsystem 3)* on water systems. Additional pressures on river water quality from upstream catchment systems, including agriculture as well as the impacts of climate change, are mapped in *subsystem 4*.

System elements around physical connectivity are then complemented by other relevant components. The role of financing water infrastructure solutions, due to regulatory positions by Ofwat was identified by stakeholders as having a considerable influence on the current situation *(subsystem 5)*.

A significant part of the SOSM is dedicated to a simplified representation of the social perspective *(subsystem 6)*, which is seen as a key driver for policy change when the information about the state of the rivers is captured and communicated effectively *(subsystem 7)*.

Regulatory *subsystem 8* is an overarching driver for multiple components, and the need for more integrated implementation mechanisms *(subsystem 9)* was mentioned as one of the key limitations of the current system.

Three key insights arise from the SOSM analysis:

- River water quality rather than storm overflows themselves seems to be a key concern of stakeholders, as it captures effects from a broad range of influences including other sources of diffuse and upstream pollution.
- Multiple stakeholders are responsible for impacting the river water quality, either directly or indirectly (e.g. water companies, housing and transport systems, and upstream catchments) and many parties have an interest in managing the state of the rivers (e.g. citizens). This creates a strong need for collaboration and joint regulatory, implementation and funding mechanisms.
- There is a clear link between increased and / or improved information and creating data that can potentially enable or drive demand for a positive change; challenges remain around how to monitor and disseminate that information.

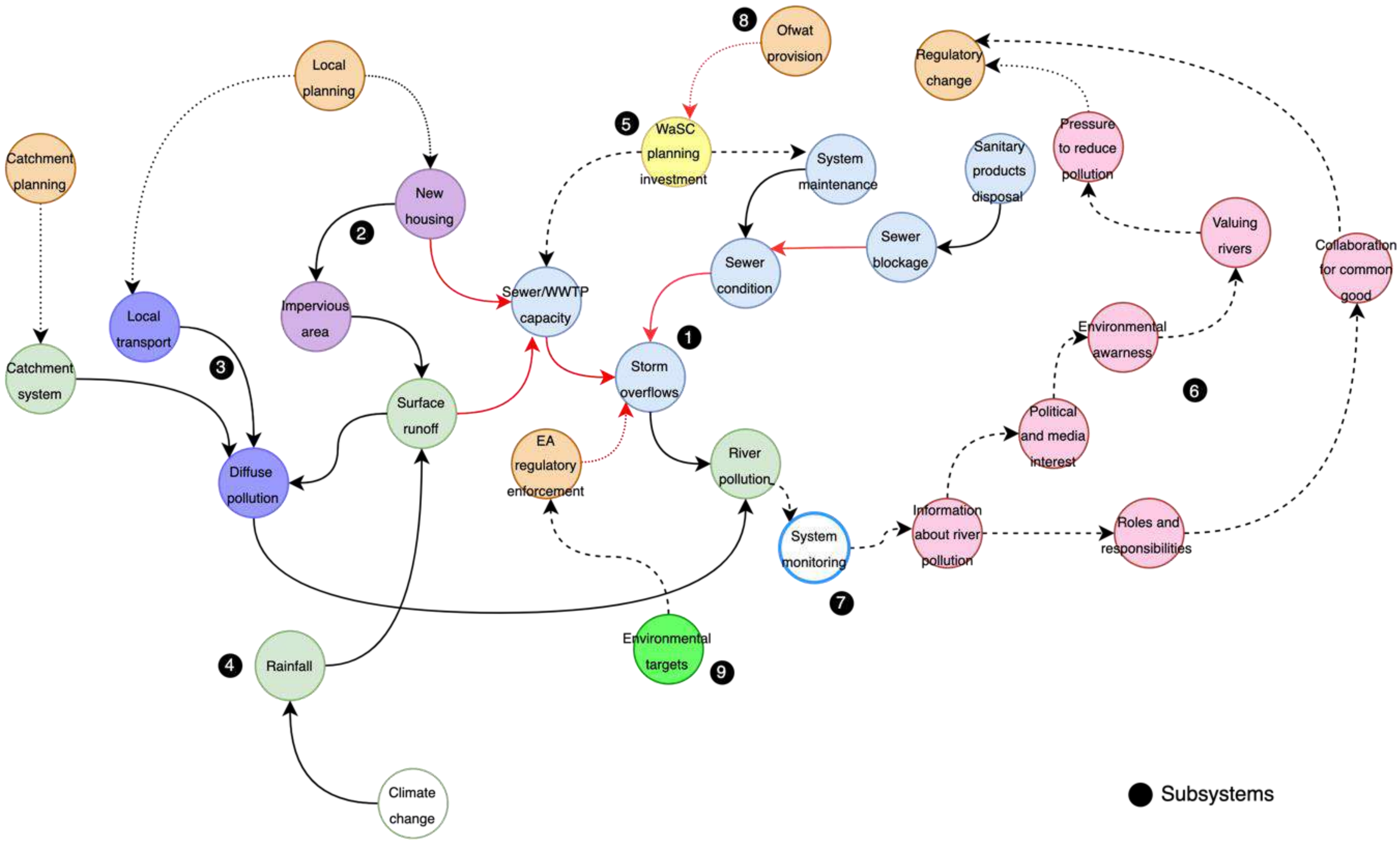


Fig. 18: Storm Overflow Systems Map including components influencing storm overflows

Future system and recommendations for managing storm overflows

The system mapping has emphasised the need to integrate solutions across all relevant subsystems. This is shown in Fig. 19. Using the concept of leverage points[113], through which *"a small shift in one thing can produce big changes in everything"*, we group the recommendations by their potential level of influence on the system and challenge in question, starting with:

- technical (low level);
- informational and implementational (medium level), and
- financial, policy and regulation (high level) interventions.

Physical interventions (low level of influence)

As a key stakeholder in the SOSM, WaSCss are seen as organisations whose investments into water infrastructure can significantly reduce the frequency, duration and impact of storm overflows (recommendation 1).

We frame this intervention under the sewerage 'System Redesign' (SR) set of measures on the SOSM, which should combine a range of infrastructure (e.g. storage or treatment works capacity increase), nature-based (e.g. SuDS) and operational solutions relating to the drainage and sewerage system.

In this context, it is the operational solutions that may create benefits without significant financial investment into new infrastructure, such as an example of the coordinated operation of water supply and wastewater systems for London[114]. Even if a large infrastructure solution is already designed and implemented, such as the Thames Tideway Tunnel in London, options for maximising its use for multiple functions (e.g., water harvesting/reuse) should be explored.

The SR options are, however, assumed to have a low level of influence on the overall system performance (in other words, the wider, underpinning pressures driving the problem) if implemented in isolation, for the following reasons:

- The SR measures will only solve the problem of storm overflows if implemented at a large scale across all the areas that are struggling with pollution from storm overflows.
- Under current light-touch regulation of new developments' automatic right to connect to the public sewer and SuDS delivery without firm arrangements for long-term adoption and maintenance, the SR measures would need to be implemented as a response to ongoing and increasing pressures on the system from housing and wider development. WaSCs may be limited in their available options to manage these pressures, including restrictions on how much they may be allowed to increase customer bills to pay for investment, or available space for infrastructure expansion.
- Even if SR measures could in themselves solve the problem of storm overflow pollution from urban systems, this still would not solve the fundamental problem of

river water quality arising from other sources of pollution (such as agricultural diffuse pollution).

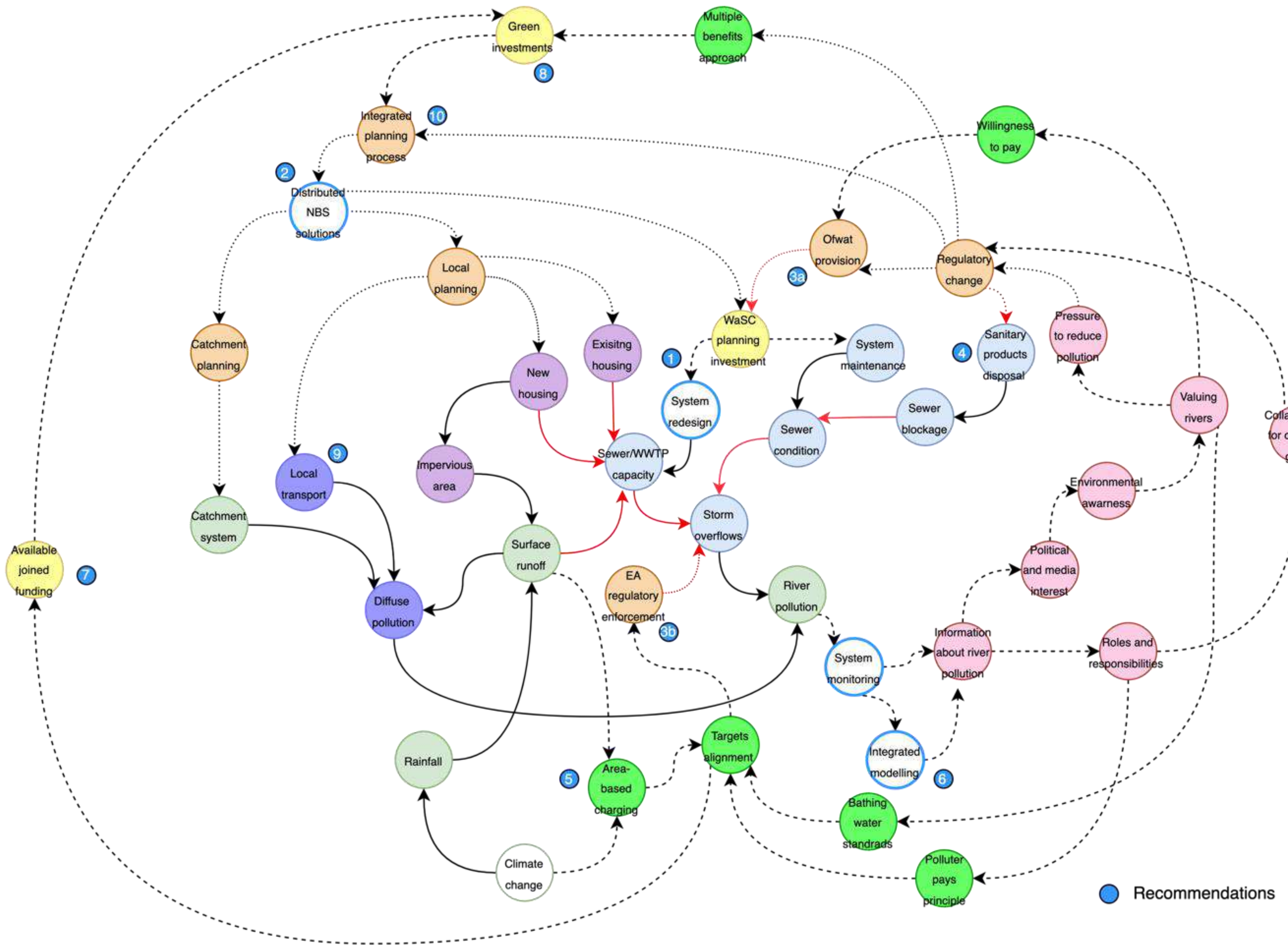


Fig. 19: Storm Overflow Systems Map including components that are recommended as elements of a solution to manage storm overflows at a systems level

Implementation and informational interventions (medium level of influence)

Nature Based Solutions in the form of SuDS are seen as one of the key measures that can reduce impacts of storm overflows by reducing surface water runoff and improving downstream water quality[115].

To increase the uptake of SuDS in a way that can maximise their performance and achieve other important multiple benefits[116], implementation of SuDS through the planning system needs to be reviewed and potentially revised (recommendation 2). The *Distributed NBS solutions* will enable multiple stakeholders to share the delivery of SuDS to achieve different outcomes such as flood risk and water quality, and potentially combine the resources necessary for their implementation and maintenance.

The multifunctional nature of SuDS and their resultant benefits are also directly linked with the Social subsystem and the evidence of increased valuing of nature[117]. This has two implications:

1. the environmental awareness and the use of blue and green spaces can increase the pressure on the institutional stakeholders to implement solutions for better protection of rivers, and
2. it can also lead to general increase in citizens' willingness to pay a contribution to environmental protection[118].

Finally, distributed NBS are seen also as a solution for the transport system (recommendation 9) as a way of managing the water quality from the highways runoff[119].

In addition to influencing WaSCs investments in the system redesign, the SOSM has indicated that both Ofwat and Environment Agency as key regulators need to improve their effectiveness in ensuring that the overall objective of healthy rivers is achieved (recommendations 3a and 3b). A range of linked interventions, such as regulatory change due to public pressure, and alignment of management targets thanks to improved information, as well as the creation of joint funding opportunities could provide more resources for effective system monitoring and enforcement.

Indirect factors which impact on the WaSCs systems performance and affect storm overflows discharge frequency include sewer blockages[120] and increased surface water runoff due to urbanisation[121]. These impacts could be managed by stronger regulation, including a ban on the use of plastic in wet wipes (recommendation 4) and reviewing the use of area-based charging for surface water drainage (recommendation 5). The link between surface water management and storm overflows discharge frequency will become increasingly important as we start experiencing significant impacts of climate change on the UK urban water systems[122].

Finally, the application of distributed NBS solutions and other catchment-scale interventions such as infrastructure upgrades, water-neutral urban design[123] and nutrient neutrality will require analysis of large (borough, cross-borough, city) scale systems, ideally evaluating both changes in flow and water quality due to proposed interventions (recommendation 6).

While a range of detailed physical models can be used for such evaluation, including urban network (e.g. Infoworks ICM[124]) and water quality (e.g. INCA[125]) models, we suggest that the integrated measures should be assessed with lower-complexity models that can account for infrastructure, environment, and decision (operational rules and policy) subsystems.

Examples of such integrated modelling include water system integration tools recently applied to case studies in London[126,127,128], Norwich[129] and the upper Thames[130]. The results from these models can provide evidence that complements data collection on the ground[131], and support collaborative decisions[132].

Financial, policy and regulation interventions (high level of influence)

The SOSM shows that implementation and maintenance of any design or operational solution requires financial mechanisms and revised regulation. In the context of storm overflows management, these can include the revision of those funding mechanisms that are primarily designed to address a specific problem, such as flood risk management, and transform them into a delivery mechanism that could support implementation of multifunctional solutions such as SuDS (recommendation 7).

This could strengthen much-needed collaboration between WaSCs, highway authorities and wider local authority functions (e.g. planning, flood risk management and green space), possibly through formal partnership funding arrangements (recommendation 8). SuDS supported by such revised funding approaches should be designed in such way that they provide benefits for a wide range of stakeholders[133].

The highest level of influence in the system is provided by establishing legal duties and enforcing them.

Such duties could focus on highway authorities and their approach to managing surface runoff through SuDS (recommendation 9) and maximising the opportunity for their delivery through coordinating various groundworks. Coordination at a systems level could also provide a significant improvement in the delivery of distributed solutions. City and local authorities are seen as organisations which could lead the coordination process because of their oversight of both infrastructure and urban planning.

There are already examples of multiple organisations creating formal collaboration agreements to address water management challenges under the leadership of city authorities. One such example is a recently signed partnership agreement between the Greater Manchester Combined Authority, United Utilities, and the Environment Agency[134], that aims *"to ensure progressive improvements in sustainable water management across the city-region, enhancement of the natural environment and ensuring all future developments and critical infrastructure are resilient to flooding and the impact of climate change."*

System mapping conclusions and recommendations

While the SOSM provides a digested overview of the complex system that influences storm overflow discharges, clearly the problem extends considerably beyond the issue of ageing or inadequately maintained water infrastructure.

WaSCs must have a significant role to play in managing storm overflow spills. They should increase their efforts in finding solutions to better operate their current assets and networks and deliver SuDS, infrastructure upgrades and innovative digital solutions within their future systems.

Nonetheless, local planning and highways authorities, Environment Agency and Ofwat all have a significant role to play in ensuring that the pressures on the water system do not increase beyond the capacity that infrastructure solutions (whether grey or green) can manage.

Finally, physical and implementational interventions will need to be complemented with regulatory and financing measures to support and enable actions at the scale needed to address the storm overflows challenge. It is only when all elements in the SOSM get connected that we will achieve the true systemic change needed to ensure long-term positive management of storm overflows.

Achieving the best outcomes: our recommendations

Matching ambition with cost-effectiveness means looking at this issue not just through a WaSC lens but from the perspective of how we manage land and water use in largely urban areas. The systems mapping exercise illustrates the breadth of influences on what happens downstream and that their interactions are complex and often nuanced.

Systems thinking and systems mapping does not propose that a complex picture requires complex solutions. Rather, it identifies where information flows, where democratic accountability exists, and where decisions are taken and how these are driven. This picture can then be used to inform understanding of where these factors may be misaligned, disproportionate, ineffectual or indeed working well.

There is currently a disconnect between the management systems governing water – essentially those relating to flood risk management, drainage, water resources, water quality and water company investment – and local government where spatial plans and policies are made and delivered, which have a significant bearing on these management systems. Common themes relating to societal value of healthy environments not consistently being reflected by robust policy and regulation, cost and funding, institutional capacity and resourcing exemplify this disconnect. However, as data transparency builds understanding levels, various interventions can be made across the water management system in its widest sense to effectively drive lasting reductions in storm overflows discharges.

Based on the outputs of expert workshops, systems mapping and identification of optimal opportunities for intervention in the wider storm overflows system, we propose the following recommendations:

1. Water companies to deploy a hierarchy of catchment-wide measures to reduce storm overflows, prioritising nature-based solutions and active system management over underground storage.

Retrofitting SuDS into urban areas with combined sewer networks offers the opportunity to reduce rainwater and surface water entering the network, slow the flow to manage flood risk, increase evapotranspiration and urban cooling, provide water quality, nature, place-making and health and wellbeing benefits.

Distributed SuDS spread individual small measures across catchments to achieve demonstrable benefit.[135] Treatment wetlands or natural storage areas at sewage treatment works can also help. ASM can help to optimise in-network flows, making best use of existing capacity before the need for hard-engineered solutions with associated operational energy and carbon costs and minimal wider benefits. These measures should be set out in DSMPs and aligned with local flood risk management strategies.

2. Government to implement Schedule 3 of the Flood and Water Management Act 2010, including mandatory multifunctional SuDS standards, a conditional right to connect development to public sewers and a route to adoption and long-term maintenance.

The current approach to implementing SuDS through the planning system too often results in poorly designed and delivered SuDS. These can fail to achieve benefits to water quality, quantity, amenity and biodiversity and have no secure arrangements for their future maintenance.

Schedule 3 sets a clear framework for unlocking SuDS' potential to enable more sustainable development. Over ten years on from its original enactment, this legislation is being reviewed by government. This should ensure the framework is workable in 2022, with responsibilities, funding and capacity suited to delivering against a range of government's environmental priorities, including minimising storm overflow discharges.

3. Strong regulation by Ofwat and the Environment Agency for PR24 and beyond

Stakeholders and the wider public have expressed concern over past performance by water companies, the balance between environmental outcomes and keeping customer bills low by Ofwat, and the capacity of the EA to hold polluters to account. Stakeholders want stronger ambition and leadership and regulators to regulate effectively.

We call on Ofwat to strongly recognise the emphasis placed on significant improvement on storm overflows as it sets out guidance to water companies in advance of their next investment plans. And we call on government to recognise the importance of healthy rivers to the public as well as wider society and the economy by ensuring the EA has the capacity to robustly monitor and enforce the levels of performance society wants to see.

4. Government to ban plastic in wet wipes

So-called 'unflushables', particularly wet wipes and other sanitary products containing plastic fibres meaning they do not break down in the sewer and worsen litter and plastic pollution, exacerbate storm overflow discharge frequency.

Combining with fats, oils and greases from food waste disposed of down sewers, they cause blockages which cost around £100m per year to remove and can make sewage back up and overflow. A 'fine to flush'[136] standard exists for wet wipes, which enables effective performance without plastic content. Given the combined challenges of pollution from storm overflows and plastic, it has no place in such single-use products and we urge government to ban plastic in wet wipes on sale in the UK.

5. Government to review the barriers and feasibility to implementing area-based charging for surface water drainage

Rain water, as surface water runoff, is a major component of the effluent which typically is discharged through storm overflows. This comes from the roofs and other hard surfaces within properties, as well as from highways. Whilst highway drainage charges to customers[137] are a fairly arbitrary, flat fee, there is scope for WaSCs to charge variable fees for surface water drainage depending on the size of impermeable area within a property.

Ofwat considers site area-based charging (ABC) to be the fairest approach[138]. Despite this there has been limited appetite amongst WaSCs to embrace it, with only four currently charging in this way. Given the need to significantly reduce surface water runoff into combined sewers and aligned with the polluter pays principle, we recommend that WaSCs should examine the potential to move forward with ABC as part of their DSMPs.

We also recommend Ofwat to review whether any additional directions within its methodology for PR24 could encourage greater use of ABC to incentivise SuDS use amongst the non-residential customer-base.

6. WaSCs and lead local flood authorities to hydraulically model key catchments to identify optimal opportunities to retrofit distributed SuDS

There are opportunities to potentially achieve both surface water and sewer flood risk benefit, alongside reducing pressure on combined sewer capacity to reduce storm overflow spills and pollution at the same time.

In urbanised areas with space constraints, individually small SuDS features, distributed across a sewer catchment may represent the only opportunity to effectively remove surface water from sewers. Where the primary driver is flood risk, it can be hard to secure flood and coastal erosion risk management grant-in-aid (FCERM GIA) because individual tree pits or raingardens will not demonstrate sufficient benefit to qualify.

The London Strategic SuDS Pilot Scheme (LSSPS)[139] was developed to demonstrate whether retrofit SuDS of this kind installed at various points in a catchment could collectively demonstrate an effective surface water flood risk management solution. It found that by hydraulically modelling the catchment-wide benefits of distributed SuDS, alongside valuing the wider benefits they delivered, it was possible to create a robust case for collaborative funding, with strong benefit: cost ratios.

Defra’s Boosting Action on Surface Water project also funded a number of local authorities to undertake more detailed surface water mapping. Use of approaches like these and those used to underpin the LSSPS should be included in DSMPs and local flood risk management strategies, to demonstrate catchment-wide benefits from distributed SuDS, should be used widely to support business cases and funding applications.

7. Government to review funding sources and rules to enable grant funding to be pooled and drawn down opportunistically over a period of time

The evidence, timescales and overall process involved in putting forward applications for FCERM GIA to deliver small-scale SuDS retrofit can discourage and preclude local authorities from being opportunistic and entrepreneurial in their delivery by partnering with other organisations.

The LSSPS noted that *“Proactive flood risk management needs to find partners for delivery in order to capitalise on opportunities to collaborate”*. Many organisations make regular investment in maintenance or other activity in the proximity of where SuDS might be delivered, potentially offering efficiency savings associated with excavation or infill costs. These may be highways or local authorities undertaking work in streets, parks or in social housing. Such works may be planned or emergency, but commonly are undertaken with limited lead-in time to enable them to be synchronised with projects where FCERM GIA funding may need to be sought or investment programmes developed to deliver SuDS.

We encourage greater flexibility in the way that FCERM GIA funds can be used to support distributed SuDS retrofit schemes, where benefits are modelled and demonstrated at an average level across a catchment, enabling delivery to be undertaken opportunistically within that catchment, over an agreed timescale.

8. WaSCs to create partnership funding pots for use with LAs on retrofit SuDS schemes where flood risk is not the primary driver

The ability for risk management authorities to make the best use of FCERM GIA for schemes which are not prioritising flood risk management relies on their ability to secure significant partner contributions under government's partnership funding rules. The LSSPS emphasises that "*distributed SuDS free up significant capacity within the sewer network, helping to reduce spills from combined sewer overflows*".

We recommend that WaSCs and local authorities should establish long-term partnership funding arrangements, so that where there is a flood risk management benefit in delivering surface water schemes in areas where there are also challenges with storm overflow discharges, partnership funding is readily available to support non-flood optimised GIA applications.

9. Establish a legal duty on highways authorities to seek opportunities to manage highway runoff through SuDS when undertaking other infrastructure or renewal works

Recognising the potential savings associated with opportunistically coordinating street and other appropriate groundworks with SuDS construction, and the volume and water quality impacts of highway runoff on sewer networks and receiving waters, we propose that highways authorities could do more to deliver small-scale SuDS when undertaking other works. These can be incorporated into regular footway or highway maintenance activities, construction of traffic calming or other infrastructure such as cycle lanes.

Highways authorities have historically not been proactive in seeking opportunities to manage the water quality impacts of their runoff, despite its often heavily polluted nature. To drive improvements in this area we recommend that government uses forthcoming levelling-up and regeneration legislation to introduce a legal duty on highways authorities to seek opportunities to manage highway runoff through SuDS when undertaking other infrastructure or renewal works. This should be supported by a review of the design standards for highway drainage to deliver improved performance on both water quality and quantity.

10. Local authorities to develop infrastructure coordination services to enable syncronised and coordinated delivery, including of SuDS.

Infrastructure coordination teams, such as that run by the GLA in London[140], may offer potential to be more proactive and achieve greater collaboration and synchronised delivery of SuDS alongside other works. A stated objective of the team is to *"help coordinate their activities across many layers of London's infrastructure, identifying interfaces and seeking alignment in shared outcomes towards the Mayor's priorities"*.

The GLA team includes SuDS amongst the types of infrastructure whose delivery it seeks to align, alongside utility, transport, streets, public realm, parks, ecological corridors and others in a concept it describes as *"complete streets"*. It is developing data and innovation tools, an infrastructure coordination service and supporting policies to enable this approach. Lessons should be sought from this experience and if effective government should seek to encourage similar approaches in authorities nationwide.

References

1 Discover Water. Collecting & treating sewage. Visited February 2022
2 Historic England. The Great Stink - How the Victorians Transformed London to Solve the Problem of Waste. Visited February 2022
3 Surfers Against Sewage. #EndSewagePollution.. 2020
4 Environment Act. November 2021
5 House of Commons. Sewage (Inland Waters) Bill. February 2020.
6 Defra. Storm Overflows Taskforce. 20202020
7 Telegraph. Not in your front yard: Ban looms for paved drives. 18th February 2022
8 Defra. Consultation on the Government's Storm Overflows Discharge Reduction Plan. 31 March 2022
9 Environment Agency. Systems water management for catchment scale processes: Development and demonstration of a systems analysis framework. Chief Scientist's Group report. May 2021
10 Ofwat. Resilience in the Round. 20172017
11 HM Government. A Green Future: Our 25 Year Plan to Improve the Environment. January 2018
12 Defra. Enabling a Natural Capital Approach guidance. August 2021
13 The Catchment Based Approach
14 Wong, T. Water Sensitive Urban Design – the Journey Thus Far. Australian Institute of Architects. August 2007
15 D. H. Meadows. Thinking in systems: A primer. Chelsea Green Publishing. 2008
16 D. H. Meadows. Leverage points: Places to intervene in a system. 1999
17 A. Mijic. Systems water management for catchment scale processes: Development and demonstration of a systems analysis framework. Environment Agency. May 2021.
18 Environment Agency. The state of the environment: water quality. 20182018
19 Environment Agency. Catchment Data Explorer: Classifications data for England – Chemical status for surface waters.September 2021 September 2021
20 Environment Agency, Catchment Data Explorer: Classifications data for England – Reasons for not achieving good status by business sector. September 2021
21 Defra. 25 Year Plan progress report, June 2020
22 MHCLG. Land use by category in England, 2018
23 Defra. Written evidence to House of Commons Environmental Audit Committee, WQR0028.
24 ENDS Report, 2020. Regulators ignoring horrific and poisonous road run off say EA insiders
25 Environment Agency. 2021 River Basin Management Plan. Pollution from water industry wastewater. October 2019
26 Stantec. Storm Overflow Evidence Project. November 2021
27 Adapted from: Water UK. 21st Century Drainage Programme – the context.2018 2018
28 Professor Peter Hammond. Written evidence to House of Commons Environmental Audit Committee, WQR0064.March 2021 March 2021
29 Professor Jamie Woodward. Written evidence to House of Commons Environmental Audit Committee, WQR0095.September 2021 September 2021
30 Environment Agency. Catchment Data Explorer.
31 HM Government. 25 Year Environment Plan2018. 2018
32 Defra & Natural England. Nature Recovery Network: policy paper overview2020. 2020
33 Environment Act 2021.
34 House of Commons Environmental Audit Committee. Water quality in rivers. Fourth Report of Session 2021–22. January 2022
35 Thames Water. River Health.
36 London Assembly. Crazy Paving. The environmental importance of London's front gardens. 20052005
37 Section 94. Water Industry Act 1991 as amended
38 Water Industry Act 1991 S.106
39 Defra. Independent report: Surface water and drainage: review of responsibilities. August 2020
40 HM Government. Water for Life. 20102010
41 Defra. Directing the flow - priorities for future water policy. 2002
42 Defra. Making space for water Developing a new Government strategy for flood and coastal erosion risk management in England. July 2004
43 Ofwat. Future Impacts on Sewer Systems in England and Wales. Summary of a Hydraulic Modelling Exercise Reviewing the Impact of Climate Change, Population and Growth in Impermeable Areas up to Around 2040. June 2011
44 Ofwat. Flow to Full Treatment (FFT) explainer.

[45] Peter Hammond, Windrush Against Sewage Pollution. WASP review of unpermitted spills from sewage treatment works. October 2021
[46] Ofwat. Water companies could face legal action after investigation launched into sewage treatment works. 18th November 2021
[47] Defra. Event Duration Monitoring - Storm Overflows - Annual Returns. March 2022
[48] Stantec. Storm Overflow Evidence Project. November 2021
[49] Defra. Consultation on the Government's Storm Overflows Discharge Reduction Plan. March 2021
[50] CIRIA. B£ST (Benefits Estimation Tool). 2019
[51] ICRA. Treatment wetland for combined sewer overflow. Factsheet.
[52] Meyer, D. et al. Constructed Wetlands for Combined Sewer Overflow Treatment – Comparisons of German, French and Italian Approaches. Water, 2013. 1-12
[53] Philadelphia Water Department. Green City Clean Waters.
[54] Defra. Storm Overflows Taskforce
[55] Water Act. 2014
[56] House of Commons Environmental Audit Committee. Transcript of Oral Evidence: Water quality in rivers, HC 74. September 2021
[57] Defra. The government's strategic priorities for Ofwat: Draft for consultation. July 2021
[58] Environment Agency. Water Industry National Environment Programme. September 2020
[59] Environment Agency. Review of the water industry national environment programme (WINEP). July 2021
[60] Water UK. 21st Century Drainage Programme – the context. 20182018
[61] CIWEM. Opportunities for collaboration across water and wastewater planning. Virtual workshop, November 2021
[62] www.theoep.org.uk
[63] Salmon and Trout Conservation. Interim OEP Complaint Form. September 2021
[64] Defra, Environment Agency, Ofwat. Press Release: Water companies could face legal action after investigation launched into sewage treatment worksNovember 2021. November 2021
[65] ENDS Report. 'Where is the shame?': OEP questions DEFRA and Ofwat over sewage pollution complaints. November 2021
[66] Defra. Water for Life. 20112011
[67] Water UK. Storm overflow assessment framework. 20182018
[68] Part 1. Environment Act 1995 as amended
[69] Salmon & Trout Conservation. Doing its job? A report by Salmon & Trout Conservation on the Environment Agency's role in protecting and enhancing the rivers, lakes and streams of England. 20212021
[70] National Rivers Authority. Discharge consent and compliance policy: a blueprint for the future1989. 1989
[71] Deregulation Act. 20152015
[72] ENDS Report. The EA chief's regulatory vision: 6 things you need to know. 19th January 2022
[73] Ofwat. Time to act, together: Ofwat's strategy. 20192019
[74] Ofwat. Letter from David Black to Chairs of Remuneration Committees - Performance related executive pay for 2021-22. 21st February 2022
[75] Helm, D. Water – what is going on? September 2021
[76] Financial Times. Sewage spills highlight decades of under-investment at England's water companies. 28 December 2021.
[77] Stantec. Storm Overflow Evidence Project. November 2021
[78] Ofwat. Monitoring Financial Resilience Report 2020-21. November 2021
[79] Ofwat. Service and Delivery Report 2020-21. November 2021
[80] Hammond, P for Windrush Against Sewage Pollution. WASP Review of Unpermitted Spills from Sewage Treatment Works. October 2021
[81] Surfers Against Sewage. Water Quality Report 2021. November 2021
[82] Dieter Helm. Floods, water company regulation and catchments: time for a fundamental rethink. March 2020
[83] Defra. Government takes action to manage surface water flood risk. August 2020
[84] Climate Change Committee. Independent Assessment of UK Climate Risk. Advice to Government For the UK's third Climate Change Risk Assessment (CCRA3). 2021
[85] HM Government. 25 Year Environment Plan2018. 2018
[86] Section 13. Flood and Water Management Act 2010.
[87] Defra. Report of a review of the arrangements for determining responsibility for surface water and drainage assets. 20202020
[88] Defra. Surface Water Management. An Action Plan. 2018
[89] Defra. Surface water management. A government update. July 2021
[90] House of Commons EFRA Committee. Future flood prevention. 2016
[91] UKWIR. Surface water assets – A review of the extent of surface water assets in England and Wales. 20192019
[92] Susdrain. SuDS Principles.
[93] MHCLG. National Planning Policy Framework. July 2021
[94] House of Commons: Written Statement (HCWS161). Sustainable drainage systems. December 2014.
[95] MHCLG. A review of the application and effectiveness of planning policy for sustainable drainage systems (SuDS). August 2018
[96] Section 106. Water Industry Act 1991 as amended.
[97] JNCC. Greener Grangetown

[98] Sheffield Council. Grey to Green Sheffield.
[99] Severn Trent Water. Mansfield sustainable flood resilience.
[100] Severn Trent Water. Our River Pledges.
[101] Greater Manchester Combined Authority. The IGNITION Project
[102] Defra. Surface water management. An action plan. July 2018
[103] Arcadis. London Strategic SuDS Pilot Study. Evaluating the Flood Mitigation, Economic, Social and Environmental Value of Catchmentscale Distributed Sustainable Drainage Infrastructure (SuDS). October 2020
[104] CIRIA. B£ST (Benefits Estimation Tool). 20192019
[105] Greater London Authority. The GLA's Infrastructure Team. Prospectus. 2020 2020
[106] https://www.ofwat.gov.uk/nonhouseholds/surface-water-drainage/site-area-based-charging/
[107] Defra. Guidance to Water and Sewerage Undertakers in relation to Concessionary Schemes for Community Groups for Surface Water Drainage Charges and Summary of Consultation Responses. December 2010
[108] Ofwat. Resilience in the Round. 20172017
[109] Section 146. Water Industry Act 1991 as amended..
[110] Defra. Surface Water Management Update. July 2021
[111] National Infrastructure Commission. National Infrastructure Assessment. 2018
[112] Defra. Assessment of How Strategic Surface Water Management Informs Sustainable Drainage Systems (Suds) Delivery in Developed Areas Through Spatial Planning and Development Management - WT15125. 20212021
[113] D. H. Meadows. Leverage points: Places to intervene in a system. 1999.
[114] B. Dobson and A. Mijic. Protecting rivers by integrating supply-wastewater infrastructure planning and coordinating operational decisions. *Environ. Res. Lett.*, vol. 15, no. 11, 2020, doi: 10.1088/1748-9326/abb050.
[115] S. Muhandes, B. Dobson, and A. Mijic. The value of aggregated city scale models to rapidly assess SuDS in combined sewer systems. *Front. Water*, p. 206, 2022.
[116] J. Ossa-Moreno, K. M. Smith, and A. Mijic. Economic analysis of wider benefits to facilitate SuDS uptake in London, UK. *Sustain. Cities Soc.*, vol. 28, 2017, doi: 10.1016/j.scs.2016.10.002.
[117] W. M. Adams. The value of valuing nature. *Science (80-.).*, vol. 346, no. 6209, pp. 549–551, 2014.
[118] A. Zalejska-Jonsson, S. J. Wilkinson, and R. Wahlund. Willingness to Pay for Green Infrastructure in Residential Development—A Consumer Perspective. *Atmosphere (Basel).*, vol. 11, no. 2, p. 152, 2020.
[119] D. Dushkova and D. Haase. Not simply green: Nature-based solutions as a concept and practical approach for sustainability studies and planning agendas in cities. *Land*, vol. 9, no. 1, p. 19, 2020.
[120] D. R. Marlow, F. Boulaire, D. J. Beale, C. Grundy, and M. Moglia. Sewer performance reporting: factors that influence blockages. *J. Infrastruct. Syst.*, vol. 17, no. 1, pp. 42–51, 2011.
[121] S. J. McGrane. Impacts of urbanisation on hydrological and water quality dynamics, and urban water management: a review. *Hydrol. Sci. J.*, vol. 61, no. 13, pp. 2295–2311, 2016.
[122] J. D. Miller and M. Hutchins. The impacts of urbanisation and climate change on urban flooding and urban water quality: A review of the evidence concerning the United Kingdom. *J. Hydrol. Reg. Stud.*, vol. 12, pp. 345–362, 2017.
[123] P. Puchol-salort, S. Boskovic, B. Dobson, M. Van Reeuwijk, and A. Mijic, "Water Neutrality Framework for Systemic Design of New Urban Developments," *Preprint*, pp. 1–29.
[124] S. Muhandes, B. Dobson, and A. Mijic. The value of aggregated city scale models to rapidly assess SuDS in combined sewer systems. Front. Water, p. 206, 2022.
[125] P. G. Whitehead *et al.* Modelling Microplastics in the River Thames: Sources, Sinks and Policy Implications. *Water*, vol. 13, no. 6, p. 861, 2021, doi: 10.3390/w13060861.
[126] B. Dobson and A. Mijic. Protecting rivers by integrating supply-wastewater infrastructure planning and coordinating operational decisions. Environ. Res. Lett., vol. 15, no. 11, 2020, doi: 10.1088/1748-9326/abb050.
[127] B. Dobson, H. Watson-Hill, S. Muhandes, M. Borup, and A. Mijic. A reduced complexity model with graph partitioning for rapid hydraulic assessment of sewer networks. *Water Resour. Res.*, no. Under review, pp. 1–26, 2021.
[128] B. Dobson, T. Jovanovic, Y. Chen, A. Paschalis, A. Butler, and A. Mijic. Integrated modelling to support analysis of COVID-19 impacts on London's water system and in-river water quality. *Front. Water*, vol. 3, p. 26, 2021.
[129] S. Muhandes, B. Dobson, and A. Mijic. The value of aggregated city scale models to rapidly assess SuDS in combined sewer systems. *Front. Water*, p. 206, 2022.
[130] L. Liu, B. Dobson, and A. Mijic. Hierarchical systems integration for coordinated urban-rural water quality management at a catchment scale. *Sci. Total Environ.*, vol. 806, p. 150642, 2022.
[131] S. J. McGrane. Impacts of urbanisation on hydrological and water quality dynamics, and urban water management: a review. *Hydrol. Sci. J.*, vol. 61, no. 13, pp. 2295–2311, 2016.
[132] A. Mijic. Systems water management for catchment scale processes : Development and demonstration of a systems analysis framework. *Environ. Agency*, no. May, p. 82, 2021.
[133] J. Ossa-Moreno, K. M. Smith, and A. Mijic. Economic analysis of wider benefits to facilitate SuDS uptake in London, UK. *Sustain. Cities Soc.*, vol. 28, pp. 411–419, 2017.
[134] GMCA. GMCA agrees Environment Agency and United Utilities partnership to manage water differently. 24th September 2021.
[135] Arcadis. London Strategic SuDS Pilot Study. Evaluating the Flood Mitigation, Economic, Social and Environmental Value of Catchmentscale Distributed Sustainable Drainage Infrastructure (SuDS). October 2020
[136] Water UK. Fine to Flush. 20192019

[137] Severn Trent Water. Understanding the highway drainage charge
[138] https://www.ofwat.gov.uk/nonhouseholds/surface-water-drainage/site-area-based-charging/
[139] Arcadis. London Strategic SuDS Pilot Study. Evaluating the Flood Mitigation, Economic, Social and Environmental Value of Catchmentscale Distributed Sustainable Drainage Infrastructure (SuDS). October 2020
[140] Greater London Authority. The GLA's Infrastructure Team. Prospectus. 2020 2020