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Catchment systems planning

This is one of 15 case studies informing the Infrastructure Systems Review.

System: Integrated river catchments.

Systems contribution and value: Participatory mapping, integrated modelling and shared data improved understanding of boundaries, stakeholders, cause-effect relationships and trade-offs. Identified opportunities for coordination and co-funding.

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Summary

The 2026 government white paper 'A new vision for water'[1] calls for water to be planned as a whole system. By framing river catchments as systems, portfolios of interventions can be co-created by catchment stakeholders to address a set of outcomes that realises synergies across different planning frameworks and reflects a balance of different interest groups.

We review a combined approach to applied systems thinking including the use of:

- participatory systems mapping to synthesise stakeholder perspectives of the whole system
- integrated modelling to provide a quantitative analysis
- cost benefit analysis of potential interventions for an economic perspective.

These three steps are designed to give the systemic planning validity with respect to people (co-creation with stakeholders), science (data and modelling) and economics.

We draw on projects from River Lea in London, the Blackwater and Colne in Essex, the River Wye straddling Wales and England, and the River Frome in Bristol. Feedback from participants was positive, noting the importance of developing a shared understanding among participants.

Drawing on the Frome, we show how different interventions become cost effective when the assessment is made under planning frameworks in which a wider set of benefits is considered. This indicates that planning frameworks need to be set up to reflect system-wide benefits, to create cost-effective place-based outcomes over and above a narrow focus on sector-specific objectives.

Scope

This review considers four projects conducted within different river catchments. In each, a portfolio of multi-benefit interventions was co-created by a group of participants to achieve a range of results.

- East London's Subregional Integrated Water Management Strategy (SIWMS)[2] [3] which integrated planning across flood risk, water environment and water resources.
- Source to Sea System Mapping for the Blackwater and Colne in Essex.[4]
- Systems planning in the River Wye.[5]

Different interventions become cost effective when the assessment is made under planning frameworks in which a wider set of benefits is considered.

- Bristol: The Resilient Frome catchment – application of catchment systems thinking principles for flood risk appraisals. This project demonstrates the economic case for integrated investments.[6]

Both the Wye and Blackwater/Colne projects pioneer a new method for the Environment Agency's (EA) river basin management planning (RBMPs).

Project context

- In London, there was limited awareness among stakeholders of the wider systemic nature of the water issues. The project therefore ran a process that enabled participants to explore this wider perspective together as a platform for collaborative planning.
- In Essex and the Wye, the EA sought a robust process for river basin planning. The principle of 'fair share' in selection of measures was important here. Therefore, with participants, we investigated trade-offs that different options would bring.
- In Bristol, the client's selection criteria emphasised the need for cost-beneficial delivery of flood risk, water quality and other social and economic outcomes

Outcomes

A practical systems approach enhanced the ability to create impactful plans and account for benefits and trade-offs when viewing the system as a whole. Figure 1 shows how outcomes derive from the actions taken in these projects.

Outcomes include improved identification of externalities.

In London, reductions in domestic per capita consumption (PCC) are advantageous to water resource planning. However, this can have a potentially negative feedback loop affecting water quality. This is because lower PCC reduces the volume of wastewater produced, which in turn reduces

1 Department for Environment, Food and Rural Affairs (Defra) (2026) A new vision for water: White paper. London. Available at: https://www.gov.uk/government/publications/a-new-vision-for-water-white-paper
2 Greater London Authority (2023) Sub-regional integrated water management strategy East London. London: Greater London Authority. Available at: 100108845-5.1-F Sub-regional integrated water management strategy East London
3 Whaley, M. E., Benton, L., Bromwich, B., Mijic, A., Rousseau, E., Whaley, M. P., & Dobson, B. (2024). Implementing a systemic approach to water management: piloting a novel multi-level collaborative integrated water management framework in east London. AQUA—Water Infrastructure, Ecosystems and Society, 73(6), 1113-1134.
4 Environment Agency (2025) Natural capital approaches at the land-sea interface: mNCEA project NC74 WP8.1 Source to Sea System Mapping for Blackwater and Colne. Available at: Blackwater and Colne – Natural Capital at the Land Sea interface.
5 Mott MacDonald and Environment Agency (2024) Understanding the Wye catchment: Project update August 2024. Available at: Understanding-the-Wye-Catchment-Project-Summary-August-2024-1.pdf (Accessed: 6 August 2026).
6 Bristol City Council Newsroom (2022) £6 million funding for Resilient Frome project. 20 December. Available at: https://news.bristol.gov.uk/press-releases/fb3845b0-2581-423c-aa2d-1e6332c4e8c1/6-million-funding-for-resilient-frome-project.

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Figure 1: From project actions to catchment outcomes

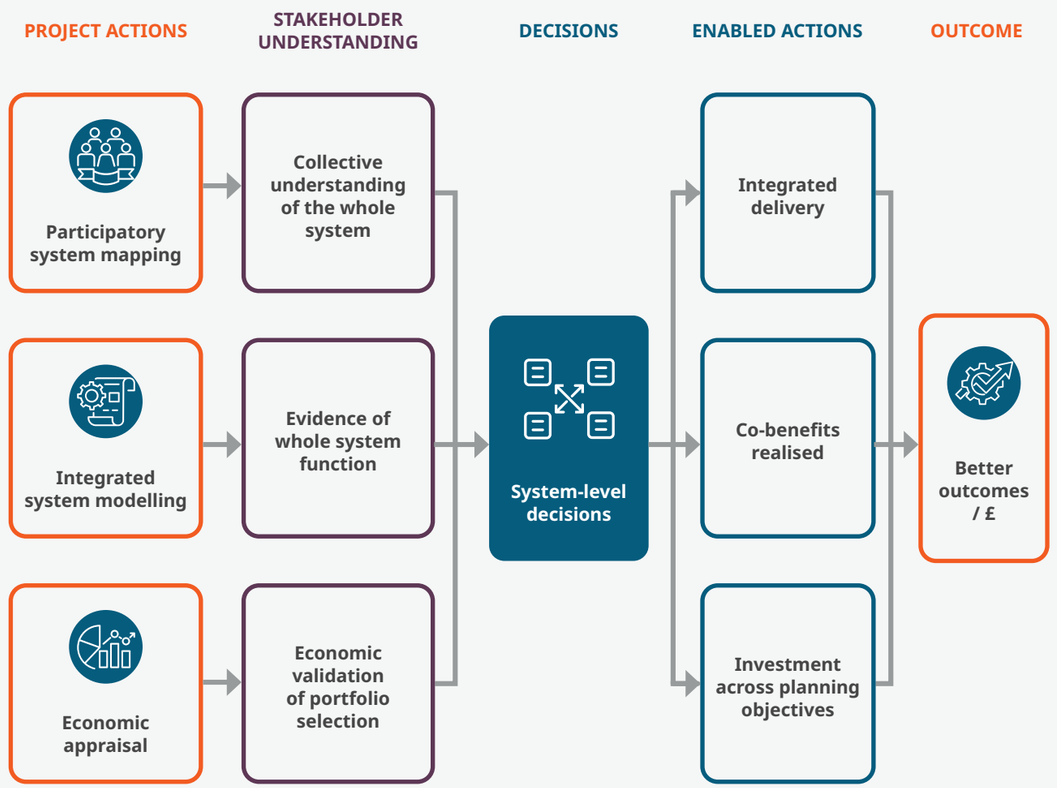
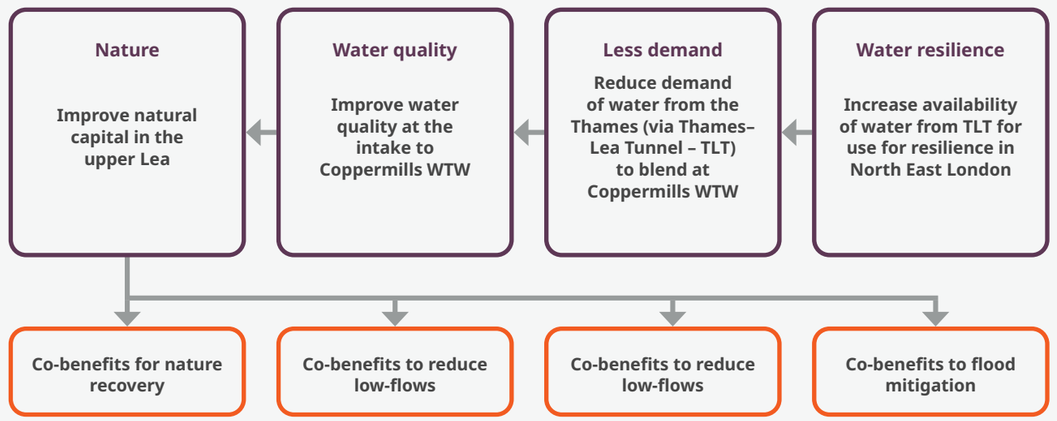


Figure 2: Cascading benefits and co-benefits



The system map was recast as a theory of change to show how interventions produce outcomes.

the discharge of treated back into the aquatic environment. Treated effluent discharges can contribute significantly to river flow in summer. Less flow would result in less dilution of pollutants from, for example, road runoff or sewer overflows resulting from in summer storms. Lower PCC could thereby heighten the risk to summer river ecology. Once identified, this externality can be managed and mitigated.

The approach also identified co-benefits and aided the resolution of market failures.

The work in London put forward a practical method of including interventions in more than one planning framework, thereby resolving the market failure inherent in siloed working. This is significant in rivers and landscapes where interventions have multiple benefits. For example, implementing sustainable drainage solutions (SuDS) has benefits to flood management, water quality and potentially water resource management.

In London, a market failure was mitigated by identifying potentially more cost effective interventions outside of the GLA area in the upstream catchment.

Also in London, cascading benefits were identified across other parts of the capital's water infrastructure, including more effective use of water abstracted from the Thames.

In Bristol, additional benefits were identified to match local ambitions to improve amenity and place value. These were included within the economic appraisal to justify the selection of options such as SuDS and natural flood management.

In each catchment, the process employed engaged diverse stakeholders and bridged their interests; it created plans addressing multiple objectives. Clients and stakeholders reported that it enabled progress on issues that had previously been considered intractable due to complex stakeholder landscapes.



£774k

cost of implementing SuDS at three demonstration sites

In London, referring to the qualitative outputs from the integrated modelling, the GLA described the work as "game-changing – in providing the evidence base for more collaborative working". In addition to the evidence base it also created patterns of collaborative behaviour that led directly into new collective actions being taken.

The EA described the progress made in the Wye and the Blackwater and Colne has as having created "enormous value" stating that the approach "helps us see the bigger picture and act in ways that influence the whole system".

The chair of the Wye Catchment Partnership stated that "the project has taken us from the storming phase to the norming phase", indicating that the level of contest in the partnership had diminished.

Systems

All four examples relate to river catchments comprising landscapes, natural capital and infrastructure. These systems lie within broader economic and social systems.

In the **London** case study, system management is provided by the boroughs, water companies, EA and the GLA (with a focus on economic development in London). However, the upper catchment, which has important opportunities for intervention, is outside the boroughs' and GLA's jurisdiction.

Poor water quality in the River Lea means that an additional water source must be blended to maintain satisfactory outcomes at Coppermills water treatment works. Implementing nature-based solutions (NbS) in the Chilterns, where the Lea originates, is a means of improving water quality and security: NbS reduces the sediment and nutrient loads in rainwater run-off, and slows the rate of flow, strengthening the resilience of water supply (Figure 2).

In the **Wye**, the system was represented[7] to stakeholders as a collection of sub-systems including agriculture, development and water utilities, which all interacted with each other around the central sub-system of river health. This overall framing gained traction with catchment stakeholders, helping them to articulate catchment trade-offs and challenges. This high-level representation was annotated with indicators under consideration for inclusion in the catchment plan as metrics. The system map was recast as a theory of change[8] to show how interventions produce outcomes.

A similar approach was taken in **Essex**. The system map was recast as a theory of change for the Blackwater and Colne[9] and can be filtered to show the overlapping place-based plans (drainage and wastewater, river basin, local nature recovery strategy, Essex highways), and annotated to show institutional responsibilities and hence identify partnership opportunities.

7 Understanding the Wye – catchment system map https://kumu.io/EDI14/wpdmmpsmkmv3#high-level-systems-map
8 River Wye theory of change https://kumu.io/EDI14/wpdmmpsmkmv3#planning-diagram
9 Blackwater and Colne theory of change https://kumu.io/SystemsECP/bwctocmmpsmjbv1

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In **Bristol**, the local authorities, water company, and the EA coordinate catchment management across flood risk management, planning, economic growth, and environmental regulation. Optioneering and stakeholder consultation identified SuDS and natural flood management (NFM) as providing the greatest benefits to amenity and environment, in addition to reducing flood risk.

Interventions

All four examples enhanced the ability of catchment stakeholders to understand the river in whole-system terms. This new shared understanding informed decision-making by improving awareness of the impact of intervening. This understanding improves catchment governance and allows more strategic deployment of the following types of intervention:

- Engineering interventions such as wastewater improvements
- Behavioural interventions such as reduced PCC
- NbS such as buffer strips, NFM and SuDS
- Agricultural interventions relating to issues such as feed ingredients and management of manure.

NbS form a significant part of catchment portfolios due to the multiple benefits they deliver across different planning objectives. However, it can be difficult to define attribution of benefits to NbS precisely. This can make it challenging to justify the inclusion of NbS in intervention portfolios. Systems mapping and integrated modelling enable visualisation of benefit attribution to interventions.

Using participatory stakeholder management, all stakeholders contribute to the selection of a system wide set of metrics which represent their own place-based priorities.

Notwithstanding the difficulty of precisely predicting benefits of NbS, it is advantageous to show the breadth of benefits and the interconnected nature impacts, which thereby enhances the case for selecting NbS interventions.

On the Frome, SuDS and natural flood management provide greatest benefits



Table 1. Economic assessment of SuDS benefits in the Resilient Frome project.

Planning domain	Benefit type	Beneficiary	Method	Present value £000 over 40 years	Sum by domain £000
Environmental	Amenity – at SuDS sites	Site owner	CIRIA B£ST	640.6	648.51
	Air pollution	Site owner	CIRIA B£ST	0.51	
	Water environment improvement	RBMP	Environmental and Historic Outcomes Valuation (EHOV) data book	7.4	
Water resources	Water treatment	Water company	CIRIA B£ST	0.154	0.154
Flood risk	Reduction in surface water flood risk at site	FCERM - site owner	Modelling & Multi-Coloured Handbook (MCH)	584.4	726.9
	Reduction in regional surface water flood risk	FCERM – lead local flood authority	Modelling & MCH	112.2	
	Reduction in catchment fluvial flood risk	FCERM – Environment Agency	Modelling & MCH	30.3	
Social	Skills, knowledge and education	Department for Education	CIRIA B£ST	184.8	184.8
			Total		£1,560.4

Table 2: Projects and methods applied

Project	Participatory system mapping	Integrated modelling	Economic appraisal
East London's Subregional Integrated Water Management Strategy	Yes	Yes	
Blackwater and Colne in Essex	Yes		Partial
River Wye	Yes	Yes	Partial
The Resilient Frome catchment - Bristol			Yes

Economic assessment

Currently, different planning domains within water and environment have their own approach to economic appraisal. Our catchment systems planning method improves on this in the following ways:

- Using participatory stakeholder management, all stakeholders contribute to the selection of a system wide set of metrics which represent their own place-based priorities. The PSM provides a rationale and audit trail for these metrics – and therefore legitimacy for the metrics with stakeholders.
- Considering a wider set of benefits and metrics enables the co-benefits of interventions to be included in their valuation. This enhances the benefit-cost ratio of interventions.
- Where a wider set of benefits are considered, multi-benefit interventions may be eligible for inclusion under more than one planning framework. Therefore, costs could be shared across funding streams for both frameworks. These co-benefit interventions may displace more costly interventions that contribute to only one planning objective. In the London project, the GLA identified a governance mechanism that could realise these synergies across different planning domains in a cost-effective manner.

In the Frome catchment, affecting Bristol, SuDS had originally been rejected when the project was appraised against flood benefits alone, under the Flood and Coastal Erosion Management policy. However, when the project was reconsidered under the Department for Environment, Food and Rural Affairs' Flood and Coastal Resilience Innovation Programme, additional co-benefits beyond flood risk were admissible for inclusion in the business case. The additional benefits considered were environmental, water resources and social.

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Inclusion of additional benefits beyond flood risk, moved the benefit-cost ratio from 0.94 to 2.02 – making the scheme cost-beneficial and eligible for progression.

The cost of implementing SuDS at the three demonstration sites was given as £774,000**.** This meant that the inclusion of additional benefits beyond flood risk, moved the benefit-cost ratio (BCR) from 0.94 to 2.02 – making the scheme cost-beneficial and eligible for progression.

Modelling in the Frome catchment showed that different interventions become cost effective when the assessment is made under planning frameworks in which a wider set of benefits is considered. This can create cost-effective place-based outcomes over and above a narrow focus on sector-specific objectives.

An economic case was made for implementation of NFM in the upper Frome catchment. It showed that for interventions that addressed only flood risk, a benefit to cost ration of 1.1 only just met value for money requirements. The inclusion of additional benefits improved the BCR to 4.0 which strengthened the business case.

Systemic assessment

The following systems thinking methods were used:

- A stepped approach to PSM[10] in which diverse stakeholders explore and illustrate how the catchment works as a whole system.
- Integrated modelling with Water Systems Integrated Modelling framework, to provide a numerical assessment of the system.[11]
- Theory of change based on the PSM so participants understand the attribution of outcomes and benefits to the portfolio of interventions they propose.[12]
- Cultural theory – to guide how system representation is informed by a diverse set of insights rather than reflecting a single perspective. Cultural theory underpins the significance of decision-making being valid when seen through the lens of people (an egalitarian worldview) science (a bureaucratic worldview) and economy (an individualist worldview).[13] [14]

This case study combines outputs from multiple projects (Table 2) to inform our systemic assessment of the quantified benefits of taking a systems approach to catchment planning.

The quantitative focus of this case is broadly aligned with Defra's Flood and Coastal Resilience Innovation Programme methodology. This is a satisfactory 'proxy' for systems thinking, as it includes holistic benefits. However, the authors are aware it is not an ideal methodology. Best practice would establish the relative benefits and costs of two approaches: one applying systems thinking, and one not. This will be considered in any future recommendations.

Recommendations

Participatory stakeholder management, mapping, modelling and appraisal (PSM) should be applied to river catchments to:

- enable co-creation of a coherent portfolio of interventions with relevant place-based benefits
- demonstrate legitimacy with participants in collaborative planning, with all relevant voices having been heard and recorded through the PSM
- enable resolution of complex multi-party and multi-sector trade-offs
- enable cost sharing across multiple funding streams, thereby enabling more cost-effective, multi-benefit options to be selected for implementation.

To realise these advantages, planning frameworks need to be set up to reflect system-wide benefits over and above a narrow focus on sector-specific objectives.

To ensure a proportionate approach, this method should be implemented in catchments with complex trade-offs or multi-faceted challenges for which multiple funding sources are relevant. It may not be needed in its full form in catchments with less complex challenges.

A key learning from this work is to recognise that applied systems thinking is about working with groups of people as well as doing more joined-up analysis. This is because people live and work in the infrastructure and environmental systems that we manage, seeking a variety of different objectives and understanding the catchment in a variety of ways. The stepped approach to PSM used in this case study reflects the fact that applied systems thinking may need to start by creating a collective understanding of the system across the stakeholders, from which they can negotiate shared objectives and work together to create an effective system-wide plan that benefits all actors.

10 Mott MacDonald and CECAN (2020). Systems Analysis for Water Resources - Final Report. Department for Environment, Food & Rural Affairs.
11 Dobson, B., Liu, L., & Mijic, A. (2023). Water Systems Integrated Modelling framework, WSIMOD: A Python package for integrated modelling of water quality and quantity across the water cycle. Journal of Open Source Software, 8(83), 4996.
12 Barbrook-Johnson, P., & Penn, A. S. (2022). Theory of Change diagrams. In Systems Mapping: How to build and use causal models of systems (pp. 33-46). Cham: Springer International Publishing.
13 Thompson, M., Ellis, R., & Wildavsky, A. (1990). Cultural theory. Westview Press.
14 Mott MacDonald and CECAN (2020). Systems Analysis for Water Resources - Final Report. Department for Environment, Food & Rural Affairs.

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