London Surface Water Strategy

Appendices

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Appendix A: Detailed policy landscape

Understanding the policy landscape

Flood risk management in London is a collaborative effort involving the Environment Agency, LLFAs which sit in London Boroughs, Thames Water, the GLA, highway authorities, emergency services, and the community.

Each organisation plays a vital role in reducing flood risk, preparing for flood events, and ensuring a coordinated and effective response to flooding incidents. The governance landscape is also complex. Landowners are responsible for their land. Local Authorities and Highways Authorities lead the management of surface water risks, while Thames Water oversees the sewerage network. Numerous stakeholders, like the Environment Agency, provide evidence and partnerships, while others focus on innovation or local delivery. Collaboration is challenging due to the diverse priorities of the different stakeholders. Each of the 32 London Boroughs and the City of London Corporation acts as the LLFA, and sets out how surface water should be managed within its boundaries. However, as we have seen, this model is problematic as rainfall often crosses these boundaries, complicating responsibilities, funding, and collaboration efforts. In addition to surface water, LLFAs have responsibilities to manage the risk of flooding from ordinary watercourses and groundwater sources, whereas the Environment Agency has responsibilities to manage flood risk from rivers and seas.

The influence of policy

The management of surface water flood risk in London is delivered through a variety of national, regional, and local policies and legislation.

The Flood and Water Management Act 2010 (FWMA)[1] sets out the roles and responsibilities of the LLFAs. The FWMA outlines key requirements for all bodies delivering this national policy including the need to cooperate, exchange information, and fulfil statutory responsibilities.

The National Planning Policy Framework, and Planning Practice Guidance,[2] assist Local Planning Authorities in the delivery of sustainable development that helps mitigate flood risk.

At a regional level, the **London Plan**[3] sets out how London will develop over the next 20 to 25 years. The policies in the London Plan inform decision making and the setting of Local Plans in London's boroughs, ensuring the planning system operates consistently and cohesively, and delivers on the London Plan's ambitions for good and sustainable growth. Policies relevant to surface water management include: the identification of 'Opportunity Areas' for investment and the delivery of development, infrastructure, and business; guidelines on the enhancement and expansion of green infrastructure; and, crucially, that flood risk is managed in a sustainable and cost-effective way that includes future expected flood risk.

At a local scale, London's boroughs use their Local Plans, Strategic Flood Risk Assessments (SFRA), and LFRMSs to facilitate the management of surface water flood risk in their areas.

An assessment of the policy and legislation landscape for surface water management in London was undertaken in the development of this Strategy. It is complementary to recent analyses undertaken by CIWEM and Defra on the suitability of, and potential improvements to, policy for managing surface water flooding.[4] Similar policy reviews with specific surface water focuses have also been completed in recent years, including by the NIC and various LLFAs' policy challenge papers as part of Defra's Flood and Coastal Resilience Innovation Programme (FCRIP) – a London-specific example is that from the Action for Silk Stream programme in North West London.

For policies relevant to surface water management, a brief description of each is provided, alongside some beneficial and constraining features of the legislation.

Table 5: Summary of strengths and weaknesses of legislation relating to surface water management

Policy	Objectives	Strengths	Limitations
Building Act 1984	Influences drainage provisions within buildings through Building Regulations	Requires building owners to establish satisfactory drainage Provides specific considerations for inner London concerning building and drainage, allowing boroughs to create byelaws	Act lacks specific references to surface water
Climate Change Act 2008	Addresses the effects of climate change and sets risk-related targets that affect flood management	Frequently updated and appraised by the Climate Change Committee (CCC)38 Mandates the publishing of updated Climate Change Risk Assessments every 5 years, setting out the risks and opportunities facing the UK, inclusive of flood risk assessment	Flood risk is not explicitly mentioned Unclear definition of role of Local Authorities and RMAs in contributing to overall 2050 target
Environment Act 2021	Aims to protect the environment, including improving water quality and waste reduction	Established an independent body (Office for Environmental Protection) which monitors and enforces implementation of environmental law	Lacks direct duties for most RMA organisations
Environmental Protection Act 1990	Specifies legal responsibilities for environmental welfare, such as preventing pollution of rivers and seas and addressing misconnections in drainage systems	Provides a robust framework for limiting negative environmental impacts Specifies responsibilities surrounding drainage systems, relating to sewer flooding	The Environment Agency and Local Authorities have specific responsibilities, but certain actions and responsibilities need clearer delineation
Flood and Water Management Act 2010	An important piece of legislation consolidating many other Acts, specifically focused on FCERM	Outlines the functions and duties of RMAs including the Environment Agency and LLFAs Sets out duties and requirements for statutory flood risk related studies and reporting, and duty to cooperate with other relevant authorities	No ringfenced funding for LLFAs to deliver statutory functions The implementation of Schedule 3 has been delayed and is subject to external factors

Policy	Objectives	Strengths	Limitations
Highways Act 1980	Outlines duties for the management and operation of highways, including considerations for highway drainage	Allows the highways authority to construct or lay drains to prevent surface water from flowing onto the road and divert surface water as necessary Local Authorities, often referred to as Highway Authorities, have the power to enter into agreements related to the construction, alteration, improvement, and maintenance of highways, including their drainage. This enables different authorities to have control over how highways are managed and maintained, especially in flood-related scenarios Duty to keep highways free from flooding	Differing design standards and levels of service to properties and people
Town and Country Planning Act 1991	Contains housing measures, including planning powers related to sustainable drainage	Requires consultation with LLFAs for major planning applications	The act has limited mention of sustainable drainage or flood risk requirements
Land Drainage Act 1991	Pertains to drainage and local authorities' powers regarding land drainage to prevent increased flood risk	Sets out clear powers to manage and prevent any increase to flood risk Allows for cross-boundary or hydrological catchment approaches to managing risk	The Act contains permissive powers, but there is limited emphasis on enforcement The Act has limitations in making LLFAs key players in land drainage, particularly in urban areas
National Planning Policy Framework 2012 (and its Flood Risk and Coastal Change planning practice guidance)	Sets planning requirements, including those related to flood risk and SuDS.	As the NPPF is a policy, it does not have the same legal status as an Act. Requires site-specific flood risk assessments and SuDS for major developments The focus on redevelopment as a means to achieve betterment, rather than merely avoiding increased flood risk, is emphasised	Focuses on mitigating any increase in flood risk, rather than reducing risk

Policy	Objectives	Strengths	Limitations
Planning Act 2008	Addresses sustainable development and enforcement measures in case of offences	Considers how adaptation and mitigation of climate change should be integrated into sustainable development	It does not explicitly highlight the role of reducing flood risk in contributing to sustainable development and climate change adaptation Does not incentivise the consideration of flood risk reduction within outline design and planning processes
Water Industry Act 1991	Defines powers and duties of water and sewerage companies (WaSCs) and outlines their responsibilities and penalties	Clearly defines responsibilities of WaSCs to undertake specific duties relating to water resources, wastewater management and treatment, and protection of customers from sewer flooding	Owners ultimately have the right to connect under the Act Does not clearly mandate corrective action for unlawful connections Does not grant enforcement powers to compel landowners to perform the work
Water Resources Act 1991	Defines the Environment Agency's functions in water resource management	Outlines key duties and powers of the Environment Agency, particularly in relation to water quality	Out of date and in need of better alignment to current legislation

Appendix B: Capture, Control, Adapt & Respond to investigations

The Strategy advocates for a solutions hierarchy to managing surface water. Solutions that capture rainfall at source – such as small- scale SuDS – should be explored first, with solutions that control surface water – such as traditional sewerage systems, or larger- scale SuDS – installed as close to the rainfall source as possible as secondary components of the hierarchy. Where surface water cannot be fully managed, stored, or conveyed by 'Capture' and 'Control' solutions, actions that help London adapt and respond to flooding should be adopted, addressing residual risk and vulnerability to flooding by actions such as planning for emergency response.

Solutions to 'Capture' rainfall where it lands
Surfaces should capture and retain the first 15mm of rainfall in-situ to prevent the accumulation of runoff into drainage networks.

Interventions to 'Control' the flow of surface water
Infrastructure should be in place to intercept rainfall runoff up to 45mm, where it can't be entirely captured.

Measures taken to 'Adapt and Respond' places to surface water flooding
Places and properties should be adapted through intervention and re-development to limit the impact of surface water flooding from rainfall up to 75mm, where it cannot be entirely captured or controlled. Actions to improve awareness and the understanding of flood risk can improve personal resilience.

Capturing rainfall

Where does rainfall need to be captured?

The Strategy has assessed the distribution and scale of action needed to reduce the risk and impacts of surface water flooding into the future. By incorporating a spatial assessment of the potential constraints to the implementation of SuDs and NbS, in relation to the areas of London that require strategic priority actions, the Strategy will help practitioners and Londoners better understand the approaches most suited to their local contexts. Increased adaptation and resilience to surface water flooding can, in part, be achieved with NbS. However, a pragmatic approach to combining blue-green and traditional grey infrastructure will still be required to deliver cost-effective and efficient reductions in flood risks and impacts.

Capturing water where it falls

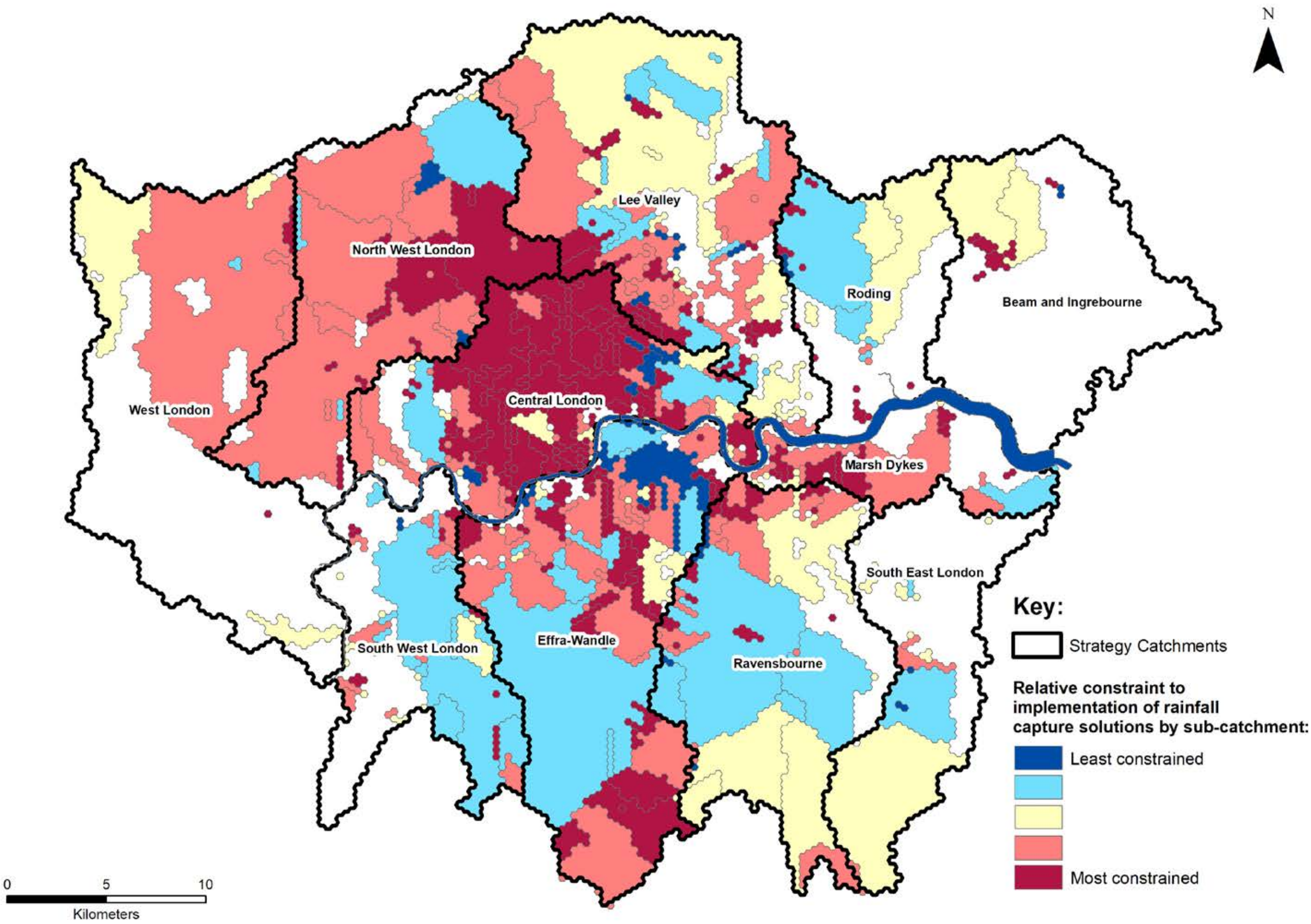
The first pillar of the strategic solutions hierarchy is to capture water where it falls. However, capturing water at source can be made more challenging by constraints to action.

The surface of London is densely populated and filled with homes and communal places, businesses, infrastructure and green spaces. The underground landscape is just as densely utilised by infrastructure. This makes finding space for solutions to capture and control rainfall and surface water challenging, and competitive. Figure 22 showcases the constraints to delivery SuDS and NbS across London's strategy catchments. Planners, developers, designers, and Londoners sometimes have limited awareness of the multiple benefits delivered by SuDS and BGI. Poor connectivity and collaboration across infrastructure organisations means that opportunities to reduce construction costs and disruptions are often missed.

A previous approach to mitigating this was the development of CDAs as part of the London Strategic SuDS Pilot.[5] These are now out-of-date and may fail to capitalise on opportunities to maximise source control in new developments. They also do not explicitly incentivise joined-up thinking and shared action planning that captures and controls surface water across multiple sites and locations in a holistic approach.

By prioritising capture of water at source, this Strategy intends to shift the thinking towards this holistic approach to water management at source.

Figure 22: Projected need for rainfall capture solutions, and their relative constraints to implementation



Unconstrained opportunity: Where capture solutions are required, there are relatively fewer constraints to delivery.

- Available existing green or blue space
- Gentle topography and permeable land cover

Constrained opportunity: Where capture solutions are required, there are relatively more constraints to delivery

- Extensive sub-surface utilities and infrastructure
- Steep sloping land or existing impermeable land cover

Mapping:

Figure 22 shows the relative difficulty in implementing solutions like SuDS and BGI. The coloured areas represent our assessment of the areas where delivery of this infrastructure is crucial to the Strategy. Where areas are not coloured, this does not imply no action is required. Rather, they are cells where action is not a strategic priority under this Strategy.

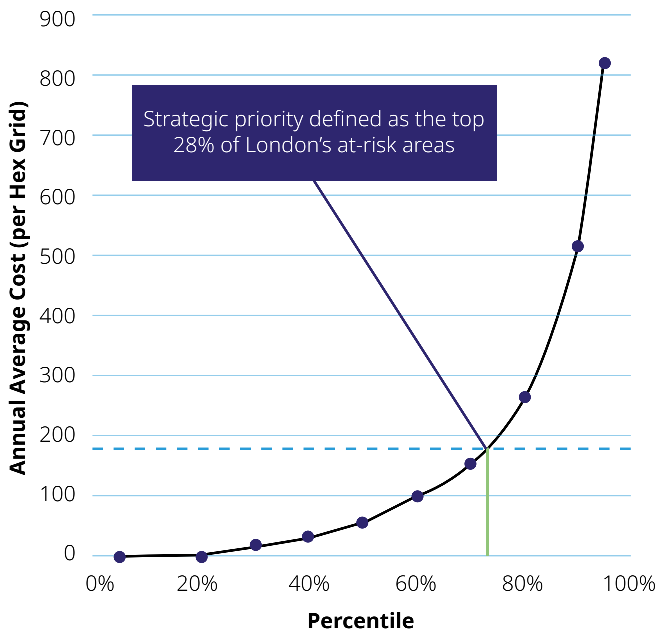
Need:

This is the relative strategic priority for the management of surface water flood risk. Strategic priority areas are those hex-grid cells that exhibit higher flood risk impact scoring than the average cell across London (Figure 23).

A composite methodology was used to classify the relative constraint to installation of 'Capture' solutions, such as SuDS and BGI on the surface, per Hex grid cell. A selection of metrics applied to the composite score is outlined below:

- Surface impermeability
- Urban morphology
- Percentage cover of blue and green space
- Length of highways
- Number of protected properties
- Area of designated protected open space

Figure 23: Defining strategic priority areas



The thresholds of constraint were defined as follows:

Constrained implementation

Constraints to delivery include the presence of existing property and infrastructure, challenging land use types, the availability of green space, and the nature of the local topography. For any given Hex grid cell, a weighting for the relative ease or difficulty of implementing surface water management solutions was applied to represent this constraint.

Unconstrained implementation

Unconstrained implementation characterises areas, or grid cells, where it is expected to be easier to implement solutions, based on engineering judgement and the absence of obvious constraints.

Constraints to action

Constraints to the delivery of 'Capture' solutions include land use type, topography, density of buildings and infrastructure, and the presence of blue, green or protected spaces. The assessment of constrained or unconstrained opportunity to implement control solutions was determined based on the relative availability or density of these characteristics.

The scale of required 'Capture' action, and the potential constraints to its implementation, is presented in Figure 24.

Figure 22 presents the distribution of priority source catchments and receptor areas across London. The level of constraint to the implementation of 'Capture' infrastructure is overlaid to indicate where rapid, high-impact and relatively simple 'no regret' action could be taken. Conversely, areas with the greatest constraints, but which are priority areas for surface water management, may be better suited to the subsequent tiers of 'Control', 'Adapt' and 'Respond' solutions that provide other adaptation and resilience benefits in London's more challenging built environments.

Across London's Strategy Catchments, in order to meet a 75% reduction in flood risk by 2075, 40% of the total required flood volume to be managed could come from capture solutions.

Action to capture rainfall and surface water at source may be best focused in London's outer Strategy Catchments.

Opportunities to implement source-control SuDS, NbS, and larger-scale attenuation schemes are less constrained in these areas, indicated by the positive values for the strategy catchments.

Given the nature of London's surface water catchments, 'Capture' solutions in these Strategy Catchments are shown to deliver hydraulic benefits to local and downstream communities and receptors. While the needs assessment – the projected required surface water flood risk reduction – indicates a higher need for action in Central London, the highly-constrained nature of this catchment indicates that 'Control', 'Adapt' and 'Respond' solutions may be more suitable here.

Figure 24: Required rainfall capture volumes per Strategy catchment

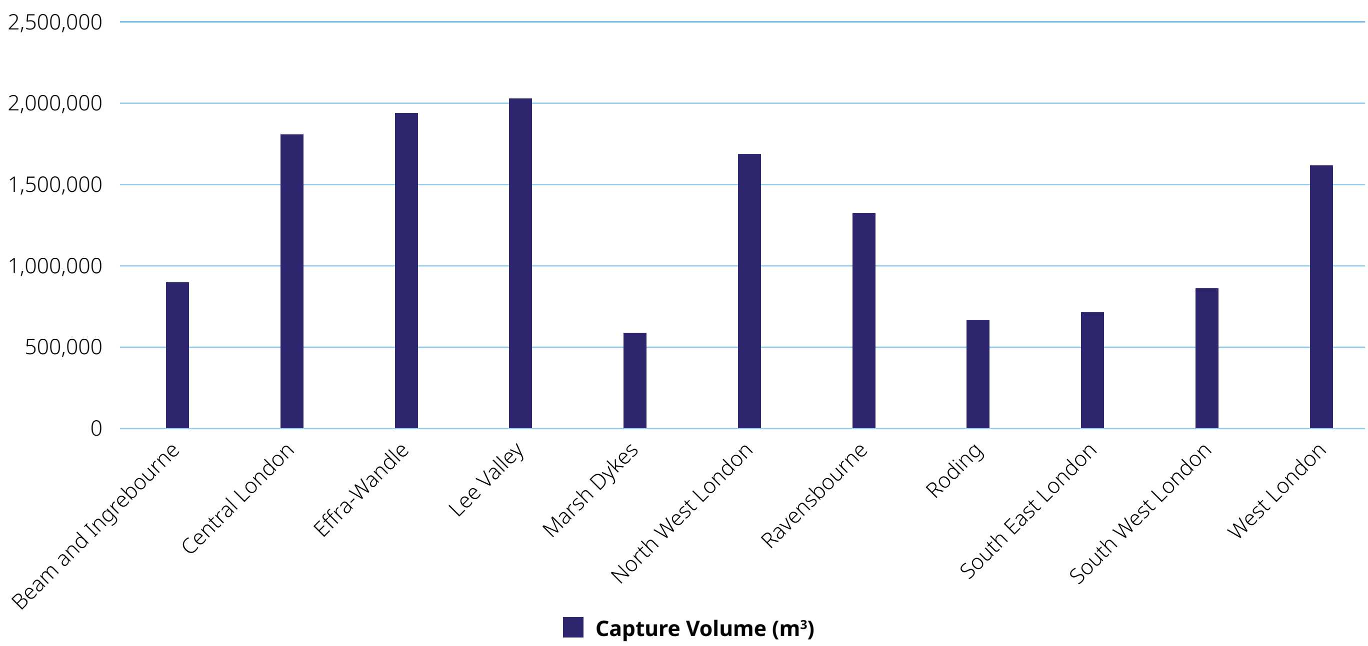
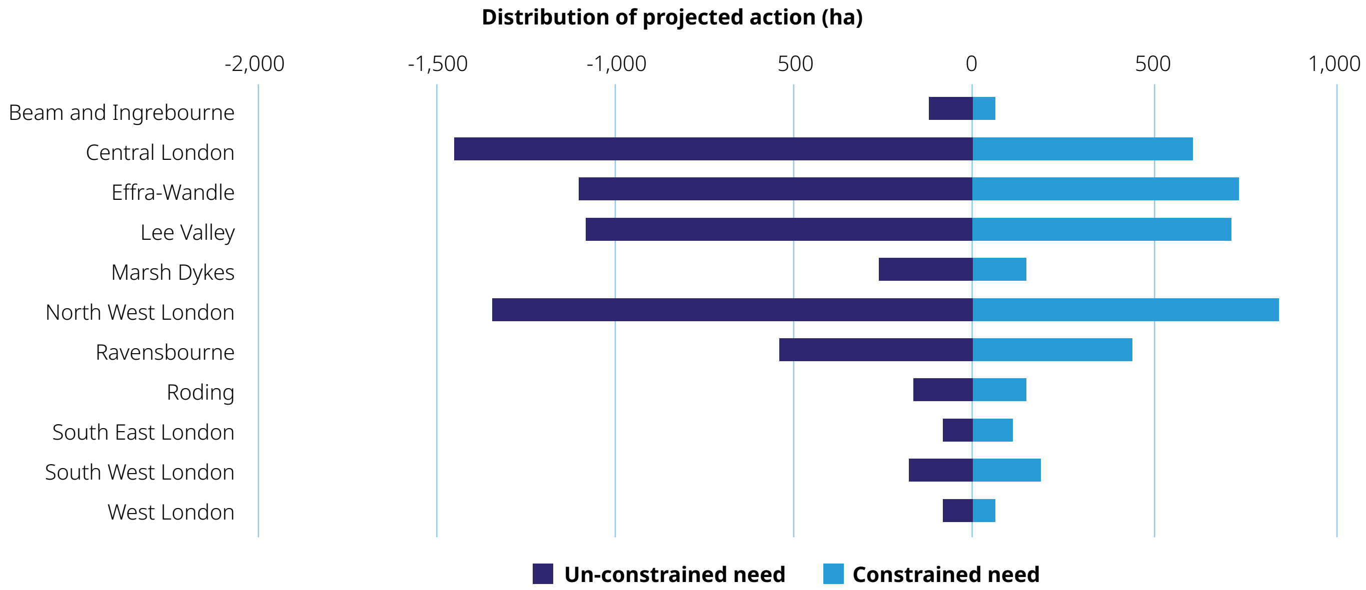


Figure 25: Constrained vs unconstrained need for rainfall capture solutions across the Strategy catchments



Control

Where does surface water need to be controlled?

In line with the Solutions Hierarchy, if water cannot suitably be captured at source, 'Control' solutions should be the next line of resilience. 'Control' solutions also include traditional 'grey' infrastructure (e.g. sewerage system upgrades) where constraints to the installation of SuDS and NbS solutions on the surface limit their constructability.

'Control' solutions are often more suitable for London's congested urban environments. Combining best-practice SuDS and NbS with conventional drainage network interventions is more feasible where available space, surface permeability, and existing infrastructure present challenges to the implementation of source-control and 'Capture' SuDS.

Central London has a relatively high need for 'Control' solutions.

The prevalence of existing underground drainage networks, alongside the general feasibility of small-scale, opportunistic implementation of SuDS solutions within existing highways, combines with more favourable topographic characteristics with the result that the constraints to delivery of this infrastructure are relatively fewer. As with the 'Capture' solutions, the strategic priorities for the control of surface water flooding are concentrated across three Strategy Catchments in the centre of London. It is important to note that the assessment of strategic priority is vulnerability-driven and therefore prioritises reducing risk and impact to the most vulnerable Londoners, many of whom live, work and socialise in these catchments.

'Control' solutions are projected to offer the potential to manage around 45% of the total surface water management need across London.

Figure 26: Distribution of need for control solutions against relative constraints to delivery

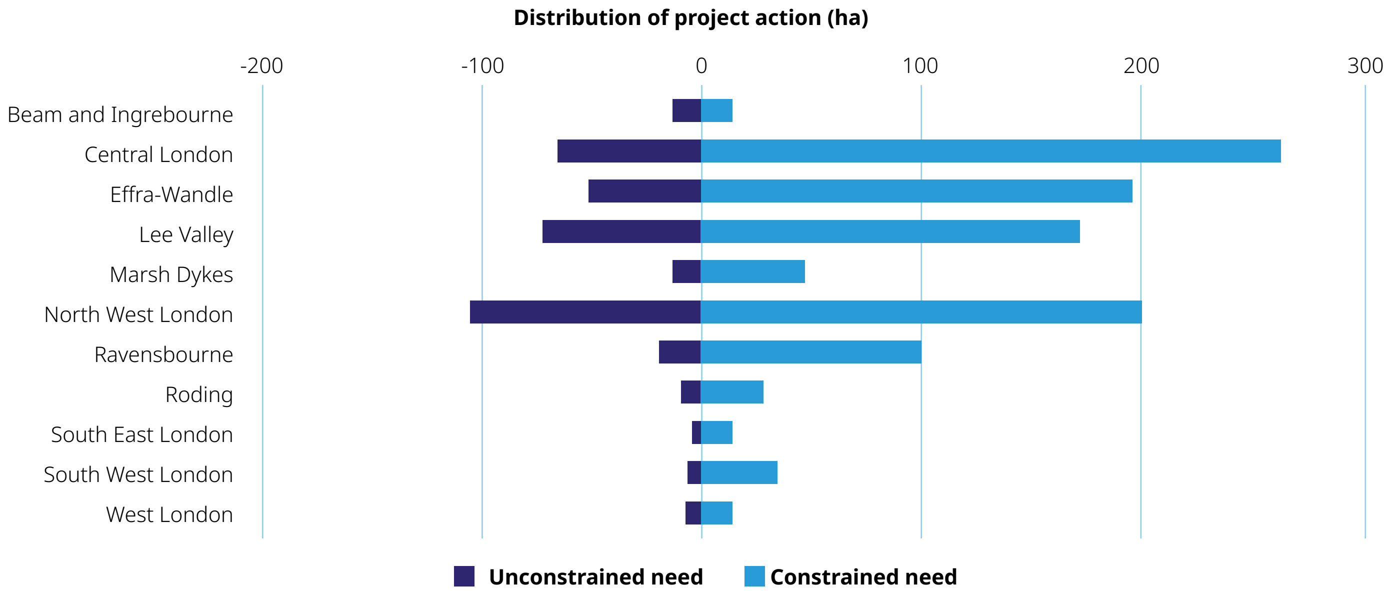
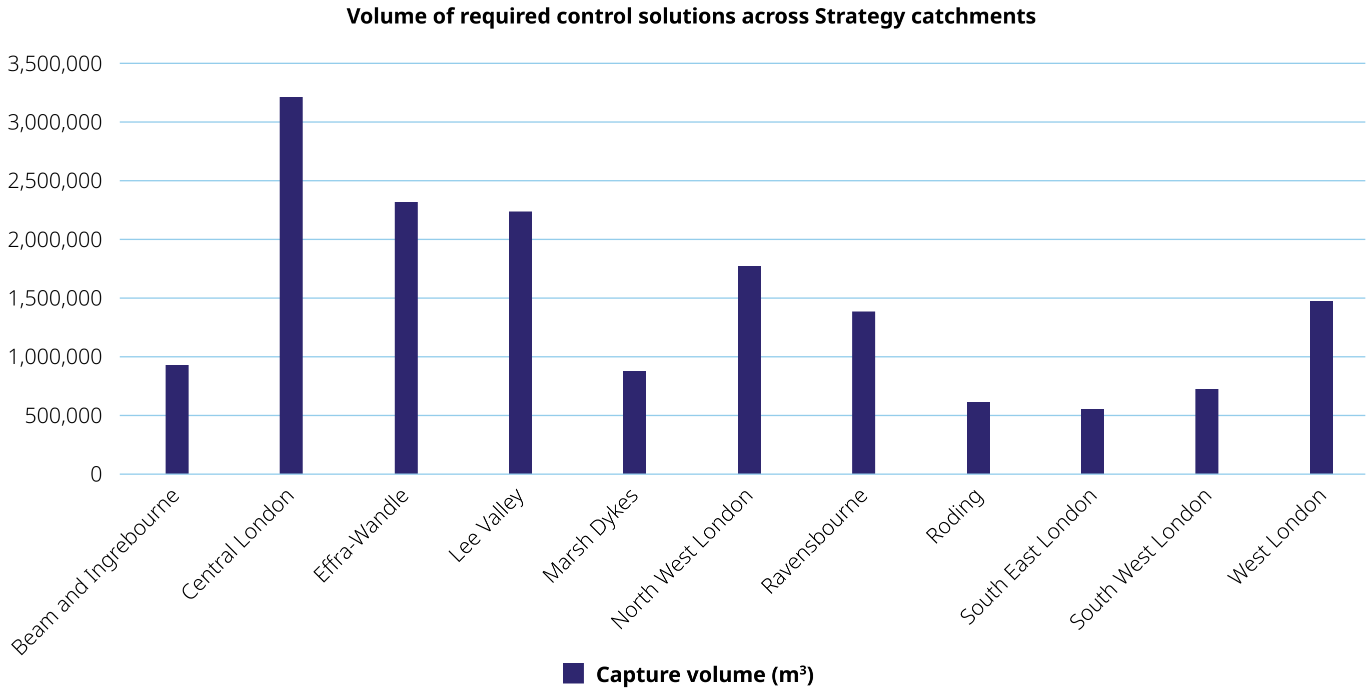


Figure 27: Total volume of required control solutions to deliver surface water flood risk reduction across London

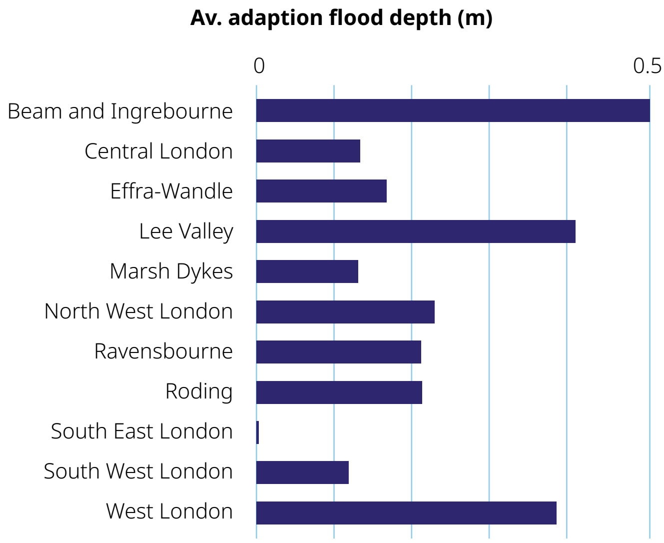


Adapt and respond

What places need to adapt and respond to flooding?

As per the Solutions Hierarchy, where 'Capture' and 'Control' solutions no longer provide sufficient management of surface water, solutions to enable Londoners to adapt and respond to flooding should be prioritised. The extent of these solutions has been identified and demonstrates that both 'Adapt' and 'Respond' solutions are applicable all across London. The proposed measures to capture and control surface water flooding are projected to deliver around 85% of the total risk management needs across the Strategy Catchments. The remaining surface water flood risk will require responsible organisations and Londoners to take action to prepare and respond to flooding.

Figure 28: Required adaptation to flooding across London's Strategy catchments



Appendix C: London's drainage systems

London's geography significantly impacts how water moves when it rains. Its clay soils limit the amount of rain that can soak into the ground, and impermeable surfaces, such as concrete, increase the chances of surface water flooding. London is served by several drainage systems which are essential for managing water and mitigating the impact of heavy rain.

London's drainage systems are critical, yet vulnerable. Addressing the challenges of urban growth, climate change, and funding limitations will require a multifaceted approach, and the Strategy alone cannot address all of these issues.

Combined sewer systems

Collect both sewage and rainwater, but often overflows during heavy storms due to increased runoff from impermeable, urbanised areas

Separate sewer systems

Separate sewers for surface water and sewage. Surface water goes directly to watercourses whilst sewage goes to sewage treatment works. The separate system is usually found in areas developed after 1970

Mainly managed by Thames Water

Highway drainage

Manages runoff from roads and footways; integrated with the city's overall drainage system to prevent flooding

Culverted watercourses

Rivers and streams enclosed in pipes or concrete channels, which limit flow capacity and can worsen flooding during heavy rain

Managed by Transport for London (TfL) and London boroughs (as Highways Authorities)

Natural watercourses

Rivers and streams, like the Lea, Wandle, and Brent, are vital for biodiversity and runoff management and require careful management to maintain their functions

Administered by London's boroughs (for ordinary watercourses), or the Environment Agency (for main rivers)

Landowners also have a role to play in maintaining any private drainage systems.

Appendix D: Hydraulic modelling

Summary

High-level rainfall runoff modelling was undertaken to categorise exposure for all locations across London; a new model was created to ensure consistent data and alignment with the agreed unit: the TfL Hex Grid. The model used industry-standard assumptions and methods, incorporating data including Thames Water sewerage network capacity, Ordnance Survey (OS) land use, and Environment Agency LiDAR topographical data. This approach enabled a representation of London's hydrology and drainage system capacity, showing where major floodwater might accumulate and flow. The model facilitated the derivation of Strategy Catchments and the identification of solution pathways. Designed for simplicity, the model minimised time and cost, fitting within the project's budget and timeline. Despite being high level, it accurately projected likely flooding areas.

Purpose of the modelling

The flood modelling for the London Surface Water Strategy broadly aimed to assess the exposure of people, property, and infrastructure to surface water flooding. This assessment helped estimate potential costs from sub- regional to pan-London levels. The modelling identified areas at risk of surface water flooding that might require cross-boundary collaboration for catchment-scale solutions, subject to detailed local mapping. These areas were defined as strategic priorities in the Strategy, guiding its principles and objectives. This consistent understanding of risk also informed targeted actions and catchment strategies.

During the Discovery Phase, existing flood maps and models from the 'Drain London' programme were considered, but it was decided to create a new model to avoid the complexities of integrating different models, developed at different times, each with varying technical approaches and detail levels. The strategic model was developed to be high level, rather than a detailed hydraulic model.

Local authorities were advised to continue using their detailed models for planning and funding applications, but it is thought that the strategic evidence gathered for this new model will enable better collaboration and planning for future detailed models and improved flood management.

Model parameters

The following information was used to guide the modelling process.

Model software

The modelling approach used for this Strategy was a 2-dimensional (2D) overland flow model, using TUFLOW HPC. TUFLOW HPC offered the capacity to estimate volumes within polygons, in this case 350m by 350m Hex Grids. Furthermore, TUFLOW HPC can estimate volumes of flow through lines, therefore offering the capability to model source-pathway-receptor dynamics at the individual Hex Grid scale.

TUFLOW is routinely used across the industry, provides fast modelling outputs in relation to the spatial scale of London, and allows for the inclusion of parameters such as rainfall, infiltration and surface roughness coefficients.

Rainfall scenarios

Rainfall events for the following return periods were used to project surface water flood risk across London. These events are reflective of the array of rainfall events that could reasonably be experienced in London, as well as aligning with the required standards of protection for surface water projects delivered by respective organisations involved in managing surface water flood risk:

- 1 in 5-year (20% AEP)
- 1 in 30-year (3.3% AEP)
- 1 in 100-year (1% AEP)

See Appendix E for how the impact of climate change has been accounted for within the modelling.

Event durations

To capture the variation in characteristics between winter and summer rainfall events, in terms of intensity and duration, a variety of rainfall event durations was used. The 1-hour and 2-hour duration events were used to characterise the typical storm duration experienced in London, reflective of the 2021 July rainfall event. Shorter storm durations have been used to inform other recent assessments of surface water flood risk, such as that undertaken by the NIC (NIC, 2022). A further 12-hour duration event was used to replicate the longer, less intense rainfall patterns experienced over London in winter. The event durations informed the assessment of suitable intervention options, as well as the proposed surface water resilience pathways.

Overland runoff modelling

The modelling undertaken for this study is overland runoff modelling. Thames Water modelling of sewer overflows was obtained separately, inclusive of flows and volumes, and added to the volumes present in each respective Hex Grid.

Model runs

Model runs were selected to match the key outputs produced by Thames Water and the Environment Agency, where possible.

The following return period events were simulated:

- 1 in 2 year (50% AEP), 1 in 5 year (20% AEP), 1 in 30 year (3.3% AEP), 1 in 50 year (2% AEP), 1 in 100 (1% AEP) and 1 in 1000 (0.1% AEP)
- 1 in 100 year plus 25% and 45% increase in rainfall intensities
- Do nothing scenario for the 100+CC (45%) event
- Sensitivity tests to assess ranges (as opposed to fixed values) for different storm durations, sea level rise, asset deterioration, and urban projection (max 10 runs)

Model outputs

The model results were set up so that:

- Volumes of flood water over the ground for each Hex Grid could be saved every 15 minutes, including the peak volume for the entire run
- The combined flow that crosses each of the six sides of the Hex Grid (6 No) was saved every 15 minutes, including the peak flow for the entire run
- The peak flows through the six sides of the Hex Grids were used to define the source-pathway-receptor status of each polygon

Flood depth maps were not produced as deliverables; however, these are available from the model outputs for the purpose of comparing against the Environment Agency surface water flood maps.

The modelling by Thames Water deals with another source of surface water flood risk, which is overflows from the sewers, via manholes and gullies. Thames Water flood volumes, derived from their DWMP, were applied to each Hex Grid by applying overflow hydrographs to the 2D model. Note that sewer overflows are different in terms of source of flood risk and impacts, when compared to the 2D modelling, which only models 2D excess overland runoff flooding.

An allowance for drainage capacity was applied, based on the work undertaken by the Environment Agency in terms of sensitivity testing, and removing some rainfall from the total modelled rainfall to represent losses (e.g. infiltration). Values of rainfall removal ranged between 12mm/ hour and 18mm/ hour. Reference was also made to other assessments, including the Greater Manchester SWMP. Sensitivity tests were applied, in terms of benchmarking the models for the July 2021 event, by testing its predicted outputs against the observed flooding.

Development of the modelling

The key principles applied for the development of the modelling approach were:

Figure 29: Model development process

1. **Develop an approach prioritising scale**
Develop an approach that prioritises scale and consistency, as opposed to assessing high-resolution predictions across London

2. **Undertake modelling following Environment Agency guidance and CIWEM Code of Practice**
Follow Environment Agency and CIWEM Code of Practice guidance, adapted to the level of detail and outputs required for this study

3. **Collect publicly available topographic and spatial data**
Use publicly available data covering core topographical and spatial data

4. **Create London-wide 2D model**
Create a London-wide 2D model, including contributions from external catchments

5. **Provide results**
Provide results as ranges, where possible, to allow for uncertainty

6. **Consider impacts of climate change**
For climate change impacts, refer to the UKCP Future Drainage project to confirm rainfall intensity uplift factors and spatial variation

7. **Assess urban development impacts**
To assess urban development impacts, refer to projections from the ONS, and TWUL, who recently undertook much of this work as part of their DWMP

Selection of modelling software

Based on the proposed modelling approach, the software for this project needed to be:

- Reasonably fast to build and run, covering large catchment areas of the order of 200-500km2 (the entire GLA area is approximately 1,600km2)
- Sufficiently accurate for providing an assessment of the magnitude of flooding within a Hex Grid measuring 350m in width
- Reasonably compatible in terms of volume outputs, so that the results can be easily modified (for the estimate of volumes within each Hex Grid, as well as volumes entering and leaving its six sides)
- Sufficiently flexible so that it can differentiate areas of different rainfall, infiltration, and Manning's n values
- Accessible and functional for the consultant

Several software options were tested as shown below:

Table 6: Modelling software comparison

Name	Speed (in respect to the scale of London)	Level of accuracy	Results compatible with Hex Grid borders	Allows for rainfall, infiltration and Manning's n zones	Easy to run sensitivity tests and climate change	Software availability
Scalgo	Fast	Assume high	No (the current version is not able to simulate different scenarios and many catchments at the same time)			No
FMP Fast 2D	Fast	Medium (no momentum equations)	No	No	No	Yes
FMP 2D GPU	Fast	High	Yes	Yes	Yes	Yes
ICM-2D	Slow	High	Yes	Yes	Yes	Yes
TuFLOW	Slow	High	Yes	Yes	Yes	Yes
TuFLOW HPC	Fast	High	Yes	Yes	Yes	Yes

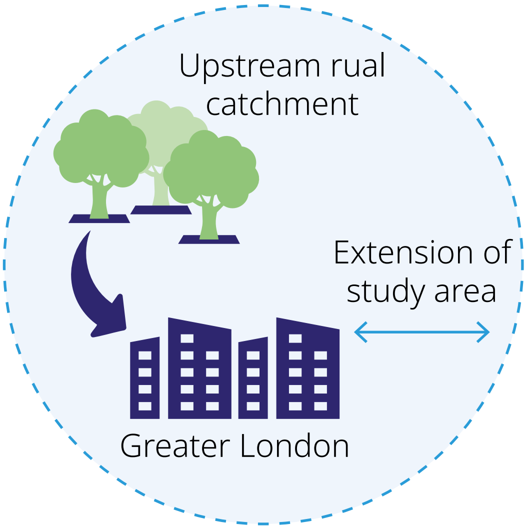
It was concluded that **TuFLOW HPC** was the best software for this project.

Application methodology

Study area

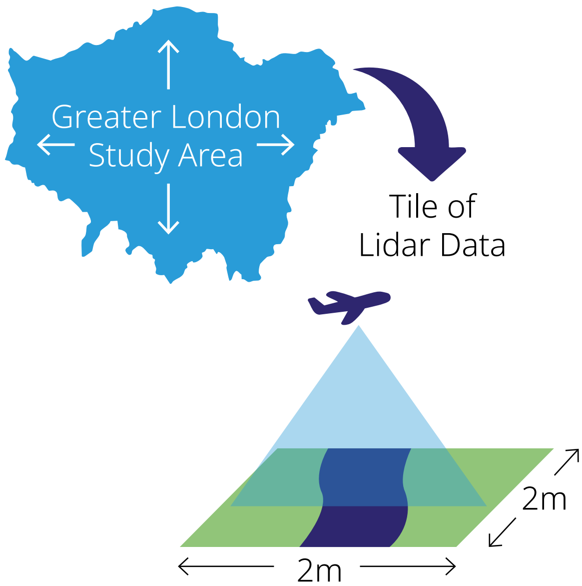
The study area was expanded beyond the Greater London area to allow for the contribution of upstream, predominantly rural, catchments.

It has not been extended to large river catchments draining to the Greater London area, as this would increase running times for little benefit; adding the contribution from these catchments as point inflows gave comparable results.



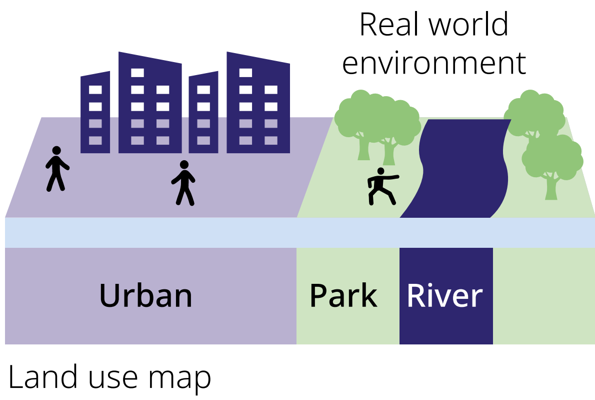
Topographic data

LiDAR data are available for the entire study area as 1m and 2m grid (2022 composite DTM). The 2m grid is sufficient due to the high-level modelling being undertaken. The extent of the 2m grid LiDAR tiles that have been downloaded covers the entire study area.



Landscape data

MasterMap data were provided by Thames Water and the GLA to cover the study area. These data will be used for the estimate of Manning's n- values in land use areas or polygons. Although building and kerb data are available in MasterMap, these layers will not be used for the modelling to avoid unnecessary increased running times.



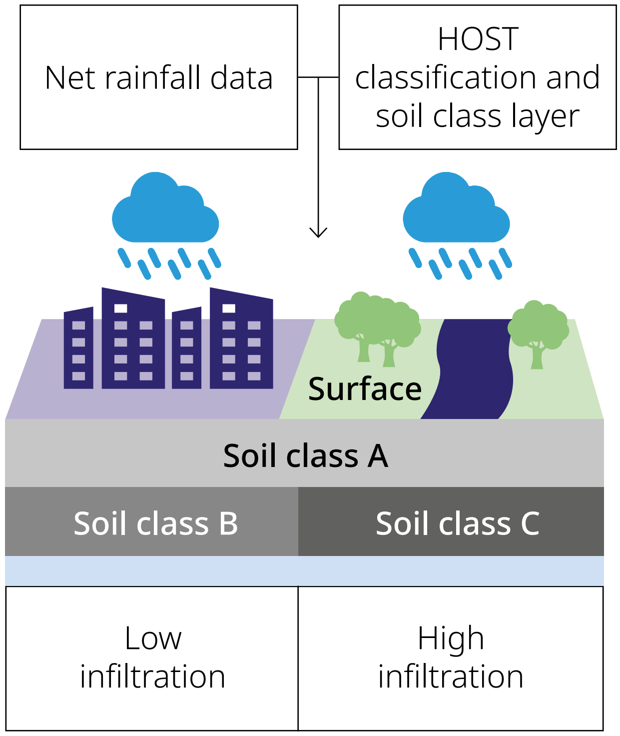
Hydrogeology data

Two options for representing infiltration were considered.

Option one was removing, from the total rainfall, a fixed portion to represent infiltration. The resulting net rainfall is then applied to the ground model. Net rainfall can be obtained from the FEH Web Service for many catchments contributing to or within the study area. This approach would remove the need to have infiltration zones in the model; however, there would be a cost associated with buying catchment descriptor data, which is five times more expensive than obtaining point rainfall data.

Option two was to apply the total rainfall to the ground model. This rainfall would then be lost beneath the ground in the 2D model with the creation of infiltration areas or polygons in the model. Infiltration zones can be generated from the HOST classification and soil class layers available from the University of Cranfield.

Based on this comparison, the infiltration modelling approach was preferred. This provided more confidence in the results, despite extending model run times.



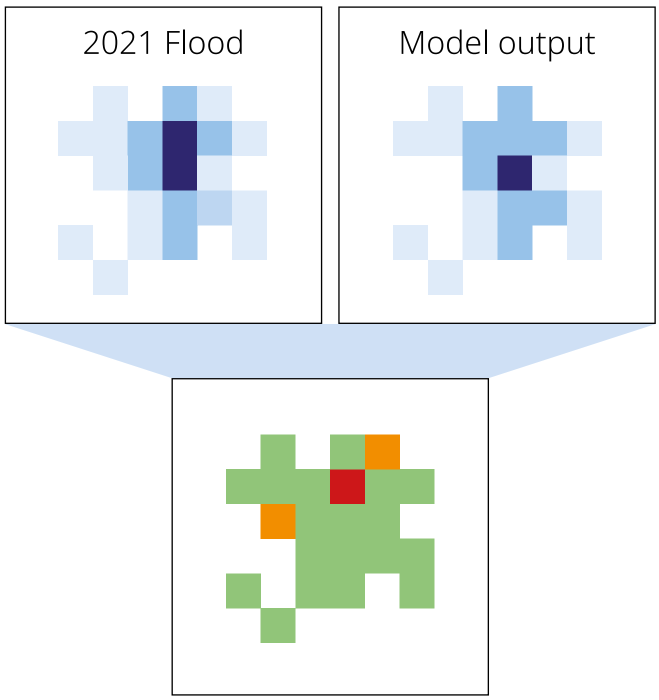
Infiltration polygons of study area based on soil class layers

Validating the modelling

To validate the model, its predictions were compared to the July 2021 flood event using recorded rainfall data.

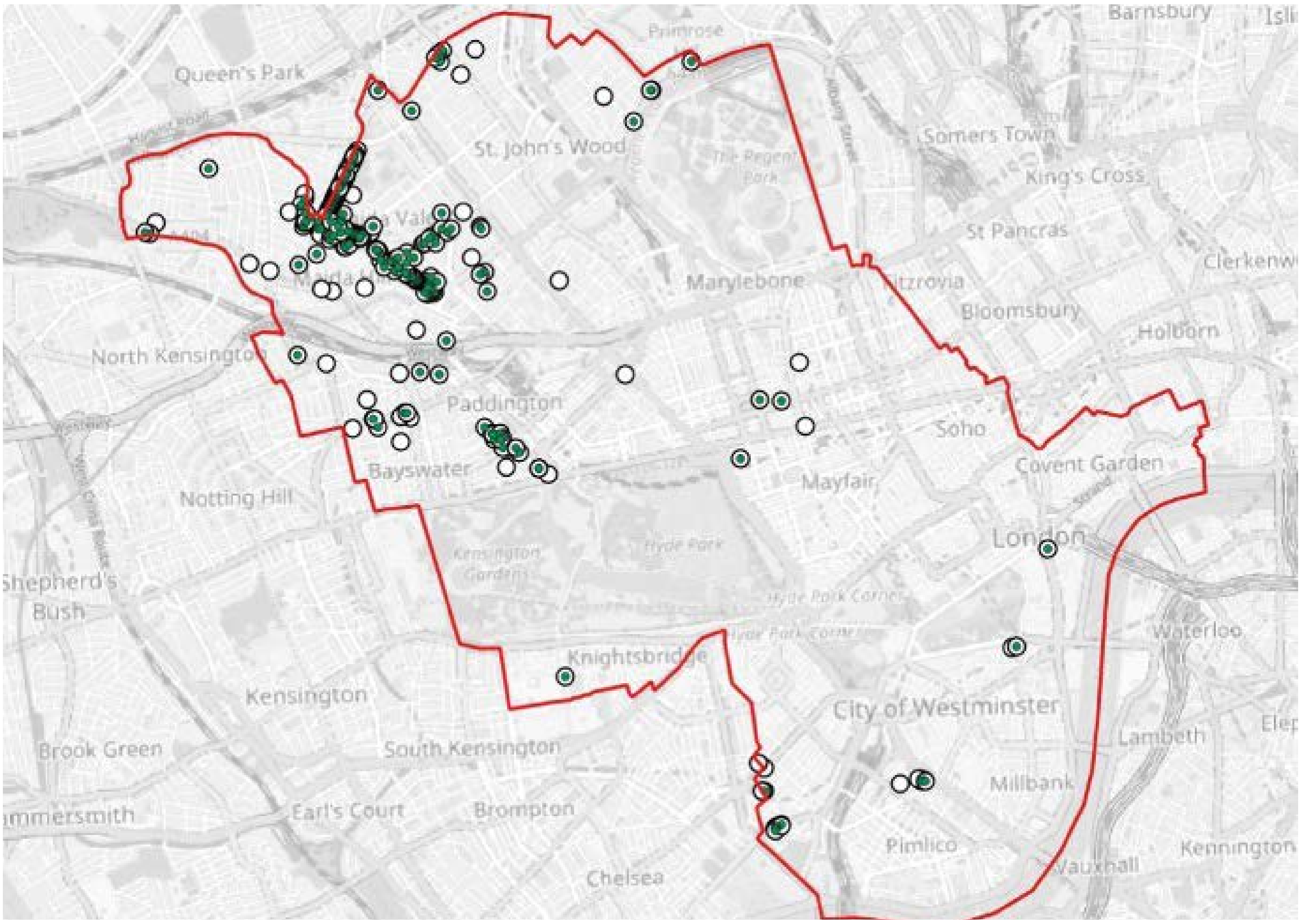
There was generally a strong comparison between the predictions generated from the rainfall of 2021, and the areas known to have flooded.

The modelling tracks similarly against the Environment Agency's Risk of Surface Water flooding mapping.



Validation by comparison shows good correlation

In Westminster, 200 of the 250 recorded flooding locations matched well with the model's predictions (indicated by green spots), demonstrating a good correlation for a model of this type and scale.



Appendix E: Climate change

To estimate the changes to surface water flood risk and its associated potential impacts, into the future, scenarios to allow for increases to peak rainfall intensity were required.

The latest Environment Agency Climate Change Allowances were used for this assessment. This approach is considered justifiable (being the current industry standard) and simple to apply.

The peak rainfall allowances show the anticipated changes in peak rainfall intensity. They are suitable for small, site-scale applications, and for broader urbanised drainage catchment mapping.

The Environment Agency provides a Central (C) and Upper (U) estimate of anticipated change. Noting that the Strategy adopted a time horizon of 50 years, up until 2075, Environment Agency guidance on the adoption of the Central or Upper allowance was followed. The guidance states that both the 3.33% (1 in 30 year) AEP and 1% (1 in 100 year) AEP events should be considered for the 2070s epoch.

The Strategy proposed to utilise a composite value, given the assessment focused on a range of annual exceedance probabilities, rather than simply these two events.

The guidance states that development with a lifetime between 2061 and 2100 should use the central allowance for the 2070s epoch (2061 to 2125). This is appropriate for the Strategy's assessment.

Table C1 outlines the approach taken to account for future climate change in London.

Considering the closeness of the uplift factors **it may be considered conservative to adopt the 1% AEP 2070s value of 33% to represent all rainfall intensities**.

This value will be assumed for the closed defined future horizon (likely to be 2075), and linearly extrapolated for other horizons (assuming 0% for the current horizon – likely to be 2025).

Table 7: Climate change allowances

Catchment	3.3% AEP				1% AEP			
	2050s		2070s		2050s		2070s	
	C	U	C	U	C	U	C	U
London Management Catchment	20%	35%	20%	35%	20%	40%	25%	40%
Roding, Beam and Ingrebourne Management Catchment	20%	35%	20%	35%	20%	40%	25%	40%
Darent and Cray Management	20%	35%	20%	35%	20%	45%	25%	40%
Average (all values)	20%	35%	20%	35%	20%	42%	25%	40%
Average (horizons)	28%		28%		31%		33%	

Appendix F: Flood impact projections

Summary

This Appendix outlines the process used for evaluating the strategic (and not just local) impact of surface water flooding in London, aiming to more comprehensively assess risk using vulnerability and cost implications, instead of just using predicted flood depths. By integrating diverse datasets and analysing exposure, vulnerability, and consequences, the strategy provides a clear overview of the effects of surface water flooding, thereby supporting effective and sustainable flood management strategies.

The evaluation framework uses the TfL Hex Grid as its spatial unit (350m x 350m), ensuring an assessment which considers multiple factors uniformly across space. This analysis incorporates landscape features, social demographics, critical infrastructure, property information, and environmental factors.

Key elements of the flood impact projection include:

Exposure to flood water
Identifying the number of people or structures at risk during rainfall events.

Vulnerability to flooding
The susceptibility and limits to adaptability of people or structures to flood depths, calculated by combining a series of social and demographic metrics.

Consequence of flooding
The financial and human costs (£) associated with a flood event on both a London-wide and community scale.

Flood impacts are derived based on the following relationship:

Exposure to floodwaters (%)	x	Vulnerability to surface water flooding (%)	x	Consequence of flooding (£)	=	**Flood impact (£)**

Flood impact was evaluated for several different rainfall events, which were subsequently used to derive an annual average value, based on the expected frequency of each surface water flood risk event.

Determination of factors

Exposure to floodwaters

Exposure was determined as the floodwater % coverage of each Hex Grid cell, split into three depth ranges: >0.15m, >0.3m, and >1.0m.

Vulnerability to surface water flooding

Vulnerability was determined as a product of sensitivity and adaptability of different 'receptors' to the three surface water flood depths defined in the previous section. Both factors for each receptor were applied a classification (very low, low, medium, high, very high) associated with a percentage value.

Engineering judgement was utilised to determine relative vulnerability, informed through collaborative discussion with the Strategy Working Groups, a desktop review of literature, and extensive engineering experience.

Receptor data was gathered from a variety of sources, primarily the National Receptor Dataset, OS geospatial data, and GLA / TfL Open data.

Calculating vulnerability

Vulnerability was calculated by combining a series of social and demographic metrics including socio-economic deprivation, primary language, health, and property type. When combined with the exposure of receptors to flooding, this allowed us to derive which Londoners were likely to be relatively more affected.

Our calculations used area data with percentages of people:

- under the age of 5
- over the age of 75
- not proficient in English
- in basement dwellings
- considered income deprived
- with disabilities
- with no formal qualifications
- with ill or poor health.

Consequence of flooding

Consequence was determined using financial values associated with the flooding of different receptor types to the surface water flood depths defined in the previous section. Cost data for the assessment were sourced from industry-standard references, including the Multi Coloured Handbook (https://www.mcm-online.co.uk/handbook/), the Office for National Statistics, and various publications from the Environment Agency.

For critical infrastructure costs, highway and rail transport information was used to deduce cost through the likely impact of surface water flood-related delays.

Considering uncertainty

All values, key assumptions, and input values included uncertainty banding; these were specified as lower, central, and upper. The flood impact calculations were run for each rainfall event and uncertainty scenario. The detailed models provide further guidance on the key assumptions relating to uncertainty banding.

Validating projections

A semi-quantitative approach was undertaken to provide an indicative validation of the impact assessment outcomes. The total cost of the summer 2021 flood events in London can be estimated by combining various reports and data points:

Insurance company losses:
Allianz and LV announced losses of £15 million and £7 million, respectively, due to the floods.[6]

Claims from loss adjusters:
Sedgwick, a leading UK loss adjuster, received over 2,000 flood claims during the key dates in July. Assuming these claims range between £25,000 and £50,000 each, the total cost would be between £50 million and £75 million.[7]

High-value individual claims:
Some individual claims exceeded £100,000, indicating significant costs for particularly severe damages.[8]

Overall cost estimates:
The higher estimate for the total cost of the summer 2021 events in London is estimated at £281 million.[9]

Combining these sources, the projected total cost for the summer 2021 flood events in London can be summarised as follows:

- Allianz and LV losses: £22 million
- Sedgwick claims: £50 million to £75 million
- Higher estimate for total costs: £281 million.

Based on this information, the total projected cost ranges from a minimum of around £50 million (Allianz, LV, and lower Sedgwick estimates) to a higher estimate of £281 million, taking into account the broader impact and more severe claims. This includes multiple flood events and provides an approximate cost of £140 million per event. These figures are expected to predominantly cover residential properties and critical infrastructure, but would not be considered to account for social wellbeing or risk to life impacts (as there was no loss of life during these events). This is also expected to represent a lower estimate, given the likelihood of further un reported damages.

The flood impact calculations were subsequently calibrated against the £140 million value for the lower uncertainty estimate. This calibration ensures the broad magnitude of estimates, and the projections for different rainfall depths and across London, are realistic.

Table 8: Table of data sources used in analysis

Name	Type	Source	Link	Used for
National Receptor Dataset	GIS (shape file)	Defra Data Services Platform	Available on request or via partnership with Local Authorities	Identification of property and critical infrastructure locations and categories
Passenger entries, exits and interchanges by station (annual), Great Britain, April 2022 to March 2023	Excel	Office of Rail and Road	https://dataportal.orr.gov.uk/statistics/ usage/estimates-of-station-usage	Station user vulnerability and disruption calculations
Mental health costs of flooding and erosion data	Excel	Environment Agency	Mental health costs of flooding and erosion - GOV.UK (www.gov.uk)	Mental health impact figures
MCM-Online, Data and Techniques, Chapter 4 – Residential Property data	Excel	MCM Online	www.mcm-online.co.uk	Calculating cost impact of flood risk for residential receptors
MCM-Online, Data and Techniques, Chapter 5 – Non-Residential Property data	Excel	MCM Online	www.mcm-online.co.uk	Calculating cost impact of flood risk for commercial or non-residential receptors.
Deprivation indices data	Excel	UK Gov	https://www.gov.uk/government/ collections/english-indices-of-deprivation	Calculating the relative flood impact costs of risk to the most deprived Londoners.
Population age data	Excel	UK Gov/ONS	Estimates of the population for the UK, England, Wales, Scotland, and Northern Ireland - Office for National Statistics (ons.gov.uk)	Calculating the relative flood impact costs in relation to the most vulnerable generations, namely children and pensioners
Language data	Excel	UK Gov/GLA Datastore	2021 census lsoa ethnicity language identity - London Datastore	Understanding vulnerability and determining needs assessment
Disability data	Excel	UK Gov/GLA Datastore	2021 lsoa qualifications health disability and care - London Datastore	Understanding vulnerability and determining needs assessment
Basement data	Shapefile (redacted to Hex grid scale)	Thames Water	On request only	Assessment of basement flooding vulnerability

Projected damages were assessed for each borough, and each was subjected to a lower, central, and higher estimate – see Table 9.

Table 9: Projected damage assessments (£) per borough

Borough	Baseline 2025 Annual Flood Damages (£)			Future 2075 Annual Flood Damages (£)			100yr NPV Damages (£)		
	Lower est.	Central est.	Higher est.	Lower est.	Central est.	Higher est.	Lower est.	Central est.	Higher est.
Hillingdon	130k	180k	170k	240k	210k	290k	4,300k	5,700k	7,000k
Hounslow	180k	200k	230k	260k	280k	320k	5,200k	6,800k	8,400k
Ealing	240k	300k	320k	400k	390k	500k	7,500k	9,900k	12,300k
Harrow	150k	210k	200k	270k	250k	340k	5,000k	6,600k	8,200k
Richmond upon Thames	170k	170k	220k	220k	270k	260k	4,600k	6,000k	7,300k
Brent	310k	440k	400k	580k	490k	720k	10,300k	13,600k	16,900k
Kingston upon Thames	180k	150k	230k	200k	290k	240k	4,600k	5,900k	7,300k
Barnet	360k	510k	480k	670k	590k	830k	12,100k	15,900k	19,800k
Wandsworth	530k	550k	690k	720k	850k	880k	14,900k	19,400k	24,000k
Hammersmith & Fulham	330k	440k	430k	590k	530k	730k	10,700k	14,200k	17,600k
Merton	210k	200k	280k	250k	350k	300k	5,600k	7,300k	8,900k
Sutton	120k	160k	160k	210k	200k	260k	3,900k	5,100k	6,300k
Kensington & Chelsea	640k	730k	840k	980k	1,040k	1,230k	19,000k	25,200k	31,400k
Westminster	1,100k	1,330k	1,440k	1,770k	1,780k	2,200k	33,700k	44,500k	55,200k
Camden	810k	990k	1,060k	1,310k	1,310k	1,620k	24,900k	32,800k	40,700k
Enfield	290k	350k	380k	450k	470k	560k	8,800k	11,500k	14,200k
Haringey	420k	520k	550k	680k	680k	830k	13,100k	17,000k	21,000k
Croydon	550k	590k	720k	760k	890k	930k	15,800k	20,500k	25,200k
Lambeth	750k	850k	980k	1,100k	1,210k	1,350k	22,200k	28,900k	35,500k
Islington	620k	770k	810k	1,030k	1,010k	1,280k	19,300k	25,500k	31,700k
City of London	220k	130k	290k	150k	350k	170k	4,700k	6,000k	7,200k
Southwark	550k	570k	720k	740k	890k	900k	15,500k	20,200k	24,800k
Hackney	470k	540k	610k	700k	760k	860k	13,900k	18,100k	22,400k

Borough	Baseline 2025 Annual Flood Damages (£)			Future 2075 Annual Flood Damages (£)			100yr NPV Damages (£)		
	Lower est.	Central est.	Higher est.	Lower est.	Central est.	Higher est.	Lower est.	Central est.	Higher est.
Bromley	350k	450k	460k	590k	570k	730k	11,100k	14,500k	17,900k
Tower Hamlets	390k	550k	510k	730k	630k	920k	13,000k	17,200k	21,500k
Lewisham	550k	670k	710k	870k	880k	1,070k	16,900k	22,000k	27,100k
Waltham Forest	290k	330k	380k	420k	480k	520k	8,600k	11,200k	13,700k
Greenwich	480k	560k	630k	730k	770k	900k	14,400k	18,800k	23,200k
Newham	270k	330k	360k	430k	440k	540k	8,400k	11,000k	13,600k
Redbridge	150k	190k	200k	250k	240k	310k	4,700k	6,200k	7,700k
Barking & Dagenham	140k	130k	190k	170k	230k	210k	3,800k	5,000k	6,100k
Bexley	180k	230k	240k	300k	290k	370k	5,600k	7,400k	9,200k
Havering	160k	240k	210k	320k	260k	400k	5,600k	7,400k	9,100k

Appendix G: Recommended needs and constraints assessment data sources

The Needs and Constraints assessment was undertaken to assess the likely scale of opportunity or constraint to each solution type, for each Hex Grid cell across London. Opportunity or constraint to action was estimated and quantified into a relative score from -2 to 2, whereby -2 characterises highly-constrained Hex Grid cells, and +2 characterises highly opportune, or unconstrained, Hex Grid cells.

A variety of physical and socio-economic metrics were adopted, and subsequently weighted, to estimate their likely influence on the implementation of a solution type.

Table 22: Recommended needs and constraints assessment data sources

Name	Type	Source	Link	Application	Metric / Classification	Conversion applied (if relevant)
Urban Morphology	GIS (shape file)	CDRC	https://mapmaker.cdrc.ac.uk/#/urban-morphology?lon=0.0282&lat=51.48&zoom=13.65		"Suburban Landscapes Railway Buzz The Old Town Victorian Terraces Waterside Setting Countryside Sceneries High street and promenades Central Business District"	Spatial join (sum)
Urban Morphology	GIS (shape file)	NRD			Detached/Semi-detached Terraced Flats Commercial"	Spatial join (sum)
Property Age	GIS (shape file)	CDRC	https://mapmaker.cdrc.ac.uk/#/dwelling-ages-prices?m=dwe_mdargb&lon=-0.2564&lat=51.4943&zoom=10.83		Average age	Spatial join (average)
Highway Network	GIS (shape file)	OS	https://osdatahub.os.uk/downloads/open/OpenRoads	Road Function	Motorway A Road B Road Minor Road Local Road Access Road"	Split & spatial join (sum)
Highway Network	GIS (shape file)	OS	https://osdatahub.os.uk/downloads/open/OpenRoads	Road Type	Length of each classification (m) Single C Dual C Slip Roundabout Busway Shared Use Collapsed Dual C"	Split & spatial join (sum)
Green Spaces	GIS (shape file)	GLA	https://data.london.gov.uk/dataset/green-and-blue- cover		No. of street trees	Spatial join (sum area)

Name	Type	Source	Link	Application	Metric / Classification	Conversion applied (if relevant)
Blue Spaces	GIS (shape file)	GLA	https://osdatahub.os.uk/downloads/open/OpenRivers		Area Coverage	Spatial split & join (sum length)
Blue Spaces	GIS (shape file)		https://data.london.gov.uk/dataset/green-and-blue-cover		Length of watercourses	
Blue Spaces	GIS (shape file)		https://gis2.london.gov.uk/portal/ apps/webappviewer/index. html?id=aab6511b947642dc846eaec0c4d4ccf5		Area Coverage	Spatial join (sum area)
Heritage & Protection	GIS (shape file)		https://opendata-historicengland.hub.arcgis.com/datasets/historicengland::national-heritage- list-for-england-nhle/explore?layer=0		Area Coverage	Spatial join (count)
Heritage & Protection	GIS (shape file)		Planning Data Map (london.gov.uk)		No. listed buildings	Split & spatial join (sum)
Topography	GIS (shape file)		Derived from LiDAR		Average slope (%)	Slope geoprocessing tool
Hydrogeological	GIS (shape file)	HOST	HOST SOIL Dataset (under license)			
Drainage Networks	GIS (shape file)		Under TWUL Data License		Length of network	
Drainage Networks	GIS (shape file)		Under TWUL Data License		Length of network (<= 750mm dia.)	Spatial join (sum length)
Drainage Networks	GIS (shape file)		Under TWUL Data License		Length of network	Spatial join (sum length)
Drainage Networks	GIS (shape file)		Under TWUL Data License		Length of network (<= 750mm dia.)	Spatial join (sum length)

Name	Type	Source	Link	Application	Metric / Classification	Conversion applied (if relevant)
Runoff Classification	GIS (shape file)		OS MasterMap		Area Coverage	Spatial join (sum length)
Runoff Classification	GIS (shape file)		OS MasterMap		Area Coverage	Split & spatial join (sum)
Runoff Classification	GIS (shape file)		OS MasterMap		Area Coverage	Split & spatial join (sum)
Property Value	GIS (shape file)		https://data.cdrc.ac.uk/dataset/dwelling-ages-and-prices		Average value	Split & spatial join (sum)
Social Deprivation	GIS (shape file)		https://mapmaker.cdrc.ac.uk/#/index-of-multiple-deprivation?m=imdh19_dc&lon=-0.1248&lat=51.5005&zoom=10.72		Average score (decile)	Spatial join (average)
Health Deprivation	GIS (shape file)		https://mapmaker.cdrc.ac.uk/#/access-healthy-assets-hazards?m=ah3g_pct&lon=-4.1091&lat=50.38&zoom=12.25		Average score (decile)	Spatial join (average)
Access to BGI	GIS (shape file)		https://mapmaker.cdrc.ac.uk/#/access-healthy-assets-hazards?m=ah3g_pct&lon=-4.1091&lat=50.38&zoom=12.25		Average score (decile)	Spatial join (average)
Landownership	GIS (shape file)		Privately Owned Public Spaces - London Datastore		Area Coverage	Split & spatial join (sum)
Access to Open Public Space	GIS (shape file)		https://data.london.gov.uk/dataset/green-infrastructure-focus-map		Hex Grid No. residents	Hex ID join
Development Opportunity	GIS (shape file)		Planning Data Map (london.gov.uk)		Area coverage for each classification	Split & spatial join (sum)
Local Boroughs	GIS (shape file)		https://osdatahub.os.uk/downloads/open/BoundaryLine		Name of borough	Spatial join (average)
TfL	GIS (shape file)		Sourced through partnership with TfL		Y/N overlaps TfL boundary	Spatial join (average)

Appendix H: Funding and investment estimates

This Appendix outlines the desktop assessment of the current funding and investment landscape for surface water management in London. The assessment utilises publicly available data and provides an indicative assessment of the total potential scale of funding availability across the capital, derived using expert weighting and judgement.

The assessment has likely not captured all sources of funding exhaustively, and weightings are derived from expert judgement, not empirical data, and are therefore subjective.

Investment estimates are capital costs and reflect the funds available for surface water management. They do not reflect the current ability of organisations to draw down upon these funds. Therefore, it is an estimated reflection of the total theoretical net capital available, rather than an assessment of the effectiveness of the provision of funding for surface water management.

Methodology

The calculation methodology for total estimated funding availability for surface water management in London is as follows.

1. **Translate national funding to London scale, via a London weighting**
   Where the funding is sourced, or administered, at a national level, a weighting to translate UK-wide funding pots to London was applied.

   A bespoke weighting was applied to each funding source, derived from expert engineering judgement and desktop assessment.

2. **Estimate likely surface water- specific funding allocation, via a surface water works weighting**
   To estimate likely funding and investment available for surface water-specific projects, a further weighting was applied to the residual value of funding from Step 1.

   A bespoke weighting was applied to each funding source, derived from expert engineering judgement and desktop assessment. The desktop assessment evaluated records of surface water schemes delivered in London, as well as other infrastructure projects that would likely have included surface water drainage interventions.

3. **Account for temporal variability**
   For funding sources that are periodic and long-term, a further weighting was applied to translate into an annual available sum.

   Intermittent funding sources were included, where appropriate.

4. **Apply allowance for uncertainty**
   An upper and lower range of uncertainty was applied to each of the assumptions.

   A final central estimate for total funding availability was calculated as the average of the upper and lower allowance. Uncertainty allowances were derived from expert engineering judgement and desktop assessment.

5. **Calculate the respective potential annual available sum**
   Applying the preceding steps, the annual available funding sum for each respective source is therefore:

Annual available sum
=
Total sum
x
London weighting
x
Surface water weighting
x
Uncertainty range
x
Temporal weighting

Weightings

Persistent funding sources

These are funding sources deemed to provide more consistent, annualised programmes of access to funding and investment. Although cyclical in nature, the Strategy assessment considered that persistent funding sources would likely remain consistent through the duration of the appraisal period. The figures in this table are derived from the consolidated table of funding sources contained at the bottom of this Appendix. For that additional detail, refer to table F-4.

Table 10: Investment weightings for London and surface water, for persistent, public funding sources

Funding / investment body	National > London adjustment (%)		Proportion attributed to action on surface water flooding (%)	
	Lower est.	Upper est.	Lower est.	Upper est.
Defra (FCERM Programme)	100%	100%	25%	50%
Defra (FCRIP)*	3%	10%	25%	75%
Local Authority (developers) (CIL)	100%	100%	0.50%	1.00%
Local Authority (developers) (Section 106)	10%	20%	1%	2.50%
TRFCC (Capital Grant)	20%	40%	10%	40%
TRFCC (local authorities) (Local Levy)	20%	40%	10%	40%
National Highways	1%	3%	5%	20%
Defra (ELMS)	3%	5%	0%	3%
NGOs and charities	100%	100%	25%	75%
TfL	100%	100%	1%	3%

*FCRIP is not explicitly persistent. This is a multi-year settlement that has the potential to be renewed.

Periodic funding sources

These are sources of funding typically made available on an ad-hoc, intermittent basis, such as for innovation investment purposes, or as part of accelerated, short-term programmes of work. The Strategy assessment assumed that periodic funding packages are available, in a variety of forms, for the duration of the appraisal period.

Table 11: Investment weightings for London and surface water, for periodic, public funding sources

Funding / investment body	National > London adjustment (%)		Proportion attributed to action on surface water flooding (%)	
	Lower est.	Upper est.	Lower est.	Upper est.
Ofwat	20%	30%	5%	20%
Defra	1%	3%	50%	75%

Private funding sources

These are sources of funding outside of public or government-sector contributions. As the RMA primarily responsible for the management of London's wastewater and surface water sewerage network, and a publicly listed company, Thames Water is included here as a private source of funding. Other private sector sources have been grouped together given that, at present, limited examples of private investment in surface water management exist in London.

Table 12: Investment weightings for London and surface water, for private funding sources

Funding / investment body	National > London adjustment (%)		Proportion attributed to action on surface water flooding (%)	
	Lower est.	Upper est.	Lower est.	Upper est.
Thames Water	20%	50%	1%	10%
Private Sector	100%	100%	1%	3%

Caveats

No allowance for inflation has been applied.

The list of potential funding sources is not expected to be exhaustive. The assessment has not captured all sources of funding across London.

Funding calculation is for both capital and revenue spending. There is no distinction provided in the annual available sum.

Funding sources

Table 13: Sources of funding and investment figures

Type	Funding / investment body	Funding / investment mechanism	Data source	Link	Metric / Classification
Persistent public funding	Defra	FCERM Programme Funding	Funding for FCERM March 2023 - updated 13102023 (Official Statistics)	Link	Government funding programme (via Defra / Environment Agency) that provides financial support for flood defence and coastal erosion risk management projects. The funding programme is aimed at local authorities and other relevant bodies to enable them to carry out flood protection activities: • £330 million (2010-2021 average in 2022/23 prices) • Funding availability tied to Environment Agency 5-year programmes • National funding pot Defra funding is administered via the Environment Agency and TRFCC
Persistent public funding*	Defra	FCRIP	Funding for FCERM March 2023 - updated 13102023 (Official Statistics)	Link	• A one-off £200 million
Persistent public funding	Local Authority (from private developers)	Community Infrastructure Levy	Mayor warns Government's Infrastructure Levy could massively reduce London's supply of new affordable homes (webpage)	Link	A charge which can be levied by Local Authorities on new development in their area. Comprised both Mayoral CIL and Borough CIL. • By the end of 2021/22 the CIL had generated approximately £1.43 billion for councils to deliver vital infrastructure and support sustainable growth across the capital.
Persistent public funding	TRFCC	Local Levy	Funding for FCERM March 2023 - updated 13102023 (Official Statistics)	Link	Funds are raised by a levy on local authorities and invested in FCERM. • £38 million

Type	Funding / investment body	Funding / investment mechanism	Data source	Link	Metric / Classification
Persistent public funding	National Highways	Environment and Wellbeing Fund	Designated funds plan 2020-2025 (report)	Link	Our Environment and wellbeing fund is helping us make sure our roads work more harmoniously with their surroundings. We are supporting environmental improvement and community wellbeing projects which go above and beyond traditional road investment. And we are developing plans with partners and stakeholders who are just as committed to protecting the environment as we are. We are investing in areas which will bring our network up to the latest environmental standards. They range from enhancing biodiversity and flood resilience, through to preserving our cultural heritage and assisting communities where the noise, light and air quality from our roads affects their daily lives.' • ~£1 billion (2020-2025) • Covers several funds – value ringfenced for flooding unknown
Persistent public funding	Defra	Environmental Land Management Scheme (ELMS)	Environmental Land Management (ELM) update: how government will pay for land-based environment and climate goods and services (Policy paper)	Link	• £2.4billion (national)
Periodic public funding	Ofwat	Innovation Fund	Water innovation competitions (Organisation webpage)	Link	• £40million 2023 fund
Periodic public funding	EA	Local Levy	Funding for FCERM March 2023 - updated 13102023 (Official Statistics)	Link	• £11million
Periodic public funding	Defra	Natural Flood Management Programme	Natural flood management programme (Guidance)	Link	• £25 million

Type	Funding / investment body	Funding / investment mechanism	Data source	Link	Metric / Classification
Private investment	Thames Water	AMP Programme (Capital & Revenue Delivery)	Thames Water annual report 2023-24 (Report)	Link	Investment plans and projects for each regulatory period, as approved by Ofwat • £4.3 billion AMP7, Waste Networks (2020-2025)
Private investment	Local Authority (developers)	Section 106 Agreements	The Incidence, Value and Delivery of Planning Obligations and Community Infrastructure Levy in England in 2018- 19 (Report)	Link	• £7 billion • 85% of private contributions from Section 106
Private investment	Private Sector	Infrastructure spending (development drainage)	Housing completions by London Borough (Statistics webpage)		The delivery of sustainable drainage infrastructure via development / re-development projects. This includes the provision of SuDS systems meeting and / or exceeding planning policy requirements • ~20k dwellings per annum (2023 figure – ONS) • Asm. 500ha of space = 0.3% per annum
Public investment	TfL	Safe & Healthy Streets Programme	TfL makes £80 million of funding available to boroughs to help make streets safer and improve bus journey times (Webpage)	Link	• £700 million (2022-2026)

* FCRIP is not explicitly persistent and currently only available until 2027. This is a multi-year settlement that has the potential to be renewed.

Table 14: Persistent public funding sources

Funding / investment body	Funding / investment mechanism	Application[10]	Raw value (£m/ annum)[11]	National > London adjustment (%)[12]		Proportion attributed to action on surface water flooding (%)		Projected funding and investment potential (£m/ annum)		
				Lower est.	Upper est.	Lower est.	Upper est.	Lower est.	Central est.	Upper est.
Defra	FCERM Programme Funding 2020-2026 (probable this programme will be repeated for another funding cycle)	Delivery	330	100%	100%	25%	75%	7	36	65
Defra	FCRIP Innovation Programme (2021- 2027)	Innovation and delivery	25	3%	10%	25%	75%	0	1	2
Local Authority (developers)	Community Infrastructure Levy	Delivery and maintenance	1,430	100%	100%	0.50%	1.00%	7	11	14
Local Authority (developers)	Section 106 Agreements	Delivery and maintenance	5,950	10%	20%	1%	2.50%	6	18	30
TRFCC (local authorities)	Local Levy	Delivery	38	20%	40%	10%	40%	1	3	6
National Highways	Environment and Wellbeing Fund 2020-2025 (indications this fund will be repeated for 2025-2030)	Delivery	936	1%	3%	5%	20%	0	3	6
Defra	Environmental Land Management Scheme	Delivery and maintenance	2,400	3%	5%	0%	3%	0	2	4
NGOs and charities	Funding contributions	Delivery								
Net		11,714						22	80	137
Net available for delivery			11,689					22	79	135
Net available for maintenance			9,780					13	30	48
Net available for innovation			25					0	1	2

Table 15: Periodic public funding sources

Funding / investment body	Funding / investment mechanism	Application	Raw value (£m/ annum)[13]	National > London adjustment (%)[14]		Proportion attributed to action on surface water flooding (%)		Projected funding and investment potential (£m/ annum)		
				Lower est.	Upper est.	Lower est.	Upper est.	Lower est.	Central est.	Upper est.
Ofwat	Innovation Fund	Innovation	40	20%	30%	5%	20%	0	1	2
Defra	Natural Flood Management Programme	Delivery	25	1%	3%	50%	75%	0	0	1
Net			17,414					28	126	1
Net available for delivery								0	0	1
Net available for maintenance								0	0	0
Net available for innovation								0	1	2

Table 16: Estimated available / applicable private investment

Funding / investment body	Funding / investment mechanism	Application	Raw value (£m/ annum)[15]	National > London adjustment (%)[16]		Proportion attributed to action on surface water flooding (%)		Projected funding and investment potential (£m/ annum)		
				Lower est.	Upper est.	Lower est.	Upper est.	Lower est.	Central est.	Upper est.
Thames Water	AMP Programme (Capital & Revenue Delivery)	Delivery and maintenance	2,600	20%	50%	1.0%	10%	5	68	130
Private Sector	Infrastructure spending (development drainage)	Delivery	567	100%	100%	1%	3%	6	11	17
TfL	Safe & Healthy Streets Programme	Delivery	97	100%	100%	1%	3%	1	2	3
Net			**3,264**					**12**	**81**	**150**
Net available for delivery			3,264					12	81	150
Net available for maintenance			2,600					5	68	130
Net available for innovation			0					0	0	0

Appendix I: Derivation of future expenditure estimates

An approach to estimating requirements for future investment to address surface water flood risk was developed for the Strategy. The approach followed similar methodologies used for fluvial and coastal investment planning.

Time Horizon

In line with the modelling and impact assessment approach, a 50-year time horizon was adopted for the estimation of Net Present Value (NPV).

Utilising a 50-year horizon was deemed to provide the following benefits:

- It considers far enough into the future to allow meaningful, observable, change to be delivered within that period of time
- It is aligned to other strategic planning documents in London, such as Water Resource Management Planning
- It achieves an appropriate balance between uncertainty around future change, and ambition to implement more strategic, long-term action in London
- It will provide a coherent timeline for shorter-term plans and documents to align with

Benefit Cost Ratio

The Strategy adopted a simplified approach to quantifying BCR for surface water infrastructure projects.

Traditionally, in England and Wales, BCR is used to calculate the economic feasibility of flood and coastal risk management schemes. In our assessment, the calculation moves away from the existing approach to provide a more simplified, pan-London method for assessing costs versus outcomes, otherwise known as 'return'.

The Strategy developed projected BCRs through consultation with the sector, expert engineering judgement, and a desktop review of previous, similar studies.
The composite BCRs produced are, therefore, a reflection of realistic returns for surface water schemes, and provide an evidence-based quantification of BCR across the differing organisations in London, many of whom use slightly different metrics and measures to identify benefit-cost, or return on investment.

Benefit Cost Bands

Three bands for BCR were developed, based on the impact a project may have on the reduction in surface water flood risk. They are designed to reflect the nature of surface water schemes in reality, given that these projects vary widely in scope and impact: some projects are likely to be more economically difficult to justify (particularly small-scale projects), and some will have greater flood risk benefits than others – especially bearing in mind the potential outcomes of some of this Strategy's larger-scale, strategic priorities in reducing surface water flood risk.

The three bands developed and applied were:

Band 1:
Higher impact, standout schemes where the flood risk reduction benefit is significant in relation to the cost

Band 2:
Medium impact, equitable schemes (i.e. 'break- even' schemes) where the flood risk benefits are equal to the cost of project implementation

Band 3:
Lower impact in terms of flood risk reduction, more economically challenging projects, where benefits must be realised from the aggregation of non-flood-risk improvements (e.g. placemaking, air quality, etc.) as well as from reductions in flood risk.

Weightings

To capture the breadth of action required in London, both on our strategic flood priorities, but also at a borough scale, the Strategy assesses different combinations of BCR weightings to produce composite estimates for likely required investment. The three bands were developed to reflect uncertainty and capture the composition of schemes at the catchment scale.

Table 17: Future expenditure estimates

Variable	Code	Lower estimate	Central estimate	Upper estimate	Calculation (based on codes)	Comments and assumptions
50yr NPV Impact Cost	NPV	£330,704k	£443,075k	£529,613k		
Band 1-BCR	B1	2.50	1.00	0.75		Upper estimate of BCR
Band 2-BCR	B2	1.00	0.25	0.10		Central estimate of BCR
Band 3-BCR	B3	0.25	0.10	0.05		Lower estimate of BCR
Band 1-%	B1a	30%	20%	10%		Proportion of funding delivered at upper estimate of BCR
Band 2-%	B2a	60%	50%	40%		Proportion of funding delivered at central estimate of BCR
Band 3-%	B3a	10%	30%	50%		Proportion of funding delivered at lower estimate of BCR
Band 1-Est. Invest Expenditure	B1I	**£41,516k**	**£92,728k**	**£73,867k**	(NPV X B1a) / B1	
Band 2-Est. Invest Expenditure	B2I	**£207,582k**	**£927,285k**	**£2,216,003k**	(NPV X B2a) / B2	
Band 3-Est. Invest Expenditure	B3I	**£138,388k**	**£1,390,927k**	**£5,540,008k**	(NPV X B3a) / B3	
Net 50yr Invest Expenditure	Nin	**£387,486k**	**£2,410,941k**	**£7,829,878k**	B1I + B2I + B3I	
Net Annual Invest Expenditure	Nain	**£7,750k**	**£48,219k**	**£156,598k**	Nin / 50	
Asm. Borough Annual Investment Expenditure		**£242k**	**£1,507k**	**£4,894k**	Nain / 32	Indicative net annual investment per borough (based on uniform split)
Average BCR		1.38	0.36	0.14		
75% Net 50yr Investment Expenditure (to meet risk reduction target)		£290,615k	£1,808,205k	£5,872,409k		
75% Net Annual Investment Expenditure		£5,812k	£36,164k	£117,448k		

Appendix J: Derivation of proposed Strategy Catchments

Summary

To support this London Surface Water Strategy, a novel approach to model and map the nature of surface water flood risk was adopted. A selection of catchments, defined by their hydrological characteristics, was identified to inform strategic action and approach surface water flood risk from a catchment scale, rather than simply focusing on flooded receptor areas.

The Strategy Catchments were formulated by grouping TfL Hex Grid cells through a series of steps:

1. Mapping how surface water would flow between cells
2. Identifying the predominant path that surface water follows
3. Charting the routes both of underground and surface-level watercourses and where they discharge
4. Tracing the catchments upstream of each watercourse's discharge location
5. Merging these catchments into eleven Strategy Catchments based on shared landscapes and drainage systems

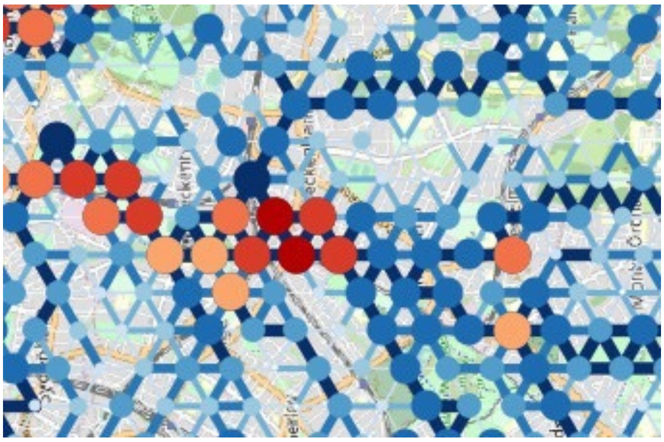
Surface water routing network

To enable the derivation of the surface water runoff areas, a routing network for surface flows and floodwater accumulation was produced. This network followed the gridded structure of the TfL Hex Grid (i.e. links from centroid to centroid).

The process utilised model predictions (and using supplementary data) equivalent to a 1 in 30-year short-duration event.

The routing network was created from the 2D model predictions, which defined the cumulative volume and flow direction between each cell and its neighbours. The dataset demonstrates how each unit of rainfall landing in every cell is routed to the 'wetspots' or areas of flooding, and ultimately drains to its terminal receptor (e.g. the River Thames, or other watercourse).

Figure 30: Excerpt from routing network for surface water overland flow



Simplified sewer network schematic

To enable the derivation of the drainage sub- network areas, a simplified schematic of the total buried drainage network was produced. This schematic followed the gridded structure of the TfL Hex Grid (i.e. links from centroid to centroid). This process considered combined and surface water sewers but omitted foul-only links.

The process used model predictions (and supplementary data) equivalent to a 1 in 30-year short duration event.

This network required the following geoprocessing steps:

1. Simplification of raw network data, specifically the removal of intermediate nodes
2. Clipping network links to TfL Hex Grid centroids
3. Merging of all clipped links (inc. peak flow and cumulative volume data)
4. Identification of common direction (i.e. the predominant flow direction)
5. Manual check of connectivity (to identify and correct any anomalies)

The derived schematic represented how each TfL Hex Grid cell is connected to its neighbours, ultimately demonstrating how flow is routed to each sewage treatment works and / or surface water outfalls.

Surface water flood areas

Flood areas functioned to provide the focal points for the surface water runoff areas and underpin the need for solutions. They were derived from the 2D model predictions, with reference to supplementary data where necessary.

Isolating whether each TfL Hex Grid cell was defined as a 'wetspot' – or flood area – was based on the calculated consequence values (as determined within the flood impact assessment).

All cells with a consequence value >= 50th percentile of all values were automatically selected. These were defined as relative 'priority areas'. Reference was made to the following supplementary data sources for comparative purposes to establish whether other cells should be defined as a 'wetspot' and validate the model predictions:

- Environment Agency Risk of Flooding from Surface Water (RoFSW)
- LB SFRAs
- LB SWMPs (flood wetspots)
- CDAs
- London Regional Flood Risk Appraisal

Where several cells are adjacent and considered to be related (in terms of flood mechanism) they were merged. Wetspots were identified for rainfall depths up to the level expected due to climate change. For each wetspot, the values from the flood impact assessment were combined (average, sum, and max), for use during later stages.

'Lost river' basins of London

To support the derivation of the regional runoff sub catchments' surface water runoff areas, the river basin boundaries for the lost rivers of London were derived. Historical maps of the 'lost rivers' of London, and Environment Agency LiDAR data, were used to define the basins. The basin boundaries were then converted to TfL Hex Grid format (clusters of cells).

Strategic development areas

To support the identification of the Strategy Catchments, the areas of London most likely to be subject to major / strategic development were identified and integrated into the method.

Datasets from the GLA Planning Datamap portal were used. A TfL Hex Grid layer was populated, based on the geographical overlap, with data from the following layers:

- Brownfield land registers
- Opportunity areas
- Areas of intensification
- Strategic housing land availability assessment
- Site allocations

Where each cell was covered (>= 50% of the area) by one (or several) of the above layers it was defined as a 'Strategic Development Area'.

In addition to this data identifying growth, the layer was populated with layers indicating land that is protected and would likely inhibit development. This information was drawn from the following datasets:

- Designated Open Space
- Site of Importance for Nature Conservation (SINC)
- Sites of Special Scientific Interest (SSSI)
- Conservation Areas Ancient Woodland
- Scheduled Monuments

The definition of a cell being a Strategic Development Area was removed where it was covered (>= 50% of the area) by one (or several) of the above 'inhibiting' layers.

Urban typologies

This dataset provided a broad classification of different urban landscapes in London, reflective of a range of key attributes useful for this Strategy.

It enabled the clustering of areas of common typology, helping to inform the boundaries for sub catchments to align common areas together.

The definition of typologies was grouped into the following:

Landscape & Environment (total 48 classes)

- Urban morphology (8 classes): Typology of neighbourhoods based on a number of built environment and urban morphologies, provided by CDRC[17]
- Property age (3 classes): broad age categories for the landscape, estates, and properties, provided by CDRC[18]
- Blue-green spaces (2 classes): existing blue-green coverage

Drainage & Hydrology (total 6 classes)

- Drainage system type (2 classes): combined or separate system
- Impermeability (3 classes): identifying areas of higher or lower permeability (coverage of green space used as a proxy for permeability in the absence of detailed infiltration potential)

Social & Economic (total 18 classes)

- Property / land value (3 classes)
- Social / health deprivation (3 classes)
- Land ownership (3 classes) – i.e. predominantly private or public

Further detail on these variables is provided in Appendix E. Each group comprised several classifications which were derived for all TfL Hex Grid cells. Adjacent cells with the same typology were merged to form clusters.

Local runoff subcatchments

The local runoff subcatchments represent the connectivity of local / community-scale runoff and floodwater accumulations, typically experienced during more frequent rainfall (i.e. a 1 in 30-year short-duration event). These catchments were used to quantify community- level need and evaluate community-scale solutions.

Hundreds of these catchments were identified across London.

Surface Water Runoff Areas

These areas were applied as a non-overlapping, contiguous dataset across Greater London. They were formulated by grouping TfL Hex Grid cells to reflect the surface runoff routing and floodwater accumulations predicted by the modelling (plus supplemental supporting data, as necessary). The data used for this process included:

- Surface water model flood predictions (using the Surface Water Routing Network): 1 in 30- year short duration event
- Environment Agency RoFSW dataset (to provide secondary predictive information)
- Topographic data (DTM contours, extracted from Environment Agency LiDAR data)

The process used was:

1. Trace the catchment upstream from the Surface Water Flood Wetspots, and combine cells
2. Stop trace once next Surface Water Flood Wetspots reached

Drainage sub-network areas

These areas were defined based on the identification of key hydraulic and / or capacity pinch-points within the simplified network and were used to segment larger networks into sub- networks. The pinch-points were identified from the predicted flooding and / or provided sewer flooding, and capacity data (from the Thames Water DWMP).

These data were used to derive sewer flood 'clusters' and identify where they intersected with the simplified sewer network schematic. Combined runoff catchments

The surface water runoff areas, and drainage sub-network areas, were combined into a single catchment. Each catchment comprised a single surface water runoff area, plus zero, one, or several drainage sub-network areas associated with it.

The association of the areas was based on their overlap. Once associated, if there was more than one drainage sub-network area, they were combined into a single area.

Approximately 50 - 100 of these catchments were identified across London.

Regional runoff subcatchments

The regional runoff subcatchments were developed to represent the connectivity of larger-scale runoff, flow routing, and floodwater accumulations, typically experienced during more extreme rainfall (i.e. a 1 in 100-year long- duration event). These catchments were used to identify longer-term resilience needs, and regional-scale solutions.

These catchments consolidate the surface water runoff areas, and drainage sub-network areas, into larger catchments. The drainage sub-network areas were derived to intentionally overlap adjacent regional runoff subcatchments. This derivation is reflected in the proposed governance, management, and partnerships structures for the strategy, recognising the fuzzy and overlapping mechanisms around the boundaries between catchments.

Consolidating the local runoff subcatchments

These areas were formed by combining the local runoff catchments, and combined runoff catchments, based on connectivity and model predictions. The process utilised the model predictions to show where multiple surface water wetspots were situated along a continuous flow path and should therefore be treated as a single catchment.

The definition also made reference to the 'lost rivers' of London, seeking to align boundaries with their river basins, where relevant.

The data used for this process comprised:

- Surface water model flood predictions (using the surface water routing network): 1 in 100- year long duration event
- Environment Agency RoFSW dataset (to provide secondary predictive information
- Topographic data (DTM contours, extracted from Environment Agency LiDAR data)

Catchments were derived from the local runoff catchment surface water runoff areas, through which it was distinguished where either there was a clear break in the flow pathway, or where flows discharged to the River Thames. Any open watercourses within Greater London were included within the catchments, and did not function to break the catchments.

25 – 50 of these catchments were identified across London.

Accounting for urban typologies

The identification of solutions was based both on the regional runoff subcatchments and the Strategy Catchments. To support this process, urban typologies were accounted for during the derivation of the boundaries through the combination of the local runoff areas.

The objective of this was to minimise the number of different typologies within each catchment. This helped to focus the likely need and solution types, and aid the alignment of catchment boundaries with existing social communities.

Strategy catchments

The Strategy Catchments define the boundaries for the Sub-Strategies, comprising focused objectives, outcomes, and local solution pathways. Their coverage is reflective of the regional runoff subcatchments and several other geographic considerations. They form the basis for connecting the RMAs) into coordinated groups.

Each catchment is formulated with a unique 'identity' that provides a bespoke approach to risk management and the development of solution pathways.

Their derivation, from the regional runoff subcatchments, was undertaken in consultation with the Flood Ready London Strategy Working Group.

Eleven Strategy Catchments were initially derived for London – NB: this will be reduced to ten following engagement work commenced for this Strategy..

Formulating preliminary catchment recommendations

Identifying which regional runoff subcatchments to combine into Strategy Catchments was undertaken with reference to the following:

- Lost Rivers of London catchment boundaries
- Thames Water DWMP - alignment along the boundaries to integrated sewer risk and solutions, and avoid unnecessary complexity and unintended misalignment of drainage systems
- Level 2 Catchments boundaries
- Catchment Strategic Plans boundaries
- Catchment Partnerships boundaries
- Thames 21 Catchment Partnerships boundaries
- Strategic Development Areas
- Existing flood risk and water management partnerships – alignment to avoid intersecting existing partnerships boundaries
    - East London Subregional integrated water management strategy (https://www.london. gov.uk/sites/default/files/iwms_new_cov- er_low_res.pdf)
    - Old Oak Common and Park Royal Integrated Water Management Strategy (https://www.london.gov.uk/sites/ default/files/2023-07/Sub-regional%20 integrated%20water%20 management%20 strategy%20East%20 London%20-%20 July%202023.pdf)
    - Old Kent Road Integrated Water Management Strategy (https://www. southwark.gov.uk/assets/attach/12826/ EIP60-OKR-integrated-Water-management-strategy-2016-.pdf)
    - Charlton to Bexley Riverside Integrated Water Management Strategy (https://www. bexley.gov.uk/sites/ default/files/2021-10/ Charlton-to-bexley-riverside-integrated-wa-ter-management-strategy-2017.pdf)
    - Isle of Dogs and South Poplar Integrated Water Management Plan (https://www. towerhamlets.gov.uk/ Documents/Plan-ning-and-building-control/Infrastructure-de- livery/IWMP-Main-Report.pdf)

The preliminary recommendations for the Strategy Catchment boundaries were shared with the Flood Ready London Strategy Working Group and Flood Ready London Officer Group for review and comment.

Refinement

The Strategy Catchment boundaries were amended following comments from the working groups. In addition to this, further adjustments were made to address the following issues:

- Avoiding London Boroughs overlapping more than two catchment boundaries (to avoid administrative complexity), where possible and/or appropriate
- Aiming to ensure areas of TfL land are within a single catchment where possible, where a TfL road runs along a catchment boundary

Confirmation of Final Strategy Catchments

The refined preliminary catchment recommendations were shared with the Flood Ready London Group for approval. This consultation presented the derivation process, showing the stages from local runoff subcatchments to regional runoff subcatchments, through to the recommendations and adjustments made.

When compared with existing partnerships and catchment groups (inc. CaBA catchments, Thames 21 catchment partnerships, and the Lee Valley Subregional Integrated Water Management Strategy), the catchment extents and boundaries show strong alignment.

Every London Borough falls within a Strategy Catchment. In sixteen cases boroughs bridge two Strategy Catchments (defined as where catchments extend over at least 5% of a borough's administrative area).

Three boroughs (Ealing, Greenwich, and Haringey) span three Strategy Catchments. This arrangement means that many boroughs will need to engage in actions across multiple Strategy Catchments.

Table 18: Boroughs in Catchment Partnerships

London Borough		Beam and Ingre-bourne	Central London	Effra-Wandle	Lee Valley	Marsh Dykes	North West London	Ravens-bourne	Roding	South East London	South West London	West London
Barking and Dagenham	2	X							X			
Barnet	2				X		X					
Bexley	2					X				X		
Brent	2		X				X					
Bromley	2							X		X		
Camden	1		X									
City of London	1		X									
Croydon	2			X				X				
Ealing	3		X				X					X
Enfield	1				X							
Greenwich	3					X		X		X		
Hackney	2		X		X							
Hammersmith and Fulham	1		X									
Haringey	3		X		X		X					
Harrow	2						X					X
Havering	1	X										
Hillingdon	1											X
Hounslow	2						X					X
Islington	2		X		X							

London Borough		Beam and Ingre-bourne	Central London	Effra-Wandle	Lee Valley	Marsh Dykes	North West London	Ravens-bourne	Roding	South East London	South West London	West London
Kensington and Chelsea	1		X									
Kingston upon Thames	1										X	
Lambeth	1			X								
Lewisham	2			X				X				
Merton	2			X							X	
Newham	2				X				X			
Redbridge	1								X			
Richmond upon Thames	2										X	X
Southwark	1			X								
Sutton	2			X							X	
Tower Hamlets	2		X		X							
Waltham Forest	1				X							
Wandsworth	2			X							X	
Westminster	1		X									

Legend

- Boroughs within only one Strategy Catchment
- Boroughs within two Strategy Catchments
- Boroughs within three Strategy Catchments

Derivation of proposed Subcatchments

Subcatchments represent the indicative source, or receptor, areas in which action ('capture', 'Control', 'adapt') should be taken to address strategic priorities. These strategic priority areas are those areas which manifest either as flooded, or which provide a source of runoff that manifests flooding elsewhere.

This simple 'Source-Pathway-Receptor' approach was discussed and agreed with Strategy Working Groups, before commencement of the modelling.

The subcatchments were derived via the following process:

Table 19: Subcatchment derivation process

Action	Description
1	Rainfall was applied uniformly over the surface of the Hex Grid cell. A network model connected each hex grid, based on the predominant flow direction and using elevation data (i.e. water will generally flow downhill, subject to the connectivity of the drainage network). Flow was calculated at each face of the Hex Grid, indicating the predominant flow direction
2	This network was then used to automatically trace (using open-source coding software) upstream from each strategic priority area, until it either reached the top of the catchment watershed OR another strategic priority area
3	The strategic priority areas could also be defined informally as 'wetspots' – i.e. the locations to which rainfall flows and eventually collects, resulting in flooding
4	These areas were defined and finalised by combining all the individual Hex Grids considered strategic priority (i.e. at greater susceptibility to rainfall than the London average) where they adjoin, then splitting those where they crossed sewage treatment works catchments
5	All the flood impact data were then agglomerated

Caveats

- The approach taken is a simplification of the hydraulic and hydrological processes taking place in London. More detailed modelling would be required for any projects or interventions intended to address the estimated flood risk for each Hex Grid cell, or agglomeration of cells.
- While topography and existing drainage systems strongly influence the nature of flow within any given Hex Grid cell, other localised factors may influence flow and therefore the 'Source- Pathway-Receptor' mapping outputs is intended to inform strategic collaboration and decision-making only, rather than showing a detailed, localised output of flow characteristics.

Appendix K: Targeted intervention assessment

Process

This process was developed to determine which intervention type (i.e. 'Capture', 'Control', 'Adapt') should be undertaken for each location. The methodology is as follows:

Table 20: Targeted intervention process

Step	Task	Description
1	Input hydraulic flood model data	Extract flood volume data, for each Hex Grid cell, from hydraulic integrated catchment model. Flood volume data was calculated as the volume of surface water flooding across the extent of the Hex Grid cell, for each specific rainfall event.
2	Input constraints data	A total of 15 factors that constrain or enable implementation of different flood risk management interventions. For each grid cell, a weighting for the relative constraint or opportunity for implementation was determined. Weighting was developed through expert engineering judgement, as well as consultation with the London Surface Water Strategy Working Groups.
3	Classify relative constraint/ opportunity for the strategic solutions hierarchy	Assess and calculate the relative constraint to action for each type of strategic solution hierarchy approach ('Capture', 'Control', 'Adapt'). A composite score, comprising the sum of weighted constraint to action, for each respective type of solution, was calculated. The composite constraint score estimates which solution type is optimal to implement, for each Hex Grid cell. By providing a scale of relative constraint, decision-makers can also determine where the relative benefit of action outweighs moderate or low constraint.
4	Derive the projected area available across London for each of the 'Capture', 'Control', 'Adapt' intervention types	The projected area available for delivery of solution types was determined using a variety of geospatial data. Variables including paved spaces, buildings, public realm, and green spaces were quantified for each Hex Grid cell. This method provides an indication of the spatial opportunity for SuDS, and indicates where traditional grey drainage engineering may be better suited for implementations.
5	Determination of 'Capture' capacity per Hex Grid cell	Adopting the Solutions hierarchy, 'capture' solutions were first prioritised. For 'capture', determine whether there is capacity to accommodate the target volume (eq. 0.15m depth x area) within the area available.

Step	Task	Description
6	Determination of 'Control' capacity per Hex grid cell	Where a deficit in 'Capture' of a volume of water exists, it is assumed to pass to the 'Control' interventions. 'Control' interventions are assumed to have capacity for the following 30mm of rainfall depth, up to 45mm.
7	Determination of 'Adapt' and 'Respond' requirement per Hex grid cell	Where a deficit remains in the capacity of 'Capture' and 'Control' solutions, the remaining deficit is assumed to require 'Adapt' and 'Respond' actions. 'Adapt' and 'Respond' capacity is calculated to account for a further 30mm of rainfall, to a depth of 75mm.

Assumptions

- This approach has been developed so that any area deficit from a previous phase is always passed on to the next intervention type: i.e. an area deficit in 'Control' is automatically passed on to 'adapt'.
- Results are derived from this process as a volume and area, which is considered easily understandable for most users given that 'area' is an easier metric for demonstrating the scale of action (i.e. it can represent, for instance, a percentage of available impermeable area required for a 'Capture' function).
- For the 'Adapt' intervention, the output is translated into the average depth of flooding to be adapted to in a given area, as providing this information as an area would not produce a meaningful answer.

Caveats

- This process has been based on best professional endeavour using relevant raw data and pragmatic assumptions to ensure a realistic and informative outcome. It is NOT intended as a detailed and numerically-precise calculation of what and where specific, project-level action needs to occur.
- The Strategy outlines the scales at which RMAs and Catchment Partnerships will need to undertake further detailed modelling to evidence and support the delivery of specific surface water flood risk reduction interventions.

Table 21: Assumptions

Assumption	Value	Units	Description
Baseline Opportunity	70%		Prior assumption of the proportion of any location viable for NbS (i.e. sets an assumption that NbS can be delivered across 70% of the suitable land in London, considered a highly positive outcome)
Motorway	30	Average Width (m)	
A Road	20	Average Area (m^2)	
B Road	15	Average Area (m^2)	
C Road/Unclassified	10	Average Area (m^2)	
Highway area runoff	90%	% of area	Net average proportional area likely to contribute runoff that could be intercepted and managed by NbS
Private area runoff rate	60%	% of area	Net average proportional area likely to contribute runoff that could be intercepted and managed by NbS
Green area runoff rate	30%	% of area	Net average proportional area likely to contribute runoff that could be intercepted and managed by NbS
Other area runoff rate	20%	% of area	Net average proportional area likely to contribute runoff that could be intercepted and managed by NbS
Capture highway area applicability	20%	% of area	Proportion of area considered typically viable for NbS (without knowledge of specific constraints)
Capture private area applicability	5%	% of area	Proportion of area considered typically viable for NbS (without knowledge of specific constraints)
Capture green area applicability	30%	% of area	Proportion of area considered typically viable for NbS (without knowledge of specific constraints)
Capture other area applicability	75%	% of area	Proportion of area considered typically viable for NbS (without knowledge of specific constraints)
Capture depth threshold	0.015	m	
Capture volume threshold	1,591	m^3 per hex grid	
Capture capacity depth	0.250	m	Typical / average depth of NbS (functional water depth)
Control highway area applicability	30%	% of area	Proportion of area considered typically viable for NbS (without knowledge of specific constraints)
Control private area applicability	10%	% of area	Proportion of area considered typically viable for NbS (without knowledge of specific constraints)
Control green area applicability	35%	% of area	Proportion of area considered typically viable for NbS (without knowledge of specific constraints)

Assumption	Value	Units	Description
Control other area applicability	50%	% of area	Proportion of area considered typically viable for NbS (without knowledge of specific constraints)
Control depth threshold	0.045	m	
Control volume threshold	4,772	m^3 per hex grid	
Average sewer capacity	375	m	40%ile of all London sewers (combined/partially separate)
Pipe full capacity	0.15	m^3/s	Asm. 1:150 gradient
Average road width	13.2	m	Asm. 9m carriageway, plus 1.5m pavements and 10% for connecting spaces
Average paved drainage capacity	0.011	$m^3/s/$linear m	
Average gully catchment	165	m^2	
Average gully discharge rate	0.010	m^3/s	
Average gully drainage capacity	1.2	m^3	
Average gully drainage capacity	0.007	m^3/m^2	
Control capacity rate	1.12	m/m^2	Typical control discharge rate per area, determined for a 2hr event
Adapt depth threshold	0.075	m	
Adapt volume threshold	7,953	m^3 per hex grid	
Control highway acceptable surface water	0.01	m	Depth of surface where runoff can be actively intercepted and managed by NbS (lower depths considered standing water)
Control private area acceptable surface water	0	m	Depth of surface where runoff can be actively intercepted and managed by NbS (lower depths considered standing water)
Control green area acceptable surface water	0.025	m	Depth of surface where runoff can be actively intercepted and managed by NbS (lower depths considered standing water)
Control other area acceptable surface water	0.025	m	Depth of surface where runoff can be actively intercepted and managed by NbS (lower depths considered standing water)
Predominant need factor	1.5		Multiplication factor to define whether a specific need is dominant (of the other two) or not
Non-priority runoff factor	0.3		Proportion of non-priority in-cell flooding that an intervention will have to accommodate (in addition to the priority flooding downstream)

Endnotes

1 UK Government. 'Flood and Water Management Act 2010' 2010 (viewed on 3 April 2025)

2 Ministry of Housing, Communities and Local Government, 'Planning practice guidance', 2024 (viewed on 3 April 2025)

3 Greater London Authority. 'The London Plan 2021' 2021 (viewed on 3 April 2025)

4 CIWEM. 'Surface water management: A review of the opportunities and challenges' 2023 (viewed on 3 April 2025)

5 Greater London Authority. 'London Sustainable Drainage Action Plan' 2021 (viewed on 3 April 2025)

6 JBA Risk Management. 'A retrospective look at summer 2021 London flash floods' 2021(viewed on 3 April 2025)

7 JBA Risk Management. 'A retrospective look at summer 2021 London flash floods' 2021(viewed on 3 April 2025)

8 Post Online. 'Analysis: The rise and flood risk of the super basement' 2021 (viewed on 3 April 2025)

9 Post Online, 'Perils pegs London's 2021 summer flood losses at £281m' 2021 (viewed on 3 April 2025)

10 Defines the potential application of the funds

11 Periodic funding figures have been converted to per annum based on the total projected funding periods

12 Adjustment factor estimates relevance of regional / national funding

13 Periodic funding figures have been converted to per annum based on the total projected funding periods

14 Adjustment factor estimates relevance of regional / national funding

15 Periodic funding figures have been converted to per annum based on the total projected funding periods

16 Adjustment factor estimates relevance of regional / national funding

17 Consumer Data Research Centre. 'Urban morphology map' 2021 (viewed on 3 April 2025)

18 Consumer Data Research Centre. 'Dwelling ages and prices' 2023 (viewed on 3 April 2025)

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