MOTT MACDONALD

London Flooding Review

Stage 4 - Recommendations

July 2022

Confidential

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Contents

Glossary

AI	Artificial Intelligence	Machine-learning from different sources of data to identify trends and inform decision making.
AMP	Asset Management Period	5-year period which is regulated by Ofwat following acceptance of price Review - (e.g., AMP7 is 2020-2025).
API	Application Programming Interface	APIs can be used to share data via the internet. For example, rain gauge data can be input directly into modelling software packages via the API.
ASFHD	All-source flooding history database	Compiled flooding history records from Thames Water, councils, S19 reports and social media reports.
BGI	Blue Green Infrastructure	A strategically planned system of natural and semi-natural components comprising water (blue) and landscape elements (green) at various scales to deal with climate challenges, which also provide multiple economic, environmental and social benefits.
CCFAS	Counters Creek Flood Alleviation Scheme	Counters Creek Flood Alleviation Scheme included detailed hydraulic study, scope definition and analysis into root causes of flooding in West London. Some material prepared for the purpose of the CCFAS study may be of relevance to this Review and has been used in terms of data inputs.
CCTV	Closed Circuit Television	Used for surveying condition of pipes. May also be used to determine locations, extents and timings of flooding.
CIRIA	Construction Industry Research and Information Association	Recognised not-for-profit organisation providing best practice guidance, training and research for the construction industry.

CIWEM	Chartered Institution of Water and Environmental Management	
CReDO	Climate Resilience Demonstrator	As part of the Digital Twin programme, the CReDo project looks specifically at the cascading impacts of flooding caused by climate change on connected energy, water and telecoms networks, by identifying critical assets and interdependencies across sectors.
DEFRA	Department for the Environment, Food and Rural Affairs	
Digital Twin		A digital “copy” of the system or systems. Scenario testing and proactive monitoring can be used to identify and predict system response to real problems safely.
DLUHC	Department for Levelling Up, Housing and Communities	
DWMP	Drainage and Wastewater Management Plans	Regulatory output required by Ofwat for business planning for PR24 and future AMPs.
FAS	Flood Alleviation Scheme	Capital scheme constructed to reduce flood risk to properties.
FCERM	Flood and Coastal Erosion Risk Management	
FEH	Flood Estimation Handbook	The Flood Estimation Handbook (FEH) and its related software offer guidance on rainfall and river flood frequency estimation and development site runoff rates across the UK.
FLIP	Flooding Local Improvement Project	A scheme designed to provide additional resilience to flooding in a local area, normally by means of stopping water entering a property via the sewer system.
FTF	First-time Flood	Properties which have reported flooding for the first time during the July flooding events.

FWMA	Flood and Water Management Act 2010	
ICMLive	Integrated Catchment Modelling software (Live)	Innovyze's software for monitoring live scenarios - connects via internet to readily available data sources such as rainfall and tide level gauges. Connects built 1D model for predictive and analytical assessment of catchment performance.
IEG	Independent Expert Group	Independent body commissioned by Thames Water to investigate the July 2021 flooding.
IVR	Interactive Voice Response	Thames Water Customer Contact Centre automated messaging service.
LBHF	London Borough of Hammersmith and Fulham	
LFB	London Fire Brigade	
LFRMS	Local Flood Risk Management Strategies	These strategies take account of the current policy and reflect the aspirations and priorities of other partners with responsibilities for FCERM along with wider local interests in linked environmental or social outcomes.
LFRZ	Local Flood Risk Zone	Defined as part of the Surface Water Management Plan process.
LiDAR	Light Detection and Ranging	LiDAR is a remote sensing technology. LiDAR technology uses the pulse from a laser to collect measurements. These are used to create 3D models and maps of objects and environments.
LLFA	Lead Local Flood Authority	County councils and unitary authorities responsible for managing local flood risks (i.e. risks of flooding from surface water, ground water and ordinary (smaller) watercourses).
LTT	London Tideway Tunnels	Consists of Thames Tideway Tunnel, Lee Tunnel and Greenwich spur. Scheme to be commissioned in 2023 with purpose of reducing spill frequency into the river

		Thames (e.g. pollution control not flooding asset).
NRV	Non-return valve	A non-return valve is a single-way valve that allows the fluid to flow only in one direction. The main importance of non-return valves is that they allow flow in the downstream direction and prevent the flow in the upstream direction.
Ofwat	Water Industry Regulator	Our duties - Ofwat
PFRM	Pluvial Flood Risk Management	Management of flood risk from rainfall before it enters a pipe or watercourse network, same as surface water risk management.
PR24	Price Review 2024	PR24 and beyond: Creating tomorrow, together - Ofwat
Rain garden		A type of SUDS consisting of landscaped depressions that can reduce rates and volumes of flow and treat pollution through the use of engineered soils and vegetation.
RBKC	Royal Borough of Kensington and Chelsea	
RFCC	Regional Flood and Coastal Committee	There are 12 regional flood and coastal committees across England. RFCCs play an important role in helping to protect communities from flooding and coastal erosion. They help the Environment Agency and partners to understand local issues better, and to balance local and national priorities.
Rider sewer		A rider sewer is a new gravity sewer to which multiple properties are connected. The sewer is sized to cope with flows from all the properties which connect to it. There is a flap valve situated at the downstream end of the rider sewer before it connects back into the main sewerage system, which prevents flows backing up into the rider sewer.
RoFfSW	Risk of Flooding from Surface Water	Risk from surface water (also known as pluvial flooding). This risk is presented in

		the national RoFfSW maps produced by the Environment Agency.
S19	Section 19	Reports produced by councils following a flooding event.
SDAC	Sewerage Drainage Area Catchment	Hydraulically separate catchment areas which drain to a single STW.
SDM	System Depth Monitors	Long-term monitors at strategic locations across the Thames Water region - usually installed with the purpose of monitoring level data at areas of high risk, such as those with frequent blockages, flooding or infiltration.
SFHD	Sewer Flooding History Database	Thames Water's asset database for flooding history. Data is added when flooding reports are received and updated following a flooding investigation.
SFRA	Strategic Flood Risk Assessment	Regional analysis of flooding carried out by the LLFA to inform the development planning process and avoid increasing overall flood risk.
SPS	Sewage Pumping Station	A mechanical system that lifts sewage from a lower level to a higher level in a way that overcomes gravity.
SSP	Strategic Stakeholder Panel	Key stakeholders including senior representatives from the Greater London Authority, Transport for London, London Councils, the London Drainage Engineers Group, the Environment Agency, the Consumer Council for Water, the Thames Regional Flood and Coastal Committee and Ofwat (as observer).
STW	Sewage Treatment Works	A place where sewage is collected and treated to remove contaminants and make it safe prior to discharge into the surrounding environment.
SuDS	Sustainable Drainage Systems	The SuDS philosophy is to mimic natural drainage that occurs prior to development and manage the water as close to its source as possible, providing

		opportunities to manage flood risk, water quality and enhance biodiversity.
SWMP	Surface Water Management Plan	A study generated by local authorities to understand the risk from local flood sources and which outlines a long-term action plan to manage these risks.
TfL	Transport for London	Organisation responsible for managing transport services across London.
TW	Thames Water	Company responsible for supplying customers across the Greater London and other areas in the south-east of England with water and wastewater services.
TWL	Top Water Level	Maximum level in the sewer at a modelled node.
UDG	Urban Drainage Group	One of CIWEM's specialist groups related to the management of urban drainage. Urban drainage management means the application of engineering, scientific, planning and analytical knowledge to the collection, treatment, control and disposal of foul and stormwater. Urban drainage management benefits society through maintaining and improving public health, environmental water quality and levels of flood risk.
VISTEC		Operational callout register - records attendance of operational teams at addresses across the Thames Water region, describes action taken and can be used to assess frequency of potential risks.

Executive summary

This Stage 4 report is the final of four reports comprising the London Flood Review, investigating severe flooding which occurred across London in July 2021.

The purpose of Stage 4 is to summarise the findings of the Review and put forward recommendations based on these findings so that the impacts of similar events can be reduced in the future.

The overall findings confirm that the amount of rain that fell during the two storms was the main cause of flooding. The average total rainfall in the month of July in London is about 45mm, so double the rainfall for the month fell during each of the events, vastly overwhelming the above-ground and below-ground systems.

In each event, the rainfall fell over a widespread area of London. The Lead Local Flood Authorities (LLFAs) have a duty to manage flood risk within their boundary, which in London is set at the Borough level. The amount of rain that fell was so large that both surface water flooding and sewer flooding occurred. Flows from one Borough may have affected other Boroughs; similarly, sewer flooding may have been exacerbated by surface water flooding and vice versa. As a result, it is very challenging for multiple parties to respond effectively during flooding events, such as those experienced in July 2021.

For example, in Kensington and Chelsea, the sewer system was surcharged because it was not designed to cope with the flow (nor is it expected to have been designed to cope with the flow). The system capacity was exceeded, manhole covers were lifted by the pressure of the water in the system and flood water was expelled onto the street resulting in surface water flooding. Conversely, in Waltham Forest, the gully capacity was such that flows could not get into the sewer system. As a result, the area experienced extensive surface water flooding, while the below-ground network still apparently had capacity in some areas.

The diverse nature of the flooding means that it is impossible to identify a single solution that could have prevented the flooding or a single organisation that is responsible for the flooding.

There were other factors, such as tide and operational performance of the system, which played a small part in worsening the impacts of flooding but, had these not been present, significant flooding would still have occurred. Both rainfall events exceeded the current, and expected design capacity of the below-ground system. However, we also found that flows were held up on the surface as the gullies in some areas did not have the capacity to deal with the flow rates, and some may have been partially blocked.

Such events are likely to occur more frequently in the future due to climate change and the various organisations which manage flood risk will need to work more collaboratively to ensure that the impacts of flooding are managed appropriately. It will not be economical or realistic to try to contain all flows in every event. Even if all the recommendations in this report are taken forward by the risk management authorities, there is still potential for large-scale flooding to occur in rare intense rainfall events. It will be how we manage the impact in the future that will make the most difference. The key recommendations include:

- Establishing a body with a strategic view and governance, with representation from all parties with responsibility for flood management, so that surface water and sewer systems can be assessed, and investments designed to optimise outcomes across different organisational boundaries

- Sharing data across multiple organisations relating to flood risk assets, including high-risk areas and vulnerable customers, including across Boroughs where flood risk may originate from other areas
- Improving forecasting and monitoring of the development of extreme events
- Improving preparedness for emergencies and enabling cross-organisational collaboration at short notice, including establishing roles and responsibilities in advance so this is clear ahead of any emergency. Existing actions taken under the London Resilience Framework may be drawn on to achieve this
- Using data and digital tools to more rapidly assess sewer network performance and prioritise responses in extreme events
- Protecting those at highest risk of flooding by installing anti-flood devices such as non-return valves, FLIPs or flood gates depending on the flood mechanisms
- Supporting homeowners and tenants to understand how they can best protect their homes from flooding, including opportunities to build in resilience
- Influencing planning policy and collaborating with developers to reduce flood risk to others from new developments and basement renovations.
- Encouraging asset owners to fully understand, develop and maintain their assets so they perform at their optimum level during high intensity events
- Understanding how the above and below ground systems operates when flow capacity of the sewers is exceeded, who will be affected and how the landscape can be altered to allow safe passage of flood waters to areas away from properties
- Adopting a suite of flood risk measures, including a combination of green (i.e. Sustainable Drainage Systems) and grey (i.e. traditional) engineering solutions, which can be installed in alignment with the planning policy to provide an agreed level of service across all organisations
- Understanding risk at the hydrological catchment level, rather than being constrained by the boundaries of LLFAs, including the modelling and assessment of flood risk

We recognise that there are limitations with what may be achieved with the current level of funding and resources available. Flooding is not any one organisation’s sole responsibility: parties must work together to identify solutions to manage multiple sources of flooding and potential funding. Promoted schemes will be assessed on the benefits they provide to customers and on the costs required to build, operate and maintain the asset. Consideration should be given to how other assets may be affected, especially across different organisations.

1 Introduction

Thames Water (TW) commissioned the Independent Expert Group (IEG) to investigate reports of extensive flooding in London, which occurred on 12 and 25 July 2021. Mott MacDonald (MM) was procured by TW, with approval of the IEG, to support the IEG in its role. To ensure independence, MM is under direction from the IEG.

The study consists of four key stages, investigating the flooding that occurred and the performance of assets within the catchment:

- Stage 1 - Investigation of reported flooding on 12 and 25 July 2021
- Stage 2 - Investigation into the catchment response and root causes that led to flooding on 12 and 25 July 2021
- Stage 3 - Assessment of the performance of TW assets, including flood alleviation schemes, critical pumping stations and operational performance of the network on 12 and 25 July 2021
- Stage 4 - Recommendations to improve resilience to future flooding events

The aim is to identify improvements to current ways of working with the stakeholder group, also referred to as the Strategic Stakeholder Panel or SSP, to minimise the impact of flooding and to optimise performance of assets for similar events in the future.

The stakeholder group consists of representatives from:

- Greater London Authority
- London Councils
- London Drainage Engineers' Group
- Environment Agency
- Thames Regional Flood & Coastal Committee
- Consumer Council for Water
- Thames Water
- Transport for London
- Ofwat (observer)

Over 1500 properties confirmed that they experienced flooding in July 2021, according to the information that was shared with us at the start of the Review. However, we acknowledge that TW and the Lead Local Flood Authorities (LLFAs) have been continuing to investigate flooding and are aware of additional flooding that was reported more recently and is not included in this Review.

The storms caused major disruption to the road and railway networks and affected properties and businesses across London and the South East. We have focused our study on the Beckton and Crossness drainage catchments, which cover Central London where the highest density of flooding was reported. However, many of the themes and recommendations of the Review are applicable at a wider scale for most urban cityscapes.

This report covers Stage 4 and includes a summary of the findings of the Review so far, plus recommendations that may be taken forward by TW and other members of the SSP. It considers a wide range of options related to data management, cross-organisational working, design of flooding schemes, rainfall forecasting and monitoring, and planning policy. We

acknowledge that some recommendations are already underway, following outcomes from other workstreams.

This report should be considered as a prompt for discussion and action: to focus on the issues and limitations with the current system and identify opportunities for improvement. However, this is just the beginning. Stakeholders will need to identify what they can implement from this Review and have open and transparent conversations about how to work together to achieve these improvements. We accept that there may be challenges with the adoption and implementation of some of these recommendations, with current levels of resourcing needing review.

2 Conclusions and findings of the Review

2.1 What happened on the days?

On 12 July 2021, intense rainfall fell over a swathe of west London during a period of just over two hours. Severe flash-flooding occurred, which is typical of convective storms.

On 25 July 2021, a similar event occurred, but this time the rain fell over a larger part of London and Essex.

Both events occurred around the peak of high tide which exacerbated the flooding and resulted in over 1500 properties reporting flooding. The storms caused major disruption to the road and railway networks and affected properties and businesses across London and the South East. The communications timeline below details our understanding of what happened before, during and after the events.

2.1.1 Overview of communications response to flooding on 12 July 2021

The Met Office uses weather warnings so that people and organisations can make preparations in advance of an event. The different categories of warnings are:

- Yellow: issued when it is likely that the weather will cause some low-level impacts, including some disruption to travel in a few places. Many people may be able to continue with their daily routine, but there will be some that will be directly impacted and so it is important to assess if you could be affected
- Amber: issued when there is the possibility of travel delays, road and rail closures, power cuts and the potential risk to life and property. You should think about changing your plans and taking action to protect yourself and your property
- Red: issued when it is very likely that there will be a risk to life, with substantial disruption to travel, energy supplies and possibly widespread damage to property and infrastructure. You should avoid travelling, where possible, and follow the advice of the emergency services and local authorities

Before the 12 July 2021 event

- The Met Office issued a yellow weather warning on the morning of 11 July 2021
- Thames Water (TW) held an adverse weather meeting on 11 July 2021. TW planned for a scenario of 20-30mm of rainfall (based on the Met Office's most likely scenario). This information was passed to TW managers. During the event, significant areas received rainfall of over 50mm, with the most affected place seeing more than 90mm. The average total monthly rainfall in July in London is about 45mm, so double the rainfall for the month fell in one single day at the worst location
- Based on the information provided by the Met Office, TW and other organisations did not anticipate that the storm would be so severe and, therefore, the emergency response procedures were not implemented. The response began as the event was already unfolding so the impacts were not fully understood until many properties were already flooded

During the event

- For TW out of hours resourcing to be triggered, an 'Incident' has to be formally raised. As only a yellow warning had been raised by the Met Office, initially, an 'Incident' was not logged on 11 July or 12 July. This meant there was a shortage of communications staff in place to prepare materials and messaging for stakeholder liaison

- Between 12 and 13 July 2021, nearly 4000 calls were made to the Customer Contact Centre (CCC) related to the flooding incident. This was nearly double the predicted number of wastewater calls (2055 calls)
- As reported in the TW Report 'July Flooding Internal Review', on 12 July 2021 there was an increase in the number of calls from 16:30 onwards, and this coincided with a scheduled 40% reduction in CCC staff after 17:00 as the day shift ended
- During this period on 12 July (i.e. after 16:30), the call times became "unacceptable", as reported by TW in the 'July Flooding Internal Review' report
- TW updated CCC telephone lines with an interactive voice response (IVR) encouraging customers to report non-flood issues via the website
- Elected representatives contacted TW for information
- Between 12 and 14 July 2021 inclusive, 6999 social media 'contacts' (i.e. all private or public messages/posts via a social media source to TW during that timeframe) were made against a forecasted 5179 contacts

After the event

- The London Resilience Group held a 'Major incident call' which was attended by TW and other relevant bodies. TW provided a list of vulnerable customers and a list of customers on the 'Priority Services Register' in the affected areas. A full list of TW's conditions for eligibility for priority services can be found at this link: https://www.thameswater.co.uk/help/extra-care/priority-services
- On the response days between 12 and 16 July 2021, TW mobilised between 98 and 106 teams to support customers and 16 specialist crews to help with clean-up of customers' properties
- TW participated in the 'storm debrief' workshops led by the London Resilience Group
- On 14 July 2021, TW contacted emergency planning teams in 10 London Boroughs to offer assistance. TW reported receiving no requests for additional help from the London Boroughs
- Between 15 and 23 July 2021, TW set up an incident support drop-in centre in Westminster. This was advertised on the TW website and through TW's communication with stakeholders
- In parallel, the Boroughs were working with their communities to determine the locations affected
- On 10 August, TW made a Sewer Flooding Questionnaire available online for customers to complete to report flooding. This was referenced in stakeholder and public meetings attended by TW

2.1.2 Overview of communications response to flooding on 25 July 2021

Before the 25 July event

- On 21 July and subsequent days, TW again received yellow weather warnings from the Met Office, forecasting a range of rainfall intensities, covering the whole of the southeast region
- TW convened adverse weather meetings with operational teams to assess the risk to services, customers and the environment, based on the Met Office's 'most likely' forecast of 20-30mm of rain and its prediction of 'low likelihood of medium impacts'. During the event, rainfall of over 50mm was even more widespread than on 12 July, with the worst affected point seeing over 80mm. Again, this is nearly double the average monthly total rainfall occurring in one day
- TW made additional CCC resources available to support calls from customers for the weekend of 25 July. This was due to the forecast which enabled improved preparations for the rainfall forecast on this day compared to the event on the 12 July
- TW contacted elected representatives in the affected areas

- TW updated the IVR message with suitable contact details ahead of 25 July 2021
- TW posted website and social media messages ahead of the storm advising of contact details

During the event

- Weather warning from Met Office was upgraded to amber during the 25 July 2021 storm
- TW made all possible CCC agents available to customers including trained people from the Billing Customer Service Centre
- The CCC was overwhelmed with more than double the number of daily contacts in just one hour
- Customers struggled to get through and many hung up before speaking to TW
- Between 25 and 26 July 2021 inclusive, 4465 social media 'contacts' were made against a forecasted 1541 contacts

After the event

- In the evening of 25 July 2021, TW contacted local authorities to offer support
- TW kept in contact with London Resilience Group to stay informed of local issues
- On 26 July, TW offered support to local authorities and Barts Health NHS Trust
- TW requested that customers from impacted households complete a Sewer Flooding Questionnaire to report flooding. This request was sent to households and posted on their website
- TW participated in the 'storm debrief' workshops led by the London Resilience Group
- Customer representatives followed up with customers after clean-ups were completed
- On the response days of 25, 26 and 27 July 2021, the number of TW crews provided ranged between 75 and 111 crews to assist with 'reactive jobs' (i.e. jobs required immediately following the event)

2.2 What have we found during the Review?

This section discusses aspects of the Review process that have highlighted areas that we believe require attention.

This section outlines the areas identified, with further discussion of these aspects and final recommendations picked up in Section 4.

2.2.1 Difficulties in data collection

When starting the Review in November 2021, we initially sent out an appeal for data from a wide range of stakeholders and we have also received feedback via the London Flood Review website inbox throughout the Review process. This feedback from residents and other affected parties has been very valuable as it has helped us to gather further information related to the extent and nature of the flooding. However, as might be expected from residents, it often related to very localised information.

As we only had seven months to gather information, carry out the analysis, draw conclusions and make recommendations, the Review required formal stages to allow for progression through the process without continually revisiting previous stages or reworking. In order to gain the most benefit from the participants, the agreed procedure for any report was for it to be reviewed by the IEG, updated, reviewed by the SSP and updated again as necessary prior to uploading to the website for public consumption.

Unfortunately, this meant it was difficult to incorporate all data received following Stage 1.

While one stage report was undergoing the above review and revision process, much of our analysis for the next stage was already concluded and we were writing the next stage report. This meant that some data received by the Review team may only have been identified once the analysis was complete. We found similar issues when trying to incorporate updates to the base dataset, such as the flooding history dataset, after the analysis had started. We recognise that TW and the Lead Local Flood Authorities (LLFAs) have continued to investigate the July 2021 events and that some of these findings may not be included in this report.

Another challenge we faced was obtaining lists of relevant data during Stage 1, such as hydraulic models held by the local authorities. The local authorities were not always able to provide the data and suggested contacting the original consultant for the models. However, it was not possible to receive these models from the consultants within the timescale required for the Review.

Overall, rapidly accessing reliable and current data and information was problematic and it seems that it is likely to be systemically problematic. We note that, under their duties in the Flood and Water Management Act (FWMA) 2010, the LLFAs are responsible for collating data related to reported flooding. However, obtaining the information from residents who have suffered the trauma of flooding can be a time-consuming and lengthy business, not least because affected residents have some urgent actions to undertake in the immediate aftermath of the flood.

It is important that any information gathered after the event is shared so that the extents and mechanisms of flooding can be more fully understood and appropriate risk measures adopted in response. Gathering and analysing flood information is likely to continue well beyond this Review. All future investigations, planning and strategy, including any future investment by any party with responsibility for flood management, will include an update of this analysis using the currently available set of reported flooding information.

2.2.2 Root causes of flooding

We carried out a detailed analysis of the rainfall event, looking at where it fell and how much rain fell. The analysis included a review of the return period, which is a measure of the likelihood of an event. Due to the nature of the July 2021 events, which are highly localised and of short duration, it is not possible to assign a single return period to each event, as return period varies depending on the area over which the rain falls, the intensity of the rainfall and the duration of the storm. This is discussed in detail in our Stage 3 report.

We used the InfoWorks ICM models of the Beckton and Crossness catchments, which cover most of central London, to study the flooding mechanisms. These models, which have been developed and calibrated over a long period, were provided by Thames Water and represent the sewer network only. We acknowledge there are some data gaps and data unreliability in some areas, along with limitations related to the representation of the surface water flooding mechanisms. In parallel, we used outputs from the LLFAs' surface water models, which have been collated by the Environment Agency, to establish where there is a known risk of surface water flooding. These were used to help define the hotspots and flooding mechanisms in Stage 2. Where reported basement flooding was supported by the outputs from the sewer network model, this gave us high confidence in the models. Similarly, where surface water flooding was reported and matched areas predicted to flood in the surface water models, we also had high confidence in the models.

Acknowledging the data gaps and uncertainties described above we decided, in discussion with the IEG, to test the performance of the sewer system at the "whole system" level, using a number of sensitivity scenarios. This is a standard technique which is used to take account of

data and model uncertainties to determine how the model predictions change depending on the variable being assessed.

The aim of the sensitivity analysis is to determine which variables have the most significant impact on the sewer system levels, by varying parameters in the data provided as part of Stage 1. This provides insight into how important data gaps are in assessing the performance of the sewer system, acknowledging that for design of local schemes, all available data is required to allow full consideration of the benefits and risks.

The variables considered included:

- The amount of rainfall that was able to enter the sewer network – to consider the split of flows that may be retained on the surface or enter the below-ground network
- Rainfall trajectory shifts – to consider how significant the location of the centre of the storm was
- Dry weather flow peak timing – to consider if the storm occurred when the normal foul sewage flow was at its peak and, if so, did this exacerbate the effects of the storm
- Thames Barrier closure – to consider if a closure of the Thames Barrier would have mitigated the flooding to any significant extent
- Impact of tidal levels on flood risk – to consider the effect of the high tide coinciding with the flood peak

For each variable, a scenario was set up in the model. Each scenario was compared against the baseline model results to determine the differences in sewer top water levels, predicted flooding volumes and observed depth monitor data. We concluded that the variables which most affected the modelled extents of flooding related to the rainfall trajectory and the variation in tide levels. Other variables had a smaller and more localised impact.

Table 2.1: Summary of variables related to sensitivity testing

Scenario	What we tested	What we found
Rainfall entering sewer network	We reduced the rainfall percentage that fell over the catchment to determine what matched best with available monitor data. This is to test how flows can get into the sewer network and determine whether it was likely that flows were prevented from entering the sewer network by being retained above ground.	The 30% reduction best represented the observed levels in the network. This meant that 70% of the rainfall was able to enter the network and 30% was retained on the surface.
Rainfall trajectory shifts	Summer storms are very localised and intense. We wanted to test what would happen if the storm had occurred over a different area to see if a similar number of people and properties would be affected, or if the location of the storm had a significant impact.	Changed the areas affected, but the scale of impact (number of properties) was not significantly changed if the storm had hit another part of London.
Dry weather flow peak timing	The sewer system takes both dry weather and surface water flows. Dry weather flow consists of domestic sewage, trade flows and infiltration of water from the ground and is present in the system all the time. Storm flows occur during periods of rainfall and enter the system via road and roof drainage. The timing of the storm (mid-afternoon) occurred when the dry weather flows were low. We wanted to test whether more people or properties would have been affected if the storm had occurred when the dry weather flow is at its highest (approx. 7am).	Had minimal contribution to the flooding.
Low tide	We wanted to understand what would happen if the events had occurred at low tide.	Low tide reduced water levels significantly (over 1m) in Hammersmith and Fulham, Kensington and Chelsea, City of

Scenario	What we tested	What we found
		Westminster, Wandsworth, City of London, Tower Hamlets, Newham, Lambeth and Greenwich.
Thames Barrier closure	Both events on the 12 and 25 July occurred at the same time as a high tide, causing an effect known as tide-locking. The closure of the barrier can have an impact on reducing the river levels, which reduces tide-locking of the sewer system. We wanted to understand the impact of the lower river levels and understand how much of an effect closure of the barrier might have had.	The closure of the barrier reduced water levels significantly (over 1m) in Hammersmith and Fulham, Kensington and Chelsea, City of Westminster, Wandsworth, City of London, Tower Hamlets, Newham, Lambeth and Greenwich.

We used the data from these sensitivity tests, plus a range of other data, to produce a root cause analysis for each London Borough we studied. If a Borough is missing it is either because the extents of flooding overlapped with another Borough with the same flooding mechanism, and are, therefore, covered by the same hotspot, or it was outside of the current study area covered by the Beckton and Crossness catchment models.

- **City of London** – sewer overload, surface water flooding, high tide
- **City of Westminster** – sewer overload, surface water flooding, high tide
- **London Borough of Camden** – sewer overload, surface water flooding,
- **London Borough of Greenwich** – surface water flooding
- **London Borough of Hackney** – sewer overload
- **London Borough of Hammersmith & Fulham** – sewer overload, surface water flooding, high tide and slightly impacted by pump operations
- **London Borough of Haringey** – sewer overload, surface water flooding
- **London Borough of Islington** – sewer overload, high tide
- **Royal Borough of Kensington & Chelsea** – sewer overload, surface water flooding, high tide and impacted by pump operations
- **London Borough of Lambeth** – sewer overload, surface water flooding, high tide
- **London Borough of Lewisham** – sewer overload, surface water flooding
- **London Borough of Newham** – sewer overload
- **London Borough of Redbridge** – sewer overload, surface water flooding, high tide
- **London Borough of Southwark** – sewer overload, surface water flooding, high tide
- **London Borough of Waltham Forest** – surface water flooding
- **London Borough of Wandsworth** – sewer overload, surface water flooding, high tide

2.2.3 Operational performance

Some of the scenarios we tested related to the operation of TW's network. These included:

- Hammersmith Pumping Station operation – to consider if the pumping station was operated in accordance with its rules
- Lots Road Pumping Station operation - to consider if the pumping station was operated in accordance with its rules
- Impact of blockages in the sewer system on pipe capacity – to consider if the presence of blockages affected flooding
- Unaccounted-for base flow in the sewers - to consider if groundwater or other infiltration affected flooding

The results of the analysis confirmed that the overall impacts at a system level were minimal (while recognising that any amount of flooding can add stress and impact residents), but a more detailed description can be found below. The fuller analysis can be found in our Stage 2 report.

Table 2.2: Summary of sensitivity analysis related to operational performance

Scenario	What we tested	What we found
Hammersmith Pumping Station operation	TW informed us that one of eight storm pumps broke down during the 12 July 2021 event, reducing the total capacity of the pumping station. This is within its operating capacity, and therefore, not a breach of its operating consent. This sensitivity test compared the impact of the difference in pump rates to see how this affected sewer levels.	Medium increase (between 100mm and 500mm) in water levels in Hammersmith and Fulham; minor increase in water levels in Kensington and Chelsea and City of Westminster. Largest increases are closest to the pumping station.
Lots Road Pumping Station (LRPS) operation	The pumps at LRPS are manually operated, meaning that an operator has to physically switch on the pumps when levels in the sewer system are high. Using the records from the pumping station, which tell us what time the pumps were switched on, we replicated what happened on the day to see if the timing of the manual switch-on affected the areas which experienced most flooding.	Minor increase (between 100mm and 300mm) in water levels in Hammersmith and Fulham and Kensington and Chelsea.
Pipe blockage removal	Sewer blockages (e.g. fatbergs, build-up of silt) are included in the model in some locations, where they were found during surveys of the sewer system. They were all removed for this sensitivity assessment to see if sewer flows were held up by the blockages, increasing water levels.	Had minimal contribution to the flooding.
Groundwater infiltration into the sewer	Some flow may enter the sewer from below-ground through joints and cracks in the pipes. This can use up capacity which might otherwise be used by storm flows. We have run a model assuming there is no groundwater infiltration to show whether this had an impact.	Had minimal contribution to the flooding.

While there were some issues identified at pumping stations, we found that all the pumping stations operated within their planned operating procedures. TW has provided operational redundancy to its pumping stations, in accordance with good practice, by adding in extra pumps. When all pumps are running, including the extra pumps, this can provide additional benefit over and above the designed operational capacity. However, if one pump fails, as it did at Hammersmith, that additional capacity is not available. However, the capacity on the day was still within the design operational requirements of the Hammersmith pumping station.

We also carried out some sensitivity testing related to gully performance, by linking the 1D hydraulic model to a 2D model representing the overland flow paths. We found that the intensity of the rainfall and subsequent flow rate of runoff was so great that, in some locations, the flow would not have been able to get into the sewer system, whether gullies were blocked or not. This was tested over quite a localised area as agreed with the IEG. Due to the time limitations of the project, we have not been able to carry this assessment out for the whole of London to confirm whether this is applicable everywhere. While intuitively, steeper catchments seem more likely to allow flow to pass across the gully without entering it, our modelling showed that the hydraulic capacity of some gullies was lower than the flow. Furthermore, due to the variability of rainfall across the catchment, it is likely that there is some variation to the rainfall response based on the sewer and surface water interaction. However, gully maintenance may play a more significant role in reducing flood risk, particularly where there is spare capacity in the sewer system.

2.2.4 Scheme performance

We analysed four Thames Water (TW) sewer improvement schemes using the 1D hydraulic model. The findings of the analysis are described below:

- Westbourne Grove Flood Alleviation Scheme (FAS) (City of Westminster): the scheme was designed to reduce flood risk for 120 properties which had previously reported flooding. The scheme operated as designed, by diverting excess flows into a storage tank. The tank nearly reached full capacity. Levels in the main sewer were reduced by 400mm, compared with a scenario which represented the network layout before the scheme was built, reducing flood risk in the area. Four properties which had been designed to be protected by the scheme reported flooding in July. Evidence suggests at least two of these properties had a Flooding Local Improvement Project (FLIP) installed. Therefore, there is a risk the FLIP failed, or was inundated through other sources, such as surface water not being able to enter the sewer system. TW is carrying out further investigations. It may be that other properties were also flooded but had not reported at the time of the Review.
- Maida Vale FAS (City of Westminster): the scheme covers three distinct areas:
  - The Tamplin Mews scheme was designed to protect 120 properties up to a 1-in-30 year storm, by reducing the water levels in the sewer locally. Six of the 120 properties protected by the scheme reported flooding, along with new properties which reported flooding for the first time. This is likely to be because these newly reporting properties are still connected to the trunk sewer. Properties which had provided evidence of flooding previously were disconnected from the trunk sewer and flows were diverted into the new sewer draining to the tank in Tamplin Mews. The trunk sewer was overwhelmed by the intensity of the event.
  - The Formosa Street/Westbourne Green scheme was designed to protect 73 properties which have previously reported flooding by reducing the water levels locally up to a 1-in-30 year storm. The principle of the scheme is to divert flows away from locations which previously reported flooding. As a result, water levels are increased in other areas due to changes to flow routes. Some properties which newly reported flooding in July are likely to drain to sewers where the top water level has increased as a result of the scheme. However, we were unable to confirm if flooding would be experienced anyway as a result of high levels in the network as there was uncertainty over existence and level of connection. We recommend that TW investigate these areas of potential detriment further to determine if solutions are required.
  - Cambridge Gardens consists of FLIPs installed at five properties. None of the properties reported flooding in July, suggesting the FLIPs performed as designed. No nearby properties reported flooding.
- London Tideway Tunnels (LTT) (across London): not yet operational. The purpose of the tunnels is to reduce combined sewer overflows into the River Thames (spills) to improve water quality, rather than being operated to act as a flood mitigation asset. However, the analysis was carried out to assess any benefits that the tunnel system and associated improvements may provide in similar events in the future. The tunnel was predicted to fill to a maximum during the 25 July 2021 event. During the 12 July 2021 event, the rainfall was more localised so the impact across the whole drainage network was reduced. In both events, there would have been only a minor improvement in reducing levels near to interceptions, demonstrating that the tunnel will not make a major difference for similar storms once connected, under current operating protocols which prioritise spill prevention.
- Counters Creek Flood Alleviation Scheme (CCFAS) (as constructed) (Royal Borough of Kensington and Chelsea, London Borough of Hammersmith and Fulham): The scheme consists of approximately 1300 FLIPs. In addition, local schemes such as rider sewers and street FLIPs were constructed, which provide street level isolation from the surcharged

sewer network to 44 properties. It also includes permeable paving schemes to offset potential detriment caused by installing several FLIPs in a localised area. As the schemes affect very localised areas, there is little impact catchment-wide on reducing top water levels. None of the 44 properties protected by local schemes reported flooding in the July events. 21 properties of the 1300 properties with FLIPs did report flooding: it is not known if this is related to a failure of the FLIP or caused by inundation from surface water. There were an additional 444 properties which reported flooding for the first time which were neither the focus of the scheme, nor were they addressed through the scheme.

The previously proposed Counters Creek tunnel scheme was also reviewed to determine any benefit it may have provided during such an event. In 2018, TW wrote to Royal Borough of Kensington and Chelsea and London Borough of Hammersmith and Fulham to inform them that the tunnel scheme was not going ahead as it was no longer cost-effective, particularly since many FLIPs had already been installed across the catchment to protect the most at-risk properties. The FLIPs were initially considered an interim measure but were proven to be more resilient than the tunnel scheme. Therefore, the tunnel scheme was not taken forward.

Had the scheme remained in the Business Plan, it would not have been operational during the July 2021 events, so the analysis is purely hypothetical. The analysis identified that approximately 64 properties, which were part of the original focus of the CCFAS, reported flooding during July 2021. Some properties had FLIPs installed, although it is not known whether the FLIP failed or if there was surface water which affected the performance of the FLIP. 31 of the 64 properties which reported flooding may have benefited from the tunnel. A cost-benefit analysis of the tunnel scheme has not been undertaken as part of this Review.

3 Potential options

3.1 Approach

We looked at potential options to reduce the risk of flooding, based on the hotspots and root causes identified in the Stage 2 report. We focused mainly on hotspots that are at risk of below-ground flooding for several reasons:

- The model we have used is most suitable for assessing the below-ground risk and impact, as it generally replicated the level in the sewer network well
- The interaction between surface water and the sewer network is complex
- There are different organisations responsible for the water depending on the source: in the below-ground system, it is solely Thames Water's (TW's) responsibility. Therefore, the process of agreeing and financing a scheme is much simpler (although still very hard)
- It would take more time than is available to build and calibrate a suitable model to assess potential solutions for more complex flooding issues. Further opportunities to collaborate on the development of solutions should be sought outside of this study

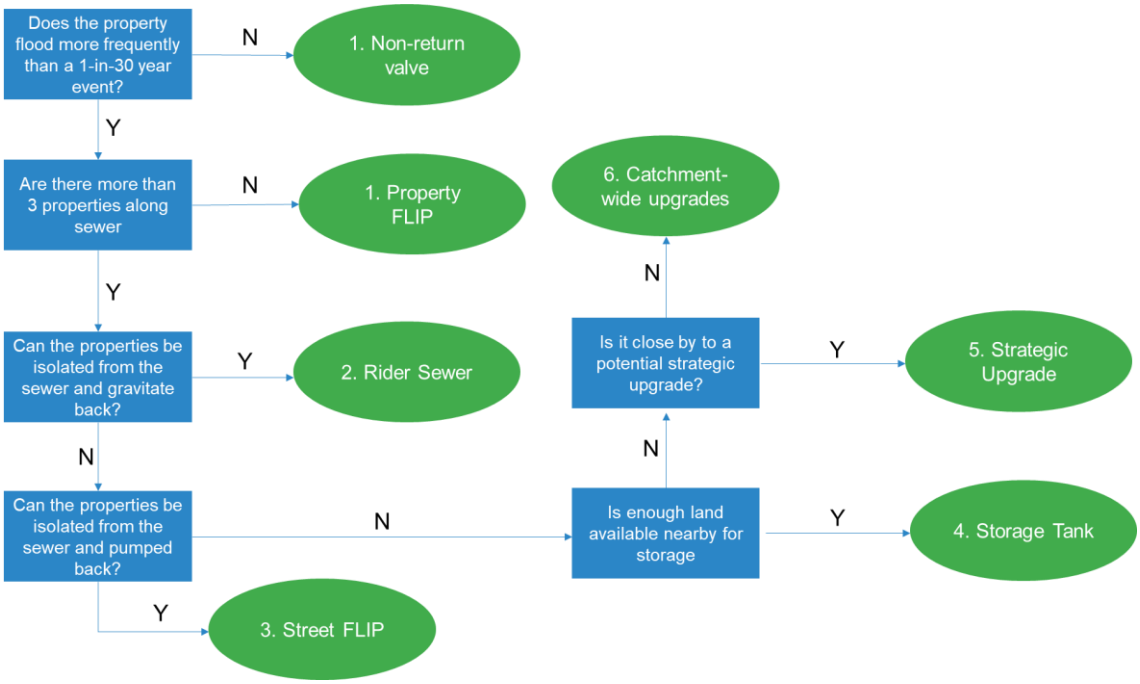
The mitigation of flooding from such extreme events needs to involve many agencies. This is also true of the development of solutions, particularly strategic solutions. Traditionally, strategic solutions developed by TW have been large, below-ground infrastructure, but this approach needs to change due to the scale of the flooding we are now facing.

The future of strategic options will be more around the management of land and the landscaping of our cities, as storage underground is not likely to be economically viable. Managing the landscape for flooding will require collaboration across all organisational bodies responsible for flooding, and also the wider network of organisations responsible for developing our cities. All designers need to consider the risks from these types of events and maximise any opportunity to deliver resilience. This change in approach will require changes in roles, policy and design specification (particularly with regard to changes to basement use), as well as raising awareness of these issues within the civil engineering profession. Future solutions are likely to be a combination of Sustainable Drainage Systems (SuDS) and hard-engineered solutions, to increase storage as well as such as increasing available network capacity in critical locations.

To identify the local solutions that can be implemented by TW in the short-term, we used model results from the events and the design storms for the 1-in-30 year and 1-in-5 year return periods. We compared reported flooding locations from the July events to the model-predicted flooding to identify properties that were at risk of frequent flooding (i.e. the model predicts flooding for a 1-in-5 year return period). We chose to focus our efforts on this return period due to time constraints. Where the model predicts properties flooding for a lower return period, the benefit provided by implementing a solution to reduce the risk of flooding will be greater. As such, the cost-benefit of the scheme will be more likely to be seen as a good investment.

We developed an option hierarchy based on our catchment knowledge developed during and prior to this Review. As the trunk sewer system is heavily surcharged during long return period storms, often isolation schemes like Flooding Local Improvement Projects (FLIPs) perform best for standalone and localised properties. The flow chart of our approach is shown in Figure 3.1.

Figure 3.1: Options considered during Stage 4



A rider sewer is a new gravity sewer to which multiple properties are connected. The sewer is sized to cope with flows from all the properties which connect to it, including stormwater. There is a flap valve situated at the downstream end of the rider sewer before it connects back into the main sewerage system, which prevents flows backing up into the rider sewer. The rider sewer may be sized such that normal sewage flows and stormwater runoff from the properties can be stored for the duration of the design event, until the levels in the main sewer network are reduced.

Many properties within a hotspot may be suitable for a FLIP, however it may be that the risk of flooding is confirmed as having less than a 1-in-30 year return period. For these cases, it is unlikely that a FLIP will be installed, as the FLIP programme will need to focus on areas of highest risk. FLIPs have the potential to reduce flood risk for the property protected, but can increase the risk of flooding to other properties in the region. This means there is a risk that, by preventing flows from surcharging into a property, flows may be displaced and cause a rise in top water levels elsewhere. There is a risk that a new area will be at risk of flooding, where it was previously not at risk.

The use of SuDS, and other nature-based solutions, is becoming more commonplace. These can have multiple benefits, not only reducing flood risk, but also creating community green spaces which can offer wellbeing and societal benefits, and improvements to pollution of rivers. SuDS can also improve above-ground surface water flooding, with greater interception capacity compared to gullies, and can retain surface water safely above-ground during flood events. However, it is possible that some residents may object to the streetscape being affected, especially if there are sensitive issues such as parking. Therefore, extensive consultation and the flexibility of the selection and implementation of the type of SuDS should be considered. Examples of nature-based solutions are given in Figure 3.2 and Figure 3.3 below.

Figure 3.2: SuDS features installed as part of CCFAS

Source: Mott MacDonald

Figure 3.3: Example of a rain garden

Source: Montgomery County Department of Environmental Protection

Please note that there is opportunity to combine schemes across multiple organisations, which can improve resilience for a wider number of customers. Recommendations on this are included in Section 4.

4 Recommendations

This section includes recommendations which we believe are critical to the mitigation of future events, similar to those experienced in July 2021. For affected residents, these floods were devastating, and many have still not returned to their homes after a year. For some, there is the wish to apportion blame for something that went wrong; for others, it is more the fear that this could happen again with similar impacts. These types of events will continue to occur and, with climate change, are likely to may occur more frequently. As such, it is important that the response to flooding improves along with the resilience of the above and below-ground infrastructure.

Throughout the Review, we have considered many aspects of flood risk management: what went well and what could be improved. The recommendations are borne out of the findings of the Review, but also other aspects of flood risk management from our collective understanding of the industry. Many Reviews have come before this one and, while things are changing, the overall impact of flooding is still extensive and highly damaging to people's wellbeing, lives and livelihoods.

For example, the Pitt Report 2008 recommended large-scale changes within the flood risk industry with a wholesale need to ensure all risk management authorities work closer together in a more collaborative manner. Further work is needed to accomplish this recommendation in the Pitt Report 2008, and this has been highlighted by the Surface Water Task and Finish Group.

The Surface Water Task and Finish Group was established by the Mayor of London following the flooding event in July 2021 and produced the report, Surface Water Flood Risk Management in London | London Councils. There are ongoing round tables with the key stakeholders to ensure improvements continue to be made and progress is reported frequently.

The Task and Finish Group's key findings listed below are similar to some of the findings of this Review:

- **Governance** - No single organisation is in overall charge of managing surface and sub-surface water flood risk in London. Furthermore, there is a lack of understanding of the overlaps and interactions between the differing responsibilities among a wide range of organisations
- **Funding** - There is insufficient funding mobilised to manage the risk. There is a lack of knowledge about potential funding opportunities and a lack of understanding of what is needed to develop and submit proposals to secure the needed funds
- **Evidence** - There is a lack of understanding of what flood assets are currently available, who owns and maintains them, and what condition they are in. In addition, there is also a lack of modelling that can help organisations understand where floods are likely to occur and what efforts should be undertaken to reduce the risk
- **Communication** - There is a lack of understanding of the risks of surface water flooding and the responsibilities of the various stakeholders to lower such risks
- **Strategic plan** – The absence of an overall strategic plan and vision, as well as a body tasked with its development and implementation, underpins all of these issues

For simplicity, we have used the same over-arching themes as we found that the recommendations we made largely fit well within these categories.

Recommendations have been scored based on three criteria:

- Complexity – ranked high (H), medium (M) and low (L) based on complexity to implement. Score is dependent on the number of stakeholders, the amount of procedural change and the general approval process
- Timescale – ranked high (H), medium (M) and low (L) based on likely timescale to implement. Timescales ranked low are likely to be achievable in the next year; medium timescales are 1-3 years and high timescales may take several years to implement
- Cost – ranked high (H), medium (M) and low (L) based on cost to implement. No formal cost estimate has been undertaken, and the ranking is based on experience.

4.1 Governance

The governance theme covers areas which fall within the remit of certain organisations, the division of roles, responsibilities and duties in terms of managing flood risk, implementing planning policy and other legislative duties. Communication and collaboration between organisations are covered more specifically in Section 4.4.

4.1.1 Roles and responsibilities for flood risk management

We undertook a Review of the organisational arrangements for the strategic management of surface water flooding and identified recommendations which aim to improve flood management programmes and the response during and after a flooding event. While duties are set out under the Flood and Water Management Act 2010, this can be confusing in situations such as the events in July. Responsible organisations could be the Environment Agency (main river and coastal flooding), the Lead Local Flood Authorities (LLFAs) (surface water, groundwater and ordinary watercourse flooding) and Thames Water (TW) (sewer flooding).

The LLFAs are defined based on the London Boroughs, although it should be noted that in other parts of England, these are usually at a county level. It is the duty of LLFAs to produce Section 19 reports, detailing the extents and reasons for flooding in their area. However, flooding does not respect administrative boundaries, and, in some cases, runoff can originate from conditions in one Borough and result in flooding in other downstream Boroughs. This may be because the sewer network has conveyed it to a different Borough, which then backs up and results in flooding. It may be because a Borough is further down the hill from another Borough and surface water flows downhill. The Environment Agency and the Regional Flood and Coastal Committee (RFCC) also have roles and responsibilities with regard to reporting, coordination and funding of flood risk management schemes. As a result, the system can be extremely complex, and it can be tempting and easy to lay the blame at someone else's door. In situations where it rains this much, however, this attitude can be unhelpful and put people's lives at risk. Where a significant change to the approach to managing catchments and risk of surface water flooding is required, collaboration needs to be mandatory, and should not be considered voluntary. The customers, and the impact on them, should be the priority, rather than organisational complexities.

Plans, known as multi-agency flood plans (MAFPs), are in place to set out how LLFAs will work with other partners during an incident. While this is a legal requirement, the level of detail and specificity of the plans may, and do, vary. The generation of MAFPs does take some effort and coordination, along with a lengthy consultation process with other partners to define the roles and responsibilities. It also requires adequate funding across all organisations.

On 10 February 2022, the London Councils Transport and Environment Committee approved the recommendation from the Surface Water Task and Finish Group to establish a Strategic Surface Water Management Group. The aim of this group is to provide collective leadership on strategic-level surface water management in London and to lead the development and delivery of a strategic-level surface water management vision, strategy and implementation plan. This has been quite complex to establish, with each member of the panel requiring investment and

endorsement from their own organisation. In addition, the structure of the group is such that no single organisation has a controlling interest so that the group approaches risk in a fair and coordinated way. The establishment of this group is seen by the Independent Expert group (IEG) as a significant step in improving the way flood risk is managed across London. However, the scope of what it will set out to achieve is not fully defined at this stage and, as such, this report may include certain recommendations which fit under its remit but may not yet be achievable or practicable.

1. **TW to work with other agencies to develop a multi-agency strategy to develop response to flooding. Engage with other organisations to identify clear roles and responsibilities during the event.**

2. **Set up an organisational body to develop strategic plans for management of surface water over Greater London. Report annually on progress against these plans.**

4.1.2 Planning and development

This section refers to items which were identified through discussions with bodies throughout the Review. These are not related specifically to analysis that we have carried out with our models but are related more specifically to perceived limitations and blockers to managing flood risk effectively.

The planning process is the primary step to eliminating flood risk, or changes to flood risk, by working with developers to limit development which may knowingly increase flood risk. To clarify, we do not want to say that development should be completely prohibited. However, where homeowners or developers propose to convert basement properties or construct developments in areas of known surface water flow paths, the risk to new and existing properties should be understood and rigorously managed.

Thames Water is currently not on the list of statutory consultees for new development. This is a list of organisations that must be consulted in the event of a planning application. However, it has requested to planning authorities that it should be consulted. Both the Environment Agency and the LLFA are included to provide comment on river and coastal flood risk and surface water flood risk respectively. There is often a trade-off between the need for more housing and the impact on flood risk. We believe that additional weight should be given to the impact on flood risk, and alternative locations may be sought for development. This may not always be possible. Furthermore, there is a gap here when considering the impact that developers may have on the sewer system and exacerbating flood risk, so Thames Water should also be part of the list of statutory consultees.

3. **Review the planning to consider adding water companies as statutory consultees in the planning process, to provide comments related to sewer flooding risk and network availability.**

The impact of this may be significant, as it is likely that there will be a large number of planning applications to review to address this function. However, we see this as the best way to promote conditions on planning and development, such as adding in non-return valves on low level sewer connections to reduce the risk of sewer flooding to a newly converted basement.

Alternatively, Thames Water may be consulted as part of the development of Local Plans for each Borough. This is an opportunity to highlight sewer network flooding issues to the Borough and allow for open and effective communication. The Local Plans may be used to set more local policies, which may be more stringent than the planning policy guidance.

Table 4.1: Summary of governance recommendations

Ref	Description	Complexity	Timescale	Cost	Current Actions
1	TW to work with other agencies to develop a multi-agency strategy to develop response to flooding. Engage with other organisations to identify clear roles and responsibilities during the event.	M	L	M	This is being developed by the London Resilience Group's 'Strategic Flooding Response Framework' and the outcomes of the Surface Water Task and Finish Group.
2	Set up an organisational body to develop strategic plans for management of surface water over Greater London. Report annually on progress against these plans.	M	L	M	This may fall under the responsibilities of the Strategic Surface Water Management Group as part of the outcomes of the Surface Water Task and Finish Group.
3	Review the planning process to consider adding water companies as statutory consultees in the planning process, to provide comments related to sewer flooding risk and network availability.	H	H	L	We are unaware of any actions currently underway regarding this recommendation.

4.2 Funding

4.2.1 Funding for flood risk schemes and Sustainable Drainage Systems

The funding process for flooding schemes can be long and laborious. At its heart, this is to make sure that the limited funds available are used wisely and for maximum benefit across the country. However, it is often easier to demonstrate that large river and coastal schemes are more cost-effective for the benefits that they achieve compared with surface water mitigation schemes. It is also considered that the total number of properties which benefit from the scheme are more easily quantifiable than for surface water, as the predicted flooding extents and property thresholds have higher confidence. For a river flooding defence scheme, the number of properties benefitted may be in the order of 10,000. When this is compared with a surface water flood risk scheme, which may benefit properties along a single street, it is much harder to demonstrate a suitable cost-benefit ratio.

Once the benefits are identified, there is a detailed process to secure funding. The Regional Flood and Coastal Committees (RFCCs) are allocated some levels of funding by the government. It is for them to decide who receives the funding. The Local Lead Flood Authorities (LLFAs) may also apply to receive partnership funding or apply levies to accrue additional funding. They may also lobby other companies responsible for flood risk, such as Thames Water (TW), as the schemes are likely to provide multiple benefits to all organisations. We agree that multiple benefits across all organisations are the best way to get schemes funded and provide benefits to the public.

4. Review the process of applying for and securing funding for flood risk schemes.

The process of applying for and securing funding should be simplified so as not to be so onerous on organisations. It should also be possible that Thames Water could apply for Flood and Coastal Erosion Risk Management (FCERM) funding on behalf of LLFAs where a scheme can be demonstrated to have benefit to both surface water and sewer flood risk. We appreciate that TW is funded by customers' bills. However, this is often significantly less than what is needed to make improvements on a wide scale to the network across the whole Thames Region. As a result, schemes need to be prioritised and programmed to comply with their funding and regulatory needs. A similar approach should also apply for implementing sustainable drainage measures. By funding

Case Study – Enfield Borough Council

The flood risk officers identified that Sustainable Drainage Systems were never going to be built with the current procedure.

The benefits of SuDS schemes are often small and localised: one rain garden is unlikely to have a significant impact. However, several hundred will have a much more tangible benefit.

The Council applied to the Thames RFCC to secure funding for a pilot to consider the wider benefit of SuDS. The original application was £70k but supplementary funds were made available by the RFCC so that SuDS schemes could be built. Further funding was then added by Thames Water.

The Council also teamed up with Cadent Gas, which maintains and operates the gas distribution network. By doing this, any excavation works carried out by Cadent could be enhanced by adding in SuDS features.

schemes in a joint partnership, this allows the stakeholders to set the terms of reference of the scheme, including the acceptable levels of risk, the standard of protection to be achieved and the resilience of the scheme for events greater than the set design standard.

Ofwat funding

Thames Water presents its business plan to Ofwat once every five years as part of the Price Review process. The next Price Review is finalised in 2024, which will secure the business plan for 2025-2030, or AMP8. Thames Water is in the process of agreeing its business plan based on needs identified across the business both at a strategic and an operational level. Within its business plan will be performance commitments which relate to reducing flooding from the sewer network. Another aspect of its current business plan is the proposal to automate Lots Road Pumping Station, which delivers an improvement on the resilience of the pumping station and the sensitivity of the pumping station to the timing of pumps being switched on.

As part of the process, TW will include in its business plan the proposed impact on customers' bills. This is often high and so there is some negotiation of the business plan to balance cost to the customers and the achievable programme of works. Therefore, there are some aspects that may change as a result.

Joined up partnership and levy opportunities are critical for funding flood risk schemes

We recommend that the approach taken by Enfield Borough Council is adopted across other London Boroughs (and potentially other cities across the UK). Ultimately, Highways and Planning departments will have best sight of future schemes. There is also the Infrastructure Mapping Application which identifies planned infrastructure work across Greater London. Incentives could be introduced to contractors to replace recently dug up surfaces with more permeable and sustainable drainage solutions when reinstating infrastructure to encourage collaboration for identifying such opportunities. Alternatively, penalties could be added where more sustainable solutions are not used to replace existing infrastructure. This is reliant on resources being available within the Boroughs to review and approve such works, so while we can suggest this as a recommendation, how and if it is implemented will be down to individual Boroughs or the Strategic Surface Water Management Group as discussed in Section 4.1.1.

5. **Seek opportunities for partnership working in areas of known flood risk to spread the cost of potential schemes, including consideration of source control as well as schemes which protect receptors. Identify blockers which prevent effective schemes being taken forward and lobby for additional resources to be made available to achieve funding.**

Challenges of current duties against future flood alleviation schemes

The funding allocated to LLFAs is not ring-fenced, which means that it can be allocated for alternative uses at each Borough's discretion. The funding is allocated by Department for the Environment, Food and Rural Affairs (DEFRA) and the Department for Levelling Up, Housing and Communities (DLUHC). The total funds, across the whole of England, amounted to £15 million in 2014.

With rising funding pressures across multiple funding streams, it is possible that some Boroughs will allocate the fund elsewhere and require officers to pick up multiple duties. This can result in under-resourcing of current duties under the Flood and Water Management Act 2010 (FWMA), such as producing Section 19 reports, but also mean that opportunities for future investment may not be actively pursued. As a result, benefits and improvements are not realised across the whole of London.

In order for the LLFA to allocate adequate resources, we recommend that the flood risk funding is ring-fenced. We would like each Borough to report back to the Strategic Surface Water

Management Group to demonstrate what has been achieved and to confirm if this has the desired effect of improving approaches to flood risk and collaborative working. To identify the reduction in flood risk, modelling and monitoring at a catchment scale would be required, and this also needs funding. By demonstrating improvements in knowledge and reduction of flood risk longer-term, it may stimulate further funding, thereby increasing availability of resources and funding.

6. **Ring-fence funding to LLFAs for flood risk duties. Lobby for additional funds to be made available so that the full remit of duties can be met.**

4.2.2 Incident response

Emergency response funding

Historically, the government has made funds available in an emergency to support response efforts. This is usually to support homeowners and businesses affected by flooding, as opposed to the coordination of efforts to respond to the flooding and to make communities more resilient in future. In some cases, this is made directly to homeowners, and in others this is made to the local authority to then distribute.

Being removed from one's home can be devastating and lengthy. Nearly one year after the flooding in July, some residents are still unable to return to their properties. If emergency funds were made available, this could be used to accelerate the clean-up, with the ability of local authorities and Thames Water to work together to increase the availability of clean-up crews, share resources and the coordinate the clean-up. This is likely to have an increased cost but would have a significant impact on the health and wellbeing of residents. Through the role of the Strategic Surface Water Management Group, the number of clean-up crews can be coordinated and deployed based on areas with the highest need after a flooding event. Given the rarity of these storms, it does not make sense for any one entity to hold sufficient capacity to manage a severe weather event. However, when called in, extra resources could be better marshalled.

7. **Enable the Strategic Surface Water Management Group to manage and coordinate response to flooding, including deployment of clean-up crews to areas of greatest need**.

4.2.3 Insurance

If a homeowner has a property that was built prior to 2009, they should be able to get insurance that covers for flooding. It is important that the property owner reads the small print and that there is no mention of exclusion due to flooding or natural events. If the property, or even your front room, is rented this may invalidate the insurance.

FloodRe is a government-backed reinsurance scheme, where government funds top up the insurance company, so that insurance can be provided for properties at risk. FloodRe is also the organisation administrating the 'build back better' scheme. In 2039, the scheme runs out and the aim is to encourage the industry to respond to the need to be climate resilient before then. Therefore, there is no intention of continuing the scheme after the planned date of 2039. The July 2021 floods highlighted some shortfalls in the FloodRe scheme, notably that houses of multiple occupancy, consisting of more than three flats, were not covered by the scheme. In addition, commercial premises are also not covered.

In April 2022, the 'build back better' scheme was announced which allowed up to £10,000 to be added to a flood claim to build in resilience (Our Future - Flood Re). As this system has only recently been announced, it is uncertain what the uptake will be and how simple it will be to access this money. In addition, properties may need significantly more investment than £10,000 to provide a satisfactory level of resilience. However, the shift in attitude to building in resilience

when repairing following a flood is a very welcome development, as previous practice was only to replace like-for-like and not to allow "betterment".

One of the greatest challenges during this Review was capturing data related to where and which properties flooded. Many local authorities reported to us their concerns related to under-reporting of flooding, believing the total numbers flooded to be significantly higher than was provided to us. This may be for a number of reasons; however, it is likely that the impact on insurance premiums and property prices is one of the key reasons for under-reporting. As part of the flood risk management community, this is frustrating, as it is often impossible to gather the full picture of flooding based on reports of flooding alone. However, reported flooding is also the basis of the funding of flood alleviation schemes; the opportunity to investigate providing a scheme is based on the number of properties currently at risk of flooding and how that figure will change with the scheme in place, compared with the cost of the scheme. There are other ways of measuring benefit, but this is at the heart of approvals for most flood risk schemes.

The way insurance premiums are determined is probabilistic and, therefore, if there are already several properties which have had flooding reported along the street, it is unlikely to have a meaningful benefit to an individual property's premium to not report flooding. We want to encourage homeowners to report flooding.

8. **Work with those who flooded to support their access to the FloodRe reinsurance scheme, the Build Back Better fund, and feedback any necessary improvements to the scheme. Consider lobbying for further investment into FloodRe scheme to include cover for houses of multiple occupancy and commercial properties to ensure they have access to insurance.**

Table 4.2: Summary of funding recommendations

Ref	Description	Complexity	Timescale	Cost	Current Actions
4	Review the process of applying for and securing funding for flood risk schemes.	L	L	L	
5	Seek opportunities for partnerships working in areas of known flood risk to spread the cost of potential schemes, including consideration of source control as well as schemes which protect receptors. Identify blockers which prevent effective schemes being taken forward and lobby for additional resources to be made available to achieve funding.	M	M	M	There are many case studies where this has been used previously, and these should be drawn on to inform discussions.
6	Ring-fence funding to LLFAs for flood risk duties. Lobby for additional funds to be made available so that the full remit of duties can be met.	H	M	M	
7	Enable the Strategic Surface Water Management Group to	M	L	M	

Ref	Description	Complexity	Timescale	Cost	Current Actions
	manage and coordinate response to flooding, including deployment of clean-up crews to areas of greatest need.				
8	Work with those who flooded to support their access to the FloodRe reinsurance scheme, the Build Back Better fund, and feedback any necessary improvements to the scheme. Consider lobbying for further investment into FloodRe scheme to include cover for houses of multiple occupancy and commercial properties to ensure they have access to insurance.	H	H	M	

4.3 Evidence

4.3.1 Monitoring and forecasting

Data monitoring

TW has a lot of monitoring data available to it, thanks to the strategic depth monitor network across its region. It is easy enough to set additional alarms, if not already done, to prioritise focus areas for responding to such extreme rainfall events. One of the key challenges will be the short, sharp nature of these types of events. Water levels can rise very quickly; in some cases, there was only 15 minutes between when it started raining and when the levels in the system were high enough for basement flooding to occur. Given this speed of sewer response, there are limited actions that operational staff will be able to take to prevent floods.

TW is proposing to expand this network of monitors and is currently developing a smart wastewater network system which improves trend analysis of the data. Once this is established, it may be possible to put this system online, to allow access by the wider stakeholder group. Until then, it appears to us to be of benefit to share available data, such as sewer cleaning regimes, pumping station performance and sewer levels. Given the rapid rate of rise in the sewer system during the events, this is unlikely to be real-time enough to be of benefit during the event. However, this will help LLFAs in the production of Section 19 reports to develop the history of what happened during the event.

Some cities across the world, particularly in Southeast Asia where they regularly experience intense storm events, have installed monitors on their roadways to determine the level of water which is ponding. By knowing the depth of water, how quickly it has risen and also where it is, they can prioritise sending crews to either manage the highway and, therefore, reduce the impact of the flooding or take measures to divert flows away from high-risk areas. This adaptive management is something that could be implemented in London, but we recognise that the steps to enable it may require some coordination given the number of bodies with responsibilities. Using the existing network of CCTV and monitoring across the city, the network could be established. It could be further enhanced by installing further road monitors across London in high-risk areas so that there is an understanding of flood routes and depths in real time. We recommend that each local authority understands where monitoring points coincide with hotspots and determine how best to access this data. Once this first exercise is completed,

there can be an informed application for additional funding to secure new monitoring locations and incorporate them into the system. There are many ways this could be implemented; however methods should be shared between Boroughs and then across the wider London stakeholders to help ensure the best response to flooding is implemented during an event.

Forecasting

One of the greatest issues with the events in July 2021 is that they were originally classified as 'yellow' risk events, which meant that there was very little opportunity for typical preparedness actions to be carried out, such as pre-emptive gully and sewer clearance. The yellow weather warning also covered a large area, from Hampshire to Essex, meaning that it was also unrealistic to mobilise crews and response teams across such a widespread area. Flood events can form quickly, so on the day, the Met Office did expect localised pockets of intense rainfall, but was unable to pinpoint where or when they would occur.

Many of the London Boroughs use HydroMaster, which is a product used to forecast rainfall using radar systems. This can then be tied into other monitoring or modelling platforms to allow for predictions of the impacts of the storm. The system is currently set up on an individual customer basis. To develop a pan-London system will require a wider trial, which is probably best coordinated by the Strategic Surface Water Management Group.

Case Study – Bangkok DSS

Mott MacDonald has delivered a pilot Flood Management Decision Support System (DSS) for Bangkok which integrates world-class rainfall estimates and flood predictions to support the first flood warning system globally for fast developing convective rainfall. The DSS unlocks the value of the underused existing rainfall radar network by automatically generating real-time rainfall estimates at a 500m resolution across Bangkok. Machine learning was applied to an hydraulic model, producing ground-breaking real-time stormwater flood maps. The DSS is delivered in Mott MacDonald's digital platform 'Moata', providing a central platform with in-built early warning alarms to enable targeted, proactive flood response and better outcomes for Bangkok communities.

Flood risk warnings may only be a few hours prior to the event, but this may give some more certainty of the scale and the location the rain will fall, allowing for homeowners and first responders to be able to take steps to prepare for the event. With technological advances and further research and development, the warning period may be extended to improve response times. Even with an increase in response time, there are limits to which pre-emptive activities may be undertaken.

We suggest that the risk management authorities, including Thames Water, Environment Agency, Transport for London and LLFAs, work together using their best available rainfall prediction tools to define an event risk zone based on likely location of an event. It is unlikely, with the current levels of certainty, that it is practical to expect model runs to be simulated and quality assurance carried out with sufficient time ahead of an extreme event. However, as the rainfall predictions and computing powers improve this may change.

9. **Investigate timescales and suitable application for multi-agency response to improve forecasting. Use forecasting to identify event risk zones and consider use of ICMLive models to develop computer learning models as a predictive tool to identify impact and operational response during an event.**

4.3.2 Modelling

Schemes are often designed using Flood Estimation Handbook (FEH) 13 rainfall depths which are distributed based on summer and winter profiles. The design storm considers a single event. In reality, rainfall is not distributed in such a way, and there may be multiple events of different intensity and depth, which occur sequentially. When considered this way, there may be implications for the design of the following features:

- Storage tanks may need to be bigger to accommodate changes in runoff and antecedent conditions
- Return pumps and subsequent pipework may need to be bigger to drain down the storage tanks more quickly, freeing up available storage volume within the tank ready for the next event
- Storage may need to be increased to accommodate additional runoff from saturated surfaces

As we demonstrated during the Review, the tide has the potential to exacerbate flooding on several areas of the network by restricting outfalls from draining to the river. There is no question that the tide, and similarly river levels, should be considered when designing new schemes and sewer systems. The Chartered Institution of Water and Environmental Management (CIWEM) Urban Drainage Group (UDG) has developed a user note providing guidance on the modelling of tide and assessing its impact on sewer systems.

We recognise that TW is using climate change uplifts for the Drainage and Wastewater Management Plans (DWMPs) to assess current and future risks in its region, which is important in adopting an appropriate planning framework. A more widely recognised approach should be incorporated into TW specifications and design standards. We recommend that these are aligned with Local Lead Flood Authority and Environment Agency guidance notes for consistency and approach. Current climate change factors are subject to change, so it is important to agree the range of climate change factors to be considered and for all agencies to update their specifications at the same time.

The analysis in the Stage 3 report identified how the Maida Vale tank filled during the event to a level that was not predicted by the model. Adding the 2D surface model to the ICM model demonstrated new flow routes which may have been missed using traditional 1D modelling approaches. We recommend that schemes are checked during design to see how they perform in events bigger than the event for which it is designed. By implementing exceedance events, stakeholders understand where flows will go when bigger events occur. This is relatively common practice for major river flooding schemes and could be adopted more widely for surface water and sewer flooding schemes.

A complex urban environment, such as London, is going to have multiple interactions between the major drainage systems (overland flow, rivers, tide and groundwater levels) and the minor systems (sewer and drainage networks). While we recommend full modelling, it may not be practicable or timely to model the whole of London in sufficient detail. It is currently very problematic for a model of this size as it requires too much computing power and would take months to run, particularly if our recommendation to add 2D to the model is carried out. As computer technology advances this may become a more viable option. Any such detailed flooding model investigation should consider the adoption of dynamically linked 2D modelling, agreed with the various stakeholders. As technology develops it may be possible for large scale regional models to also be 2D by default, so review of specifications should be made in the light of future technological advances.

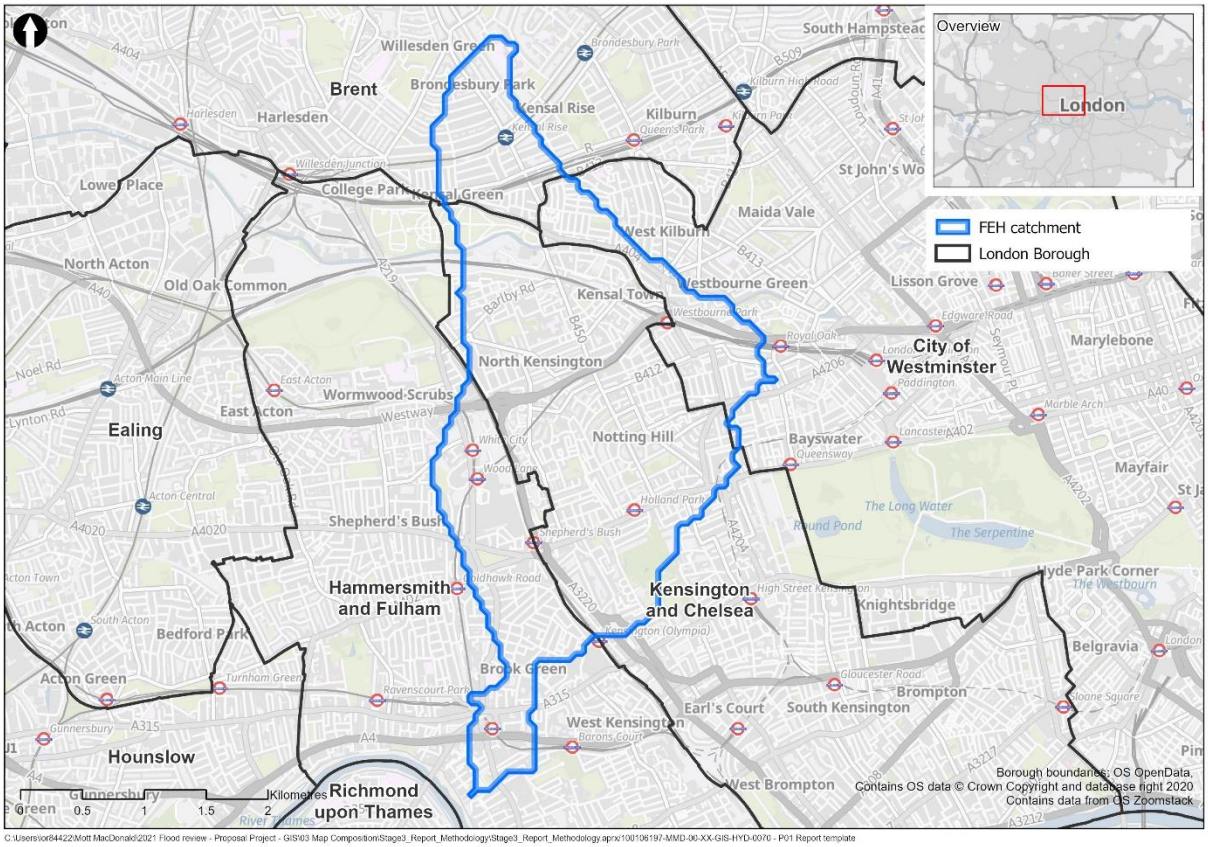
Flooding observed on 12 July 2021 was best represented in the Maida Vale 2D model by including the runoff from green spaces, notably Paddington Recreation Ground which then

drained towards Kilburn Park Road. The results from the model testing suggested that, in extreme events, the full picture of flood risk can only be appreciated when contributions from all land uses are accounted for. However, this leaves us with a challenge, as the bulk of this contribution only occurs for extreme events, when the permeable ground becomes saturated, and not for the more frequent events that models may be analysing. In addition, it is highly unlikely that an extreme event would be captured by short-term flow surveys, which are the usual basis for designs, so there will remain uncertainty as to the exact contribution from these surfaces.

During extreme intense events, not all the water falling can get into the system. This needs further investigation to identify the best way of representing this restriction in the model. Simply applying the rainfall to the 2D surface restricts flow into the system, and the flow in the pipes is then less than observed. Some water companies have developed 2D modelling specifications, such as Scottish Water's 2Di approach.

LLFAs commission the building of surface water models as part of developing their understanding of surface water flood risk, which then informs their Local Flood Risk Management Strategy. While we are aware that such surface water models exist, we were unable to analyse them during the Review, as many LLFAs were unable to provide them to us. It is important, and more cost-effective, that LLFAs make sure they maintain ownership of their models, building on historical knowledge of areas at risk and flood risk assets. It should also be recognised that often surface water or river catchment boundaries extend beyond the Borough boundaries of the LLFA – an example is given in Figure 4.1, which shows the lost river catchment boundary in blue and shows that the boundary crosses four LLFAs. This demonstrates the need to develop models which cover the catchment area, not only the LLFA area, as flows may originate from outside the Borough and result in increased flood risk.

Figure 4.1: Comparison of hydrological catchment boundaries and LLFA boundaries



10. Develop existing modelling specifications, or create new ones, which provide clear guidance on the use of rainfall, boundary conditions and complex flow mechanisms. Ensure that a common model environment is used so that shared risks between LLFAs and TW are well understood.

4.3.3 Asset performance

The performance of various assets can have a significant impact on how the system responds to flooding. It is important to understand which assets have an impact on reducing flood risk, such as pumping stations, storage tanks, flood gates, etc. During an event, how the asset performs can be an indication of what is happening across the wider system. It is important that each asset owner understands their assets. By understanding the asset, we would expect the asset owner to know:

- Where the asset is located
- What the asset is supposed to do
- What the asset is supposed to protect
- What happens in the event of failure of the asset
- What happens in the event of exceedance of the design criteria of the asset (e.g. where does the flow go if the asset is unavailable or full?)
- How the asset performed during recent events

Thames Water understands its assets and how they are performing. This understanding is from monitoring using SCADA systems or telemetry, either monitored locally or through the Control

Centre, and responses to certain alarms can be coordinated by this system. Sometimes the telemetry systems are old and the assets themselves may be so old that there are compatibility issues, so this should not be considered as the best system. However, there is a lot of data available, and we suggest that this could be used more constructively. For example, SCADA is often used by operational staff to determine how well the pumps within a pumping station are operating. In some cases, they could be used to assess whether there is risk of upstream flooding. Similarly long-term monitors are used to try and identify blockages or infiltration in the sewer but could also be used to identify storm responses in the network.

Thames Water, however, is only one asset owner. Its data is not readily shared with other asset owners, nor vice versa. Other asset owners may not have the resources available or the regulatory performance commitment requirements to drive such intensive monitoring and data gathering. Therefore, it can be challenging, across multiple asset owners, to identify how one asset may interact with another and how it may affect the operation of the whole system.

Another asset that should be considered is the gullies which are installed for draining the highways. These fall under the remit of the local authorities. It is the duty of the local authorities to maintain these assets. During the study we found that, for the July events, the rainfall was so intense in some locations that the capacity of the gullies was the limiting factor; even if they were all clear, not all the water would have been able to pass through them into the drainage network due to lack of physical space to allow the water to pass.

However, there was anecdotal evidence from residents that water was held on the surface when there was capacity below-ground in the sewers, as when a manhole was lifted water drained away. The retention of water on the surface would suggest the gullies in this location may have been blocked.

In smaller intensity events, a blocked gully may be the difference between no flooding and flooding and may also prolong the duration water is ponded above ground. By maintaining the asset, it will continue to perform as designed and at its most efficient. It is possible clearing all blocked gullies can allow more water into the system that could worsen flooding downstream. In certain circumstances holding water at the surface may be preferable if it does not result in flooding of properties. We consulted most Boroughs regarding their gully cleaning regime. Most Boroughs indicated that this cleaning occurs around once every two years unless the gully is considered to be at a high-risk location when it is cleaned more frequently. The gullies are often cleaned by a contractor working on behalf of the Borough. Anecdotally, we are aware that this is not always well coordinated, and the cleanliness of the gully is not always well documented after the visit. It should be possible to incorporate a requirement into the contractor’s work package to include recording visits and providing photographic evidence of each cleaned gully (e.g. using a mobile phone) georeferenced to the gully. This would improve both the knowledge of the condition and location of every gully within the Borough and provide evidence to ensure that the gully had been thoroughly cleaned.

Gullies which are prioritised more highly are often in areas where flood waters collect, as these are perceived to be areas of highest risk. We recommend that LLFAs question this assumption. If gullies further upstream are more effectively managed, more flow can get into the below-ground system and, therefore, less water may accumulate at the problem gully. This may not always be the case as topography and sewer capacities will have significant influences, but we recommend it is reviewed

Event response

Currently, much of the information gathered about flood occurrences comes from customer contacts. Many customers had difficulties in reporting flooding during the July events, for various reasons. By understanding assets and how they perform, triggers and alarms can be set for any abnormal operations (for example, if a monitor in the sewer rises within 2m of ground level,

there is potential for basement flooding). In such cases, operational crews might be sent to investigate and confirm if there is flooding, and the potential cause for that flooding.

During a widespread flooding event, many crews will already be responding to issues and may be unavailable for rapid redeployment. However, it would be helpful to prioritise areas where you have both the customer reports and other data to try and drive short-term fixes to reduce the risk of flooding. This would allow for prioritisation of emergency response to those actually in greatest need or at greatest risk, as opposed to responding solely to frequency of calls. This way, even if only a handful of calls are picked up by the Customer Contact Centres, decisions can be made as to how best to respond.

11. **Review critical assets and identify ways of monitoring data and information, such as data sharing platforms, during an event to inform decision-making and prioritisation. This may draw on data from all organisations as well as freely available data. Consider whether a digital twin is of benefit to replicate the system and understand the impact of various operations on system performance.**

12. **Assess impact of gully cleaning to determine the gullies which should be cleaned most frequently. This may not be the gullies where flows pond but may be further upstream to allow for flows to get into the system and be conveyed away from risk zones. The impact on other infrastructure should be considered.**

4.3.4 Reporting and forming evidence bases for future investment

The reporting of flooding, as previously mentioned in Section 4.2.3, may not always be complete. Individuals may choose not to report flooding for several reasons: whether they are tenants of the property, rather than owners; unable to report due to lack of access; stress of reporting; impact on property value; impact on insurance premiums. These are only some of the reasons. However, this makes collecting evidence related to the reporting of flooding very challenging. We need to understand where flooding has occurred, where properties have flooded and why, as this knowledge will ultimately lead to the best solutions being implemented. Therefore, we recommend that a number of modes of recording flooding history, from mobile phone apps and online forms to telephony and paper records, are used. This will require resources to collate and consolidate the responses into a single format for use in production of Section 19 reports. We do acknowledge that some LLFAs already undertake this responsibility, however this is not consistent across all Risk Management Authorities (RMAs).

There are several organisations that are responsible for flooding in any area. This could be the Environment Agency (main river and coastal flooding), the LLFAs (surface water and ordinary watercourse flooding) or Thames Water (sewer flooding). In extreme events, especially in urban areas, it is sometimes impossible to immediately understand where the flood water has come from, so deciding who to report to can be complex, especially during a difficult time when so many things may be up in the air. When flooding is reported to only one organisation, it is easy to collate flooding records. However, collating information in different formats across multiple organisations is apparently extremely hard to manage effectively. Also, where LLFAs are required to produce S19 reports, it is possible that, due to the Borough boundaries, the extents and mechanisms of flooding are not fully understood where they cross boundaries.

We recommend that a data manager is appointed who is responsible for housing and managing flooding history data. The data manager will undertake an in-depth study to determine what information should be collated and is suitable to be shared, while also complying with regulations pertaining to the sharing of personal data. It is probable that this person should sit within the Strategic Surface Water Management Group and will take responsibility for

establishing the coordination and appropriate dissemination of flooding records following an event.

13. **Review current data collection processes across all stakeholders and identify improvements. Establish a suitable data platform to host flooding history data and manage appropriately. Appoint a data manager to be responsible for data and how it is shared.**

Table 4.3: Summary of evidence recommendations

Ref	Description	Complexity	Timescale	Cost	Current Actions
9	Investigate timescales and suitable application for multi-agency response to improve forecasting. Use forecasting to identify event risk zones and consider use of ICMLive models as a predictive tool to identify impact and operational response during event	M	L	M	Many local authorities are using HydroMaster which can be used as a predictive tool. However, this is not coordinated across London.
10	Develop existing modelling specifications, or create new ones, which provide clear guidance on the use of rainfall, boundary conditions and complex flow mechanisms. Ensure that a common model environment is used so that shared risks between LLFAs and TW are well understood.	L	L	L	
11	Review critical assets and identify ways of monitoring data and information, such as data sharing platforms, during an event to inform decision-making and prioritisation. This may draw on data from all organisations as well as freely available data. Consider whether a digital twin is of benefit to replicate the system and understand the impact of various operations on system performance.	M	H	M	A bespoke product is required as no ‘off-the-shelf’ option currently exists to meet the needs of the RMAs
12	Assess impact of gully cleaning to determine the gullies which should be cleaned most frequently. This may not be the gullies where flows pond but may be further upstream to allow for flows to get into the system and be conveyed away from risk zones. The impact on other infrastructure should be considered.	M	M	H	

Ref	Description	Complexity	Timescale	Cost	Current Actions
13	Review current data collection processes across all stakeholders and identify improvements. Establish a suitable data platform to host flooding history data and manage appropriately. Appoint a data manager to be responsible for data and how it is shared.	M	M	M	

4.4 Communication

4.4.1 Preparing for events

Since July 2021, many organisations have been working more collaboratively, recognising that the impact on residents and business owners across London was not well coordinated. The London Resilience Group has established a 'Strategic Flood Response Framework' which identifies certain triggers, actions and responsibilities during a flooding event. The trigger levels also align with the Multi-Agency Flood Plans, which have been developed by the LLFAs. We acknowledge that the production of these flood response plans is a significant improvement and will likely lead to better outcomes for Londoners.

There are four defined response levels to flooding included in the framework. These are also aligned to the multi-agency flood plan (MAFP) trigger levels.

1. Level 1 which includes long-term flood mitigation and business as usual
2. Level 2 which includes a planning phase in advance of an event which may have a flooding impact
3. Level 3 includes responses once flooding has been reported, or there is likely to be an increased risk of flooding as a result of a failed asset or structure
4. Level 4 is when a severe weather warning is issued or the response to flooding requires escalation

There are a few minor recommendations that should be incorporated into the flood plans. It is important to acknowledge that further specific actions may be included already as part of the framework, which are not specifically stated.

- There is a jump in triggers between Level 2 and 3; from a weather warning and preparedness to receiving reports of flooding.
- There is little call for interaction with Thames Water, which may have insights and additional information to share regarding performance of assets and flooding reports. Sharing information is indicated but relies on the defined partners being part of the Framework and could be extended to be more explicit.
- The requirement for capturing and sharing flooding data is stipulated and it is suggested that a mechanism is put in place, but the responsibility for coordination and what this mechanism may look like is currently hard to visualise.

Thames Water has prepared a Hydraulic Flooding Playbook with clear processes in place for responding to recorded incidents, following July's storms. This includes a control tower system with separate roles for:

- Incident Commander
- Return to Service Lead

- System Operations Lead
- Customer Resolution Lead

The Hydraulic Flooding Playbook defines roles and responsibilities that would be adopted during a future flooding incident. This need was identified during the July events. Thames Water has also taken steps to improve engagement with political stakeholders and Boroughs during the event.

Influential political stakeholders should be informed in good time before flooding events occur. Ideally, this would be two to three days ahead of an event (which did not happen on 12 July 2021), although we recognise this may be challenging with the current confidence in forecasting such an event. However, it is often possible to identify the risk of convective storms over London, for example, and engage with all stakeholders. Information disseminated to affected MPs, councillors and other stakeholders could be shared with customers. This should be targeted and coordinated through a stakeholder engagement tracker that monitors stakeholders that receive and issue engagement during flooding events.

The following areas should feed into the engagement plan with stakeholders, with the aim to improve communications with the public but also help those at risk of flooding or who are vulnerable:

- Sharing awareness of flooding and possible dangers
- Sharing awareness of steps that residents can take to mitigate some of the potential impacts on properties ahead of flooding or to safeguard themselves and their valuables
- Sharing awareness of contact information and how to find out more information about the flooding events

14. **Set trigger points, likely to be aligned with the multi-agency flood plan and London Resilience Group's triggers, to mobilise operational and TW Customer Contact Centre staff and engage with key stakeholders to prewarn of a potential event.**

15. **Ensure that the current response plan includes alerting customers who have either signed up to be notified of risks in their area, previously experienced flooding, or are on the priority services register, that there is a potential risk of extreme weather in advance of the event so that they may prepare.**

16. **Carry out exercises to practice new flood response and communications plans to improve preparedness and cooperation across multiple organisations.**

4.4.2 Responding during events

The average waiting times for the Customer Contact Centre were very high during the 12 and 25 July flooding events. This is likely to have contributed to generating distress among residents, a lack of information and possible spread of disinformation. We recommend that TW improves its 'trigger' for mobilising out of hours/emergency staff resources during flooding events. The trigger for out of hours communications and customer contact staff was not in time on 12 July. By improving the methodology for triggering increased resources, TW will be more prepared to accommodate an increase in demand for Customer Contact Centre calls. We acknowledge TW is looking into outsourcing emergency Customer Contact Centre support when required, but further details on how this may be implemented were not provided. TW has also implemented a 'call-back' system that enables customers to arrange a call back if a

Customer Contact Centre operator cannot be reached in time. Additionally, we recommend that improved reactive messaging is put in place on TW's website during flooding events. This messaging should provide information about the flooding event and point customers towards contact details. We also recommend the use of social media to have a wider-reaching audience.

There were elements of failure to communicate and coordinate with local authority emergency planning teams and the London Resilience Group during the event. The responsibility for this lies across all organisations. Therefore, we recommend that, as part of the emergency response planning, communications leaders are identified from each organisation. During a flooding event, the relevant identified communications leaders should establish a group of affected authorities and lead on public communication during flood events.

17. **Implement process for updates to website messaging and key lines of communication to be shared across all key stakeholders as an event unfolds.**

4.4.3 Post-event response and clean up

TW has already taken steps to improve its flood reporting process. Previously, this was done by submitting a paper form to TW. It is now possible to submit this in paper format or online. This way more customers can report flooding following an event and receive the help, support and follow-up that they need.

On 14 July, TW contacted the following council emergency planning teams to offer assistance: Hammersmith and Fulham; Kensington and Chelsea; Merton; Richmond; Westminster; Ealing; Barnet; Brent; Kingston; and Harrow.

Early and agreed messaging should be in place for communicating to the public during and following emergency events. It is critical that all customer facing staff, including Customer Contact Centre staff, are aware of lines to take to enable consistent messages to be provided to the public. This would assist TW in providing its customers with trust and confidence during emergencies. In addition, clear briefing from TW to LLFAs will also improve the dissemination of information across multiple organisations. This should not be just one-way but should encourage sharing of information to ensure that the public are well-informed.

Emergency response crews should be briefed earlier and more regularly on the ground to ensure consistent messaging. On 12 July, it was reported that different messages were given to residents by different members of staff.

18. **Create and disseminate an 'emergency communications group messaging' briefing document to staff and stakeholders. Update regularly during and after flooding events to enable clear and consistent messaging across the various stakeholders.**

4.4.4 Coordinating and sharing information across organisational bodies

Data sharing plays an important role in flood management. Different organisations will collect different data during and following any event. It is important that organisations share their data across the various Risk Management Authorities, so that everyone has a coordinated and complete understanding of the various assets and responses being undertaken. This could be made available on a London-wide basis, to include flood reporting, register of assets, monitoring equipment and alarms.

Currently, data is shared between TW, local authorities and other stakeholders that deal with flooding, such as the London Resilience Group. However, no proper data sharing agreements have been implemented to set out in detail how and what data should be shared. This results in the following risks:

- A lack of knowledge about what data is available and up to date

- Data not being shared
- Data not being in a usable and accessible format

Currently, stakeholders responsible for flood management record data about flood assets, receptors, etc. in a wide variety of ways and formats. To ensure that different datasets are as complete as possible, and align with each other where necessary, we suggest a range of pre-agreed, consistent formats are made available for those contributing data.

We recommend that the relevant bodies undertake a thorough analysis that helps streamline the data collection process in flood management. This, in turn, should help everyone involved to better understand what is currently available and synchronise different datasets provided by different stakeholders. This will allow for completion of a gap analysis to identify the most important data gaps across all organisations and allow for prioritisation to obtain additional data to fill those gaps.

In terms of flood reports, one method of ensuring synchronisation could be the use of online reporting tools. For example, to compare S19 and council reports with the Sewer Flooding History Database (SFHD) dataset effectively, we had to reformat and ‘clean up’ the datasets that were provided. The existing datasets included spelling inconsistencies and a lack of more detailed addresses, which made it difficult to use without significant cleaning.

The use of online reporting tools should help ensure improved data quality through built-in data validation and data filters, which help to enforce correct and relevant information. Pictures or small videos could be included in an interactive new online form, based on the current pdf sewer flooding questionnaire. This would not only inform people about how to distinguish between different types of flooding while filling out the questionnaire, but also allow customers to submit their own photos of the flooding.

19. Establish a data sharing agreement between TW and other relevant stakeholders which sets out what and how data is shared. Enable LLFAs quick access to data.

4.4.5 Coordinating and sharing information for customers

In addition to the actions that are taken by the various organisations responsible for flood management, there are also actions people can take to protect themselves. This includes a range of activities that can lead to better understanding of what risks you may face and how to take steps to reduce your risk of flooding, reduce your impact on the urban environment, or reduce the damage to properties and valuable items.

Further advice and support can be obtained from National Flood Forum. We recommend members of the public consider joining an existing flood action group in their area. If the local community want to form a new flood action group, we recommend they contact the nearest flood action group to find out more about what is involved.

TW should improve its educational resources to help prepare customers for flooding events, including tailored information for properties at higher risk. TW should ensure educational resources are made accessible for customers via appropriate website pages, mailshots, social media posts and through stakeholder liaison.

Informing people about how to recognise different types of flooding could also help with customers identifying the dominant cause of flooding. Below-ground and above-ground flooding is regularly reported to TW, but it is unknown which one is the dominant mechanism. Having a better insight into the flooding mechanism will help with analysing the data and identifying root causes. This information piece could also include content regarding roles and responsibilities during a flood event, emphasising the various organisations which should receive reports of

flooding. This awareness campaign should be carried out with the LLFAs to ensure the messaging is consistent.

Customers who have previously experienced flooding, or are on the priority services register, should be notified that there is a potential risk of extreme weather in advance of the event so that they may prepare. Alternatively, customers could subscribe to the service for free, thereby consenting to be contacted, similar to the service provided by the Environment Agency for river flooding. This could be coordinated with the help of flood action groups and the LLFAs to consider the risk and likelihood of vulnerable customers being affected. There is a risk that, due to the nature of surface water flooding, customers may be alerted more frequently to the risk of flooding. The trigger for notifications could also be difficult as customers may be alerted falsely and then become desensitised to warnings.

London has undergone a significant amount of change, which has inevitably had an impact on flooding. Increasing the amount of paved areas has had an impact on the amount and speed of runoff which enters the sewer network. Property owners have a duty to consider their own property footprint and have the opportunity to make small-scale improvements to reduce the area of hard paving. If every homeowner adds a water butt to collect stormwater flows, or adds permeable paving to their parking area, this will have a larger impact across the whole of London. By increasing education around this cause and effect, and implementing more stringent planning policy, there could be slow but long-term catchment-wide improvements to reduce the risk of surface water flooding.

After the event, many customers were requesting FLIP devices to protect their properties. It is important that FLIPs are installed correctly and that the impact of the FLIP on neighbouring properties is fully assessed, otherwise it may result in putting other properties at risk. It would be valuable to expose the process that TW use to select properties for the FLIP programme, to improve confidence and transparency in the system.

Homeowners may wish to install a FLIP privately to protect their home, rather than rely on an external agency. There are risks to this approach which should be shared with homeowners: it may not be installed correctly, therefore having little impact on reducing the risk of flooding; it may put other properties at risk; it will be the duty of the homeowner to maintain the FLIP to ensure adequate ongoing protection. LLFAs and TW also need to know where these FLIPs are installed so that they can adapt their flood risk schemes to consider any impact of these measures. We recommend that the installation of pump devices requires planning permission, for which an informative could be placed on the permission so that TW is notified. This can build on existing work undertaken by the GLA to improve awareness of the risks associated with basement developments.

20. **Create cross-organisation educational campaign regarding flood risk to help residents and businesses to understand their risk and steps that they can take to reduce that risk and gain insurance.**

21. **TW to share policy on procedure for assessing FLIP installation with stakeholders for clarity and openness**.

22. **Understand where customers implement their own measures. This data will help RMAs to understand the cumulative impact of these measures on flood risk. Create digital form for consultation process so that TW is informed.**

Table 4.4: Summary of communication recommendations

Ref	Description	Complexity	Timescale	Cost	Current Actions
14	Set trigger points, likely to be aligned with the multi-agency flood plan and London Resilience Group's triggers, to mobilise operational and Customer Contact Centre staff and engage with key stakeholders to prewarn of a potential extreme event.	L	M	M	
15	Ensure that the current response plan includes alerting customers who have previously experienced flooding, or are on the priority services register, that there is a potential risk of extreme weather in advance of the event so that they may prepare.	M	H	M	
16	Carry out exercises to practice new flood response and communications plans to improve preparedness and cooperation across multiple organisations.	M	M	M	
17	Implement process for updates to website messaging and key lines of communication to be shared across all stakeholders as an event unfolds.	L	L	L	
18	Create and disseminate an 'emergency communications group messaging' briefing document to staff and stakeholders. Update regularly during and after flooding events to enable clear and consistent messaging across the various stakeholders.	L	L	L	
19	Establish a data sharing agreement between TW and other relevant stakeholders which sets out what and how data is shared. Enable LLFAs quick access to data.	M	M	M	
20	Create cross-organisation educational campaign regarding flood risk to enable residents and businesses to understand their risk and steps that	L	M	M	

Ref	Description	Complexity	Timescale	Cost	Current Actions
	they can take to reduce that risk.				
21	TW to publish policy on procedure for assessing FLIP installation with stakeholders for clarity and openness.	L	L	L	
22	Understand where customers implement their own measures. This data will help RMAs to understand the cumulative impact of these measures on flood risk. Create digital form for consultation process so that TW is informed.	M	L	M	

4.5 Strategic plan

4.5.1 Network and system improvements

It is important to continue to invest in the long-term resilience of both the sewer network and above ground system. How organisations respond to known and emerging risks will define the scale of investment in flood risk management strategies and business plans.

Over the years, there have been a number of planning frameworks used by water companies to identify risks in the network and to inform their investment planning process, the latest of which is the Drainage and Wastewater Management Plan (DWMP). The aim of the DWMP is to understand how the network performs in its current state, but also identifies emerging risks. Every water company is required to produce a DWMP. Thames Water's DWMP, which highlights the areas most at risk across its network, can be found online.

The DWMP identified several potential options which will require significant investment in the network over the next 25 years. The funding routes for these schemes will need to be confirmed and may have an impact on customers' water bills. To reduce the cost to customers, it is important for TW to identify partnership ways of working, such as the pilot currently being developed for Waltham Forest. The benefits of this may be significant, as not only can the overall cost of the scheme be shared, but the benefits can also be wider reaching.

The current sewer system, as discussed throughout the Review, does not achieve the current target of 1-in-30 year standard of protection. To achieve this across the whole of London, the upgrades required to the sewer network and strategic pumping stations would be at a disproportionate cost and impact. When the costs, disruption and environmental impacts are considered, this upgrade is not practicable. The current alternative is to seek and seize opportunities to separate the combined system so that the sewers do not continue to be burdened by rainwater. It is unhelpful to set such a high standard of protection where it may not be practical to achieve it. In Denmark, a 1-in-10 year design standard is used for combined systems, and a 1-in-5 year for separate systems. How systems perform once exceeded, so that they are exceeded safely, is more critical.

The LLFAs are responsible for developing and updating their Local Flood Risk Management Strategy (LFRMS) which is a statutory document that must be produced, reviewed and updated under the LLFA's duties. These plans set out the current and future understanding of flood risk in conjunction with schemes that may be implemented. Both the LFRMS and DWMP rely heavily on collaboration with other Risk Management Authorities. These documents can set out

key guiding principles such as the establishment of designated flood risk areas or more stringent planning policy.

The current requirement is to do this by Borough boundary. However, in more complex systems such as found in London, there are flow connections between the Boroughs that would make it more applicable to carry out modelling across catchments rather than Borough boundaries, and to design and install flood management schemes by catchment. In this case, LLFAs may need to work in partnership to form larger LFRMS.

4.5.2 Asset resilience

Design standards

We recommend further discussion in the industry as to whether it is better to contain the flows on the surface, in a managed way such as in designated flood channels, or if it is better to drain them to below-ground systems. The middle ground is to design for rainwater flows to enter the sewer system, but to design for the sewer system capacity to be exceeded safely. This way you know exactly where it will overflow and can contain and divert flows away from properties, commercial areas and critical infrastructure, such as roads, rail networks, power supply and hospitals. By maximising opportunities for disconnection and Sustainable Drainage Systems (SuDS), the resilience of the below-ground systems can be improved over time. The outcome of this discussion will then inform updates to specifications and best practice across the industry.

We recommend that the Strategic Surface Water Management Group considers and determines an acceptable level of risk in terms of return period for flooding. This may vary across the city, depending on the receptors and impact of potential flooding. Once the level of risk is agreed across the organisations responsible, it will be possible to establish required standards of protection for any future schemes.

A recent Met Office paper indicated more rapid weather change, stating that 30mm/hour intensity storms in London (approximately a 1-in-15 year event) could be twice as likely in 2030 and 2.5 times as likely in 2070. Climate change uplifts change frequently as our understanding of the impacts improve. The uplifts should be checked against the latest guidance on data.gov.uk to ensure the most up to date values are being applied.

Rising sea levels will mean that operation of the Thames Barrier will become more frequent. Barrier operation lowers water levels in the reach of the river where stormwater is discharged and may result in reduced flooding from storm rainfall. However, storm conditions in central London play no part in operational decisions for the barrier, so any benefits in terms of flooding should be considered a bonus rather than any part of system planning.

The climate change uplifts used can vary depending on the design horizon of any flood alleviation scheme, and the design approaches of the lead organisation implementing the study. It is, therefore, important that stakeholders are consulted on factors such as climate change uplifts and sea level rise to establish a standard of protection that the stakeholder group has accepted.

Organisations often have different modelling standards or modelling approaches. This not only applies to the interaction between TW's assets and the local authority assets, but also across Borough boundaries. There is not a standardised approach regarding the layout and set up of surface water models so that these can be easily shared or integrated. As part of this Review, we had difficulty obtaining knowledge of coverage and setup of models from local authorities, and it is acknowledged that there are some limitations in this area. We recommend, therefore, that the organisational bodies agree a standard of modelling which is acceptable to them and the customers they serve.

23. Set out clear terms of reference of what flood risk resilience schemes are aiming to achieve, in terms of acceptable levels of risk, desired standard of protection and design requirements, in conjunction with Recommendation 11. Agree across the RMAs. Understanding the flood risk mechanisms in play will result in a scheme which delivers the maximum benefit potential to all stakeholders.

Flood risk mitigation measures

Installation of FLIPs should be carefully assessed, and not considered a default response to reduce flood risk. They should be installed in areas where it is not possible to otherwise achieve the 1-in-30 year design standard (or other agreed design standard) or where there are particularly vulnerable customers. For basement properties which reported flooding in July, but for which flooding in lower return period events is not confirmed, it is likely that a non-return valve (NRV) will be sufficient as it will be used less frequently. All mitigation measures will need to be maintained and operated once built, to mitigate the risk of failure during an event when they are needed most. The ongoing maintenance requirements are often considered as part of the costs.

Where schemes are designed to address multiple mechanisms of flooding, we recommend that there is a standardised approach regarding the layout and set up of surface water models so that these can be easily shared or integrated to determine surface water flood risk and the need for investment across multiple authorities. Sharing assumptions, such as the application of climate change factors and design horizons including potential growth, is also important to demonstrate how the various systems will work together. As an alternative, any surface water models developed should be built so that they can be shared with InfoWorks ICM and, therefore, integrated with TW network models.

Assessing critical assets

There are two aspects for consideration: firstly, to identify which assets may be at risk of flooding; and secondly, to identify where the operation (or maloperation?) of assets may increase the risk of flooding and to whom.

Assets may be receptors. These could vary from properties and domestic dwellings to commercial properties and major infrastructure hubs, such as power substations and transport links. The National Planning Policy Framework sets out the details of this criticality assessment, otherwise known as vulnerability. Assets under review should be assigned a criticality which is a combined score of the impact and likelihood of failure of the asset. Assets which are designated highest criticality may require mechanisms, such as walls or pumps, to divert flooding away from the asset. The Strategic Surface Water Management Group may alternatively decide to define a higher standard of protection for the most critical assets, such as hospitals.

Assets may also be flood assets which help to manage flooding. Local authorities, through their duties as LLFAs, are responsible for maintaining a flood asset register for their Borough. Attempts have been made to consolidate this across London, but this is ongoing. Understanding the location of assets and their function is critical to enabling cross-organisational collaboration and determining how best to respond to flooding.

It would be useful to identify crucial assets in a shared space, such as an online GIS platform. In an emergency, or major incident, these assets can be viewed holistically across multiple organisations. Decisions can be made using the full asset database and prioritised in the correct way. For example, if flows are diverted away from an electrical substation towards a hospital, this may warrant further diversions of flow, such as constructing temporary flood defences which will need to be included in the event response planning.

24. Strategic Surface Water Management Group to assess criticality of strategic assets and assign required standard of protection. Review measures in place to ensure continuity of performance during flooding events. Review current Flood Asset Register compiled by LoDEG and make recommendations to improve consistency and understanding of assets. Assess assets which are critical for flood risk management and the implications for other assets where they may fail. Communicate findings to all stakeholders.

4.5.3 Re-greening London

The installation of Sustainable Drainage Systems (SuDS) or rolling back the amount of impermeable area is an important part of the toolbox for reducing flood risk. SuDS slow the flow by attenuating water in green spaces, such as rain gardens or swales. Water can then drain more slowly to the sewer network or infiltrate to the groundwater once the storm has passed. Often the cost-benefit of individual SuDS schemes is difficult to justify, as discussed in Section 4.2.1. However, the cumulative impact of SuDS schemes will be to begin to reverse problems caused by the high levels of urbanisation which have occurred across London over the last two centuries.

By using existing best practice with widespread SuDS installations, such as the city policy in Copenhagen and New York, we would no longer need to demonstrate the cost-benefits of SuDS to secure funding. Individual SuDS schemes are not economical, but the whole-scale city approach, which could be supported with modelling and planning policy, would demonstrate large-scale improvements. By engaging with suppliers to LLFAs and water companies, it may be possible to introduce incentives and penalties for contractors who do not include SuDS schemes in their developments. Incentives could be introduced such as to waive certain fees for applications from contractors to replace with more permeable and sustainable drainage solutions when reinstating infrastructure and to encourage collaboration for identifying such opportunities. Alternatively, penalties could be added where more sustainable solutions are not used to replace existing infrastructure.

25. Consider incentivisation of Nature Based Solutions to form part of the flood risk management infrastructure to improve the 'grey to green' water and reduce runoff into the drainage network to encourage widespread promotion and uptake of installation.

4.5.4 Planning policy

The London Plan 2021 currently states that flood risk should be managed in a sustainable and cost-effective way. The focus on flood risk management is very much based on those areas at risk from surface water flooding, reported by the various London Boroughs, and the risk from the River Thames. We endorse this approach, but also recognise that there is interaction between surface water and sewer flooding, and this should also be considered.

In addition, the London Plan sets out expectations for developers to include surface water management techniques to reduce runoff from new developments. New developments are only 1% of the total area of London, and so the opportunity for installing surface water management techniques should not be limited to new developments. This could be incentivised by the Boroughs to encourage uptake across the construction industry.

The London Plan sets the aspiration that sites should aim to achieve the “greenfield runoff rate” and, where this is not possible, a minimum reduction in runoff of 50%. Flows should be managed as much as possible at their source. Each individual Borough can set more stringent targets and, indeed, some have. This will have a significant benefit for the existing sewer system, but also have wider benefits in terms of green space in newly developed areas.

Furthermore, this supports the widely cited advice of the European Environment Agency: “think about green before investing in grey.”

In some cities, the roadways are designed and expected to safely carry floodwater in extreme storms. By implementing this strategy, the floodwater can be safely contained in the urban space, and areas can quickly return to their everyday use. Appropriate measures may involve minor but wholesale amendments to kerb lines, low point attenuation areas (i.e. blue corridors and informal detention basins) and designation of flood risk spaces. By working in collaboration with landscape architects and public realm designers, an urban spaces design guide could be developed to encourage safe routing and storage of surface water built into the streetscape.

Under the current planning procedure, basement developments may be undertaken through permitted development, unless the dwelling will be converted into a standalone flat or a light well is to be constructed. This means that developments may occur without the planning authorities being consulted and without the opportunity to highlight and stipulate that certain flood risk measures should be followed to reduce the risk of sewer flooding.

26. **Identify the significant flow paths in the city, which often follow the path of the lost rivers. These should be formally designated as protected overland flow routes. Formalisation of these routes may involve minor but wholesale amendments to kerb lines, low point attenuation areas (i.e. blue corridors and informal detention basins) to make these routes safe for conveying flood waters. Additional policy should be written preventing changes within these designated routes without a full assessment and understanding of how these changes may affect their function.**

27. **Local authorities to consider implementing more stringent development policies so that greenfield runoff rates must be achieved. This should also be followed up to encourage developers to implement realistic and functional solutions.**

28. **Local planning authorities to amend their planning policies where there is a known risk of sewer flooding to incorporate any basement development or construction work. This will increase the workload of the planning authorities, so we recommend that funding is increased to meet this change in demand.**

Table 4.5: Summary of strategic plan recommendations

Ref	Description	Complexity	Timescale	Cost	Current Actions
23	Set out clear terms of reference of what flood risk resilience schemes are aiming to achieve, in terms of acceptable levels of risk, desired standard of protection and design requirements, in conjunction with Recommendation 11. Agree across the RMAs. By understanding the flood risk mechanisms in play will result in a scheme which delivers the maximum benefit potential to all stakeholders.	L	L	M	

Ref	Description	Complexity	Timescale	Cost	Current Actions
24	Strategic Surface Water Management Group to assess criticality of strategic assets and assign required standard of protection. Review measures in place to ensure continuity of performance in flooding events. Review current Flood Asset Register compiled by LoDEG and make recommendations to improve consistency and understanding of assets. Assess assets which are critical for flood risk management and the implications for other assets where they may fail. Communicate findings to all stakeholders.	L	L	L	
25	Consider incentivisation of Nature Based Solutions to form part of the flood risk management infrastructure to improve the 'grey to green' water and reduce runoff into the drainage network to encourage widespread promotion and uptake of installation.	M	L	L	
26	Identify the significant flow paths in the city, which often follow the path of the lost rivers. These should be formally designated as protected overland flow routes. Formalisation of these routes may involve minor but wholesale amendments to kerb lines, low point attenuation areas (i.e. blue corridors and informal detention basins) to make these routes safe for conveying flood waters. Additional policy should be written preventing changes within these designated routes without a full assessment and understanding of how these changes may affect their function.	H	M	M	
27	Local authorities to consider implementing more stringent development policies so that greenfield runoff rates must be achieved. This	L	M	L	Many local authorities may have implemented this already

Ref	Description	Complexity	Timescale	Cost	Current Actions
	should also be followed up to encourage developers to implement realistic and functional solutions				
28	Local planning authorities to amend their planning policies where there is a known risk of sewer flooding to incorporate any basement development or construction work. This will increase the workload of the planning authorities, so we recommend that funding is increased to meet this change in demand.	M	H	M	Many local authorities may have implemented this already

5 Discounted options

Throughout the Review, our engagement with stakeholders has generated numerous suggestions for possible changes that TW and other bodies could make, which we investigated but rejected as recommendations. These options are considered here as catchment-wide or city-wide options. However, specific ideas may have been considered on a more local scale in earlier sections of the report. This section summarises these discounted options.

5.1 Upsizing all the pipes in London

Some areas of London have a risk of sewer flooding of less than a 1-in-5 year return period event, when the current design standard for new sewers is to manage flows from a 1-in-30 year event. This raises the question: why do we not just upsize the system to cope with a 1-in-30 year event?

There are multiple reasons why this is not possible. There are various causes of flooding, only one being the size of pipes, others include tide/river locking of outfalls, restrictions of pumps, treatment works and other ancillaries. If we were to upsize all the pipes that are restricting flow, it will add more pressure on the pumps and ancillaries. In addition, increasing capacity in some areas may result in more water getting more quickly to a location that may flood for other reasons, worsening flood risk downstream of the area addressed. A further complication to this approach is the congestion of below-ground services in London; this often makes it technically impossible to install new, larger pipes due to the lack of space.

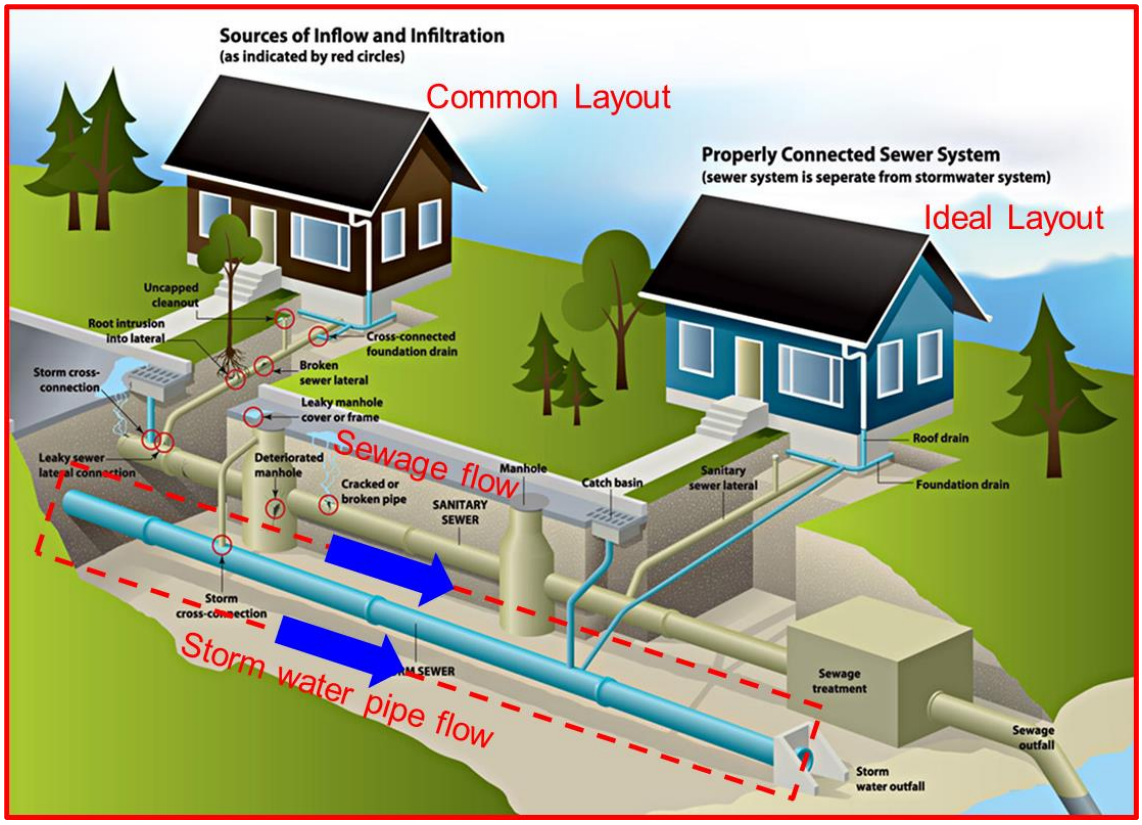
Even in areas where it is technically feasible for upsizing, the cost of this overhaul would be significant and would require significant increases in everybody's water bills to pay for it, including those not at risk of flooding.

5.2 Separating the systems

Current best practice is to separate wastewater and stormwater flows to reduce the pressure on the combined system during storm events. Stormwater flows can be managed by either infiltrating into the soil, storage within the catchment or discharging via a separate sewer system to a nearby river or waterbody. This separation, which does not mix with wastewater, opens up opportunities for using greenspace to temporarily store water on the surface during extreme events.

It is extremely difficult to separate out stormwater from an existing combined system, as it would involve altering the connection point for all downpipes and road gullies. Therefore, these systems are often installed during the construction of a new development, maximising the opportunity to install a separate system. The Greater London Authority has set an objective for all new developments to have a separate system, an example of which is given in Figure 5.1, with most of the stormwater flows being held so that they discharge to the sewer system at a slower rate or are infiltrated into the soil and do not affect the sewer system at all.

Figure 5.1: Example of a combined and separate sewer system



Source: https://sewerdiagnostics.com/sewer-system-explained/

TW is looking at separation programmes to contribute to this aim by installing permeable paving systems when roads are excavated by other authorities. However, this requires a large amount of coordination which can be difficult.

5.3 Bigger pumps

As described above, in some locations one constraint to flood management may be the pump size, but in others it is the network draining to the pump. In some circumstances, upsizing the pumps alone would not benefit the catchment because the water would not be able to get to the pumping station without increasing the pipe sizes upstream. In addition, there would be a constraint of space due to the congestion of services below the ground, similar to the challenges described with upsizing pipes above. Bigger pumps require bigger pumping stations, larger power connections and possibly increased power network protections. Many of these pumps transfer flows to another part of the network which is not sized to receive the additional flows, and this could make flooding worse for properties downstream.

For pumps that discharge excess water to a river during storm events, upsizing would increase the untreated discharge and pollution, reducing the positive impact the Thames Tideway will have on water quality.

Pump upsizing is one of the options that TW considers as part of Flood Schemes, but this is in conjunction with associated pipe upsizing, both upstream and downstream of any upsized pump.

5.4 Large formal storage areas

The total volume of water that fell over London in eight hours on 12 July 21 is estimated to be over 3.5 million m^3, compared with approximately 1 million m^3 of available storage volume in the drainage network. Over 2.5 million m^3 of rainwater would need to have been stored somewhere during the July events to avoid flooding. To visualise this amount of water, imagine standing on the pitch at Wembley Stadium and water fills up to your head (approximately 2m), and then multiply that volume 125 times. London is very constrained for space, both above and below-ground, so to store that amount of water would not be practical. In addition, it would require significant pipework to get the rainwater to these storage spaces, which has the same challenges as upsizing pipes. Finally, this volume of storage would be for this event in this location; there are other locations in London where similar storms would require similar storage. Given the comparative rarity of such storms and the high additional cost rise on all residents' bills, on what basis would one area be safely prioritised over another?

5.5 Sustainable Drainage Systems

The installation of Sustainable Drainage Systems (SuDS) is an important part of the toolbox for reducing flood risk. SuDS can be seen as a "silver bullet" solution whereas, in reality, they tend to offer the most benefit for smaller storm events. It is unlikely that SuDS as the sole solution to this type of flooding is practical, as many of the challenges are similar to the challenges of large storage volumes – the volume of water for these extreme events is so vast it is not possible to accommodate the flood water through storage and infiltration of SuDS. In the example of Counters Creek Flood Alleviation Scheme, SuDS were used to offset the detriment caused by stopping water entering people's basements through FLIPs. This is a much smaller volume of water to deal with, rather than trying to address the whole challenge of dealing with these extreme events through SuDS.

5.6 Urban deculverting

Deculverting refers to open up river systems that are currently within pipes to form open channels. It is a practice generally to be encouraged as it is easier to spot issues in an open channel and to maintain and operate the system. Open channel watercourses also usually have far greater capacity than pipes. They also have a secondary capacity called the floodplain, which is used once the capacity of the river channel is exceeded. By defining the floodplain as an area where flooding is likely to occur, landscaping and land management can be used to create a good public space which can also act as a flood risk reduction measure.

However, the situation in London is complex. The lost river watercourses have been so integrated into the sewer network over time, that the water is not clean so there would be a hygiene concern if they were open channels. There are so many connections and cross connections in the system it would be a hugely difficult and costly process to separate these systems from the rest of the sewer network to allow for them to be opened up. Furthermore, it is likely that the land above the culverted watercourse has been developed on and, therefore, it would not be possible to open up this space using the old floodplain, without a significant land acquisition and clearance programme.

5.7 Using the Thames Barrier

As the tide-locking of the outfalls to the River Thames worsened flooding during the July 2021 events, it was suggested that closing the Thames Barrier at low tide could be used to keep the Thames low and maintain discharge of flood water into the river during these extreme events. This is not the current purpose of the Thames Barrier, which has the sole role of protecting against coastal and river flooding.

The Thames Barrier needs significant warning to plan a closure event, and several hours to close. For the events experienced in July 2021, there was little warning due to the nature of the storm. Even if a sufficient warning system could be established, it is unlikely to have the required lead time for the barrier to be mobilised. If it could be closed in time, the Thames Barrier would be used more frequently, which would affect its performance and lifespan. It would also require a change in legislation at UK government level to enable the Thames Barrier to be used to reduce the impact of tide-locking on sewer outfalls.

In addition, encouraging spilling to the Thames in flood conditions is contrary to the joint ambition of the Environment Agency and Thames Water to reduce sewer spills into our water bodies, which the Thames Tideway Tunnel is aimed to address.

5.8 Pre-emptive gully cleaning

Similar to the challenges of using Thames Tideway, in the July 2021 events there was no warning to allow anyone to mobilise teams to clean critical gullies ahead of the events. Even if a warning system could be established, it is unlikely to be able to provide sufficient have the lead time to allow the local authorities to respond ahead of the event.

In addition, the resources available within local authorities would not be able to provide for this additional duty without significant additional budget or cutting spending on another public service.

6 Next steps

It seems imperative in the face of the current and future risks of flooding that the approach taken across London is consistent and, therefore, a cross-London approach is recommended. This Review provides a first step in identifying possible actions to improve the resilience to this type of extreme event in the future. Many of the actions fall under the responsibility of multiple agencies so the implementation of these recommendations may not be straightforward.

6.1 Dissemination

The Independent Expert Group (IEG) will be focussing, over the next few months, on engaging with wider stakeholders and the general public regarding the findings of the report. The stakeholders consist of two key groups:

- Political stakeholders, such as Members of Parliament, Councillors of London Boroughs and Secretaries of State and their advisors
- Technical bodies, such as the Institution of Civil Engineers (ICE), the Chartered Institution of Water and Environmental Management (CIWEM), and technical bodies advising government such as the National Infrastructure Commission (NIC) and the London Council's Transport and Environment Committee. The London Drainage Engineers' Group (LoDEG) and flooding officers within the Lead Local Flood Authorities (LLFAs) may also be considered to fall within this group as they have a technical interest in the findings of the Review.

We will prepare and distribute briefing packs for these groups to inform discussion around the key recommendations. We encourage debate and engagement among practitioners and the general public as to how these recommendations may be achieved.

We have received much communication from the wider public as part of the Review process. This indicates that there is a lot of interest in our findings. Members of the IEG are willing to attend town hall discussions to share the findings and recommendations of the Review, however, this may be limited due to timescales and availability. We encourage council members and MPs to reach out to the IEG via the website.

6.2 Implementation

The purpose of the Review is to identify and propose recommendations. However, our report has no regulatory force, and we cannot make or require the changes we recommend, so the process for implementing any recommendations will evolve over a period of time. Through this process, various stakeholders, along with the newly formed Strategic Surface Water Management Group, the Environment Agency, Regional Flood and Coastal Committee, NIC, and others, will need to confront many of the high-level governance and associated funding issues which we have discussed in Sections 4.1 and 4.2.

The recently formed Strategic Surface Water Management Group is likely to be the best group to formulate or at least monitor the implementation plan, where there are strategic recommendations which need collaboration across multiple organisations. Individual organisations should reflect on what they could implement and develop their own action plans. For transparency, we recommend that each member of the Strategic Stakeholder Panel shows what steps they will take and which recommendations they will take forward. We recognise that the recommendations are quite strategic and will likely be turned into implementation plans. These will cover the steps required to achieve the recommendation, identify responsibilities and drive SMART actions to encourage those progressing these recommendations to be accountable.

It is likely that some recommendations will not be achievable in the short-term due to the need for funding or legislative changes. Bold changes should be considered, such as forming a single organisation responsible for surface water flooding management. For these recommendations, a roadmap should be identified to outline the steps that must be taken to ensure progress is still made towards these longer-term goals. By identifying the desired approach, structure and funding mechanisms, it will be possible to influence new and changing legislation, taking a more proactive approach in future.

In addition to the recommendations outlined in this Review, there will also be progress by TW and the LLFAs to develop further flood schemes to address the areas thought to be at greatest risk, which can only be achieved by working together collaboratively. TW is currently developing a plan for implementing further FLIPs and considering local schemes in a response to this Review. The next steps to this progress will include an update to the information on actual flooding during the July events, allowing for information missing from this Review to be incorporated prior to any decision being made on where new schemes are to be prioritised.

6.3 Yearly reviews

The Strategic Surface Water Management Group will be best placed to carry out an annual review of the progress towards actioning the recommendations and provide a brief report on progress that should be made publicly available. Some recommendations may be considered quick wins and, therefore, will be easy to demonstrate that they have been achieved. Others will experience difficulties due to the complexity of the current organisational structure and step changes will be required to enable recommendations to be taken forward. The report will include progress on these interim steps. If blockers are identified, the Strategic Surface Water Management Group should be enabled to challenge these blockers and seek ways to drive forward the necessary changes.