Counters Creek
Technical Appendix
Modelling

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Section 1

Introduction

1.1 This is a technical appendix which provides supplementary information to the main Counters Creek Understanding of Flood Risk and Long-Term Strategy report. Table 1 shows the clauses in the performance commitment to which the supporting evidence relates.

1.2 We recognise that we did not provide sufficient transparency of the granularity of our hydraulic model and the extent to which it is integrated with other catchment models when we submitted evidence for our AMP6 performance commitment. For that reason, this appendix sets out the work we have done historically to build and improve the model over the last 30 years alongside the work we have undertaken in AMP7.

1.3 Our Beckton model is increasingly capable of replicating the large storm events and resulting flooding such as occurred in the extreme weather events on 12 and 25 July 2021. The model improvements have developed along with technology and improved data collection, resulting in greater insight into the changing risks of flooding and allowing assessment and implementation of more sophisticated solutions, better integrated across different asset owners.

Table 1: Mapping performance commitment requirement to section of report

Requirement	Appendix section
Further model build and verification work, applying industry best practice throughout, to improve its understanding of the risk of flooding in the Counters Creek catchment as a whole and in localised flooding areas. It is considered likely that this would include an improved understanding of both localised as well as more strategic catchment wide flooding mechanisms, following guidance from the CIWEM Urban Drainage Group (UDG) (2017) Code of Practice for the Hydraulic Modelling of Urban Drainage Systems (COP) or successors as well as other guidance where required	2
The inclusion in the model of basements and domestic connections at key flooding locations, to a Type III level of detail, as per the COP, where necessary, to predict the onset of flooding at property level.	3
The limitations of any resultant model should be clearly stated. In particular it should be stated, at headline level, the conditions under which the model cannot be used with confidence to provide a sufficient level of understanding regarding the risk of flooding in the Counters Creek catchment.	4 3.16

Section 2

Evolution of our modelling approach

A Stages and types of model

2.1 Counters Creek is modelled as part of the much larger Beckton Catchment, as shown in Figure 2. For the Drainage and Wastewater Management Plan we combined the strategic models of the Beckton and Crossness Catchments with the detailed Beckton model so we can fully assess the impact of the Tideway Tunnel, growth, and climate change on central London. As a sub-catchment of the combined model, this means that any analysis we undertake to understand the risk of flooding in Counters Creek automatically takes into account the impact of rainfall across a wide area and the impact from and to upstream and downstream catchments.

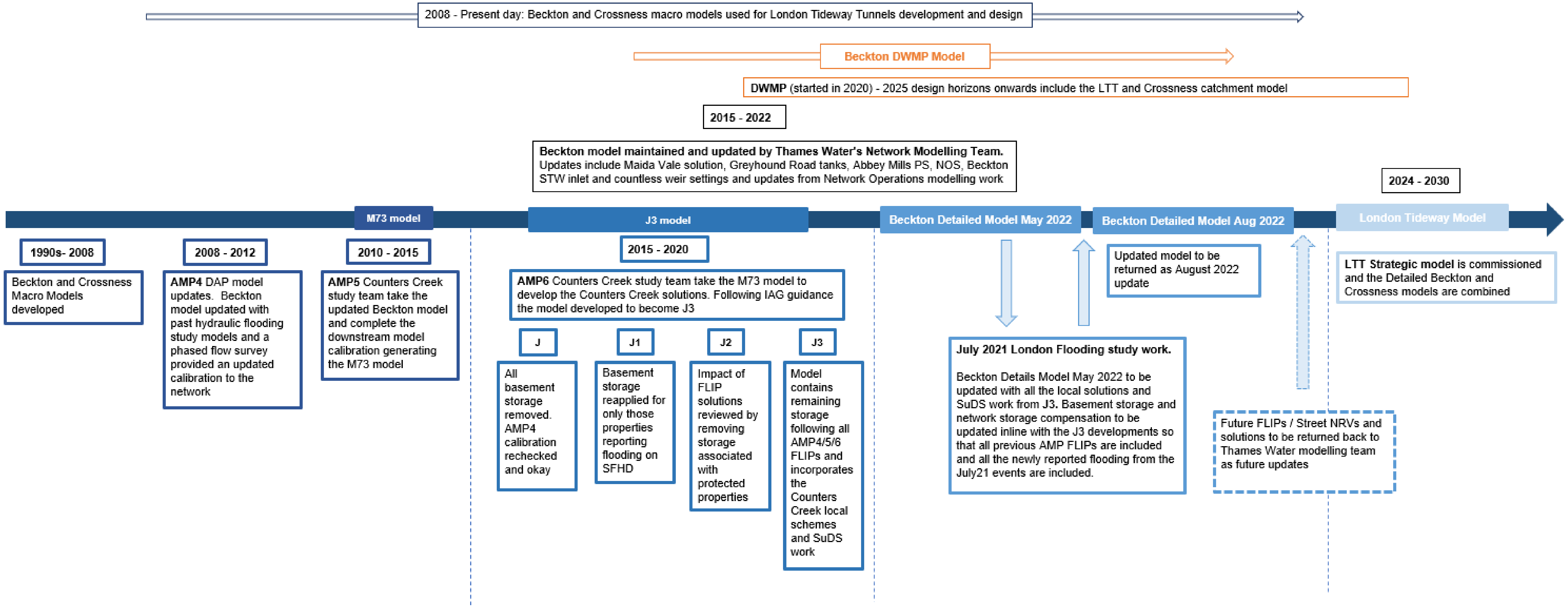
2.2 Our models are used to understand the risk of flooding as a result of different rainfall patterns across the whole catchment, and to pinpoint the root causes of flooding. Table 2 shows we use different, appropriate modelling components for different purposes.

Table 2: Types of model/system

Type	Use
Strategic Model	Beckton strategic model has been combined with the Crossness strategic model for the purpose of developing the control philosophy for London Tideway Tunnels, as it represents flows in the trunk sewers and the spills to the river. Used for drainage and wastewater management plan (DWMP) modelling.
Beckton Detailed Model	Assessing flooding risk in Counters Creek including any impacts on the upstream and downstream risk. Testing operational interventions and developing safe systems of work for access to sewers. Post event analysis and catchment learning to continuously update and improve the catchment model. Used for DWMP modelling
ICMLive modelling platform is used in conjunction with Beckton model	Operational use of the model against live rainfall and tidal events in order to test operational performance and interventions in real time. To manage safe systems of work for access to sewers by raising forecast alarms based on model predicted levels and flow rates.

2.3 Figure 1 shows how the Beckton hydraulic model in which the Counters Creek catchment is modelled has evolved over time.

Figure 1: Evolution of hydraulic model used for the Counters Creek area and impact on adjacent catchments



2008 - Present day: Beckton and Crossness macro models used for London Tideway Tunnels development and design

DWMP (started in 2020) - 2025 design horizons onwards include the LTT and Crossness catchment model

Beckton model maintained and updated by Thames Water's Network Modelling Team. Updates include Maida Vale solution, Greyhound Road tanks, Abbey Mills PS, NOS, Beckton STW inlet and countless weir settings and updates from Network Operations modelling work

Beckton and Crossness Macro Models developed

AMP4 DAP model updates. Beckton model updated with past hydraulic flooding study models and a phased flow survey provided an updated calibration to the network

AMP5 Counters Creek study team take the updated Beckton model and complete the downstream model calibration generating the M73 model

AMP6 Counters Creek study team take the M73 model to develop the Counters Creek solutions. Following IAG guidance the model developed to become J3

All basement storage removed. AMP4 calibration rechecked and okay

Basement storage reapplied for only those properties reporting flooding on SFHD

Impact of FLIP solutions reviewed by removing storage associated with protected properties

Model contains remaining storage following all AMP4/5/6 FLIPs and incorporates the Counters Creek local schemes and SuDS work

July 2021 London Flooding study work.

Beckton Details Model May 2022 to be updated with all the local solutions and SuDS work from **J3.** Basement storage and network storage compensation to be updated inline with the J3 developments so that all previous AMP FLIPs are included and all the newly reported flooding from the July21 events are included.

Updated model to be returned as August 2022 update

Future FLIPs / Street NRVs and solutions to be returned back to Thames Water modelling team as future updates

LTT Strategic model is commissioned and the Detailed Beckton and Crossness models are combined

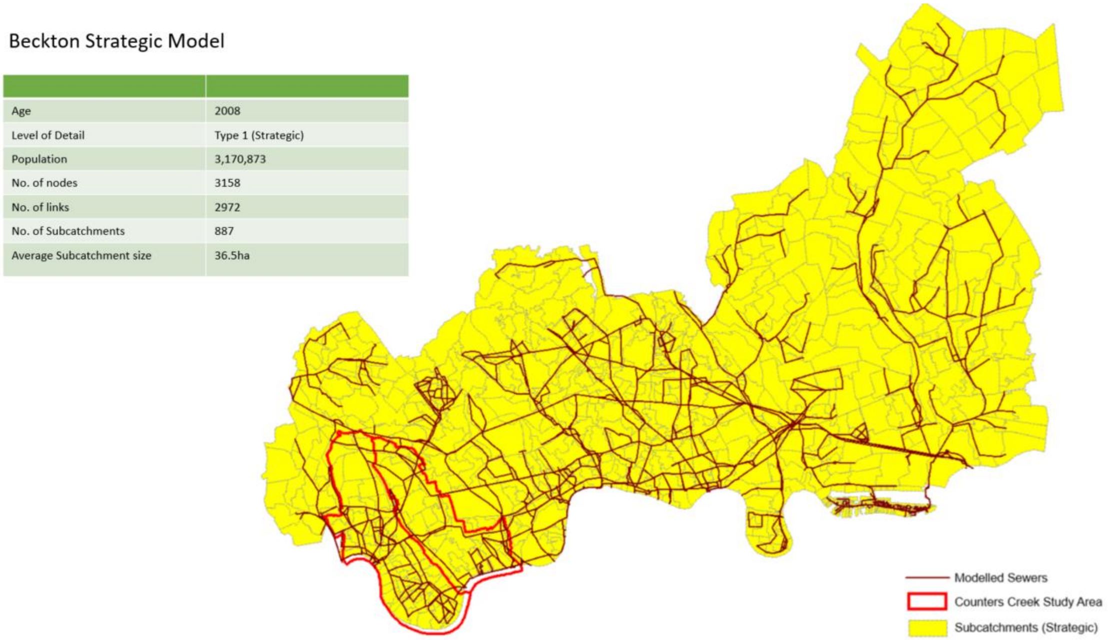
2.4 Model development has occurred in four main stages, of which stages 2 and 3 overlapped timewise.

- Stage 1: Building of the skeletal Beckton model, which includes the representation of all major trunk sewer assets and hydraulic control points (intersections between trunk and storm relief systems) within the catchment.
- Stage 2: Calibration of the model to ensure the runoff parameters and flow paths within the model match the observed data in flow surveys and operational telemetry data from pumping stations and storm tanks.
- Stage 3: Ongoing verification of the Beckton model to ensure what is observed through day-to-day operational activities (for example assets out of service) and flooding events on the ground is mirrored in the model.
- Stage 4: The full detailed Beckton Model (including the Counters Creek Catchment) was combined with the Tideway Tunnel and Strategic model of south London to understand the impact of growth and climate change up to 2050 as part of DWMP.

B Stage 1 – skeletal model 1990s - 2008

2.5 The original Beckton Type 1 strategic hydraulic model was built and calibrated in the late 1990s, and included key details of the major network junctions and control points such as bifurcations, combined sewer overflows (CSOs) and pumping stations. It was limited in size by the software limitations of the time but was used in the design and assessment of many previous flood alleviation schemes. Pockets of more detailed sewer networks were modelled and calibrated with flow surveys, and these were added to the trunk sewer model to provide the boundary conditions. In 2008, six of these detailed areas were joined together and the gaps around them filled in to create the basis of the detailed model we have today.

Figure 2: Beckton strategic model in 2008



Beckton Strategic Model

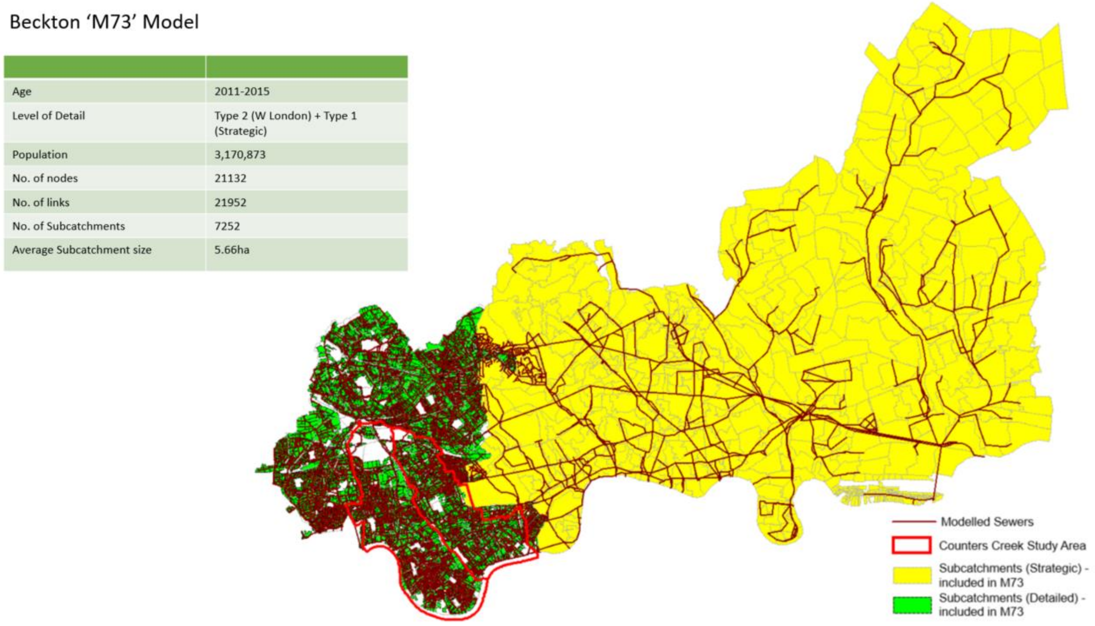
Age	2008
Level of Detail	Type 1 (Strategic)
Population	3,170,873
No. of nodes	3158
No. of links	2972
No. of Subcatchments	887
Average Subcatchment size	36.5ha

C Stage 2 – detailed calibration 2008 – 2012, 2015 – 2020

2.6 From 2008 to 2010, detailed re-calibration of the Beckton model was undertaken via a series of catchment-wide surveys, with 72 flow monitors which were moved sequentially from west to east. In 2011, a further localised flow survey[1] with 18 loggers was undertaken within the Counters Creek catchment to infill the areas, as shown in green in Figure 3. Calibration of the model using the data collected continued until 2012.

2.7 An additional flow survey was undertaken in Maida Vale, upstream of Counters Creek, to ensure the model was calibrated to past flooding events, and this was used for design and construction of the Maida Vale flood alleviation scheme in AMP5. This model was subject to an internal audit[2] by Optimise, who developed this scheme.

Figure 3: Re-calibrated detailed M73 model



Beckton 'M73' Model

Age	2011-2015
Level of Detail	Type 2 (W London) + Type 1 (Strategic)
Population	3,170,873
No. of nodes	21132
No. of links	21952
No. of Subcatchments	7252
Average Subcatchment size	5.66ha

2.8 From 2012, infilling of the detail of the rest of the Beckton catchment (Figure 4) continued so it could be used to assess the impact of flows downstream of Counters Creek, as far as Abbey Mills and the Northern Outfall Sewer (NOS) to Beckton STW. This model was used for much of the system analysis and business case development for the Counters Creek Flood Alleviation Scheme.

2.9 From 2015-2020, sensitivity analysis was undertaken on the model during the development of the design of the Counters Creek scheme in order to build confidence in model predictions. The sensitivity analysis included further investigation of the modelling of basements (through increasing the amount of survey information and reviewing the representation of basements in the model (see section 3)) and calibration against the long-term monitoring and historical storms in the catchment which resulted in the J3 Model

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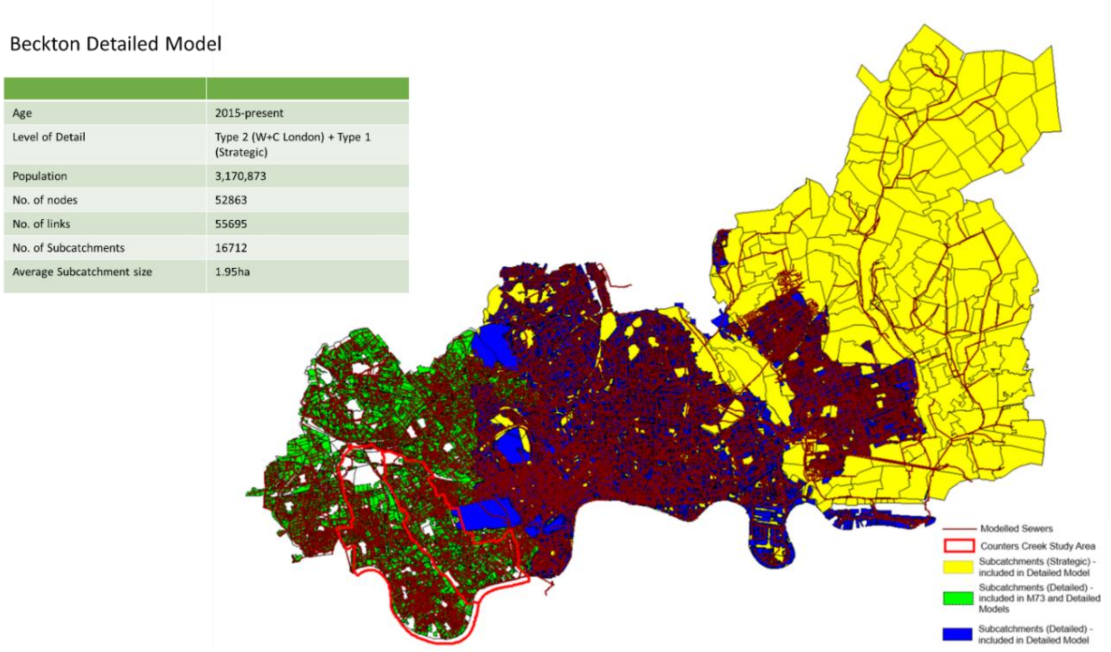
[1] Survey was undertaken to address an audit recommendation as part of an independent model audit undertaken by Clear Environmental Ltd.

[2] Counters Creek Flood Alleviation - Assured Report - AuditData_WN - All Documents (sharepoint.com)

shown in Figure 4. The density of model nodes has increased substantially, and the average sub-catchment size has reduced by over 200%, thereby increasing granularity.

Figure 4: J3 model



Beckton Detailed Model

Age	2015-present
Level of Detail	Type 2 (W+C London) + Type 1 (Strategic)
Population	3,170,873
No. of nodes	52863
No. of links	55695
No. of Subcatchments	16712
Average Subcatchment size	1.95ha

D Stage 3 – ongoing verification 2011 – date

2.10 Once the model was calibrated ongoing verification was undertaken using a variety of data sources to ensure the model reflected operational reality.

2.11 In 2011, a trial was undertaken in Shepherds Bush within the Counters Creek area to use live forecasting of rainfall data and continuous simulations of the Beckton model within the modelling software called FloodWorks. This trial area was extended out across the wider Beckton Catchment prior to the 2012 Olympics in order to support forecasting of the risk of flooding along the major transport routes and in the competition areas.

2.12 In the 2015-2020 period the following verifications and surveys were undertaken:

- A study of the operation and performance of Western Pumping Station located on the Chelsea Embankment at the lower end of the Counters Creek catchment. The study was to understand the future interaction and control philosophy in relation to the Tideway Tunnel. This enhanced the model with detail on the operation of Western Deep Storm Relief Sewer, its own lift pumping station, and Western Pumping Station. The additional flow monitoring and calibration work confirmed a good verification of flows and levels between the model and the actual operation.

- Changes to the number and operation (filling and emptying) of Acton Storm tanks following removal of two of the six storm tanks due to the construction of a Tideway Tunnel shaft.

- ICMLive, the successor to FloodWorks, was used with the hydraulic model at Hammersmith Pumping Station to provide a safe system of work before allowing operators to enter the storm relief lines during connection of the Tideway Tunnel.
- Modelling of Hammersmith PS inlet was carried out to represent the construction works taking place and the way flow is managed at the station. Flume pipes and protective weirs around the construction works have been represented in the model.
- Following the storms on the 23 June 2016, 27 and 28 May 2018 and 24 September 2019 the model was reviewed against depth logger and pumping station telemetry data. Comparisons were made between the predicted and observed maximum levels in the network, as well as the timing of rise in water level, the duration of surcharge and the short-term outage of a pump to ensure that the model accurately replicated actual impacts. The model-predicted levels were then compared with reported flooding on the Sewer Flooding History Database to confirm how the model aligned with reported flooding locations.
- In 2019 the model was used to assess the maximum water levels and flooding along Greyhound Road. Survey data was used to update the flap valves, silt levels, tank spills and return settings in the model.
- We have incorporated our learning from the London 2021 floods into the model, in particular the performance of the Maida Vale scheme, as described in section 4.3.2 of the Stage 3 London Flood Review Report.

E Stage 4 – drainage and wastewater management plan model – 2022

2.13 To understand the long-term impacts of growth and climate change on the performance of the Beckton Catchment, we considered the impact of the Tideway Tunnel which will be operational from 2025. The design and operating parameters were developed by combining the strategic hydraulic models for Beckton and Crossness.

2.14 We have merged the strategic Beckton and Crossness model with the detailed Beckton model[3] for the purposes of modelling emerging risk as part of the DWMP. This has allowed us to model the impact of climate change, growth and urban creep on the whole Beckton catchment area, including the interactions between Counters Creek and the upstream and downstream catchments for the 2025, 2030, 2035 and 2050 periods.

2.15 This model includes all the local solutions, FLIPS and sustainable urban drainage work that has been undertaken to date and the actual flooding occurring from the extreme rainfall in June 2021. The model reflects the impact on basement storage and network storage compensation, used to represent unmodelled pipes and manholes.

2.16 The model, in conjunction with real time depth monitors installed at key strategic trunk locations, is used frequently to confirm operational issues and identify risks. The process to update the model is iterative and involves collaboration between operational staff and the Systems Modelling team at Thames Water. If the operational staff identify an issue or require access into a section of the sewer system, the Systems Modelling Team will simulate the

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[3] Type III model as defined by CIWEM Urban Drainage Group (2017) Code of Practice

impact of any diversions and where risks related to flooding or adverse operational performance is likely to occur.

2.17 The real time depth monitors provide early insight into equipment failure so operational teams can ensure equipment is repaired in a timely fashion.

2.18 Over the next six months, 50 further depth loggers will be installed at key trunk sewer intersections across Beckton. They will provide valuable data on how flows move from one section of the network to another providing further insight on the interaction between trunk system arteries.

2.19 The model is continually improved upon using real-time data. The depth logger data will feed into our smart waste systems and operational trends will be generated by this platform as described in the main report. This allows deviations from the normal to be flagged to control room staff in much the same way that the blockage loggers are working now.

Section 3

Representation of basements in the model

3.1 This section describes how basements and domestic connections at key flooding locations are represented in the model, and how this is used to predict the onset of flooding at property level. In paragraph 3.11 we also respond to Ofwat's previous correspondence on the ability to represent all basements directly in the model. We explain how this is impacted by the sheer volume of basements in the area and the current limitations of the best available modelling software.

B Data gathering

3.2 In 2006, a digitisation exercise was undertaken to collect data from several sources to map assumed locations of basements in West London. The original basement GIS layer was created from clean water connection data for the whole of the Thames region, where flows were split to serve multiple residents in converted buildings and where there was a record referring to the meter being located in a basement/cellar/lightwell.

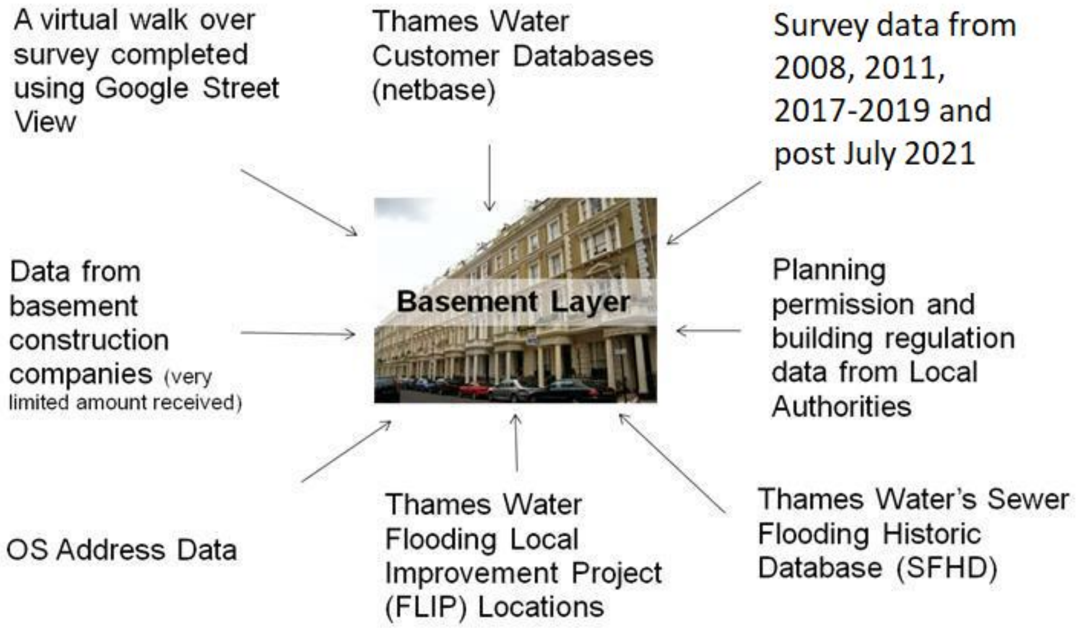
3.3 Since that date, a number of improvements have been made to refine the basement register:

- removal of sheds and coal cellars by reviewing small area polygons in the GIS database
- the collection of additional survey data to validate the original basement register, basement locations and where properties may be at higher risk of flooding.

3.4 In 2009, the basement layer was refined to provide a more location-based representation of known basements which was used for modelling the Counters Creek project. This process is described in Appendix E of the original Counters Creek Feasibility Report submitted to you as part of our Business Plan for PR14.

3.5 We have now added basement levels from surveys to basement locations to improve our understanding of flood risk (see Figure 5).

Figure 5: Current data used to compile basement location information used to assess risk of flooding to basements



C Representation of basements in the hydraulic model

3.6 We have carried out a detailed review of how basements are represented in the hydraulic model in conjunction with the Independent Advisory Group.

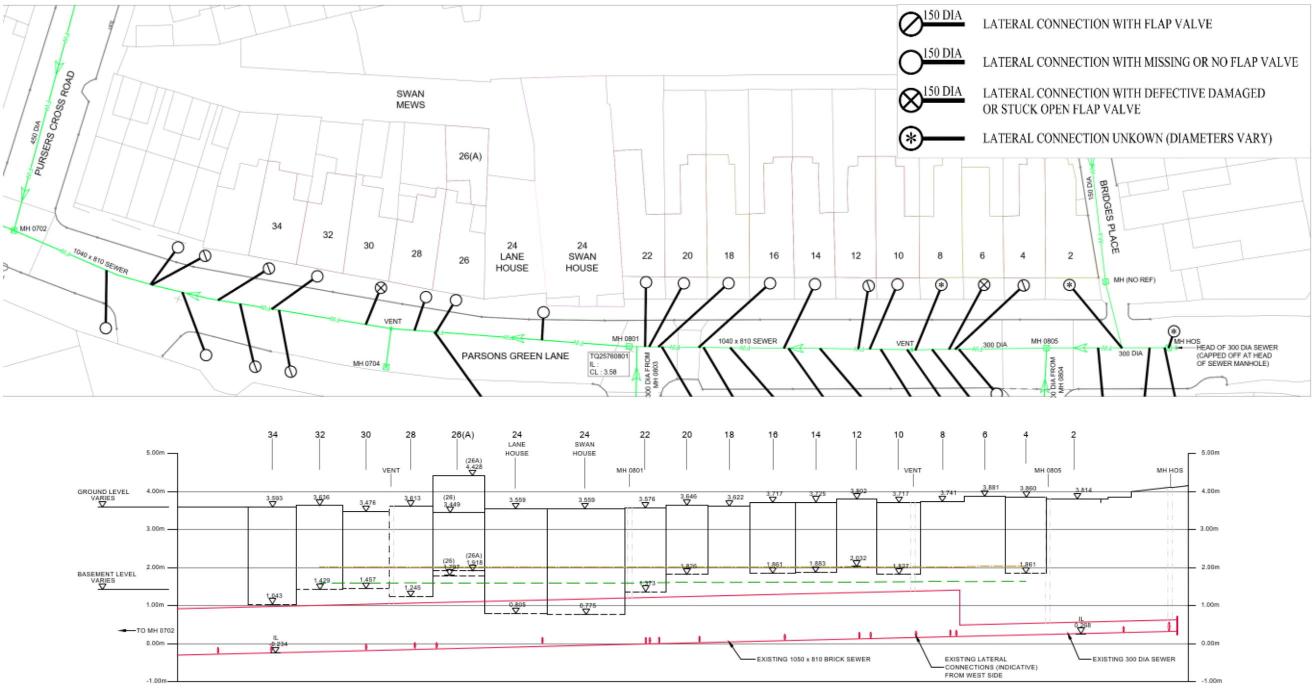
3.7 The original model had approximately 44,000 basements but we felt this represented too much storage available when the modelled surcharge reached basement level. This was thought to be due to the uncertainties in direct connections to the sewer system, including number of connected basements, depth, and storage. Therefore, we started by removing all basements from the model.

3.8 We agreed with the Independent Advisory Group that basements should be represented in the model as they provide potential storage for the system to surcharge into during a large storm event. If the basement is then isolated from the system, that volume of storage is removed and surcharge levels may increase locally, increasing modelled risk at other properties. It is important that this risk is understood.

3.9 We agreed that all basements that were listed on the sewer flooding history database as having been flooded should be added back into the model, as the connectivity of that basement was confirmed by the flooding report.

3.10 Figure 6 demonstrates the difficulty and variability of basements in reality, with many having different sizes, connection types and depths of basement.

Figure 6: Connectivity of basements



3.11 Replicating the variability of basements in the model presented challenges which were addressed by considering modelling basements in two different ways:

- Method 1: Model every basement, where a node represents each basement property, and they are connected using an orifice to the nearest sewer to represent the piped connection between the basement and the sewer. This resulted in a model with increased instabilities, due to:
    - short lengths of pipe and a significant increase in the number of modelling links requiring complex computational interactions.
    - Increased simulation time.
    - modelled head losses at each new junction which artificially increased the modelled maximum water levels along a sewer length.
- While Method 1 increased the accuracy of representation of basements in the model, it exceeded the limits of what is already one the most advanced hydraulic modelling tools available.
- Method 2: Represented locally (medium simplification method) applied basement storage to the nearest node to the basement, either immediately upstream or downstream of the basement location and assumed connection point. We relate what the hydraulic modelling tool is telling us to where we know or assume basements exist using a GIS based software tool. This resulted in:
    - greater model stability.
    - reasonable run times.

    - improved representation and utilisation of basement storage volume under surcharge conditions.
    - improved spatial representation of the impact of the removal of any basement storage due to FLIPs and Non-Return Valve devices.
- Method 2 was selected as the preferred method and agreed with the Independent Advisory Group. It was used for designing and assessing the Counters Creek Flood Alleviation scheme.

3.12 Once method 2 had been chosen, we needed to ensure the model replicated observed and historical flow data. We re-ran the model with and without the storage provided by connected basements. Once the basements were removed, the original model verification was revisited. The original flow survey storm events were re-run and the verification at the 72 monitor sites was compared against the original model outputs. It was found that there was little difference to the verification. During normal rainfall, there is a limited amount of surcharge, and as such the system does not reach basement level to mobilise potential storage. Under higher return period storm events, levels rise in the sewer system so that the basement storage is utilised.

3.13 We have explored multiple ways of representing basements within the model application and have concluded that our current methodology provides the best representation of reality without compromising the speed and stability of the models. This has been peer reviewed by industry experts and the Independent Advisory Group.

D Assessment of current risk of flooding to customers

3.14 To define the risk level of a basement, we compare the maximum water levels predicted in the model to the basement threshold level using the GIS basement extrapolation tool. Where the basement threshold level was unknown, an average basement depth below ground level was used of 1.923m based on sample surveys from 2,662 basements. This tells us whether a basement is likely to be at risk of flooding.

3.15 The nature of the GIS basement extrapolation tool means that if the maximum water level is below the threshold level, even by 1mm, it is not considered to be at risk of flooding, and if the maximum water level is above the threshold level it is designated at risk of flooding.

3.16 A limitation of such a tool is its sensitivity related to basement levels and to flood levels. Where the basement level is exceeded by only a few millimetres, this may be the difference between a property reporting flooding or not. No allowance is made for:

- the dynamic interactions taking place with the small amount of storage in the connecting pipework.
- the head losses of that pipework.
- the hydraulic head required to push flow back into the basement.
- the duration of surcharge above the basement connection for flooding to take place.

3.17 It was agreed that the basement interpolation tool provided a conservative assessment of the overall risk of basement flooding, in particular where flooding has already been reported. The tool was used in assessing how certain schemes influenced maximum water levels in the catchment and has continued to be used in the assessment up to a 1 in 30-year return period design storm.

3.18 The relationship between basement connectivity and flood risk is complex. Even though basements exist it does not mean they are connected because they may not contain a basin or toilet. Even if a basement is connected and may be modelled as at risk, the homeowner may have taken steps to mitigate the risk. Basements that are not connected can still be flooded through overland flow entering through the light well, air bricks, doors and windows. Therefore, it is not as straight forward as to whether a property is or is not connected and it is a continually changing picture as homeowners undertake renovations which they are not required to notify us of. Therefore, surveys in response to flooding and learning from historic events will remain key to us having an as full as possible picture of flooding risk.

3.19 We have undertaken a number of surveys into the connectivity of basements, the most recent of which followed the London Flooding in 2021. As described in section 2G and 3C of the main report, we are in the process of surveying every property that has reported flooding within the Holland Park area to understand the basement levels and to confirm the flooding mechanism i.e., was flooding from sewer surcharge or inundation from storm activated overland flow paths? This provides the most accurate way of verifying the outputs of the model.

3.20 In summary, in response to Ofwat's question as to why all basements are not included in the model, current computing and model application capacity are insufficient to cope with the enormous extension of the model and its run time. Even if the model could cope, the number and vulnerability to flooding of basements in the catchment are unknown in full at any time, except where flooding has been reported and/or detailed survey has been carried out. Adding all the assumed connections would be adding uncertain data which would likely not provide improved outputs.

Section 4

Fitness for purpose of the model

A Compliance with modelling guidance

4.1 In accordance with the CIWEM Urban Drainage Group (2017) Code of Practice, the whole of the Beckton catchment is modelled at Type II – meeting the recommended granularity for determining the level of flood risk. Type III is applied in the many areas where we have undertaken investigations or design work to understand how individual customers' properties are affected.

4.2 The M73 model verification was independently audited to confirm that the model was 'fit for purpose'. The most recent versions of models are frequently tested against real-time data. A network of long-term monitoring equipment exists across the Beckton catchment, which has been installed with the purpose of determining risk in the catchment and of validating the model performance against real-time data. This is not the same as a traditional 5-week short term flow survey but is more resilient in that the monitors are in place for a longer period, observing a wider range of storms and operational variances. Therefore, it leads to a much better understanding of the system and its performance over the wider range of events.

4.3 By using ICMLive, the systems modellers can create scenarios to test how the system might behave in an event (predictive), or replicate an event or operational issue (reactive/post event learning).

4.4 External Model Audits: A detailed audit of the Beckton M73 model was carried out by Clear Environmental Ltd in 2011. This concluded that the model was acceptable with reservations as a tool for understanding the hydraulic performance of the trunk sewers on a strategic catchment wide scale. A summary of key findings requiring action and how these have been addressed is shown in Table 3.

Table 3: Audit findings and actions

Findings	Action undertaken
Lack of Model Build and Verification Report and verification changes log to keep records of model process and assumptions in developing the model	A draft modelling report was made available to the auditor and issues raised were discussed and worked through in a series of workshops where the auditor could view the model, calculations sheets and notes regarding the modelling of all the ancillaries. Queries were raised and addressed in these workshops and the auditor took away boxes of data and hand calculation sheets to check and review key audit points. The Paddington team then completed the additional infill flow survey and calibration along with finalising the lower sections of the model. The Paddington team

Findings	Action undertaken
	produced this report for the additional flow survey. 801-RG-MDL-00000-00003-AA-Verification. We also have detailed calibration cards for each flow monitor site through the catchment which are in Excel. These 'cards' were a suggestion by the auditor, and we now use these for all our verification work, and they largely replace the need for a verification report.
No detailed or local level verification was undertaken as part of the audit. It was recommended that once the initial strategic assessment was completed that further flow surveys be undertaken in areas at high risk of flooding to allow for verification of local hydraulic mechanisms	Detailed flow surveys were undertaken post the audit to re-calibrate the model as described in Section 2C
A limited hydraulic verification has been undertaken. This should be viewed as an ongoing process to understand flooding mechanisms and improve model confidence.	Ongoing verification now part of our processes post a flooding event, and day-to-day operational findings. Examples are described in Section 2D of the main report and through ongoing use of ICM Live
The representation of slow response runoff is calibrated, and the catchment may perform differently under various rainfall event types. Sensitivity testing should be carried out.	The sensitivity of the catchment to groundwater-induced infiltration is covered in the Resilience Appendix
Ongoing use of permanent depth loggers to assess the performance of the model against monitor data	An example of how depth loggers are used see section 2.6 and the Infiltration Appendix.

4.5 There were commendations over the modelling of complex ancillaries. At the time of the audit, the model was verified using a short-term flow survey with monitors primarily located on the trunk sewer system. Throughout the model audit process, there were some iterations which improved the representation of dry weather flow by more accurately representing the domestic and trade flows, and storm flows including slow response in the trunk sewer to rainfall events and rainfall-induced infiltration into the network.

4.6 Internal Model Audits: When our models are updated by our partner organisations, they go through their internal technical checking and verification processes before they are returned to us. This forms part of the first two lines of defence in our internal audit process. The Thames Water hydraulic modelling process is annually audited to ISO9001.

B Areas for further improvement

4.7 There are two areas currently identified for further improvement in modelling capability:

- We are moving our modelling onto the Cloud so processing power and the ability to run more complex models in real time will continue to improve.
- We are infilling our model with a higher proportion of 2D modelling when it is feasible to do so. The current model has pockets of 2D modelling in areas where there is a mix of surface water and above ground sewer flooding. It helps us understand the impact of flows above ground and which property they may flow into.

4.8 The detailed Beckton model is the largest and most complex model at Thames Water, and possibly in the UK. It is also the most monitored and understood network, and the model reflects this in the way it can replicate the flow from the large storms that have passed over the catchment in recent years. The runoff routing, trunk sewer flows, and storm relief sewer interaction are excellent.

4.9 It is not possible to model every property connection in a catchment serving approximately 3 million people. However, the certainty in determining runoff and routing those flows provides good confidence in the surcharge levels around the catchment and so the likely flood risk to basement properties.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