# Appendix C1 – Surface Water Modelling

## *Introduction*

Capita Symonds has constructed seven TUFLOW hydraulic models across the London Boroughs in Group 1. The extents of the models have generally been based upon catchment boundaries and not borough boundaries to limit the amount of cross-boundary interaction between models. This was carried out to limit the dependency of one model on the results of another. Consequently, the model results for each borough are divided over a number of models and in some cases have been modelled by more than one consultant. The following table outlines the models that cover the London Borough of Hillingdon, along with the name of the final model, percentage coverage of the Borough by each model, and the names of any other Boroughs falling within the model extent. Figure 1 shows the extent of the models listed.

Table 1: Model coverage for the London Borough of Hillingdon

| Consultant | Model Name | Naming Convention (100 year Flood Event) | Borough Coverage | Other Boroughs covered by the Model |
|---|---|---|---|---|
| Capita Symonds | Harefield | DLT2_G1HF_0100R_026 | 16% | - |
| Capita Symonds | Ruislip | DLT2_G1RS_0100R_026 | 20% | Harrow |
| Capita Symonds | Harrow | DLT2_G1HW_0100R_030 | 25% | Ealing, Ealing |
| Capita Symonds | West Drayton | DLT2_G1WD_0100R_025 | 17% | - |
| Capita Symonds | Hounslow | HO_I_100yr_5m_1p25s_03 | 1% | Hounslow and Ealing |
| Capita Symonds | Heathrow | HR_1_100yr_5m_1p5s_01 | 21% | Hounslow |

The naming convention has generally been derived to reference the tier of work, the name of the model, the flood event being modelled and the version number. A standard naming convention was not adopted for all models built for the Drain London project, hence different conventions may have been adopted by other consultants.

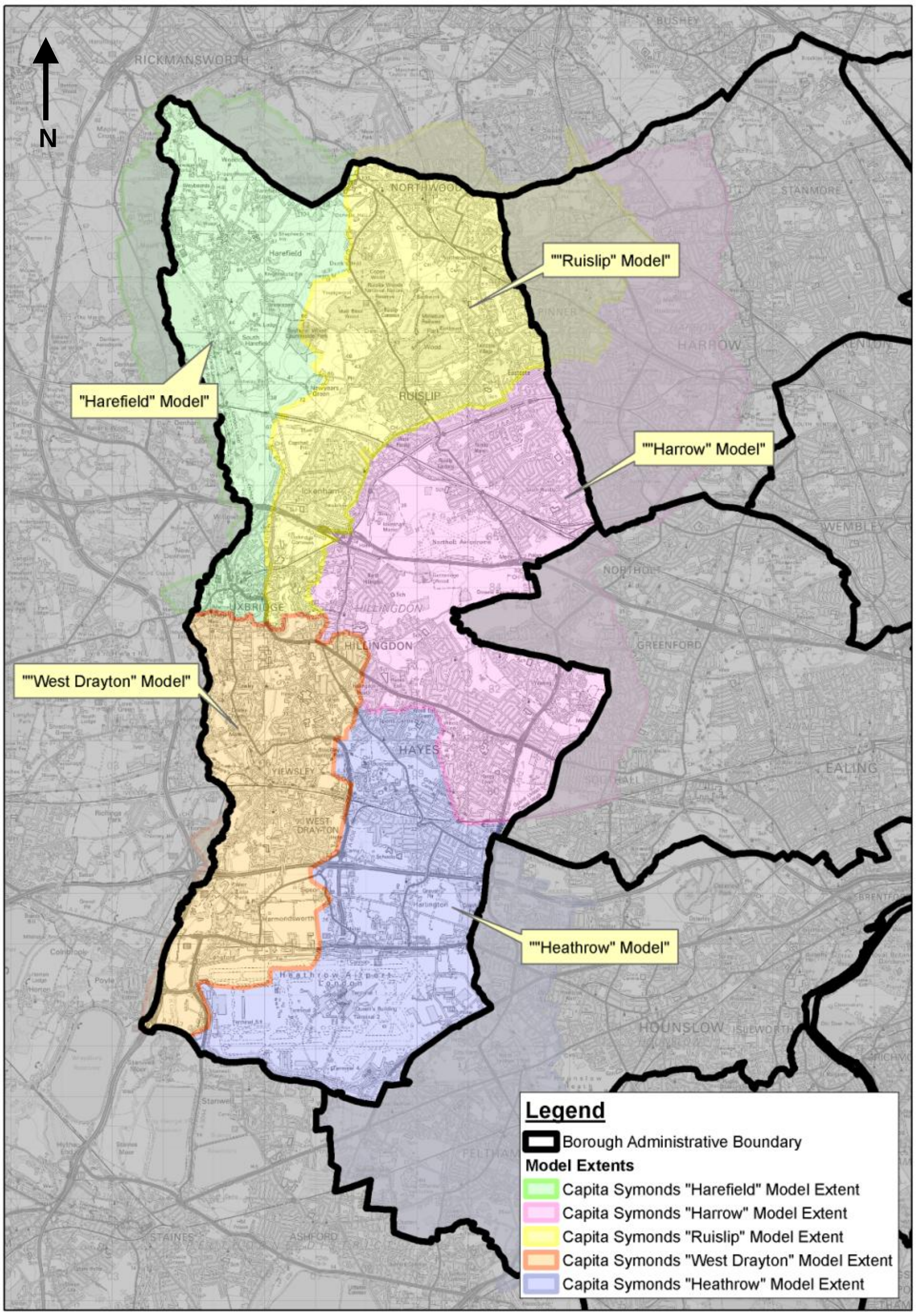


Figure 1: Model coverage for the London Borough of Hillingdon

## Software Version

All models have been run using TUFLOW build 2010-10-AA-iDP as agreed by all Drain London consultants using the TUFLOW software. All models within the Borough of Hillingdon were run on the 64bit version of this build to take advantage of the faster simulation times and more advanced handling of larger models.

## *Model Parameters*

All hydraulic models have been constructed following the guidance outlined in the Drain London: Data and Modelling Framework V1.0 (December 2010). The following sections of this appendix describe in more detail how this guidance was applied and where amendments or additions were made.

### Direct Rainfall Methodology

The Drain London modelling was designed to analyse the impact of heavy rainfall events across each London Borough by assessing flow paths, velocities and catchment response. The Drain London Data and Modelling Framework specified that the direct rainfall method should be used in the modelling approach. This method incorporates conservative allowances for the drainage network and infiltration. The following key assumptions were made to generate the model input:

- Initial Loss – None
- Infiltration Loss – None
- Allowance for Drainage System – A constant value of 6.5mm/hr was applied
- No aerial reduction factor applied
- ‘Summer’ rainfall profile was used

To comply with the Drain London framework requirements rainfall inputs were generated at a standard 10km grid square resolution. As specified in the framework guidance hyetographs for the following rainfall events were generated:

- 1 in 30 year
- 1 in 75 year
- 1 in 100 year
- 1 in 100 year plus climate change (+30%)
- 1 in 200 year

Total rainfall depths at each 10km grid centroid for all required return periods were extracted from the FEH CD-ROM (v3) Depth Duration Frequency (DDF) model. A comparison between the peak rainfall depths in adjacent 10km grid squares was completed to confirm the suitability of the 10km grid resolution for modelling purposes. The difference in total rainfall depths between the grid centroids for 10km grid squares was mostly less than 5%, with the maximum difference being 17%. This suggests that the 10km grid data is suitable for use in the study as a finer grid would have a minimal effect on the hyetographs.

Critical duration is a complex issue when modelling large areas for surface water flood risk. The critical duration can change rapidly even within a small area, due to the topography, land use, size of the upstream catchment and nature of the drainage systems. The ideal approach would be to model a wide range of durations. However, this is not always practical or economic when modelling large areas using 2D models which have long simulation times – such as within the Drain London study.

A high level investigation was undertaken to understand the effect of rainfall event duration on the Drain London Study area using a rapid modelling technique. The intention of the investigation was to show variation in critical duration across the study area and thus identify whether it was possible to identify single critical durations for each sub-model. The study used the 1 in 100year hyetographs for 1, 3, 6 and 12 hour durations along with a simplified terrain model to route overland flow. The key result was that critical duration is highly variable across surface water catchments – but the influence was not sufficiently significant to justify considering multiple event durations within the Drain London Study. Therefore, a single duration of 3hrs was selected for all model runs to ensure result consistency and comparability across the Greater London area. It is strongly recommended that an analysis of possible result sensitivity to duration is considered for future studies.

## Grid Size

All models within the boundary of the London Borough of Hillingdon have been constructed with a 5m grid size, within the recommended range detailed in the Data and Modelling Framework. This grid size was chosen as it represented a good balance between the degree of accuracy (i.e. ability to model overland flow paths along roads or around buildings) whilst maintaining reasonable model run ("simulation") times. For example, refining the grid size from a 5m grid to a 2m grid is likely to increase the model simulation time from 21 hours to approximately 11 days.

## Structures

Structures within the study area were generally modelled in 2D, an approach consistent with the strategic nature of the Drain London project. Structures modelled in 2D include those on watercourses and underpasses or culverts within the floodplain. The structures were modelled by using the ZSHP function in TUFLOW which allows the user to specify the object width representing the structure opening. Invert levels were determined by inspecting the LiDAR DTM with widths of structures either measured on site visits, from Google Maps, or from the LiDAR DTM.

The limitations of modelling structures in 2D, rather than as a 1D element, are that the width of the structures is limited by the grid size (i.e. structure width is a multiple of the grid size). The depth of water within the structure can also be over-estimated as rainfall is allowed to enter the structure from above and not just through the entrances of the structure. For this reason, only short structures (e.g. generally less than 40m) have been modelled in 2D.

## Adjustments to Topography

When reviewing the model's representation of the LiDAR DTM, it was observed in some locations of new development that excavation pits had been captured by the DTM whereas aerial photos showed buildings. Where this occurred in critical areas of the model or where the pits were particularly large, these were manually filled in to match the elevation of surrounding areas.

## Building Footprints

Building footprints have been largely represented in the model as outlined in the Data and Modelling Framework. In situations where the polygon representing the building was large or long, the use of a single elevation to represent the floor level resulted in parts of the building being raised metres above the surrounding ground level. This can therefore misrepresent the potential for the building to flood. In these cases, the building 'polygon' was assigned a varying elevation such that the finished floor level remained 100mm above the ground level across the area of the polygon.

## Runoff Coefficients

The runoff coefficients applied to the hydraulic models were in line with those stated in the Drain London Data and Modelling Framework. The runoff coefficients were applied to the rainfall profiles in order to represent the varying level of infiltration on each surface, therefore altering the input data directly.

## Formal and Informal Defences

A GIS layer containing defences from the Environment Agency's NFCDD dataset was provided. These defences have been included in all models. Where additional data was provided by the Borough or informal defences such as walls were observed on site or through Google Maps, these were included in the model where it was thought that their presence would influence surface water flowpaths. No such defences were defined within the Borough of Hillingdon.

## Model Boundaries

Downstream boundaries in the models were included where it was observed that water was able to flow outside of the model extent. This might include locations where water was found to flow into a neighbouring catchment or model. The type of downstream boundary generally used was a flow vs. stage (level) relationship, or HQ boundary. These were applied to the 2D component of the models only. The rating relationship is generated by TUFLOW automatically using a gradient provided by the modeller. The 'outflow' from the model is then applied as an 'inflow' to the downstream model.

There are a number of 2D downstream boundaries included within all models within Hillingdon; these have mainly been located on roads that make up overland flow routes for the surface water.

## Cross-Boundary Issues

In some cases, it was not possible to avoid interaction with a neighbouring model due to the nature of the topography. Consequently, the extents for a few of the models with the London Borough of Hillingdon extent overlap. This was carried out to ensure that the entirety of the overland flow into the sub-catchment is modelled and that the model results would not be sensitive to the model extents. Within the overlap, the results of both models were compared. In the majority of cases, the results were found to be very similar, in both maximum depth and in flood outline. In cases where there was a notable difference, the results were analysed to determine from which catchment the surface water originated. The results from this model were then deemed to take priority. Table 4 below lists the priority of models within the overlapping areas:

Table 4: Priority levels of models within the London Borough of Hillingdon

| Location of overlap | NGR | Models Involved | Model Priority |
|---|---|---|---|
| Between the junction of Airport Way and Sprout | 504520, 175190 | West Drayton<br>Heathrow | West Drayton |

| Location of overlap | NGR | Models Involved | Model Priority |
|---|---|---|---|
| Lane and Beavers Lane Camp | | | |
| Hillingdon Golf Course | 506600, 183340 | Ruislip<br>West Drayton | Ruislip |

## Simulation Time

All models were initially run for six hours in compliance with the Data and Modelling Framework document. The models were then assessed to determine whether this duration was suitable for each specific model. This was carried out by viewing the model results for the final few timesteps. The results were checked to determine if water depths were still increasing significantly, and whether new flowpaths were forming or existing flowpaths still propagating. If either of these conditions were found to exist, the simulation time was extended for a further hour after which the checks were repeated until none of the conditions were satisfied. The simulation times for each of the models within the London Borough of Hillingdon have been listed below in Table 5 (overleaf):

Table 5: Model simulation times

| Model Name | Model Simulation Time (hrs) |
|---|---|
| DLT2_G1HF_0100R_026 | 6 |
| DLT2_G1RS_0100R_026 | 7 |
| DLT2_G1HW_0100R_030 | 6 |
| DLT2_G1WD_0100R_025 | 6 |
| HR_1_100yr_5m_1p5s_01 | 6 |
| HO_I_100yr_5m_1p25s_03 | 6 |

## *Sensitivity Testing*

The sensitivity of the model results to changes in drainage loss was tested. This was carried out for all models on the 1 in 200 year return period flood event. The original drainage loss of 6.5mm/hr was adjusted by +/-25% giving values of 8.125mm/hr and 4.875mm/hr to be used for the analysis. The two sensitivity test results were compared with the baseline results by producing a depth difference grid. This output shows the difference in depth as a result of the change in drainage loss. The model results are deemed to be sensitive to changes in the tested parameter, if the percentage change in depth is greater than the percentage change in the parameter.

As a whole, the models within the Borough of Hillingdon were not found to be sensitive to changes in drainage loss. Changes in maximum depth were less than 25% compared to the baseline results. A number of intermittent locations in the model did show a larger change in depth. These were generally located in areas where there are sudden changes in elevation, i.e. at railway cuttings.

## *Model Stability*

Assessing the stability of a model is a critical step in understanding the robustness of a model and its ability to simulate a flood event accurately. Stability in a TUFLOW model can be assessed by examining the cumulative error (or mass balance) of the model as well as the warnings outputted by the model during the simulation.

As can be seen in Figures 3 to 8 below, the cumulative error of the models in the Borough is largely within the recommended range of +/-5% for the majority of the simulation. High values are reported at the beginning of the rainfall event when the model cells first wet then settle down for the remainder of the simulation. The cause and location of the high cumulative errors was investigated by examining a number of other output files provided by TUFLOW. The high values were found to occur at random locations throughout the study area for a single timestep and were not found to persistently occur at a single cell. This suggests that the high cumulative error is a consequence of the initial wetting process at the start of the rainfall event. The high cumulative error values are therefore considered to have a negligible impact on the overall model results.

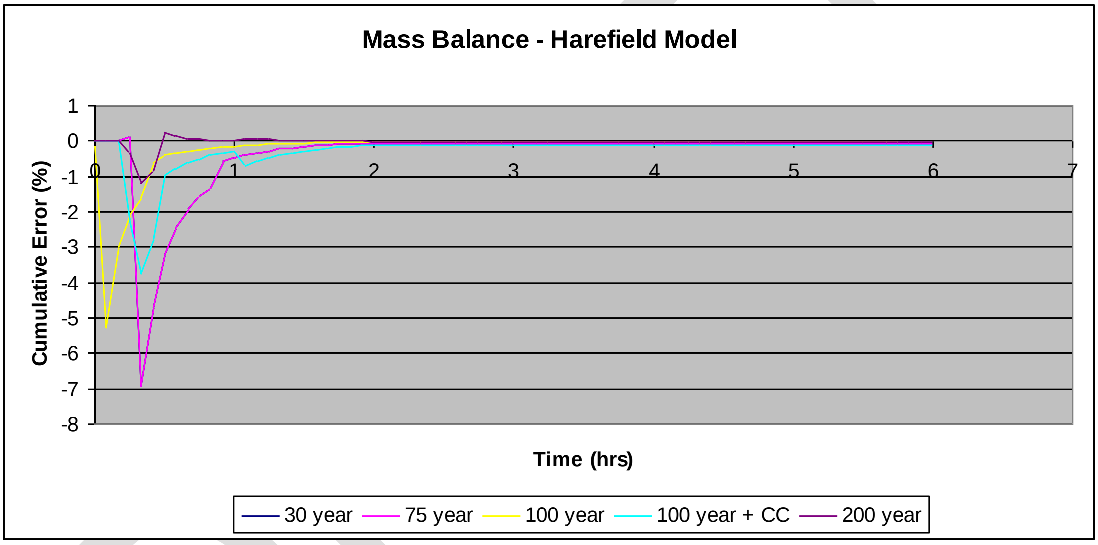


Figure 3: Mass Balance of Harefield Model

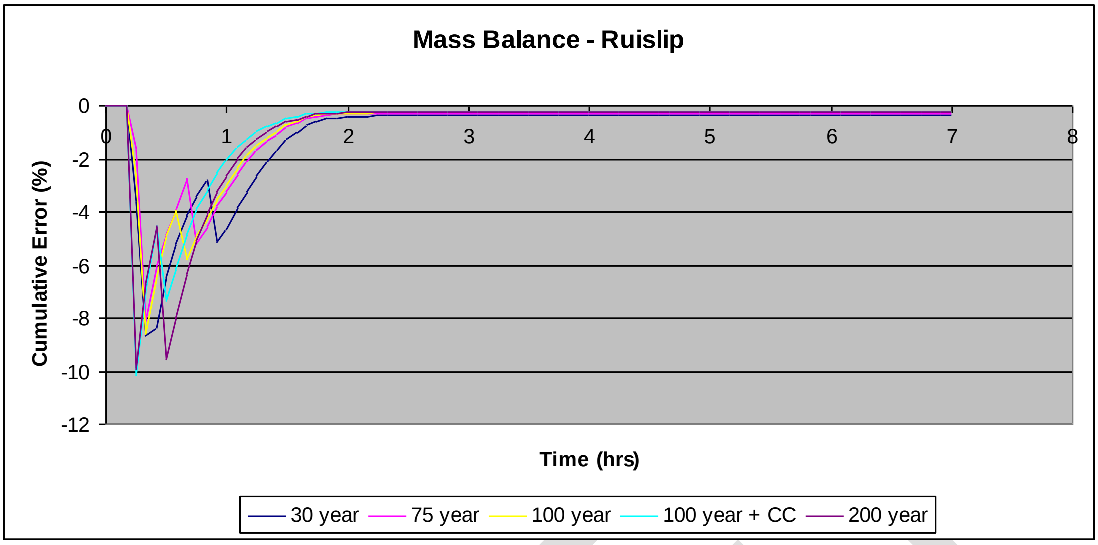


Figure 4: Mass Balance of Ruislip Model

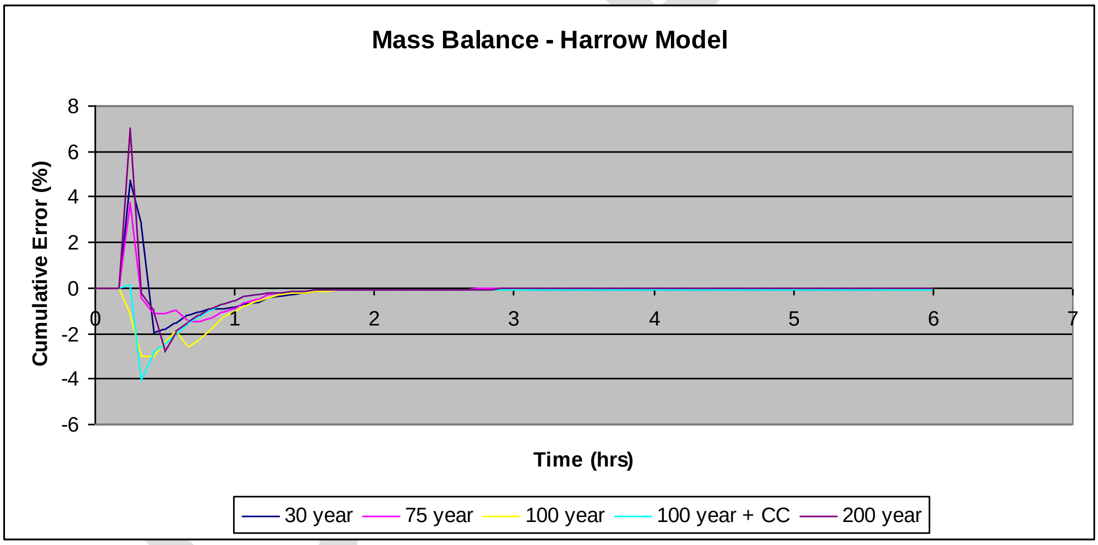


Figure 5: Mass Balance of Harrow Model

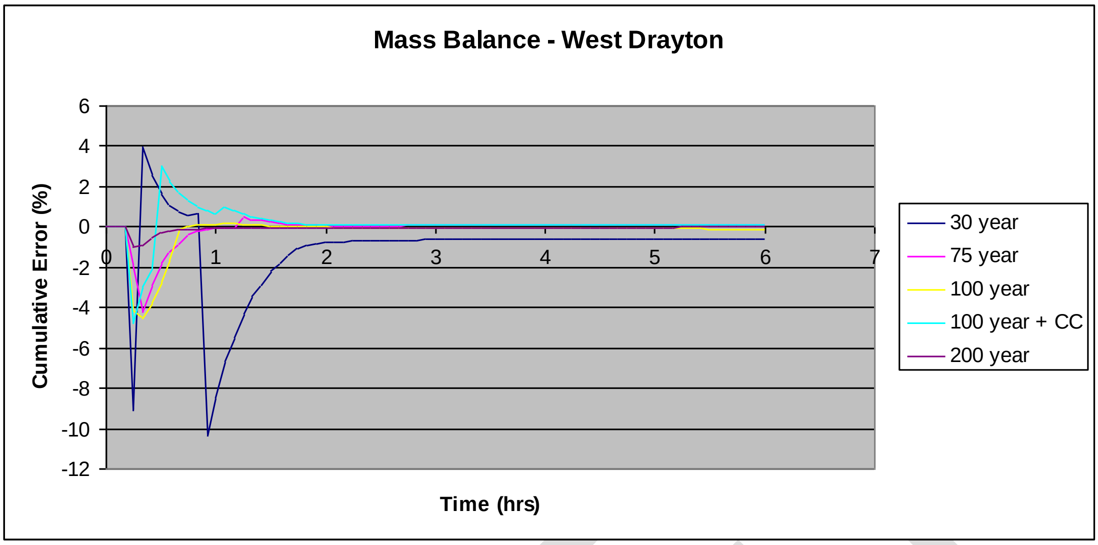


Figure 6: Mass Balance of West Drayton Model

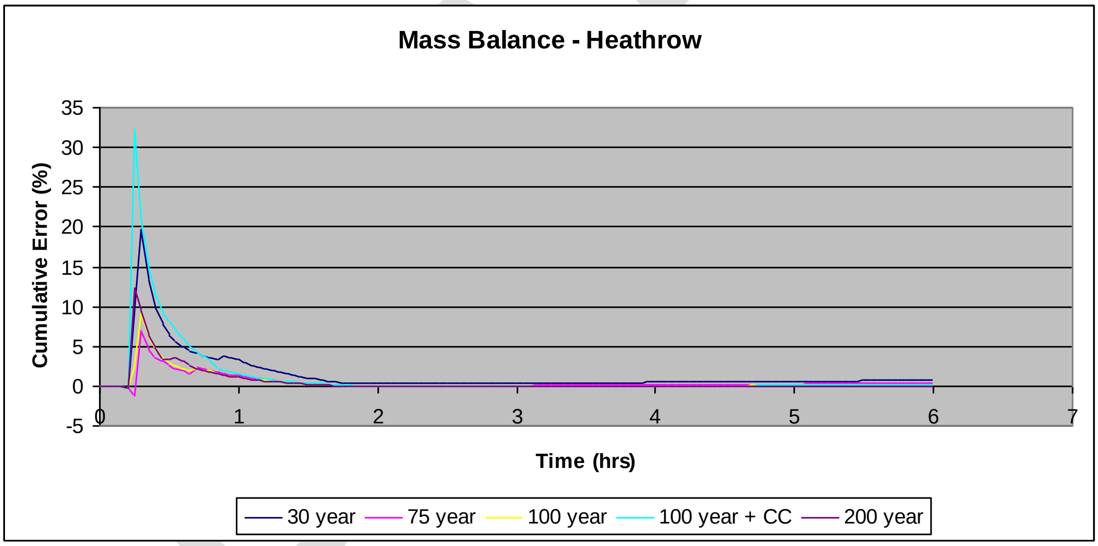


Figure 7: Mass Balance of Heathrow Model

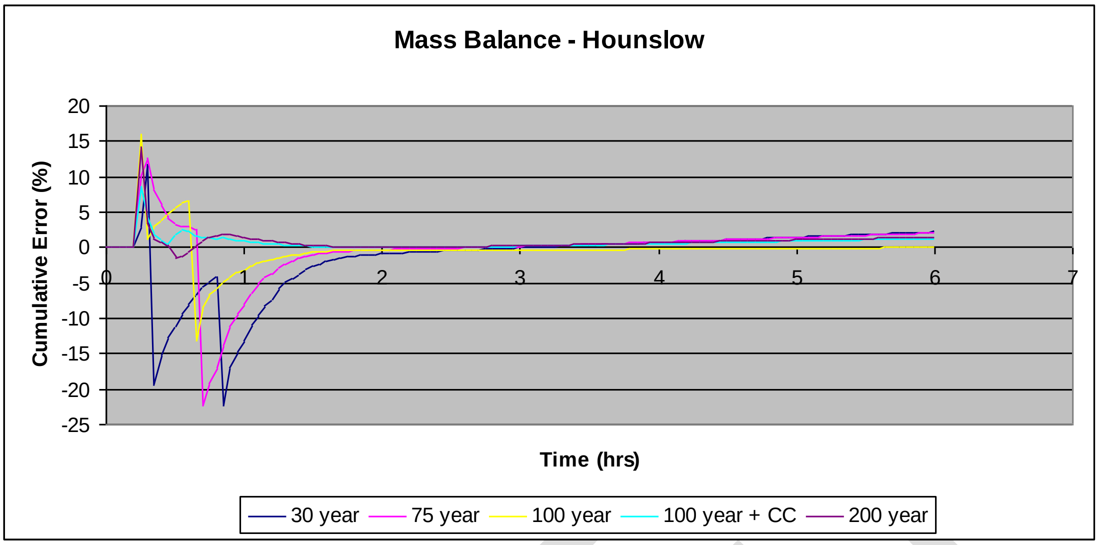


Figure 8: Mass Balance of Hounslow Model

A number of warnings occur in all models, with between 30 and 50 messages outputted during the simulation for each of the five flood events. The warnings relate to areas of poor convergence, or in other words, where TUFLOW has had trouble finding a solution. The warnings were found to be spatially varied and non-persistent in time, which is a relatively common occurrence in these types of models. As the warnings were not found to repeatedly occur, these have a negligible impact on the overall model results and the model is considered fit for purpose.

## *Conclusions and Recommendations*

The hydraulic models constructed for Phase 2 of the Drain London project represent a strategic approach to identify areas at risk of surface water flooding. It represents a significant refinement on the previously available information on surface water flooding in Hillingdon. The models and their mapped results should only be used after a thorough review of this technical appendix and the Drain London Data and Modelling V1.0 (December 2010). Recommendations for future improvements to the models include (but are not limited) to the following:

- Explicitly model the existing drainage network in key areas of risk, as opposed to a London wide assumption on drainage capacity;
- Inclusion of survey data for critical structures;
- Inclusion of river flows and channel capacity (where applicable);
- Reduction in model grid size in key areas of risk;
- Testing of different storm durations;
- Inclusion of defacto defences outside of the scope of the Drain London project (e.g. assets identified through the Asset Register process); and
- The use of better quality or more up to date topographic information particularly in areas of recent development