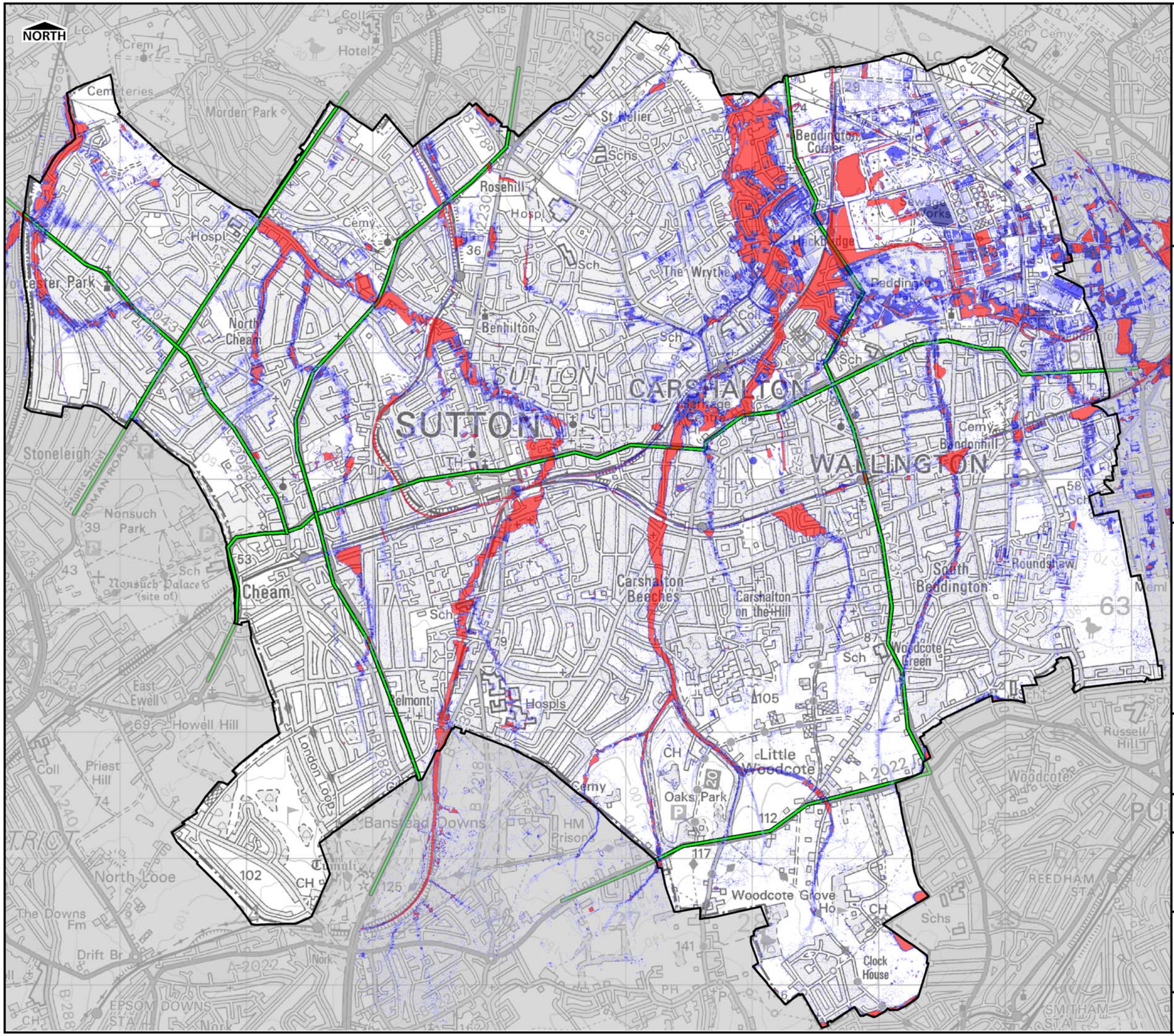
# Appendix D: Intermediate Pluvial Modelling Figures




# London Borough of Sutton

Sutton

## Surface Water Management Plan

**Legend**

- Model Boundary
- <100mm
- 100mm to 200mm
- 200mm to 300mm
- 300mm to 400mm
- 400mm to 500mm
- >500mm
- Major Routes & TfL Roads

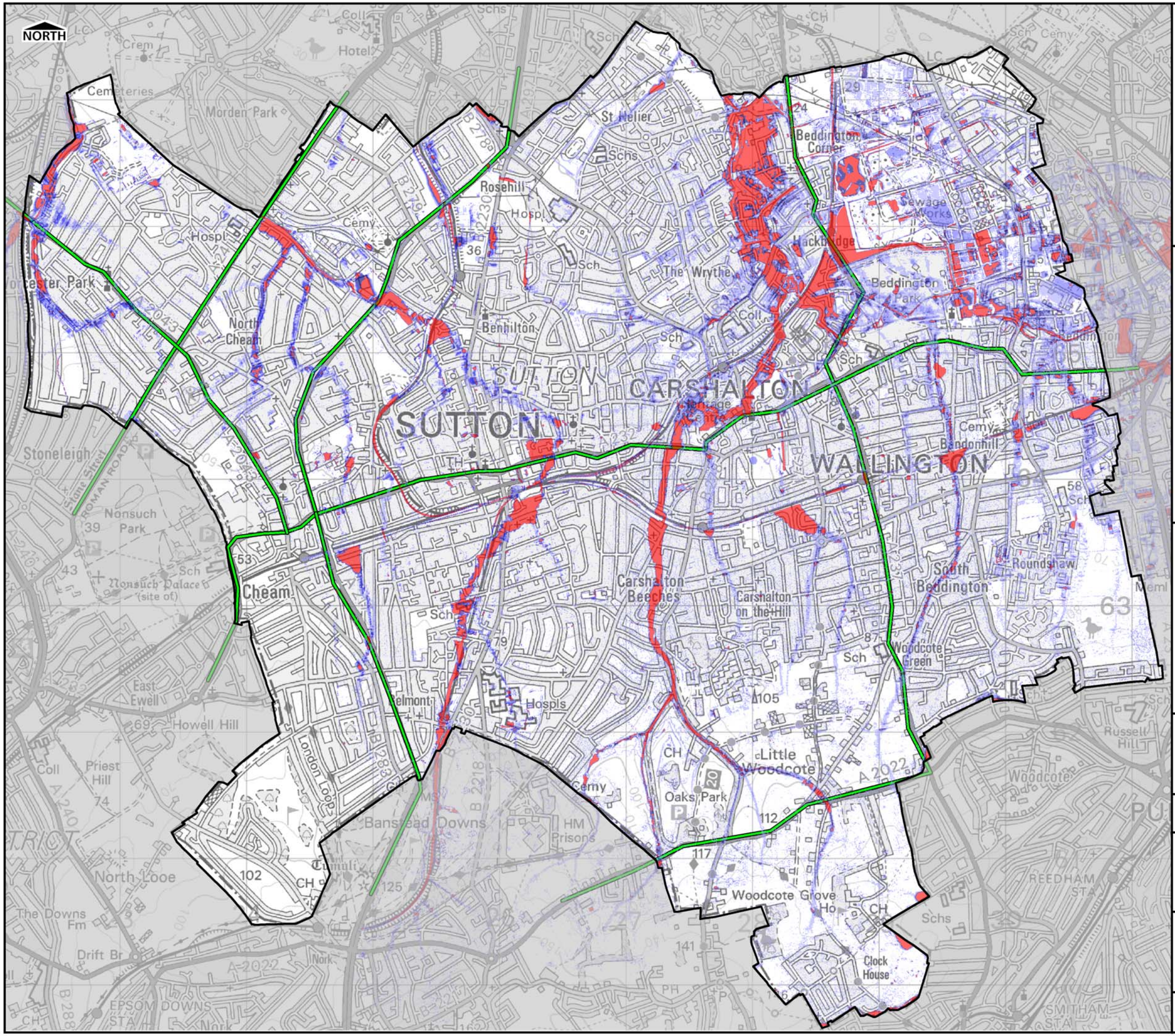


| Scale @ A3 | Date | Drawn by | Approved |
|---|---|---|---|
| 1:30,000 | Jul 2010 | SL | EB |

**London Borough of Sutton**
**Surface Water Flooding**
**1.0% AEP + Climate Change**

Scott Wilson
6-8 Greencoat Place
London, SW1P 1PL
Tel: (020) 7798 5000

**FIGURE 01**




# London Borough of Sutton

Sutton

## Surface Water Management Plan

**Legend**

- Model Boundary
- <100mm
- 100mm to 200mm
- 200mm to 300mm
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| Scale @ A3 | Date | Drawn by | Approved |
|---|---|---|---|
| 1:30,000 | Jul 2010 | SL | EB |

**London Borough of Sutton
Surface Water Flooding
1.3% AEP + Climate Change**

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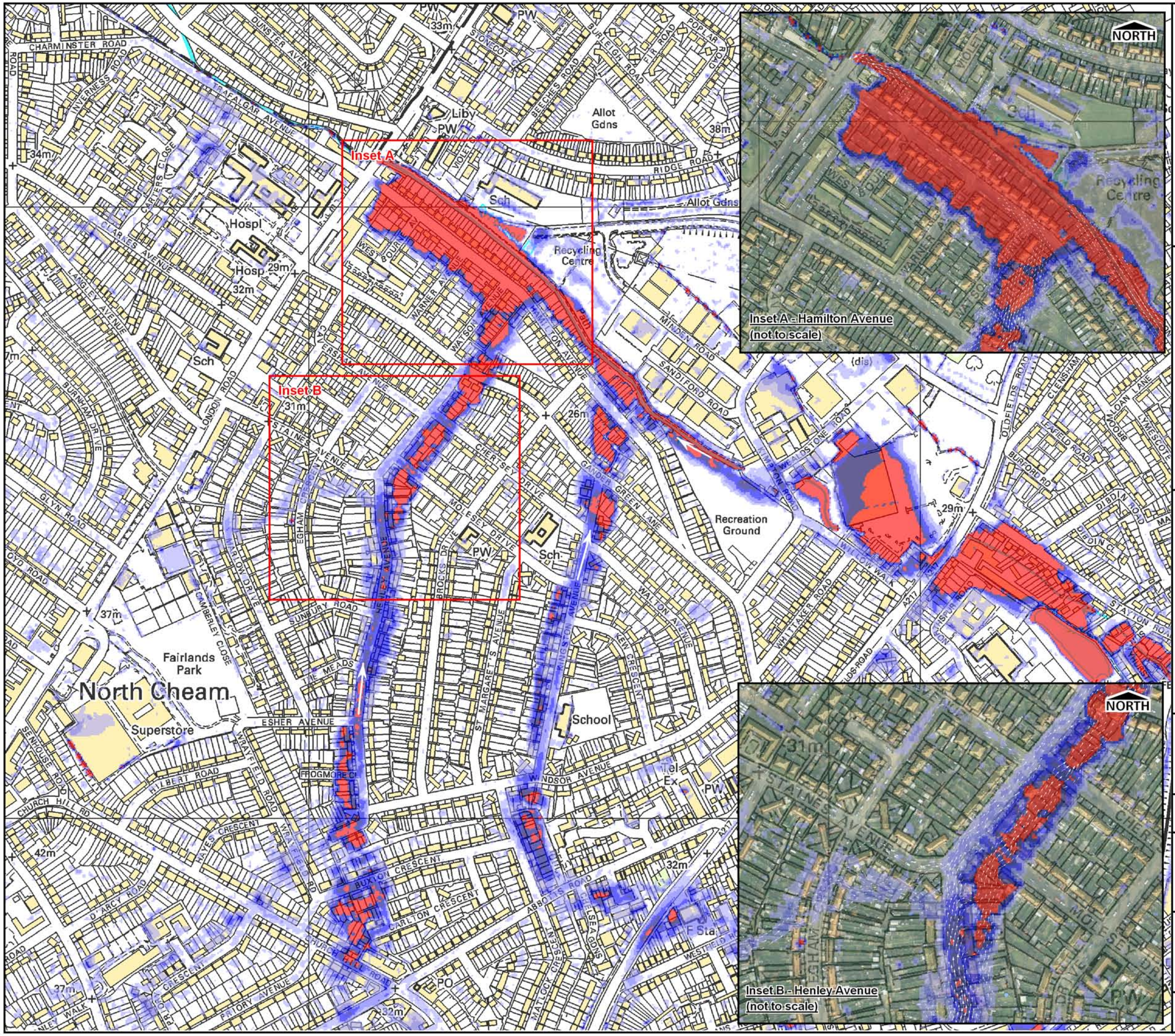
Scott Wilson

**FIGURE 02**



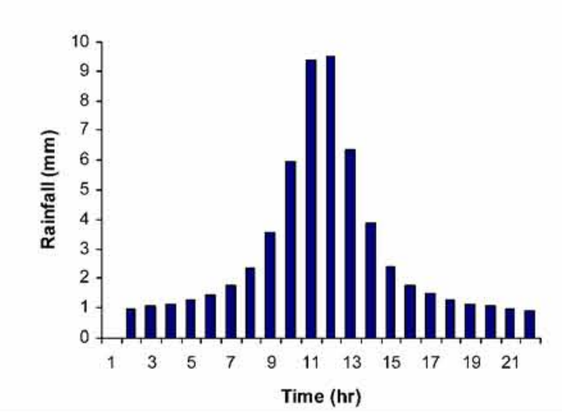

# London Borough of Sutton

Sutton

## Surface Water Management Plan

**Legend**

| | |
|---|---|
| Model Boundary | |
| <100mm | |
| 100mm to 200mm | |
| 200mm to 300mm | |
| 300mm to 400mm | |
| 400mm to 500mm | |
| >500mm | |






| Scale @ A3 | Date | Drawn by | Approved |
|---|---|---|---|
| 1:6,000 | Mar 2010 | SL | EB |

## North Cheam Surface Water Depth Grid 1.3% AEP

Scott Wilson
6-8 Greencoat Place
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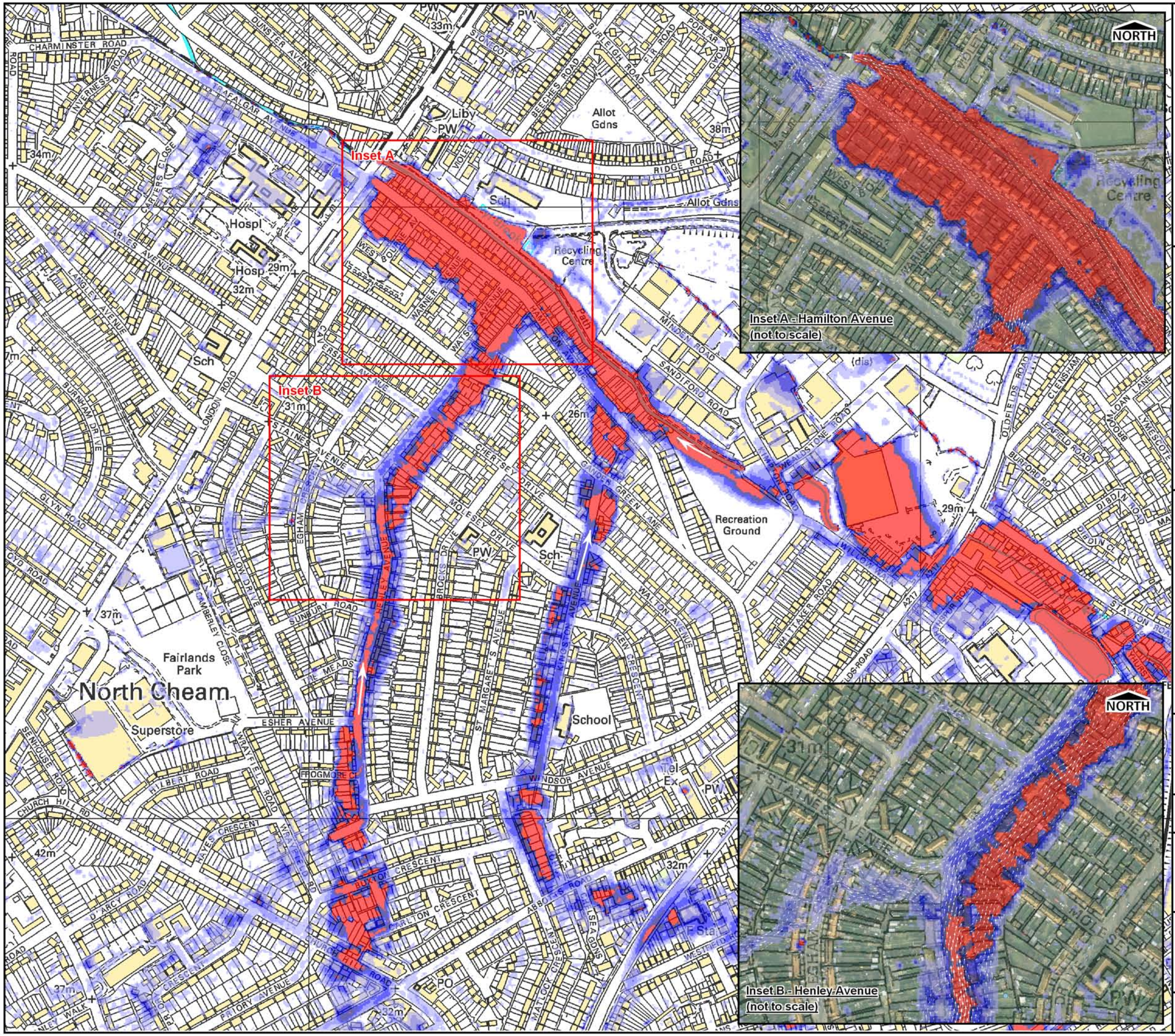
FIGURE 03




# London Borough of Sutton

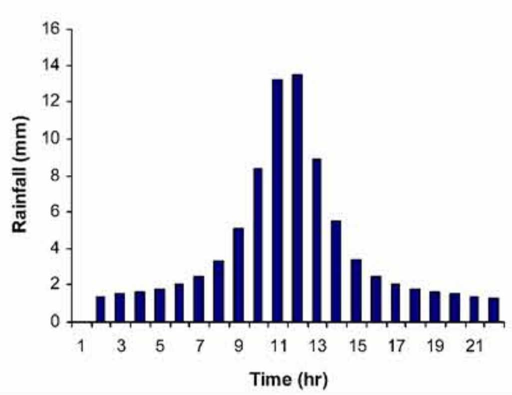
Sutton

## Surface Water Management Plan

**Legend**

- Model Boundary
- <100mm
- 100mm to 200mm
- 200mm to 300mm
- 300mm to 400mm
- 400mm to 500mm
- >500mm

**Sutton West Area 100 yr + CC Rainfall Profile**






| Scale @ A3 | Date | Drawn by | Approved |
|---|---|---|---|
| 1:6,000 | Mar 2010 | SL | EB |

## North Cheam Surface Water Depth Grid 1.0% AEP + Climate Change

Scott Wilson
6-8 Greencoat Place
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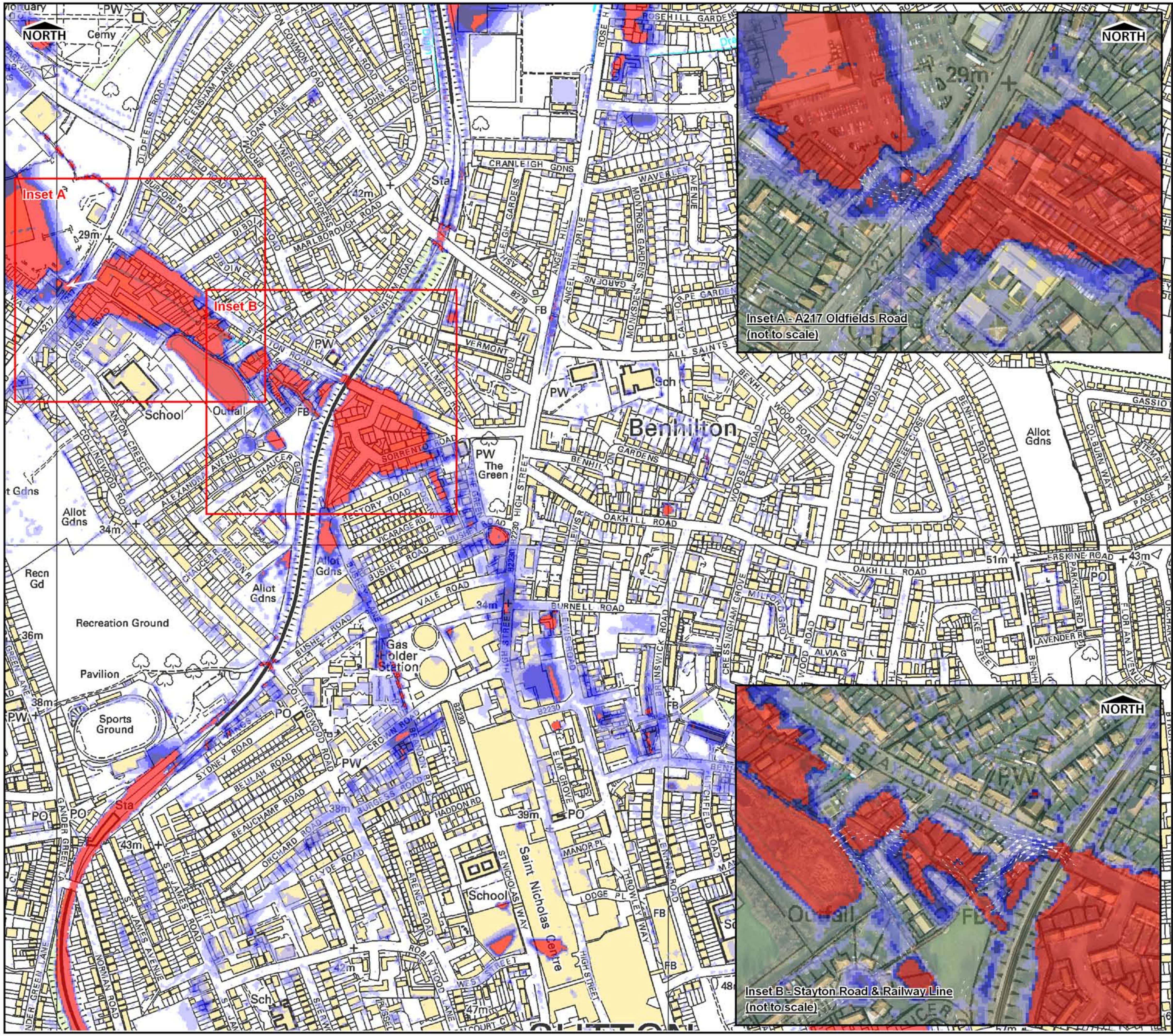
Tel: (020) 7798 5000

Scott Wilson

**FIGURE 04**



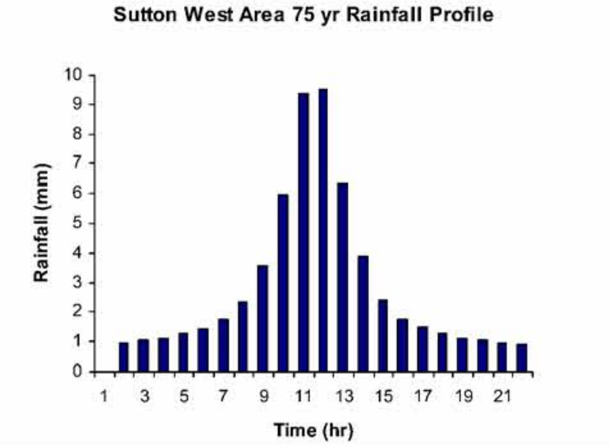

# London Borough of Sutton

Sutton

## Surface Water Management Plan

**Legend**

- Model Boundary
- <100mm
- 100mm to 200mm
- 200mm to 300mm
- 300mm to 400mm
- 400mm to 500mm
- >500mm





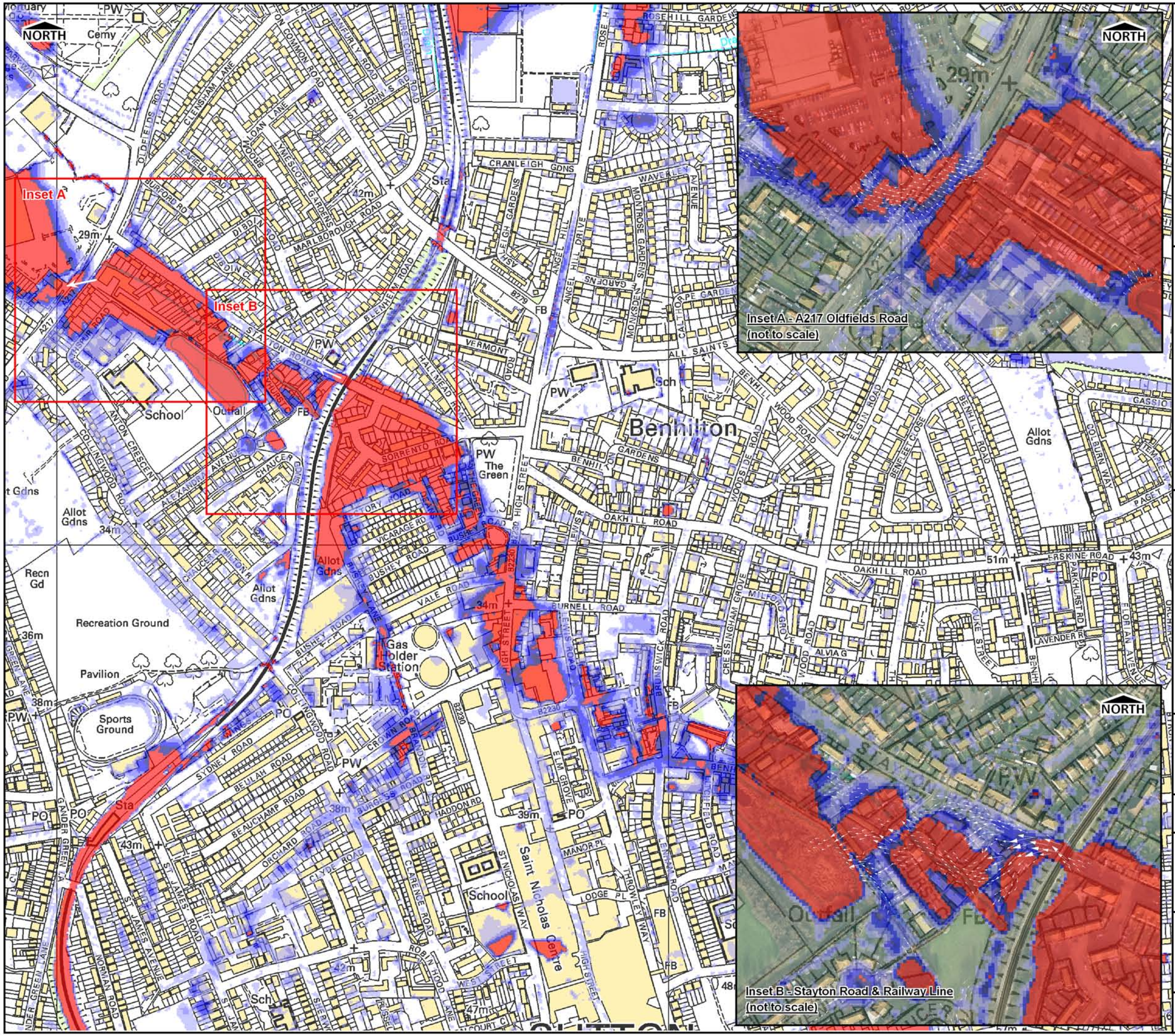

| Scale @ A3 | Date | Drawn by | Approved |
|---|---|---|---|
| 1:6,000 | Mar 2010 | SL | EB |

## Sutton Town Centre North Surface Water Depth Grid 1.3% AEP

Scott Wilson
6-8 Greencoat Place
London, SW1P 1PL
Tel: (020) 7798 5000

Scott Wilson

**FIGURE 05**



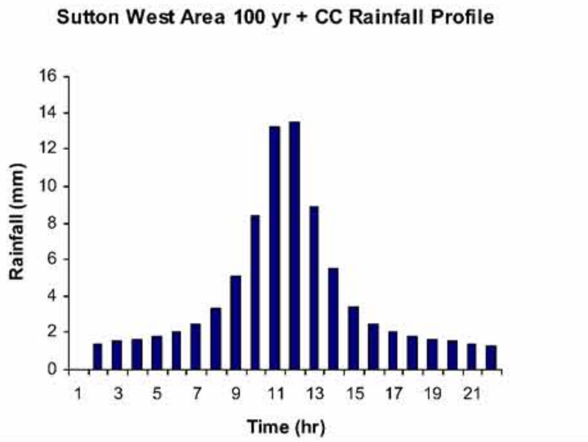

# London Borough of Sutton

Sutton

## Surface Water Management Plan

**Legend**

- Model Boundary
- <100mm
- 100mm to 200mm
- 200mm to 300mm
- 300mm to 400mm
- 400mm to 500mm
- >500mm



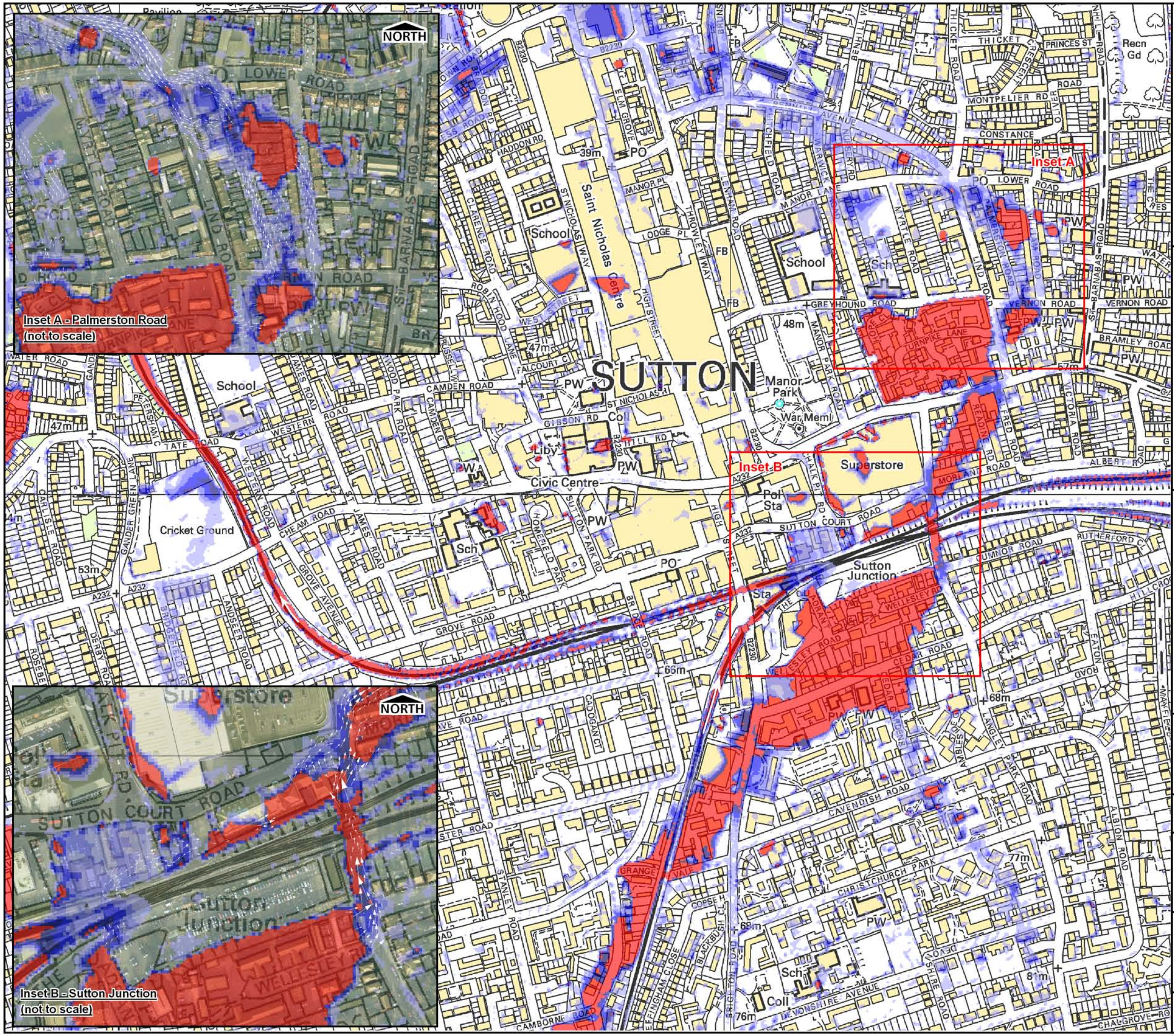



| Scale @ A3 | Date | Drawn by | Approved |
|---|---|---|---|
| 1:6,000 | Mar 2010 | SL | EB |

## Sutton Town Centre North Surface Water Depth Grid 1.0% AEP + Climate Change

Scott Wilson
6-8 Greencoat Place
London, SW1P 1PL
Tel: (020) 7798 5000

**FIGURE 06**




# London Borough of Sutton

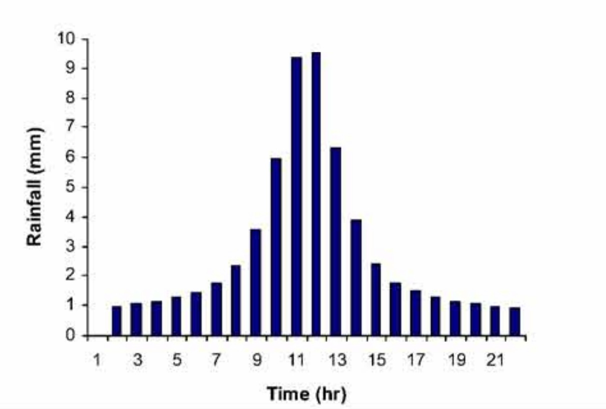
Sutton

## Surface Water Management Plan

**Legend**

- Model Boundary
- <100mm
- 100mm to 200mm
- 200mm to 300mm
- 300mm to 400mm
- 400mm to 500mm
- >500mm

Sutton West Area 75 yr Rainfall Profile





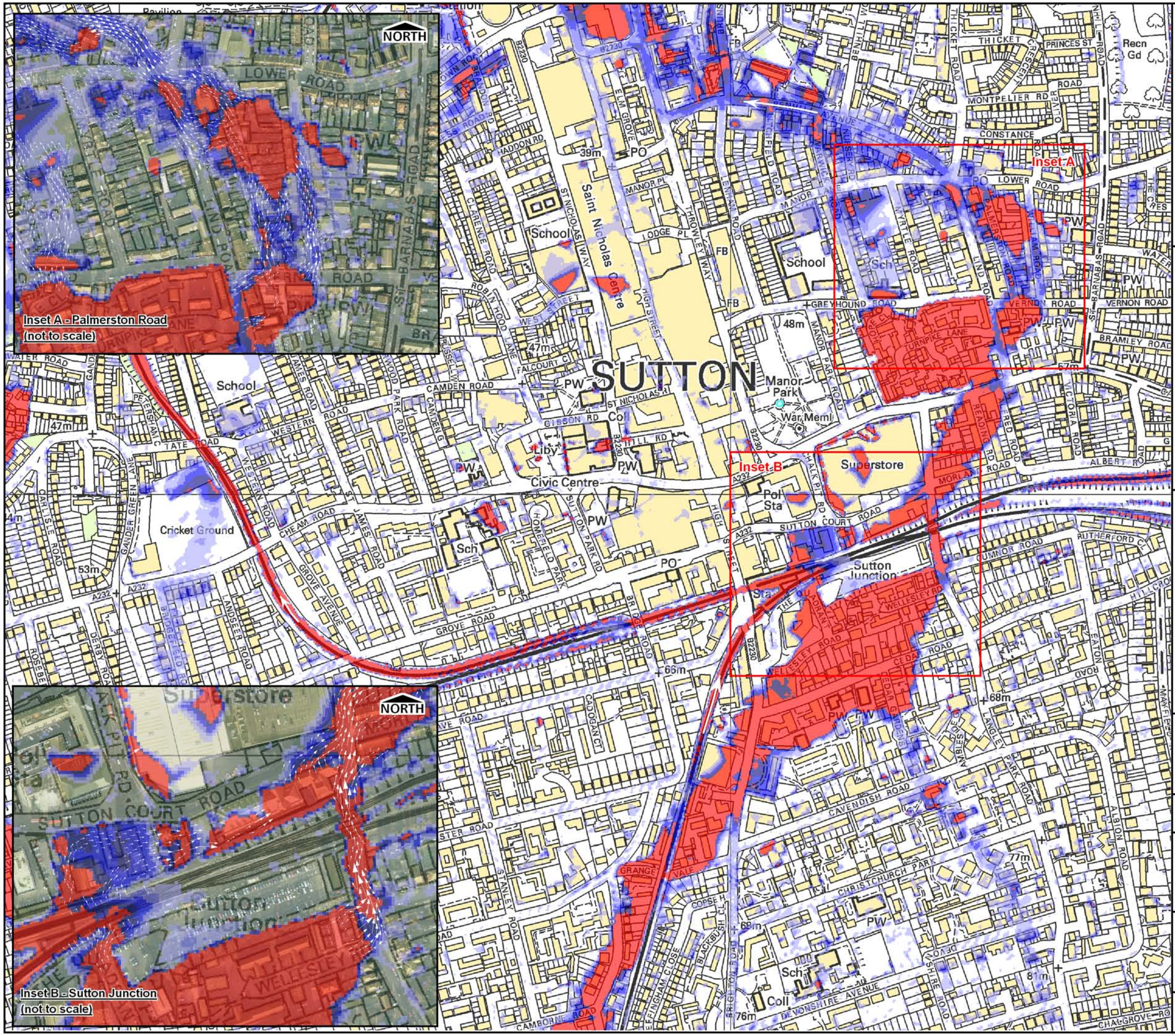

| Scale @ A3 | Date | Drawn by | Approved |
|---|---|---|---|
| 1:6,000 | Mar 2010 | SL | EB |

## Sutton Town Centre South Surface Water Depth Grid 1.3% AEP

Scott Wilson
6-8 Greencoat Place
London, SW1P 1PL
Tel: (020) 7798 5000

Scott Wilson

**FIGURE 07**



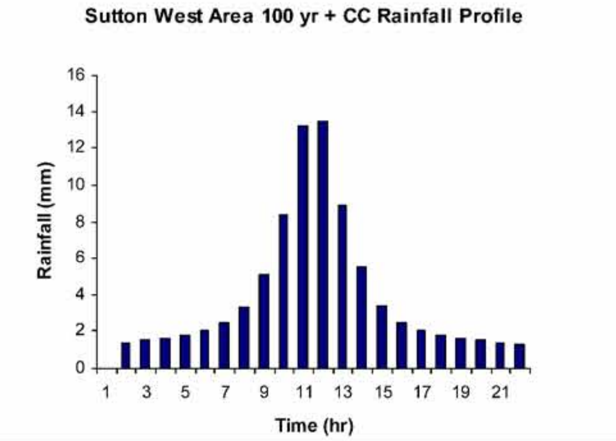

# London Borough of Sutton

Sutton

## Surface Water Management Plan

**Legend**

| | |
|---|---|
| | Model Boundary |
| | <100mm |
| | 100mm to 200mm |
| | 200mm to 300mm |
| | 300mm to 400mm |
| | 400mm to 500mm |
| | >500mm |



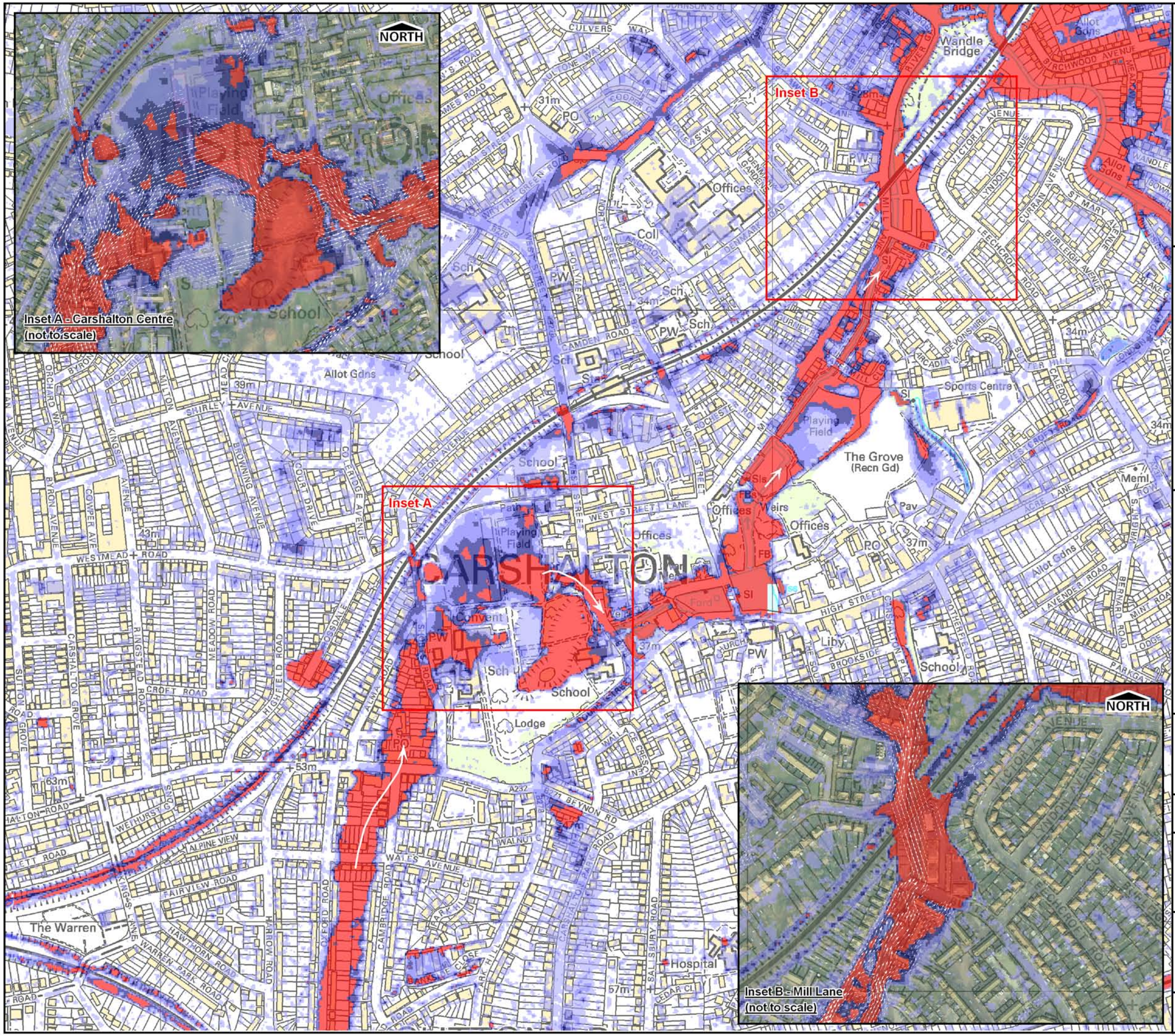



| Scale @ A3 | Date | Drawn by | Approved |
|---|---|---|---|
| 1:6,000 | Mar 2010 | SL | EB |

## Sutton Town Centre South Surface Water Depth Grid 1.0% AEP + Climate Change

Scott Wilson
6-8 Greencoat Place
London, SW1P 1PL
Tel: (020) 7798 5000

**FIGURE 08**



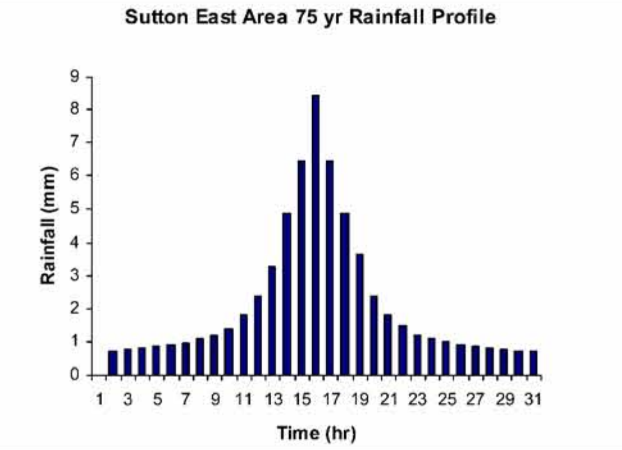

# London Borough of Sutton

Sutton

## Surface Water Management Plan

**Legend**

- Model Boundary
- <100mm
- 100mm to 200mm
- 200mm to 300mm
- 300mm to 400mm
- 400mm to 500mm
- >500mm



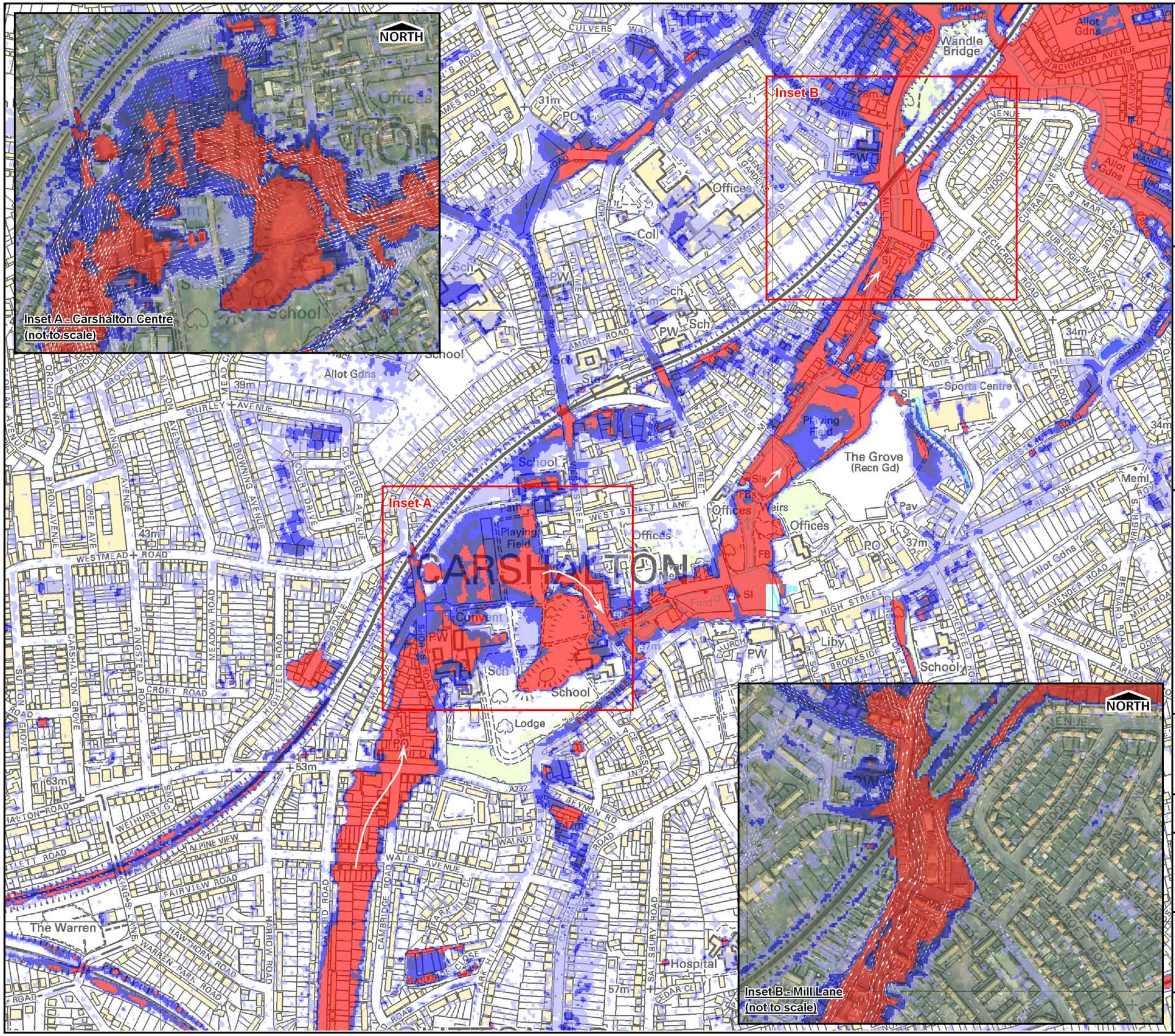



| Scale @ A3 | Date | Drawn by | Approved |
|---|---|---|---|
| 1:6,000 | Mar 2010 | SL | EB |

## Carshalton Surface Water Depth Grid 1.3% AEP

Scott Wilson
6-8 Greencoat Place
London, SW1P 1PL
Tel: (020) 7798 5000

**FIGURE 09**



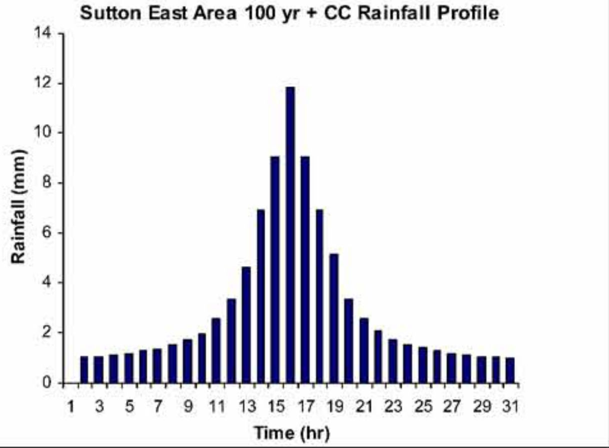

# London Borough of Sutton

Sutton

## Surface Water Management Plan

**Legend**

- Model Boundary
- <100mm
- 100mm to 200mm
- 200mm to 300mm
- 300mm to 400mm
- 400mm to 500mm
- >500mm



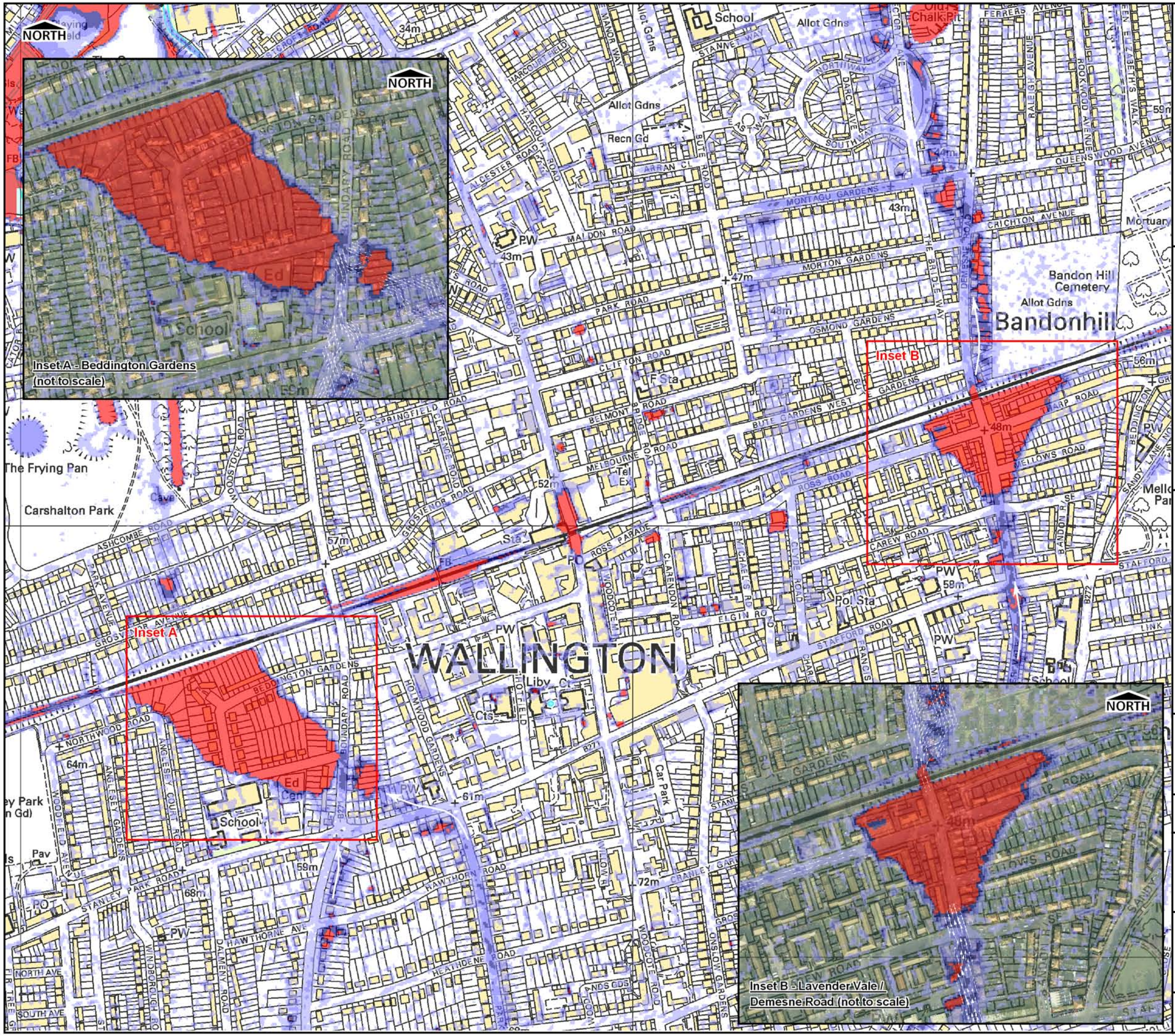



| Scale @ A3 | Date | Drawn by | Approved |
|---|---|---|---|
| 1:6,000 | Mar 2010 | SL | EB |

## Carshalton Surface Water Depth Grid 1.0% AEP + Climate Change

Scott Wilson
6-8 Greencoat Place
London, SW1P 1PL
Tel: (020) 7798 5000

**FIGURE 10**




# London Borough of Sutton

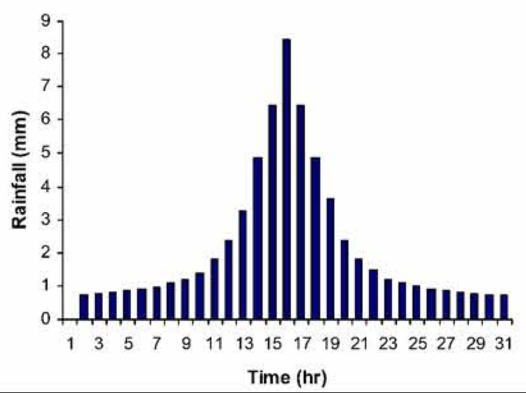
Sutton

## Surface Water Management Plan

**Legend**

- Model Boundary
- <100mm
- 100mm to 200mm
- 200mm to 300mm
- 300mm to 400mm
- 400mm to 500mm
- >500mm

**Sutton East Area 75 yr Rainfall Profile**



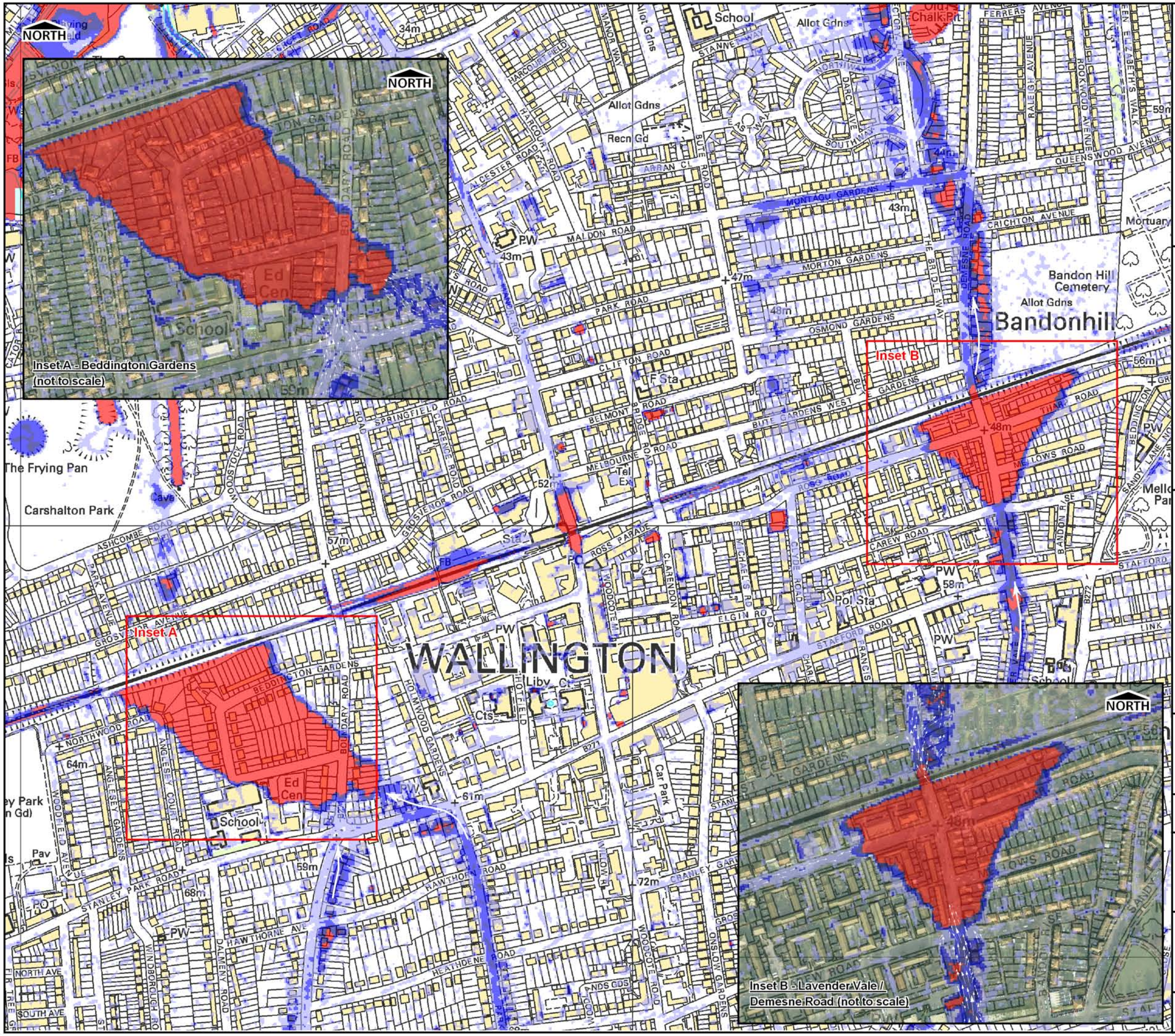



| Scale @ A3 | Date | Drawn by | Approved |
|---|---|---|---|
| 1:6,000 | Mar 2010 | SL | EB |

## Wallington Surface Water Depth Grid 1.3% AEP

Scott Wilson
6-8 Greencoat Place
London, SW1P 1PL
Tel: (020) 7798 5000

**FIGURE 11**



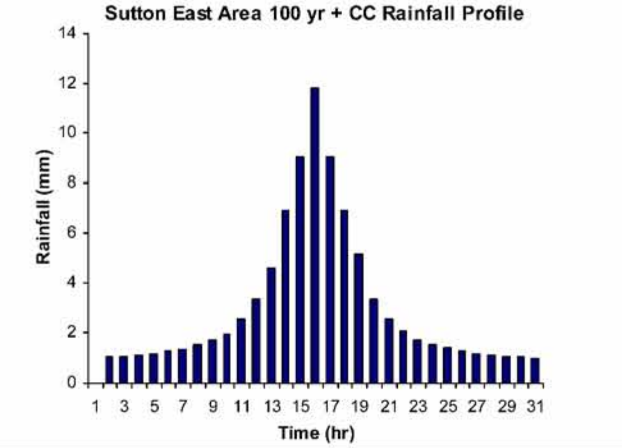

# London Borough of Sutton

Sutton

# Surface Water Management Plan

**Legend**

- Model Boundary
- <100mm
- 100mm to 200mm
- 200mm to 300mm
- 300mm to 400mm
- 400mm to 500mm
- >500mm






| Scale @ A3 | Date | Drawn by | Approved |
|---|---|---|---|
| 1:6,000 | Mar 2010 | SL | EB |

## Wallington
## Surface Water Depth Grid
## 1.0% AEP + Climate Change

Scott Wilson
6-8 Greencoat Place
London, SW1P 1PL
Tel: (020) 7798 5000

Scott Wilson

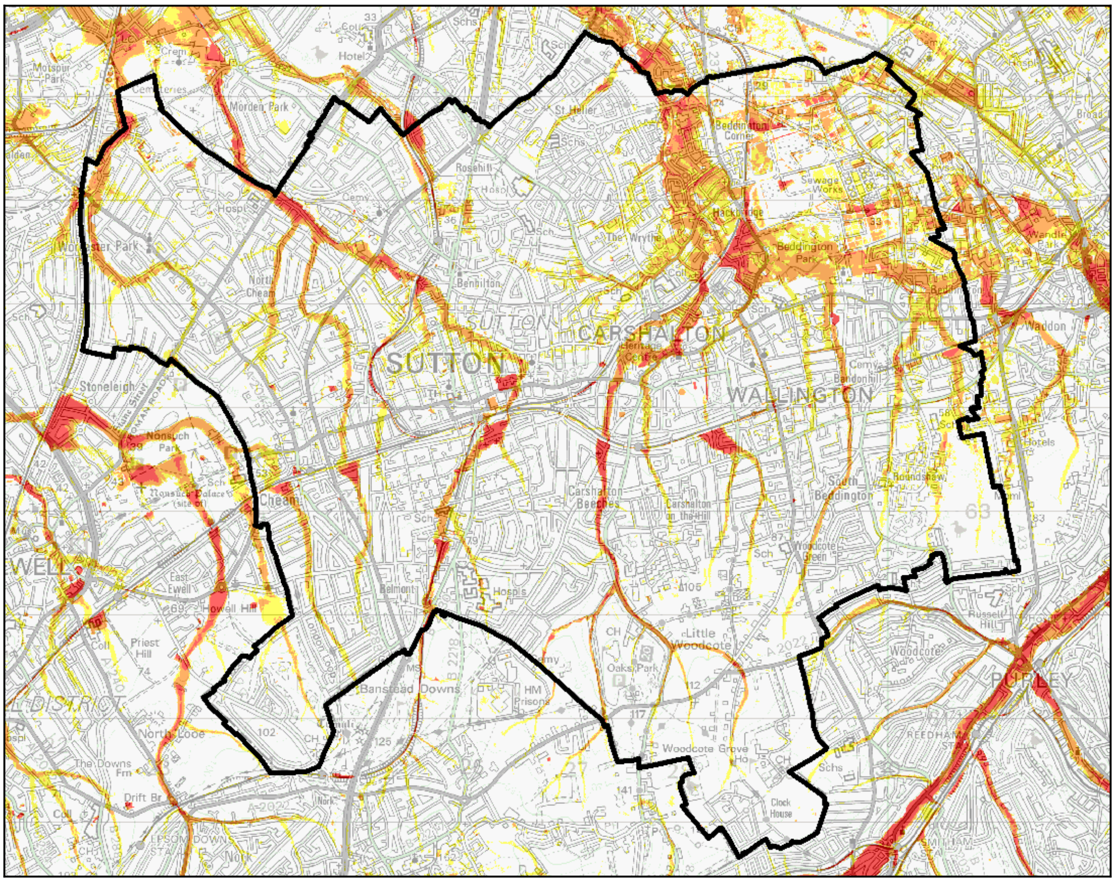
**FIGURE 12**

# Appendix E: Intermediate Pluvial Modelling Methodology

## Model Coverage

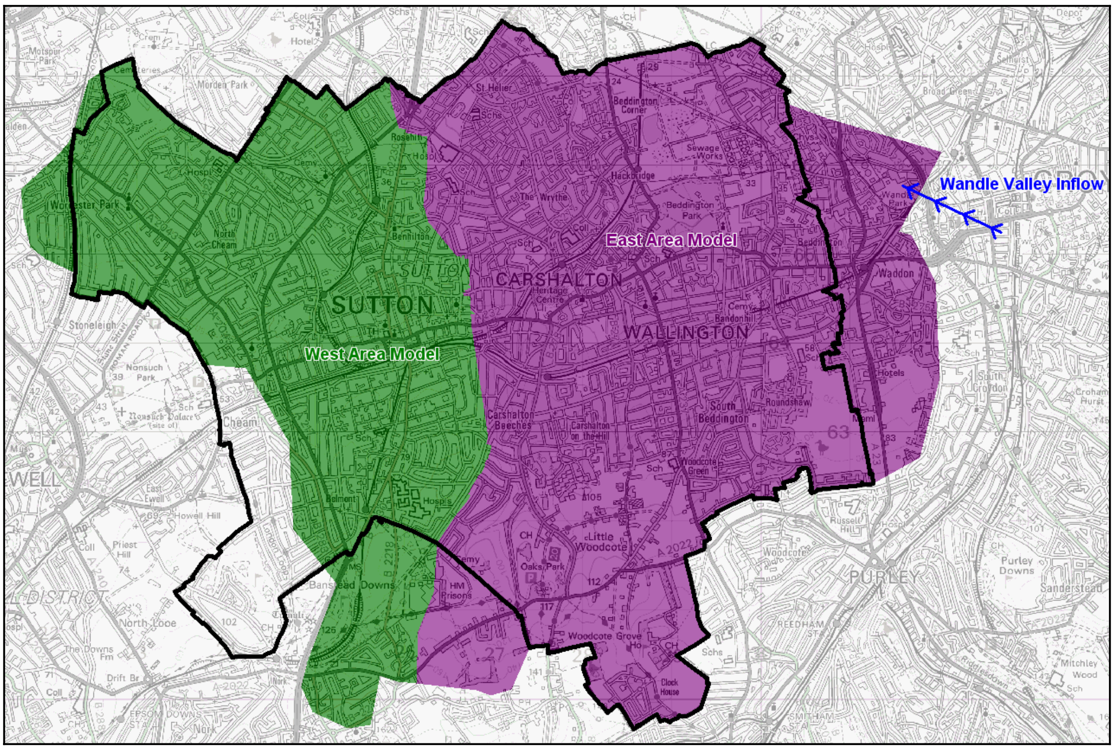
Site visits and existing data were used to highlight Critical Drainage Areas within the LB Sutton. Five CDAs were identified. It was initially proposed that hydraulic modelling be completed for each of these five areas in order to provide a better understanding of the flood dynamics in these locations. An initial review of the data and study area highlighted that LB Sutton is relatively small. For this reason two pluvial models have been created covering the whole borough. The catchment naturally divides into two catchments being east and west determined using the Environment Agency's Areas Susceptible to Surface Water Flooding Maps shown below.

**Figure D-1: Environment Agency's Areas Susceptible to Surface Water Flooding Maps**




It is important to remember that surface water flooding within the Borough can be affected by rainfall from outside of the borough. Therefore LiDAR was used to illustrate topography from the surrounding London boroughs. LiDAR showed that LB Sutton receives water from the west, south and east and passes water to the north. In order to account for this, the coverage of the models was extended to the south (i.e. in the upper rainfall catchments) and the Wandle Valley catchment was included as a point inflow (hydrograph).

**Figure D-2: London Borough of Sutton Boundary and Model Coverage**




The result of this model set up is that LB Sutton has pluvial modelling available for the whole of their borough rather than just for the 5 identified CDAs. The total coverage area of the western catchment is 18.42 km$^2$ and includes CDAs of:

- Sutton Town Centre,
- Worcester Park.

The total coverage area of the eastern catchment is 31.37 km$^2$ and includes CDAs of:

- Carshalton,
- Hackbridge,
- Wallington

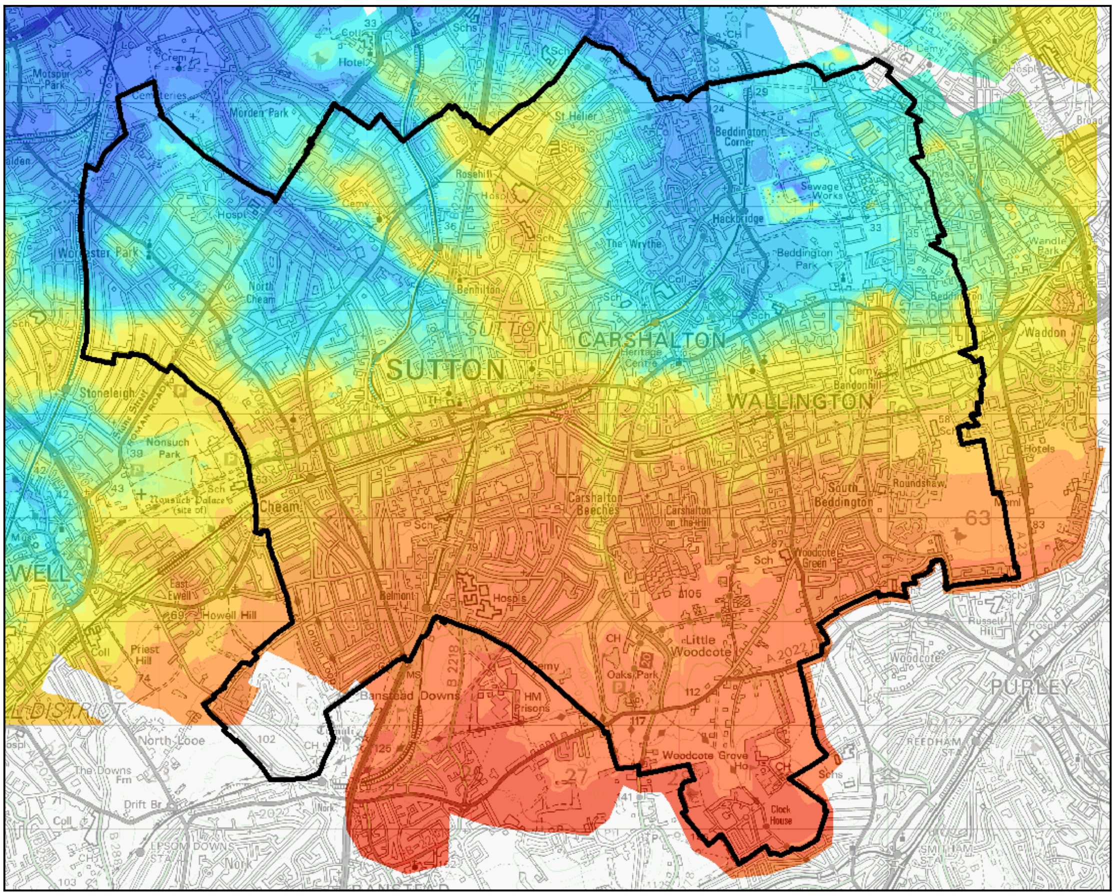
## Model Setup

We have used the latest double precision version of TUFLOW two-dimensional hydraulic modelling software (2009-AB-iDP) to assess surface water flood risk across the borough of Sutton.

Both the western and eastern models have been developed using a grid size of 5m throughout the model. The benefits of this has been to allow for more detailed outputs to be available through the London Borough of Sutton, and not just for the critical areas of Carshalton, Hackbridge, Sutton Town Centre, Wallington and Worcester Park.

The initial 5m grids written by TUFLOW have been populated with ground level data from an underlying digital elevation model, which in this instance has been a 1m digital terrain model (DTM - in the form of filtered LiDAR).

**Figure D-3: LiDAR Coverage for London Borough of Sutton**




# Model Boundaries

## Inflow Boundaries

Rainfall boundaries have been applied to both the western and eastern models based upon a rainfall analysis undertaken on the respective catchments. TUFLOW allows direct rainfall to be applied to an area covered by a GIS polygon. In the instance of the western and eastern models, the model boundary has been used as the polygon to apply direct rainfall. The polygon is then linked via a command in TUFLOW to a look-up spreadsheet which contains the relevant rainfall information (per time step).

In addition to the application of direct a rainfall, the eastern catchment also has a point inflow to represent rainfall from the upper catchment which has been conveyed along the Wandle Valley. This has been applied as an (point) inflow hydrograph at the location where the Wandle Valley intersects the eastern model boundary. The return period for the inflow hydrograph matches the return period for the direct rainfall, for each model run.

## Downstream Boundary

The downstream boundary of both models has been set with a normal depth boundary in place, thus to prevent surface water from ponding at the edge of the model and essentially glass-walling and backing up levels in the lower reaches of the model. In addition to the downstream boundary, any of others at the edges of the models where ponding occurs (following an initial model run) have also had normal depth boundaries applied, once again to prevent un-natural levels of ponding.

# Representation of Key Features

## Structures

The results of the initial run of each model were interrogated to determine any areas of ponding behind structures, which may be as a result of the misrepresentation of structures causing an obstruction to flow.

However following the initial review it was considered that the areas of ponding were a true representation of likely flooding and this was confirmed with cross checks against ordnance survey mapping and aerial photographs.

## Watercourses

Watercourses have been included in the model using the data contained within the primary DTM. Without any more detailed topographical data it has not been possible to further enforce river centrelines.

It would be considered prudent to supplement the DTM with detailed topographical survey for any further detailed modelling.

# Manning's Roughness Coefficients

Master Map data provided by the client has been used to determine Manning's roughness coefficients applied across both the east and west models. Topographic area layers have been queried in MapInfo and the land uses have been split into the following groups, with a Manning's roughness coefficient assigned to each land use category.

- Road and paths – 0.020,
- Buildings – 0.500,
- Lakes and ponds – 0.030,
- Railways – 0.200,
- Grass and gardens – 0.040,
- Roadside (paths and verges) – 0.035,
- Tress and scrub – 0.075

# Rainfall Analysis

An important aspect of estimating a rainfall profile is that of the critical storm duration. In order to ensure that the worst case scenario is assessed and that the entire catchment is contributing surface water runoff, the critical storm duration should be estimated. In order to achieve this, the Revitalised Flood Estimation handbook (ReFEH, Centre for Hydrology, 2005) method was used, based on the following assumptions and parameters:

- Hydrological inputs derived from the 'Catchment Descriptors' function of the Flood Estimation Handbook CD-ROM,
- Area of the Western Catchment is 17.74km$^2$,
- Area of the Eastern Catchment is 36.15km$^2$ (entire Eastern Catchment – Wandle Valley Catchment = 145.17km$^2$ – 109.02km2),

- Area of the Wandle Valley Catchment is 109.02km$^2$,
- Due to the highly urbanised nature of the Western and Eastern Catchments, the summer profile was used, as suggested by ReFH,
- For the Wandle Valley catchment, the winter profile was used due to the lower urban land cover value, as suggested by ReFH.

### Western and Eastern Catchments

The completion of the ReFH spreadsheet resulted in the following critical storm durations:

- Western Catchment - 3.5 hours (210 minutes),
- Eastern Catchment (with amended area) - 5 hours (300 minutes).

In order to obtain the rainfall profiles (hyetograph) for each catchment during the 30, 50, 75 and 100 year return period events, the relevant Catchment Descriptors and storm durations were input into the Rainfall Profile function of WinDes® software. The Rainfall Profile provides rainfall intensity (in mm/hr) for each minute of the storm. However, TUFLOW operates more effectively when provided with a volume of rainfall per time step (in this case, 10 minute intervals were used). Therefore, the rainfall intensity values obtained from the Rainfall Profile were converted to a volume of rainfall per 10 minute time step using a simple spreadsheet. In addition, the Rainfall Profile function of WinDes® is unable to include an addition for climate change. Therefore, the spreadsheet was used to add 30% (i.e. the figure provided by PPS25 to account for climate change for rainfall over the next 100 years) to each minute in the hyetograph. In order to estimate the worst case scenario, such an addition for climate change was only applied to the 100 year return period event.

### Wandle Valley

- As the Wandle Valley extends outside of the 2D domain of the eastern model, a direct inflow was required to account for additional surface water generated from the Wandle Valley catchment. The outputs from ReFH were used to apply (hydrograph) point inflows into the eastern model at the location where the Wandle Valley joins the wider model. An initial analysis using ReFH determined that the critical storm duration for the Wandle Valley is 8 hours (480 minutes).
- In order to obtain inflow hydrographs for the 30, 50, 75 and 100 year return period events, the relevant Catchment Descriptors were uploaded into the ReFH spreadsheet, the critical storm duration (8 hours) was selected and the relevant return period event was also selected.

The ReFH spreadsheet is unable to include an addition for climate change; therefore the design hydrograph from the 100 year return period event was increased by 20% (i.e. the figure provided by PPS25 to account for climate change for flows over the next 100 years).

## Design Runs

The two models developed as part of this study have been run for the following design (direct rainfall and inflow from Wandle Valley) events:

- 30 year,
- 50 year,
- 75 year,
- 100 year,

- 100 year plus climate change.

## Model Outputs

TUFLOW outputs data in a format which can be easily exported into GIS. As part of the Sutton pluvial modelling a series of ASCII grids and MapInfo TAB files has been created (for all model runs):

### ASCII Format

- Depth Grids,
- Velocity Grids,
- Hazard Grids.

### MapInfo TAB Format

- Velocity Vectors.

Although all of these have not been mapped as part of this study, they are in a format ready for transfer to the London Borough of Sutton Council for upload onto their in-house systems.