Havering Flooding, June 2016

London Borough of Havering

Flood Investigation Report

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Havering Flooding, June 2016

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1. Introduction

1.1 Background

The London Borough of Havering (LBH) experienced a major flood event on 22 and 23 June 2016. There were reports of flooding at 36 different locations and properties subjected to flooding within the Borough. According to the Environment Agency flood report, more than 460 properties were flooded across the Rom, Roding and Ingrebourne catchments. This flood investigation report focusses on the hydrological conditions at the time of the event, possible factors contributing to the event and the response of Flood Risk Management Authorities (FRMAs).

Jacobs were commissioned by LBH, in September 2016, to complete a flood investigation report in accordance with Section 19 of the Flood and Water Management Act (2010)[1]. The scope of the investigation includes:

- an assessment of the rainfall;
- flood relief asset and watercourse conditions at the time of the flood event on 22 and 23 June;
- high level analysis of the possible causes of the flooding;
- liaison with responsible FRMAs to establish incident response functionality and how these functions were carried out as part of their response to the flood event in question; and
- recommendations for improvements to flood response for FRMA's, where necessary.

This report covers 17 flood locations across the Borough (see Appendix E) where properties were affected by internal flooding (from fluvial or surface water sources), foul sewer flooding or where key highways across the Borough were affected. The locations investigated do not include all locations (reported or unreported) to have flooded within LBH during the June 2016 event. Table 1-1 provides details of the reported flood locations and identifies those considered further as part of this investigation report. The given location reference corresponds to those in Figure B-1 in

Table 1-1 : Locations of reported flooding

Location	Issue reported	Investigated further?	Figure B-1 location reference
Abbs Cross Lane	Carriageway flooded		
Asten Way	Mass flood internal 3ft deep	Yes	1
Betterton Road	Rear gardens. Internal basement of HMO		
Briscoe Road	Carriagway flooded		
Brookside Infants School	Internal flood £1,000,000.00 damages	Yes	2
Calmore Close	Garage flooding		
Cedar Road	Carriagway flooded		
Collier Row Road	Internal flood	Yes	3
Crownfield School	Internal flood		

[1] Flood and Water Management Act (2010). Available from: http://www.legislation.gov.uk/ukpga/2010/29/pdfs/ukpga_20100029_en.pdf

Location	Issue reported	Investigated further?	Figure B-1 location reference
Fairtykes	Internal flood		
Ferry Lane North	Mass flood	Yes	4
Frinton Road	Internal flood	Yes	5
Gabriel Close	Flood from blocked gully		
Glanville Road	Carriagway flooded		
Gorse Way	Properties flooded internally	Yes	6
Hacton Lane	River exceedence	Yes	7
Havering Road	Properties flooded internally	Yes	8
Heath Park Road	Carriagway flooded		
Hilldene Junior	Internal flood	Yes	9
Hitchin Close	Properties flooded internally	Yes	10
Hornchurch Road	Carriageway		
Hylands School	Internal flood		
Lodge Lane	Internal flood	Yes	11
Mawney School	Internal flood		
Norfolk Road	Flood from blocked gully		
Parkside Avenue	Carriagway flooded		
Penn Gardens	Main river exceeded/properties internal 40 plus	Yes	12
Reginald Road	Flooding externally		
River Close, Rainham	Carriagway flooded		
RJ Mitchell School	Internal flood		
Spinney Close	Carriagway/garages flooded		
St. Edwards School	Internal flood	Yes	13
Sunset Drive. Harold Hill	Internal flood	Yes	14
Upper Rainham Road j/w Elm Park Avenue	Road closure due to flooding. Maylands Health Centre internal damage	Yes	15
Wallace Way	Internal flood	Yes	16
Windmill Pub, St. Marys Lane	Internal flooding of pub	Yes	17

1.2 Flood and Water Management Act, Section 19

As Lead Local Flood Authority (LLFA), London Borough of Havering has a duty to investigate, where appropriate, all flood events that occur within its jurisdiction in accordance with the Flood and Water Management Act (2010). The Act details the responsibilities of a LLFA with respect to investigating flooding and any action taken by FRMAs. Section 19 states:

> *"(1) On becoming aware of a flood in its area, a lead local flood authority must, to the extent that it considered it necessary or appropriate, investigate –*
>
> *(a) Which risk management authorities have relevant flood risk management functions, and*
>
> *(b) Whether each of those risk management authorities has exercised, or is proposing to exercise, those functions in response to the flood.*
>
> *(2) Where an authority carried out an investigation under subsection (1) it must –*
>
> *(a) Publish the results of its investigation, and*
>
> *(b) Notify any relevant risk management authorities."*

Prior to Section 19 of the Act coming into force in April 2011, the Environment Agency Area Office for Hertfordshire and North London had investigated major flood events by assembling a Flood Reconnaissance Team. The introduction of Section 19 clearly defined a responsibility for LLFAs to investigate flooding within their jurisdiction where considered 'necessary or appropriate'.

1.3 Risk management authority responsibilities

On 22 December 2011, the Environment Agency published guidance for LLFAs on producing Preliminary Flood Risk Assessments (PFRAs)[2]. In light of this guidance, it is the responsibility of LLFAs to record flooding information if an event occurs.

Table 1-2 indicates the FRMA responsible for all sources of flooding. It is important to note that in Havering, LBH assumes the position of LLFA, District Council and Highways Authority.

Table 1-2 : Flood risk management authority responsibilities for all flood sources

Flood Source	Environment Agency	Lead Local Flood Authority (LBH)	Thames Water	Transport for London	Highways authority (LBH)
Main river					
The sea					
Surface water					
Surface water (on/from highways)					
Sewer flooding					
Ordinary watercourse					

[2] PFRA Guidance. Available from: https://www.gov.uk/government/publications/preliminary-flood-risk-assessments-and-flood-risk-areas/preliminary-flood-risk-assessments-and-flood-risk-areas, accessed on 12/01/16

Groundwater					
Reservoirs (as defined by the Reservoirs Act)					

Transport for London (TfL) is responsible for the maintenance of several major roads within the Borough; however the majority of the roads fall under the jurisdiction of LBH Highways. LBH Highways are also responsible for highway gullies and any lateral drainage to the Thames Water sewer infrastructure.

2. Flood incident, extent and impact

2.1 Sources of information

A number of sources were used to inform this section of the report:

- Environment Agency Historic Flood Warnings dataset[3];
- Environment Agency flood report for the Roding, Beam and Ingrebourne Catchments[4];
- Environment Agency Flood Zones[5];
- Environment Agency water situation report: June 2016;
- Environment Agency rain gauge and gauging station data (22 and 23 June 2016);
- Environment Agency updated Flood Map for Surface Water[6];
- Flood Forecasting Centre Flood Guidance Statements (20 to 26 June 2016);
- LBH Emergency Planning Manager incident log;
- LBH Strategic Flood Risk Assessment (October 2014);
- Met Office Averages Maps (accessed 12/01/2017);
- Photographs available online from local press and social media sources;
- Responses from FRMAs;
- Site walkover observations.

2.2 Antecedent conditions

A hydrological assessment of the antecedent conditions has been completed as part of this study alongside a review of the hydrology of the Rom, Beam and Ingrebourne catchments during the event. Soil saturation analysis was completed using the Revitalised Flood Hydrograph model (ReFH2) in an attempt to model the flows observed during the flood event and develop an understanding of the saturation conditions prior to the event. The initial moisture content (C_{ini}) and maximum soil moisture capacity (C_{max}) parameters were calculated from catchment descriptors and fixed throughout the ReFH2 analysis.

The total storm duration for the recorded event at each of the Environment Agency rainfall gauges (Havering Bower (000180TP), Nag's Head Lane (237740TP) and Central Park (238097TP) – see Figure 2-1) was applied to the ReFH2 model. The aim was to match the modelled rainfall depths to the recorded rainfall depths thus identifying a return period for the rainfall event.

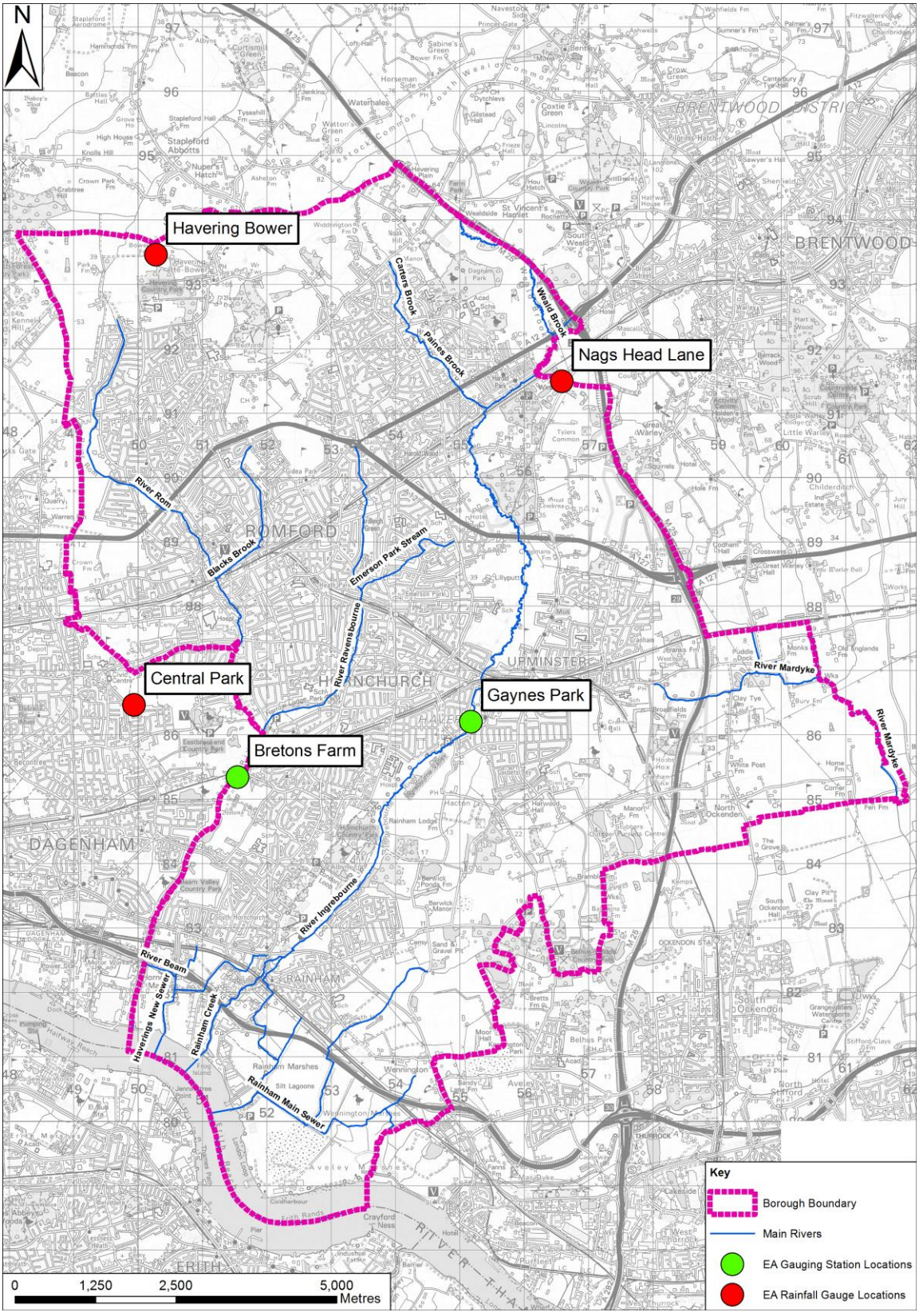
Although the observed June 2016 rainfall is the highest on record, analysis showed the estimated peak flows (with the chosen soil moisture parameters) to be less than the observed peak flows at the Environment Agency gauging stations. This indicated that the June 2016 rainfall event could not have produced the recorded peak flows with the chosen soil moisture parameters. In order to achieve the recorded peak flows in the model, higher soil moisture input parameters would be required.

This indicates soil moisture was high across the Borough prior to the rainfall event.

This conclusion is consistent with the contextual information in the Environment Agency water situation report, which states the soil moisture deficit decreased across most of England through June with the largest decreases occurring in the south-east England. Wet antecedent conditions combined with high rainfall produced particularly high flows within watercourses across the Rom, Beam and Ingrebourne catchments.

[3] Available from: data.gov.uk. Accessed on: 12/01/2017
[4] Summer Thunderstorms 23 June 2016, Roding, Beam and Ingrebourne Catchments (Environment Agency, December 2016)
[5] Available from: https://flood-warning-information.service.gov.uk/long-term-flood-risk/map. Accessed on: 12/01/2017
[6] Available from: https://flood-warning-information.service.gov.uk/long-term-flood-risk/map. Accessed on: 12/01/2017

Figure 2-1 : Environment Agency rainfall gauges and flow gauging stations



2.3 Rainfall and river flow analysis

Three 15-minute tipping bucket gauges are located at Havering Bower (000180TP) and Central Park (238097TP) in the Rom catchment and Nag's Head Lane (237740TP) in the Ingrebourne catchment, giving a good spread across the study area (Figure 2-1). Rainfall data obtained from the Environment Agency suggests the onset of rainfall shortly after 22:15 on Wednesday 22 June 2016. The rainfall profiles from all three rainfall gauges indicate there were three intense periods of rainfall between 22:15 on the 22 June and 08:00 on the 23 June (Appendix B). A smaller storm can be observed between 15:00 and 20:00 on the 23 June.

The Havering Bower rainfall gauge recorded approximately 55mm of rainfall in 20 hours between 22:00 on the 22 June and 20:00 on the 23 June. Met Office Averages Maps[7] indicate that an average rainfall depth for the month of June in Havering is approximately 40mm to 60mm. Thus approximately one month's rainfall fell on Havering in under 24 hours.

Analysis of the recorded rainfall and river flows for the June 2016 event has been undertaken. These recorded data have been compared with long-term rainfall and river flow statistics and the Environment Agency monthly water situation report[8] for the south east region (which provides information on soil moisture deficit) to estimate the return period of the event.

A comparison of the recorded rainfall for both the period of most intense rainfall and the entire storm duration, with the Flood Estimation Handbook (FEH) rainfall statistics, indicates return periods for the June 2016 event varying between 12.5% (1 in 8) and 6.67% (1 in 15) annual chance respectively. The rainfall data in isolation therefore indicates significant, yet not extreme, rainfall was experienced across the Borough.

Rainfall gauges in the south-east of England (Heathrow, 45 km southwest of the study area, and Manston, 80 km southeast of the study area) recorded up to three times the depths of rainfall in June 2016 (96mm and 96mm respectively) compared with June 2014 (40mm and 41mm respectively). These indicate that rainfall was substantially higher than would normally be expected for the time of year across the South East of England. Flow analysis indicates that the return period at the Bretons Farm and Gaynes Park gauging stations, in the south of the Borough, was above the 4% (1 in 25) annual chance event and could be as high as the 1% (1 in 100) annual chance event.

It can be concluded that the wet antecedent conditions, combined with a high intensity storm, resulted in particularly high runoff from the catchments of concern. This suggests a joint probability element to the analysis and that the overall rarity of flows associated with this event may be greater than 4% (1 in 25) and up to 1% (1 in 100) annual probability.

2.4 Observed flooding

Both fluvial and pluvial sources of flooding contributed to the flooding on 22 and 23 June 2016. Record peak levels were observed at the Romford, Harold Wood and Gaynes Park gauging sites on the Rivers Rom and Ingrebourne with recorded levels of 1.32m, 3.13m and 1.75m respectively.

In all, 17 of the reported flooding locations have been investigated as part of this study (see Figures 2-1 and 2-2). Locations have also been included within the scope of this report if flooding to local roads had a significant negative effect on the rest of the road network throughout the Borough. Otherwise locations that solely experienced external flooding have been omitted from this investigation.

Table 2-1 indicates the number of flooded properties at the investigated locations based on figures from the Environment Agency (where sufficient information is available). It should be noted that these figures are reliant on flooding being reported to the appropriate agencies and that it is possible that additional unreported property flooding occurred.

[7] Met Office Averages Maps (1981-2010). Available from: http://www.metoffice.gov.uk/public/weather/climate
[8] Environment Agency, Monthly Water Situation Report for June 2016. Available from: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/536457/WSR_June2016.pdf

Table 2-1 : Number of flooded properties by location (source: Environment Agency)

Location	Number of flooded properties	
	Internal	External only
Asten Way	4	0
Collier Row Road	5	0
Frinton Road	4	46
Gorse Way	0	49
Hacton Lane	1	0
Lodge Lane	11	12
Penn Gardens	10	0
Upper Rainham Road	1	0

Observations from the site walkover, LBH incident logs and the Environment Agency flood report can be found in Section 3, along with observations of the considered locations and comments on the likely sources of flooding for each. Figure B-1 in Appendix A indicates the locations investigated as part of this investigation as well as locations where properties were subjected to external flooding. The Environment Agency flood report includes observed extents of flooding in each location, along with some photographs (see Appendix E).

2.5 Predicted flood risk

2.5.1 Environment Agency Flood Zones

The Environment Agency Flood Zones 2 and 3 can be found in Figure 2-2. The areas with no shading are designated as being within Flood Zone 1. Flood Zone 1 indicates the areas that are not at risk of flooding from rivers or the sea in an event with greater than 0.1% (1 in 1,000) annual chance of occurring. Flood Zone 2 indicates the areas at risk of flooding, from fluvial sources, from an event with between 1% (1 in 100) and 0.1% (1 in 1,000) annual chance of occurring. Flood Zone 3 indicates the areas at risk of flooding, from fluvial sources, from an event with greater than 1% (1 in 100) annual chance of occurring.

2.5.2 Environment Agency updated Flood Map for Surface Water

The Environment Agency updated Flood Map for Surface Water (uFMfSW) can be found in Figure 2-3. This indicates the extent of flooding likely to be observed for the 3.33%, 1.33% and 1% annual chance events.

2.5.3 Comparison with observed flood extents

A comparison of the extent of flooding as seen in the Environment Agency flood report with the Environment Agency Flood Zones and uFMfSW, for several locations, can be found in Table 2-2. Overall, the comparison shows good agreement between the predicted and observed extent for the majority of the locations assessed.

Table 2-2 : Comparison of observed and predicted flood extent

Location	Observed flood extent	Environment Agency Flood Zone extent	Environment Agency uFMfSW Extent	Comparison
Asten Way	Covers all four properties on Asten Way including the driveway and Asten Way itself.	Asten Way is located within Flood Zone 1. However a small area of the northern bank of the River Rom, immediately adjacent to the river, is designated as Flood Zone 2.	The 3.33% (1 in 30) uFMfSW extent indicates flooding to the northern bank of the River Rom. The Asten Way properties are located on the edge of the uFMfSW extent north of the river.	Poor agreement. The observed flooding indicates overtopping of the river bank and the decommissioned Cross Road Flood Storage Area (FSA) embankment; however the uFMfSW indicates a flow path further downstream.

Location	Observed flood extent	Environment Agency Flood Zone extent	Environment Agency uFMfSW Extent	Comparison
Collier Row Road	Flooding from the River Rom to the north of Collier Row Road. The extent covers the Gospel Hall and 150 to156 Collier Row Road.	The observed flood extent is designated as Flood Zone 3.	3.33% (1 in 30) annual chance event uFMfSW extents indicate a relatively similar flood extent to Flood Zone 3. This extent includes the properties indicated as flooding as part of the Environment Agency flood report.	Good agreement. Both the fluvial Flood Zones and the 3.33% (1 in 30) annual chance event uFMfSW indicate predicted flooding extents that roughly match those observed during event.
Frinton Road	The flow path reaches Frinton Road from the north, via alleyways between properties. The extent observed covers approximately 175m of the eastern end of the road. Several properties flooded internally with the majority of the driveways along the road inundated.	Frinton Road is within Flood Zone 1.	uFMfSW indicates flow path arrives from the north at the western end of Frinton Road. 3.33% (1 in 30) annual chance event uFMfSW flow paths on Lodge Lane and through Penn Gardens are similar to the observed extent.	Good agreement. The 3.33% (1 in 30) annual chance event uFMfSW indicates predicted flooding extents that roughly match those observed during event.
Gorse Way	The observed extent covers the western bank and back gardens of the properties that back onto the River Rom. No internal flooding was reported.	A narrow strip of the back gardens of the Gorse Way properties, immediately adjacent to the river, is designated as Flood Zone 2. The properties on Gorse Way are located in Flood Zone 1.	3.33% (1 in 30) annual chance event uFMfSW extent indicates flooding to the road on Gorse Way and some localised flooding to the back gardens of properties.	Poor agreement The observed extent was substantially greater than the two predicted extents (extent flooded covers back gardens of almost all properties backing onto the River Rom). It could be that a summative effect of both flood sources occurred here. Alternatively, it could be that the Environment Agency models require updating in this area.
Hacton Lane	The observed extent covers the recreation park to the north of Hacton Lane, as well as the nearest property to the river on the south bank.	The Flood Zone 3 extent covered the affected property adjacent to the River Ingrebourne. The recreational park to the north is also included in Flood Zone 3.	The affected property is not shown at risk of flooding except for the north-western corner of the building which is shown to be at 'High' risk of flooding. The recreational park to the north is also shown as having 'High' risk to flooding.	Good agreement. The Flood Zone 3 extent indicates the affected property on Hacton Lane and the recreational park to the north area affected, as observed during the flood event.
Lodge Lane	Flooding observed between the entrance to Frinton Road and approximately 75m south along Lodge Lane.	Lodge Lane is designated as Flood Zone 1.	3.33% (1 in 30) annual chance event uFMfSW extent on Lodge Lane and similar to the observed extent.	Good agreement. The 3.33% (1 in 30) annual chance event uFMfSW indicates predicted flooding extents that roughly match those observed during event.

Location	Observed flood extent	Environment Agency Flood Zone extent	Environment Agency uFMfSW Extent	Comparison
Penn Gardens	Properties on the western side of the road affected, extent does not cover those on the eastern side of the road. Properties at the southern end of Penn Gardens, near Miller Close, were also affected by internal flooding.	Penn Gardens is designated as Flood Zone 1. Small area immediately adjacent to the watercourse on the western bank is designated as Flood Zone 3.	For the 3.33% (1 in 30) annual chance event the extent indicates flooding along the western side of the road at Penn Gardens. Properties between Lodge Lane and Penn Gardens and at the southern end of Penn Gardens also shown to be at risk of flooding.	Good agreement The 3.33% (1 in 30) annual chance event uFMfSW indicates predicted flooding extents that roughly match those observed during event.

2.6 Site walkover observations

A site walkover was conducted in October 2016, 17 weeks after the flood event, to assess the conditions of key assets and infrastructure close to a number of locations reported to have been affected by severe flooding during the June 2016 flood event. Site walkover observations and key information obtained from LBH staff or local residents during the walkover are highlighted in Table 2-3. It should be noted that during the time between the flood event and the site walkover, some evidence of flooding is likely to have been lost. The Environment Agency flood report (see Appendix E) identifies the observed flood extent and for some of the areas considered in and includes additional information regarding flood mechanisms.

Table 2-3 : Site walkover observations and information

Location of flooding	Observations and information
Asten Way	• Over 1m of flood water experienced outside the front of the houses (houses at a lower level than main road). • Local pump (used to pump water against topographical gradient from Asten Way into the sewer beneath Cross Road) failed during the event. • The decommissioned Cross Road FSA (behind Asten Way) appears to have had large sections that remained dry during the flood event. • Upstream of Cross Roads FSA river came out of banks and flows across Crownfield School playing fields (no internal flooding). • River Rom adjacent to Cross Road FSA and upstream was flowing at capacity during event.
Brookside Infants School	• Located immediately adjacent to Paines/Carters Brook. • Floods assumed to be attributed to the overtopping of the watercourse.
Collier Row Road	• Properties at topographical low point and immediately adjacent to River Rom. • Culvert under Collier Row Road observed to be in good condition and clear of obstruction.
Ferry Lane North	• Existing vegetation within the watercourse is overgrown and likely to restrict conveyance. • Poor conveyance of water during flood event is assumed to have resulted in overtopping of riverbank. • Flooding to commercial properties on the industrial estate opposite.
Frinton Road	• Culvert beneath Frinton Road cleared a few weeks prior to the event by LBH. • It is understood that the sewers beneath Frinton Road and Lodge Lane are both 225mm diameter. It is assumed the capacity was exceeded during the event.
Gorse Way	• River Rom caused flooding within back gardens and garages of properties along Gorse Way (some garages have reportedly been converted into secondary living spaces or sitting rooms). • Flood alerts and warnings were issued after several properties were affected. • Some residents have invested in property level flood protection but the untimely warning meant they were still affected. • Anecdotal evidence from residents suggesting the water within the river channel was flowing at high speeds. • Thames21 charity hoping to re-generate the area by adding amenity value to the river and re-profiling the watercourse by creating meanders.
Hacton Lane	• Closest property to the River Ingrebourne on Hacton Lane suffered internal flooding (water entered via airbricks beneath floorboards).
Havering Road	• Unclear how flooding occurred to properties that aren't situated at a topographic low-point. • Observed ground levels reinforced the flow path down Bower Close behind the houses and then through the garage area/back gardens; however it is unlikely this would have happened without flooding to properties on Bower Close. • A 90^{o} connection between sewers beneath Havering Road may have caused surcharging of the manholes on the road
Hilldene Primary School	• Flow path from large upstream greenfield catchment arrived from the north, crossed Grange Road and entered school.

Location of flooding	Observations and information
	• Shallow gullies along Grange Road packed with dead leaves (likely that fewer leaves were present in gullies during the June flood event).
Hitchin Close, Romford	• Flooding believed to arise from overtopping of a drainage ditch that becomes culverted immediately north of Hitchin Close. • Heavy vegetation in vicinity of drainage ditch with potential to cause blockages. However no major blockage reported during flood event. • At least half a foot of internal flooding in one of the blocks, with two others also affected. • Existing mounds between the housing blocks likely to cause localised ponding in garden areas. • Fences with concrete bases likely to restrict surface water flow out of properties and gardens.
Lodge Lane	• Existing ground levels suggest flooding to properties from surface water from Frinton Road and property thresholds below road level. • Properties have airbricks at low levels in the walls.
Penn Gardens	• Very deep flood water reported. • Bank vegetation along River Rom adjacent to Penn Gardens cut and left on the river banks has the potential to cause blockage at structures downstream. It is understood that this work took place following the flood event, but if representative of standard maintenance practice could be a contributing factor.
St. Edwards C of E Primary School	• School located in a topographical low-point. • Runoff from surrounding land flows towards school and accumulates.
Sunset Drive, Harold Hill	• Three static caravans affected. • Culvert beneath road believed to have collapsed during demolition of the site on the opposite site of the road to the east. • New culvert being fitted as part of the new sports ground development opposite Sunset Drive.
Upper Rainham Road j/w Elm Park Avenue	• Flood alerts and warning arrived after several properties were affected. Maylands Healthcare Centre • Situated at the confluence of the River Beam and River Ravensbourne. Limited information available as to the source of the flooding but given the reported flows is assumed to be from river banks overtopping. • Located within floodplain. • Original building has airbricks with no covers; newer extension has flood protection covers – flood water entered via the older section of the building.
Wallace Way Estate	• Four properties affected. • Thames Sewer exceeded capacity and surcharged nearby manholes. • Residents called the LBH Fire Brigade but all teams were occupied, a fire engine from Dagenham Fire Brigade attended. • Residents used their own pump to pump water into another nearby surface water sewer which had spare capacity.
Windmill Pub. St. Marys Lane	• Pub located in a topographical low point. • Water from the River Ingrebourne overtopped (possibly due to blockage at the bridge due to narrow opening and channel encroachment by abutments). • Car park became inundated before flows entered the back of the pub.

2.7 Historic flood incidents

As stated in the LBH Strategic Flood Risk Assessment (SFRA)[9], Thames Water provided flood location data, from a range of sources, for the Drain London project in 2011; these Drain London historic flood extents have been included in Figure B-1 in Appendix A.

In some cases the locations identified in Figure B-1 as flooding in the Drain London data are similar to those observed during the June 2016 floods; indicating these locations flood consistently during heavy storm events.

No information is available for the consequences of the flooding detailed in the Drain London and Environment Agency data.

[9] London Borough of Havering SFRA (October 2014). Available from: https://www.havering.gov.uk/Documents/Planning/LDF/strategic-flood-risk-assessment-level-1.pdf

Figure 2-2 : Environment Agency Flood Zones

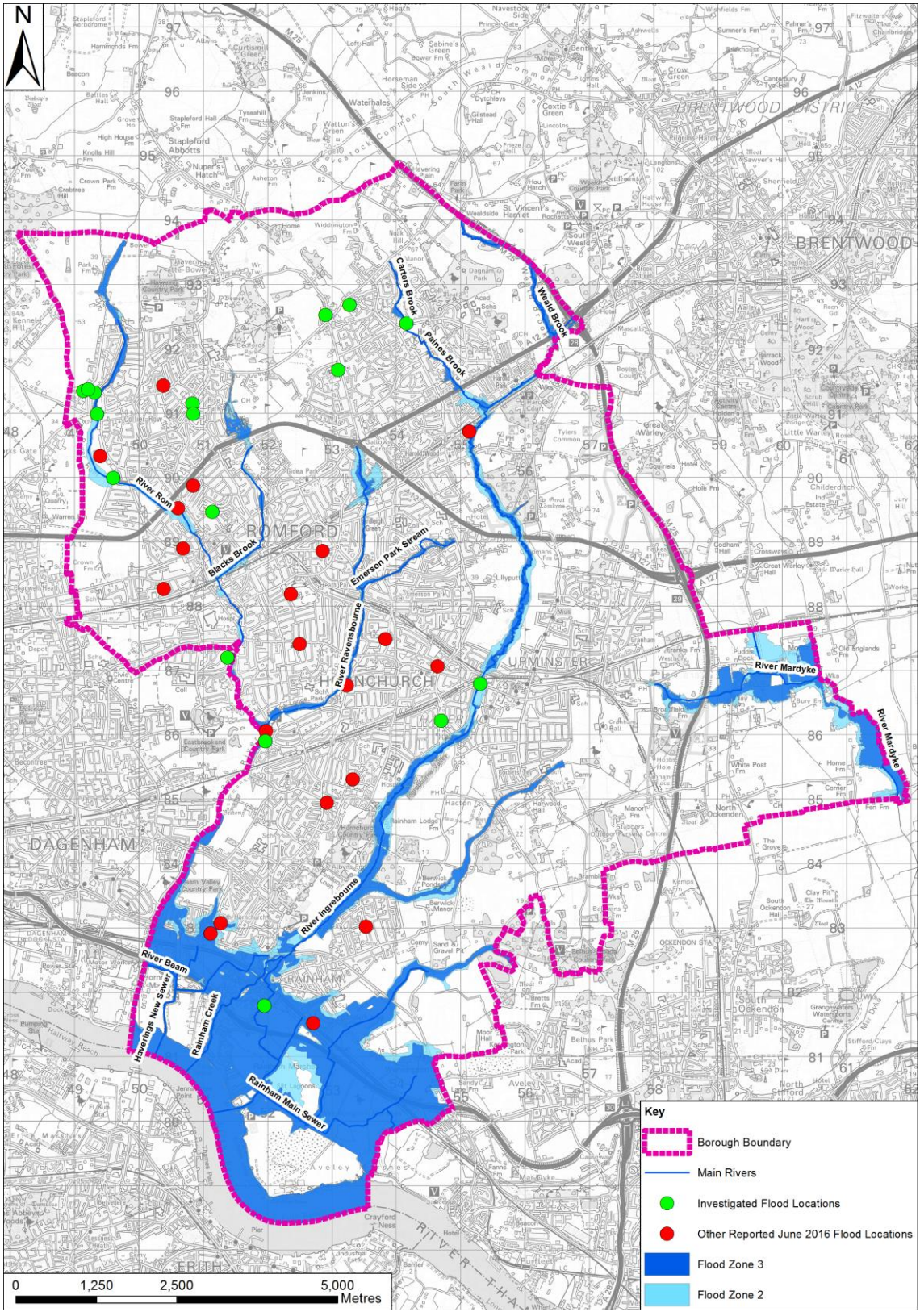


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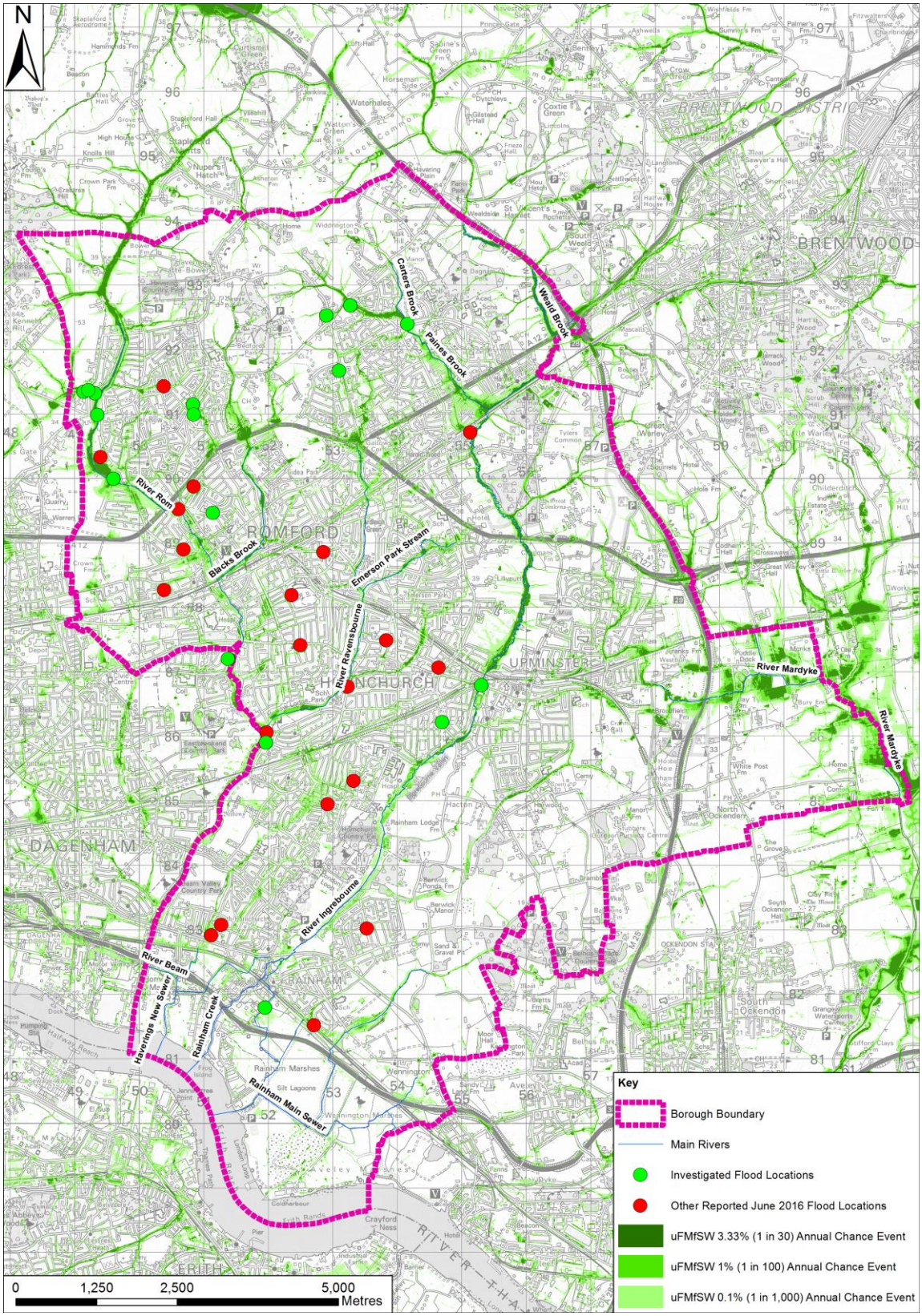
Figure 2-3 : Environment Agency updated Flood Map for Surface Water



3. Organisational responses

This section includes key actions undertaken by responsible authorities before, during and after the June 2016 flood event; a timeline is included in Section 3.1. Sections 3.3 to 3.9 include additional actions undertaken by each authority during the event where a specific time was not given.

3.1 Timeline of key actions

Key actions during the flood event undertaken by LBH, LBH Highways, Highways England, the Met Office and the Environment Agency can be found, with the date and time of action, in Table 3-1. This information is based on responses provided by the RMA's to requests for activity logs and other available information on their flood response.

Table 3-1 : Timeline of key actions

Logged date and time	Key information received	Action taken
22 June 2016		
-	Environment Agency Flood Alert for the Ravensbourne catchment issued	
22:15	Onset of intense rainfall (30mm in two hours)	
During Night	N/A	Meteorological Office issued a heavy rainfall alert to Hertfordshire and North London (maximum of 80mm and average of 25mm forecast with medium confidence) until midday on 23 June.
During Night	N/A	Highways team closed several roads across the Borough that were too dangerous to use due to the ponding of flood water.
23 June 2016		
Early morning	Heaviest of the storms experienced. Total rainfall over Roding and Rom catchments was 52.2mm. Total rainfall on the Ingrebourne catchment was 56.8mm (maximum recorded intensity of 14.5mm in 15 minutes).	
02:34	Flood water observed by Highways England in two of the live lanes of the M25 near Junction 28.	
02:36	The cause of the M25 flooding was reported to be due to the surcharging of a nearby slot drain as a result of the volumes of flood water experienced.	Highways England signalled red crosses above the affected lanes.
02:51	The water on the M25 near Junction 28 had receded.	Highways England reopened lanes and the red crosses on the overhead signalling had been replaced by 50mph signs.
05:15	Initial reports of flooding in the Collier Row area received from the Emergency Services.	LBH created incident log.
05:43	Environment Agency Flood Alerts issued for River Ingrebourne.	LBH started flood monitoring of River Ingrebourne via staff on the ground.
05:59	N/A	LBH Gathered flooding information to relay to members of the public and other Flood Risk Management Authorities.
07:00	N/A	Meteorological Office issued a new heavy rainfall alert, for 1pm to 10pm (maximum of 40mm and average of 15mm forecast with medium confidence).
07:39 – 07:45	Environment Agency Flood Warnings for River Ingrebourne at Harold Park and Hornchurch issued. Up to 30 properties may be flooded.	LBH continued monitoring flooding due to River Ingrebourne.
07:55	N/A	Environment Agency opened flood incident room.

Logged date and time	Key information received	Action taken
07:57	N/A	LBH Highways requested authorisation from LBH Emergency Planning Manager to close Upper Rainham Road due to flooding observed by council staff on site (authorised).
08:01	LBH Received request for sandbags at two vulnerable properties on Carter Drive.	None by LBH (no sandbags provided) – policy is to not supply sandbags due to the number available for individual properties across the Borough. Sandbags are reserved for aiding mitigation of critical infrastructure failure.
08:18	Environment Agency Flood Warnings for River Rom at Romford issued. Flooding expected, including Rush Green. Up to 10 properties may be flooded.	LBH started flood monitoring on the ground of River Rom at Romford.
08:22	Reports of internal and external flooding at several properties on Abbs Cross Lane, source unknown.	LBH liaised with LBH Highways to highlight the locations of a number of internally flooded properties.
08:22	LBH Emergency Planning Manager advised Highways team of a number of flooding reports, across the Borough.	LBH Highways investigated flooding reports.
08:48	N/A	LBH Flood Engineer investigated several reported issues across the Borough. Confirmed number of formally (fully or partially) closed roads: Collier Row Road, Ferry Lane, Upper Rainham Road, Ardleigh Green Road, Gide Park, Lodge Lane and Pettits Lane.
08:48	N/A	Co-ordination of response to flooding continued through LBH Highways team.
09:41	Environment Agency Flood Alerts for River Beam and River Rom at Romford, Hornchurch, Dagenham and Rainham issued.	LBH Emergency Planning manager circulated Flood Alerts to other LBH teams. Continued monitoring flooding due to River Beam and River Rom.
10:23	Observed flood water starting to recede.	LBH liaised with affected residents; the general consensus was that residents preferred to be evacuated to temporary housing provided by their insurers rather than the council evacuation centre. LBH Emergency Planning Manager implemented Multi-Agency Flood Plan and liaised with Fire Service on Lodge Lane.
12:15	Highest flood water level of the River Ingrebourne at Hacton Lane was witnessed by residents from adjacent property.	
12:41	Request for inventory of all LBH available flood defence resources to deploy if Fire Service required them.	LBH Emergency Planning Manager sent inventory of flood defence resources to Fire Service.
12:46	Observed flooding at Collier Row Road properties; approximately 2ft deep internal flooding caused by water surcharging sewerage system.	
13:00	Power and Gas disrupted in Penn Gardens.	None - handled by UK Power Networks and National Grid.
14:29	Report of problems and request for sandbags from a Fire Fighter at Cross Road. Asten Way road pump had failed. Areas of the decommissioned Cross Road FSA remained dry.	None by LBH (no sandbags provided) – policy is to not support sandbags due to the number required to aid with critical infrastructure failure. LBH Emergency Planning Manager requested land registry to trace owners of Asten Way properties (as newly-built houses). File recalled from Iron Mountain to check plans and pumping arrangements (response time unknown). Pump reset and road cleared of all flood water.
15:40	Received enquiry regarding flooding and actions	LLBH Emergency Planning Manager liaised with LBH

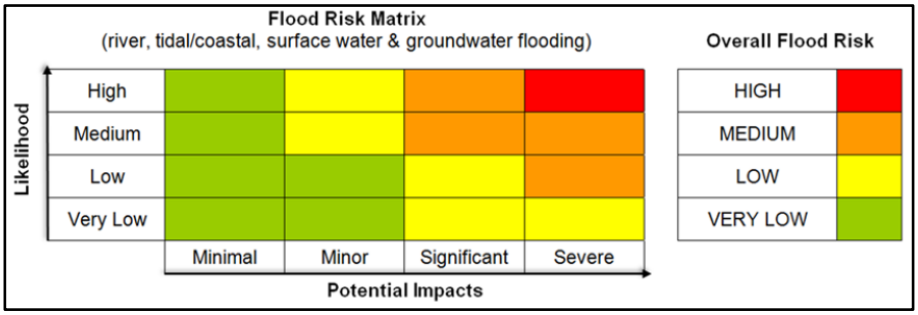
Logged date and time	Key information received	Action taken
	taken for next few hours (additional rainfall forecast).	Communications team about events and actions throughout the day.
16:00	N/A	Meteorological Office updated heavy rainfall alert, extending the previous event end time to midnight on 23 June.
17:01	Response to Asten Way land registry inquiry; private cul de sac therefore maintenance responsibility (including that of the road pump) lies with residents.	
17:30	Additional rainfall and flooding to properties in Penn Gardens; the LBH Emergency Planning Manager attributed this to the poor construction quality of guttering system.	LBH were asked by the Environment Agency to construct a temporary sandbag barrier at the bottom of Willoughby's Hill to try to slow down surface water in the Havering Park area. On their way back to the depot, some sand and bags remained; therefore LBH Highways provided sandbags to residents on Penn Gardens in efforts to protect the properties that had recently been pumped out by LFB – the properties had already internally flooded earlier and therefore the sandbags were provided to little effect.
19:30	Central Park and Havering Bower rainfall gauges show it stopped raining at approximately 19:30.	
20:46	Met Office cancelled south-east England and Greater London rain warnings; no further impacts anticipated.	LBH Emergency Planning Manager advised LBH communications and management of the situation and cancellation of the warning.
24 June 2016		
05:33	Environment Agency Flood Warnings for River Ingrebourne at Harold Park cancelled.	
	Water back within River Ingrebourne bank and no further flooding anticipated in this area.	LBH continued monitoring of flooding from the River Ingrebourne at Harold Park.
05:42	Environment Agency Flood Warnings for River Ingrebourne at Hornchurch cancelled.	
	Water back within River Ingrebourne bank and no further flooding anticipated in this area.	LBH continued monitoring of flooding from the River Ingrebourne at Hornchurch.
Unknown		LBH stand down.

3.2 Flood guidance statements

The Flood Forecasting Centre combines forecasting information from the Environment Agency and the Met Office to produce Flood Guidance Statements (FGSs) every day at approximately 10:30am. FGSs detail the estimated flood risk for the next five days. A general overview of flood risk across England and Wales is given as well as a brief assessment of flood risk from fluvial, surface water, tidal and groundwater sources. The FGS also details the number of flood alerts and warnings and severe weather warnings currently in force. Appendix C includes the complete FGSs for 20 to 26 June 2016.

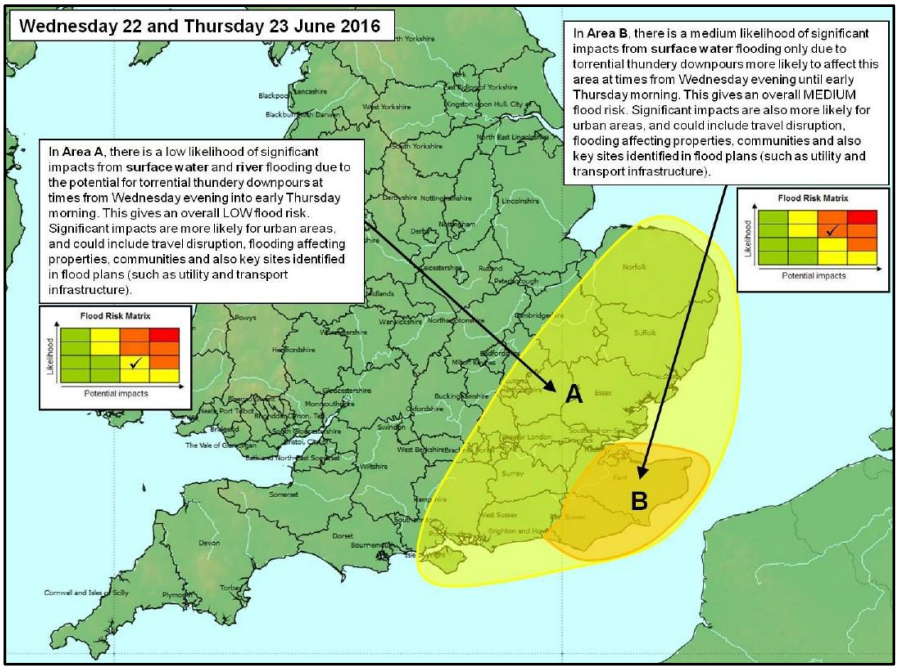
FGSs use a colour coded flood risk matrix (see Figure 3-1) to represent the overall risk of flooding to an area. The overall flood risk is a product of the likelihood of flooding and the severity of the potential impacts.

Figure 3-1 : Flood Guidance Statement flood risk matrix



Using the same colour coded designation of flood risk, an Area of Concern (AoC) map is included in the FGS to differentiate between areas with different overall risks of flooding. Figure 3-2 is an extract from the 22 June FGS showing the standard format for the AoC map.

Figure 3-2 : Areas of concern map extract



An initial reference to the heavy rainfall experienced in south-east England was included within the general flood risk overview of Monday 20 June FGS; however flood risk from all sources was classified as ‘very low’.

The Tuesday 21 June FGS indicated a ‘low’ risk of flooding from late Wednesday until Friday morning. The general overview predicted the potential for heavy, thundery downpours in south-east England from Wednesday night until Friday morning. The risk of flooding from surface water and fluvial sources between Wednesday night and Friday morning was classified as ‘low’; the risk from tidal and groundwater sources was classified as ‘very low’.

The FGS issued on Wednesday 22 June identified a ‘medium’ flood risk from Wednesday evening until Thursday morning for surface water flooding in the far south-east of England (parts of Kent and Sussex) and a ‘low’ flood risk for the rest of south-east England. Torrential, thundery downpours were deemed likely to affect parts of the south-east of England between Wednesday evening and Friday morning. The risk of flooding from fluvial sources was identified as ‘low’ for south-east England. Tidal and groundwater sources of flooding were classified as having ‘very low’ levels of flood risk. Severe Weather Warnings and three Flood Alerts were in force as of 10:30 on 22 June.

The Thursday 23 June FGS included warnings of torrential, thundery downpours, in the south-east of England and Greater London, for the afternoon of the 23 June (when flooding in the London Borough of Havering was observed). The flood risk from both surface water and fluvial sources was classified as 'medium' in south-east England and Greater London. Flooding from tidal and groundwater sources remained classified as 'very low'. Severe Weather Warnings, 39 Flood Alerts and seven Flood Warnings were in force as of 10:30 on 23 June.

The potential impacts of flooding were also considered in the 21, 22 and 23 June FGSs. It was indicated that properties and communities could be affected as well as there being possible disruption to roads and travel within the south-east of England. The FGSs stated any river response was likely to continue until early morning on Friday 24 June.

The FGS from 24 June indicated the flood risk from surface water flooding had returned to 'very low' following the investigated rainfall events. The FGSs from 24 to 26 June detailed the observed falling of river levels within south-east England. Appendix C includes the complete FGSs for 20 to 26 June 2016.

3.3 Environment Agency response

The Environment Agency has produced a flood report covering the Roding, Beam and Ingrebourne catchments for the flood event in June 2016. The report can be found in Appendix E. It states the Environment Agency's responsibilities under the Flood and Water Management Act:

> *"…forecasting and mapping flood risks, providing flood warnings for river and coastal flooding, building and keeping defences in good working order and taking part in emergency planning and response. We manage central government grants for capital projects carried out by all risk management authorities."*

The Environment Agency flood report describes the rainfall event as a significant thunderstorm resulting in 30mm of intense rain falling in the area over a 2 hour period. A hydrological assessment completed as part of these investigations indicates the return period for the rainfall event is between the 12.5% (1 in 8) annual chance event and 6.67% (1 in 15) annual chance event. The River Rom and adjoining surface water sewers were believed to have insufficient capacity. Flood alerts and warnings were issued for the Ingrebourne and Rom catchments; however in some locations properties had already suffered internal flooding and flood warning thresholds were under review to ensure future warnings are given in a timelier manner.

The report identifies key flood locations, from the River Rom and River Ingrebourne catchments, that were investigated by Field Incident Support Officers (FISOs) during the flood event. Mapping showing the approximate extent of flooding in each location can be found in the flood report in Appendix E. Table 3-2 includes a brief overview of the conditions during the event and actions taken by the Environment Agency.

In addition to the flooded locations considered throughout this study, several other flood locations were identified in the Environment Agency's flood report (see Appendix E). These areas include Taylor Close, Carter Drive, Carter Close, Abbotts Close, Frimley Avenue, Reginald Road and Dovers Corner.

Table 3-2 : Environment Agency observations and actions

Location	Observations	Action(s) taken
River Rom catchment		
Asten Way	All four properties were internally flooded. Cross Roads Flood Storage Area (FSA) decommissioned by the Environment Agency in 2010 (section of the reservoir embankment removed to revert it to a natural flood basin).	No action taken in this location during the flood event. Investigation is underway into the cause of flooding through modelling studies to identify why the flood water responded in a way that wasn't anticipated during studies undertaken associated with the decommissioning of Cross Roads FSA. This study will indicate any necessary remedial works to reduce the risk of flooding downstream of the Cross Roads decommissioned FSA.
Collier Row Road	High river flows exceeded the capacity of the culvert beneath Collier Row Road on the River Rom during the event; water backed up and overtopped upstream of the culvert. Water reportedly came out of the river banks at the recreation ground upstream of Collier Row Road which contributed to flooding. Four residential properties and the Gospel Hall flooded internally.	No action taken in this location.
Frinton Road	46 property gardens and driveways affected. Flood water flowed from fields to the north, through alleyways and ponded approximately halfway along Frinton Road. Evidence of internal flooding on the northern side of Frinton Road (three properties affected).	FISOs liaised with residents and confirmed flood extent.
Havering Park	Access in the Bacon Link bridge area was difficult due to the extent of surface water flooding and ongoing emergency response.	Visited by FISOs who were able to confirm impacts from affected residents. Liaised with London Fire Brigade to combine resources and pump water away from properties. Public surgery held since the event to discuss with affected residents.
Lodge Lane	23 properties affected by flood water. 11 properties on the eastern side of Lodge Lane internally flooded due to threshold levels being below road level (flood water came from Frinton Road). One property garden flooded on Turpin Avenue.	No action taken in this location.
Penn Gardens	10 properties internally flooded. Residents from four properties were evacuated due to deep water. Property level is significantly lower than the road level.	Visited by FISOs who were able to confirm impacts from affected residents. Public surgery held since the event to discuss with affected residents.
Rush Green and Gorse Way	Rear gardens of 49 properties on Gorse Way were affected (no internal flooding of properties but a number of outbuildings were flooded). River Rom flood warning triggered, several hours after the first flooding was experienced, following several reports of flooding in Gorse Way from residents and the Fire Service. River overtopped banks at the upstream of the YMCA building and was unable to drain back into the river due to an embankment. Floodwater pooled to the south until it reached a gap in the embankment at the southern end of Gorse Way.	Since the 2012 floods, LBH have completed works to raise a low point in the west bank of the River Rom around the sewer pipe, upstream of Gorse Way. No work on the river channel has been completed in this location by the Environment Agency since 2012. River Rom flood warning triggered in light of several reports of flooding in Gorse Way from residents and the Fire Service. Flood warning trigger levels at the Romford telemetry site have been reviewed following the June 2016 flood event and the flooding that occurred at Gorse Way.

Location	Observations	Action(s) taken
Upper Rainham Road (Maylands Health Care)	Lies at the confluence of the River Ravensbourne and the River Rom. Building internally flooded, car park affected. It is thought that the River Ravensbourne came out of bank upstream near to the boating lake at Harrow Lodge Park.	No action taken in this location. Washlands FSA, located in Dagenham, was used to store flood water flowing down the Rivers Rom and Beam at high tide. Flood water was released into the River Thames at low tide to prevent flooding to properties downstream of the FSA. Environment Agency working with the medical centre to create flood plans for their community.
River Ingrebourne catchment		
Hacton Lane	One house affected by internal flooding (water entered through airbricks below threshold level), highest flood water level was witnessed at approximately 12:15 on 23 June. Recreation park to the north of Hacton Lane was extensively flooded. Hacton Lane bridge restricted flows on the River Ingrebourne.	No action taken in this location.

During the event the Environment Agency issued flood alerts and warnings, co-ordinated their response and liaised with the public from an area incident room. Flood Incident Support Officers (FISOs) were sent to verify river levels at gauging stations, record property flooding and capture physical extents of flooding on the ground. Field teams were deployed to clear trash screens and river blockages where possible. Flood ambassadors were sent to deliver information to affected communities, answer queries and report back to the area incident room.

The incident room dealt with a large number of calls and was used alongside social media to liaise with members of the public during the event.

In light of the June 2016 flood event and in addition to the responses at the specific flood locations, the Environment Agency has held flood surgeries and public meetings. They have commissioned modelling projects to better understand the areas at risk of surface water and fluvial flooding. They are also working with London Borough of Havering to identify catchment wide options for alleviating flood risk throughout the Rom, Beam and Ingrebourne catchments. The Environment Agency is also looking to engage with interested parties in affected locations.

The Environment Agency has been revising flood alert and flood warning trigger levels since the June 2016 floods to reduce the risk of late flood alerts and warnings in the future. Flood alert threshold level at the Romford telemetry site has been reduced from 2.0m to 0.7m Above Site Datum (ASD); the flood warning threshold level has been reduced 1.1mASD. Mitigation schemes in the affected areas have been prioritised in an attempt to reduce flood risk.

3.4 Highways authority (London Borough of Havering Highways)

LBH Highways were responsible for road closures. They also carried out pumping at a number of properties across the Borough during the event. The majority of the efforts were focussed on assisting those subjected to flooding at Penn Gardens; over 2,000 sandbags were provided in this area and a number of properties had flood water pumped out.

After the flood event, LBH Highways were involved in the large scale clean-up across the Borough; this included culvert clearance and the de-silting of roads.

3.5 Highways England

Highways England was contacted in order to establish their views on the event and how they responded as a FRMA. Highways England is responsible for the motorways across England as well as a number of major highways; the M25 is the main asset they are responsible for within the London Borough of Havering.

A response was received from Connect Plus Services (managers, operators and maintainers of the M25 and its linking roads on behalf of Highways England). The response included a detailed incident report and action log of their response to the June 2016 flooding (see 23 June, 02:34 in Table 3-1).

The response from Connect Plus Services states they believe the exceptional rainfall caused exceedance in capacity of the existing drainage system.

3.6 Transport for London

Transport for London (TfL) has a responsibility to manage London's principal road network; the A12 and A13 fall under their jurisdiction within the London Borough of Havering.

TfL managed responses and queries from the public throughout the event through a centralised 'storm desk' in the London Streets Traffic Control Centre (LSTCC). Known flooding 'hotspots' on the TfL road network were monitored throughout the event.

Delays of up to 1 hour 45 minutes on the A12 and A13 were experienced. The total disruption time experienced on roads, based on cumulative delays as a result of the flood event, is estimated to have been up to 42.5 hours. Traffic signal timing strategies were used to maximise capacity on alternative routes and to keep the roads moving as best as possible.

The TfL Road Space Management team indicate for the roads they maintain there was only correspondence relating to flooding on Lodge Lane, Romford and Movers Lane, Barking on 23 June. Additional resources were drafted in by TfL, including tankers and gully machines.

3.7 Thames Water

A request for information was submitted to Thames Water early in September 2016 for Thames Water's views on the June 2016 flood event and any action they took during or after the event as a FRMA for Havering. At the time of writing, no response has been received.

3.8 London Fire Brigade

London Fire Brigade (LFB) provided an overview of their response during the June 2016 flood event, including an incident log of the calls made to the Fire Service in the early hours of 23 June. LFB estimated 100 properties were affected by localised flooding, specifically in Lodge Lane and Penn Gardens.

A summary, provided by the LFB, of their response during the flood event is included below:

> *''The LFB responded according to well prepared, generic "batch mobilising" procedures for severe rain/wind storms or during a thaw following freezing weather conditions where the Brigade may receive a large number of calls to affected premises. Where a large number of incidents occur in a specific area or on more than one stations' ground the control will collate a number of calls into batches. These batches will be allocated to individual pumping appliances in accordance with its locality, in this case the flooding incidents in the Lodge Lane area of Collier Row. Priority attendance is given to special service calls where incidents involve a risk of fire, explosion or injury and to calls received from hospitals, care homes, public utility services and food storage depots.*
>
> *Smaller incidents were dealt with by individual fire crews. Due to the severity of the flooding and large number of houses affected in Lodge Lane, Penn Gardens and Frinton Road, additional LFB resources were requested. As a result six fire engines and two fire rescue units (that carry specialist equipment) attended throughout the morning, coming from Hornchurch, Romford, Dagenham, Ilford, Barking and Edmonton. Forty firefighters and two portable pumps were deployed to pump out houses in the area and two rescue boats with specialist swift water rescue trained firefighters were used to rescue 30 people from their homes.''*

LFB pumped flood water out of four houses during the event and from Penn Gardens into the River Rom, performed rescues and provided assistance to the public. The LFB has also stated the following in regards to its response:

> *''The LFB responded according to its established policies and procedures and will respond in the same way for similar future incidents either within Havering or across London.''*

3.9 Metropolitan Police

A request for information was submitted to the Metropolitan Police early in September 2016 for their views on the June 2016 flood event and any action they took during or after the event. At the time of writing, no information has been received.

4. Likely causes of flood incident

It is envisaged that the primary causes of the flooding experienced throughout the 22 and 23 June 2016 were the antecedent soil conditions and the depth and intensity of rainfall. The wet antecedent conditions of the catchments increased the percentage runoff as the ground was already saturated. These primary causes are difficult to manage without the implementation of capital works to attenuate or convey flood water or major changes in terms of installing SuDS across the Borough.

4.1 Primary causes

The primary contributing factor to the flooding observed in June 2016 is the depth and intensity of rainfall that fell within 24 hours. More than one month's rainfall fell across the Borough and the surrounding catchments. This depth of rainfall, combined with the wetter than average soil moisture conditions and urbanised catchments produced a high percentage runoff. Surface water entered sewers and watercourses quicker than it normally would for the time of year.

The Havering Bower rainfall gauge recorded approximately 55mm of rainfall in 20 hours between 22:00 on the 22 June and 20:00 on the 23 June. Met Office Averages Maps indicate that an average rainfall depth for the month of June in Havering is approximately 40mm to 60mm. Thus approximately one month's rainfall fell on Havering in under 24 hours.

The resulting flows within the watercourses have been estimated as being equivalent to between a 4% (1 in 25) and 1% (1 in 100) annual chance event, resulting in culvert and river channel capacities being exceeded.

In addition, the surface water sewer infrastructure across the Borough is not designed to convey surface water runoff in excess of a 1.33% (1 in 30) annual exceedance probability. It is possible that, prior to the June 2016 event, the sewer system was nearly at capacity. The flows and volumes exceeded capacity and therefore excess water was forced to flow overland.

4.2 Contributing factors

The impact of flooding, particularly at Gorse Way, was exacerbated by unsuitable flood alert and flood warning trigger levels, which lead to the issue of flood alert and warnings after the onset of flooding. In June 2016, Environment Agency alerts and warnings were issued as a result of public reports of flooding. In particular, the properties on Gorse Way were affected by the external flooding of their gardens and flooding to outhouses prior to receiving the flood alert for the River Rom. A number of residents on Gorse Way were unable to install property level protection before flooding occurred due to the untimely nature of the alert.

5. Conclusions and recommended actions

5.1 Conclusions

The primary causes of the flooding experienced throughout the 22 and 23 June 2016 were the antecedent soil conditions and the volumes of rainfall experienced during the rainfall event. The wet antecedent conditions of the catchments increased the percentage runoff, culminating in an estimated annual exceedance probability of the rainfall event between 12.5% (1 in 8) and 6.67% (1 in 15). Flow analysis indicates that the return period of the flows at the Bretons Farm and Gaynes Park gauging stations was between the 4% (1 in 25) annual chance event and could be as high as the 1% (1 in 100) annual chance event.

The primary causes are difficult to manage without the implementation of capital works to attenuate or convey flood water or major changes in terms of installing SuDS across the Borough. Opportunities to implement natural flood management could be investigated in the upper reaches of each catchment.

The response from FRMAs to the flooding experienced in June 2016 was relatively effective. The London Borough of Havering was able to work alongside the Environment Agency and the London Fire Brigade to manage the flooding and the affected residents as best as possible. Due to the nature of the likely causes, it was difficult to predict the magnitude of the event before it occurred and therefore FRMAs were forced to react to flooding with little to no warning.

On the River Rom, the Environment Agency flood alert and warning was issued after the onset of flooding. Timelier flood alerts and warnings would have allowed residents to implement property level and small scale protection measures in advance of flooding, thereby reducing flood damages. Flood alert and warning trigger levels are now being improved.

In accordance with the Flood and Water Management Act, the London Borough of Havering is the Lead Local Flood Authority within the Borough. Section 19 of the Act includes regulations relating to flood investigations within an LLFA's jurisdiction. LBH have adhered to these regulations by:

- Maintaining a register of properties flooded during the June 2016 floods;
- Investigating the actions of FRMAs during the June 2016 flood event; and
- Devising a list of recommended actions for FRMAs to ensure a more effective response is achieved if a similar event should occur in the future.

5.2 Recommended actions

Table 5-1 indicates future actions recommended for the management of the June 2016 flood event. A response timescale is also included, giving a priority to the actions.

This report should be circulated by LBH to the FRMAs identified in Table 5-1. These authorities should ensure they fully understand the actions suggested within this report as well as their own responsibilities to managing flood risk within the Borough. If no response is received from the FRMAs identified in Table 5-1, the LLFA should follow up with the FRMA directly. It should be noted that where a response from a FRMA has not been received, it has not been possible to fully analyse their response to the flood event.

Table 5-1 : Recommended actions for responsible FRMAs

Responsible FRMA	Recommended action(s)	Required response timescale
Environment Agency	Review flood alert and warning threshold levels.	Ongoing
Environment Agency	Review flood prediction modelling from fluvial and pluvial sources.	Ongoing
Environment Agency and LBH	Develop systematic maintenance regime of watercourses and assets within the area.	Ongoing
Thames Water	Provide information on response to flood event to LBH.	February 2017
Environment Agency and LBH	Investigate opportunities to provide storage at the Cross Roads decommissioned FSA.	Summer 2017
LBH	Investigate opportunities for land management and flow management in the upper reaches of each catchment	Summer 2017
LBH	Investigate scope to supply airbrick covers to properties at risk (particularly those with thresholds at a level lower than road level).	Summer 2017
LBH	Investigate scope to increase bridge clearance / culvert capacity at locations where overtopping occurred due to capacity exceedance.	Summer 2017
LBH	Investigate scope to increase surface water sewer capacity in the locations affected by flooding.	Summer 2017

Appendix A. Surface water flood incident map

Figure B-1 indicates the locations flooded during the June 2016 event and highlights those investigated in greater detail throughout this report. These locations were prioritised for investigation as a result of internal or sewer flooding of properties. Locations have also been included if flooding to local roads had a negative effect on the rest of the road network throughout the Borough.

N

River Rom
Blacks Brook
Emerson Park Stream
River Ravensbourne
Weald Brook
Paines Brook
River Mardyke
River Ingrebourne
River Beam
Havering New Sewer
Rainham Creek
Rainham Main Sewer

ROMFORD
HORNCHURCH
UPMINSTER
DAGENHAM
RAINHAM
BRENTWOOD

Key

- Investigated Flood Locations
- Borough Boundary
- Main Rivers
- Other Reported June 2016 Flood Locations

Drain London Historic Flooding

- Multiple Sources
- Ordinary Watercourse Flooding
- Sewer Flooding
- Unknown Source

Fluvial Flood Extents

- 1992
- 2000
- 2003
- 2007
- 1707
- 1953
- 1968
- 1974

Havering LONDON BOROUGH

JACOBS

TITLE

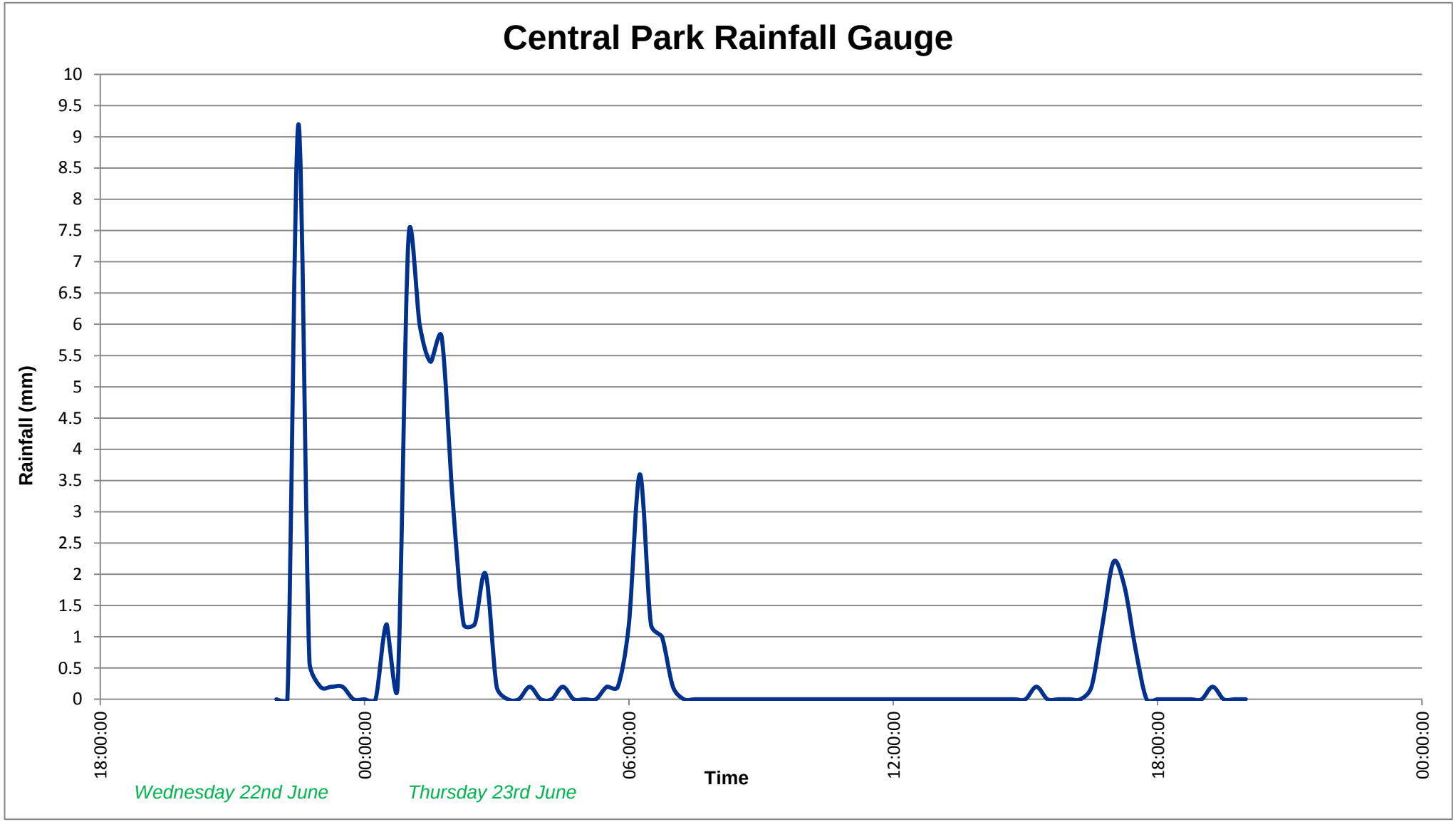
Section 19 Flood Investigations Flood Incident Map

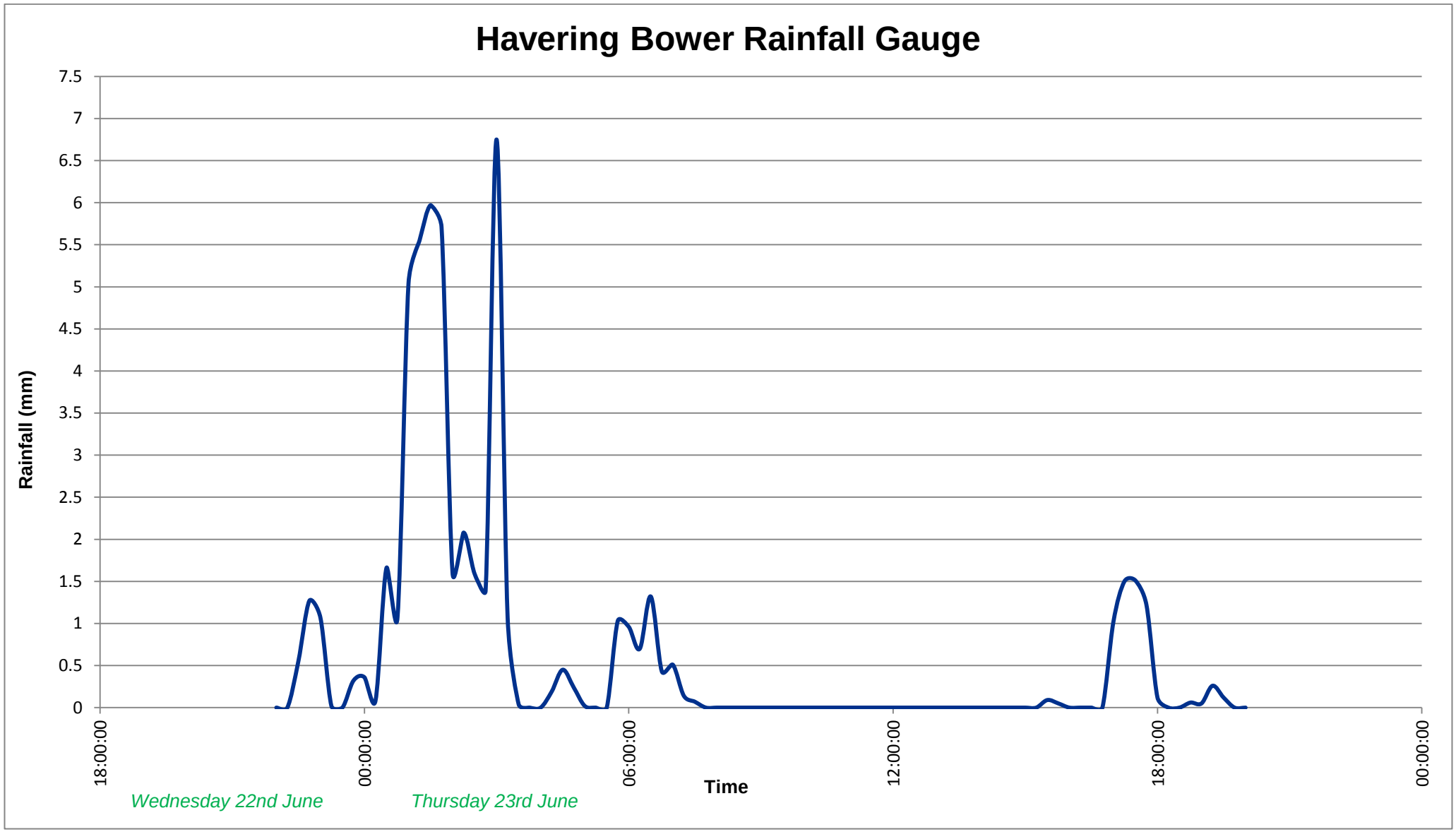
DRG No	
B08600D2-O-B-1	
Not to Scale (SCALE)	20/01/2017 (DATE)

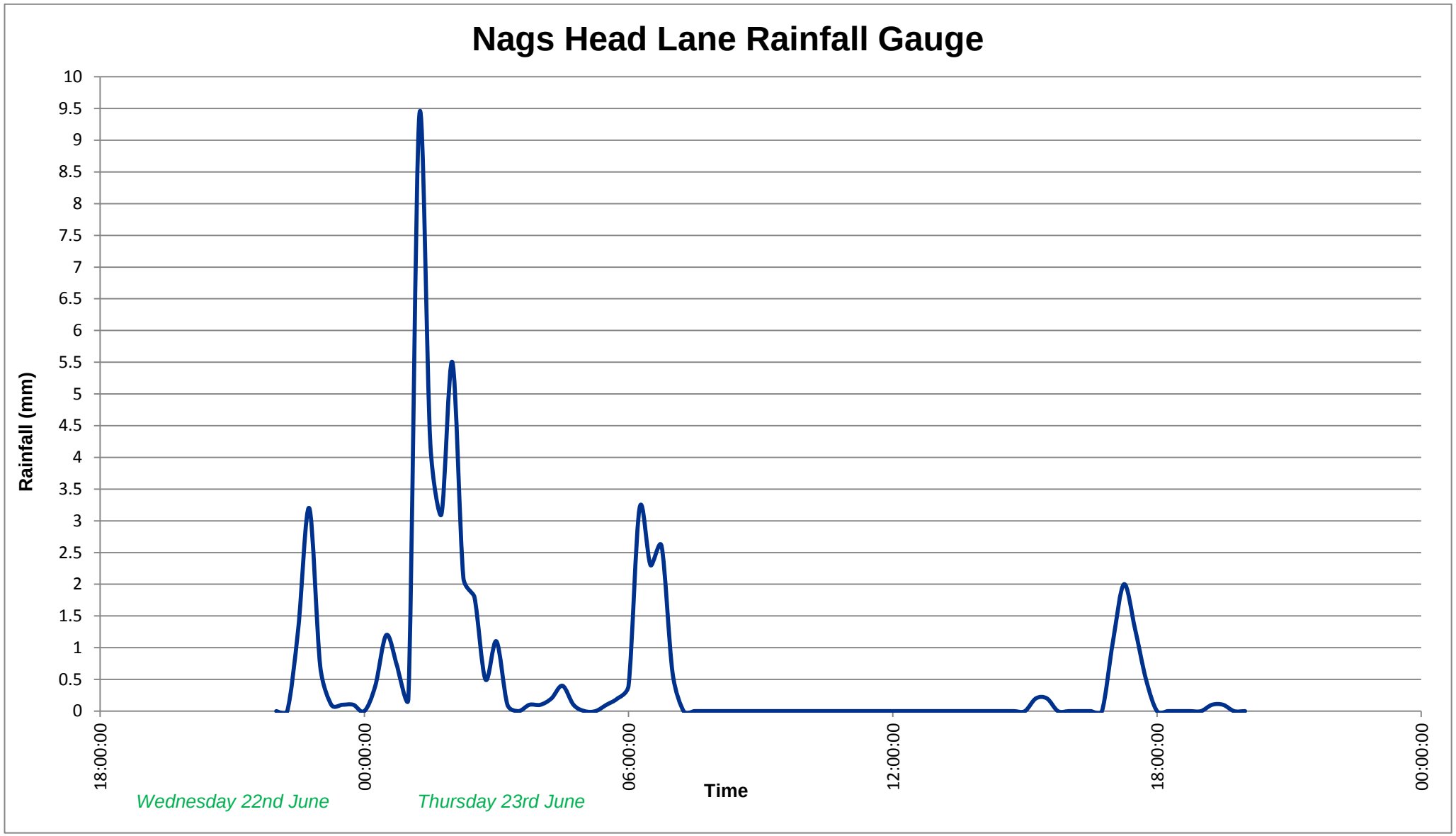
DRN	CHKD	REVD	APRV'D
MA	DS	AK	RC

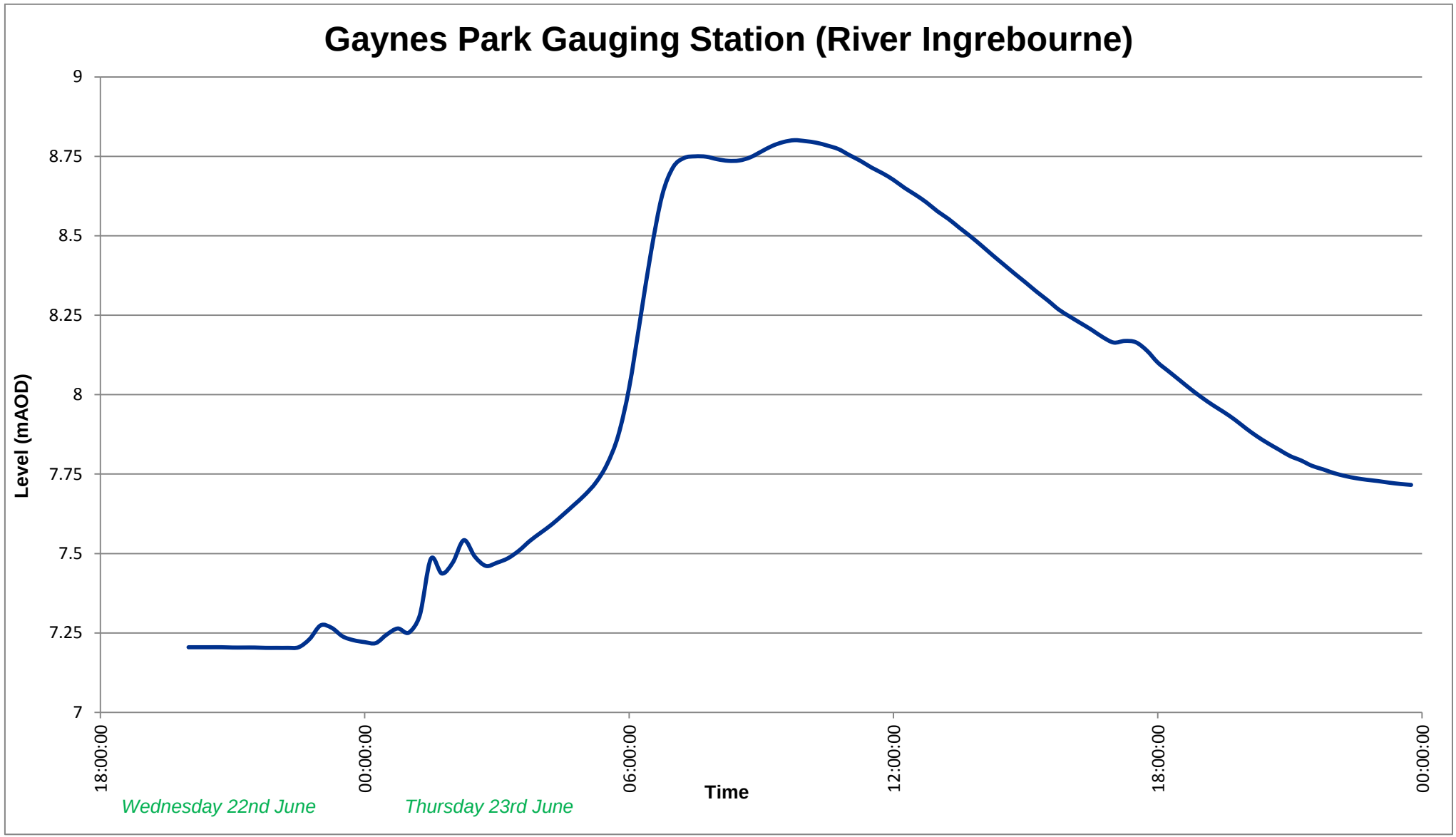
Appendix B. Environment Agency rainfall and gauge station data

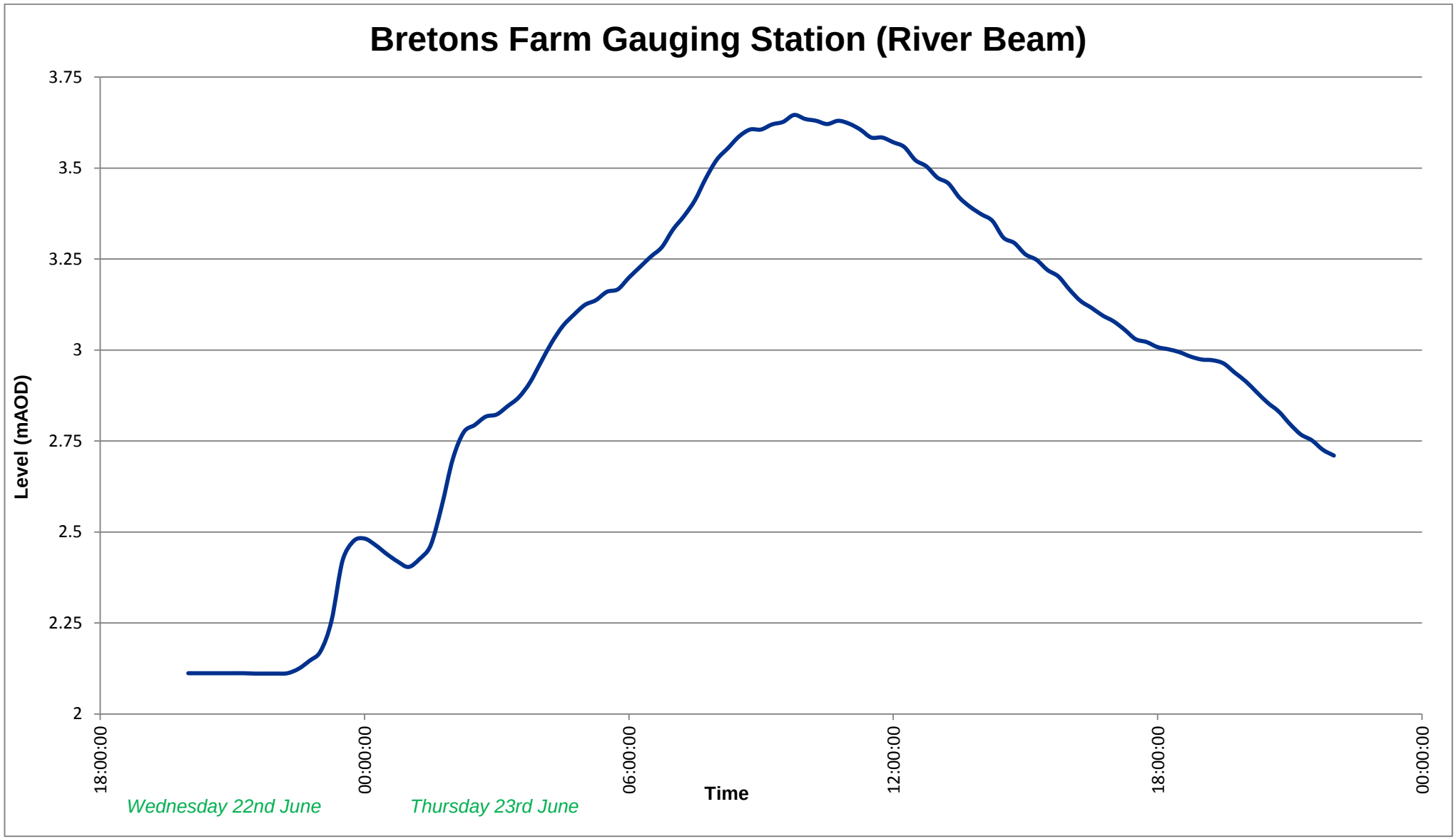
The information presented in the graphs in this appendix was received from the Environment Agency in September 2016.


Central Park Rainfall Gauge
Rainfall (mm)
10
9.5
9
8.5
8
7.5
7
6.5
6
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
18:00:00
00:00:00
06:00:00
12:00:00
18:00:00
00:00:00
Time
Wednesday 22nd June
Thursday 23rd June


Havering Bower Rainfall Gauge
Rainfall (mm)
7.5
7
6.5
6
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
18:00:00
00:00:00
06:00:00
12:00:00
18:00:00
00:00:00
Time
Wednesday 22nd June
Thursday 23rd June


Nags Head Lane Rainfall Gauge
Rainfall (mm)
10
9.5
9
8.5
8
7.5
7
6.5
6
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
18:00:00
00:00:00
06:00:00
12:00:00
18:00:00
00:00:00
Time
Wednesday 22nd June
Thursday 23rd June

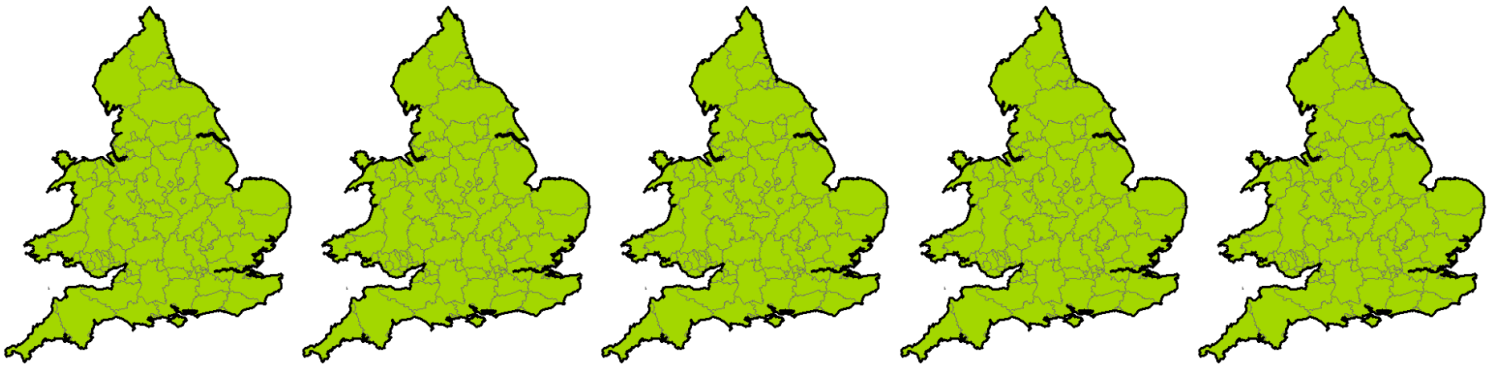

Gaynes Park Gauging Station (River Ingrebourne)
Level (mAOD)
9
8.75
8.5
8.25
8
7.75
7.5
7.25
7
18:00:00
00:00:00
06:00:00
12:00:00
18:00:00
00:00:00
Time
Wednesday 22nd June
Thursday 23rd June


Bretons Farm Gauging Station (River Beam)
Level (mAOD)
3.75
3.5
3.25
3
2.75
2.5
2.25
2
18:00:00
00:00:00
06:00:00
12:00:00
18:00:00
00:00:00
Time
Wednesday 22nd June
Thursday 23rd June

Appendix C. Flood Guidance Statements

Flood Guidance Statement 10:30hrs Monday 20 June 2016

Our assessment of daily flood risk for England and Wales, working with flood forecasting teams in the Environment Agency and Natural Resources Wales, is below.



10:30 - 23:59hrs

Monday	Tuesday	Wednesday	Thursday	Friday
20 June 2016	21 June 2016	22 June 2016	23 June 2016	24 June 2016

General overview of flood risk

The overall flood risk is currently VERY LOW for the next five days, but heavy rainfall is possible in south-east England later in the week. The flood risk may be increased if confidence increases in flooding impacts.

Assessment of flood risk

Surface water

The surface water flood risk is VERY LOW for all counties throughout the next five days.

Isolated heavy showers are possible across central and eastern parts of England this afternoon, bringing a very low likelihood of minor surface water flooding impacts to counties there. Impacts such as localised flooding of land and roads and disruption to travel are possible but the surface water flood risk remains VERY LOW.

Some heavy downpours are possible on Wednesday night and during Thursday, most likely across south-east England, with further heavy showers possible across any parts of England and Wales on Friday. Surface water flooding is possible but given the large uncertainty in the forecast details at this stage the surface water flood risk remains VERY LOW.

Rivers

The river flood risk is VERY LOW for all counties throughout the next five days.

Rivers are expected to cope with rain from last night and showers and rain today.

Some heavy downpours are possible on Wednesday night and during Thursday, most likely across south-east England, with further heavy showers possible across England and Wales on Friday. These may cause some river response, especially in small, rapidly responding and urban catchments but forecast details are very uncertain so the river flood risk remains VERY LOW.

Coastal / tidal

The coastal flood risk is VERY LOW for the next five days.

Groundwater

The groundwater flood risk is VERY LOW for the next five days.

Warnings and Alerts in force in England and Wales at 10:30hrs

Flood (click here)	
Severe Flood Warnings	0
Flood Warnings	0
Flood Alerts	3

Severe Weather (click here)	
Warnings	No
Alerts	No

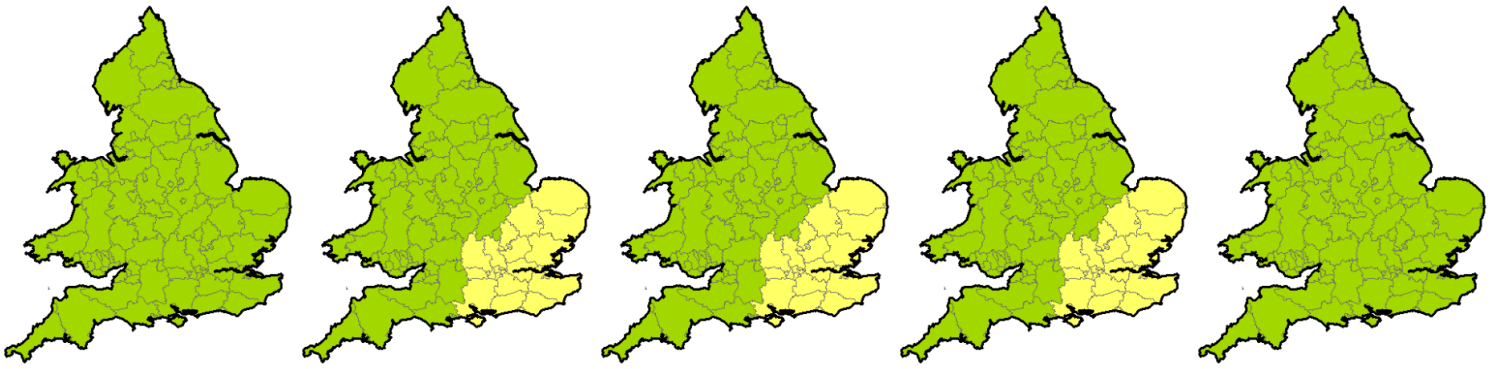
Next statement due: 10:30hrs Tuesday 21 June 2016 (all times are local)

Contact details: Flood Forecasting Centre Duty Hydrometeorologist: 0300 12345 01

Website: www.ffc-environment-agency.metoffice.gov.uk

Flood Guidance Statement 10:30hrs Tuesday 21 June 2016

Our assessment of daily flood risk for England and Wales, working with flood forecasting teams in the Environment Agency and Natural Resources Wales, is below.



10:30 - 23:59hrs

Tuesday	Wednesday	Thursday	Friday	Saturday
21 June 2016	22 June 2016	23 June 2016	24 June 2016	25 June 2016

There is a LOW flood risk from late on Wednesday until Friday morning.

General overview of flood risk

The potential for heavy, thundery downpours across the south-east of England from Wednesday night, through Thursday and into the early part of Friday gives a very low likelihood of significant impacts from surface water and river flooding. Further scattered thunderstorms are likely elsewhere on Friday and Saturday.

Assessment of flood risk

Surface water

Heavy, thundery downpours are possible on Wednesday night and throughout Thursday into Friday morning, most likely across south-east England. This gives a very low likelihood of significant surface water flooding impacts and a LOW overall flood risk, particularly if thunderstorms fall over urban areas. Impacts, if realised, could include flooding affecting properties and parts of communities, disruption to key sites identified within flood plans and travel with a number of road closures possible.

On Friday and Saturday, further but more scattered thunderstorms are possible elsewhere across England and Wales, bringing a low likelihood of minor surface water flooding impacts to any one location, and a VERY LOW flood risk overall.

Elsewhere, and at other times, the surface water flood risk remains VERY LOW.

Rivers

Heavy, thundery downpours are possible on Wednesday night and through Thursday, most likely across south-east England. This gives a very low likelihood of significant river flooding impacts and a LOW overall flood risk, particularly if thunderstorms fall over fast responding, urban catchments. Impacts, if realised, could include flooding affecting properties and parts of communities, disruption to key sites identified within flood plans and travel with a number of road closures possible. Any river response is likely to continue into the early part of Friday.

Later on Friday and on Saturday, further but more scattered thunderstorms are possible elsewhere across England and Wales, bringing a very low likelihood of minor river flooding impacts to any one location, and a VERY LOW flood risk overall.

Elsewhere, and at other times, the river flood risk remains VERY LOW.

Coastal / tidal

The coastal flood risk is VERY LOW for the next five days.

Groundwater

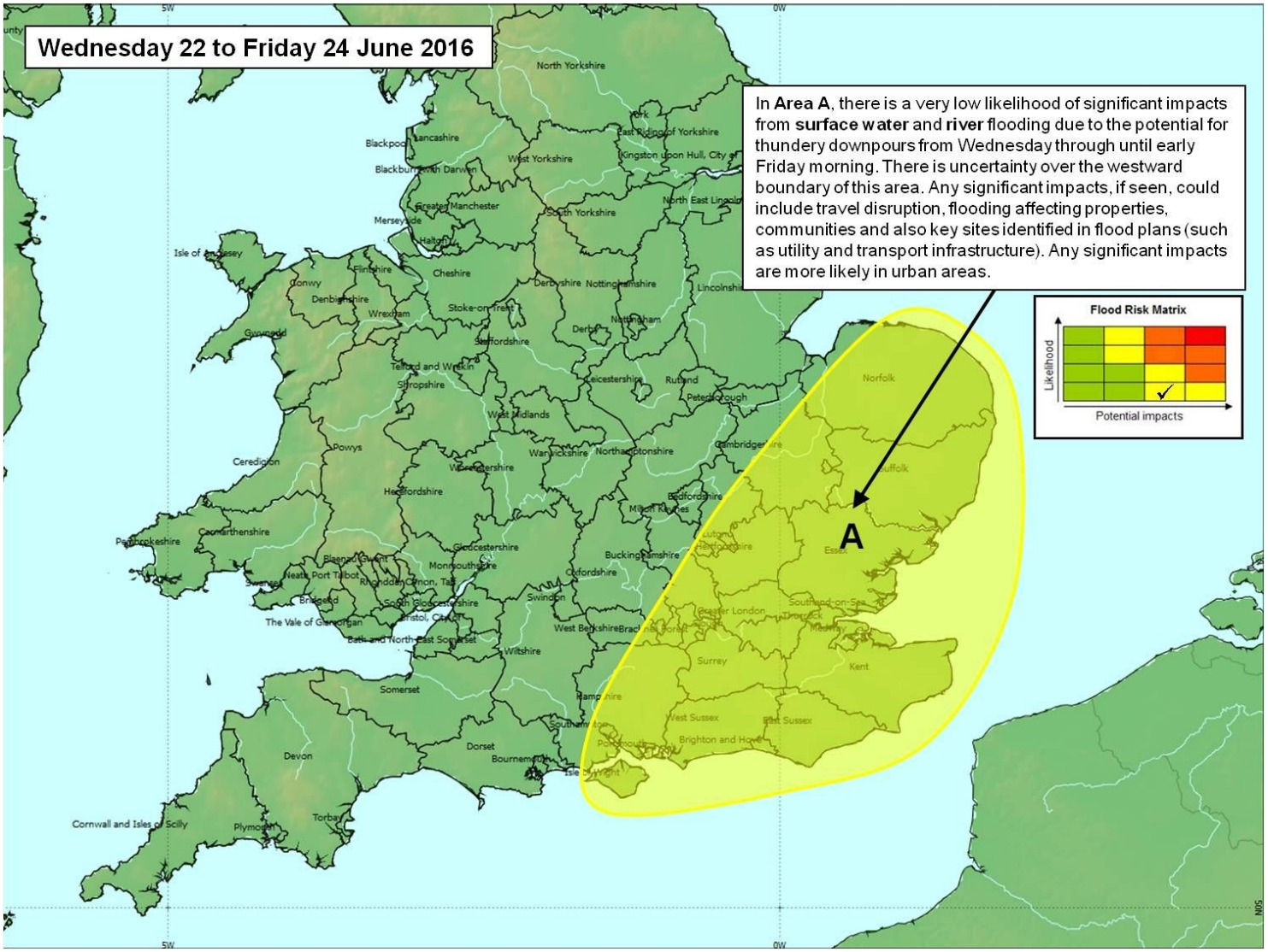
The groundwater flood risk is VERY LOW for the next five days.

Warnings and Alerts in force in England and Wales at 10:30hrs

Flood (click here)	
Severe Flood Warnings	0
Flood Warnings	0
Flood Alerts	5

Severe Weather (click here)	
Warnings	No
Alerts	No

Specific areas of concern

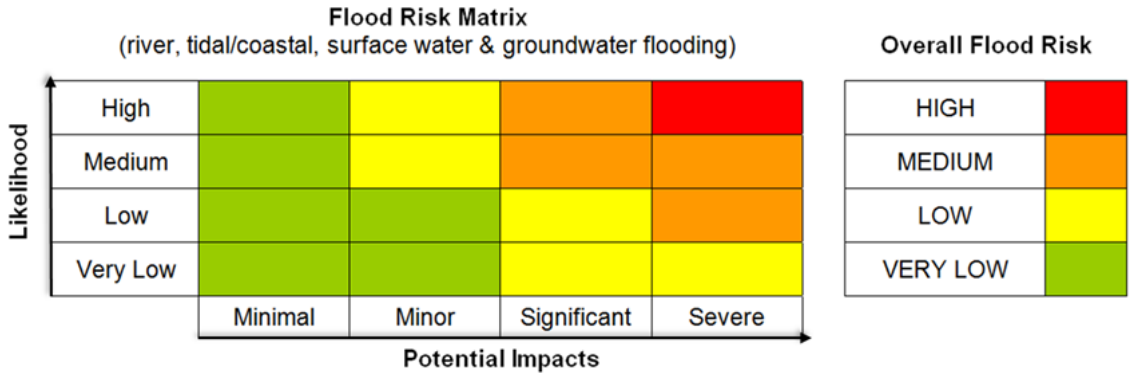


Next statement due: 10:30hrs Wednesday 22 June 2016 (all times are local)

Contact details: Flood Forecasting Centre Duty Hydrometeorologist: 0300 12345 01

Website: www.ffc-environment-agency.metoffice.gov.uk

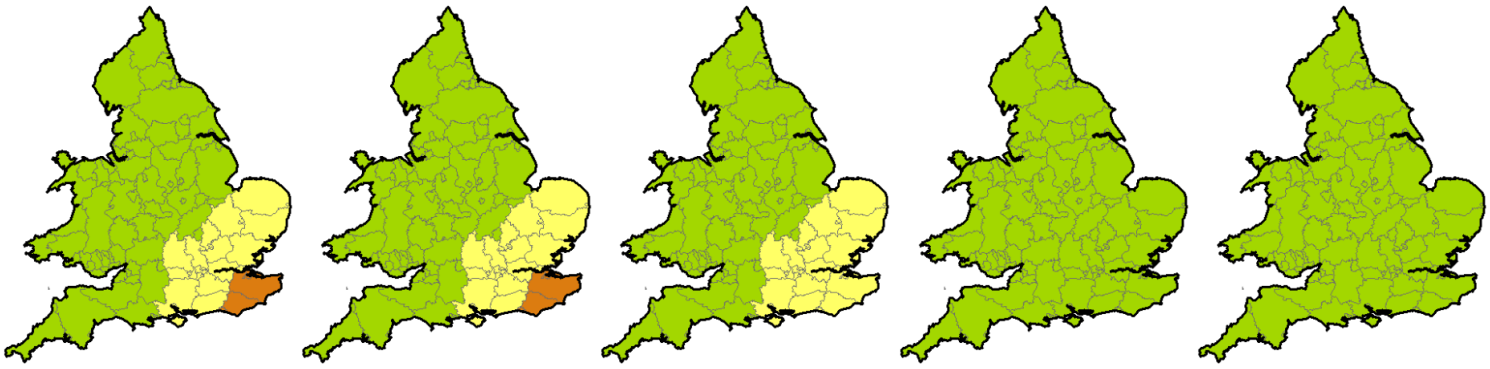
This guidance is produced to support decision making by Category 1 and 2 emergency responders.



Click here for the Flood Guidance Statement User Guide.

Flood Guidance Statement 10:30hrs Wednesday 22 June 2016

Our assessment of daily flood risk for England and Wales, working with flood forecasting teams in the Environment Agency and Natural Resources Wales, is below.



10:30 - 23:59hrs

Wednesday	**Thursday**	**Friday**	**Saturday**	**Sunday**
22 June 2016	23 June 2016	24 June 2016	25 June 2016	26 June 2016

There is a MEDIUM flood risk from Wednesday evening until early Thursday morning for surface water flooding in the far south-east of England.

General overview of flood risk

Torrential, thundery downpours are likely to affect some parts of south-east England at times from Wednesday night, and on Thursday and into the early part of Friday. This brings a medium likelihood of significant surface water flooding impacts in the far south-east of England from Wednesday evening into Thursday morning. There is also a low likelihood of significant surface water flooding impacts in any one county elsewhere across the south-east of England until Friday.

Assessment of flood risk

Surface water

Torrential, thundery downpours are likely to affect parts of the south-east of England at times from Wednesday evening until early Friday. On Wednesday evening through to Thursday morning, there is a medium likelihood of significant impacts from surface water flooding and an overall MEDIUM flood risk in the Area marked B in the AOC map, particularly if thunderstorms fall over urban areas. There is also a low likelihood of significant surface water flooding impacts in any one county, and a LOW overall flood risk in the Area marked A in the AOC map, particularly if thunderstorms fall over urban areas. Impacts could include flooding affecting properties and parts of communities, disruption to key sites identified within flood plans and travel with a number of road closures possible.

On Friday and Saturday, further but more scattered thunderstorms are possible elsewhere across England and Wales, bringing a low likelihood of minor surface water flooding impacts to any one location, and a VERY LOW flood risk overall.

Elsewhere, and at other times, the surface water flood risk remains VERY LOW.

Rivers

Torrential, thundery downpours are likely to affect parts of the south-east of England at times from Wednesday evening until early Friday. This gives a low likelihood of significant river flooding impacts and a LOW overall flood risk, if thunderstorms fall over fast responding, urban catchments. Impacts could include flooding affecting properties and parts of communities, disruption to key sites identified within flood plans and travel with a number of road closures possible. Any river response is likely to continue into the early part of Friday.

Later on Friday and on Saturday, further but more scattered thunderstorms are possible elsewhere across England and Wales, bringing a very low likelihood of minor river flooding impacts to any one location, and a VERY LOW flood risk overall.

Elsewhere, and at other times, the river flood risk remains VERY LOW.

Coastal / tidal

The coastal flood risk is VERY LOW for the next five days.

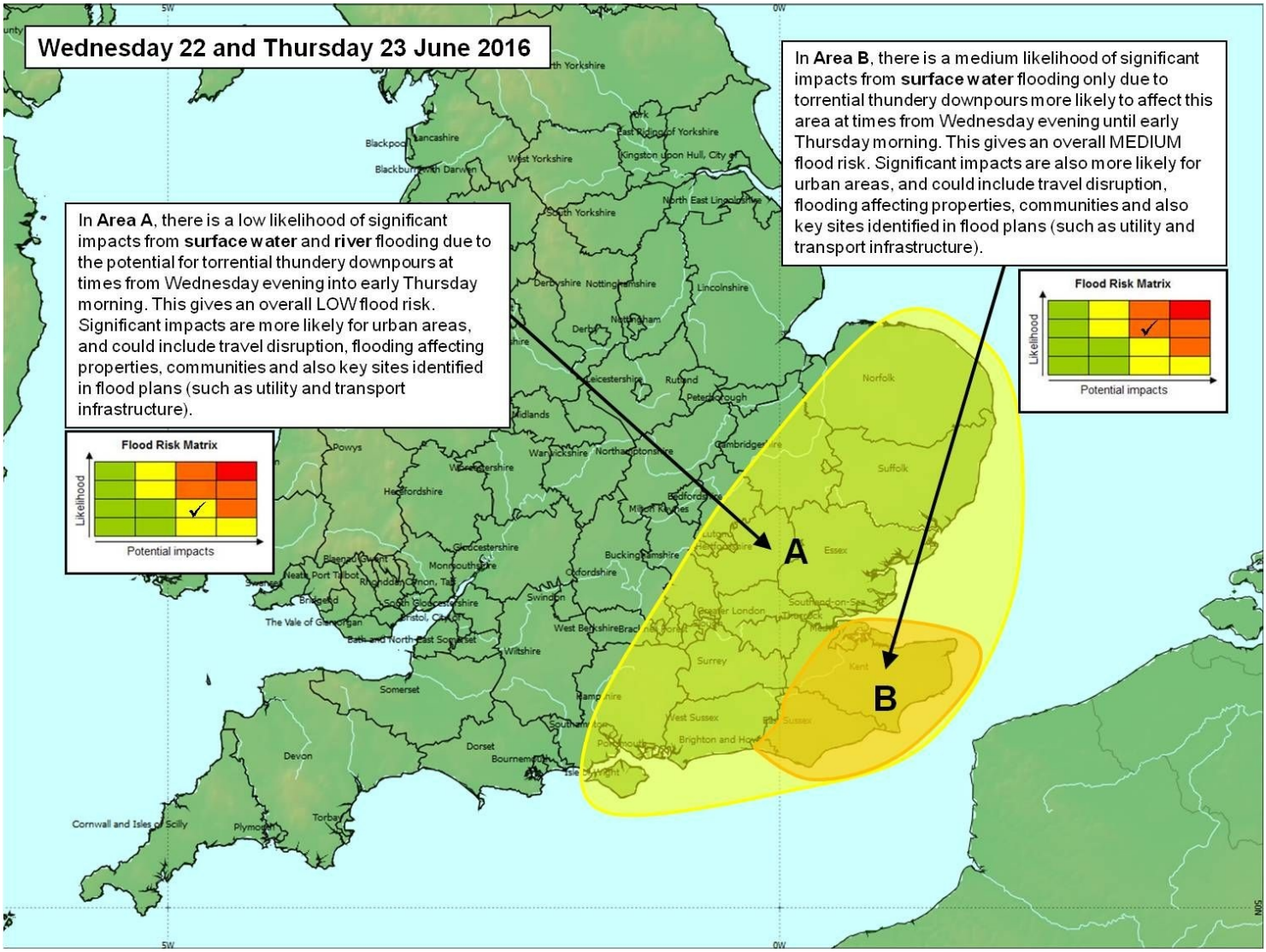
Groundwater
The groundwater flood risk is VERY LOW for the next five days.

Warnings and Alerts in force in England and Wales at 10:30hrs

Flood (click here)	
Severe Flood Warnings	0
Flood Warnings	0
Flood Alerts	3

Severe Weather (click here)	
Warnings	Yes
Alerts	Yes

Specific areas of concern

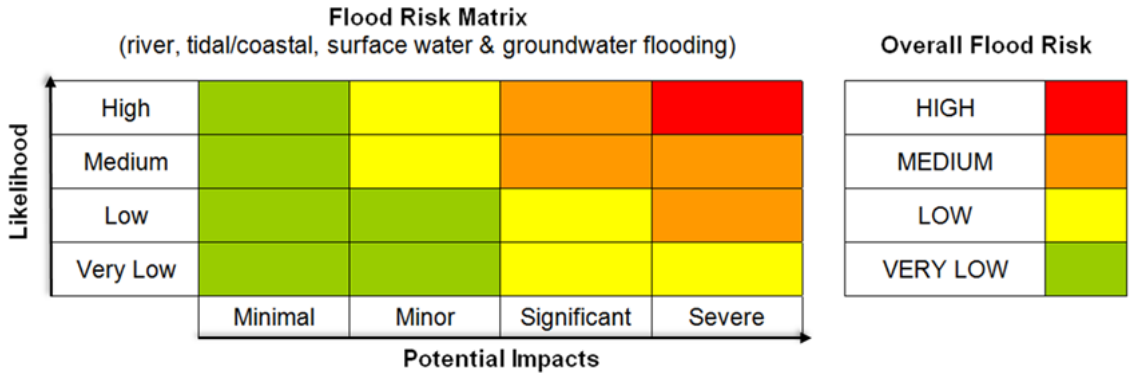


Next statement due: 10:30hrs Thursday 23 June 2016 (all times are local)

Contact details: Flood Forecasting Centre Duty Hydrometeorologist: 0300 12345 01

Website: www.ffc-environment-agency.metoffice.gov.uk

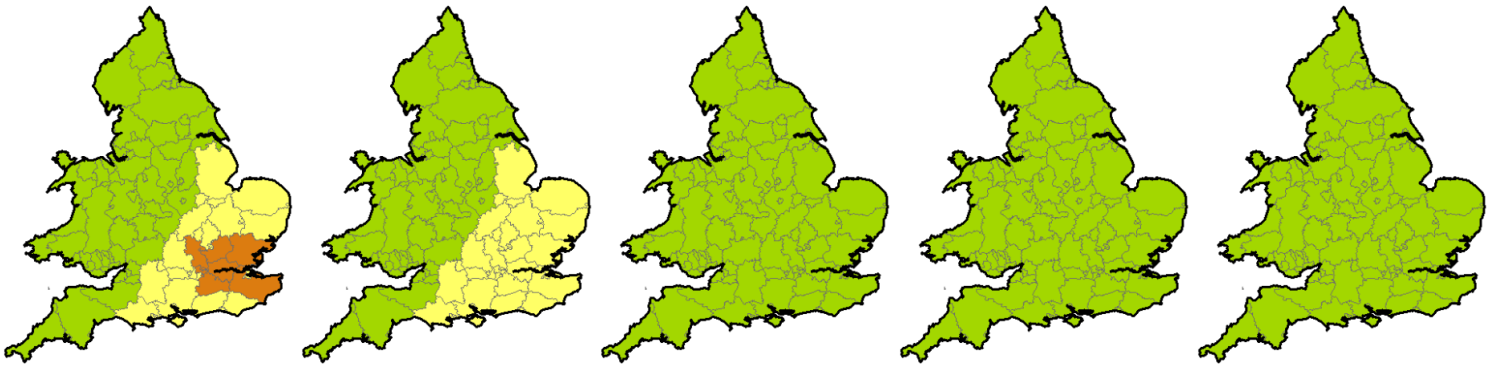
This guidance is produced to support decision making by Category 1 and 2 emergency responders.



Click here for the Flood Guidance Statement User Guide.

Flood Guidance Statement 10:30hrs Thursday 23 June 2016

Our assessment of daily flood risk for England and Wales, working with flood forecasting teams in the Environment Agency and Natural Resources Wales, is below.



10:30 - 23:59hrs				
Thursday	**Friday**	**Saturday**	**Sunday**	**Monday**
23 June 2016	24 June 2016	25 June 2016	26 June 2016	27 June 2016

There is a MEDIUM flood risk for surface water flooding today (Thursday) across parts of the south-east of England including Greater London.

General overview of flood risk

Torrential, thundery downpours may affect parts of the south-east of England including Greater London this afternoon. This brings a medium likelihood of renewed and continuing significant surface water flooding impacts, giving a MEDIUM overall flood risk here. Further rain or showers today and tomorrow across across parts of the south-east of England and the East Midlands give a low likelihood of significant impacts to these areas.

Assessment of flood risk

Surface water

Torrential, thundery downpours may affect parts of the south-east of England including Greater London this afternoon. This brings a medium likelihood of renewed and continuing significant surface water flooding. Impacts could include flooding affecting properties and parts of communities, disruption to key sites identified within flood plans and significant delays to travel, with a number of further road and rail closures possible. Across other parts of the south-east of England and the East Midlands today and tomorrow, there is a low likelihood of significant surface water impacts from scattered showers or thunderstorms.

On Saturday, scattered thunderstorms are possible elsewhere across England and Wales, bringing a low likelihood of minor surface water flooding impacts to any one location, and a VERY LOW flood risk overall.

Elsewhere, and at other times, the surface water flood risk remains VERY LOW.

Rivers

Torrential, thundery downpours may affect parts of the south-east of England including Greater London this afternoon. This gives a medium likelihood of significant river flooding, giving an MEDIUM overall flood risk, especially where any thunderstorms fall over already sensitive fast responding rivers and urban catchments. Impacts could include further flooding affecting properties and parts of communities, disruption to key sites identified within flood plans and significant travel delays. River response may continue into Friday. Across other parts of the south-east of England and the East Midlands today and tomorrow, there is a low likelihood of significant impacts from river flooding in fast responding rivers in urban catchments.

On Saturday, scattered thunderstorms are possible across England and Wales, bringing a very low likelihood of minor river flooding impacts to any one location, and a VERY LOW flood risk overall.

Elsewhere, and at other times, the river flood risk remains VERY LOW.

Coastal / tidal

The coastal flood risk is VERY LOW for the next five days.

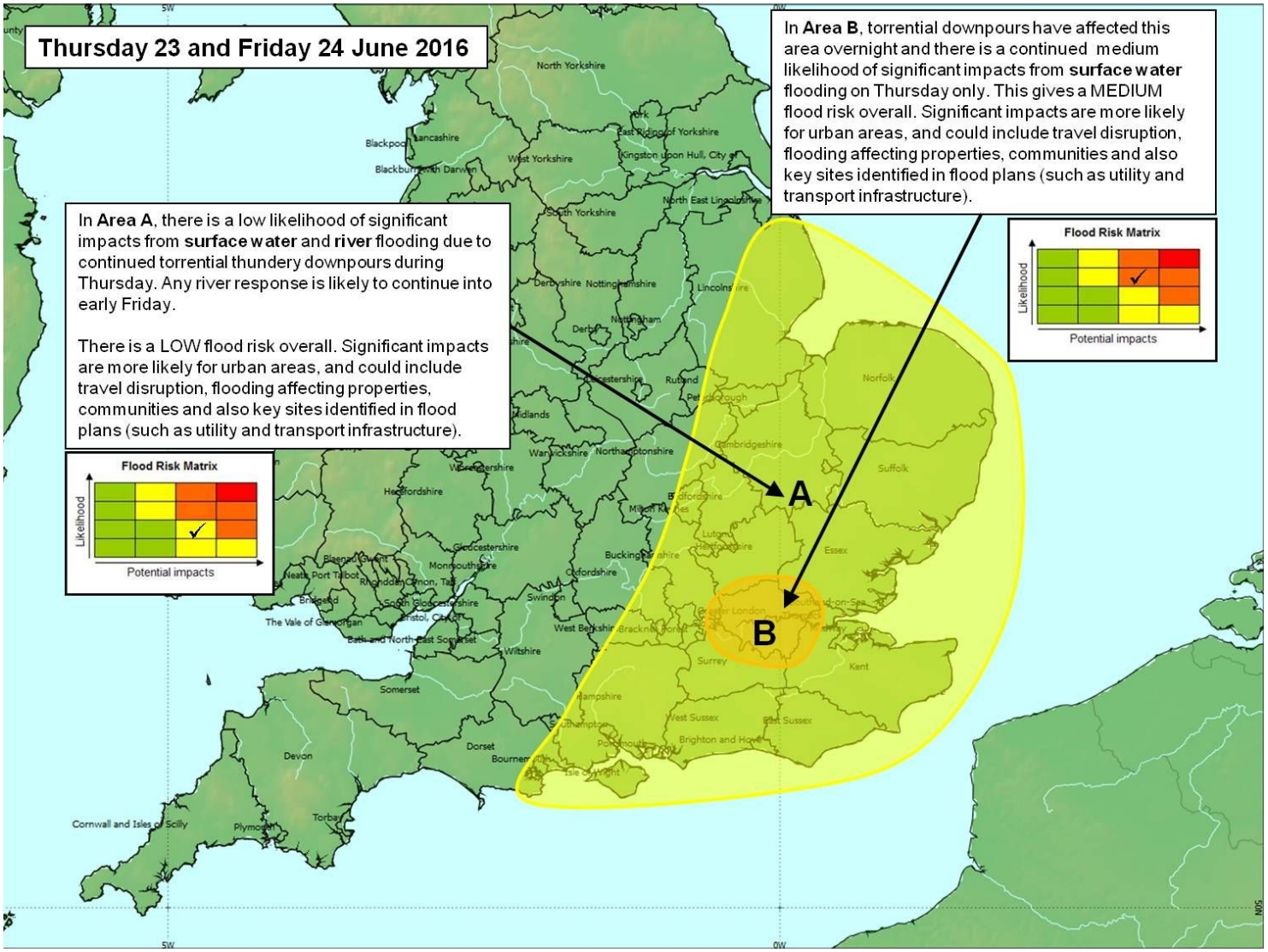
Groundwater
The groundwater flood risk is VERY LOW for the next five days.

Warnings and Alerts in force in England and Wales at 10:30hrs

Flood (click here)	
Severe Flood Warnings	0
Flood Warnings	7
Flood Alerts	39

Severe Weather (click here)	
Warnings	Yes
Alerts	Yes

Specific areas of concern

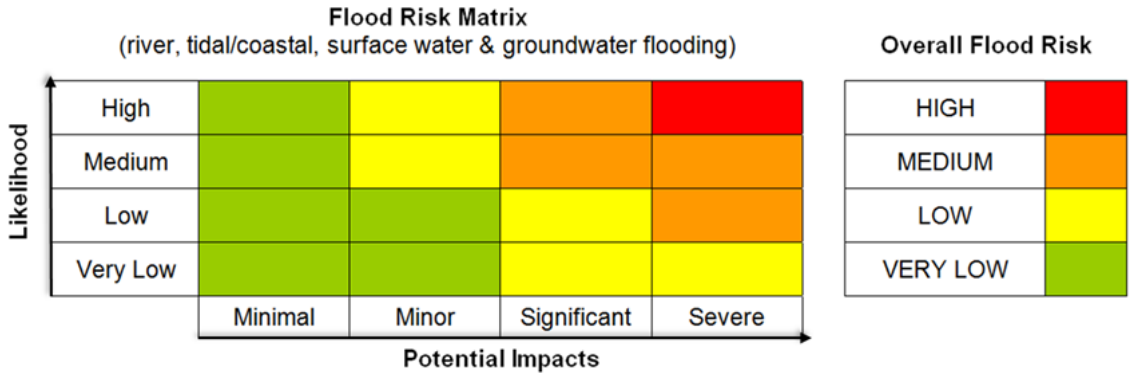


Next statement due: 10:30hrs Friday 24 June 2016 (all times are local)

Contact details: Flood Forecasting Centre Duty Hydrometeorologist: 0300 12345 01

Website: www.ffc-environment-agency.metoffice.gov.uk

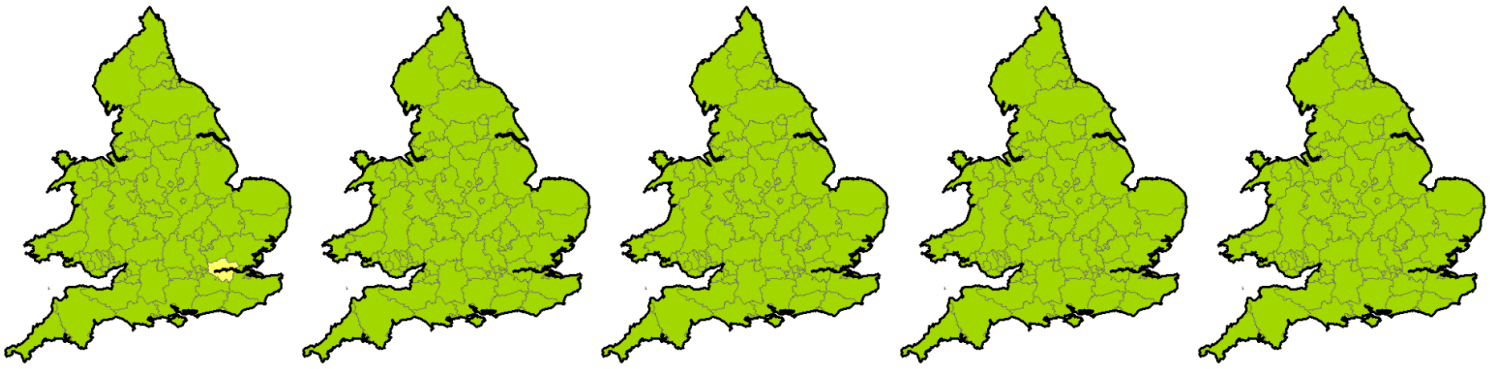
This guidance is produced to support decision making by Category 1 and 2 emergency responders.



Click here for the Flood Guidance Statement User Guide.

Flood Guidance Statement 10:30hrs Friday 24 June 2016

Our assessment of daily flood risk for England and Wales, working with flood forecasting teams in the Environment Agency and Natural Resources Wales, is below.



10:30 - 23:59hrs				
Friday	**Saturday**	**Sunday**	**Monday**	**Tuesday**
24 June 2016	25 June 2016	26 June 2016	27 June 2016	28 June 2016

Ongoing LOW river flood risk in London this morning.

General overview of flood risk

Following torrential rain yesterday, rivers remain high particularly in some parts of Greater London. Here there is a high likelihood of minor impacts through this morning, giving a LOW flood risk overall. Flooding impacts include localised property flooding and some travel disruption. However, no new flooding impacts are expected today.

Assessment of flood risk

Rivers

Rivers remain high particularly in some parts of Greater London. Here there is a high likelihood of minor impacts through this morning, giving a LOW flood risk overall. No new flooding impacts are expected today.

On Saturday, scattered thunderstorms are possible across England and Wales, bringing a very low likelihood of minor river flooding impacts to any one location, and a VERY LOW flood risk overall.

Elsewhere, and at other times, the river flood risk remains VERY LOW.

Surface water

The surface water flood risk is VERY LOW for the next five days. Heavy showers will affect parts of northern and western England today, and more widely across England and Wales on Saturday. There is a low likelihood of minor impacts arising from these showers where multiple showers affect vulnerable urban areas. Impacts could include localised flooding of land and roads or localised flooding of individual properties.

Coastal / tidal

The coastal flood risk is VERY LOW for the next five days.

Groundwater

The groundwater flood risk is VERY LOW for the next five days.

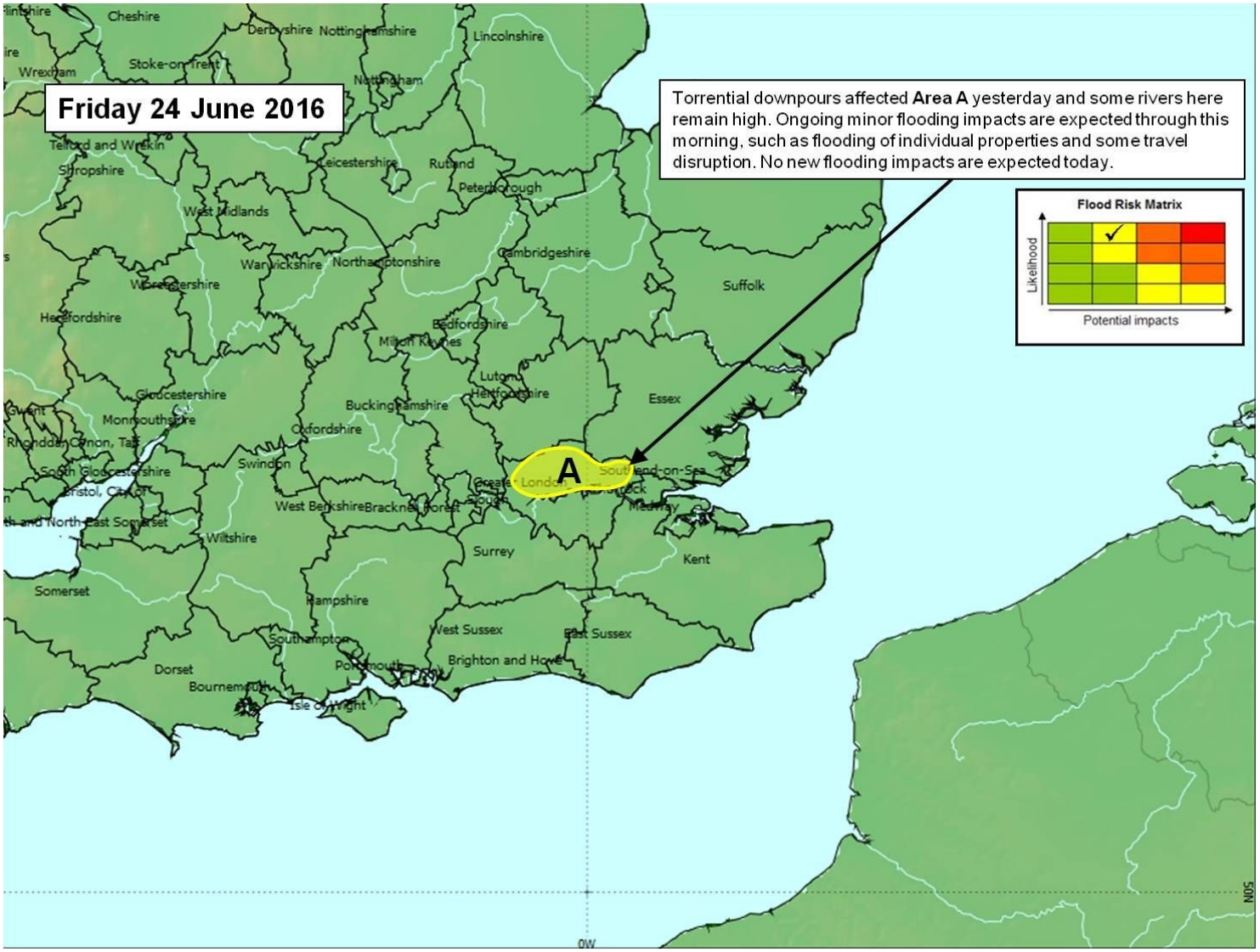
Warnings and Alerts in force in England and Wales at 10:30hrs

Flood (click here)	
Severe Flood Warnings	0
Flood Warnings	10
Flood Alerts	32

Severe Weather (click here)	
Warnings	No
Alerts	No

This guidance is produced to support decision making by Category 1 and 2 emergency responders.

Specific areas of concern



Next statement due: 10:30hrs Saturday 25 June 2016 (all times are local)

Contact details: Flood Forecasting Centre Duty Hydrometeorologist: 0300 12345 01

Website: www.ffc-environment-agency.metoffice.gov.uk

Flood Risk Matrix
(river, tidal/coastal, surface water & groundwater flooding)

Likelihood	Minimal	Minor	Significant	Severe
High				
Medium				
Low				
Very Low				

Potential Impacts

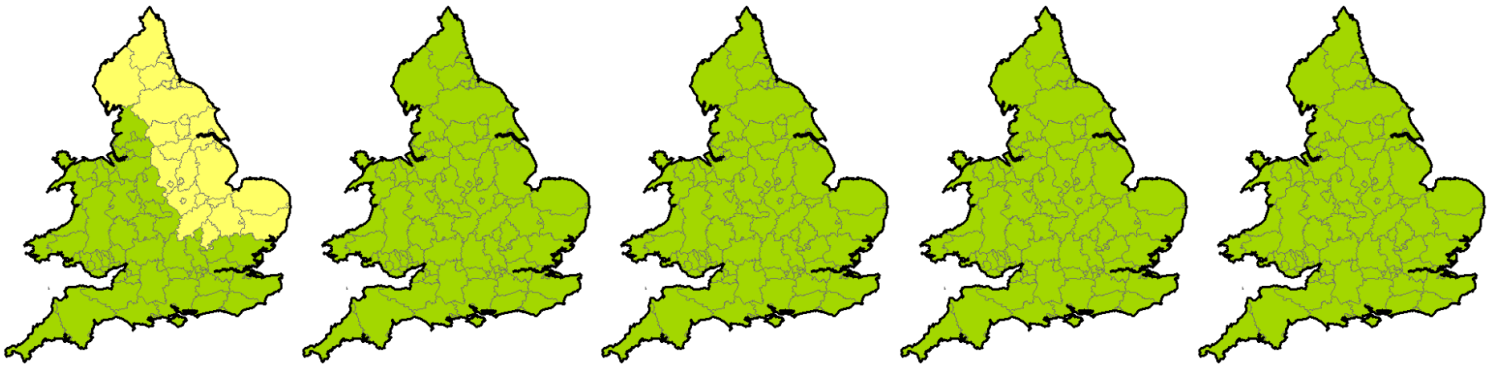
Overall Flood Risk	
HIGH	
MEDIUM	
LOW	
VERY LOW	

Click here for the Flood Guidance Statement User Guide.

This guidance is produced to support decision making by Category 1 and 2 emergency responders.

Flood Guidance Statement 10:30hrs Saturday 25 June 2016

Our assessment of daily flood risk for England and Wales, working with flood forecasting teams in the Environment Agency and Natural Resources Wales, is below.



10:30 - 23:59hrs

Saturday	Sunday	Monday	Tuesday	Wednesday
25 June 2016	26 June 2016	27 June 2016	28 June 2016	29 June 2016

LOW surface water flood risk for northern and eastern England today.

General overview of flood risk

There is a LOW surface water flood risk today for parts of northern and eastern England due to slow moving, heavy showers.

Assessment of flood risk

Surface water

The surface water flood risk is LOW today (Saturday) due to slow moving, heavy showers especially across parts of eastern and northern England. If realised, impacts could include localised flooding of land and roads or localised flooding of individual properties particularly in urban areas. Elsewhere, across much of the rest of England and eastern Wales there is a low likelihood of minor impacts resulting in a VERY LOW surface water flood risk.

Further showery rain on Tuesday and through Wednesday also brings a low likelihood of minor surface water flooding impacts in parts of Wales and the west of England.

Rivers

Some rivers remain high in parts of the south-east of England and heavy showers and thunderstorms today bring a low likelihood of minor river flooding impacts. Across much of the rest of England and eastern Wales there is a very low likelihood of minor river impacts in fast responding and urban river catchments, particularly in northern and eastern England. This brings a VERY LOW river flood risk to any one location.

Coastal / tidal

The coastal flood risk is VERY LOW for the next five days.

Groundwater

The groundwater flood risk is VERY LOW for the next five days.

Warnings and Alerts in force in England and Wales at 10:30hrs

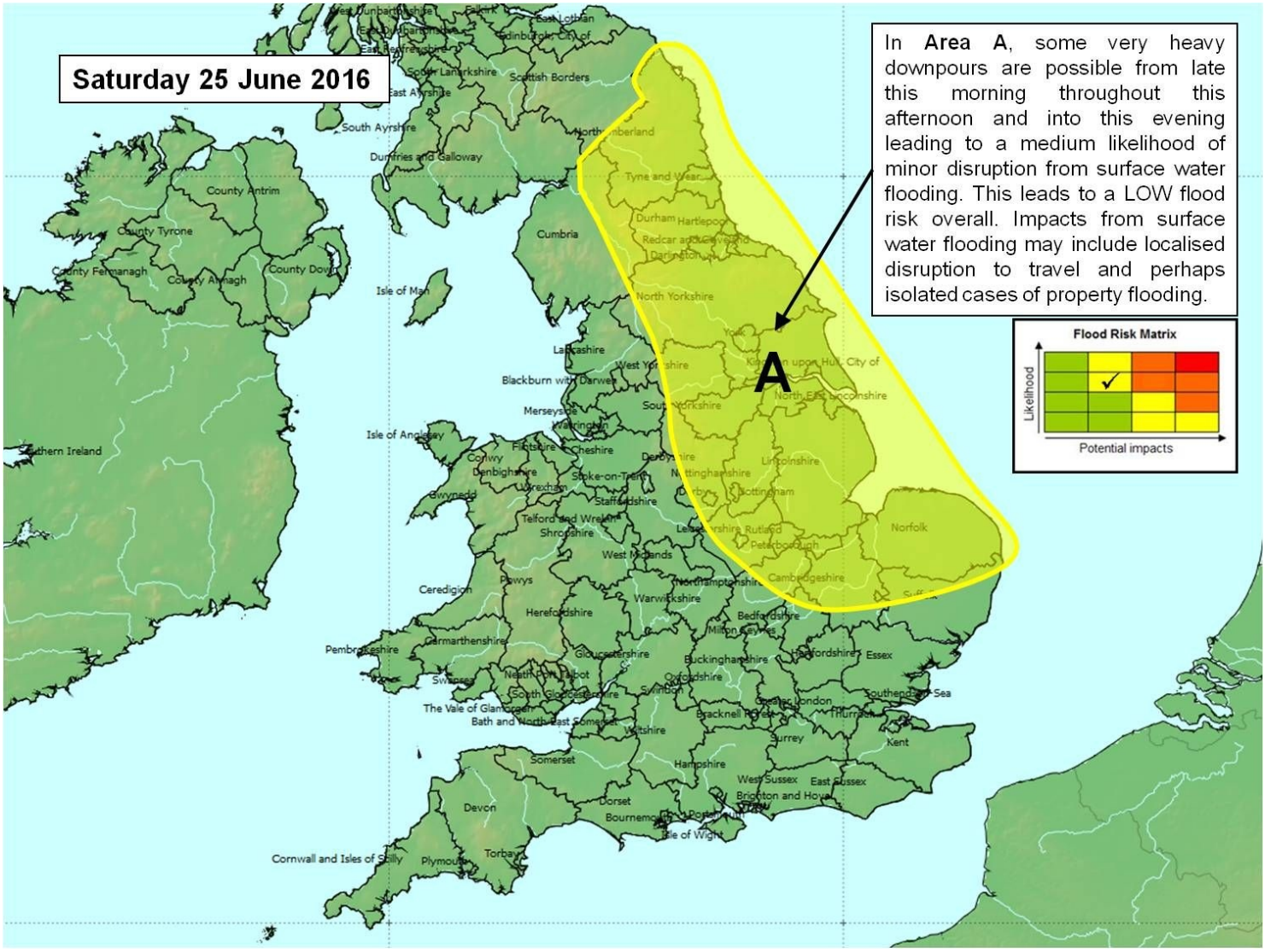
Flood (click here)	
Severe Flood Warnings	0
Flood Warnings	1
Flood Alerts	27

Severe Weather (click here)	
Warnings	Yes
Alerts	No

Specific areas of concern are on the following page

This guidance is produced to support decision making by Category 1 and 2 emergency responders.

Specific areas of concern



Next statement due: 10:30hrs Sunday 26 June 2016 (all times are local)

Contact details: Flood Forecasting Centre Duty Hydrometeorologist: 0300 12345 01

Website: www.ffc-environment-agency.metoffice.gov.uk

Flood Risk Matrix
(river, tidal/coastal, surface water & groundwater flooding)

Likelihood	Minimal	Minor	Significant	Severe
High				
Medium				
Low				
Very Low				

Potential Impacts

Overall Flood Risk

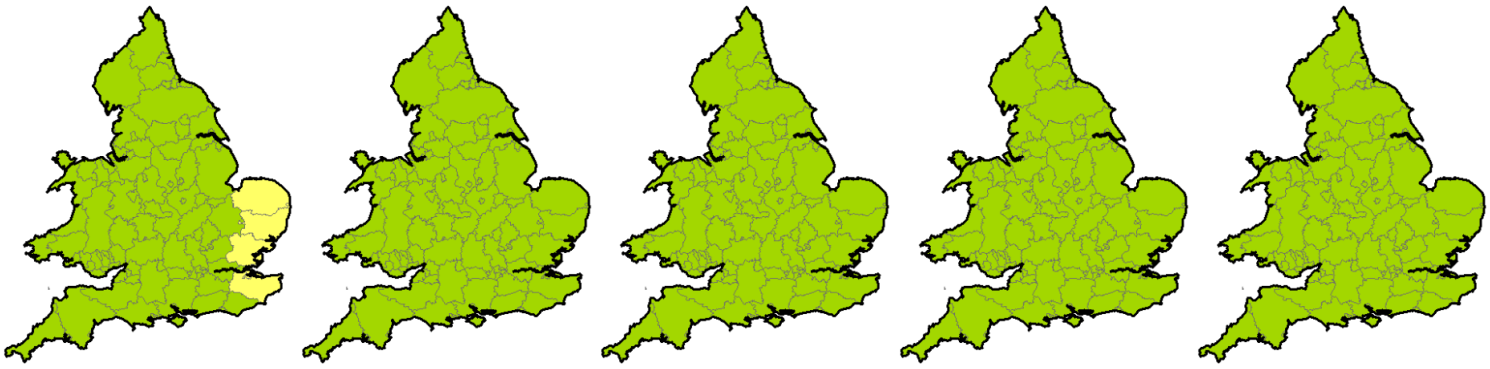
HIGH
MEDIUM
LOW
VERY LOW

Click here for the Flood Guidance Statement User Guide.

This guidance is produced to support decision making by Category 1 and 2 emergency responders.

Flood Guidance Statement 10:30hrs Sunday 26 June 2016

Our assessment of daily flood risk for England and Wales, working with flood forecasting teams in the Environment Agency and Natural Resources Wales, is below.



10:30 - 23:59hrs				
Sunday	**Monday**	**Tuesday**	**Wednesday**	**Thursday**
26 June 2016	27 June 2016	28 June 2016	29 June 2016	30 June 2016

LOW surface water flood risk for the far south-east of England today (Sunday) with minor impacts possible.

General overview of flood risk

There is a medium likelihood of localised minor impacts from surface water flooding due to isolated heavy showers in the far south-east of England for the rest of this morning and afternoon.

Rain on Tuesday and Wednesday may be heavy and showery, particularly in parts of Wales and the west of England, giving a low likelihood of minor impacts.

Assessment of flood risk

Surface water

Further isolated heavy showers are likely for a time this morning and afternoon across the far south-east of England. This gives a medium likelihood of minor surface water flood impacts and a LOW flood risk overall. Impacts, could include localised disruption to travel and perhaps isolated cases of property flooding.

Elsewhere and at other times, the surface water flood risk remains VERY LOW. Rain on Tuesday and on Wednesday brings a low likelihood of minor surface water flooding impacts, mainly in parts of Wales and the west of England.

Rivers

The river flood risk is VERY LOW for the next five days. Some rivers remain high in parts of the south-east of England from heavy showers and thunderstorms over the past week, but are now falling.

Coastal / tidal

The coastal flood risk is VERY LOW for the next five days.

Groundwater

The groundwater flood risk is VERY LOW for the next five days.

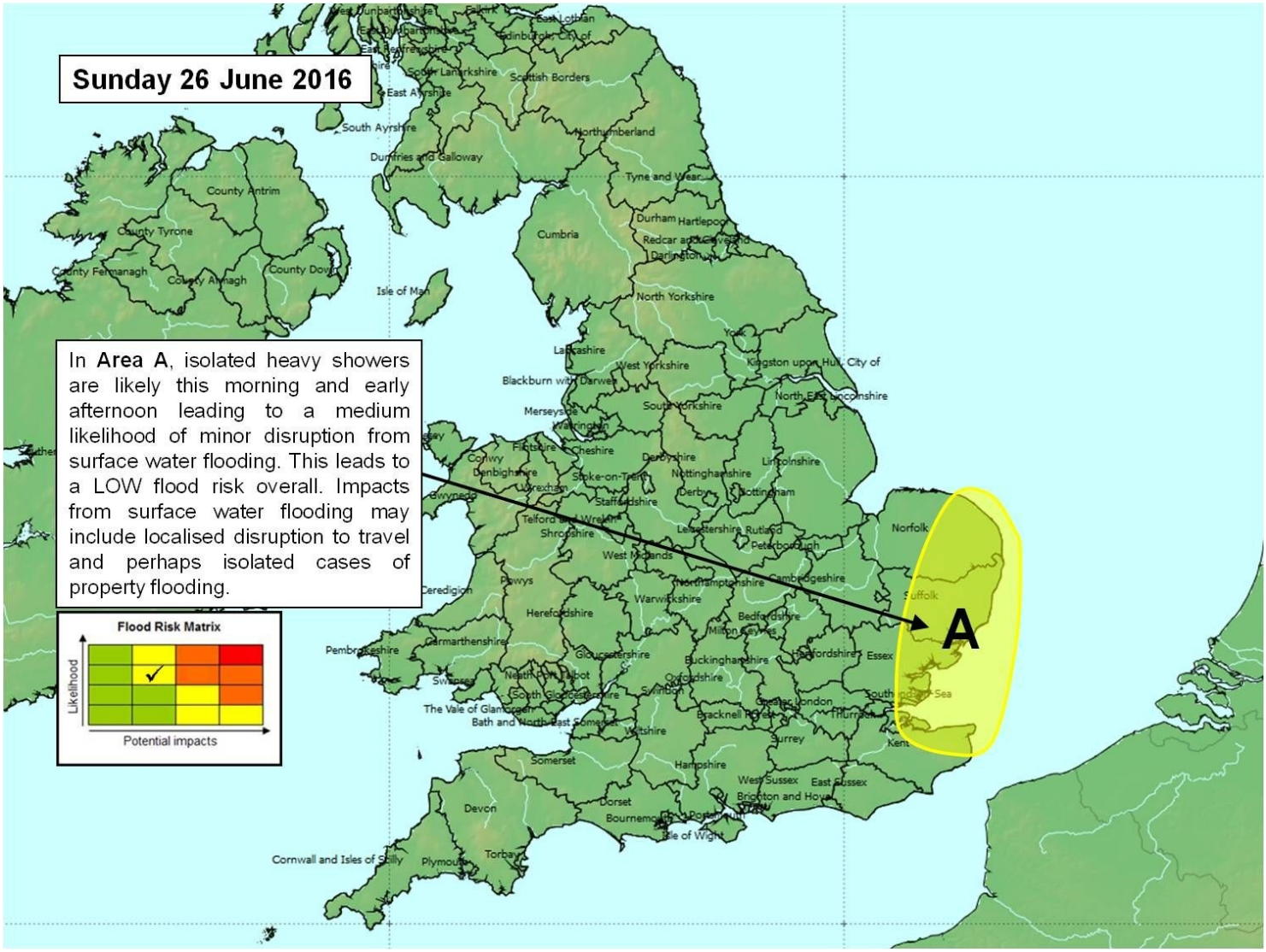
Warnings and Alerts in force in England and Wales at 10:30hrs

Flood (click here)	
Severe Flood Warnings	0
Flood Warnings	1
Flood Alerts	21

Severe Weather (click here)	
Warnings	No
Alerts	No

This guidance is produced to support decision making by Category 1 and 2 emergency responders.

Specific areas of concern



Next statement due: 10:30hrs Monday 27 June 2016 (all times are local)

Contact details: Flood Forecasting Centre Duty Hydrometeorologist: 0300 12345 01

Website: www.ffc-environment-agency.metoffice.gov.uk

Flood Risk Matrix
(river, tidal/coastal, surface water & groundwater flooding)

Likelihood	Minimal	Minor	Significant	Severe
High				
Medium				
Low				
Very Low				

Potential Impacts

Overall Flood Risk	
HIGH	
MEDIUM	
LOW	
VERY LOW	

Click here for the Flood Guidance Statement User Guide.

This guidance is produced to support decision making by Category 1 and 2 emergency responders.

Appendix D. Hydrology report

1. Section 19 Flood Investigations Hydrology

1.1 Introduction

Jacobs have been commissioned by the London Borough of Havering to undertake a study into the flood event that occurred in June 2016. A Flood Incident Report is to be produced as part of this study and this hydrological analysis is required to inform the report of the likely event rarity.

1.2 Site Description

Havering London Borough is located in East London and its administrative boundary covers an area of 111.4km^2. Over 70% of the Borough is urbanised. The main communities are Romford located to the north, Hornchurch, Upminster in the centre and Rainham located to the south of the borough (See Figure 1-1).

The main rivers within the borough are; the River Ingrebourne, River Mardyke, River Ravensbourne, River Rom and River Beam. The rivers Ingrebourne and Ravensbourne are gauged at the Gaynes Park (Flow Gauging Station reference 37018) and Bretons Farm (Flow Gauging Station reference 37019) respectively (See Figure 1-2). These rivers are tributaries of the River Thames.

Three intensity rainfall gauges are located within or in close proximity to the study area. These are Nag's Head Lane, Havering Bower and Central Park (See Figure 1-2).

Fifteen minute recorded data for the June 2016 event at rain and river gauges were made available by the Environment Agency for this assessment.

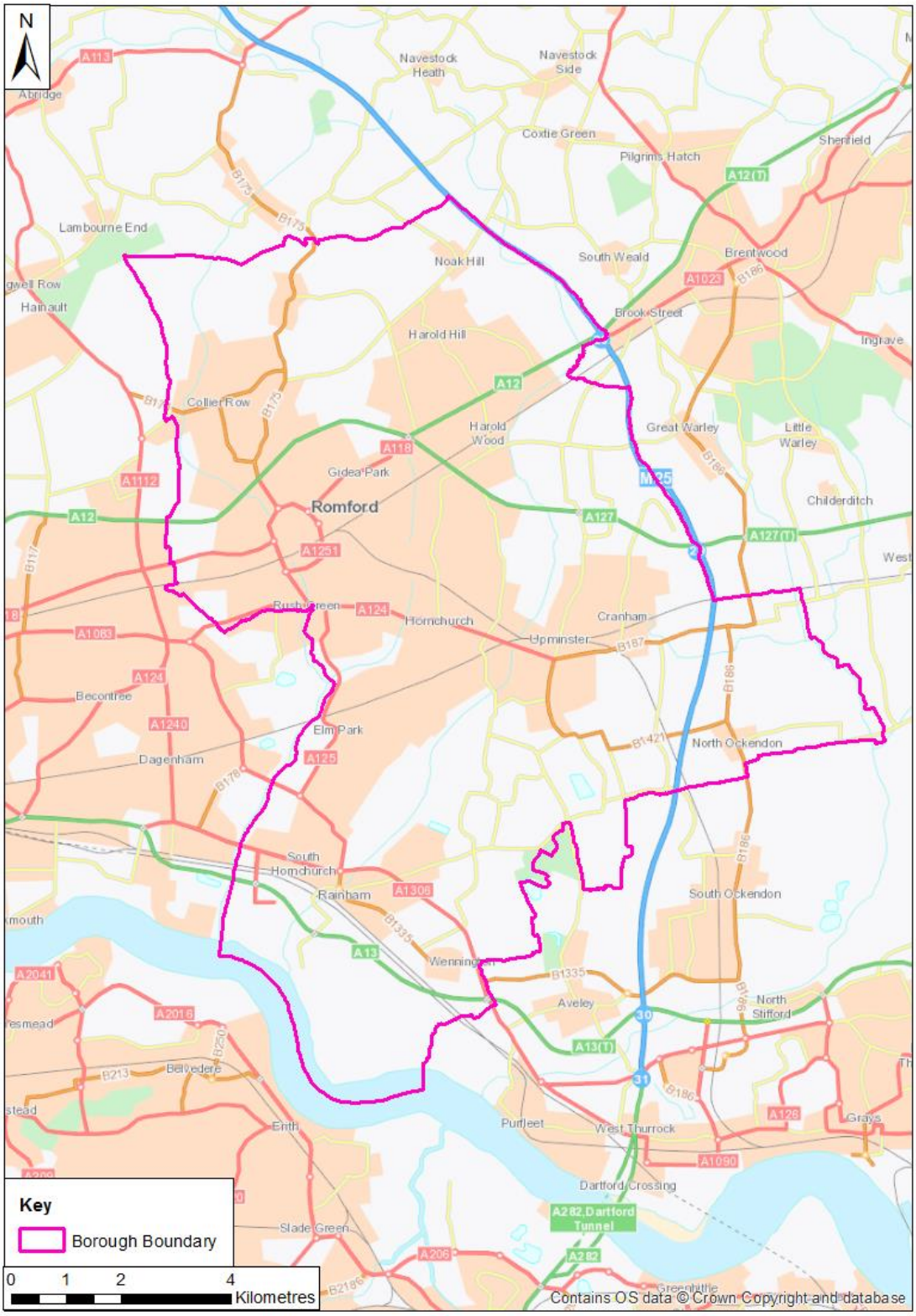


Figure 1-1: Location Plan

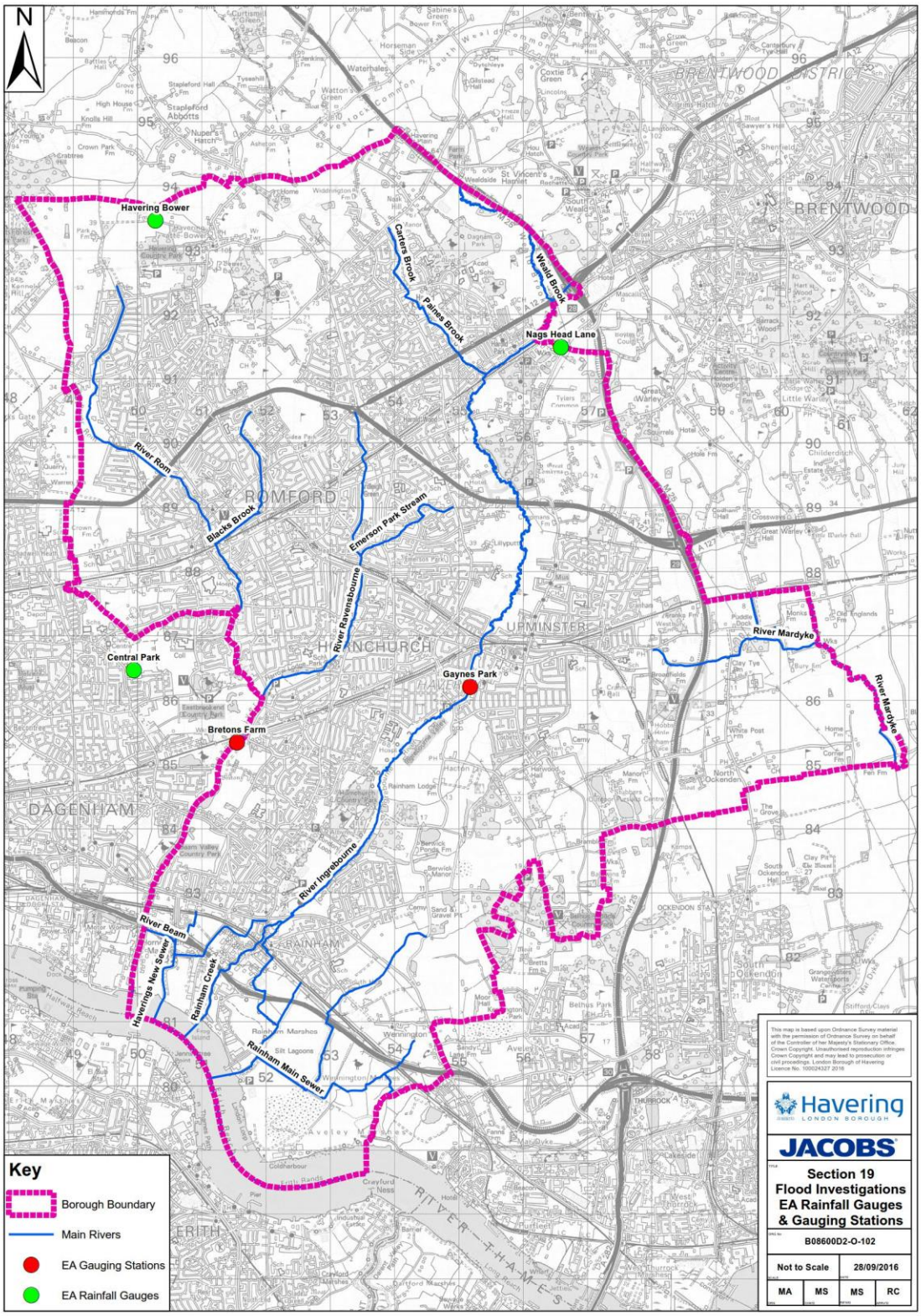


Figure 1-2: Location of Rainfall Gauges and Gauging Stations

1.3 Methodology

The following approach was used for the analysis.

1.3.1 Event Rainfall Rarity

- Fifteen minute rainfall data for the event were plotted against time at each gauge to establish the most intense rainfall period and overall storm durations.
- Total rainfall depths over differing storm durations were calculated from the recorded data at each of the rain gauges.
- Long term rainfall depth-duration-frequency statistics at each of the gauge locations were downloaded from the Flood Estimation Handbook (FEH) web service[1]. The FEH long term statistics were compared with the recorded rainfall data at each of the rain gauge locations and the return period for the rainfall event was estimated for different storm durations for each of the gauges.

1.3.2 River Flow Rarity

- Catchment descriptors for the gauging stations were taken from Hiflows UK database v4.1 dated July 2016, published on the Centre for Hydrology and Ecology (CEH)[2] website.
- The Median Annual Maximum Flow (QMED) was calculated from the observed Annual Maximum Flows (AMAX) recorded from 1970 to 2016. The details are provided in the Audit Trail in Appendix A.
- The QMED data were plotted against the recorded event to ascertain the occurrence of a fluvial flood event.
- Single site analysis was not possible at the gauging stations due to insufficient high flow data to confirm the high flow rating relationship and therefore the reliability of the higher flows is unknown.
- A pooling group analysis was undertaken using FEH CD-ROM Version 3.0 (2009) using WINFAP-FEH Version 3.0.003 (2009) and the latest Hiflows UK database v4.1 downloaded from the CEH website. WINFAP-FEH allows for pooled analysis to be completed from a group of hydrologically similar catchments to generate flood growth curves. For this assessment, the catchment for gauging station 37018 was deemed representative (i.e. stations had hydrologically similar catchment descriptors) of the two catchments and was used in the construction of the pooling group analysis. The growth curve factors produced were used to estimate flows for all two locations. The pooling group analysis has been detailed in the audit documents in Appendix A.
- The FEH estimated flows were compared with the June 2016 flow data at each of the gauge stations and return period was estimated where appropriate.
- Single Site and ReFH2 analysis were also undertaken at the two river gauges and compared with the June 2016 flow data to also estimate the return period.

1.3.2.1 Soil Saturation Analysis

- Sensitivity analysis was undertaken in ReFH2 in an attempt to recreate the observed flows to reflect the saturation conditions indicated by rainfall records. The total storm duration for the recorded event at each of the rainfall gauges (i.e. Havering Bower, Nag's Head Lane and Central Park) was chosen as a parameter in the ReFH2 model and the return period adjusted until the total rainfall depth was equivalent to or close to the record rainfall values.
- The C_{ini}[3] and C_{max}[4] parameters in ReFH2 provides context for the antecedent condition at the start of the event. These values were calculated from catchment descriptors. Alterations to these values were not possible in ReFH2.

[1] https://fehweb.ceh.ac.uk/
[2] http://nrfa.ceh.ac.uk/winfap-feh-files
[3] Cini – Initial Moisture Content
[4] Cmax – maximum Soil Moisture Capacity

1.4 Results

1.4.1 Results - Rainfall Gauges Analysis

Figure 1.2 shows the rainfall recorded during the event at the three local rain gauges.

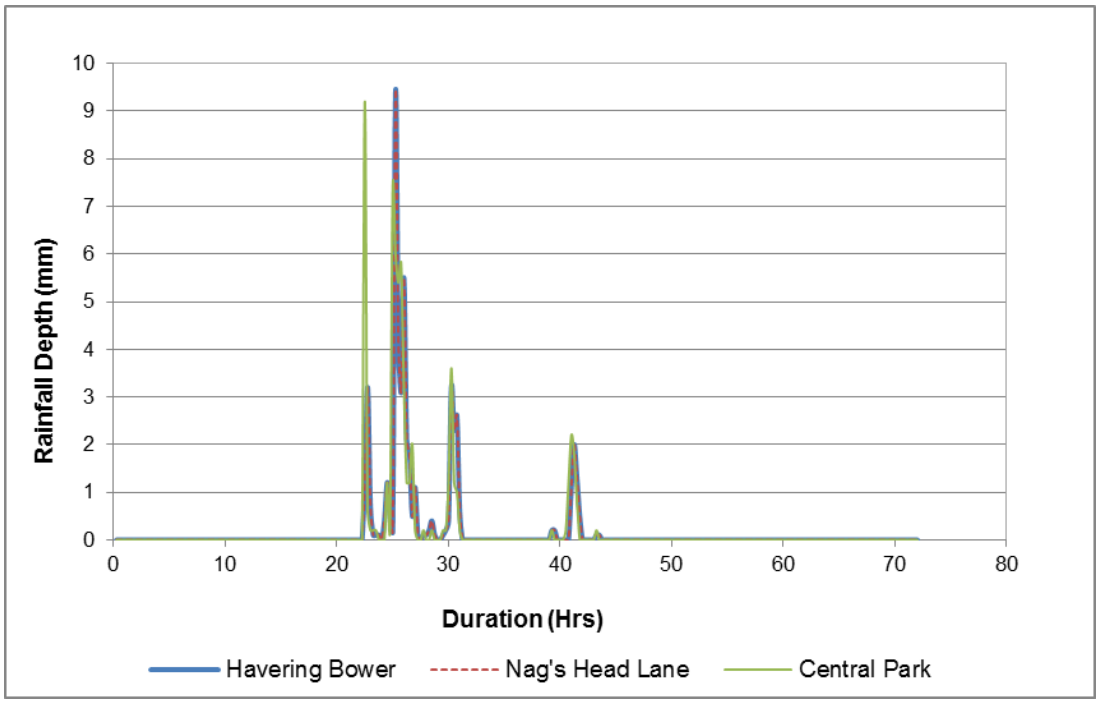


Figure 1-3: Rain gauge recordings

Tables 1.1 and 1.2 show the recorded rainfall totals and the estimated corresponding FEH return period for the intense and overall storm durations.

Table 1.1: Summary of results for the most period of the storm

Gauge Name	Recorded Total Rainfall (mm)	Recorded Storm Duration (hrs)	Return Period estimated from FEH rainfall statistics (years)	Probability estimated from FEH rainfall statistics (AEP[5])
Havering Bower	42.64	4.75	10	10%
Nag's Head Lane	30.3	3.00	5	20%
Central Park	33.8	2.50	8	12.5%

[5] AEP – Annual Exceedance Probability

Table 1.2: Summary of results for the duration of the storm

Gauge Name	Recorded Total Rainfall (mm)	Recorded Storm Duration (hrs)	Return Period estimated from FEH rainfall statistics (years)	Probability estimated from FEH rainfall statistics (AEP[6])
Havering Bower	55.25	21.00	11	9.1%
Nag's Head Lane	51.60	21.00	8	12.5%
Central Park	58.80	20.75	14	7.1%

1.4.2 Fluvial Analysis - Recorded QMED and Flows at Fluvial Gauges

A summary of the calculated QMED and June 2016 peak flows are shown in Table 1.3.

Table 1.3: Recorded QMED and June 2016 peak flows

Gauge Name	Recorded Peak Flow (June 2016 event) (m^3/s)	QMED (AMAX data) (m^3/s)
37018 - Bretons Farm	35.11	6.93
37019 - Gaynes Park	43.30	8.36

Figures 1.3 and 1.4 show plots of the recorded hydrographs against the QMED flows at each of the river gauges.

[6] AEP – Annual Exceedance Probability

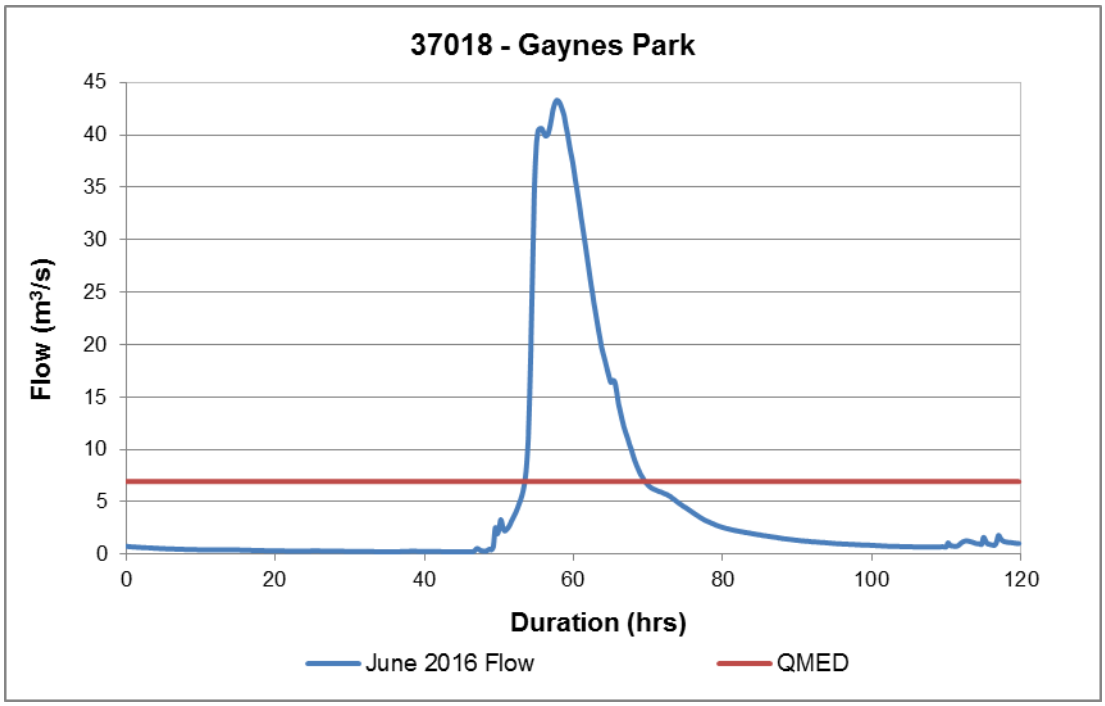


Figure 1-4: QMED against June 2016 event at gauging station 37018

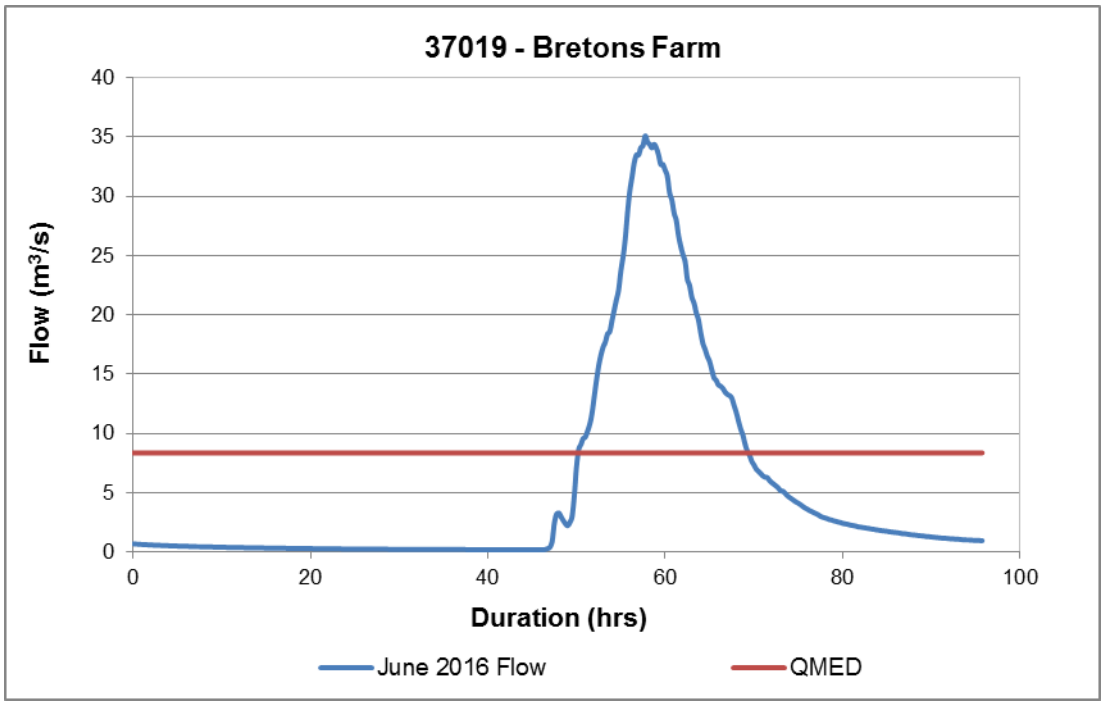


Figure 1-5 : QMED against June 2016 event at gauging station 37019

1.4.3 Results - Fluvial Analysis (estimated design peak flows) at River Gauges

Table 1.4: Summary of results for ReFH2, FEH Pooled and Single Site Analysis at Station 37018 – estimated design peak flows

Return Period (years)	Return Period (% AEP)	FEH Statistical Flows (m^3/s)	Single Site Analysis (SSA) Flows (m^3/s)	ReFH2 Flows (m^3/s)
2	50.00	6.93	7.44	13.48
3	33.33	8.45	9.48	15.49
5	20.00	10.20	12.07	18.16
7	14.28	11.34	13.89	20.04
10	10.00	12.58	15.99	22.20
15	6.67	14.04	18.64	24.92
20	5.00	15.13	20.72	27.04
25	4.00	16.01	22.47	28.79
30	3.33	16.75	23.99	30.32
50	2.00	18.96	28.76	35.07
75	1.33	20.87	33.16	39.40
100*	1.00	22.32	36.67	**42.82***
200**	0.50	26.14	**46.66****	52.42
500	0.20	32.06	64.07	68.81
600	0.17	33.37	68.23	72.85
800	0.12	35.54	75.35	79.66
900	0.11	36.46	78.48	82.57
1000	0.10	37.30	81.38	85.23

**ReFH2 design flows and return period corresponding to the observed peak flow*
***SSA design flows and return period corresponding to the observed peak flow*

Table 1.5: Summary of results for ReFH2, FEH Statistical and Single Site Analysis at Station 37019 – estimated design peak flows

Equivalent Return Period (m^3/s)	Return Period (% AEP)	FEH Statistical Flows (m^3/s)	Single Site Analysis (SSA) Flows (m^3/s)	ReFH2 Flows (m^3/s)
2	50.00	8.36	8.83	17.74
3	33.33	10.20	9.96	20.29
5	20.00	12.31	11.29	23.64
7	14.28	13.68	12.17	26.00
10	10.00	15.17	13.14	28.68
15	6.67	16.94	14.30	32.01

Equivalent Return Period (m^3/s)	Return Period (% AEP)	FEH Statistical Flows (m^3/s)	Single Site Analysis (SSA) Flows (m^3/s)	ReFH2 Flows (m^3/s)
20	5.00	18.25	15.17	34.60
25*	4.00	19.31	15.88	**36.74***
30	3.33	20.21	16.49	38.60
50	2.00	22.88	18.30	44.31
75	1.33	25.18	19.89	49.48
100	1.00	26.92	21.10	53.53
200	0.50	31.54	24.37	64.78
500	0.20	38.68	29.55	83.60
600	0.17	40.26	30.71	88.16
800	0.12	42.87	32.65	95.81
900	0.11	43.98	33.47	99.10
1000**	0.10	45.00	**34.23****	102.11

**ReFH2 design flows and return period corresponding to the observed peak flow*

***SSA design flows and return period corresponding to the observed peak flow*

1.4.4 Results - ReFH2 Event Analysis

Further assessment was undertaken in the 'design' ReFH2 model[7] to investigate how the total recorded rainfall depth at the three rain gauges could have produced the observed peak flows or how saturated soil prior to event may have contributed. The rainfall totals for the entire storm of 21 hours were input into the 'design' ReFH2 model and the resultant estimated flows recorded. A summary of the results are shown in Table 1.6.

Table 1.6: Estimated peak flows for recorded rainfall at Havering Bower, Nag's Head Lane and Central Park

Gauge Name	Recorded Peak Flow (June 2016 event) (m^3/s)	ReFH2 modelling	
		Recorded rainfall for the event at the rain gauges (mm)	Modelled peak flow (m^3/s)
37018 - Bretons Farm	35.11	Havering Bower = 55.25 Nag's Head Lane = 51.60 Central Park = 58.80	25.38
37019 - Gaynes Park	43.30	Havering Bower = 55.25 Nag's Head Lane = 51.60 Central Park = 58.80	31.46

[7] 'design' ReFH2 model represents a scenario where the catchment being modelled is not as wet as the actual catchment have to be.

1.5 Discussion

1.5.1 Discussion - Rainfall Analysis

Analysis of the recorded rainfall and river flows for the June 2016 event has been undertaken. These recorded data have been compared with long term rainfall and river flow statistics and the Environment Agency Monthly Water Situation Report[8] for the south east region to estimate the return period of the event.

A comparison of the total rainfall recorded at the three rain gauges (i.e. Havering Bower, Nag's Head Lane and Central Park), for both the period of most intense rainfall and the entire storm duration, with the FEH rainfall statistics indicates return periods for the June 2016 to varying between 8 years and 15 years (i.e.12.5% and 6.67% AEP respectively). The rainfall data in isolation therefore indicates significant, yet not extreme rainfall was experienced within the catchments.

The Monthly Water Situation Report suggests the rainfall for the month of June 2016 was above the average rainfall for the whole of England. Parts of east and south-east England had exceptionally high June rainfall including Essex and East Suffolk, where it was the third wettest June on record (since 1910). This amounted to more than 240% of the long term average rainfall for June for the hydrological areas in North Essex. Monthly rainfall data at two other rain gauges (i.e. Heathrow and Manston[9]) within the south eastern region were reported. The monthly average rainfall data over the last three years for these rain gauges (Refer to Appendix C) both indicated an increase of over three times the long term records for June 2016.

The high rainfall totals caused soil moisture deficits to decrease across most of England with the largest decrease occurring in the south-east and central England through June 2016. As a result, the response of the local watercourses to the rainfall event produced flows two thirds greater than the long term monthly mean flows and, based on the analysis. All these factors show a similar increase in rainfall pattern across the region and not localised at Havering.

This supplementary information provides additional context for the events of June 2016 which, combined with the ReFH2 analysis presented in Section 1.4.4, suggests that antecedent catchment wetness conditions combined with the rainfall that was received to produce particularly high flows within the catchments.

1.5.2 Discussion – Fluvial Analysis

For the estimation of the return period for the fluvial event, the recorded June 2016 river flow at gauging stations 37018 and 37019 were analysed. Plots of the observed river flows compared with the QMED value at the gauges suggest an out-of-bank event at both stations (assuming QMED is roughly bankful).

Further analyses using FEH pooling group analysis, ReFH2 and a single site approaches were undertaken to estimate the return period for the fluvial event. The FEH pooling group method produced the lowest flows in comparison to the flows generated from the Single Site and ReFH2 analysis. The reason for this is believed to reflect the fact that gauging stations pooled from WINFAP FEH are all essentially rural and also there is a limitation on the dataset available in WINFAP from which small catchments can be pooled. Based on these limitations, the FEH method is therefore unlikely to produce high growth factors and flows that are representative of the urbanised catchments under consideration here.

The Single Site analysis utilises observed AMAX records at the gauged stations and produces a steeper growth curve and higher peak flow estimates at the Gaynes Park gauge but marginally lower growth curve at Bretons Farm, however, the relatively short period of the records at both gauges places a limit on the reliability of higher return period estimates.

[8] Environment Agency, Monthly Water Situation Report https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/536457/WSR_June2016.pdf

[9] UK Climate Historic Station data http://www.metoffice.gov.uk/public/weather/climate-historic/#?tab=climateHistoric

The ReFH2 model produced the highest flows out of the three approaches considered. This method accounts for the urban rainfall response better than the FEH pooling group analysis but does not benefit from the use of observed data as with the Single Site Analysis. In the case of both gauges, the method suggests that the return period of the observed June 2016 flows is higher than the return period of the rainfall that was observed at the rain gauges discussed in Section 1.5.1.

1.5.2.1 Soil Saturation Analysis (ReFH2)

Sensitivity analysis was undertaken in the 'design' ReFH2 model in an attempt to reproduce the observed flows to reflect the saturation condition indicated by the rainfall records. The total storm duration for the recorded event at each of the rainfall gauges (i.e. Havering Bower, Nag's Head Lane and Central Park) was applied to the ReFH2 model for each river catchment and the return period adjusted until the total rainfall depth utilised within the model was equivalent to or close to the record rainfall values.

Although the observed June 2016 rainfall is the highest on record, analysis showed the observed rainfall depths to be approximately equivalent to a 1 in 15 year (6.67% AEP) event and the estimated peak design flows to be less than the observed peak flows at stations 37018 and 37019. This suggests that the June 2016 rainfall event could not have produced the observed peak flows under the ReFH2 models 'design' parameters circumstances and that the unusually saturated soil prior to the storm event may have been a contributory factor.

The C_{ini} and C_{max} parameters in ReFH2 give an indication of the soil wetness prior to an event and the maximum soil moisture capacity respectively. That the 'design' C_{ini} value could not reproduce the observed flows is an important outcome, as it implies that a higher C_{ini}, reflecting wetter catchment conditions would be required to do so, which is consistent with the contextual information from analysis of the rain gauges at Heathrow and Manston the information in the Environment Agency Water Situation Report.

1.6 Conclusion

Analysis of the June 2016 rainfall and flow recordings at the rain and river gauges locations has been undertaken. These recorded data have been compared to long term rainfall and river flow statistics and the water situation report across the south east region to estimate the return periods for the June 2016 event.

The observed rainfall for June 2016 was above the average monthly total rainfall for England and exceptionally high in parts of the east and south-east of England. The Environment Agency Monthly Water Situation Report suggests the June 2016 total rainfall was over three times the monthly long term records. Soil moisture deficits also decreased across most of England through June with the largest decrease occurring in the south-east and central England. The response of the local watercourses to the rainfall event produced flows two thirds greater than the long term monthly mean flows as a result of the rainfall. These suggest a regional pattern and not a localised effect at Havering.

A comparison of the total rainfall over the three rain gauges (i.e. Havering Bower, Nag's Head Lane and Central Park) recordings for the storm duration against the FEH rainfall statistics indicates return periods for the June 2016 to varying between 8 years and 15 years. Further analysis of the observed rainfall depth in ReFH2 also indicated the total rainfall depths to produce design peak flows with return periods approximately equivalent to 1 in 15 year (i.e. 6.67% AEP). The 'design' ReFH2 model, which can be used to produce higher peak flow estimates at the two gauges relative to the FEH pooled analysis and Single Site Analysis, in combination with the observed rainfall was not sufficient to produce the observed flows at gauging stations 37018 and 37019. The implication is that, the 'design' ReFH2 model requires a greater soil saturation (higher C_{ini} value) in order to do so, which reflects the contextual information provided from other sources.

In summary, three methods have been used to assess the rainfall observed, the flows observed and to better understand the antecedent catchment conditions at the time of the event. Rainfall analysis suggests a return period of no greater than 1 in 15 years (6.67% AEP) and flow analysis indicates that the return period at the gauging stations was between 1 in 25 years (4% AEP) and could be as high as 1 in 100 years (1% AEP). The driver for the increased fluvial return period relative to the rainfall return period is understood to be wetter than average soil moisture conditions for that time of year. These wetter conditions, combined with a high intensity storm resulted in particularly high runoff from the catchments of concern. The frequency of the soil wetness for

the catchment may be of an equivalent magnitude to a return period. This suggests a joint probability element to the analysis and that the overall rarity of this event may be greater than 1 in 25 (4% AEP) or 1 in 100 (1% AEP).

Appendix A. Pooling Group and Single Site Analysis

Jacobs flood study audit trail
FEH pooling group analysis

37018 - Ingrebourne@ Gaynes Park

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FEH pooling group analysis

Project details

Project title: Section 19 Flood Investigation
Project number: B08600D2
Work Stage: O Sec 19 June 2016
Client: Havering London Borough
Flood study site: 37018 - Ingrebourne @ Gaynes Park

Jacobs flood study audit trail
FEH pooling group analysis

Contents

Jacobs flood study audit trail

FEH pooling group analysis

1 General

Jacobs have been commissioned by Havering London Borough to undertake a study into the flood event that occurred in June 2016. A Flood Incident Report is to be produced as part of this study and hydrological analysis is required to inform the report on the Annual Exceedance Probability (AEP) of the 2016 event.

Two fluvial gauging stations (i.e. 37018 and 37019) are located within the study area. Recordings of the 2016 events were made available for this analysis. These stations have insufficient information on high flows and are therefore not reliable for the estimation of flows. Single site analysis has not been undertaken. However, to give an indication on the AEP of the recorded event at these gauged locations, estimated flows using the FEH pooling group analysis was undertaken.

The following analysis was undertaken using the FEH CD-ROM Version 3.0 (2009) and Winfap-FEH Version 3.0.003 (2009).

The Jacobs Winfap-FEH database uses the HiFlows-UK database v4.1 dated May 2016, published on the CEH website.

2 Catchment description

The catchment descriptors at the two gauging stations are hydrologically similar and gauging station 37018 catchment has been selected and used to generate the growth factors for the both locations.

Grid Reference at Gauging Station 37018: 555951,192571.

2.1 FEH catchment descriptors:

AREA	44.83
ALTBAR	62
ASPBAR	203
ASPVAR	0.09
BFIHOST	0.284
DPLBAR	9.86
DPSBAR	43.2
FARL	0.985
FPEXT	0.0435
LDP	17.48
PROPWET	0.27
RMED-1H	11.1
RMED-1D	31.1
RMED-2D	37.9

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SAAR	594
SAAR4170	609
SPRHOST	45.42
URBCONC2000	0.833
URBEXT2000	0.1675
URBLOC2000	0.846

2.2 Presence of significant land-use or catchment factors:

Factors	Comment	Potential Significance
Reservoir\lake	There is some attenuation due to the presence of reservoirs or lakes, FARL value is 0.985.	Presence of lake/reservoirs may provide some form of attenuation.
Urban	Catchment is heavily urbanised. The settlements Brentwood to north east, Harold Hill to the west and Upminster to the south of the catchment. URBEXT2016 = 0.1733	Extensive urban development tends to increases the uncertainties. This is not the case for this catchment.
Land use	Land cover: Catchment is predominantly grassland with some arable woodland. Habitats: Seasonally wet pastures and woodlands. Land use: Heavily urbanised with the Brentwood, Harold Hill and Upminster as main settlement within the catchment.	Nothing atypical that would challenge the adequacy of using the pooling group approach.
Soils\Geology	Geology: the bedrock geology is London Clay formation (Clay, Silt and Sand). Superficial geology is a combination of Alluvium (Clay, Silt, Sand and Gravel), Lynch Hill Gravel (Sand and Gravel), Black Park Gravel Member (Sand and Gravel) and Lowestoft Formation-Diamicton. Soils are classed as seasonally wet slightly acid but base-rich loamy and clayey soils. SPRHOST = 45.42 BFIHOST = 0.284	Nothing atypical that would challenge the adequacy of using the pooling group approach

2.3 Flow record:

Target site: Gauged

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FEH pooling group analysis

3 Estimation of QMED

3.1 Approach used

Used	Condition	Approach followed
	N >=30	Estimate QMED using annual maxima
	14=< N =<29	Estimate QMED from annual maxima & optionally adjust for climatic variation
	2=< N= <13	Estimate QMED from POT data & adjust for climatic variation
	N <2 & suitable donor site with 20 years or more of record	Ignore record at subject site; transfer QMED from donor site
	N <2 & suitable donor with 10 to 19 years of record & 12 month overlap between records	Estimate QMED using procedure based on flood peak regression
	N <2 & suitable donor with 10 to 19 years of record but no 12 month overlap	Ignore record at subject site; transfer QMED from donor site
	N <2 & no long-record site nearby	Estimate QMED from very short POT record
	N <2 & no long-record site nearby	Treat site as ungauged catchment
	N <2 & no long-record site nearby	Defer analysis until longer flow record available
	N <2 & no long-record site nearby	(Abstract flood event information and apply the UH rainfall-runoff model as an alternative, to the pooling group procedure. Particularly recommended when site is urbanised)
✓	Ungauged catchment	Estimate QMED from catchment descriptors
	Ungauged catchment	Estimate QMED by data transfer from donor catchment
	Ungauged catchment	Estimate QMED by data transfer from analogue catchment
	Ungauged catchment	Estimate QMED from channel dimensions
	Ungauged catchment	Compare to regional pattern of mapped QMED adjustment factors

(*preferred method)

3.2 QMED estimation from observed Annual Maximum Flows (AMAX)

Year	Observed Flows
14-Nov-70	8.11
01-Aug-72	3.33
21-May-73	12.4
10-Mar-74	8.4
21-Nov-74	29
28-Nov-75	3.19
30-Nov-76	5.96
05-May-78	10.1
01-May-79	5.72
01-Apr-80	4.95
16-Oct-80	4.36
14-Dec-81	5.3
08-Dec-82	16.3
23-Jan-84	4.438
26-Jan-85	5.567
26-Dec-85	8.686
23-Aug-87	10.633
29-Jan-88	13.073
17-Mar-89	6.169
03-Feb-90	12.224
08-Aug-91	5.075
18-Sep-92	4.334
20-Oct-92	15.535
02-Oct-93	10.428
30-Jan-95	6.169
09-Jan-96	4.041
26-Jun-97	2.416
05-Jan-98	3.829
01-Nov-98	6.011
28-May-00	15.059
30-Oct-00	19.209
04-Feb-02	9.001
30-Dec-02	17.364
24-Aug-04	5.668
19-Nov-04	3.731
13-Jun-06	3.237
14-Feb-07	5.351
12-Aug-08	7.443
10-Feb-09	15.237

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FEH pooling group analysis

Year	Observed Flows
28-Feb-10	6.931
18-Jan-11	7.366
08-Jul-12	28.778
25-Dec-12	15.57
17-Jan-14	6.418
23-Jun-16	43.3
QMED	**6.931**

4 Steps involved in construction and analysis of a pooling group.

4.1 Pooling group construction

Site of interest

(a) Station Number	37018	(b) Name	
Name of saved **.feh** group file		37018.feh	
Target return period (years) for 5T rule		100	

4.2 Initial Pooling group details

Total number of sites	524	Total number of years	13

Total number of initial high discordancy sites	0
List them:	
Total number of short records (< 7 years) removed	0
List them:	
Number of pooled years after sites removed	524

4.3 Subject Site Details

Is subject site included as Rank 1 in pooled group: ~~yes~~ no

If no state reason why: Subject site is not suitable for pooling.

4.4 Test statistics on validity of pooling group for flood frequency analysis

Heterogeneity test H2 value = 2.96

Status			
	Review not necessary		H2 < 1
	Review optional		1 < H2 < 2
	Review desirable	✓	2 < H2 < 4
	Review essential		H2 > 4

Goodness-of-fit test	Z values				Value
		GL	acceptable	/ not acceptable	1.81
		GEV	acceptable	/ ~~not acceptable~~	-0.72
		PT3	acceptable	/ ~~not acceptable~~	-0.91
	other				

(Note: in the FEH the GL is the generally favoured distribution for use)

ACTION is construction of flood frequency curve valid?
No Yes

4.5 Revision of Pooling Group

Revision No. 1

Station Number	Reason for changes in pooling group
26803, 42011	Removed. SPRHOST< 20%
38002	Added to increase pooling to 500 years.

Number of sites 12 Years 540

Heterogeneity test H2 value = 1.87

Status			
	Review not necessary		H2 < 1
	Review optional	✓	1 < H2 < 2
	Review desirable		2 < H2 < 4
	Review essential		H2 > 4

Note: FEH Vol.3, chapter 16.3.2: "The ideal pooling-group is homogeneous. However, a representative but heterogeneous pooling-group gives better flood frequency estimates than either single-site data or a pooling-group that has been made homogeneous by inappropriately removing sites. In general, it is anticipated that a significant proportion of pooling-groups will remain heterogeneous, even after review."

Goodness-of-fit test					Value
	Z values	GL	acceptable	/ ~~not acceptable~~	0.75
		GEV	acceptable	/ ~~not acceptable~~	-1.46
		PT3	acceptable	/ not acceptable	-1.65
	other				

ACTION is construction of flood frequency curve valid?
~~No~~ Yes
Comment? Pooling group refined

4.6 Flood frequency analysis of pooling group

Distributions selected	GL	✓	PT3		
	GEV	✓	other		

Standardisation method selected — Median (this acts as a check as median is the only method allowed within the pooling group method)
~~Mean~~

Construct flood frequency curve

			If yes				
URBEXT updated	yes	~~no~~	from	0.1675	to	0.1733	
Urban adjustment*	~~yes~~	no					
Value of QMED =		6.93	m^3/s				

GL

Return period (yrs)	Growth factors	Design flows (m^3/s)
2	1.000	6.93
3	1.220	8.45
5	1.472	10.20
7	1.636	11.34
10	1.815	12.58
15	2.026	14.04
20	2.183	15.13
25	2.310	16.01
30	2.417	16.75
50	2.736	18.96
75	3.012	20.87
100	3.220	22.32
200	3.772	26.14
500	4.626	32.06
600	4.815	33.37
800	5.128	35.54
900	5.261	36.46
1000	5.383	37.30

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FEH pooling group analysis

GEV	*for comparison*	
Return Period (yrs)	**Growth factors**	**Design flows (m^3/s)**
2	1.000	6.93
3	1.243	8.61
5	1.521	10.54
7	1.696	11.76
10	1.880	13.03
15	2.088	14.47
20	2.236	15.50
25	2.352	16.30
30	2.446	16.95
50	2.714	18.81
75	2.931	20.31
100	3.086	21.39
200	3.468	24.03
500	3.990	27.65
600	4.097	28.39
800	4.266	29.56
900	4.336	30.05
1000	4.399	30.49

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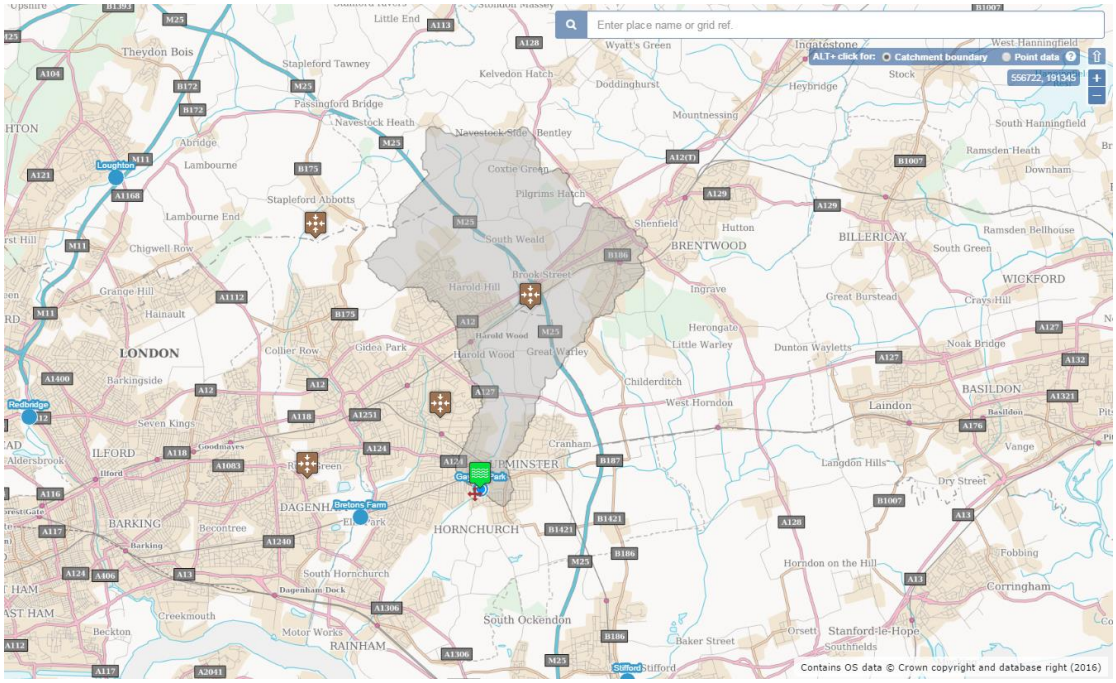
FEH pooling group analysis

Appendix 1 Location of catchment



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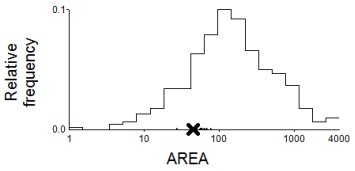
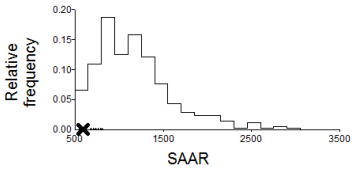
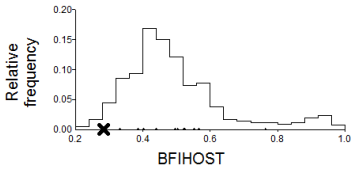
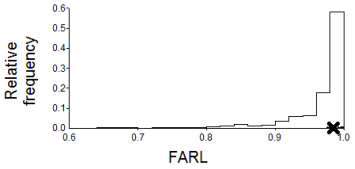
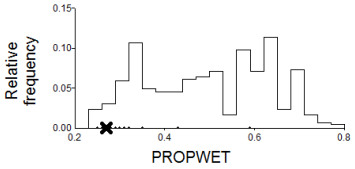
Appendix 2 Pooling Group Details – Graphs

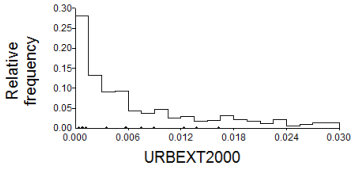


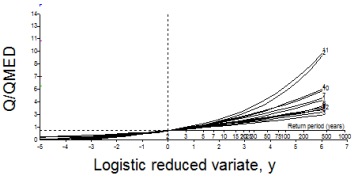


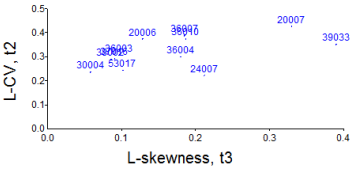


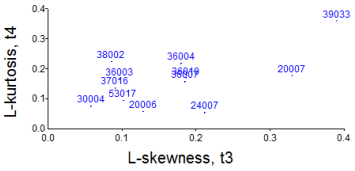


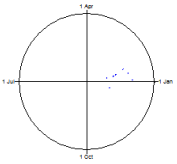












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FEH pooling group analysis

Appendix 3 Pooling Group Details – Tables

AM Data

Station	Distance	Years of data	QMED AM	L-CV	L-SKEW	Discordancy
36004 (Chad Brook @ Long Melford)	0.305	47	5.186	0.3	0.18	0.317
39033 (Winterbourne Stream @ Bagnor)	0.392	52	0.403	0.352	0.390	2.591
30004 (Lymn @ Partney Mill)	0.533	52	6.778	0.236	0.058	0.695
36007 (Belchamp Brook @ Bardfield Bridge)	0.554	49	4.640	0.388	0.185	0.524
37016 (Pant @ Copford Hall)	0.575	50	7.240	0.293	0.090	0.249
53017 (Boyd @ Bitton)	0.600	41	13.820	0.245	0.101	0.487
20006 (Biel Water @ Belton House)	0.617	28	11.748	0.375	0.128	1.228
24007 (Browney @ Lanchester)	0.655	15	10.981	0.222	0.212	2.507
36003 (Box @ Polstead)	0.655	53	3.910	0.308	0.096	0.362
36010 (Bumpstead Brook @ Broad Green)	0.685	47	7.500	0.375	0.186	0.332
20007 (Gifford Water @ Lennoxlove)	0.779	33	17.238	0.427	0.329	1.550
38002 (Ash @ Mardock)	0.788	73	6.764	0.290	0.085	1.157
Total		540				
Weighted means				0.318	0.169	

Catchment Descriptors Data

Station	Distance SDM	AREA	SAAR	FPEXT	FARL	URBEXT 2000
36004 (Chad Brook @ Long Melford)	0.305	50.320	589	0.065	1.000	0.006
39033 (Winterbourne Stream @ Bagnor)	0.392	45.340	717	0.033	1.000	0.001
30004 (Lymn @ Partney Mill)	0.533	60.240	686	0.061	0.979	0.006
36007 (Belchamp Brook @ Bardfield Bridge)	0.554	58.160	560	0.079	0.996	0.004
37016 (Pant @ Copford Hall)	0.575	63.780	588	0.069	0.997	0.009
53017 (Boyd @ Bitton)	0.600	47.710	806	0.050	0.998	0.016
20006 (Biel Water @ Belton House)	0.617	57.550	742	0.019	0.981	0.001
24007 (Browney @ Lanchester)	0.655	44.590	797	0.015	1.000	0.001
36003 (Box @ Polstead)	0.655	56.460	566	0.094	0.993	0.012
36010 (Bumpstead Brook @ Broad Green)	0.685	27.580	588	0.045	0.999	0.007
20007 (Gifford Water @ Lennoxlove)	0.779	67.750	770	0.029	0.977	0.000
38002 (Ash @ Mardock)	0.788	78.100	619	0.049	1.000	0.014

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FEH pooling group analysis

Appendix 4 **37018 - Single Site Analysis**

Gauge name and number
QMED: 6.675m^3/s
Record length: 1970 – 2014
Station years: 44

GL- LMoment

Return period (years)	Growth factors	Design flows (m^3/s)
2	1.114	7.44
3	1.420	9.48
5	1.808	12.07
7	2.081	13.89
10	2.396	15.99
15	2.793	18.64
20	3.104	20.72
25	3.366	22.47
30	3.594	23.99
* 50	4.308	28.76
* 75	4.968	33.16
* 100	5.493	36.67
* 200	6.990	46.66
* 500	9.598	64.07
* 600	10.222	68.23
* 800	11.289	75.35
* 900	11.757	78.48
* 1000	12.192	81.38

* return period > 2 x record length

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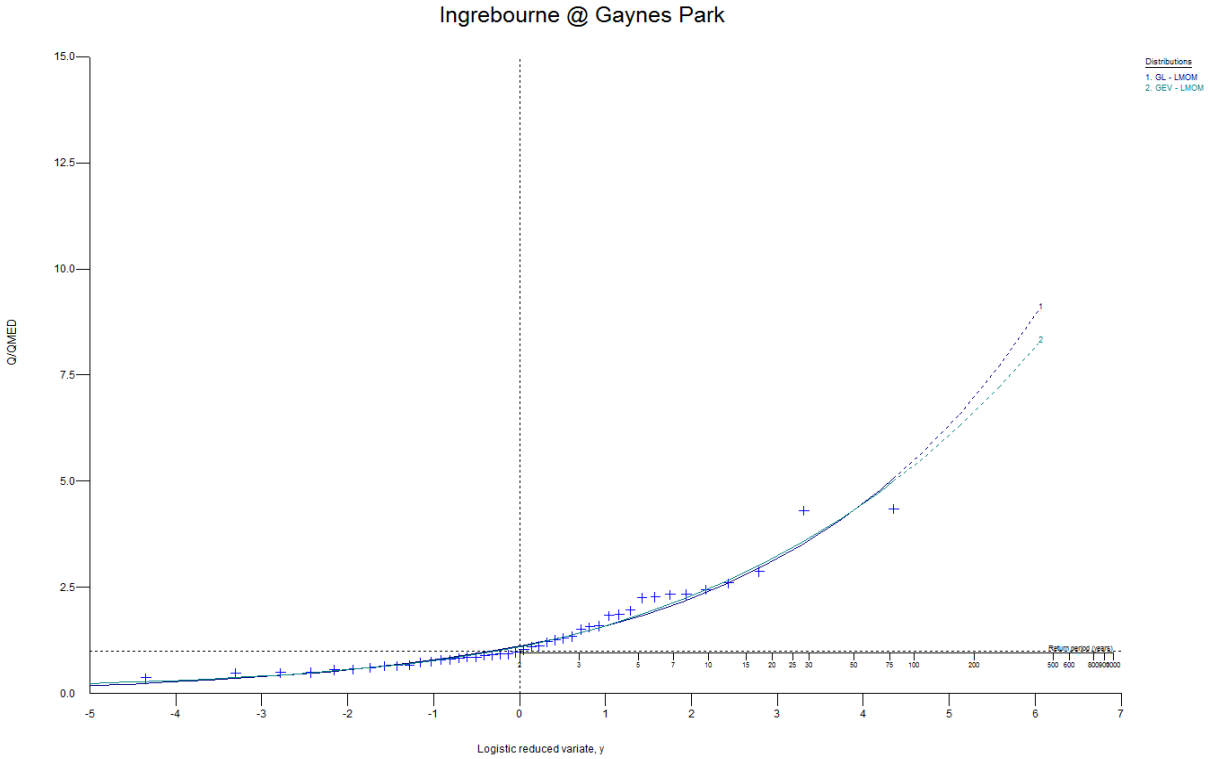
FEH pooling group analysis

Appendix 5 37018 - Single Site Analysis (Graph)



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FEH pooling group analysis

Appendix 6 **37019 - Single Site Analysis**

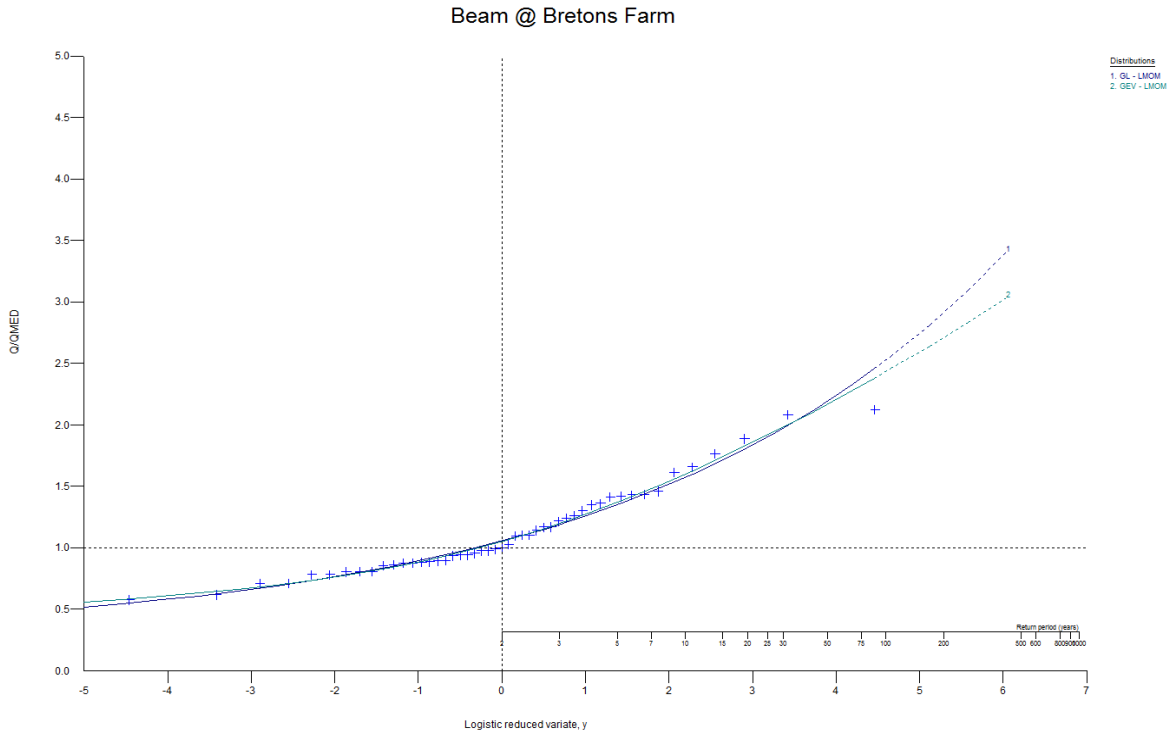
Gauge name and number
QMED: 8.358m^3/s
Record length: 1965 - 2014
Station years: 49

GL- LMoment

Return period (years)	Growth factors	Design flows (m^3/s)
2	1.056	8.83
3	1.192	9.96
5	1.351	11.29
7	1.456	12.17
10	1.572	13.14
15	1.711	14.30
20	1.815	15.17
25	1.9	15.88
30	1.973	16.49
* 50	2.19	18.30
* 75	2.38	19.89
* 100	2.525	21.10
* 200	2.916	24.37
* 500	3.535	29.55
* 600	3.674	30.71
* 800	3.906	32.65
* 900	4.005	33.47
* 1000	4.096	34.23

* return period > 2 x record length

Appendix 7 37019 - Single Site Analysis (Graph)



Appendix B. Annual Maximum Flows (AMAX) at 37018 and 37019

37018 - Gaynes Park

Year	Observed AMAX Flows (m^3/s)
14-Nov-70	8.11
01-Aug-72	3.33
21-May-73	12.4
10-Mar-74	8.4
21-Nov-74	29
28-Nov-75	3.19
30-Nov-76	5.96
05-May-78	10.1
01-May-79	5.72
01-Apr-80	4.95
16-Oct-80	4.36
14-Dec-81	5.3
08-Dec-82	16.3
23-Jan-84	4.438
26-Jan-85	5.567
26-Dec-85	8.686
23-Aug-87	10.633
29-Jan-88	13.073
17-Mar-89	6.169
03-Feb-90	12.224
08-Aug-91	5.075
18-Sep-92	4.334
20-Oct-92	15.535
02-Oct-93	10.428
30-Jan-95	6.169
09-Jan-96	4.041
26-Jun-97	2.416
05-Jan-98	3.829
01-Nov-98	6.011
28-May-00	15.059
30-Oct-00	19.209
04-Feb-02	9.001
30-Dec-02	17.364

Year	Observed AMAX Flows (m^3/s)
24-Aug-04	5.668
19-Nov-04	3.731
13-Jun-06	3.237
14-Feb-07	5.351
12-Aug-08	7.443
10-Feb-09	15.237
28-Feb-10	6.931
18-Jan-11	7.366
08-Jul-12	28.778
25-Dec-12	15.57
17-Jan-14	6.418
23-Jun-16	43.3
QMED	**6.931**

37019 – Bretons Farm

Year	Observed AMAX Flows (m^3/s)
20-Jul-65	8.241
23-Jun-66	6.763
25-Jun-67	6.763
15-Sep-68	11.98
17-Dec-68	9.194
11-Mar-70	4.84
23-Jan-71	5.185
31-Jul-72	5.949
20-Sep-73	6.56
10-Mar-74	6.743
21-Nov-74	13.871
28-Nov-75	6.56
20-Feb-77	9.782
31-Jul-78	10.914
09-Mar-79	7.501
29-Jul-80	15.8
06-Aug-81	9.24
15-Jul-82	7.398
09-Dec-82	12.204
26-Nov-83	7.224
05-Oct-84	10.391
26-Dec-85	8.195
23-Aug-87	17.403
29-Jan-88	11.316
16-Mar-89	9.567
03-Feb-90	12.009
27-Sep-91	9.242
29-May-92	10.188
25-Nov-92	9.765
02-Oct-93	17.778
29-Jan-95	7.417
23-Aug-96	7.852
26-Jun-97	5.934
26-May-98	7.34
01-Nov-98	8.358

Year	Observed AMAX Flows (m^3/s)
28-May-00	8.607
08-Feb-01	11.864
31-Jul-02	11.387
30-Dec-02	14.779
07-Jul-04	7.515
17-Dec-04	7.147
13-Jun-06	7.992
14-Jun-07	7.872
26-May-08	8.276
10-Feb-09	11.84
28-Feb-10	7.892
17-Jan-11	8.174
08-Jul-12	13.502
25-Dec-12	10.57
24-Dec-13	7.34
23-Jun-16	35.1
QMED	**8.36**

Appendix C. Long Term Rainfall Statistics at nearby Rain Gauges

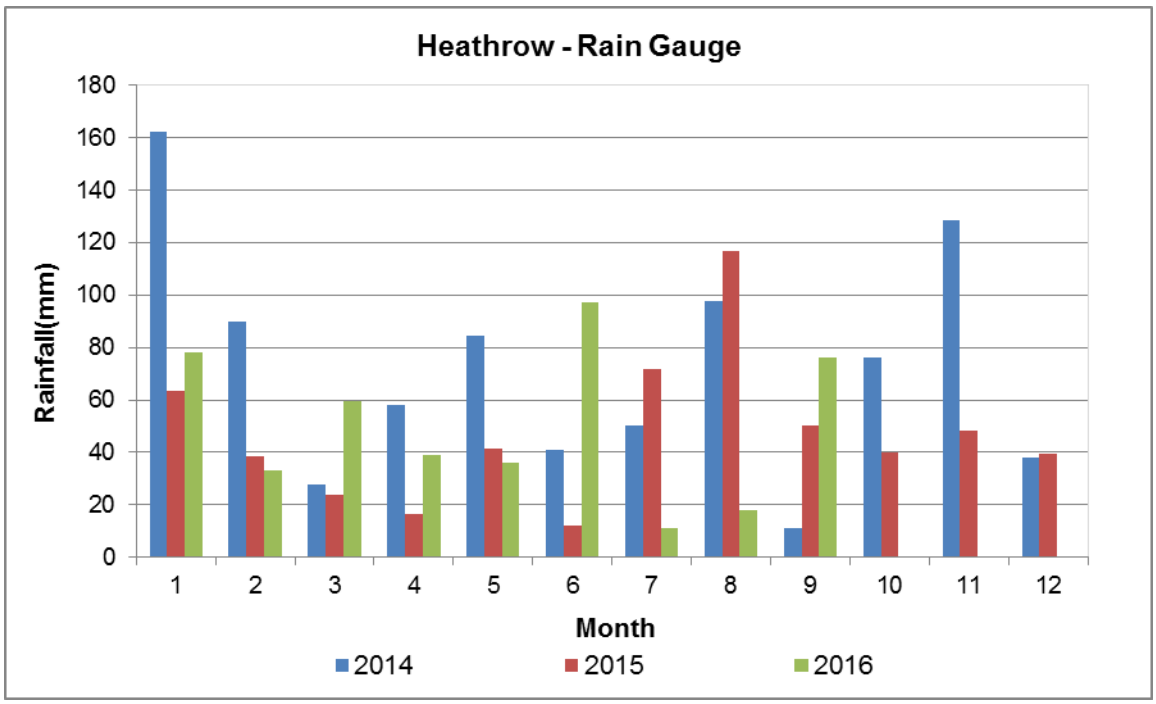


Figure 1-6: Comparison of three year rainfall data at Heathrow

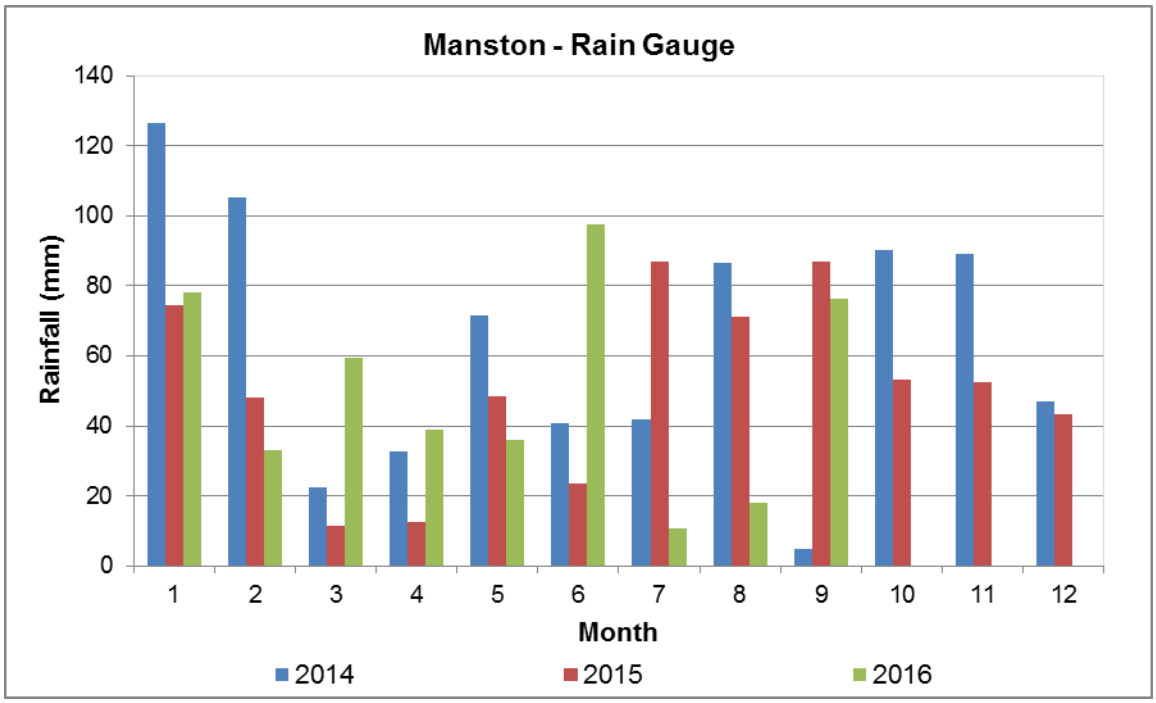


Figure 1-7: Comparison of three year rainfall data at Heathrow

Appendix E. Environment Agency flood report

Summer Thunderstorms 23 June 2016

Roding, Beam and Ingrebourne Catchments

Hertfordshire and North London Area

December 2016

We are the Environment Agency. We protect and improve the environment and make it a better place for people and wildlife.

We operate at the place where environmental change has its greatest impact on people's lives. We reduce the risks to people and properties from flooding; make sure there is enough water for people and wildlife; protect and improve air, land and water quality and apply the environmental standards within which industry can operate.

Acting to reduce climate change and helping people and wildlife adapt to its consequences are at the heart of all that we do.

We cannot do this alone. We work closely with a wide range of partners including government, business, local authorities, other agencies, civil society groups and the communities we serve.

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www.gov.uk/environment-agency

Executive summary

During the early hours of 23 June 2016, a significant thunderstorm passed over north east London resulting in 30mm of intense rain falling over the widespread area in a 2 hour period. Around 50mm of rain was recorded widely throughout the Roding, Beam and Ingrebourne catchments over 7.5 hours.

A total of 3 flood alerts and 4 flood warnings were issued on the 3 catchments in response to the rainfall, however in some locations, flooding had already affected properties. The worst affected areas included the Havering Park area on the River Rom where 180 properties were affected by both fluvial and surface water flooding. In Seven Kings 54 properties were affected by flooding, 31 of these were flooded internally. Many other communities were also affected by the flooding. These are listed in detail in section 2 of this report.

Our field teams were out across the area clearing trash screens and river blockages to ensure that, wherever possible, rivers and streams were flowing freely. Field incident support officers (FISOs) were deployed to flooded areas throughout the event recording property flooding and capturing the physical extents of flooding on the ground, and delivering key information to affected communities.

Since the flooding, we have been reviewing our flood warning thresholds at our gauging stations so in future, our flood warnings are timelier. We have also worked closely with the London Borough of Havering to engage with the local communities that were affected to increase resilience to flooding in future.

Contents

1. Introduction

June was an extremely wet month in the Hertfordshire and North London area which received 193% of the long term average (LTA) rainfall for June.

The North London catchments recorded notably high rainfall, while the Lower Lee recorded above normal rainfall. The Roding catchment recorded notably exceptionally high rainfall at 136mm (237% LTA) which was the wettest June on record since 1910.

Heavy thunderstorms occurred throughout the month, with the worst on 22 and 23 June 2016. The largest daily rainfall total of 56.6mm was recorded on 22 June at Stanford Rivers rain gauge within the Roding catchment. Half of this fell within an hour between 2am and 3am.

The Soil Moisture Deficit decreased throughout June in the Lee Chalk and Roding Catchments but continued to increase in the rest of the catchments. Despite this, all of the catchments ended the month with a soil moisture deficit smaller than the long term average.

Our river flow indicator sites located within the chalk catchments all recorded normal monthly mean flows. The River Crane, River Ingrebourne and River Roding recorded exceptionally high flows.

In response to the heavy thunderstorm a peak in river flows was seen across the Area on 23 and 24 June. The River Roding at Redbridge recorded the largest average flow monthly flow for June at 3.7 cumecs.

There were 27 flood alerts and 15 flood warnings issued for the Area throughout June. They were all issued in the clay and urban catchments with the majority (8 alerts and 10 warnings) issued on 23 June.

Overall, more than 460 properties were affected by flooding between 22 and 24 June on the Rom, Roding and Ingrebourne catchments. During this period, 81 properties suffered internal flooding. Of these, 48 flooded from main rivers. The remainder were flooded by a combination of surface water and flooding from ordinary watercourses. Over 390 properties had limited access to their properties with gardens and roads flooded.

We issued 3 flood alerts and 4 flood warnings over these catchments with mostly the fast responding urban catchment areas affected on 23 June.

Staff from across the area worked on the flood event, either in the incident room to manage our response, out in the field clearing rivers and monitoring the flooding, or taking calls and social media messages from those affected. During the flooding our staff collected data direct from flooded locations, to help increase our understanding of what had happened.

We held debriefing sessions to capture detailed feedback from our staff about the wide range of tasks they performed during the incident. We attended debriefing sessions held by our professional partners and held community flood surgeries to gather further information on the flood event. These sessions provided an opportunity to inform local residents about our flood warning service and to offer advice on flood resilience measures that could be taken.

By learning from our experiences, we aim to maintain and improve the quality of our response to future incidents in Hertfordshire and North London.

This report details the circumstances of the floods on the Roding Beam and Ingrebourne catchments and the actions we took to mitigate the direct effects and manage the aftermath, including the continuing reduction of flood risk in the future.

2. What happened?

2.1. Weather

June 2016 was an exceptionally wet month in Herts and North London, with frequent heavy thunderstorms over the area leading to an average of 104mm of rainfall over the month. This was nearly double (193%) the long term average for June.

The Meteorological Office issued a heavy rainfall alert to the Hertfordshire and North London and Kent and South London Areas during the early evening of 22 June 2016 for the time between 8pm on 22 June and midday on 23 June. The forecast was for torrential thundery downpours to affect the region from Wednesday evening and overnight into early Thursday morning, with an increasing chance of these towards the South East of the region around south east London and Kent. At the time of issue, there was high uncertainty in the exact spatial distribution of the largest rainfall totals through the period, with event forecast average rainfall of 25mm of rain and a maximum of 80mm over north London and Hertfordshire. During this event, there was medium confidence (40-60%) of 10mm or more rain in 1 hour or less, and medium confidence of 30mm or more of rain in 12 hours or less.

Up to 40mm in 1 hour and 80mm in 6 hours was forecast, especially in the far south-east of the region in Kent and south London. Event totals had low confidence.

An update at 8:45pm on 22 June was issued extending the event time, to cover the remainder of Thursday morning as showers were forecast to remain heavy throughout the period.

Figure 1: The counties affected by the heavy rainfall alert, and probability of rainfall thresholds being breached

On 23 June 2016 at 7am, a new heavy rainfall alert was issued, for the period 1pm till 10pm. An area of further showers was expected to spread in to the region from the English Channel during the afternoon and evening. Showers had the potential to be aligned into bands bringing high local rainfall totals. There was a very low likelihood of that an isolated location could see 50mm in 6 hours where more than one storm affects the same place. Most showers were forecast to die away by late evening. During this afternoon's event an average of 15mm and maximum of 40mm was forecast with medium confidence of 10mm or more rain in 1 hour or less, and low confidence 20-40% chance of 30mm or more of rain in 12 hours or less.

A further update was made at 4pm, extending the event end time to midnight on 23 June 2016.

According to the Flood Guidance Statement issued on 22 June, the torrential thundery downpours gave a low likelihood of significant river flooding impacts and a low overall flood risk, if thunderstorms were to fall over the fast responding, urban catchments. Potential impacts forecast included flooding affecting properties, and parts of communities, disruption to key sites identified within flood plans and travel with a number of road closures possible.

The Flood Guidance Statement also brought a medium likelihood of significant surface water flooding impacts in the far south east of England from Wednesday evening into Thursday morning particularly if thunderstorms were to fall over urban areas.

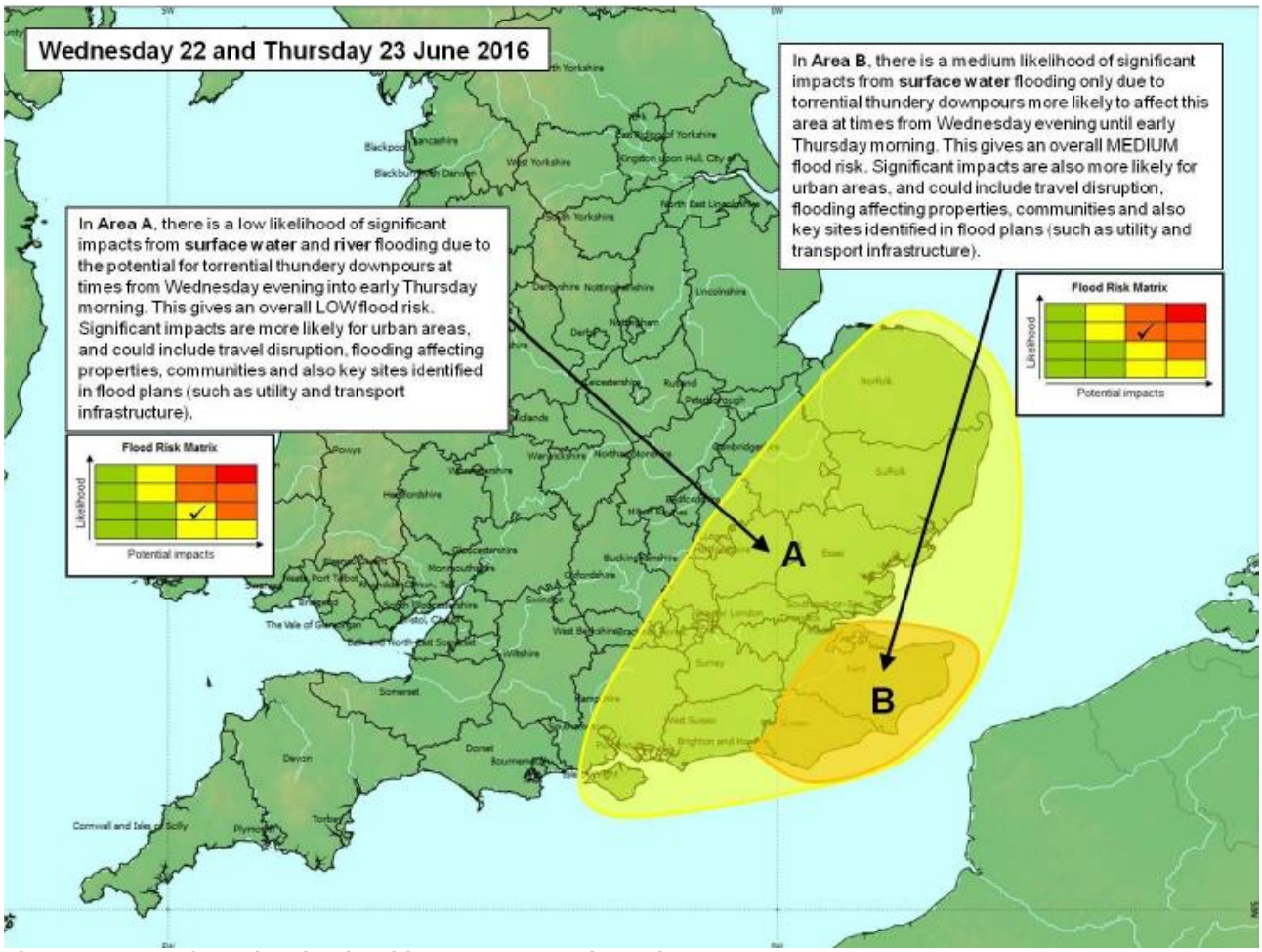

Figure 2: A map from the Flood Guidance statement issued at 10:00 on 23 June 16

The heaviest of the storms occurred on the evening of 22 June and into the morning of 23 June affecting the far eastern and western London catchments. In the east, a total of 52.2mm of rain was recorded at the Environment Agency's Central Park rain gauge over the Roding and Rom catchments. The rain gauges located at Gascoigne Road recorded 50mm and Stanford Rivers gauge recorded 56.8mm both on the Ingrebourne catchments. Intensities at these sites recorded maximum totals of 9.4mm and 14.5mm in 15 minutes giving a good indication of torrential downpours over a short period of time.

2.2. Flooded communities

The tables, maps and text in this report outline the events of the June 2016 floods in HNL. This assessment is based upon data collected by our Field Incident Support Officers and other staff on the ground, photographs collected from various sources, and from information passed to us by the public. The data therefore represents the facts to the best of our knowledge. Where we have shown flood extents, the outline represent the area of land thought to have flooded, it should not be assumed that properties within this outline were flooded internally.

This report will go through the affected catchments in HNL, and look in further depth at the flooded communities.

Table 1: table of communities most affected by flooding, as reported to the Environment Agency

Affected Road/Community	Catchment	Properties flooded internally	Properties flooded externally only
Frinton Road	Rom	4	46
Lodge Lane	Rom	11	12
Turpin Avenue	Rom	0	1
Taylor Close	Rom	0	5
Penn Gardens	Rom	10	0
Carter Drive	Rom	0	54
Carter Close	Rom	0	16
Collier Row Road	Rom	5	0
Asten Way	Rom	4	0
Cross Road	Rom	0	2
Abbotts Close	Rom	0	16
Gorse Way	Rom	0	49
Upper Rainham Road	Rom	1	0
Hillmans Cottages	Roding	0	0
Chester Road	Seven Kings	5	15
Spencer Road	Seven Kings	23	6
Westrow Drive	Mayes Brook	0	30*
Steven Jewers Gardens/ Upney	Mayes Brook	0	5*
Westminster Gardens	Mayes Brook	0	24
Waverley Gardens	Mayes Brook	0	34
Frimley Avenue	Ingrebourne	0	31
Hacton Lane	Ingrebourne	0	1
Reginald Road	Ingrebourne	0	1
			*approximately

2.3. Roding, Beam and Ingrebourne catchment

The Roding, Beam and Ingrebourne catchments cover around 520km² extending from the Thames to Epping in the west, Brentwood and Thurrock in the east and Stansted in the north.

The upper reaches of the catchments comprise rural farmland. Here, some stretches of the rivers have been modified for mills and agriculture. Further downstream, the rivers encounter highly urbanised areas such as Ilford, Barking, Dagenham and Romford. Here, rivers have been modified to accommodate major transport infrastructure such as motorways, other major roads, railways and flood defences.

The impermeable geology within the catchments influences the rivers' base flows, how they behave to rainfall events and the amount and type of sediment. Generally, the rivers have a 'flashy' response to any rainfall, meaning water reaches the rivers quickly due to urbanisation and the limited amount of water that can be stored within the soils. This is particularly noticeable when the ground is already saturated.

Each of the sub-catchments affected by flooding in this catchment are considered in turn below.

2.3.1. The River Rom

The River Rom is a tributary of the River Beam. It is Main River from the northern side of Romford until it joins the River Beam at Eastbrookend Country Park. Our records show that there were 3 main locations affected by flooding during this event. Their locations are shown in Figure 3 below and the affected areas are discussed in more detail in the following section.

Flood warning information

The Environment Agency have the ability to monitor river levels at two locations on the River Rom, approximately 2.5km downstream of Collier Row Road in Romford and approximately 2km downstream of Gorse Way at Bretons Farm. These sites are where we set our flood warning thresholds in relation to the surrounding area and property levels.

To some extent this means that we often rely on our partners and the public to report flooding where it happens elsewhere in the catchment.

While the river level information we received from our systems did not indicate that the river was out of its banks, we did receive information from the Fire Service and the public that this was the case, so we issued a flood warning. Before the flood warning was issued, staff at Floodline answering phone calls from the public were not aware that there was flooding from the river in the local area.

As a result of this extreme rainfall event, our level gauge on the River Rom in Romford recorded 1.32m. This is the highest level recorded by this gauge since it was installed in 2006. The data we have received from the recent rainfall events in this area is helping us to review our flood warning trigger levels so they provide better warning in future.

Table 2: Flood alerts and warnings issued on the Rivers Beam and Rom

Type	Target area code	Flood alert or warning name	Description	Date and time issued
Flood alert	062WAB55BeamRom	The Rivers Beam and Rom	The Rivers Beam and Rom at Romford, Hornchurch, Dagenham and Rainham	09:41 23 June 16
Flood warning	062FWF55Romford	The River Rom at Romford	The River Rom at Romford including Rush Green	08:18 23 June 16

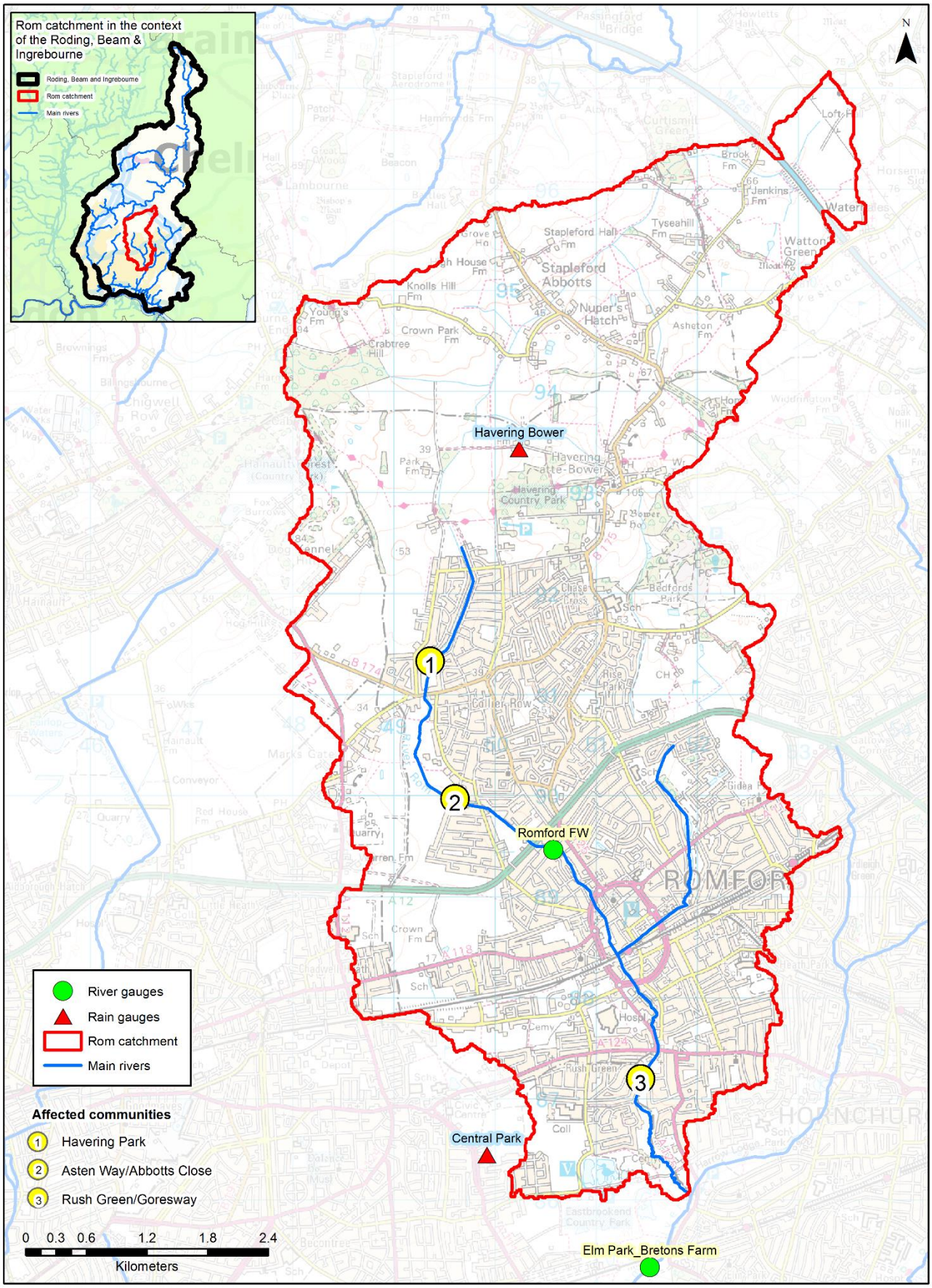

Figure 3: Map showing communities affected by flooding in the River Rom catchment

1. Havering Park, Romford

During the early hours of 23 June, a significant thunderstorm passed over the Romford area resulting in 30mm of intense rain falling over the area in a 2 hour period. A total of 52mm of rain was recorded over 7.5 hours at the nearby Central Park tipping bucket rain gauge. The River Rom and adjoining surface water sewers had insufficient capacity to cope with the surface water run off which resulted in flooding to the local area.

Figure 4: A map of the Havering Park area showing the extent of flooding 23 June 16

Environment Agency Field Incident Support Officers (FISOs) went to the Havering Park area and were able to discuss and confirm flood impacts with many affected residents. Additional information was obtained from London Fire Brigade (LFB) who had a large number of resources in the area, both pumping water away from properties and evacuating residents. Access to the general area was difficult due to the ongoing emergency response and the wide extent of the flooding. Several streets were revisited by FISOs after the London Ambulance and Fire Services had left the area and access was possible.

Figure 5: A map showing the flood extent on Frinton Road, Lodge Lane, Taylor Close and Penn Gardens, Romford, 23 June 16

Frinton Road

FISOs liaised with many residents of Frinton Road to confirm the flood extent which affected 46 property gardens and driveways. The floodwater originated from drainage ditches in fields to the north west of Frinton Road where it pooled to the rear of properties on the north side, before flowing south through alleyways between houses to low points on Frinton Road.

There was evidence of internal flooding on the north side of Frinton Road, where 3 properties were affected. The road level is lower than the surrounding property level so water pooled on the road and flowed east towards the adjoining low point on Lodge Lane. One property on the south side of Frinton Road was flooded internally, but a number of other gardens and driveways were affected. LFB were evacuating residents of Frinton Road by boat.

Figure 6: Photo showing surface water on Frinton Road at 12:42pm, 23 June 16. The emergency services carrying out a media interview. LFB evacuated residents to safety by boat. Taken from the Frinton Road/Lodge Lane junction, facing west.

Lodge Lane

On Lodge Lane 23 properties were affected by flood water. Eleven residents on the east side of Lodge Lane were internally flooded, claiming the floodwater came from Frinton Road to the west. Surface water gathered in a large depression on Lodge Lane, adjacent to Frinton Road as it flowed east over drive ways through to rear gardens, making its way to Penn Gardens via Taylor Close.

In Turpin Avenue, one property garden was flooded.

Taylor Close

In Taylor Close, residents confirmed garden flooding at 5 properties where water flowed to the south side of the road.

Penn Gardens

At Penn Gardens, 10 properties flooded internally. Residents of 4 properties on the western side of Penn Gardens were evacuated due to deep water pooling in and around properties. The property level is significantly lower in this area than road level. Water was being pumped from the properties into the River Rom by the fire brigade.

Figure 7: Photo showing properties on Penn Gardens at 12:19pm on 23 June 16. These properties had been evacuated by LFB and were being pumped out.

Carter Drive and Carter Close, Romford

Figure 8: A map to show the flood extent on Carter Drive and Carter Close, Romford, 23 June 16

To the east side of the River Rom on Carter Drive, there was evidence of 54 properties flooding from surface water, however no water reportedly entered properties. It is thought that surface water runoff from Dominion Drive and Lynwood Drive increased the volume of surface water on Carter Drive where it gathered and pooled. Resident's photos showed that flood water rose to approximately 400mm in centre of the street on Carter Drive.

Further south at Carter Close, 16 gardens were flooded by high levels on the River Rom. Evidence showed that the Rom came out of banks in this location, with depths of approximately 800mm recorded, however no internal flooding was observed by the public.

Collier Row Road, Romford

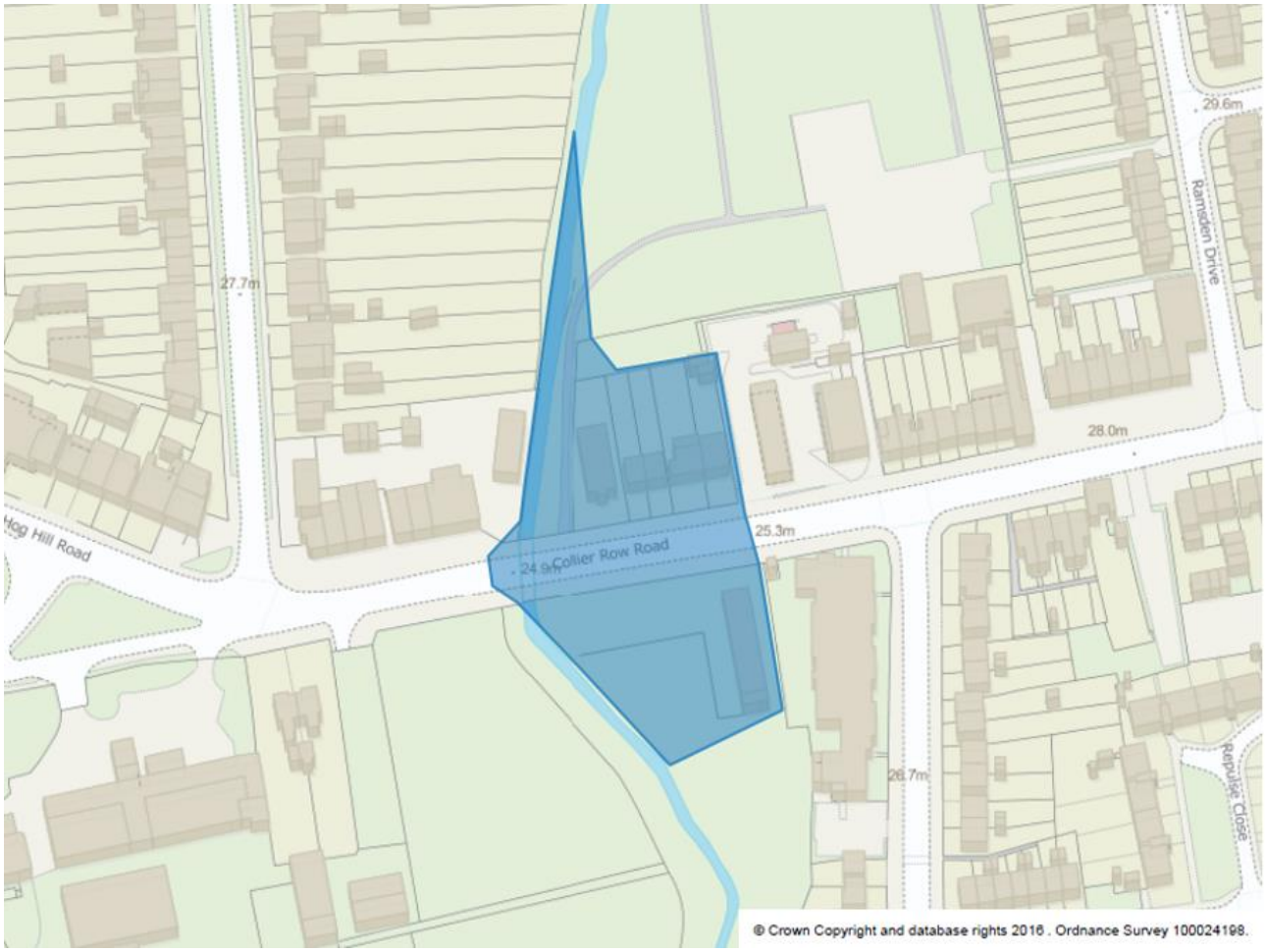

Figure 9: Map, Showing the estimated flood extent at Collier Row Road, Romford, 23 June 16

The River Rom flows underneath Collier Row Road through a culvert, located at the southern end of Lodge Lane. The main cause of flooding on Collier Row Road was the culvert capacity being exceeded by high river levels during this event. This caused water to backup, upstream of the bridge and come out of banks flooding properties and the road on Collier Row Road including the Scout group hall and grounds on the south side of the road. This road was closed to traffic for several hours. Our operational teams, who were working in the local area, reported no evidence of any blockages in the channel. The flood extent shown is based on reports of flooding and photos received from residents.

Water also reportedly came out of river banks at the recreation ground to the rear of Collier Row Road and is believed to have contributed to the flooding of properties. Four residential properties, the Gospel Hall and the Scout hall flooded internally on Collier Row Road.

2. Asten Way, Abbotts Close, Romford

Figure 10: A map showing the estimated flood extent at Asten Way, Romford, a new housing development, 23 June 16

Asten Way is a new development of 4 houses located off Cross Road, Romford. All 4 properties in Asten Way were flooded internally. The flood extent in this area is based on photos received from a resident of Asten Way.

Cross Roads Flood Storage Area (FSA) lies to the rear of Asten Way. In 2010, a hydrological study carried out by the Environment Agency was independently reviewed and accepted by the inspecting reservoir panel engineer showing that the FSA offers no additional flood risk benefit in comparison to natural flood plain, acting as effectively as natural floodplain with no increase in flood risk downstream.

Works were carried out to remove a section of the reservoir embankment in the downstream riverside corner to maintain a natural flood basin. It is thought that the river came out of banks at this breach location and entered Asten Way at the low point of the embankment, although further investigation is required to confirm the cause.

Upstream of the FSA, the river was observed coming out of banks and flowing through Crownfield School playing fields but did not enter the school buildings.

At least 2 properties were affected externally by floodwater from the Rom on Cross Road and one on Mawney Close. We also received a report of flooding at one property in Linley Crescent. Isolated surface water flooding was reported at one property at Northill Drive and Roslyn Gardens, Romford, but these are unconfirmed.

Figure 11: Photo from resident of Asten Way, showing flooded properties on Asten Way, Romford, 23 June 16

Abbotts Close

Garden flooding occurred to up to 16 riverside properties according to a resident in Abbotts Close, however FISOs were unable to attend the site to confirm this.

Figure 12: A map showing the estimated flood extent at Abbotts Close, 23 June 16

3. Rush Green/Gorseway

Figure 13: A map showing the flood extent at Gorseway, Romford, 23 June 16

Several reports of flooding were received from residents and the Fire Service in Gorseway which triggered us to issue a flood warning to the River Rom at Romford flood warning area. Our river level gauging station 2.5km upstream of Gorseway did not indicate that the river was out of its banks, so we wanted to assess the impacts and extent of flooding in the Gorseway area.

When FISOs arrived on site, residents of Gorseway informed the Environment Agency that their gardens had flooded several hours before they received an Environment Agency flood warning.

Flooding affected 49 rear gardens of properties adjacent to the Rom on Gorseway, however no internal flooding occurred to houses, although outbuildings in the gardens to the rear of a number of these properties were flooded.

It is thought that the river came out of banks at the YMCA as there was evidence showing floodwater had flowed south across the car park, towards property gardens on Gorseway.

Following investigations after the flooding in 2012, the London Borough of Havering completed works to raise a low point in the west bank around the sewer pipe upstream of Gorseway near the YMCA. The Environment Agency have not made any specific improvements to the main river channel since 2012.

An embankment on the west side of the Rom at Gorseway means that water is not able to drain back into the river, so it pools southwards until it reaches a breach in the embankment at the southern end of Gorseway.

Threshold levels at Romford flood warning telemetry site, have been reviewed since the June flood event and have been lowered based on the flooding that happened at Gorseway. This means that our flood warnings will be triggered at a lower river level being reached in future.

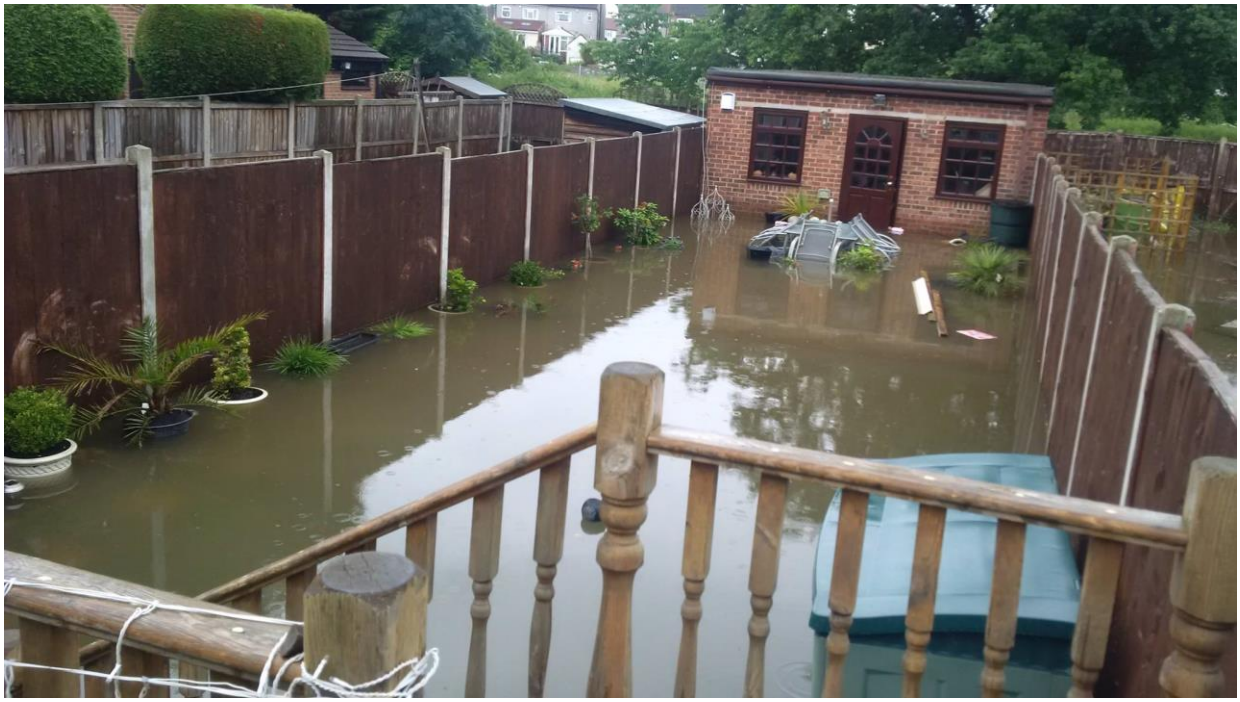

Figure 14: Photo showing a property garden affected by flooding on Gorseway. Water levels are representative for other properties on Gorseway affected by high river levels on the Rom, 23 June 16.

Maylands Health Care, Upper Rainham Road.

Maylands Health Care centre lies at the confluence of the River Ravensbourne and River Rom. The health care centre was internally flooded, with flood water also affecting the car park. It is thought that the Ravensbourne came out of banks upstream of the medical centre near the boating lake at Harrow Lodge Park, although no Environment Agency staff were able to visit this location during the event to confirm this. Due to the uncertainty of exactly where the source of flooding came from, and the area of land that was affected, we have not been able to determine the flood extent in this area.

Further downstream of Upper Rainham Road, reports of river flooding to one garden in Western Avenue, Rainham, and 3 property gardens in Lower Mardyke Road, Rainham were received, however FISOs were unable to attend these areas to confirm the impacts.

Operational Information.

Washlands Flood Storage Area located in Dagenham, was used to store flood water flowing down the rivers Rom and Beam. Water was stored during high tide to prevent flooding to properties downstream of the FSA and then released downstream to the Thames where it could evacuate safely at low tide.

River Rom Catchment investigations and Recommendations:

The Environment Agency have commissioned modelling projects to better understand the areas at risk of surface water and fluvial flooding, in response to a range of different rainfall events. We are working with London Borough of Havering to investigate the causes of flooding to identify catchment wide options for alleviating flood risk throughout the Rom, Beam and Ravensbourne catchments.

At Cross Roads decommissioned flood storage area, we are investigating what caused the flooding at Asten Way through modelling studies so we are able to understand why the flood water responding in a way that wasn't expected during the decommissioning stage. The study will help us plan any remedial works to the local area to reduce the risk of flooding downstream of the site.

We are keen to work closely with the affected communities to encourage them to create flood plans, so whole communities at risk are better prepared and more resilient to flooding in future. We are currently in touch with Maryland's Medical Centre of Upper Rainham Road in Hornchurch to help their community do this and are looking for opportunities to engage with interested parties in other affected locations.

The public can play an important role that can contribute to reducing local flood risk. Riverside property owners can ensure gardens are well maintained by cutting back and clearing any overgrown vegetation on the river bank that may be obstructing flows. Blockages within the river channel that may increase flood risk, or high river levels or flooding to infrastructure or properties can also be reported to the Environment Agency by contacting the Incident Hotline on 0800 80 70 60.

2.3.2. The River Roding and Seven Kings Water

The Upper Roding flows through undeveloped countryside as a predominantly natural river system. The Middle and Lower Roding stretches are much more developed flowing though the heavily urbanised areas of Woodford, Wanstead, Ilford and Barking.

At the confluence of the Roding and the Thames, the Barking Barrier protects the Roding catchments from tidal flooding, operating in conjunction with the Thames Barrier.

Seven Kings Water (also known as Loxford Water) is a tributary of the Roding. It flows through the urban areas of Seven Kings and Loxford before joining the Roding in Barking.

Our records show that there were 2 main locations affected by flooding during this event. Their locations are shown in Figure 15 below and the affected areas are discussed in more detail in the following section.

Flood warning Information

The Environment Agency have 7 gauging stations that are used to monitor river levels on the River Roding. During this event, telemetry triggered flood alerts to be issued for the whole of the Roding catchment. Flooding to property was recorded on the Mayes Brook and Seven Kings/Loxford Water, both tributaries of the lower river Roding. No telemetry is currently located on these tributaries, therefore the flood warning service is limited to flood alerts.

Table 3: showing flood alerts issued on the river Roding catchment

Type	Target area code	Flood alert or warning name	Description	Date and time issued
Flood alert	062WAF54UpRoding	The Upper River Roding	The Upper River Roding including Molehill Green, Dunmow, Ongar, Fyfield, High Ongar and Stapleford	3:47pm 23 June 16
Flood alert	062WAF54MdRoding	The Middle River Roding	The Middle River Roding including Abridge, Loughton and Buckhurst Hill	5:37am 23 June 16
Flood alert	062FWF54LwRoding	The Lower River Roding	The Lower River Roding including Redbridge, Woodford, Wanstead, Ilford, East Ham and Barking	10:43am 23 June 16
Flood alert	062WAF54Cripsey	The Cripsey Brook	The Cripsey Brook including Thornwood Common, North Weald Bassett, Moreton and Chipping Ongar	8:18am 23 June 16

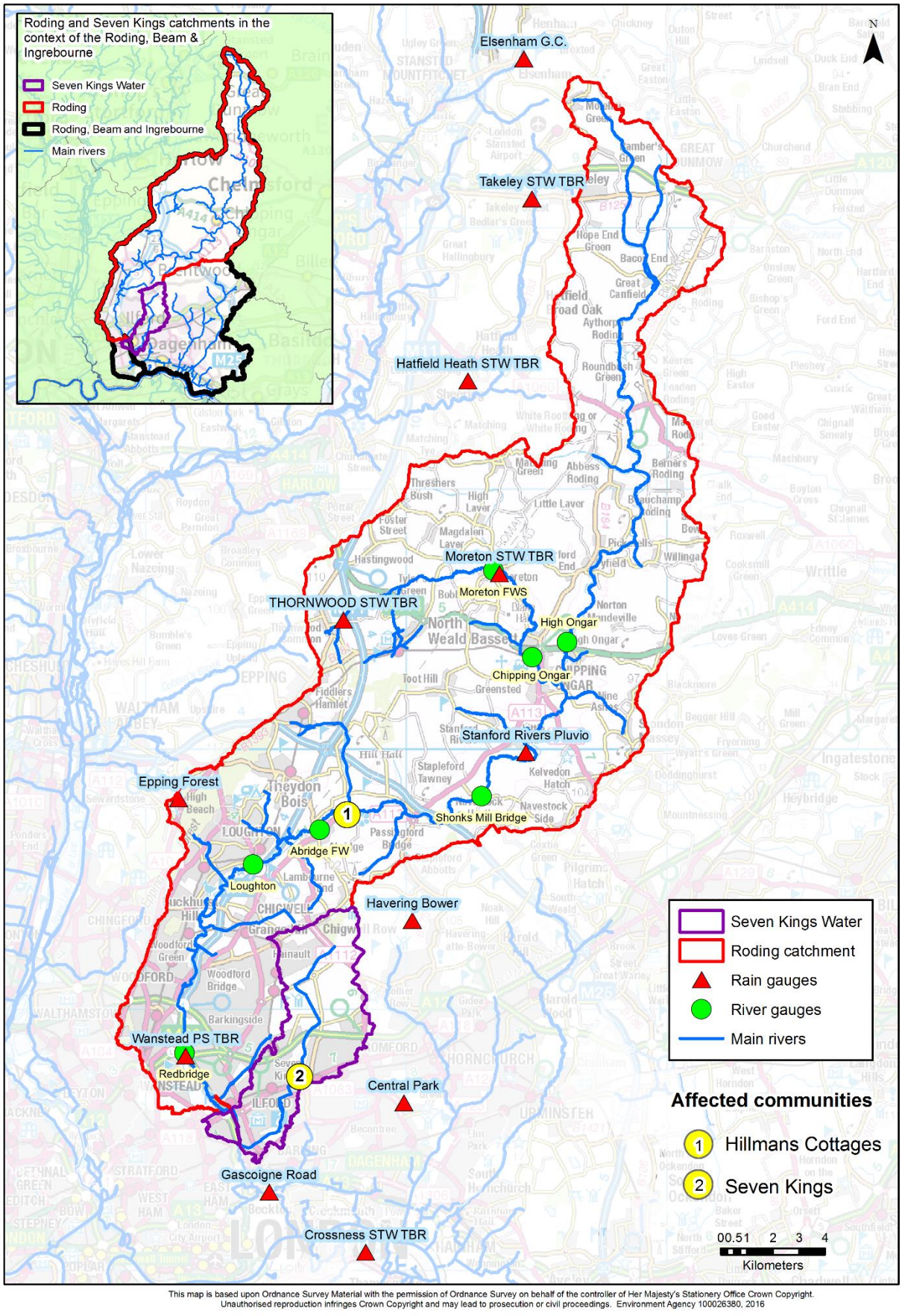

Figure 15: Map showing communities affected by flooding in the River Roding catchment

1. Abridge, Hillmans Cottages

Residents of Hillmans Cottages, located upstream of Abridge, stated that some of their gardens flooded, however no property flooding occurred. The culverts that flow to the front and parallel to the cottages were about 500mm deep, and water remained within the channel.

High water levels were observed on the River Roding at Abridge. At the bridge at Abridge, looking upstream, the river level had reached the top of the second stage channel and had flooded a relatively small area of the field on the north side following the B192 north. Flooding was similar on the downstream side on the north side of the river. There was no evidence of river flooding on the built up, south side.

Further south in Loughton, one isolated riverside property on Roding Road reported internal flooding from the Loughton Brook. No FISOs were available to confirm impacts.

Operational info:

Operational teams went to Hillmans cottages to ensure pumps were working correctly to remove ponding water in residential gardens. Successful pumping was confirmed at 10:25am, 23 June 2016.

Figure 16: A picture showing high water levels looking down steam at Abridge, 23 June 16

Figure 17: A picture showing high water levels looking up stream at Abridge, 23 June 16

2. Seven Kings

Figure 18: A map to show the flood extent in the Seven Kings Water area, based on information received from residents and observations made by FISOs and LB Redbridge.

Flooding of the Seven Kings Water area originated from Seven Kings Water Main River that flows south through Westwood Recreational local park where the river enters an 1800m culvert in the park.

There was evidence of a lot of vegetation, debris and broken branches in the watercourse leading up to the culvert which is likely to have contributed to blocking the culverts entrance and resulting in water backing up and flooding nearby residential streets. Our local rain gauges on the Roding catchment recorded totals up to 52mm of rain at Gascoigne Road which also recorded a maximum 15 minute total of 14.5mm of rain giving a good indication of the intense rainfall. Other nearby sites recorded totals of 52.8mm at Wanstead and 56.8mm at Stanford.

We suspect with heavy rain, the culvert can easily become blocked with debris, litter and vegetation that may be washed down the river during high flows. There was too much water and not enough capacity in the culvert to drain away before flooding occurred.

Water gathered and pooled in Westwood Park. The Fire Brigade estimated the volume to be around 11 million litres. Water flowed southwards into adjacent residential gardens in Chester Road and via a passageway by St James Court in the top corner of Spencer road, where it flooded 2 properties before flowing underneath houses and through the airbricks of multiple properties along Spencer Road.

Figure 19: A photo showing flooding to Westwood Park, where the river came out of banks, 23 June 2016

Flood water flowed farther south along Spencer Road where it caused flooding on the A110 High Road, affecting commercial car parks on the south side of the road up to the railway line. No water entered commercial premises. The police closed the end of Spencer Road to traffic due to the depth of water making it impossible to cross safely.

Police, fire services and the London Borough of Redbridge were present in the area during the flooding. Sandbags were distributed to a number of affected residents. Staff from the Environment Agency and the London Borough of Redbridge spoke to a number of residents on Spencer Road and Chester Road to confirm flooding details, however it was not possible to make contact with a number of affected residents.

Figure 20: A photo showing flood water looking north along Spencer Road. Water is flowing south towards the A118 High Road, 23 June 16.

Shortly after the flooding, FISOs worked with London Borough of Redbridge to carry out a door knocking exercise to gather more information about the impacts of flooding from residents.

There were many residents who were not at home but some impacts were observed due to water damaged furniture and sandbags being left in their front gardens. Questionnaires were delivered to houses in Spencer Road, and Chester Road, and around 40 were returned, helping to clarify the impacts and which properties were affected.

In the Seven Kings Water catchment, a total of 28 properties flooded internally and 21 were flooded externally, with the worst affected road being Spencer Road where 23 properties flooded internally and 6 external. Records show that water was between 30mm to 50mm deep, entering through doors and air bricks, damaging carpets, furniture and electrics.

Upstream of Seven Kings, 2 riverside properties reported internal and garden flooding on Eastern Avenue, Ilford, however FISOs were unable to visit these properties to confirm impacts.

Investigations to improve flood risk in the Seven Kings area.

Modelling studies have been commissioned by London Borough of Redbridge to better understand surface water and fluvial flows from Loxford Water. This study aims to inform the options for using Westwood recreation park for flood storage.

2.3.3. Mayes Brook catchment

The Mayes Brook is a small tributary of the Roding in Barking. It flows through Mayesbrook Park and the urban area of Barking, before joining the Roding downstream of the A13.

Our records show that there were 2 main locations affected by flooding during this event. Their locations are shown in Figure 21 below and the affected areas are discussed in more detail in the following section.

Flood warning Information

No telemetry is currently located on the Mayes Brook tributary, therefore the flood warning service is limited to flood alerts. A flood alert for the Lower River Roding was issued which also covers properties at risk on the Mayes Brook.

Table 4: showing flood alerts issued on the river Roding catchment

Type	Target area code	Flood alert or warning name	Description	Date and time issued
Flood alert	062FWF54LwRoding	The Lower River Roding	The Lower River Roding including Redbridge, Woodford, Wanstead, Ilford, East Ham and Barking	10:43am 23 June 16

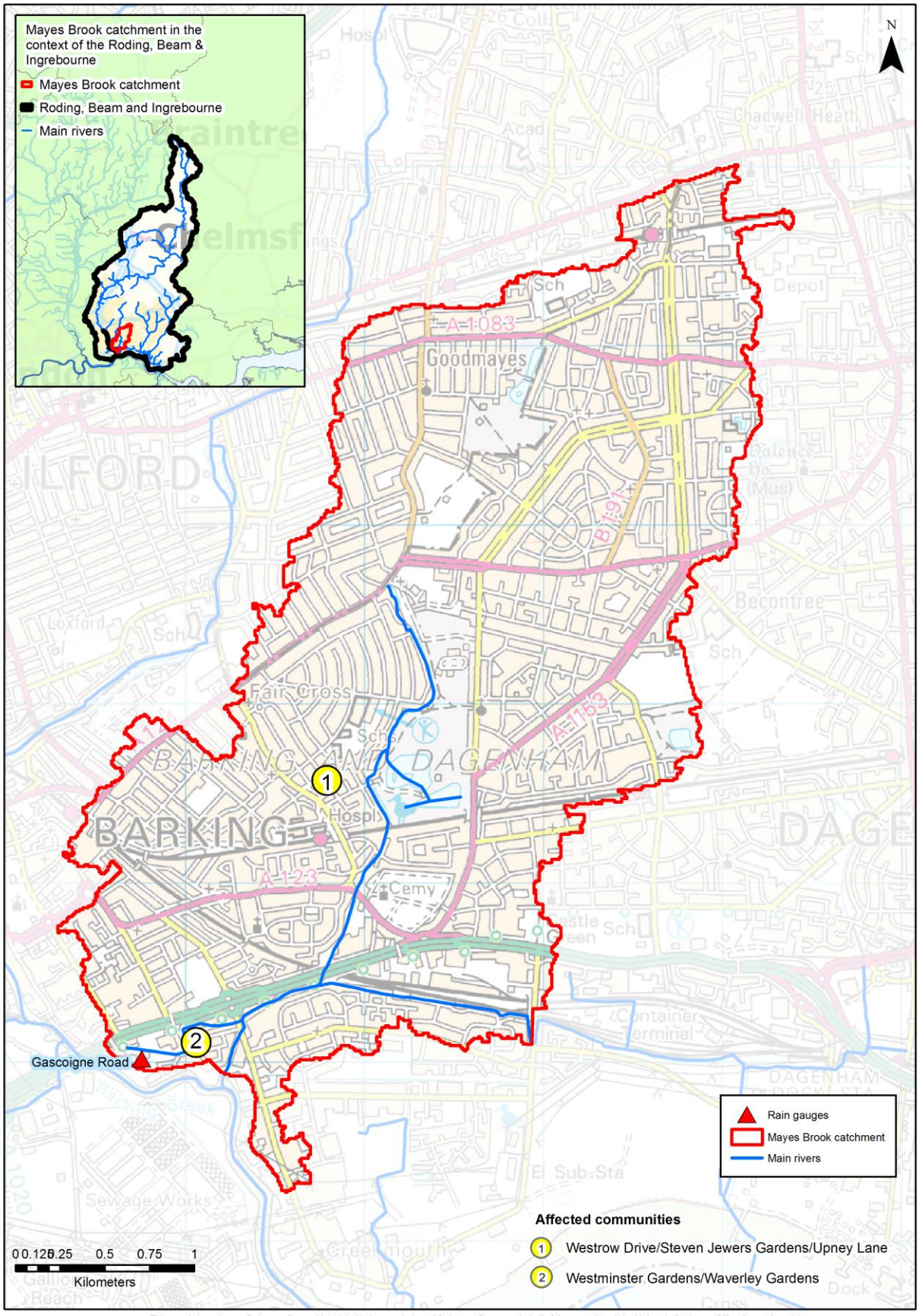

Figure 21: Map showing communities affected by flooding in the Mayes brook catchment

1. Westrow Drive and Steven Jewers Gardens/Upney Lane

Figure 22: A map showing the known flood extent in the Upney area, 23 June 16

The London Borough of Barking and Dagenham reported flooding to up to 30 properties in this area, but we have been unable to confirm the exact locations of those properties affected and impacts. The key areas we know that were affected include Westrow Drive, Manor Road, Claire Gardens and Steven Jewers Gardens.

The full flood extent in the Mayes Brook Park/Upney area was difficult to determine by Environment Agency staff, due to staff arriving after the flood water had subsided and a road sweeper cleaning the street of debris left by flood water. Some residents helped to indicate some of the affected properties and impacts.

Operational information:

11:30am 23 June 2016 Mayes Brook gates were lowered to provide additional storage at Mayes Brook Park

Figure 23: Photo taken by local resident taken on the morning of 23 June 16. Facing south west on Westrow Drive looking towards the junction of Manor Road and Westrow Drive showing road flooding along Westrow Drive.

There was evidence of flooding on Steven Jewers Gardens, including a strong odour, silt and sewage litter remnants. There was a stranded vehicle, the owners of which indicated that gardens within the area had been flooded.

Figure 24: Photo taken at 4:43pm on Steven Jewers Gardens. Looking northwest towards the junction with Westrow Drive. Strong odour on site. Evidence of flooding from silt remnants in road. Note water line on stone banking, (orange line) approximately 0.5-0.7m up from road level.

2. Westminster Gardens and Waverley Gardens

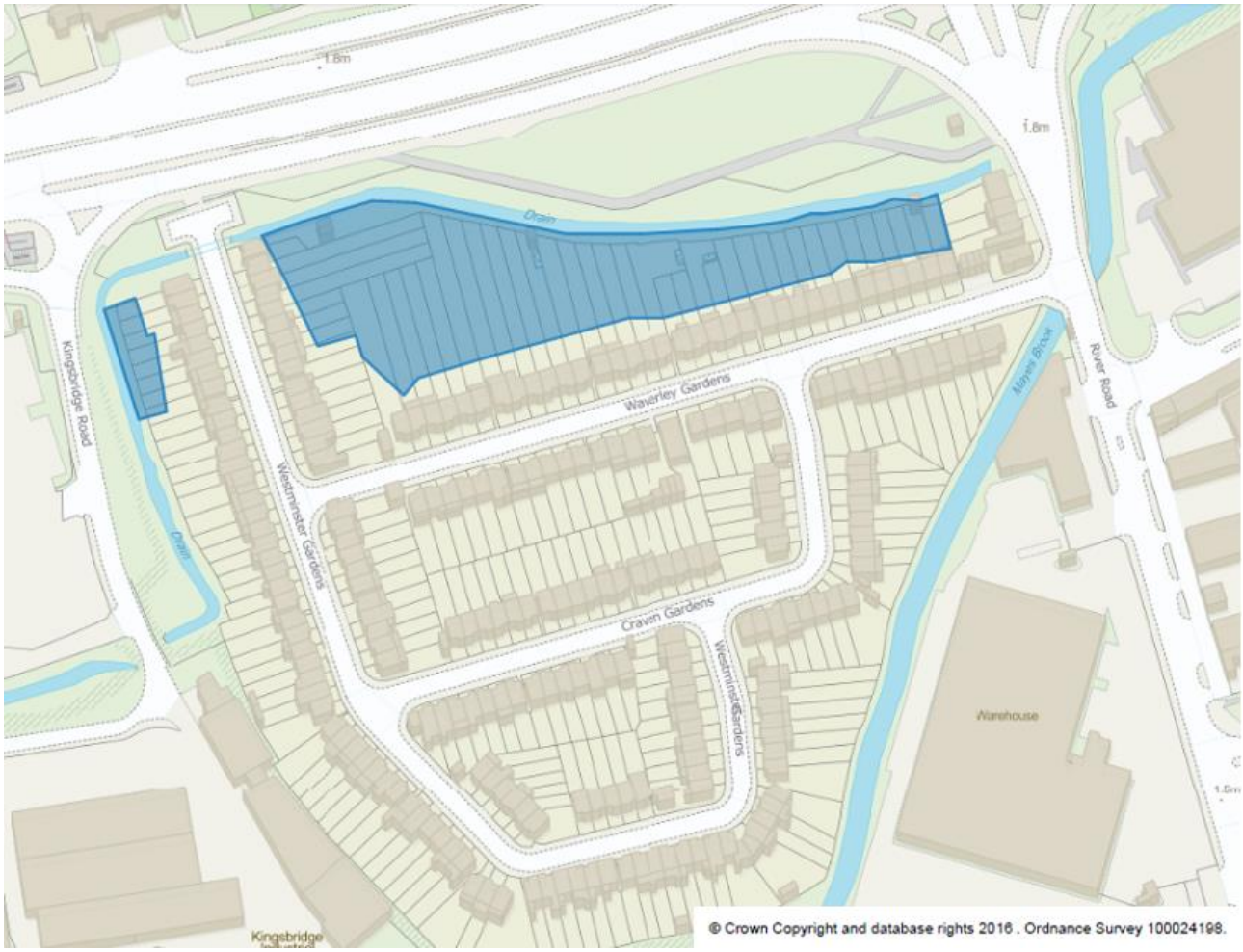

Figure 25: A map to show the flood extent at Waverley Gardens and Westminster Gardens

Westminster Gardens

Rear gardens of 24 properties flooded only.

Residents reported that on Thursday morning their gardens and sheds were flooded 30cm to 70cm deep. Flooding did not enter properties due to the slope of their gardens and in most cases raised patio areas next to the back door of properties.

Waverley Gardens

Rear gardens of 34 properties flooded only.

Residents reported flooding on Thursday morning and Thursday evening. Dependent on the length of the garden and terracing this affected either the bottom end of the garden, up to approximately three quarters of the way up their gardens. No internal flooding of properties was recorded.

Several residents commented that they believed the flooding to be due to lack of maintenance in the Mayes Brook stating it was overgrown.

We have been unable to confirm details of flooding to properties in Felton Road, Alfred's Gardens and Saxham Road, just upstream of Waverley Gardens.

2.3.4. River Ingrebourne catchment

The Ingrebourne catchment includes a number of tributaries such as Paines Brook and Weald Brook and flows into the Thames through Rainham Creek. For most of its length the Ingrebourne flows in a semi-natural channel through undeveloped areas, but some of its tributaries drain impermeable areas.

Our records show that there were 4 main locations affected by flooding during this event. Their locations are shown in Figure 26 below and the affected areas are discussed in more detail in the following section.

Flood warning service

There are 2 telemetry gauging sites on the river Ingrebourne, at Harold Park and downstream at Gaynes Park in Upminster. New record peak levels were set at both of the sites, with 3.13m at Harold Wood and 1.75m at Gaynes Park. Flood warnings were issued for both Harold Park and Hornchurch in advance of the flooding at Reginald Road, Frimley Avenue and Hacton Lane.

Table 5: flood alerts and warnings issued on the river Ingrebourne Catchment 23 June 16

Type	Target area code	Flood alert or warning name	Description	Date and time issued
Flood alert	062WAF55Ingrebrn	The River Ingrebourne at Harold Park and Hornchurch	The River Ingrebourne at Harold Park and Hornchurch including Harold Wood, Upminster and Rainham	23 June 16
Flood warning	062FWF55Harold	The River Ingrebourne at Harold Park	The River Ingrebourne at Harold Park including Harold Wood	7:38am 23 June 16
Flood warning	062FWF55Hornchur	The River Ingrebourne at Hornchurch	The River Ingrebourne at Hornchurch including Upminster and Rainham	7:45am 23 June 16

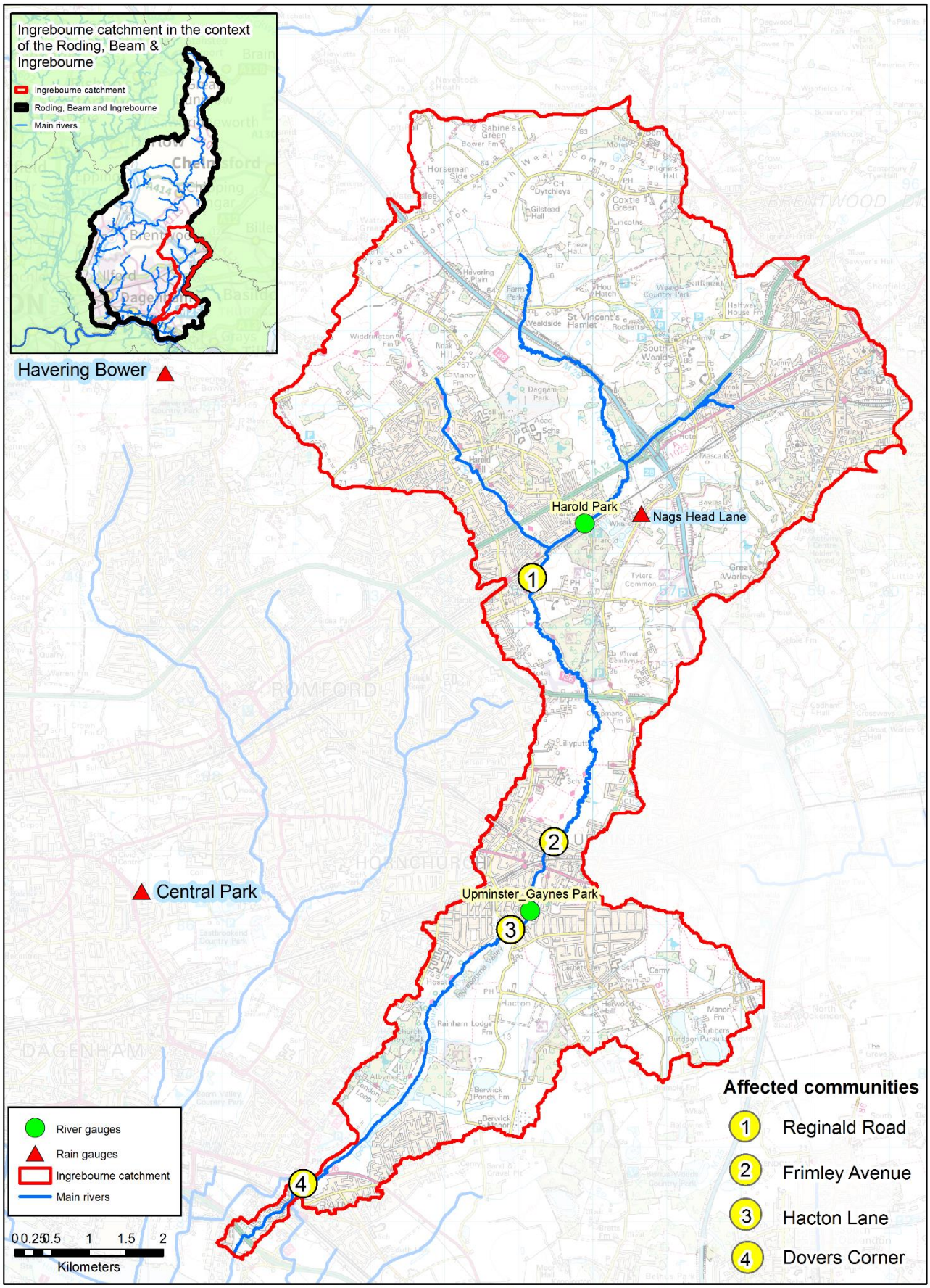

Figure 26: Map showing communities affected by flooding in the River Ingrebourne catchment

Reginald Road

Figure 277: A map to show the extent of flooding at Reginald Road, Hornchurch

Most of Reginald Road is a new housing area on what used to be a bus depot south of Woodlands Road in Harold Wood. Outbuildings to one riverside property had been flooded to a depth of about 250mm but the house was not affected. Another garden of Reginald Road was also affected.

There was evidence that the grassy area between the new build houses and the Ingrebourne had been flooded, as well as the meadow on the other side of the river. None of the other new build houses had been affected.

Frimley Avenue

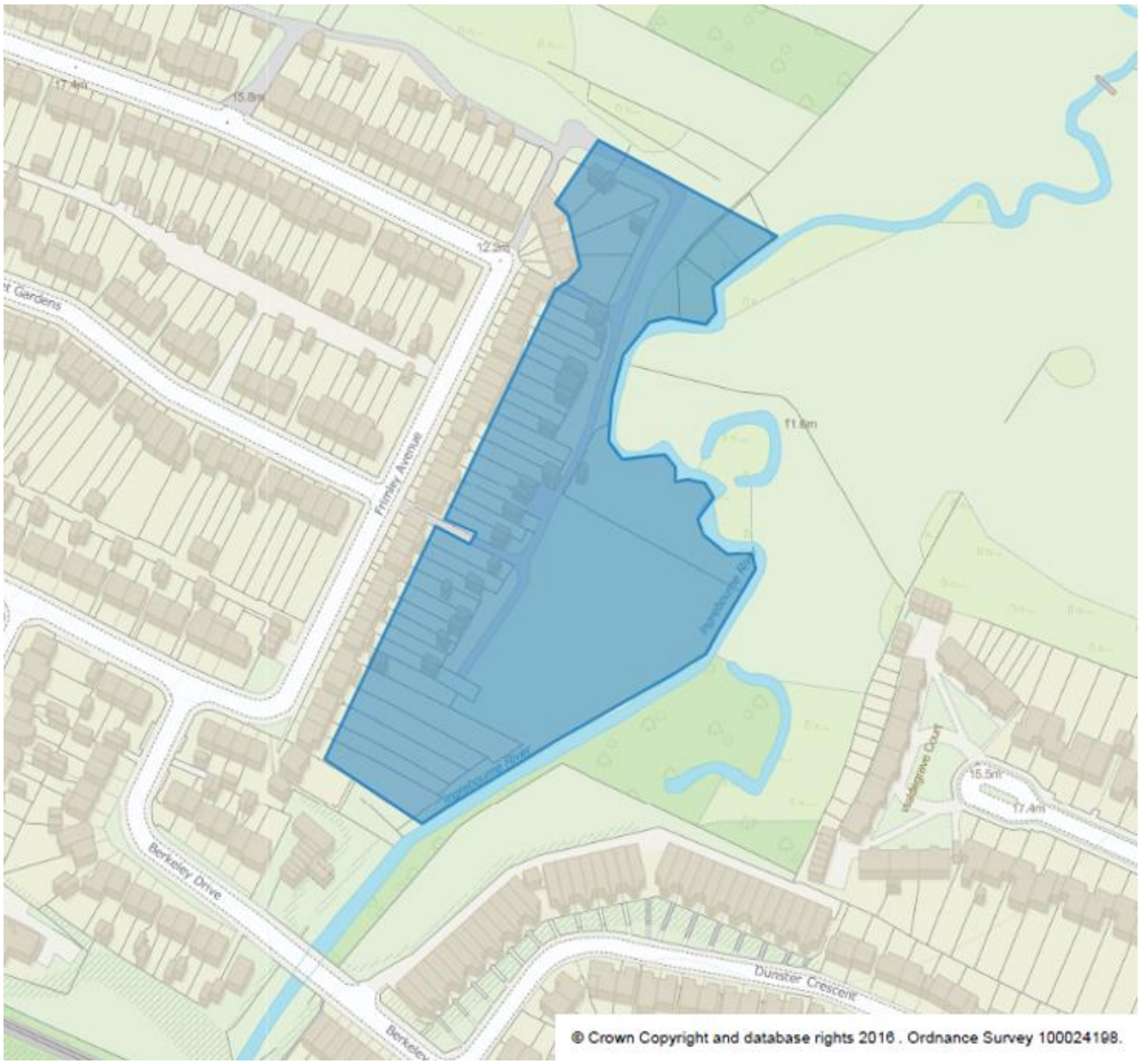

Figure 28: A map to show the flood extent on Frimley Avenue

The Ingrebourne flows to the east of properties on Frimley Avenue. All 36 houses adjacent to the river were affected by flooding from the Ingrebourne. Gardens were inundated and some outbuildings were affected too, particularly garages at the eastern end of the properties, but no internal flooding was reported.

The track along the eastern boundary of the properties which allows access to the garages was submerged to a depth of between 100mm to 200mm. The water was flowing quickly from north to south, suggesting that the water was from the Ingrebourne.

Figure 28: Photo looking SSW, showing flooding on a track behind Frimley Avenue

Figure 29: A photo showing garden flooding to a property on Frimley Avenue, 23 June 16

Hacton Lane

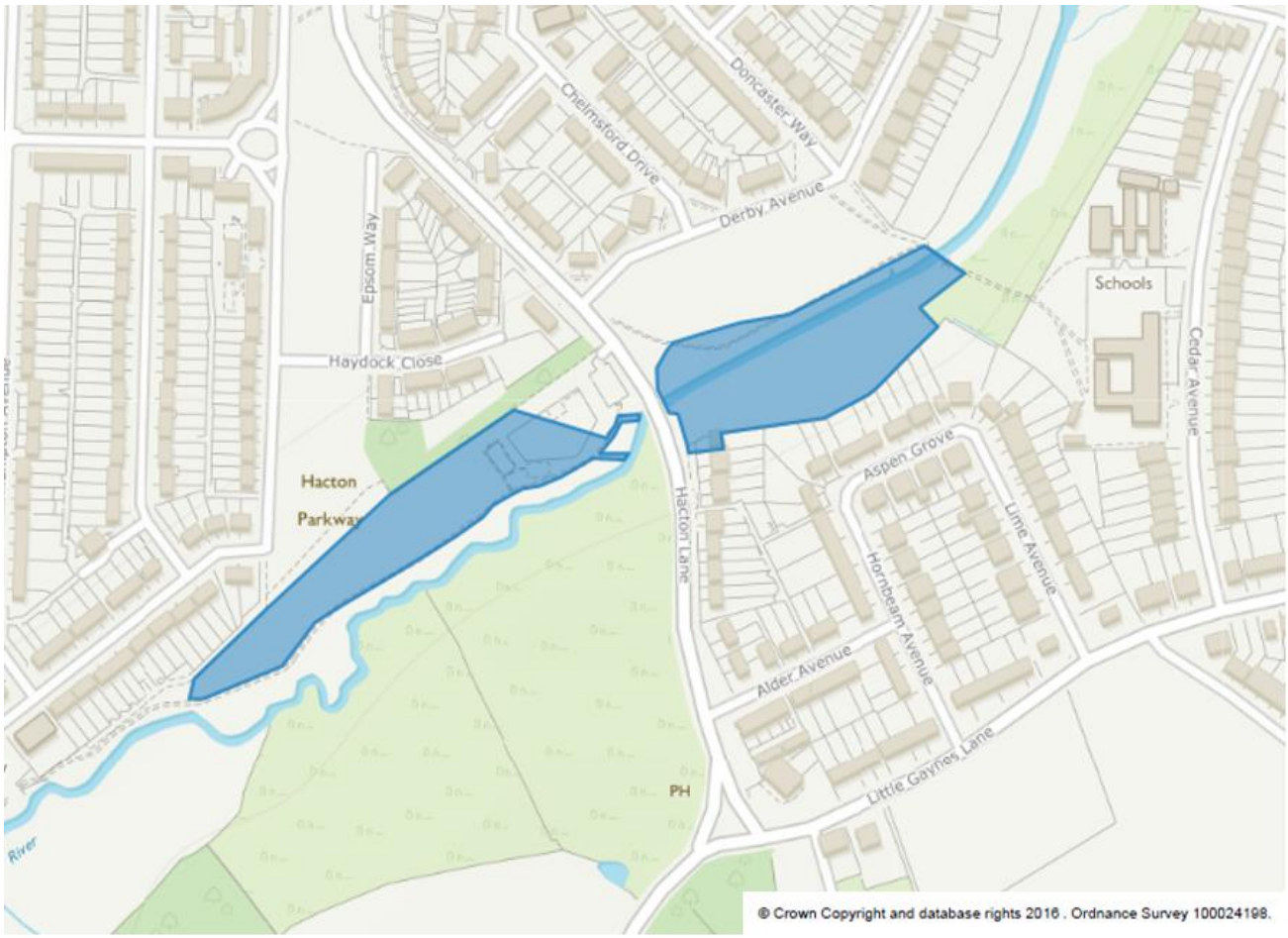

Figure 31: A map showing the flood extent at Hacton Lane and surrounding parkland, 23 June 16

One house on Hacton Lane, suffered internal flooding. The water had not come above the floorboards, but had entered through airbricks. The river level peaked between midday and 12:30pm according to the occupants. The recreation park to the north of Hacton Lane, was extensively flooded.

Flows on the Ingrebourne, were restricted by Hacton Lane bridge. Extensive areas of the parkland downstream of the bridge (to the west) were also flooded.

Figure 30: Flood water at Hacton Lane, looking East, 23 June 16

Figure 31: View of flooding in Hacton Parkway from Hacton Lane bridge looking west

Dovers Corner, Rainham

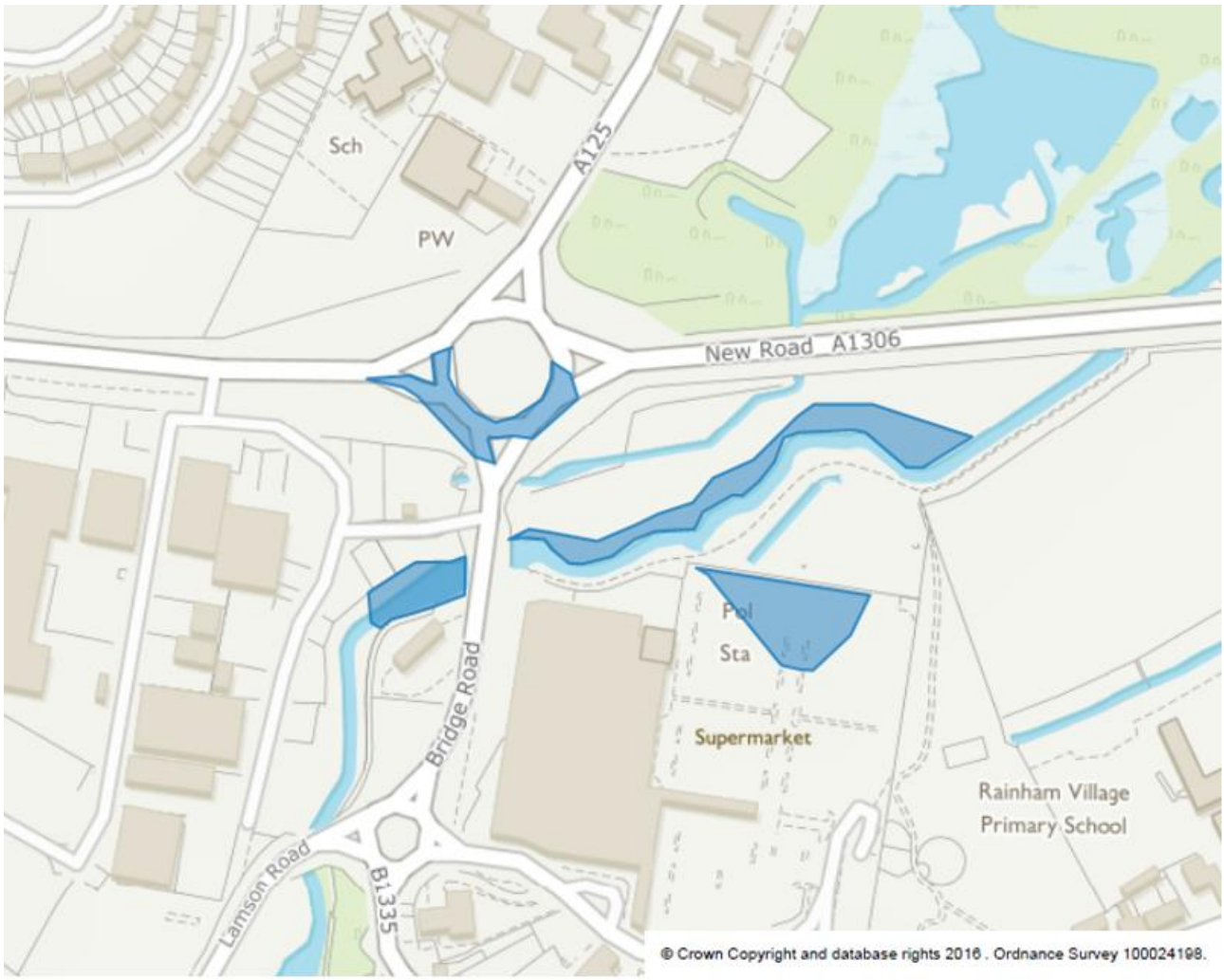

Figure 32: A map to show the extent of flooding at Dovers Corner, 23 June 16

In addition to river and surface water flooding experienced across the Area, we also managed potential flooding from the flood storage area at Dovers Corner. Dovers Corner flood storage area (next to the Ingrebourne) had the potential to overtop due to a breach of the embankment and high water levels. Sandbags and plastic sheeting were used to strengthen the breach location. Pumps downstream at Frog Island were used to over pump water from the Ingrebourne into the Thames during high tide, to increase the capacity of the Ingrebourne and the flood storage area in the tide locked channel. At low tide the tidal sluice gates released flow so the water level at Dovers Corner eventually reduced down to normal levels.

The river did not come out of banks nearby or downstream of Dovers Corner, other than a grassy area of flood plain by Bridge Road. The river level exceeded the capacity of the road bridge culvert, however water had not reached the road.

The roundabout in Dovers Corner was also flooded, however it is unclear if this was due to fluvial or surface water flooding.

Works are currently being carried out to Dovers Corner flood storage area to reinforce the embankment with steel sheet piling within the immediate vicinity of the where the bank erosion occurred and softer natural materials will reinforce the wider embankment. These improvement works are due to complete by the end of March 2017.

Figure 33: Photo showing flooding at Dovers corner roundabout

Figure 34: Photo showing Dovers Corner Flood Storage Area, 23 June 16

Upon arriving at Tesco in Rainham at 3:15pm on 23 June 2016 a large area of the car park had been submerged by water. The approximate area was 40m by 45m, with a depth of an estimated 200mm based on the presence of a shopping trolley in the water.

3. Incident Response

3.1. How flood risk is managed

Responsibility for flooding issues is managed by several flood risk authorities including lead local flood authorities (LLFAs), Thames Water and the Environment Agency. The Flood and Water Management Act 2010 gives responsibilities for planning for and managing any local flood risk issues, including surface and groundwater flooding problems, to LLFAs. The highway authority, county councils or unitary authorities are also responsible for drainage systems associated with the highways. Thames Water is responsible for the sewer system and managing flood risk from their own assets. The Environment Agency has responsibilities relating to flooding from main rivers and the sea.

Our responsibilities include forecasting and mapping flood risks, providing flood warnings for river and coastal flooding, building and keeping defences in good working order and taking part in emergency planning and response. We manage central government grants for capital projects carried out by all risk management authorities.

3.2. Our warnings

Flood warnings and flood alerts issued over the summer period have been included in the catchment information of section 2.3. A full list of flood warnings and alerts is provided in the Appendix.

3.3. Area Incident Room (AIR)

The Area Incident Room was open for 3 days over the June flooding. A roster was used to ensure that the AIR could be manned 24 hours a day.

Our staff in the AIR carried out a range of duties:

- Monitoring river levels and the weather: providing flooding forecasts and operational information to other responders and Tactical Coordination Centres
- Issuing flood alerts and flood warnings
- Updating flood alerts and flood warnings daily
- Coordinating our staff on the ground and working with other responding agencies and the emergency services
- Coordinating our operational staff to maintain our flood defences and clearing blockages from main rivers
- Taking calls from the public: providing help and advice, as well as acting on information received
- Coordinating our communications with MPs and other partners, as well as internal communications with our staff
- Working with our Flood Forecasting staff

3.4. Operations

Our field teams were out across the area clearing trash screens and river blockages to ensure that, wherever possible, rivers and streams were flowing freely.

3.5. Field incident support officers

Field incident support officers (FISOs) were deployed to flooded areas throughout the Hertfordshire and North London area. They are trained to verify river levels at gauging stations, record property flooding and capture the physical extents of flooding on the ground.

The information they logged was tracked by the AIR to help us build a picture of the flooding extent. This detail also helps support us in increasing the accuracy and timeliness of our flood warnings in the future.

On the ground, observations by FISOs were used to help validate our flood warning areas and the accuracy of our triggers for flood warnings.

Where possible we produce flood extents of affected communities. We have strict rules regarding the use of personal information, in accordance with the Data Protection Act. We do not release flood information about specific properties. Flooding to an individual property can not be confirmed, even if the house is surrounded by flood water in the flood extents shown in section 2.3.

Figure 35: one of our officers recording flood data

3.6. Flood ambassadors

Flood ambassadors were deployed to flooded communities throughout the Rom and Roding catchments. We send ambassadors to deliver key information to affected communities. Our ambassadors are trained to:

- provide information on the latest flooding situation
- raise awareness of our Floodline service and information available on our website
- answer queries and provide advice on what to do before, during and after a flood
- maintain our presence and where possible reassure the public
- inform our AIR of developments on-the-ground and feedback from communities affected

Ambassadors were sent to residential areas where property flooding had either occurred or had the potential to happen.

3.7. Engagement during the floods

3.7.1. Communications

Our AIR dealt with a high volume of calls from members of the public. Typical topics covered included: reports of flooding, reports of blockages, requests for sandbags, questions about dredging and people asking us if they were going to flood.

3.7.2. Social media

Social media was an important channel for direct communication with the public and our partners. Social media channels (primarily Twitter) were monitored throughout the incident.

We used social media as one of the tools to inform the public about the latest situation, where to find the latest information and how to prepare for flooding.

Figure 36: a tweet sent by @EnvAgencySE showing our work in Hornchurch

We posted photos of our Operations teams to demonstrate what we were doing on the ground and to reassure members of the public. During the incident, the regional Twitter account, @EnvAgencySE, was contacted by members of the public with questions about flooding and telling us where flooding had occurred. Social media was used widely by residents at risk of flooding. The social media duty officers were solely responsible for ensuring all questions coming in were answered.

4. Since the floods

4.1. Our work with flooded communities

4.1.1. Flood surgeries and public meetings

We held a public flood surgery in the affected community of Havering Park, Romford. This provided an opportunity for residents within the London Borough of Havering to share their concerns and discuss flooding issues with us and local partner organisations. We used the flood surgeries as an opportunity to gather further information on the flood event, with residents encouraged to provide photographs of the flooding and to fill out a questionnaire describing their experiences. The flood surgery also provided an opportunity to inform local residents about our flood warning service and to offer advice on flood resilience measures that could be taken.

4.1.2. Questionnaires

A questionnaire was developed following the flooding and distributed at the flood surgeries and public meetings. In addition, Environment Agency staff delivered the questionnaire door-to-door in the Seven Kings area. We have incorporated the findings from the questionnaires into the data that we have for this flood event. This data will help to inform our historic flood outlines, future flood modelling work and will help us to better allocate resources in the future.

4.1.3. Post flooding enquiries

We received over 30 enquiries, complaints or pieces of correspondence regarding flooding. This number excludes all the urgent enquiries that were dealt with by the AIR. Of these, 4 were classed as complaints. We provided 24 proactive updates to Members of Parliament throughout Hertfordshire and North London area and 7 reactive updates from Members of Parliament correspondence with us.

4.2. Our work for flooded communities

4.2.1. Threshold reviews

The Environment Agency operates a telemetry network for monitoring and flood warning purposes across England. We have set thresholds at the telemetry stations which trigger alarms for us to take certain actions.

We constantly assess the thresholds at our river gauging stations, set for flood warning purposes. Following the floods we undertook a review and made necessary amendments to our telemetry site at Romford. Our threshold level we use to trigger a flood alert is now set at 0.7mASD (metres above site datum). The level prior to the change was 2.0mASD. The new threshold we use to trigger a flood warning where properties are expected to flood is 1.1mASD. These levels have been changed to reflect the flooding of property gardens downstream of the site at Gorse Way.

We have also reviewed our threshold levels at Harold Park on the Ingrebourne, however no changes were required.

We are planning to review threshold levels at our telemetry site at Bretons Farm on the Rom, and Gaynes Park on the Ingrebourne.

4.2.2. Flood alleviation schemes

The timing of the flood event gave us the opportunity to reassess our priorities for the 2017 financial year. As a result, some work in the flood affected areas was brought forward or the scope of our work was altered. The early stage of this work was to identify locations where there were opportunities to implement schemes that will reduce flood risk. Once the best method of alleviating flooding at these locations was decided, we developed these options further. We determined if the schemes had the required benefit to cost ratio for us to be able to apply for funding to undertake the works in the future. Information on resulting projects have been detailed in section 2.3 of this report.

5. List of abbreviations

AIR	Area Incident Room
CEH	Centre for Ecology and Hydrology
FISO	Field incident support officer
FWD	Floodline Warnings Direct
HNL	(Environment Agency area covering) Hertfordshire and North London
LLFA	Lead Local Flood Authority
LTA	Long term average
SMD	Soil moisture deficit
TBR	Tipping bucket rainfall gauge

6. Glossary

Term	Definition
Areal average rainfall	The estimated average depth of rainfall over a defined area. Expressed in depth of water (mm).
Effective rainfall	The rainfall available to percolate into the soil or produce river flow. Expressed in depth of water (mm).
Groundwater	The water found in an aquifer.
Recharge	The process of increasing the water stored in the saturated zone of an aquifer. Expressed in depth of water (mm).
Soil moisture deficit (SMD)	The difference between the amount of water actually in the soil and the amount of water that the soil can hold. Expressed in depth of water (mm).
Long term average (LTA)	Classed relative to an analysis of respective historic totals.

Categories of mean river flow

Exceptionally high	Value likely to fall within this band 5% of the time
Notably high	Value likely to fall within this band 8% of the time
Above normal	Value likely to fall within this band 15% of the time
Normal	Value likely to fall within this band 44% of the time
Below normal	Value likely to fall within this band 15% of the time
Notably low	Value likely to fall within this band 8% of the time
Exceptionally low	Value likely to fall within this band 5% of the time

7. Appendix

7.1. What warnings and alerts were issued in HNL

Warning or alert area code	Warning or alert area name	Warning or alert area description	Type	Date issued	Date removed
062WAB55BeamRom	The Rivers Beam and Rom	The Rivers Beam and Rom at Romford, Hornchurch, Dagenham and Rainham	Flood alert	9:41am 23/06/16	8:09pm 24/06/16
062FWF55Romford	The River Rom at Romford	The River Rom at Romford including Rush Green	Flood warning	8:18am 23/06/16	8:09pm 24/06/16
062WAF54Cripsey	The Cripsey Brook	The Cripsey Brook including Thornwood Common, North Weald Bassett, Moreton and Chipping Ongar	Flood alert	8:18am 23/06/16	8:09pm 24/06/16
062WAF54UpRoding	The Upper River Roding	The Upper River Roding including Molehill Green, Dunmow, Ongar, Fyfield, High Ongar and Stapleford	Flood alert	3:47pm 23/06/16	8:13am 26/06/16
062WAF54MdRoding	The Middle River Roding	The Middle River Roding including Abridge, Loughton and Buckhurst Hill	Flood alert	5:37am 23/06/ 16	10:23am 27/06/16
062FWF54LwRoding	The Lower River Roding	The Lower River Roding including Redbridge, Woodford, Wanstead, Ilford, East Ham and Barking	Flood alert	10:43am 23/06/16	8:13am 26/06/16
062WAF55Ingrebrn	The River Ingrebourne at Harold Park and Hornchurch	The River Ingrebourne at Harold Park and Hornchurch including Harold Wood, Upminster and Rainham	Flood alert	23/06/16	24/06/16
062FWF55Harold	The River Ingrebourne at Harold Park	The River Ingrebourne at Harold Park including Harold Wood	Flood warning	7:38am 23/06/16	5:32am 24/06/16
062FWF55Hornchur	The River Ingrebourne at Hornchurch	The River Ingrebourne at Hornchurch including Upminster and Rainham	Flood warning	7:45am 23/06/16	10:11am 26/06/16

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