Flood estimation calculation record

Introduction

This calculation record is based on a supporting document to the Environment Agency's flood estimation guidelines (Version 4, 2012). It provides a record of the calculations and decisions made during flood estimation. It will often be complemented by more general hydrological information given in a project report. The information given here should enable the work to be reproduced in the future. This version of the record is for studies where flood estimates are needed at multiple locations.

Contents

Approval

	Name and qualifications
Calculations prepared by:	Matthew Roberts BSc MSc DIC
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Abbreviations

AM.................................. Annual Maximum

AREA .... Catchment area (km^2)

BFI .... Base Flow Index

BFIHOST .... Base Flow Index derived using the HOST soil classification

CFMP.............................. Catchment Flood Management Plan

CPRE.............................. Council for the Protection of Rural England

FARL............................... FEH index of flood attenuation due to reservoirs and lakes

FEH................................. Flood Estimation Handbook

FSR................................. Flood Studies Report

HOST .... Hydrology of Soil Types

NRFA .... National River Flow Archive

POT................................. Peaks Over a Threshold

QMED .... Median Annual Flood (with return period 2 years)

ReFH .... Revitalised Flood Hydrograph method

SAAR .... Standard Average Annual Rainfall (mm)

SPR................................. Standard percentage runoff

SPRHOST .... Standard percentage runoff derived using the HOST soil classification

Tp(0) .... Time to peak of the instantaneous unit hydrograph

URBAN .... Flood Studies Report index of fractional urban extent

URBEXT1990 .... FEH index of fractional urban extent

URBEXT2000 .... Revised index of urban extent, measured differently from URBEXT1990

WINFAP-FEH .... Windows Frequency Analysis Package – used for FEH statistical method

1 Method statement

1.1 Overview of requirements for flood estimates

Item	Comments
Give an overview which includes: • Purpose of study • Approx. no. of flood estimates required • Peak flows or hydrographs? • Range of return periods and locations	This hydrological assessment was undertaken to inform the Surface Water Management Plan for Marden, Kent. Peak flows are required for the following Annual Exceedance Probability (AEP) events; 50%, 10%, 5%, 3.33%, 2%, 1.33%, 1% and 0.1%. The effects of climate change are to be considered for the 1% AEP event. For this event, flow will be increased by 20% as stated within the FCDPAG3 Economic Appraisal (DEFRA, 2006).

1.2 Overview of catchment

Item	Comments
Brief description of catchment, or reference to section in accompanying report	Marden is a village located approximately 11km south of Maidstone, Kent. The drain catchments within Marden are predominantly covered with Arable (Horticultural) land with a mixture of woodland and grassland. The main built-up area is Marden and part of Staplehurst is located in the upper Marden drain catchment. The total catchment area of the Marden Drains is 17.5km^2. A map showing the catchment boundaries is shown in Figure 2-1. The catchments within Marden are underlain predominantly by mudstone deposits (Weald Clay formation) and therefore the catchments are quite impermeable and consequently a more flashy response is expected. There are a few outcrops of limestone (Weald Clay formation) to the east of Marden, although these deposits are fairly limited in extent. This is supported by fairly low BFIHOST values in the range of 0.281 to 0.302; the average SPRHOST value is 47%. These geological formations are overlain by superficial deposits of Alluvium and River Terrace deposits which mainly consist of sands, gravel, clays and silts. The superficial deposits are mostly confined to the centre of Marden and along some of the river reaches. The soils within the Marden catchment predominantly consist of slowly permeable wet clayey soils with impeded drainage. There are freely draining loamy soils to the east of Marden (associated with the Limestone outcrop) but these are fairly limited in extent. There is fairly shallow gradient across the catchment with the highest elevation point at approximately 97mAOD (Foxridge Wood) and the lowest elevation point at approximately 15mAOD at the downstream model extent.

1.3 Source of flood peak data

Was the HiFlows UK dataset used? If so, which version? If not, why not? Record any changes made	Yes – Version 3.3.4, August 2014

1.4 Gauging stations (flow or level)

(at the sites of flood estimates or nearby at potential donor sites)

Water-course	Station name	Gauging authority number	NRFA number (used in FEH)	Grid reference	Catch-ment area (km²)	Type (rated / ultrasonic / level…)	Start and end of flow record
Ungauged catchment.							

1.5 Data available at each flow gauging station

Station name	Start and end of data in HiFlows-UK	Update for this study?	Suitable for QMED?	Suitable for pooling?	Data quality check needed?	Other comments on station and flow data quality e.g. information from HiFlows-UK, trends in flood peaks, outliers.
Ungauged catchment.						
Give link/reference to any further data quality checks carried out			N/A			
Note – include plots of flood peak and flood hydrograph data at relevant gauging stations along with interpretation, e.g. in the Annex.						

1.6 Rating equations

Station name	Type of rating e.g. theoretical, empirical; degree of extrapolation	Rating review needed?	Reasons e.g. availability of recent flow gaugings, amount of scatter in the rating.
N/A			
Give link/reference to any rating reviews carried out		N/A	

1.7 Other data available and how it has been obtained

Type of data	Data relevant to this study?	Data available ?	Source of data and licence reference if from EA	Date obtained	Details
Check flow gaugings (if planned to review ratings)	N/A				
Flow data for events	N/A				
Results from previous studies	N/A				

1.8 Initial choice of approach

Is FEH appropriate? (it may not be for very small, heavily urbanised or complex catchments) If not, describe other methods to be used.	Yes. The catchments are fairly small but they are quite impermeable and mostly rural. FEH is appropriate as all catchments are > 0.5km² even though the small Marden Drain is not defined on the FEH CD-ROM (v3). The 1% AEP floodplain extents are quite high in the Marden catchments as FPEXT values are generally in excess of 0.21 with the

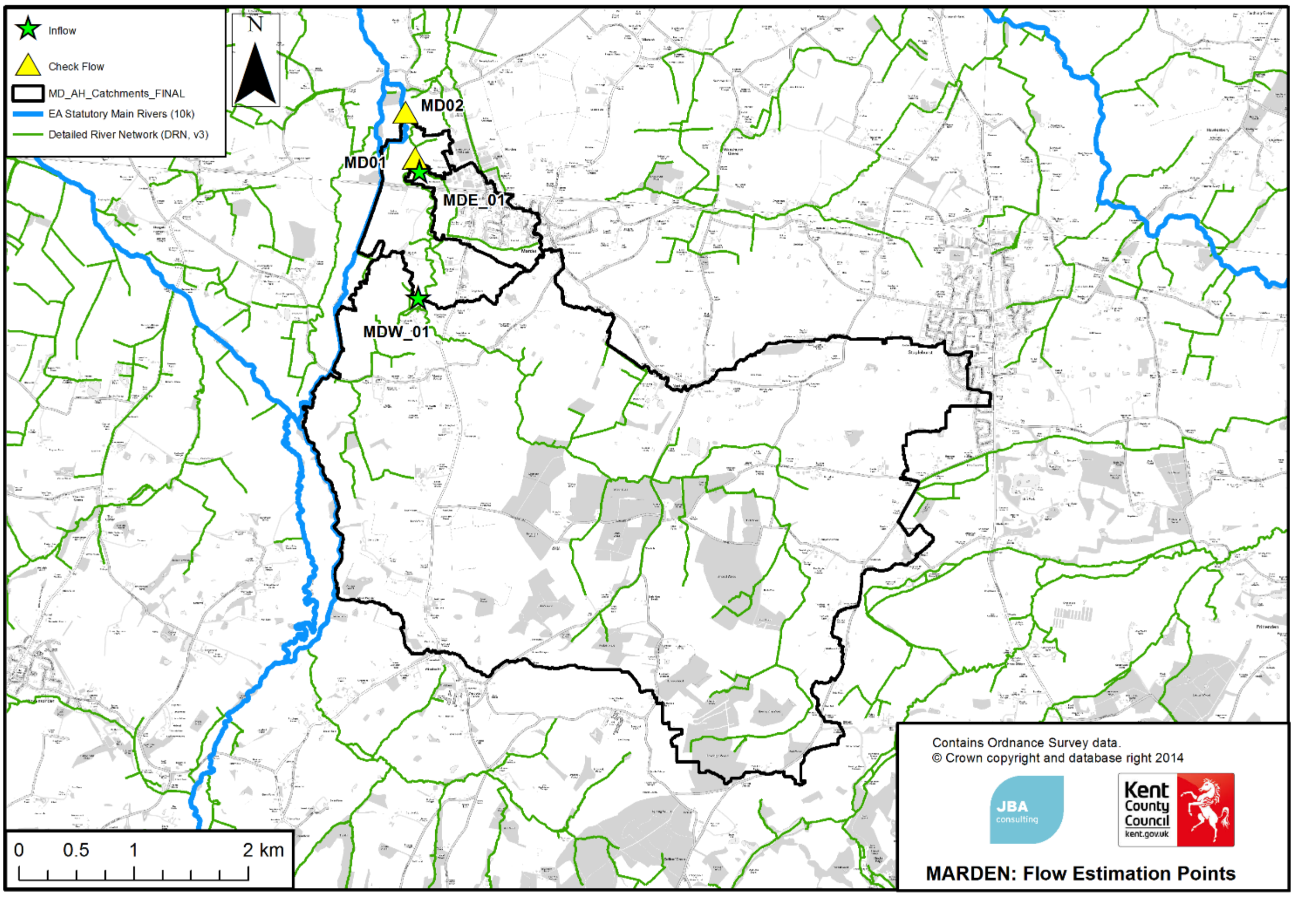
	highest FPEXT value being 0.36 i.e. 36% of the catchment being inundated during a 1% AEP event. The small Marden Drain (East) is heavily urbanised and therefore ReFH is not really appropriate. The FEH Statistical method can be applied and the ReFH method could also be applied to provide a comparison with the FEH Statistical estimates as there is no observed flow data to compare against.
Outline the conceptual model, addressing questions such as: • Where are the main sites of interest? • What is likely to cause flooding at those locations? (peak flows, flood volumes, combinations of peaks, groundwater, snowmelt, tides…) • Might those locations flood from runoff generated on part of the catchment only, e.g. downstream of a reservoir? • Is there a need to consider temporary debris dams that could collapse?	The main area of interest is the village of Marden which is located south of Maidstone in Kent. The catchments within Marden are likely to be impacted by peak flows due to underlying impermeable geological deposits and also within Marden due to the increase in impervious urbanised area. There is a history of flooding within Marden (see table below). It is unclear whether this flooding is associated with high levels in the adjacent Main River catchments. This will be assessed within the flood history report for Marden which aims to determine catchment response within Marden and whether the flood events are due to insufficient capacity within the drainage network or due to fluvial flooding. This is the main reason for undertaking Direct Rainfall analysis and fluvial analysis to derive a combined fluvial-surface water hydraulic model. **Date** / **Source**: 2000 (Autumn?) – Fluvial March 2012 – Surface Water December/January 2013-2014 – Foul Sewer February 2014 – Sewer February 2009 – Fluvial and Surface Water
Any unusual catchment features to take into account? e.g. • highly permeable – avoid ReFH if BFIHOST>0.65, consider permeable catchment adjustment for statistical method if SPRHOST<20% • highly urbanised – avoid standard ReFH if URBEXT1990>0.125; consider FEH Statistical or other alternatives; consider method that can account for differing sewer and topographic catchments • pumped watercourse – consider lowland catchment version of rainfall-runoff method • major reservoir influence (FARL<0.90) – consider flood routing, extensive floodplain storage – consider choice of method carefully	The catchments within Marden are quite impermeable (average BFIHOST is 0.29 and SPRHOST is 47%). As the majority of the catchments are essentially rural, both the FEH Statistical and ReFH methods can be used to derive peak flows.
Initial choice of method(s) and reasons Will the catchment be split into subcatchments? If so, how?	Both the FEH Statistical and ReFH methods will be used as the catchments are suited to either method and will therefore enable comparison between the two recommended flow estimation methods. Inflows will be derived at the upstream model extents with check flows derived at key locations; confluences and downstream model extent.
Software to be used (with version numbers)	FEH CD-ROM v3.0[1] WINFAP-FEH v3.0.002[2]

Date	Source
2000 (Autumn?)	Fluvial
March 2012	Surface Water
December/January 2013-2014	Foul Sewer
February 2014	Sewer
February 2009	Fluvial and Surface Water

[1] FEH CD-ROM v3.0 © NERC (CEH). © Crown copyright. © AA. 2009. All rights reserved.
[2] WINFAP-FEH v3 © Wallingford Hydro Solutions Limited and NERC (CEH) 2009.

2 Locations where flood estimates required

Figure 2-1: Locations of flow estimates



2.1 Summary of subject sites

Site code	Watercourse	Site	Easting	Northing	AREA on FEH CD-ROM (km^2)	Revised AREA if altered
MDE_01	Marden Drain (East)	Upstream model extent of Marden Drain (East)	573530	145047	N/A	0.6
MDW_01	Marden Drain (West)	Upstream model extent of Marden Drain (West)	573550	143800	14.2	16.0
MD01	Marden Drains	Confluence of the East and West Drains	573500	145050	15.8	17.3
MD02	Marden Drains	Downstream model extent of the Marden Drains.	573450	145450	16.0	17.5
As there is no gauged data and the geology is fairly consistent across the catchments, the upstream and downstream model extents were selected as the flow estimation points. For the Marden Drain (East), the catchment area derived at the downstream extent was used to inform the model inflow for this catchment as there was no representative catchment at the upstream model extent.						

2.2 Important catchment descriptors at each subject site (incorporating any changes made)

Site code	FARL	PROPWET	BFIHOST	DPLBAR (km)	DPSBAR (m/km)	SAAR (mm)	SPRHOST	URBEXT 1990	URBEXT 2000	FPEXT
MDE_01	0.994	0.36	0.540	0.74	10.3	650	46.69	0.1890	0.1985	0.2301
MDW_01	0.997	0.36	0.281	4.22	25.8	689	47.56	0.0084	0.0090	0.2122
MD01	0.994	0.36	0.301	5.53	24.6	686	46.69	0.0223	0.0236	0.2301
MD02	0.995	0.36	0.302	5.94	24.5	686	46.64	0.0222	0.0234	0.2357

Note: Red text denotes catchment descriptor values which have been changed from the FEH CD-ROM values. URBEXT1990 and URBEXT2000 values have been updated to 2014.

2.3 Checking catchment descriptors

Record how catchment boundary was checked and describe any changes (refer to maps if needed)	The catchment boundaries were checked using 1m resolution DTM data. In the upper catchment, there is a lack of LIDAR coverage and in the absence of any higher resolution data, OS Open Terrain 50k data was used to infer the catchment boundary. In some locations the FEH catchment boundary was amended to take account of the Detailed River Network (DRN v3) so that the rivers do not cut across subcatchment boundaries. The ArcHydro 'rolling ball' analysis tool within ArcGIS was used to define the topographical catchment using a composite elevation dataset which consisted mostly of 1m resolution LIDAR data with some OS Open Terrain 50k data in the upper reaches. For the catchments where AREA has changed significantly (>10%), the FEH DPLBAR value was also updated. This is because DPLBAR is based on catchment area and should therefore be updated to reflect the change in area. The standard equation for DPLBAR, given in the FEH Volume 5, uses a power term of 0.548 which is based on research for the UK as a whole. This has been used to update DPLBAR where AREA has changed significantly.
Record how other catchment descriptors (especially soils) were checked and describe any changes. Include before/after table if necessary.	Soil values (SPRHOST and BFIHOST) were checked against the 1:250,000 Soil Survey of England and Wales map for South East England for both catchments to assess if the FEH CD-ROM values across the study area are reasonable. It was found that the FEH Catchment Descriptors represent the soil types well. The urban areas shown on the FEH CD-ROM (v3) were compared against OS 1:50,000 mapping and were deemed to be representative of the study catchment. Therefore the URBEXT values on the FEH-CD ROM (v3) were retained and updated to 2014 values using the CPRE formulae in accordance with the EA Flood Estimation Guidelines. The FARL value was checked against the OS mapping for surface water features within the study catchment. There are no major surface water within the Marden drain catchments. Therefore the FARL values from the FEH CD-ROM were used as this corresponds with the OS 1:50,000 Mapping.
Source of URBEXT	$URBEXT_{1990}$ has been used for the ReFH method. $URBEXT_{2000}$ has been used for the FEH Statistical method.

Method for updating of URBEXT	$URBEXT_{1990}$ - CPRE formula from FEH Volume 4. $URBEXT_{2000}$ - CPRE formula from 2006 CEH report on $URBEXT_{2000}$.

3 Statistical method

3.1 Search for donor sites for QMED (if applicable)

Comment on potential donor sites	
Mention: • Number of potential donor sites available • Distances from subject site • Similarity in terms of AREA, BFIHOST, FARL and other catchment descriptors • Quality of flood peak data Include a map if necessary. Note that donor catchments should usually be rural.	A brief assessment of donor stations was carried out for this study using WINFAP-FEH to assess stations that are suitable for QMED within the HiFlows-UK dataset. No suitable donor stations could be located within 40km as the donor catchments were more than 12 times larger than the subject catchment. Therefore QMED estimates were derived using catchment descriptors.

3.2 Donor sites chosen and QMED adjustment factors

NRFA no.	Reasons for choosing or rejecting	Method (AM or POT)	Adjust-ment for climatic variation?	QMED from flow data (A)	QMED from catchment descriptors (B)	Adjust-ment ratio (A/B)
40004	REJECT: The donor catchment is nearly 13 times larger than the subject catchment. SAAR at the donor catchment is approximately 25% higher than the subject catchment and the catchment is located nearly 20km away. The donor catchment also has a slightly higher attenuation due to reservoirs and lakes (FARL=0.975).	AM	N/A	37.2	49.8	0.747
39029	REJECT: The donor catchment is only 4 times larger than the subject catchment. However, the donor catchment is much more permeable (BFIHOST=0.885) than the subject catchments. SAAR at the donor catchment is approximately 18% higher than the subject catchment and the catchment is located nearly 68km away. The donor catchment also has a much higher attenuation due to reservoirs and lakes (FARL=0.879).	AM	N/A	2.0	1.5	1.333

NRFA no.	Reasons for choosing or rejecting	Method (AM or POT)	Adjust-ment for climatic variation?	QMED from flow data (A)	QMED from catchment descriptors (B)	Adjust-ment ratio (A/B)
41020	REJECT: As the subject catchment at MDE_01 is very small and urbanised, there are no representative donor catchments. The only donor catchment that is reasonably representative in terms of catchment area is located approximately 47km away. The donor catchment is still over 60 times larger than the subject catchment. However, the donor catchment is much more impermeable (BFIHOST=0.355) than the subject catchments. SAAR at the donor catchment is approximately 36% higher than the subject catchment. Even so, applying this donor would only adjust QMED down by 1%.	AM	N/A	13.5	13.8	0.978

3.3 Overview of estimation of QMED at each subject site

Site code	Method	Initial estimate of $QMED_{RURAL}$ (m^3/s)	Data transfer						Final estimate of $QMED_{URBAN}$ (m^3/s)
			NRFA numbers for donor sites used (see 3.3)	Distance between centroids d_{ij} (km)	Power term, a	Moderated QMED adjustment factor, $(A/B)^a$	If more than one donor		
							Weight	Weighted ave. adjustment	
MDE_01	CD	4.50	N/A						4.53
MDW_01	CD	0.12	N/A						0.16
MD01	CD	4.55	N/A						4.63
MD02	CD	4.60	N/A						4.69
Are the values of QMED consistent, for example at successive points along the watercourse and at confluences?					Yes, QMED estimates are consistent along successive locations along the same reach. MDW_01 is a separate tributary and the sum of flows upstream of MD02 is greater than the downstream estimate as expected.				

Important note on urban adjustment

The method used to adjust QMED for urbanisation, for both subject sites and donor sites, is that published in Kjeldsen (2010)[3] in which PRUAF is calculated from BFIHOST. The result will differ from that of WINFAP-FEH v3.0.003 which does not correctly implement the urban adjustment of Kjeldsen (2010).

[3] Kjeldsen, T. R. (2010). Modelling the impact of urbanization on flood frequency relationships in the UK. Hydrol. Res. **41**. 391-405.

Significant differences will occur only on urban catchments that are highly permeable.
Notes Methods: AM – Annual maxima; POT – Peaks over threshold; DT – Data transfer; CD – Catchment descriptors alone. When QMED is estimated from POT data, it should also be adjusted for climatic variation. Details should be added below. The data transfer procedure is the revised one from Science Report SC050050. The QMED adjustment factor A/B for each donor site is given in Table 3.3. This is moderated using the power term, a, which is a function of the distance between the centroids of the subject catchment and the donor catchment. The final estimate of QMED is (A/B)a times the initial estimate from catchment descriptors. If more than one donor has been used, use multiple rows for the site and give the weights used in the averaging. Record the weighted average adjustment factor in the penultimate column.

3.4 Derivation of pooling groups

The composition of the pooling groups is given in the Annex. Several subject sites may use the same pooling group. The top three stations within the default pooling group were investigated as these stations will have a greater impact on the growth curve and therefore the final design flow estimates.

Name of group	**Site code from whose descriptors group was derived**	**Subject site treated as gauged? (enhanced single site analysis)**	**Changes made to default pooling group, with reasons** Note also any sites that were investigated but retained in the group.	**Weighted average L-moments,** L-CV and L-skew, (before urban adjustment)
MD02	MD02	No	<u>Stations investigated</u> 27073 (Brompton Beck @ Snainton Ings) • Theoretical rating but gaugings show considerable scatter. • Fully contained with no likelihood of drowning. Theoretical rating should apply for the whole range. • Not very representative of the study catchment and variability in the highest AMAX peaks is low (small L-skew) however L-moments are representative of others in the group, although the growth curve is flat there is another site with a similarly shallow growth curve. • As this site is not discordant and fits well with the other stations in the group, the site was retained. 20002 (West Peffer Burn @ Luffness) • Similar catchment descriptors to the subject site and no observable trend in AMAX series. Mainly impervious catchment which is consistent with the subject catchment. • Site is within the main cluster of pooling group stations on the L-CV and L-Kurtosis plots. Therefore this site was retained. 33054 (Babingly @ Castle Rising) • Subject to drowning. AMAX3 is just above modular limit. • Chalk catchment. Regime influenced by groundwater abstraction / recharge. • AMAX1 and AMAX2 have the same value and occur in water years 1976 and 1978; AMAX 3 is only slightly lower and occurs in water year 1980.	0.248, 0.093

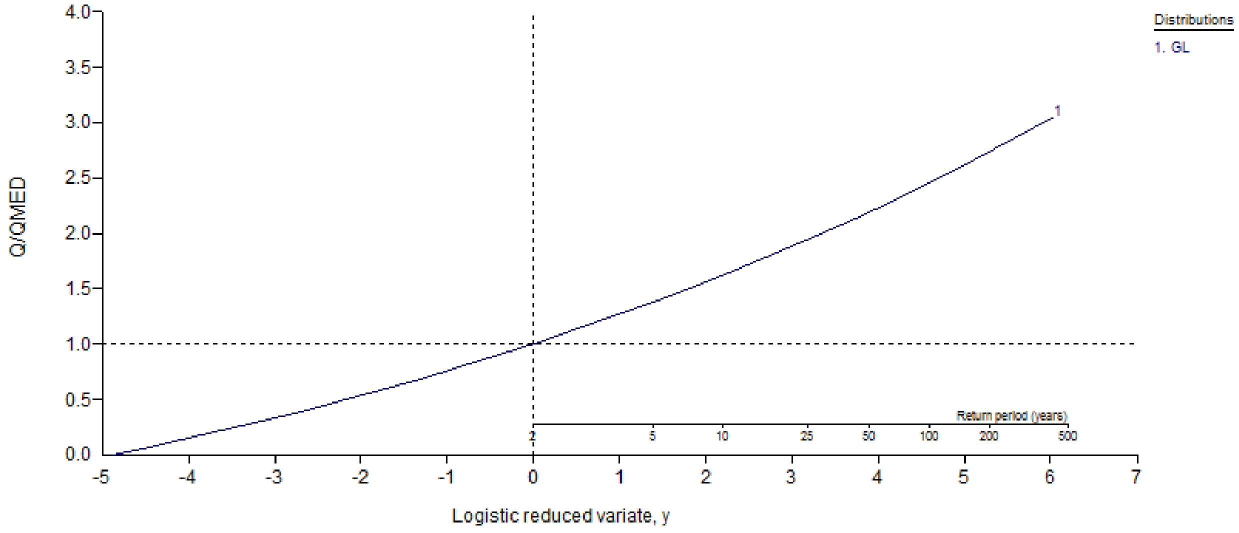
Name of group	Site code from whose descriptors group was derived	Subject site treated as gauged? (enhanced single site analysis)	**Changes made to default pooling group, with reasons** Note also any sites that were investigated but retained in the group.	**Weighted average L-moments,** L-CV and L-skew, (before urban adjustment)
			• AMAX values for water years 1983-1986 are almost the same. Similar values for one year following the next: 1994 & 1995, 1997 & 1998, 2002 & 2003. • Some uncertainty in data quality and Chalk not representative of the study catchment but nothing to suggest that retaining this station will skew the growth curve. • Site is within the main cluster of pooling group stations on the L-CV and L-Kurtosis plots. Total of 474 years; no stations added as unlikely to improve pooling group. The final pooling group composition can be found within the Annex.	
Notes Pooling groups were derived using the revised procedures from Science Report SC050050 (2008). The weighted average L-moments, before urban adjustment, can be found at the bottom of the Pooling-group details window in WINFAP-FEH.				

3.5 Derivation of flood growth curves at subject sites

The rural growth curve for the pooling group (MD02) is shown in Figure 3-1.

Site code	Method (SS, P, ESS, J)	If P, ESS or J, name of pooling group	Distribution used and reason for choice	Note any urban adjustment or permeable adjustment	**Parameters of distribution** (location, scale and shape) after adjustments)	Growth factor for 100-year return period
MDE_01	P	MD02	Generalised Logistic (GL) distribution selected as GL is the recommended distribution for UK catchments. GEV and P(III) provided the best fit to the data. However, GL provided the most conservative estimates at higher return periods.	Urban adjustment made using v3 method (Kjeldsen, 2010). No permeable adjustment – SPRHOST >20%.	1.000, 0.253, -0.094	2.45
MDW_01	P	MD02			1.000, 0.225, -0.125	2.40
MD01	P	MD02			1.000, 0.251, -0.097	2.45
MD02	P	MD02			1.000, 0.251, -0.097	2.45
Notes Methods: SS – Single site; P – Pooled; ESS – Enhanced single site; J – Joint analysis A pooling group (or ESS analysis) derived at one gauge can be applied to estimate growth curves at a number of ungauged sites. Each site may have a different urban adjustment, and therefore different growth curve parameters. Urban adjustments are all carried out using the v3 method: Kjeldsen (2010). Growth curves were derived using the revised procedures from Science Report SC050050 (2008).						

Figure 3-1: Pooling group growth curve (Rural)



3.6 Flood estimates from the statistical method

Site code	Flood peak (m^3/s) for the following Annual Exceedance Probabilities (%)								
	50	**10**	**5**	**3.33**	**2**	**1.33**	**1**	**1 (+CC)**	**0.1**
MDE_01	0.2	0.2	0.3	0.3	0.3	0.4	0.4	0.4	0.5
MDW_01	4.5	7.3	8.4	9.1	9.9	10.6	11.1	13.3	15.7
MD01	4.6	7.5	8.6	9.3	10.1	10.8	11.3	13.6	16.0
MD02	4.7	7.6	8.7	9.4	10.2	11.0	11.5	13.8	16.2

4 Revitalised flood hydrograph (ReFH) method

4.1 Parameters for ReFH model

Site code	Method: OPT: Optimisation BR: Baseflow recession fitting CD: Catchment descriptors DT: Data transfer (give details)	Tp (hours) Time to peak	C_{max} (mm) Maximum storage capacity	BL (hours) Baseflow lag	BR Baseflow recharge
MDE_01	CD	1.203	424.637	18.881	1.335
MDW_01	CD	4.426	228.304	31.841	0.659
MD01	CD	5.054	243.715	33.490	0.710
MD02	CD	5.281	244.484	34.050	0.713
Brief description of any flood event analysis carried out (further details should be given below or in a project report)					

4.2 Design events for ReFH method

Site code	Urban or rural	Season of design event (summer or winter)	Storm duration (hours)	Storm area for ARF (if not catchment area)
MDE_01	URBAN	SUMMER	2.25	Catchment area
MDW_01	RURAL	WINTER	7.5	Catchment area
MD01	RURAL	WINTER	8.5	Catchment area
MD02	RURAL	WINTER	9.5	Catchment area
Are the storm durations likely to be changed in the next stage of the study, e.g. by optimisation within a hydraulic model?			The recommended storm duration, based on the standard ReFH equation at the downstream extent is 8.913hrs (with a 0.53-1.06hr data interval). The storm duration and time step used for these estimates are 9.5hr and 0.5hr respectively. The ARF is 0.955 for the 9.5hr duration. These parameters have also been used to derive the hydrograph shape for the FEH Statistical hydrographs. A brief assessment of storm durations and peak flows was carried out in order to determine the critical duration at the downstream location for the hydraulic model. A storm duration of 15.25 hours was found to produce the highest 1% AEP flow estimate at MD02 (ARF=0.962) so therefore this storm duration should be tested within the hydraulic model. As the Marden Drain (East) is a fairly small tributary, it is recommended that the shorter storm duration (2.25hrs) is also tested within the hydraulic model. The standard storm duration at the downstream extent (9.5hrs) will also be tested.	

4.3 Flood estimates from the ReFH method

Site code	Flood peak (m^3/s) for the following Annual Exceedance Probabilities (%)								
	50	10	5	3.33	2	1.33	1	1 (+CC)	0.1

Site code	Flood peak (m^3/s) for the following Annual Exceedance Probabilities (%)								
	50	**10**	**5**	**3.33**	**2**	**1.33**	**1**	**1 (+CC)**	**0.1**
MDE_01	0.2	0.4	0.5	0.5	0.6	0.6	0.7	0.8	1.6
MDW_01	5.8	9.4	11.2	12.2	13.9	15.3	16.4	19.7	31.5
MD01	5.7	9.1	10.8	11.8	13.3	14.7	15.7	18.9	29.7
MD02	5.6	9.1	10.7	11.7	13.2	14.5	15.6	18.7	29.3

5 Discussion and summary of results

5.1 Comparison of results from different methods

This table compares peak flows from various methods with those from the FEH Statistical method at example sites for two key return periods. Blank cells indicate that results for a particular site were not calculated using that method.

Site code	Ratio of peak flow to FEH Statistical peak	
	Return period 2 years	Return period 100 years
	ReFH	ReFH
MDE_01	1.41	1.86
MDW_01	1.27	1.48
MD01	1.22	1.38
MD02	1.20	1.36

5.2 Final choice of method

Choice of method and reasons – include reference to type of study, nature of catchment and type of data available.	The FEH Statistical method was chosen due to the consistency of flow estimates downstream and as a result of the Marden Drain (East) catchment being heavily urbanised and small. The ReFH estimates have been provided as a comparison with the FEH Statistical estimates. As hydrographs are required for the hydraulic model, the ReFH hydrograph shapes will be scaled to fit the FEH Statistical peak flow estimates.

5.3 Assumptions, limitations and uncertainty

List the main assumptions made (specific to this study)	The main assumptions in this study are that: • The pooling groups is suitably representative of the Marden catchments. • ReFH hydrograph shape is representative of the catchment response; particularly the small urban Marden Drain (East) catchment.
Discuss any particular limitations, e.g. applying methods outside the range of catchment types or return periods for which they were developed	The FEH Statistical method is generally believed to only be suitable for return periods up to 200 years. ReFH is calibrated for return periods up to 150 years. Estimates of flows beyond these return periods are extrapolations and have a higher degree of uncertainty.
Give what information you can on uncertainty in the results – e.g. confidence limits for the QMED estimates using FEH 3 12.5 or the factorial standard error from Science Report SC050050 (2008).	It is not possible to easily assess the uncertainty of the larger flood flow estimates. The FEH allows for calculating confidence intervals for QMED based on catchment descriptors (CDs). MDW_01 – QMED: 2.2 – 9.2 (m^3/s) MD01 – QMED: 2.3 – 9.5 (m^3/s) MD02 – QMED: 2.3 – 9.6 (m^3/s) Providing 95% confidence intervals for QMED on the urbanised subcatchments (MDE_01) would imply a false level of accuracy in the QMED estimates, given the uncertainty in the UAFs. For ungauged catchments it is not possible to consider uncertainty in pooled flow estimates but they are likely to be considerably larger than the uncertainty in QMED.

Comment on the suitability of the results for future studies, e.g. at nearby locations or for different purposes.	The design flow estimates have been derived for the purposes of this hydrological assessment in order to inform the fluvial component of a Surface Water Management Plan. If peak flow estimates are required for different purposes it is recommended that, at a minimum, a review of results is carried out.
Give any other comments on the study, for example suggestions for additional work.	As in most ungauged catchments, it is recommended that temporary flow gauges be installed to better inform the design peak flow estimates. There are no other specific suggestions relevant to this study.

5.4 Checks

Are the results consistent, for example at confluences?	Yes, the FEH Statistical peak flow estimates are consistent along reaches and at confluences.
What do the results imply regarding the return periods of floods during the period of record?	N/A, ungauged catchments.
What is the 100-year growth factor? Is this realistic? (The guidance suggests a typical range of 2.1 to 4.0)	The 1% AEP event growth factors vary between 2.40 and 2.45 which are within the typical range.
If 1000-year flows have been derived, what is the range of ratios for 1000-year flow over 100-year flow?	The 0.1% / 1% AEP event ratios vary between 1.41 and 1.45 which are within the typical range (1.3 – 1.8).
What range of specific runoffs (l/s/ha) do the results equate to? Are there any inconsistencies?	The 1% AEP specific runoff range between 6.5 and 7.0 l/s/ha which are within the typical range (2 – 10 l/s/ha).
How do the results compare with those of other studies? Explain any differences and conclude which results should be preferred.	N/A.
Are the results compatible with the longer-term flood history?	TBC – will be confirmed against model outputs. There is no gauged data within these catchments to compare the design flow estimates against.
Describe any other checks on the results	N/A

5.5 Final results

Site code	Flood peak (m^3/s) for the following Annual Exceedance Probabilities (%)								
	50	**10**	**5**	**3.33**	**2**	**1.33**	**1**	**1 (+CC)**	**0.1**
MDE_01	0.2	0.2	0.3	0.3	0.3	0.4	0.4	0.4	0.5
MDW_01	4.5	7.3	8.4	9.1	9.9	10.6	11.1	13.3	15.7
MD01	4.6	7.5	8.6	9.3	10.1	10.8	11.3	13.6	16.0
MD02	4.7	7.6	8.7	9.4	10.2	11.0	11.5	13.8	16.2

If flood hydrographs are needed for the next stage of the study, where are they provided? (e.g. give filename of spreadsheet, name of ISIS model, or reference to table below)	Flood hydrographs are required for the hydraulic modelling and will be provided in individual ISIS Event Data (.IED) files. A brief assessment of storm durations and peak flows was carried out in order to determine the critical duration at the

	downstream location for the hydraulic model. A storm duration of 15.25 hours was found to produce the highest 1% AEP flow estimate at MD02 (ARF=0.962) so therefore this storm duration should be tested within the hydraulic model. As the Marden Drain (East) is a fairly small tributary, it is recommended that the shorter storm duration (2.25hrs) is also tested within the hydraulic model. The standard storm duration at the downstream extent (9.5hrs) will also be tested.

6 Annex – supporting information

6.1 Pooling group composition

Table 6-1: Marden Drain (DS) Final Pooling Group

Rank	Station Number	Similarity Distance Measure	Years of Data	AREA	QMED AM	L-CV	L-SKEW	Discordancy
1	27073	1.091	32	8.06	0.813	0.197	-0.022	0.681
2	20002	1.348	41	26.31	3.299	0.292	0.015	1.662
3	33054	1.963	36	48.51	1.129	0.214	0.069	0.080
4	203046	2.022	30	22.51	10.934	0.136	0.091	1.039
5	41020	2.099	43	35.42	13.49	0.214	0.208	1.411
6	33032	2.107	44	56.18	0.461	0.315	0.099	1.089
7	72014	2.130	45	28.99	17.703	0.193	0.059	0.971
8	34005	2.166	51	72.12	3.146	0.281	0.181	0.942
9	73015	2.197	21	30.06	12.239	0.156	0.001	0.639
10	26003	2.241	52	59.40	1.739	0.243	-0.015	0.696
11	36010	2.247	45	27.58	6.759	0.418	0.228	1.943
12	26802	2.306	13	15.85	0.109	0.261	0.199	0.860
13	36003	2.308	49	56.46	3.841	0.310	0.109	0.987
	Total		502					
	Weighted					0.248	0.093	

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