Appendix F : Flood Estimation Proforma

Flood estimation calculation record

Introduction

This document is a supporting document to the Environment Agency's flood estimation guidelines. 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

	Signature	Name and qualifications	For Environment Agency staff: Competence level (see below)
Calculations prepared by:		**Georgia Athanasia/Anna Velkov**	
Calculations checked by:		**Kerry Foster**	
Calculations approved by:			

Environment Agency competence levels are covered in Section 2.1 of the flood estimation guidelines:

- Level 1 – Hydrologist with minimum approved experience in flood estimation
- Level 2 – Senior Hydrologist
- Level 3 – Senior Hydrologist with extensive experience of flood estimation

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 • Approx. time available	The purpose of the King's Lynn Ordinary Watercourse Study is to undertake a more detailed assessment of flood risk from ordinary watercourses within King's Lynn and its interaction with surface water flooding. No hydrology report or ISIS inflow boundaries are available for the Pierrepoint Model and the previous study recommended to re-estimating flow boundaries using updated methods (since the FEH rainfall-runoff method has been superseded by the Revitalised FEH method) and data. Therefore, hydrological calculation will be done for the Pierrepoint and Middleton Stop Drains to derive inflows for the ISIS model. The inflows applied to the model will consist of a combination of point inflows applied to the watercourses and rainfall hyetographs applied to the entirety of the 2D model extent. The point inflows represent runoff from the upper parts of the catchment that are not explicitly modelled.

1.2

1.3 Overview of catchment

Item	Comments
Brief description of catchment, or reference to section in accompanying report	Refer to King's Lynn Ordinary Watercourse Study: Technical Note

1.4

1.5 Source of flood peak data

Was the HiFlows UK dataset used? If so, which version? If not, why not? Record any changes made	No – not required

1.6 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
N/A							

1.7 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.
N/A						
Give link/reference to any further data quality checks carried out						

1.8 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			

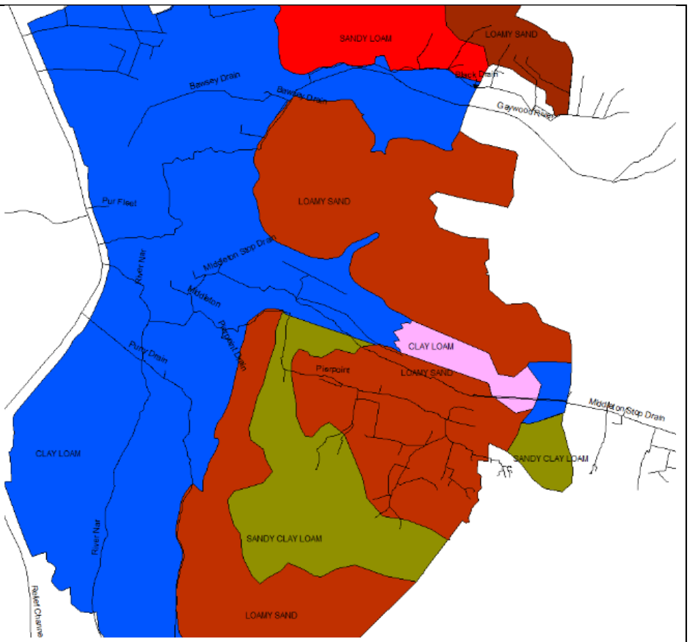
1.9 Other data available and how it has been obtained

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)					
Historic flood data – give link to historic review if carried out.					
Flow data for events					
Rainfall data for events					
Potential evaporation data					
Results from previous studies					
Other data or information (e.g. groundwater, tides)					

1.10 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.	
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?	
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	
Initial choice of method(s) and reasons Will the catchment be split into subcatchments? If so, how?	The Middleton Stop Drain and the Pierrepoint drain ordinary water courses are located in a close proximity to the River Gaywood. The catchments are permeable and covered by similar soil type (see the soil map extract below). No gauging stations (flow or level) exist on the ordinary water courses and the nearest gauge is the Sugar Fen Gauging Station located on River Gaywood and used as a donor station for the River Gaywood flood estimation (River Gaywood Flood Modelling, PBA, 2014). Therefore a decision was made to use the same approach and method used in the Gaywood river Flood Modelling report: 2014 200117 Model Report Revision A (draft), (P:\environment\ZWET\CS072082_KingsLynnOrdinary Watercourses\Data)

	
Software to be used (with version numbers)	FEH CD-ROM v3.0[1]/ ISIS v3.7

[1] FEH CD-ROM v3.0 © NERC (CEH). © Crown copyright. © AA. 2009. All rights reserved.

2 Locations where flood estimates required

The table below lists the locations of subject sites. The site codes listed below are used in all subsequent tables to save space.

2.1 Summary of subject sites

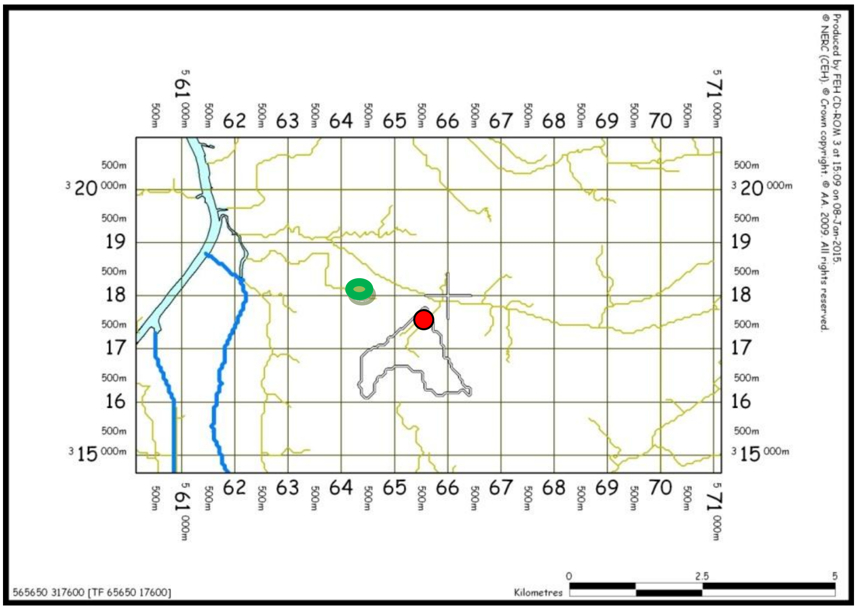
Site code	Watercourse	Site	Easting	Northing	AREA on FEH CD-ROM (km^2)	Revised AREA if altered
MPS	Middleton Stop Drain	Upstream model extent.	566850	317800	13.77	
PP	Pierrepoint drain	Upstream model extent.	565650	317600	1.58	
Reasons for choosing above locations		Flood estimation points located at model 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	FPEXT
MPS	0.983	0.23	0.74	3.53	14.2	635	24.79	0.0165	0.24
PP	1	0.23	0.735	1.31	11.6	620	22.66	0.1016	0.23

2.3 Checking catchment descriptors

<table>
<tr><td>Record how catchment boundary was checked and describe any changes (refer to maps if needed)</td><td>The catchment boundaries were checked using LiDAR data and topographical survey and the FEH CD-ROM.
For the Middleton Stop Drain the catchment boundaries from the different sources were matching.
However the selection of the boundaries for the Pierrepoint drain catchment was a bit arbitrary. According to the FEH CD ROM the point where the drain starts in the TuFlow model is actually on a tributary to the Middleton Stop drain and the Pierrepoint drain starts a bit further to the west (the green point) with a very small catchment area contributing to the start of the drain. For the purpose of this assessment we have assumed that the FEH is out of date and that the Pierrepoint drain is artificially extended further east with a network of drains, as shown in the DRN. Therefore the inflow node location was selected as shown in the figure below (the red node) with delineated catchments area.



</td></tr>
<tr><td>Record how other catchment descriptors (especially soils) were checked and describe any changes. Include before/after table if necessary.</td><td>Catchment descriptors for the flow nodes were sensibility checked against soils and geology maps and DTM data. No adjustments to the catchment descriptors were made.</td></tr>
<tr><td>Source of URBEXT</td><td>URBEXT1990 / URBEXT2000 - FEH CD-ROM</td></tr>
<tr><td>Method for updating of URBEXT</td><td>CPRE formula from FEH Volume 4 / CPRE formula from 2006 CEH report on URBEXT2000 – Technical Report FD1919/TR</td></tr>
</table>

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.	As stated in Section 1.8 above there do not appear to be any suitable local donors that could have been used for this study. The catchments for the Middleton Stop Drain and Pierrepoint Drain are relatively small and situated immediately to the south of the River Gaywood catchment. Therefore, for consistency with the rivers in the north of the catchment, the same approach which was applied for River Gaywood flow nodes has been used for Middleton Stop Drain and Pierrepoint Drain.

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)
33077	Sugar Fen GS used in Gaywood River flow derivation. In this case the estimates are presented for comparison purpose only.			0.71	1.36	
Which version of the urban adjustment was used for QMED at donor sites, and why? Note: The guidelines recommend great caution in urban adjustment of QMED on catchments that are also highly permeable (BFIHOST>0.8).				WINFAP-FEH v3.0.003 / Kjeldsen (2010) / other (delete as applicable)		

3.3 Overview of estimation of QMED at each subject site

Site code	Method	Initial estimate of QMED (m^3/s)	Data transfer				If more than one donor		Final estimate of QMED (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, $(A/B)^a$	Weight	Weighted average adjustment factor	
MSP	Statistical	0.71							0.71
PP	Statistical	0.11							0.11
Are the values of QMED consistent, for example at successive points along the watercourse and at confluences?									
Which version of the urban adjustment was used for QMED, and why?									

			Data transfer						
							If more than one donor		
Site code	Method	Initial estimate of QMED (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, $(A/B)^a$	Weight	Weighted average adjustment factor	Final estimate of QMED (m^3/s)

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.

When QMED is estimated from catchment descriptors, the revised 2008 equation from Science Report SC050050**Error! Bookmark not defined.** should be used. If the original FEH equation has been used, say so and give the reason why.

The guidelines recommend great caution in urban adjustment of QMED on catchments that are also highly permeable (BFIHOST>0.8). The adjustment method used in WINFAP-FEH v3.0.003 is likely to overestimate adjustment factors for such catchments. In this case the only reliable flood estimates are likely to be derived from local flow data.

The data transfer procedure is 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.

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)

Notes

Pooling groups were derived using the revised procedures from Science Report SC050050 (2008). Amend if not applicable.

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

Site code	**Method** (SS, P, ESS, J)	**If P, ESS or J, name of pooling group (3.4)**	**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**

Site code	**Method** (SS, P, ESS, J)	**If P, ESS or J, name of pooling group (3.4)**	**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**

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 to growth curves should use the version 3 option in WINFAP-FEH: Kjeldsen (2010).

Growth curves were derived using the revised procedures from Science Report SC050050 (2008). Amend if not applicable.

Any relevant frequency plots from WINFAP-FEH, particularly showing any comparisons between single-site and pooled growth curves (including flood peak data on the plot), should be shown here or in a project report.

3.6 Flood estimates from the statistical method

Site code	**Flood peak (m^3/s) for the following return periods (in years)**								
	2								

4 Revitalised flood hydrograph (ReFH) method

4.1 Parameters for ReFH model

Note: If parameters are estimated from catchment descriptors, they are easily reproducible so it is not essential to enter them in the table.

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

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)

Are the storm durations likely to be changed in the next stage of the study, e.g. by optimisation within a hydraulic model?	

4.3 Flood estimates from the ReFH method

Site code	Flood peak (m^3/s) or volumes (m^3) for the following return periods (in years)								
	2								

5 FEH rainfall-runoff method

5.1 Parameters for FEH rainfall-runoff model

Methods:
FEA : Flood event analysis
LAG : Catchment lag
DT : Catchment descriptors with data transfer from donor catchment
CD : Catchment descriptors alone
BFI : SPR derived from baseflow index calculated from flow data

Site code	Rural (R) or urban (U)	Tp(0): method	Tp(0): value (hours)	SPR: method	SPR: value (%)	BF: method	BF: value (m^3/s)	If DT, numbers of donor sites used (see Section 5.2) and reasons

Note:

The FEH rainfall-runoff method was used to generate hydrographs using catchment descriptors. The same scaling factors used in the Gaywood River flow estimation (2014, PBA) were applied as follows:

-Baseflow set to the estimated baseflow for 10 year event for each of the catchments. The base flow was estimated in the Gaywood study (Table A7, River Gaywood Flood Modelling report, PBA, 2014) and scaled to reflect the smaller catchments size of Middleton Stop and Pierrepoint catchments.

-Quickflow scaled by 0.4,

-Unit hydrograph TB scaled by 1.5 (derived iteratively in the Gaywood study, to give a longer falling limb similar to the observed data for Sugar Fan)

5.2 Donor sites for FEH rainfall-runoff parameters

No.	Watercourse	Station	Tp(0) from data (A)	Tp(0) from CDs (B)	Adjustment ratio for Tp(0) (A/B)	SPR from data (C)	SPR from CDs (D)	Adjust-ment ratio for SPR (C/D)
1								
2								

5.3 Inputs to and outputs from FEH rainfall-runoff model

Site code	Storm duration (hours)	Storm area for ARF (if not catchment area)	Flood peaks (m^3/s) for the following return periods (in years)							
			100yr							
MPS	3.5	**CA**	1.33							
	16		1.78							
	22.5		1.82							
	26		1.81							
PP	3.5	**CA**	0.37							
	16		0.40							
	22.5		0.37							
	26		0.36							

Site code	Storm duration (hours)	Storm area for ARF (if not catchment area)	Flood peaks (m^3/s) for the following return periods (in years)							
			100yr							
Are the storm durations likely to be changed in the next stage of the study, e.g. by optimisation within a hydraulic model?										

6 Discussion and summary of results

6.1 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	Other method	Other method	ReFH	Other method	Other method

6.2 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 method has been chosen to provide the best estimate of peak flows and the generate hydrographs. This was the method applied for the flow estimation of River Gaywood and based on the close location and similarity of the catchments, and for consistency, the same method was applied for the flows generation of the Middleton Stop and Pierpont Drains. Tp and SPR remained unchanged from catchment descriptor values. BF has been altered based on the analysis carried out in the previous (River Gaywood) study. The calculations for the scaling factors are in the "Critical_Duration_FEH_ReFH.xls" (P:\environment\ZWET\CS072082_KingsLynnOrdinaryWatercourses\Hydrology). It is worth noting that the Gaywood River upstream catchment is permeable and the MSP and PD are less permeable with SPR values greater than 20%. A quick test as part of ths review identified that there is little difference in the final flows if a BF calculated by FEH catchment descriptors is used. Therefore is it reasonable to use the scaled BFs as these have been inferred from local data.

6.3 Assumptions, limitations and uncertainty

List the main assumptions made (specific to this study)	Usual FEH assumptions. The same factors for adjustment of the hydrograph shape as described in the Gaywood modelling report were applied. The adjustments are as follows: -Baseflow set to the estimated baseflow for 10 year event for each of the catchments. The base flow was estimated in the Gaywood study and we scaled it to reflect the smaller catchments size. -Quick flow scaled by 0.4, -Unit hydrograph TB scaled by 1.5 (derived iteratively in the Gaywood study, to give a longer falling limb similar to the observed data for Sugar Fan)
Discuss any particular limitations, e.g. applying methods outside the range of catchment types or return periods for which they were developed	No directly observed flow data or suitable donor station was available. Therefore the same approach and the scaling factors derived for the River Gaywood flow estimation were used.
Give what information you can on uncertainty in the results – e.g.	No data was available for flow calibration.

confidence limits for the QMED estimates using FEH **3** 12.5 or the factorial standard error from Science Report SC050050 (2008).	
Comment on the suitability of the results for future studies, e.g. at nearby locations or for different purposes.	
Give any other comments on the study, for example suggestions for additional work.	

6.4 Checks

Are the results consistent, for example at confluences?	
What do the results imply regarding the return periods of floods during the period of record?	The 100yr return period flow appears reasonable for the respective catchments size.
What is the 100-year growth factor? Is this realistic? (The guidance suggests a typical range of 2.1 to 4.0)	
If 1000-year flows have been derived, what is the range of ratios for 1000-year flow over 100-year flow?	
What range of specific runoffs (l/s/ha) do the results equate to? Are there any inconsistencies?	
How do the results compare with those of other studies? Explain any differences and conclude which results should be preferred.	
Are the results compatible with the longer-term flood history?	
Describe any other checks on the results	

6.5 Final results

Site code	Flood peak (m^3/s) for the following return periods (in years)							
	10	20	40	100	200			
MS	1.05	1.28	1.52	1.88	2.22			
PP	0.20	0.24	0.30	0.37	0.43			

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)	P:\environment\ZWET\CS072082_KingsLynnOrdinaryWatercourses\Hydrology\IED_South Catchment\FEH\MS\Other hydrographs; P:\environment\ZWET\CS072082_KingsLynnOrdinaryWatercourses\Hydrology\IED_South Catchment\FEH\PP\Other return periods

7 Annex - supporting information

7.1 Pooling group composition

7.2 Additional supporting information