Flood estimation report: Gavray Drive, Bicester – Langford Brook

Introduction

This report template is a supporting document to the Environment Agency's Flood Estimation Guidelines. It provides a record of the hydrological context, the method statement, the calculations and decisions made during flood estimation and the results. This document can be used for one site or multiple sites. If only one site is being assessed, analysts should remove superfluous rows from tables.

Guidance notes (in red text) are included throughout this document in column titles or above tables. These should be deleted before finalising the document. Where relevant, references to specific sections of the Flood Estimation Guidelines document are included to indicate where further useful information can be found.

Note: Column size / page layout can be adapted, where necessary, to best present relevant information, for example, maps do not need to be within the tables if they would be better as a separate page.

Contents

Approval

Revision stage	Analyst / Reviewer name & qualifications	Amendments	Date
Method statement preparation	Zoe Nixon MSc (Hons)	N/A	23/08/22
Method statement sign-off	Simon Mirams Bsc (Hons) MCIWEM C.WEM CSci	N/A	23/08/22
Initial calculations preparation	Zoe Nixon MSc (Hons)		23/08/22
Initial calculations sign-off	Simon Mirams Bsc (Hons) MCIWEM C.WEM CSci	N/A	23/08/22
Calculations - Revision			N/A

1 preparation			
Calculations - Revision 1 sign-off		N/A	
Calculations - Revision 2 preparation			N/A
Calculations - Revision 2 sign-off		N/A	

Abbreviations

AEP .... annual exceedance probability
AM .... Annual Maximum
AREA .... Catchment area (km^2)
BFI .... Base Flow Index
BFIHOST .... Base Flow Index derived using the HOST soil classification
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
OS .... Ordnance Survey
POT .... Peaks Over a Threshold
QMED .... Median Annual Flood (with return period 2 years)
ReFH .... Revitalised Flood Hydrograph method
ReFH2 .... Revitalised Flood Hydrograph 2 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 SUMMARY OF ASSESSMENT

1.1 Summary

This table provides a summary of the key information contained within the detailed assessment in the following sections. The aim of the table is to enable quick and easy identification of the type of assessment undertaken. This should assist in identifying an appropriate reviewer and the ability to compare different studies more easily.

Catchment location	The Langford Brook catchment is located in the town of Bicester, Oxfordshire.
Purpose of study and scope	This study provides a review of the Bicester_012 model inflows. The model was provided to Hydrock by the EA, and has been reviewed by Hydrock. The scope is moderate.
Key catchment features	The catchment is relatively permeable with an SPRHOST value of 25.22 and a BFIHOST19 value of 0.629 however, the catchment is not considered to be groundwater-dominated (BFIHOST<0.65).
Flooding mechanisms	The key flooding mechanism is considered to be fluvial.
Gauged / ungauged	The catchment is un-gauged.
Final choice of method	ReFH2
Key limitations / uncertainties in results	The study is limited by the lack of gauged data and historical flood records.

1.2 Note on flood frequencies

The frequency of a flood can be quoted in terms of a return period, which is defined as the average time between years with at least one larger flood, or as an annual exceedance probability (AEP), which is the inverse of the return period.

Return periods are are output by the Flood Estimation Handbook (FEH) software and can be expressed more succinctly than AEP. However, AEP can be helpful when presenting results to members of the public who may associate the concept of return period with a regular occurrence rather than an average recurrence interval. Results tables in this document contain both return period and AEP titles; both rows can be retained or the relevant row can be retained and the other removed, depending on the requirement of the study.

The table below is provided to enable quick conversion between return periods and annual exceedance probabilities.

Annual exceedance probability (AEP) and related return period reference table

AEP (%)	50	20	10	5	3.33	2	1.33	1	0.5	0.1
AEP	0.5	0.2	0.1	0.05	0.033	0.02	0.0133	0.01	0.005	0.001
Return period (yrs)	2	5	10	20	30	50	75	100	200	1,000

2 METHOD STATEMENT

2.1 Requirements for flood estimates

Overview	The purpose of this study is to provide inflows for the Bicester_012 model which Hydrock has been requested to review. The Biecester model consists of the Langord Brook, and several tribuytaires however, Hydrock's model review only involves a section of the model with one inflow: at the upstream extent of Langford Brook. This study will provide peak flows for the following design events: • 50% AEP – 1 in 2-year (QMED) • 20% AEP – 1 in 20-year • 1% AEP – 1 in 100-year • 0.1% AEP – 1 in 1,000-year The calculated peak flows will be used to produce hydrographs for the 2% AEP, 1% AEP, 1% + Central CC Allowance and 0.1% AEP fluvial event, which will be used as point inflows for the hydraulic model. The central climate change allowance applied to the 1% AEP fluvial event is 15%, in line with the Cherwell and Ray Management Catchment peak river flow allowances. The purpose of this document is to provide a record and justification of the methodology and outputs of the hydrological assessment of peak flows for the catchment.
Project scope	The scope of the project is moderate and will involve a review of the existing hydrological study undertaken for the Bicester_012 model.

2.2 The catchment

Description	**Langford Brook (LA)** The Langford Brook is a small catchment (19.34km^2) shown in Figure 1. The catchment is 'moderatey urbanised' (URBEXT2000 = 0.100) and is relatively permeable (BFIHOST19 = 0.629, SPRHOST = 25.22). British Geological Survey (BGS) Mapping shows the catchment to be underlain by a mixture of bedrock geologies, predominantly consisting of limestone. Soilscapes shows the catchment to be predominantly overlain by 'freely draining' soils.

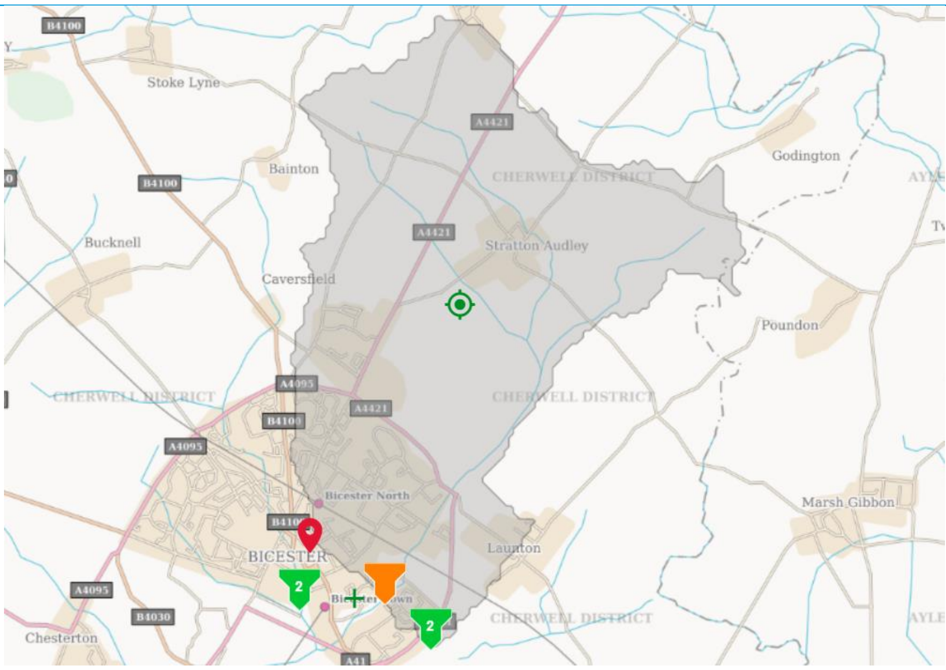


Figure 1. Langford Brook FEH Catchment

2.3 Source of flood peak data

Source	NRFA peak flows dataset, Version 10, released August 2021. This contains data up to water year 2019-20.

2.4 Gauging stations (flow or level)

Water-course	Station name	Gauging authority number	NRFA number	Catchment area (km²)	Type (rated / ultrasonic / level…)	Start of record and end if station closed
NA						

2.5 Other data available and how it has been obtained

Type of data	Data relevant to this study?	Data available?	Source of data	Details
Check flow gaugings	NA	-	-	-
Historical flood data	NA	-	-	-
Flow or river level data for events	NA	-	-	-
Rainfall data for events	NA	-	-	-
Potential evaporation data	NA	-	-	-
Results from previous studies	Yes	Yes	EA Bicester_012 model peak flows	Peak flows for the Bicester_012 model were provided to Hydrock by the EA. These are used for comparison with the flows estimated in this study.
Other data or information	NA	-	-	-

2.6 Hydrological understanding of catchment

Conceptual model	The main site of interest is the Site, which is located off Gavray Drive, Bicester. The main source of flooding at this location is fluvial flooding from the Langford Brook.
Unusual catchment features	The Langford Brook catchment is relatively permeable with an SPRHOST value of 25.22 and a BFIHOST19 value of 0.629 however, the catchment is not considered to be groundwater-dominated (BFIHOST<0.65). The catchment is small (19.34km^2) and as such, the use of small catchment pooling method and guidance from the Small Catchment Phase 2 Research (SC090031) was considered.

2.7 Initial choice of approach

Is FEH appropriate?	FEH is considered to be appropriate in this instance.
Initial choice of method(s) and reasons How will hydrograph shapes be derived if needed? Will the catchment be split into sub-catchments? If so, how?	Flows will be estimated for the catchment using both WINFAP 5 and ReFH2. Professional judgement will be undertaken in the comparison of the results in order to determine which are most appropriate in this instance. Hydrograph shapes will be derived using ReFH2.
Software to be used (with version numbers)	FEH Web Service[1] / ReFH2.2 / Flood Modeller Pro / WINFAP v5

[1] CEH 2015. The Flood Estimation Handbook (FEH) Online Service, Centre for Ecology & Hydrology, Wallingford, UK.

3 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.

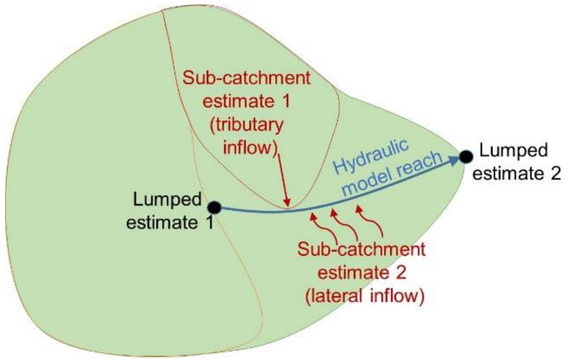
3.1 Summary of subject sites

Site code	Type of estimate L: lumped catchment S: Sub-catchment	Watercourse	Name or description of site	Easting	Northing	AREA on FEH CD-ROM (km^2)	Revised AREA if altered
LA	S	Langford Brook		459350	222000	19.338	-

Note: Lumped catchments (L) are complete catchments draining to points at which design flows are required.

Sub-catchments (S) are catchments or intervening areas that are being used as inputs to a semi-distributed model of the river system. There is no need to report any design flows for sub-catchments, as they are not relevant: the relevant result is the hydrograph that the sub-catchment is expected to contribute to a design flood event at a point further downstream in the river system. This will be recorded within the hydraulic model output files. However, catchment descriptors and ReFH model parameters should be recorded for sub-catchments so that the results can be reproduced.

The schematic diagram illustrates the distinction between lumped and sub-catchment estimates.



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

Site code	FARL	PROPWET	BFIHOST19	DPLBAR (km)	DPSBAR (m/km)	SAAR (mm)	URBEXT 2000	FPEXT
LA	0.965	0.32	0.629	4.81	14.7	633	**0.124**	0.181

3.3 Checking catchment descriptors

Record how catchment boundary was checked and describe any changes	**LA** The AREA of the catchment was checked using OS contour mapping and available LiDAR data. This exercise identified little difference between the FEH catchment and that identified using topographical information. In addition, no obvious cross-catchment flows from watercourses, land drainage ditches, or sewer networks were identified, and as such, the Catchment Descriptors AREA value remains appropriate and was used in these calculations.
Record how other catchment descriptors were checked and describe any changes.	**LA** The Catchment Descriptors provide a SPRHOST of 25.22 which implies the underlying conditions are considered to be relatively permeable. Given the potential impact of this value on calculated flows this was checked using available soil mapping information. This information shows that the majority of the catchment is underlain by 'freely draining line-rich loamy soils', with some areas of the catchment overlain by 'slowly permeable, seasonally wet, slightly acid but base-rich loamy and clayey soils'. This suggests that the underlying ground conditions are relatively permeable, and as such, the SPRHOST value is considered acceptable.

Source of URBEXT	URBEXT2000
Method for updating of URBEXT	**LA** In order to verify the URBEXT value, a review of OS mapping and the FEH URBEXT2000 mapping was undertaken to identify any significant areas where recent development has occurred. Recent areas of urban development were identified that were not included in the calculation of the FEH URBEXT2000 value. As such, the urban area was measured using aerial imagery (3.745km^2). This represents an URBAN value of 0.194. Using the equations provided in FEH Volume 5 Section 6.5.5, the URBEXT2000 value was calculated as 0.124. The updated URBEXT value was used in the calculation of peak flows for the catchment.

4 STATISTICAL METHOD

4.1 Application of Statistical method

What is the purpose of applying this method?	The Statistical Method was applied in order to estimate peak flows for the hydraulic modelling study.

4.2 Overview of estimation of QMED at each subject site

Site code	QMED (rural) from CDs (m^3/s)	Final method	Data transfer					Urban adjust-ment factor UAF	Final estimate of QMED (m^3/s)
			NRFA numbers for donor sites used (see 4.3)	Distance between centroids d_{ij} (km)	Moderated QMED adjustment factor, $(A/B)^a$	If more than one donor			
						Weight	Weighted ave. adjustment		
LA	1.401	D	39021	20.33	0.966	0.306	-	1.199	1.354

Are the values of QMED spatially consistent?		NA
Method used for urban adjustment for subject and donor sites		WINFAP v5
Parameters used for WINFAP v4 urban adjustment if applicable		
Impervious fraction for built-up areas, IF	Percentage runoff for impervious surfaces, PR_{imp}	Method for calculating fractional urban cover, URBAN
0.3	70%	From updated URBEXT2000

Notes

Methods: AM – Annual maxima; POT – Peaks over threshold; DT – Data transfer (with urban adjustment); CD – Catchment descriptors alone (with urban adjustment); BCW – Catchment descriptors and bankfull channel width (add details); LF – Low flow statistics (add details).

The QMED adjustment factor A/B for each donor site 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 (rural) estimate from catchment descriptors.

Important note on urban adjustment

The method used to adjust QMED for urbanisation published in Kjeldsen (2010)**Error! Bookmark not defined.** in which PRUAF is calculated from BFIHOST is not correctly applied in WINFAP-FEH v3.0.003. Significant differences occur only on urban catchments that are highly permeable. This is discussed in Wallingford HydroSolutions (2016)**Error! Bookmark not defined.**.

4.3 Search for donor sites for QMED (if applicable)

Comment on potential donor sites	**LA** The potential donor gauging stations for QMED are located between 9.60 and 39.43km from the flood estimation point, and have between 5 and 78 years of data. The potential donors were reviewed and all stations have FARL values of > 0.9. Enslow Mill (39021), Cassington Mill (39034), Days Weir (39002) and Abingdon (39018) were within +/- 20% of the subject site's BFIHOST19 value, and as such all other stations were rejected. From the remaining four stations, all stations were within +/- 30% of the subject site's SAAR value. Enslow Mill (39021) was selected as the most suitable donor as it was the closest suitable donor to the target site. The small catchment research advised on the use of just one donor catchment for catchments under 20km^2.

4.4 Donor sites chosen and QMED adjustment factors

NRFA no.	Method (AM or POT)	Adjustment for climatic variation?	QMED from flow data (A)	QMED from catchment descriptors (B)	Adjustment ratio (A/B)
39021	AM	NA	18.730	37.817	0.495

4.5 Derivation of pooling groups

Name of group	Site code from whose descriptors group was derived	Subject site treated as gauged?	Changes made to default pooling group, with reasons	Weighted average L-moments
Langford	LA	No	In line with guidance (FEH Volume 3 Section 16.2.3), Black Burn @ Pluscarden Abbey was removed from the pooling group as it has a record shorter than 8 years. Leven @ Easby was removed from the pooling group due to its high discordancy. The L-SKEW value and flood frequency curves of the remaining stations were reviewed and all station were accepted. This provided a final pooling group with a H2 value of 2.75 (heterogeneous but within the allowable range of below 4). The pooling group has a total of 505 years of data.	-
Note: Pooling groups were derived using the procedures from Science Report SC050050 (2008).				

4.6 Derivation of flood growth curves at subject sites

Site code	Method	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	Growth factor for 100-year return period / 1% AEP
LA	P	Langford	Kappa 3 – best fit	NA	-	3.018

Notes
Methods: SS – Single site; P – Pooled; ESS – Enhanced single site; J – Joint analysis
Urban adjustments are all carried out using the method of Kjeldsen (2010).
Growth curves were derived using the procedures from Science Report SC050050 (2008).

4.7 Flood estimates from the statistical method

Site code	Flood peak (m^3/s) for the following return periods (in years)									
	2	20	100	1,000						
	Flood peak (m^3/s) for the following AEP (%) events									
	50	5	1	0.1						
LA	1.354	2.901	5.25	8						

5 REVITALISED FLOOD HYDROGRAPH 2 (REFH2) METHOD

5.1 Application of ReFH2 method

What is the purpose of applying this method?	To provide peak flow estimates and the hydrograph shape for the peak inflow point.

5.2 Catchment sub-divisions for ReFH2 model

URBEXT values were used in the calculation, these values were checked using OS mapping and aerial imagery, and updated where needed.

5.3 Parameters for ReFH2 model

Site code	Method	Tp_{rural} (hours)	Tp_{urban} (hours)	C_{max} (mm)	PR_{imp}	BL (hours)	BR
LA	CD	7.35	5.51	578.41	0.7	55.51	2.38
Brief description of any flood event analysis carried out			NA				
Methods: OPT: Optimisation, BR: Baseflow recession fitting, CD: Catchment descriptors, DT: Data transfer (give details)							

5.4 Design events for ReFH2 method: Lumped catchments

Site code	Urban or rural	Season of design event (summer or winter)	Storm duration (hours)
NA			

5.5 Design events for ReFH2 method: Sub-catchments and intervening areas

Site code	Season of design event	Storm duration (hours)	Storm area for ARF (if not catchment area)	Reason for selecting storm
LA	Winter	11	NA	A winter storm profile was selected as the catchment is rural.

5.6 Flood estimates from the ReFH2 method

Site code	Flood peak (m^3/s) for the following return periods (in years)									
	2	20	100	1,000						
	Flood peak (m^3/s) for the following AEP (%) events									
	50	5	1	0.1						
LA	1.91	3.73	5.25	8.87						

7 DISCUSSION AND SUMMARY OF RESULTS

7.1 Comparison of results from different methods

Site code	Ratio of peak flow to FEH Statistical peak					
	Return period 20 years / 5% AEP			Return period 100 years / 1% AEP		
	ReFH	ReFH2	PREVIOUS STUDY	ReFH	ReFH2	PREVIOUS STUDY
LA	NA	1.29	1.29	NA	1.29	3.25

7.2 Final choice of method

Choice of method and reasons	Comparison of the peak flows calculated using the Statistical Method and the Rainfall Runoff Method show the flows calculated using the Rainfall Runoff Method to be slightly larger than those calculated using the Statistical Method. The choice between methods is not always clear cut. Given the larger flows calculated by the Rainfall Runoff Method and the lack of local data to compare with the flows, the Rainfall Runoff Method was selected as the conservative approach.
How will the flows be applied to a hydraulic model?	The flows will be applied at a point inflow, at the upstream extent of the Langford Brook watercourse.

7.3 Assumptions, limitations and uncertainty

List the main assumptions made (specific to this study)	It has been assumed that the ReFH2 hydrograph shapes are representative of the catchment.
Discuss any particular limitations	Confidence in results is reduced due to the lack of catchment hydrometric gauges with sufficient record length to improve the design peak flow estimates and hydrographs. There is also very little historical flood records available against which to verify the results.
Provide information on the uncertainty in the design peak flow estimates and the methodology used	It is not possible to quantify the uncertainty in the results however, there is a high degree of uncertainty due to the lack of gauged data and historic flood records to verify the results. Another source of uncertainty is the pooling group – there is limited gauged data from small catchments and as such the pooling group relies heavily on data from larger catchments, which may not be representative of the catchment in this study. However, this uncertainty was reduced by using the Small Catchments Pooling Method which gives less weight to area. Uncertainty in the estimation of QMED has been reduced by transferring data from local hydraulically similar gauging stations.
Comment on the suitability of the results for future studies	The design peak flow estimates and hydrographs have been derived for the purposes of this study alone. If the results are required for another purpose, it is recommended that a further review is undertaken.
Give any other comments on the study	NA

7.4 Checks

Are the results consistent, for example at confluences?	NA
What do the results imply regarding the return periods / frequency of floods during the period of record?	NA
What is the range of 100-year / 1% AEP growth factors? Is this realistic?	ReFH2: 2.75 - This is realistic. Stats: 3.02 – This is realistic.
If 1000-year / 0.1% AEP flows have been derived, what is the range of ratios for 1000-year / 0.1% AEP flow over 100-year / 1% AEP flow?	ReFH2: 1.69 - This is realistic. Stats: 1.52 – This is realistic
How do the results compare with those of other studies? Explain any differences and conclude which results should be preferred.	Comparison of the estimated peak flows with the previous flows used in the Bicester_012 model shows much higher inflows from the Environment Agency model. The 100 year +15% climate change scenario was run using both inflows to investigate the affect the flows have on the site.
Are the results compatible with the longer-term flood history?	NA
Describe any other checks on the results	The hydraulic model results were sense-checked.

7.5 Final results

Site code	Flood peak (m^3/s) for the following return periods (in years)									
	2	20	100	1000						
	Flood peak (m^3/s) for the following AEP (%) events									
	50%	5%	1%	0.1%						
LA	1.91	3.73	5.25	8.87						

7.6 Uncertainty bounds

This table reports the flows derived from the uncertainty analysis detailed in Section 7.3. The 'true' value is more likely to be near the estimate reported in Section 7.5 than the bounds. However, it is possible that the 'true' value could still lie outside these bounds.

Site code	Flood peak (m^3/s) for the following return periods (in years)							
	2		20		100		1,000	
	Flood peak (m^3/s) for the following AEP (%) events							
	50		5		1		0.1	
	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper
LA	1.3	2.7	2.6	5.3	3.7	7.5	6.2	12.7

If flood hydrographs are needed for the next stage of the study, where are they provided? (e.g. give filename of spreadsheet, hydraulic model, or reference to table below)	The hydrographs are included within the provided modelling files.

8 ANNEX

Langford Pooling

AM Data | Catchment Descriptors

	Station	Distance (SDM)	Years of data	QMED AM	L-CV Observed	L-CV Deurbanised	L-SKEW Observed	L-SKEW Deurbanised	Discordancy
1	36010 (Bumpstead Brook @ Broad Gree	0.352	53	7.500	0.377	**0.379**	0.173	**0.172**	1.583
2	26016 (Gypsey Race @ Kirby Grindalythe	0.536	23	0.101	0.312	**0.312**	0.258	**0.258**	0.238
3	26014 (Water Forlornes @ Driffield)	0.553	22	0.431	0.298	**0.299**	0.120	**0.119**	1.486
4	39033 (Winterbourne Stream @ Bagnor)	0.762	58	0.401	0.342	**0.342**	0.383	**0.382**	1.541
5	33054 (Babingley @ Castle Rising)	0.764	44	1.132	0.204	**0.205**	0.069	**0.068**	1.285
6	36004 (Chad Brook @ Long Melford)	0.784	53	4.938	0.304	**0.305**	0.167	**0.166**	0.692
7	27073 (Brompton Beck @ Snainton Ings	0.786	40	0.816	0.214	**0.215**	0.020	**0.019**	0.839
8	25019 (Leven @ Easby)	0.801	42	5.384	0.338	**0.339**	0.386	**0.385**	1.613
9	33032 (Heacham @ Heacham)	0.877	52	0.442	0.298	**0.299**	0.139	**0.138**	0.225
10	36003 (Box @ Polstead)	0.910	60	3.875	0.314	**0.317**	0.088	**0.086**	0.911
11	30004 (Lymn @ Partney Mill)	0.926	58	7.184	0.224	**0.225**	0.030	**0.029**	0.586
12									
13	Rejected Stations								
14	26013 (Driffield Trout Stream @ Driffield)	0.840	10	2.685	0.292	0.293	0.281	0.280	
15	7011 (Black Burn @ Pluscarden Abbey)	0.860	7	5.205	0.544	0.544	0.571	0.571	
16									
17									