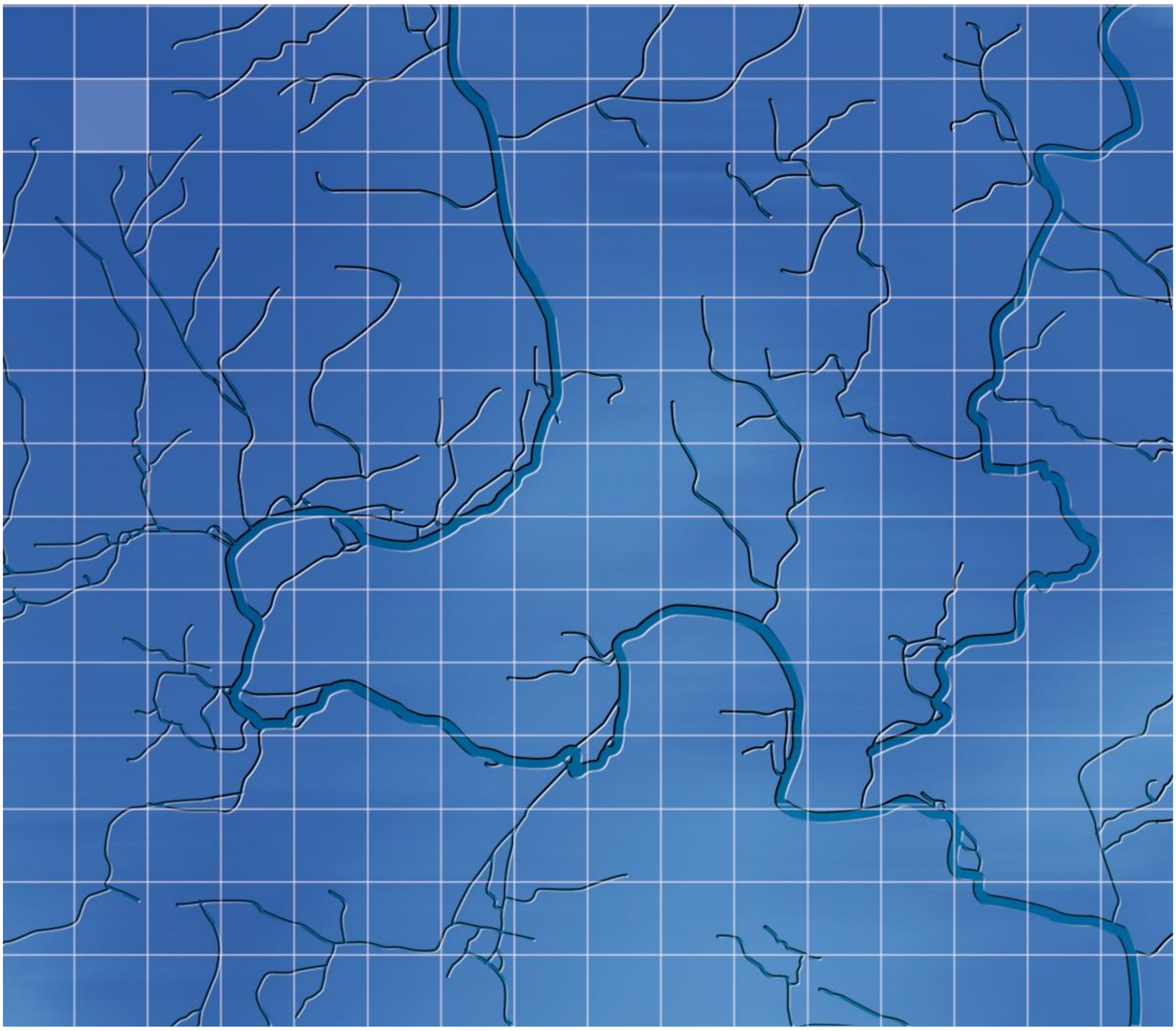
Network Rail and Chiltern Railways

January 2014

MOD Sidings Hydrology Report



Wallingford HydroSolutions Limited

Network Rail and Chiltern Railways

MOD Sidings Hydrology Report

Document issue details

WHS 1160

Version number	Issue date	Issue status	Issuing Office
Version 1	17/10/2013	Final	Wallingford
Version 2	28/01/2014	Final	Cardiff

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Contents

1 Introduction

Wallingford HydroSolutions Ltd. (WHS) is completing a Level 3 Flood Risk Assessment (FRA) to comply with the requirements of an Order under the Transport and Works Act 1992 (TWA). The TWA Application was made to the Secretary of State for Transport, for statutory powers to authorise the EWR Phase 1 project, comprising the redevelopment and operation of the railway between Oxford and Bicester.

WHS has completed the Level 2 FRA, including a revision in July 2010. The Level 3 FRA work builds upon this. The hydrological input to the hydraulic model used to complete the Level 3 FRA work for proposed access roads at Langford Lane and works adjacent to the M40 is outlined within the main report; Langford Lane Hydrology[1]. This report is an addendum to the main report documenting the development of the hydrology input for an independent hydraulic model developed to assess the flood risk impacts of proposed works at the MOD sidings, north of the existing hydraulic model.

Flood hydrographs are required the two new sites at Langford Village and Bicester Village. Flood design hydrographs are required for the 1 in 5, 1 in 20, 1 in 100, 1 in 100 year + climate change and 1 in 1000 year design events. A 20% increase in peak flow is used to allow for climate change as per Planning and Policy Statement 25 (PPS25)[2].

2 Flood Estimation Approach

The recommended methodologies for flood estimation are reviewed within the main report[1], as well as a review of the data utilised within a previous flood study for Bicester completed by Peter Brett Associates (PBA)[3].

The location of the additional sites, those associated with the original hydraulic model (Gagle Brook and Langford Brook) and the level gauges used to generate flood estimates within the PBA study are shown within **Error! Reference source not found.**.

[1] WHS. 2013. Langford Lane Hydrology Report.
[2] Communities and Local government (CLG), 2010, Planning Policy Statement 25.
[3] Peter Brett Associates, 2009, Bicester Flood Risk Mapping Study, Ref 15945/006.

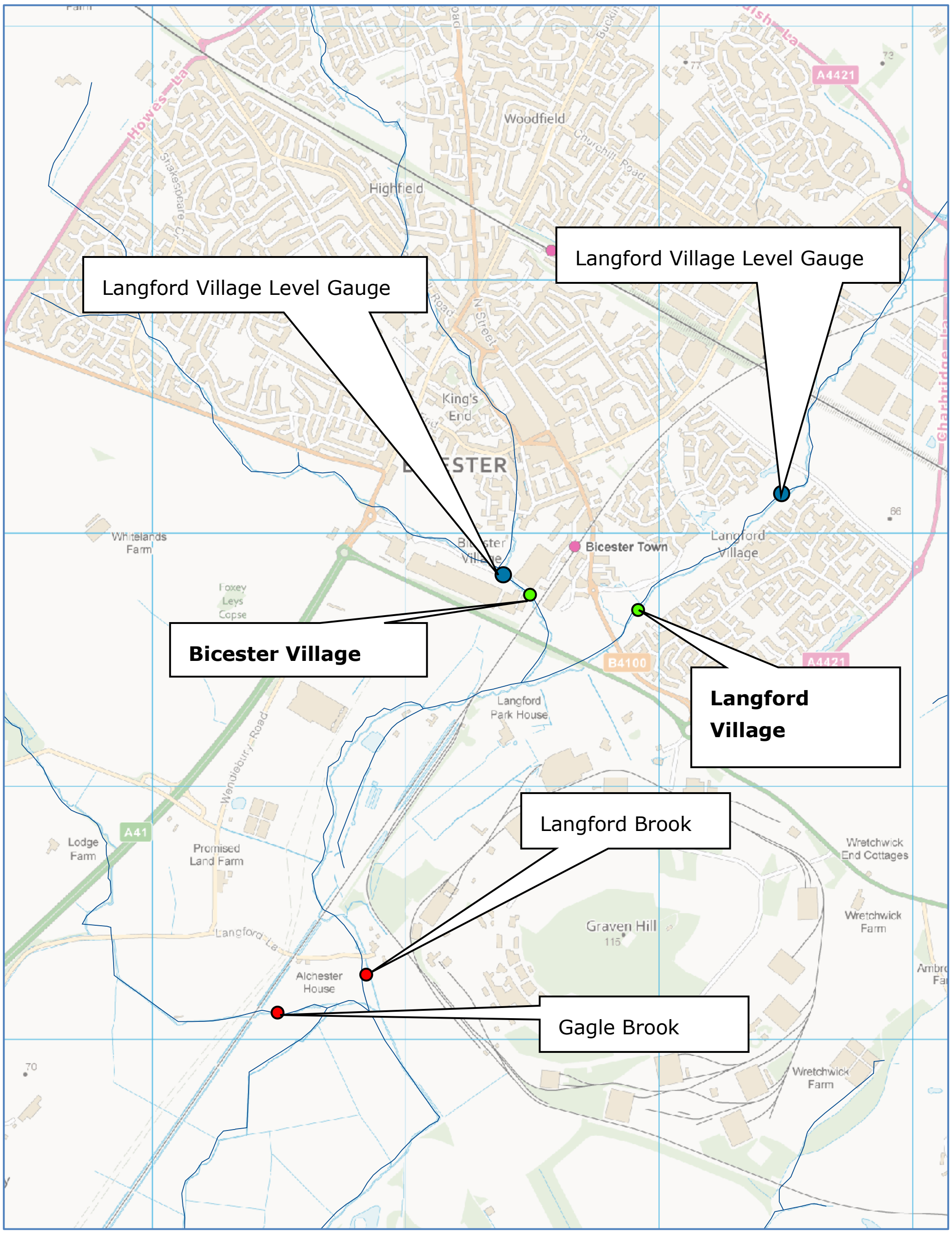

Figure 1 Location of the Hydrology Sites and Level Gauges. Contains Ordnance Survey data © Crown copyright and database right 2013

The main methodologies used are the statistical methodology, as implemented within WINFAPv3 and the Revitalised rainfall runoff methodology (ReFH). The data from the PBA study has been used to enhance the estimation of the QMED for each site using the donor transfer methodology. The close proximity of the sites to the level gauges means that the data from the level gauges will have a large impact on the estimation of the QMED. The QMED values from the PBA study is discussed within the main report but the main findings are presented below:

- The stage-discharge relationship used to estimate the flows within the reaches was based on spot gauges which were, mainly, at low flows.
- A non-standard method of estimating the QMED was used due to the short length of observed hydrometric data.
- The PBA QMED values are high in comparison with the QMED derived using the catchment descriptor methodology (adjustments were made to account for the urban extents within the catchments). The values are also outside the confidence limits associated with the catchment descriptor technique. Note however, that the confidence limits used are an underestimate of the total uncertainty as these only account for the uncertainty associated with the rural estimate of QMED.
- The uncertainty associated with the PBA QMED values is unknown, and cannot be calculated since the values were based on hydrological judgement. In applying the donor transfer model it is necessary to assume that the uncertainty associated with the level records is equivalent to a long record (i.e. the error is far less than the model error). This assumption is unlikely to be true given the uncertainties associated with the PBA QMED values acknowledged within the PBA report and the discrepancy between these and the catchment descriptor estimates. A greater weighting than is necessarily appropriate is therefore placed on the PBA QMED values and as such these are likely to be high and are interpreted as a conservative scenario.

The donor transfer methodology is therefore applied to the QMED catchment descriptor values using the PBA QMED values. This is applied to the two catchments which are directly downstream of the level gauges. The Bicester Village and Langford Village level gauge catchments are impacted by upstream urban developments with (8% and 10% Urbext2000 respectively). Guidance indicates that the transfer methodology should only be applied in exceptional circumstances when either catchment is impacted by urbanisation. The methodology is only recommended where the data is of good quality, the donor and subject catchment are hydrologically similar and the urbanisation and drainage provision are similar. In this case both catchments are directly downstream of the level gauges and impacted by the same urban area (Bicester) with very similar Urbext2000 values (8% and 10% respectively). The transfer methodology is therefore appropriate and has been used to ensure that the rural catchment descriptor QMED values are used for the transfer methodology. The ratio of the QMED observed and QMED rural for the Bicester Village and Langford Village level gauges captures both the uncertainty within the catchment descriptor QMED model and the impact of urbanisation within the catchments.

2.1 Additional Data

The PBA report was completed in 2009 and consequentially more up to date information from the Environment Agency (EA) was requested. Additional spot gauge data and level data was used to improve the confidence associated with the flood estimates at these locations. The spot gauge data was used to improve the stage - discharge relationship and the additional level data to improve the validity of using the data to establish the QMED. The EA was able to provide the following data:

- Bicester Village Level data (15/10/2003 to 26/03/2010)
- Langford Village Level data (1/12/2004 to 30/09/2013)
- Bicester Village spot gaugings (last recorded 17/04/2009); and
- Langford Village spot gaugings (last recorded 17/04/2009)

There is an additional year of level data for Bicester Village level gauge totalling six years of data overall. There is an additional four years of data for Langford Village level gauge totalling eight years of data overall. Whilst an improvement on the data utilised within the PBA methodology this is still less than the 14 years recommended within the FEH methodology for estimating the QMED using the annual maxima series although the peaks over threshold methodology could be used.

There are no additional spot gaugings taken at either site. This means that there is no data to inform the definition of the rating relationship over the flow range of interest. The absence of spot gauges at high flows was one of the main weaknesses within the original estimation process completed by PBA.

Whilst there are additional years of data which improves the estimation of the QMED (although this is still less than the 14 year threshold for using the AMAX methodology) as the rating stage-discharge relationship cannot be improved it is not appropriate to use this data.

3 Flood Estimates

The flood estimates for Langford Village and Bicester village are presented within this section.

3.1 Langford Village

The Langford Village catchment is approximately 20.61km^2 and includes a proportion of Bicester. The average annual rainfall is 632mm[4] and the annual runoff 181mm[5].

The catchment is dominated by the Hydrology of Soil Type (HOST) classes 2 and 25. Characteristics of these are described on Table 1. The base flow index value (BFIHOST) of 0.63 suggests a flow regime of relatively high permeability and relatively unresponsive to rainfall.

Table 1 - Dominant HOST Soil Classifications Occurring in the Catchment.

HOST class	Fractional extent (%)	Description of substrate	Description of soils	Permeability
2	45.21	Limestone	Mineral soils, no gleyed layer	High
25	33.8	Impermeable – soft massive clays	Mineral soil, shallow depth to gleyed layer	Low

3.1.1 Statistical Method

Estimate of the index flood (QMED)

Estimates of the index flood were derived from catchment characteristics. An adjustment for urbanisation is required (URBEXT= 0.1085). The estimates of QMED from catchment descriptors were calculated to be;

$$QMED_{CDS\_raw} = 1.45m^3s^{-1}$$

Adjusted for urbanisation using the urban adjustment factor gives the QMED estimate as;

$$QMED_{CDS\_urban} = 1.79m^3s^{-1}$$

Using the donor transfer methodology and the PBA estimates of QMED values for Langford Village level gauge, gives the QMED scenario estimate as;

$$QMED_{scenario} = 2.86m^3s^{-1}$$

[4] NERC (CEH). 2009. Flood Estimation Handbook CD-ROM 3.
[5] WHS LowFlows Enterprise.

Both the urban adjusted QMED and the QMED scenario estimate were utilised to derive alternative peak flows and hydrographs for the required return periods.

Pooling Group and Growth Curve

An initial pooling group was created for the catchment using WINFAP FEHv3. A target return period of 100 years was adopted; hence a minimum of 500 station years is desirable. The initial pooling group of 15 stations was reviewed and 11 stations were removed. Ten extra stations were then added, based on catchment similarity and appropriateness for inclusion in a pooling group, see Table 2. The final pooling group of 14 stations includes a total of 502 station years. The group is classified as being heterogeneous (H_2 = 2.77).

The pooled data was calculated to fit the Pearson Type III distribution best (Z=-1.16); the Generalised Logistic (GL) distribution had a Z value of 1.22. There are a number of permeable catchments (SPRHOST < 20%) within the pooling group hence it is necessary to apply the permeable adjustment. The specifics of the methodology are presented for the GL distribution with the guidance[6]. Since the Z value is also acceptable for the GL distribution (<1.64) the GL distribution was adopted to estimate the flood growth curve for the catchment, see Figure 2.

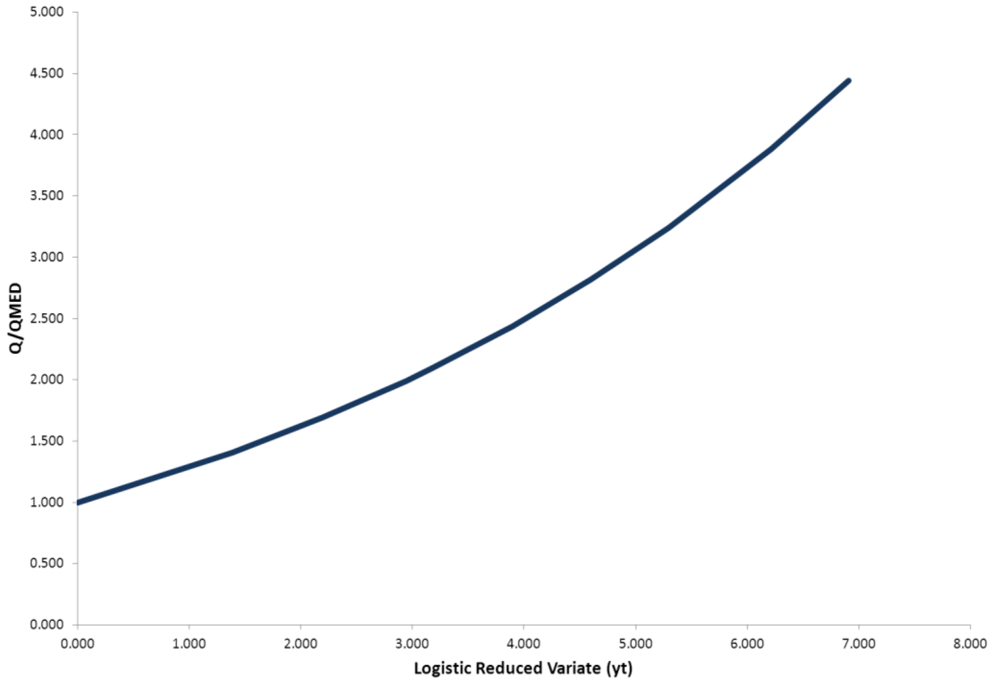

Figure 2 - Adopted Growth Curve for Target Catchment

[6] Robson, A.J. and Reed, D.W. (1999) Statistical procedures for flood frequency estimation.Volume 3 of the Flood Estimation Handbook. Centre for Ecology & Ecology.

Table 2 - Pooling Group Selection and Reasons for Retaining or Removing from Final Pooling Group

Station	Distance SDM	Years of Rec.	AREA	SAAR	FARL	URBEXT 2000	Suitable for pooling	Suitable for QMED	Decision	Notes
Target			***20.6***	***632***	***0.97***	***0.109***				
33045 (Wittle @ Quidenham)	0.419	41	27.55	608	0.177	0.974	Y	Y	Retain	
29009 (Ancholme @ Toft Newton)	0.6	35	29.52	616	0.206	0.997	Y	Y	Retain	
20002 (West Peffer Burn @ Luffness)	0.727	41	26.31	616	0.128	0.996	Y	Y	Retain	
33054 (Babingley @ Castle Rising)	1.414	33	48.51	686	0.118	0.944	Y	Y	Retain	SPRHOST <20. Permeable adjustment required.
27073 (Brompton Beck @ Snainton Ings)	1.484	29	8.06	721	0.237	1	Y	Y	Added	SPRHOST <20. Permeable adjustment required.
41020 (Bevern Stream @ Clappers Bridge)	1.565	40	35.42	886	0.076	0.993	Y	Y	Added	
203046 (Rathmore Burn @ Rathmore Bridge)	1.578	27	22.51	1043	0.073	1	Y	Y	Added	
33032 (Heacham @ Heacham)	1.598	41	56.18	688	0.116	0.983	Y	Y	Added	SPRHOST <20. Permeable adjustment required.
36010 (Bumpstead Brook @ Broad Green)	1.614	42	27.58	588	0.045	0.999	Y	Y	Added	
72014 (Conder @ Galgate)	1.711	42	28.99	1183	0.082	0.975	Y	Y	Added	
36003 (Box @ Polstead)	1.746	46	56.46	566	0.094	0.993	Y	Y	Added	
34005 (Tud @ Costessey Park)	1.774	48	72.12	649	0.158	0.973	Y	Y	Added	
26802 (Gypsey Race @ Kirby Grindalythe)	1.787	10	15.85	757	0.03	1	Y	Y	Added	SPRHOST <20. Permeable adjustment required however, not possible as all years are flood years.
203049 (Clady @ Clady Bridge)	1.794	27	29.38	1079	0.06	1	Y	Y	Added	

Station	Distance SDM	Years of Rec.	AREA	SAAR	FARL	URBEXT 2000	Suitable for pooling	Suitable for QMED	Decision	Notes
39017 (Ray @ Grendon Underwood)	0.292	42	21.15	622	0.158	0.982	N	Y	Reject	Unsuitable for pooling
54060 (Potford Brook @ Sandyford Bridge)	0.617	32	22.37	677	0.133	0.998	N	Y	Reject	Unsuitable for pooling
33048 (Larling Brook @ Stonebridge)	0.685	32	21.99	635	0.233	0.907	N	Y	Reject	Unsuitable for pooling
33052 (Swaffham Lode @ Swaffham Bulbeck)	0.757	40	33.25	567	0.202	0.998	N	Y	Reject	Unsuitable for pooling
36009 (Brett @ Cockfield)	0.87	39	25.62	598	0.113	1	Y	Y	Reject	Bounded. Remove due to quality of data.
54052 (Bailey Brook @ Ternhill)	0.896	36	38.38	707	0.18	0.97	N	N	Reject	Unsuitable for pooling
41028 (Chess Stream @ Chess Bridge)	1.147	45	24.92	849	0.097	0.983	N	Y	Reject	Unsuitable for pooling
68011 (Arley Brook @ Gore Farm)	1.162	9	33.76	831	0.25	0.998	N	Y	Reject	Unsuitable for pooling
33049 (Stanford Water @ Buckenham Tofts)	1.199	7	46.42	645	0.165	0.915	N	Y	Reject	Unsuitable for pooling
30014 (Pointon Lode @ Pointon)	1.267	37	10.94	591	0.105	1	N	Y	Reject	Unsuitable for pooling
30017 (Witham @ Colsterworth)	1.416	31	50.13	641	0.124	0.993	N	Y	Reject	Unsuitable for pooling

Flood Frequency Curve

A flood frequency curve for the catchment was derived using the adopted QMED estimates of 1.72m^3s^{-1} and 2.86m^3s^{-1} and the pooling group growth curve. Note the same growth curve was used for both. The resulting design flood peak flow estimates are shown in Table 3.

Table 3 - Statistical Method Estimated Flood Flows for a Range of Design Return Period Events

Return Period	Baseline Peak Flow (m^3s^{-1})	Scenario Peak Flow (m^3s^{-1})
5	2.52	4.19
20	3.57	5.94
100	5.04	8.39
100 + 20%	6.05	10.07
1000	7.95	13.24

3.1.2 Flood Estimation Using the ReFH Rainfall Runoff Method

The ReFH Model was used to estimate a range of return period flood event hydrographs. The resulting peak flow estimates from the design hydrographs for the catchment are shown in Table 4.

Table 4 ReFH Estimated Flood Flows for a Range of Design Return Period Events

Return Period	Peak Flow (m^3s^{-1})
5	3.4
20	4.61
100	6.49
100 + 20%	7.79
1000	11.5

3.1.3 Summary of results

The final flood hydrographs were estimated by rescaling the ReFH hydrographs by the statistical peak flow estimates; see Figure 3 for the scenario peak flow hydrographs. The scenario hydrographs, based on the original PBA estimates, have been adopted within the hydraulic model as these are considered to represent a conservative estimation of flood peaks, see Section 2.

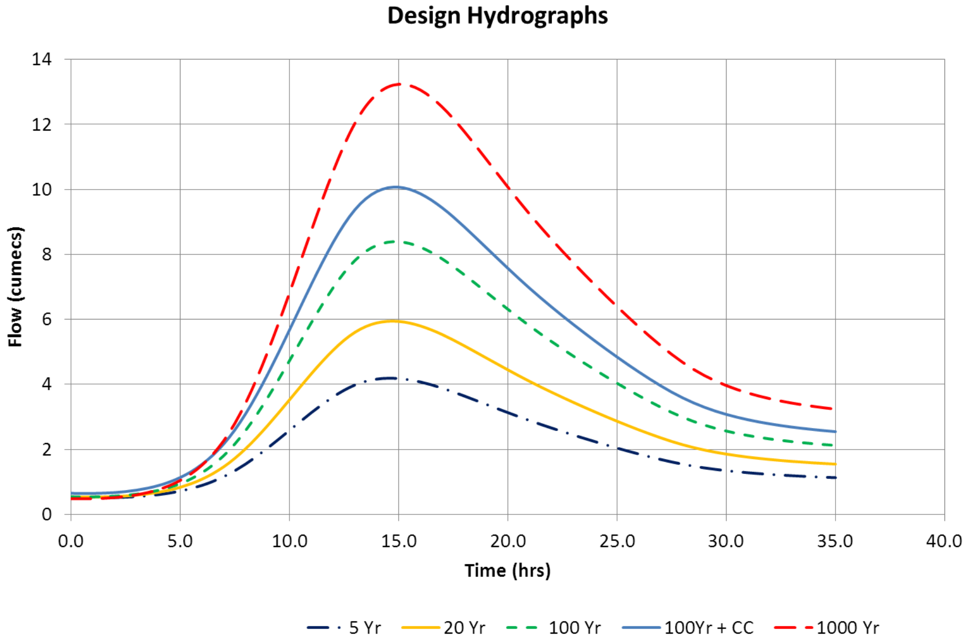

Figure 3 Final Design Hydrographs Adopted for the Scenario QMED.

3.2 Bicester Village

The Bicester Village catchment is approximately 15.88km^2. The average annual rainfall is 639mm[7] and the annual runoff 207mm[8].

The catchment is dominated by the Hydrology of Soil Type (HOST) class 2. Characteristics of this is described in Table 5. The base flow index value (BFIHOST) of 0.87 suggests a flow regime of high permeability, unresponsive to rainfall. However, the response of the oolitic limestones to rainfall is highly variable and can be relatively rapid as localised fracturing can offer quick flow paths for rainfall to reach river systems hence it is possible that this is not reflected within the BFIHOST value.

Table 5 Dominant HOST Soil Classification Occurring in the Catchment

HOST class	Fractional extent (%)	Description of substrate	Description of soils	Permeability
2	78.6	Limestone	Mineral soils, no gleyed layer	High

[7] NERC (CEH). 2009. Flood Estimation Handbook CD-ROM 3.
[8] WHS LowFlows Enterprise.

3.2.1 Statistical Method

Estimate of the index flood (QMED)

Estimates of the index flood were derived from catchment characteristics. An adjustment for urbanisation is required (URBEXT=0.0769). The estimates of QMED from catchment descriptors were calculated to be;

$QMED_{CDS\_raw} = 0.44m^3s^{-1}$

Adjusted for urbanisation using the urban adjustment factor gives the QMED estimate as:

$QMED_{CDS\_urban} = 0.62m^3s^{-1}$

Using the donor transfer methodology and the PBA estimates of QMED values for Bicester Village and Langford Village gauges, gives the QMED scenario estimate as:

$QMED_{scenario} = 1.84m^3s^{-1}$

Both the urban adjusted QMED and the QMED scenario estimate were utilised to derive alternative peak flows and hydrographs for the required return periods.

Pooling Group and Growth Curve

An initial pooling group was created for the catchment using WINFAP FEHv3. A target return period of 100 years was adopted; hence a minimum of 500 station years is desirable. The initial pooling group of 15 stations was reviewed and 11 stations were removed. Twelve extra stations were then added, based on catchment similarity and appropriateness for inclusion in a pooling group, see Table 6. The final pooling group of 16 stations includes a total of 524 station years. The group is classified as being heterogeneous (H_2 = 2.87).

The pooled data was calculated to fit the Generalised Logistic (GL) distribution best (Z=0.2772). There are a number of permeable catchments (SPRHOST < 20%) within the pooling group hence it is necessary to apply the permeable adjustment. The GL distribution was adopted to estimate the flood growth curve for the catchment, see Figure 4.

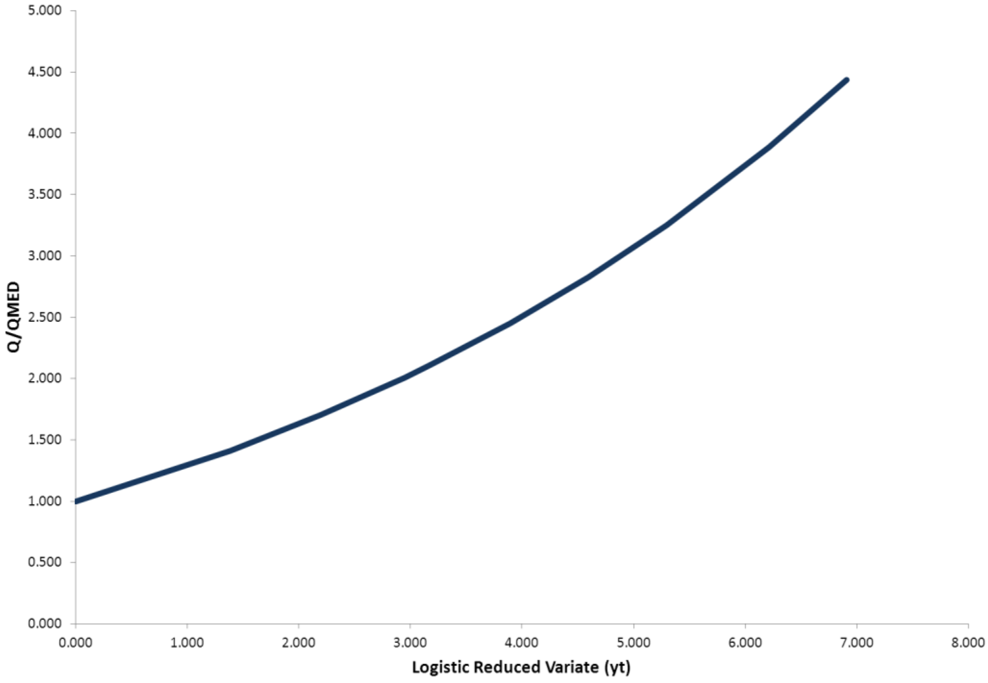

Figure 4 Adopted Growth Curve for Target Catchment

Table 6 Pooling Group Selection and Reasons for Retaining or Removing from Final Pooling Group

Station	Distance SDM	Years of Rec.	AREA	SAAR	FARL	URBEXT 2000	Suitable for pooling	Suitable for QMED	Decision	Notes
Target			***15.88***	***639***	***0.98***	***0.0769***				
20002 (West Peffer Burn @ Luffness)	0.771	41	26.31	616	0.128	0.996	Y	Y	Retain	
26802 (Gypsey Race @ Kirby Grindalythe)	0.867	10	15.85	757	0.03	1	Y	Y	Retain	SPRHOST <20. Permeable adjustment required however, not possible as all years are flood years.
36010 (Bumpstead Brook @ Broad Green)	1.019	42	27.58	588	0.045	0.999	Y	Y	Retain	
25019 (Leven @ Easby)	1.056	31	15.07	830	0.019	1	Y	Y	Retain	
203046 (Rathmore Burn @ Rathmore Bridge)	1.11	27	22.51	1043	0.073	1	Y	Y	Added	
33045 (Wittle @ Quidenham)	1.146	41	27.55	608	0.177	0.974	Y	Y	Added	
41020 (Bevern Stream @ Clappers Bridge)	1.318	40	35.42	886	0.076	0.993	Y	Y	Added	
27010 (Hodge Beck @ Bransdale Weir)	1.351	41	18.84	987	0.009	1	Y	Y	Added	
44008 (Sth Winterbourne @ W'bourne Steepleton)	1.356	30	20.17	1012	0.015	1	Y	Y	Added	SPRHOST<20. Permeable adjustment required.
44006 (Sydling Water @ Sydling st Nicholas)	1.399	35	12.06	1030	0.016	0.944	Y	Y	Added	SPRHOST<20. Permeable adjustment required.
203049 (Clady @ Clady Bridge)	1.405	27	29.38	1079	0.06	1	Y	Y	Added	
29009 (Ancholme @ Toft Newton)	1.459	35	29.52	616	0.206	0.997	Y	Y	Added	
72014 (Conder @ Galgate)	1.464	42	28.99	1183	0.082	0.975	Y	Y	Added	

Station	Distance SDM	Years of Rec.	AREA	SAAR	FARL	URBEXT 2000	Suitable for pooling	Suitable for QMED	Decision	Notes
27051 (Crimple @ Burn Bridge)	1.473	37	8.15	855	0.013	1	Y	Y	Added	
22003 (Usway Burn @ Shillmoor)	1.509	13	21.87	1056	0.006	1	Y	Y	Added	
44009 (Wey @ Broadwey)	1.514	32	7.95	894	0.015	1	Y	Y	Added	SPRHOST<20. Permeable adjustment required.
30014 (Pointon Lode @ Pointon)	0.553	37	10.94	591	0.105	1	N	Y	Reject	Unsuitable for pooling
54060 (Potford Brook @ Sandyford Bridge)	0.609	32	22.37	677	0.133	0.998	N	Y	Reject	Unsuitable for pooling
36009 (Brett @ Cockfield)	0.7	39	25.62	598	0.113	1	Y	Y	Reject	Bounded. Remove due to quality of data.
39017 (Ray @ Grendon Underwood)	0.751	42	21.15	622	0.158	0.982	N	Y	Reject	Unsuitable for pooling
41028 (Chess Stream @ Chess Bridge)	0.833	45	24.92	849	0.097	0.983	N	Y	Reject	Unsuitable for pooling
41016 (Cuckmere @ Cowbeech)	0.902	42	19.09	855	0.043	0.966	N	Y	Reject	Unsuitable for pooling
32029 (Flore @ Experimental Catchment)	0.924	5	8.34	624	0.086	1	Y	Y	Reject	Short Record
31025 (Gwash South Arm @ Manton)	1.023	31	23.93	663	0.027	0.995	N	Y	Reject	Unsuitable for pooling
27038 (Costa Beck @ Gatehouses)	1.025	39	7.98	722	0.125	0.99	N	Y	Reject	Unsuitable for pooling
52016 (Currypool Stream @ Currypool Farm)	1.027	39	15.7	934	0.037	1	N	Y	Reject	Unsuitable for pooling
52015 (Land Yeo @ Wraxall Bridge)	1.037	30	23.33	906	0.058	0.933	N	Y	Reject	Unsuitable for pooling

Flood Frequency Curve

A flood frequency curve for the catchment was derived using the adopted QMED estimates of $0.62m^3s^{-1}$ and $1.84m^3s^{-1}$ and the pooling group growth curve. Note; the same growth curve was used for both. The resulting design flood peak flow estimates are shown in Table 7.

Table 7 - Statistical Method Estimated Flood Flows for a Range of Design Return Period Events

Return Period	Baseline Peak Flow (m^3s^{-1})	Scenario Peak Flow (m^3s^{-1})
5	0.87	2.6
20	1.24	3.69
100	1.75	5.2
100 + 20%	2.10	6.24
1000	2.74	8.16

3.2.2 Flood Estimation Using the ReFH Rainfall Runoff Method

The ReFH Model was used to estimate a range of return period flood event hydrographs. The resulting peak flow estimates from the design hydrographs for the catchment are shown in Table 8.

The ReFH methodology is not recommended for estimating peak flows within the catchments which are highly permeable (SPRHOST<20%)[9]. For the Bicester Village catchment (SPRHOST is 11.8), peak flows were estimated using the statistical methodology peak flows to rescale the ReFH flood hydrographs. In addition, ReFH is not recommended for use within catchments dominated by storage, where the shape of the hydrograph is less likely to resemble the simple ReFH hydrograph. The catchment is mostly limestone where groundwater flow is predominantly more rapid fracture flow (rather than storage dominated) thus the ReFH hydrograph is considered to be appropriate.

Table 8 - ReFH Estimated Flood Flows for a Range of Design Return Period Events

Return Period	Peak Flow (m^3s^{-1})
5	0.24
20	0.47
100	0.99
100 + 20%	1.18
1000	2.85

[9] Environment Agency. 2012. Flood Estimation Guidelines: Operational Instruction 197_08.

3.2.3 Summary of Results

The final flood hydrographs were estimated by rescaling the ReFH hydrographs by the statistical peak flow estimates, see Figure 5 the scenario peak flow hydrographs. The scenario hydrographs, based on the original PBA estimates, have been adopted within the hydraulic model as these are considered to represent a conservative estimation of flood peaks, see Section 2.

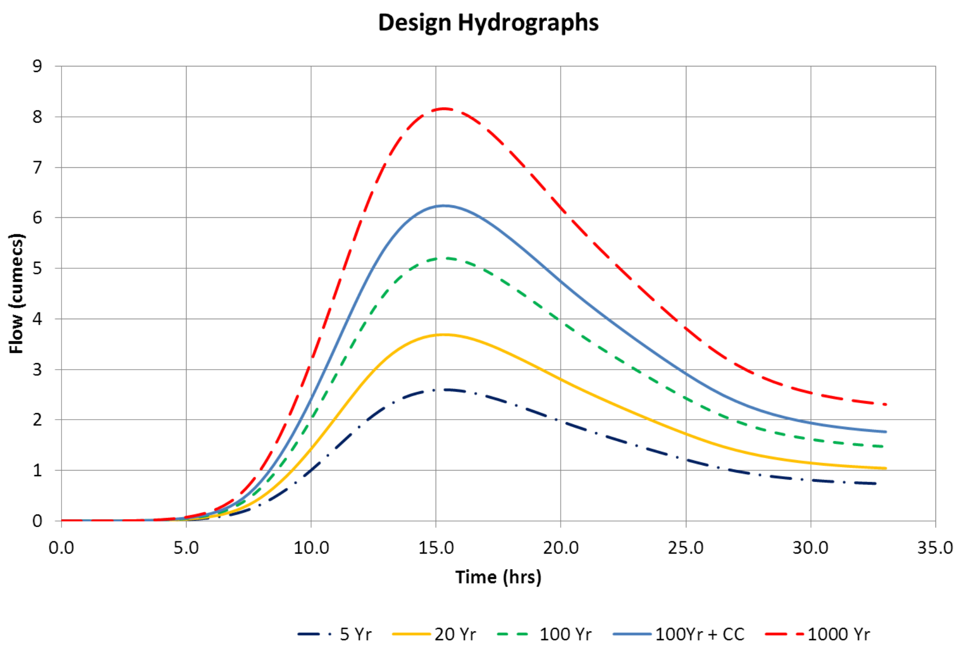

Figure 5 Final Design Hydrographs Adopted for the Scenario QMED.