# 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 a multiple locations.

Note for analysts: This document contains guidance notes shown in hidden text. If they are not visible, they can be revealed by clicking the Show ¶ button on the toolbar.

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## Approval

| | Signature | Name and qualifications | For Environment Agency staff: Competence level (see below) |
|---|---|---|---|
| Calculations prepared by: | | Helena Wicks MSc, BSc (Hons) | 1 |
| Calculations checked by: | | Stuart Niven MSc, BSc (Hons) | 2 |
| 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 |
| URBEXT | FEH index of fractional urban extent |
| WINFAP-FEH | Windows Frequency Analysis Package – used for FEH statistical method |

# 1 Method statement

## 1.1 Overview of requirements for flood estimates

| Item | Comments |
|---|---|
| Purpose of study<br>Approx. no. of flood estimates required<br>Peak flows or hydrographs?<br>Range of return periods and locations.<br>Approx. time available | Flow estimates are required for two unnamed watercourses and a watercourse known as "The Link", to be used in hydraulic modelling to determine the likely impacts of introducing culverts along the watercourses.<br><br>Peak flows are required as one main inflow at the upstream extent of the hydraulic model for each of the three watercourses.<br><br>Peak flows are required for the 1 in 100 year return period. No hydrograph is required. |

## 1.2 Overview of catchment

| Item | Comments |
|---|---|
| Brief description of catchment, or reference to section in accompanying report | All three watercourses are small catchments of 2.32km$^2$, 1.32km$^2$ and 0.9km$^2$ respectively, for Watercourses 1, 2 and 3.<br><br>The catchments are all ungauged and have no attenuation (FARL = 1 for all three watercourses).<br><br>The catchments are classed as rural (URBEXT1990 = 0, 0 and 0.0028 respectively, URBEXT2000 = 0.0005 for Watercourse 1 and 0 for both Watercourses 2 and 3).<br><br>The catchments are relatively slow responding with SPRHOST of 20.93, 19.38 and 26.46 respectively. It is important to note that one of the Watercourses (2) has a SPRHOST value of <20% and therefore is classified as permeable within FEH guidelines. As such some methodologies are not considered to be appropriate for application. |

## 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 | Not required for the methodologies applied. |

## 1.4 Gauging stations (flow or level)

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

| Watercourse | Station name | Gauging authority number | NRFA number (used in FEH) | Grid reference | Catchment area (km²) | Type (rated / ultrasonic / level...) | Period of record |
|---|---|---|---|---|---|---|---|
| - | | | | | | | |
| - | | | | | | | |

## 1.5 Data available at each flow gauging station

| Station name | Period 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 |
|---|---|---|---|---|---|---|
| N/A | | | | | | |
| | | | | | | |
| Give link/reference to any further data quality checks carried out | | | | | | |

## 1.6 Rating equations

| Station name | Type of rating e.g. theoretical, empirical | Rating review needed? | Reasons |
|---|---|---|---|
| N/A | | | |
| | | | |
| Give link/reference to any rating reviews carried out | | | |

## 1.7 Other data available and how it has been obtained

| | |
|---|---|
| Flow gaugings (if planned to review ratings) | No flow gauging as none of the catchments are gauged. |
| Historic flood data | None available. |
| Flow data for events | Catchments are ungauged – no flow data available. |
| Rainfall data for events | N/A |
| Results from previous studies (e.g. CFMPs, Strategies) | - |
| Other data or information (e.g. groundwater, tides) | All watercourses are tributaries of the River Len which is in turn a tributary of the River Medway. |

## 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. | The Revitalised FSR/FEH rainfall-runoff method will be applied via the ISIS ReFH Boundary Unit.<br><br>The IH124 method will also be applied. |
| Outline the conceptual model.<br>Where are the main sites of interest?<br>What is likely to cause flooding at those locations? (peak flows, flood volumes, combinations of peaks, groundwater, snowmelt, tides…)<br>Might those locations flood from runoff generated on part of the catchment only, e.g. downstream of a reservoir?<br><br>Is there a need to consider temporary debris dams that could collapse? | Potential impact of culverting of each of the watercourses.<br><br>Peak flows and the capacity of the culverts running under the motorways and the railway lines.<br><br>No<br><br>No |
| Any unusual catchment features to take into account?<br>e.g.<br>• highly permeable (SPRHOST<20%) – avoid ReFH, use permeable catchment adjustment for statistical method<br>• highly urbanised – prefer FEH statistical, or consider alternative methods<br>• pumped watercourse – consider lowland catchment version of rainfall-runoff method.<br>• major reservoir influence (FARL<0.90) – consider flood routing<br>• extensive floodplain storage – consider choice of method carefully | Very small catchment areas, Watercourse 1 = 2.32km$^2$, Watercourse 2 = 1.32km$^2$ and Watercourse 3 = 0.69km$^2$<br><br>Very rural catchments, Watercourses 1 and 2 URBEXT1990 = 0 and Watercourse 3 URBEXT1990 = 0.0028. Watercourse 1 URBEXT2000 = 0.0005, Watercourses 2 and 3 URBEXT2000 = 0.<br><br>Ungauged catchment<br><br>Watercourse 2 is relatively permeable catchment SPRHOST = 19.38, whereas Watercourse 1 and 3 are slightly less permeable SPRHOST = 20.93 and 26.46 respectively.<br><br>ReFH method is not considered suitable for SPRHOST<20% and therefore would not be appropriate for Watercourse 2. |

| | |
|---|---|
| Initial choice of method(s) and reasons<br><br>Will the catchment be split into subcatchments? If so, how? | Revitalised FSR/FEH rainfall-runoff method using ISIS ReFH Boundary units and Catchment Descriptors.<br><br>Secondly, as the catchments are small the IH124 method was applied.<br><br>No sub-catchments – each watercourse will be entered into a MIKE11 hydraulic model as a single inflow location. |
| Software to be used (with version numbers) | ▪ FEH CD-ROM V2.0<br>▪ ISIS v3.0.1.29 |

# 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 |
|---|---|---|---|---|---|---|
| W1 | The Link | Maidstone, Kent | 580800 | 156400 | 2.32 | N/A |
| W2 | Watercourse 2 | Maidstone, Kent | 581300 | 155800 | 1.32 | N/A |
| W3 | Watercourse 3 | Maidstone, Kent | 582000 | 155200 | 0.90 | N/A |
| **Reasons for choosing above locations** | | Downstream extent of watercourses where they enter the study area form the north. | | | | |

## 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 |
|---|---|---|---|---|---|---|---|---|---|
| W1 | 1.00 | 0.34 | 0.772 | 1.48 | 95.2 | 714 | 20.93 | 0 | 0.0005 |
| W2 | 1.00 | 0.34 | 0.761 | 1.41 | 75.5 | 711 | 19.38 | 0 | 0 |
| W3 | 1.00 | 0.34 | 0.631 | 1.05 | 45.6 | 703 | 26.46 | 0.0028 | 0 |

## 2.3 Checking catchment descriptors

| | |
|---|---|
| Record how catchment boundary was checked and describe any changes (refer to maps if needed) | The FEH CD-ROM (V2.0) catchment boundaries were checked against the OS 1:25,000 scale mapping (OS Explorer Map 148). The catchment was deemed to be appropriate as it followed a ridge of high ground that had already been assumed to create the boundary.<br><br>Therefore no revision to the area was carried out. |
| Record how other catchment descriptors (especially soils) were checked and describe any changes. Include before/after table if necessary. | The FARL value was checked against the OS map to ensure that the value of 1 i.e. no attenuation is correct and this appears to be correct. |
| Source of URBEXT | URBEXT2000 |
| Method for updating of URBEXT | - |

# 3 Statistical method

## 3.1 Overview of estimation of QMED at each subject site

| Site code | Method [1] | Initial estimate of QMED ($m^3/s$) | AM or POT Adjustment for climatic variation? [2] | Data transfer: NRFA numbers for donor/analogue sites used (see 3.4) and reasons for choice[3] | Data transfer: QMED adjustment factor | Final estimate of QMED ($m^3/s$) (note: QMED urban) |
|---|---|---|---|---|---|---|
| | | | | | | |
| | | | | | | |
| Are the values of QMED consistent, for example at confluences? | | | | | | |

**Notes**
1. Methods: AM – Annual maxima; POT – Peaks over threshold; DT – Data transfer; CD – Catchment descriptors alone.
2. Give details of any adjustment for climatic variation below.
3. If more than one donor or analogue has been used, give the weights used in the averaging.

## 3.2 Search for donor or analogue sites for QMED

| | |
|---|---|
| **Comment on potential donor sites** | |
| **Method for seeking out analogue sites** | |

## 3.3 Characteristics of potential donor and analogue sites

| Subject sites needing donors or analogues | | | | | | |
|---|---|---|---|---|---|---|
| **Site code** | **AREA** | **FARL** | **BFIHOST** | **SAAR** | **SPRHOST** | **URBEXT** |
| | | | | | | |

| Potential donors and analogues | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **NRFA no.** | **Watercourse** | **Station** | **AREA** | **FARL** | **BFIHOST** | **SAAR** | **SPRHOST** | **URBEXT** |
| | | | | | | | | |
| | | | | | | | | |

## 3.4 Decision on choosing or rejecting donor and analogue sites

| NRFA no. | Reasons for choosing or rejecting (mention location, catchment properties, data quality…) | Method (AM or POT) | Adjustment for climatic variation? | QMED from flow data (A) | QMED from catchment descriptors (B) | Adjustment ratio (A/B) |
|---|---|---|---|---|---|---|
| | | | | | | |
| | | | | | | |

## 3.5 Derivation of pooling groups

The composition of the pooling groups is given in the Annex. Several subject sites may use the same pooling group.

| Target return period (years) for all pooling groups | | | | |
|---|---|---|---|---|
| **Name of group** | **Site code for which group derived** | **Changes made to default pooling group, with reasons** Note also any sites that were investigated but retained in the group. | **Distribution and reason for choice** | **Parameters (before urban adjustment)** Note any permeable catchment adjustments |
| | | | | |

### 3.6 Derivation of flood growth curves at subject sites

| Site code | **Method:**<br>SS – Single site<br>P – Pooled<br>J – Joint analysis | If P or J, name of pooling group (3.5) | If SS, distribution used and reason for choice<br>If J, details of averaging | **If SS, parameters of distribution** (location, scale and shape) | Growth factor for 100-year return period |
|---|---|---|---|---|---|
| | | | | | |

### 3.7 Flood estimates from the statistical method

| Site code | Flood peak ($m^3/s$) for the following return periods (in years) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 2 | 5 | 10 | 15 | 25 | 50 | 75 | 100 | 200 | 1000 |
| | | | | | | | | | | |

## 4 Revitalised flood hydrograph (ReFH) model

This method has been applied for all of the catchments, to provide a peak flow and hydrograph.

### 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:<br>FEA : Flood event analysis<br>CD: Catchment descriptors<br>DT: Data transfer (give details) | Tp (hours)<br>Time to peak | $C_{max}$ (mm)<br>Maximum storage capacity | BL (hours)<br>Baseflow lag | BR<br>Baseflow recharge |
|---|---|---|---|---|---|
| W1 | CD | 1.790 | 604.861 | 43.379 | 1.923 |
| W2 | CD | 1.855 | 596.671 | 42.651 | 1.893 |
| W3 | CD | 1.773 | 499.399 | 36.404 | 1.547 |
| **Brief description of any flood event analysis carried out** (further details should be given below or in a project report) | No further flood event analysis. | | | | |

### 4.2 Design events for ReFH model

| Site code | Urban or rural | Season of design event (summer or winter) | Storm duration (hours) | Storm area for ARF (if not catchment area) |
|---|---|---|---|---|
| W1 | Rural | WINTER based on URBEXT value | 6.25 | N/A |
| W2 | Rural | WINTER based on URBEXT value | 6.25 | N/A |
| W3 | Rural | WINTER based on URBEXT value | 5.75 | N/A |
| Are the storm durations likely to be changed in the next stage of the study, e.g. by optimisation within a hydraulic model? | | | A realistic range of durations should be tried for the design storm, to find the critical duration at the subject site by trial and error. This optimisation can be carried out automatically in ISIS. The critical duration is the one that gives the highest flow or water level if optimised within the hydraulic model. | |

### 4.3 Flood estimates from the ReFH model

| Site code | Flood peak ($m^3/s$) for the following return periods (in years) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 2 | 5 | 10 | 25 | 50 | 75 | 100 | 200 | 500 | 1000 |
| W1 | | | | | | | 0.972 | | | |
| W2 | | | | | | | 0.597 | | | |
| W3 | | | | | | | 0.769 | | | |

## 5 Small Catchment Methods

This section records any estimates of design flows for small catchments using methods other than the FEH. In this case, the Institute of Hydrology Report 124 method has been used.

### 5.1 Parameters for IH Report 124 method

| Site code | Area (km2) | SAAR (mm) | URBEXT 2000 | Fraction of catchment covered by WRAP class | | | | | Hydrometric area |
|---|---|---|---|---|---|---|---|---|---|
| | | | | 1 | 2 | 3 | 4 | 5 | |
| W1 | 2.32 | 714 | 0.0005 | 55% | | | 45% | | 7 |
| W2 | 1.32 | 711 | 0 | 41% | | | 59% | | 7 |
| W3 | 0.90 | 703 | 0 | 18% | | | 82% | | 7 |

$QBAR_{urban}$ and $QBAR_{rural}$ were both calculated and the ratio identified. However as the Urban Extent is 0, for Watercourses 2 and 3, the ratio is 1 and therefore the mean annual flood is identical for both. For Watercourse 1 the $URBEXT_{2000}$ is very small and therefore there is very little difference between $QBAR_{urban}$ and $QBAR_{rural}$.

The same growth factor was used for all catchments as they are located in the same hydrometric region, the growth factor applied for the 1 in 100 year was 3.19. The following are the growth factors applied to all return period events:

| Return Period | Region 7 Growth Factor |
|---|---|
| 2 | 0.88 |
| 5 | 1.28 |
| 10 | 1.62 |
| 25 | 2.14 |
| 50 | 2.62 |
| 100 | 3.19 |
| 200 | 3.86 |

### 5.2 Flood estimates from the IH Report 124 method at each subject site after Urban Adjustment

| Site code | Flood peak ($m^3/s$) for the following return periods (in years) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 2 | 5 | 10 | 25 | 50 | 75 | 100 | 200 | 500 | 1000 |
| W1 | 0.286 | 0.416 | 0.526 | 0.695 | 0.851 | - | 1.036 | 1.254 | - | - |
| W2 | 0.236 | 0.343 | 0.434 | 0.574 | 0.702 | - | 0.855 | 1.035 | - | - |
| W3 | 0.248 | 0.361 | 0.457 | 0.604 | 0.739 | - | 0.900 | 1.089 | - | - |

# 6 Discussion and summary of results

## 6.1 Comparison of results from different methods

This table normally 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. As the Statistical method has not been applied it is not possible to carry out the ratio assessment.

| Site code | Ratio of peak flow to FEH Statistical peak | | | | | |
|---|---|---|---|---|---|---|
| | Return period 2 years | | | Return period 100 years | | |
| | ReFH | FEH rainfall-runoff | Other method | ReFH | FEH rainfall-runoff | Other method |
| W1 | | | | | | |
| W2 | | | | | | |
| W3 | | | | | | |

## 6.2 Final choice of method

| Choice of method and reasons | The ReFH method was applied using Catchment Descriptors from FEH V2.0 and is based solely on these, providing peak 100 year flows of:<br><br>Watercourse 1 = 0.97<br>Watercourse 2 = 0.60 (N/A)<br>Watercourse 3 = 0.77<br><br>The ReFH method is not applicable to Watercourse 2 due to the permeability of the catchment and therefore the IH124 method is the only method carried out for this catchment that is applicable. ReFH can be used for Watercourses 1 and 3 along with IH124.<br><br>The IH124 method was also applied using Catchment Descriptors. It is considered that due to the size of the catchments this method is suitable as it may reflect the characteristics. The 1 in 100 year peak flows were calculated as:<br><br>Watercourse 1 = 1.04<br>Watercourse 2 = 0.86<br>Watercourse 3 = 0.90<br><br>These values are not that dissimilar and therefore produce reasonable estimates of the 1 in 100 year flow. Greatest variation is seen in Watercourse 2 however ReFH is not deemed an appropriate methodology due to the permeability of the catchment.<br><br>**The use of the IH124 method has been agreed with the Environment Agency as being a suitable methodology and as this is appropriate for all three of the watercourses has been chosen for input to all three of the hydraulic models.** |
|---|---|

### 6.3 Assumptions, limitations and uncertainty

| | |
|---|---|
| List the main assumptions made (specific to this study) | Assumption that catchment area is the same as the Catchment Descriptor outline. This has been checked using OS 1:25,000 map. |
| Discuss any particular limitations, e.g. applying methods outside the range of catchment types or return periods for which they were developed | The application of methods only using Catchment Descriptors limits the reliability of the flow data. A comparison using gauged data from other hydrologically similar catchments i.e. statistical pooling group method would be beneficial to carry out a validity check. |
| Give what information you can on uncertainty in the results, for example in the QMED estimates using FEH **3** 12.5 or 13.8 | |

| | |
|---|---|
| Comment on the suitability of the results for future studies, e.g. at nearby locations or for different purposes. | Results are not applicable for use at other nearby sites. They may be suitable for use on the same catchment for different purposes, although this should be taken with caution. |
| Give any other comments on the study, for example suggestions for additional work. | Completion of the Statistical method |

### 6.4 Checks

| | |
|---|---|
| Are the results consistent, for example at confluences? | No confluences in the catchments. |
| What do the results imply regarding the return periods of floods during the period of record? | No observed records for the catchments as they are ungauged. |
| What is the range of 100-year growth factors? Is this realistic? (The guidance suggests a typical range of 2.1 to 4.0) | Growth factor applied currently is 3.19 therefore it appears realistic as indicated by FEH guidelines. |
| If 1000-year flows have been derived, what is the range of ratios for 1000-year flow over 100-year flow? | Not derived. |
| What range of specific runoffs (l/s/ha) do the results equate to? Are there any inconsistencies? | Not checked in this study. |
| How do the results compare with those of other studies? | No other studies known to have been undertaken on these catchments. |
| Are the results compatible with the longer-term flood history? | - |
| Describe any other checks on the results | - |

### 6.5 Final results

| Site code | Method | Flood peak ($m^3/s$) for the following return periods (in years) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 2 | 5 | 10 | 25 | 50 | 75 | 100 | 200 | 500 | 1000 |
| W1 | IH124 | 0.286 | 0.416 | 0.526 | 0.695 | 0.851 | - | 1.036 | 1.254 | - | - |
| W2 | IH124 | 0.236 | 0.343 | 0.434 | 0.574 | 0.702 | - | 0.855 | 1.035 | - | - |
| W3 | IH124 | 0.248 | 0.361 | 0.457 | 0.604 | 0.739 | - | 0.900 | 1.089 | - | - |

To allow for climate change an increase of 20% has been applied to the 1 in 100 year peak flows:

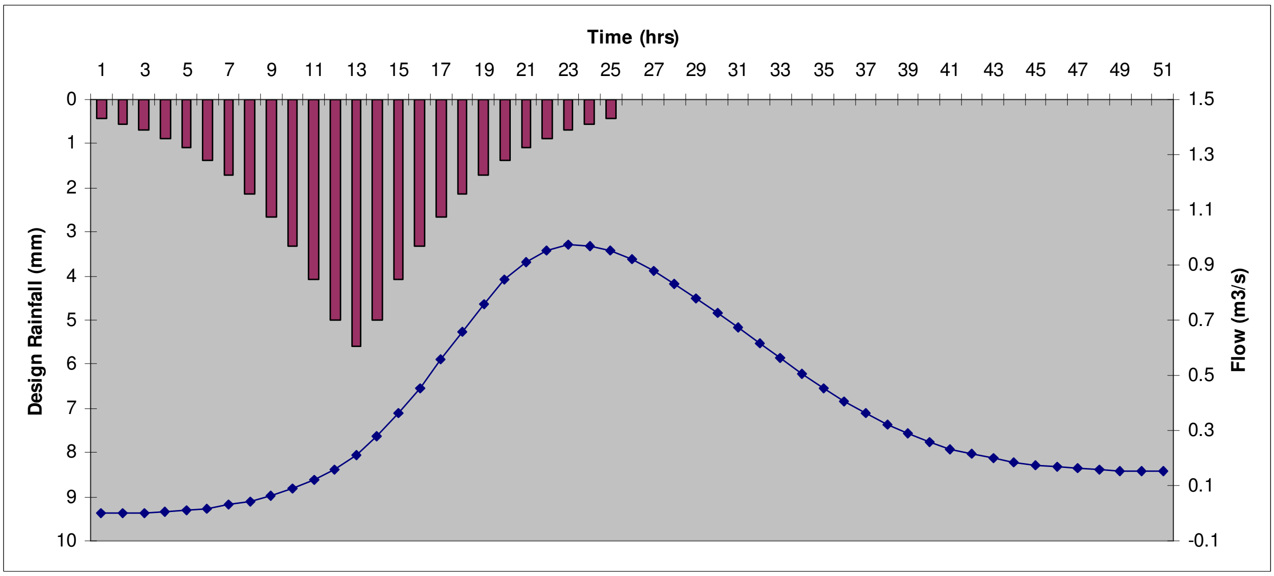
| Site code | Method | Flood peak ($m^3/s$) for the following return periods (in years) including an allowance for climate change | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 2 | 5 | 10 | 25 | 50 | 75 | 100 | 200 | 500 | 1000 |
| W1 | IH124 | 0.34 | 0.50 | 0.63 | 0.83 | 1.02 | - | 1.24 | 1.50 | - | - |
| W2 | IH124 | 0.28 | 0.41 | 0.52 | 0.69 | 0.84 | - | 1.03 | 1.24 | - | - |
| W3 | IH124 | 0.30 | 0.43 | 0.55 | 0.72 | 0.89 | - | 1.08 | 1.31 | - | - |

| | |
|---|---|
| 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) | It is understood at this stage that the MIKE11 model only requires peak inflows.<br><br>There are no hydrographs for the IH124 method as this method does not produce a hydrograph.<br><br>There are three s/sheets available for the application of the IH124 for each of the watercourses. |

## 7 Annex - supporting information

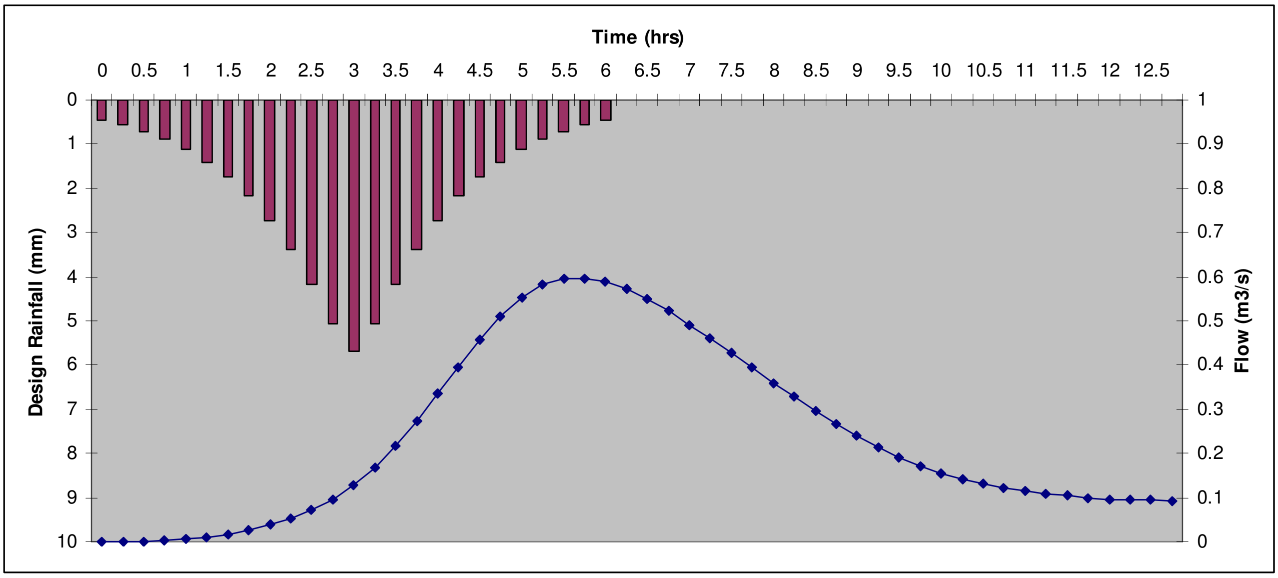
### 7.1 ReFH Hydrographs

***Watercourse 1: Critical Storm Duration Hydrograph (1 in 100 year)***




***Watercourse 2: Critical Storm Duration Hydrograph (1 in 100 year)***

***This methodology is not appropriate due to permeability of the catchment.***



***Watercourse 3: Critical Storm Duration Hydrograph (1 in 100 year)***