Flood Estimation Report

RSPB Conwy

Final

27/06/2024

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Description

This report template is based on a supporting document to the Environment Agency's Flood Estimation Guidelines (LIT 11832). It provides a record of the hydrological context, the method statement, the calculations, the decisions made, and the results of flood estimation.

Contents

Approval

Revision stage	Analyst	Approved by	Amendments	Date
Method statement	James Davidson BSc MSc	Sam Cogan BSc MSc		21/06/2024
Calculations - Revision 1	James Davidson BSc MSc	Sam Cogan BSc MSc	Revision to calculations following 1st review	25/06/2024
Calculations - Revision 2				

Revision history

Revision reference	Date issued	Amendments	Issued to

Abbreviations

AEP	annual exceedance probability
AMAX	annual maximum
AREA	catchment area (km^2)
ARF	areal reduction factor
BFI	baseflow index
BFIHOST19	baseflow index derived using the HOST soil classification, revised in 2019
CPRE	Council for the Protection of Rural England
FARL	FEH index of flood attenuation due to reservoirs and lakes
FEH	Flood Estimation Handbook
HOST	Hydrology of Soil Types
NGR	national grid reference
NRFA	National River Flow Archive
OS	Ordnance Survey
POT	peaks over a threshold
QMED	median annual flood (with return period 2 years)

ReFH2	Revitalised Flood Hydrograph 2 method
SAAR	standard average annual rainfall (mm)
Tp	time to peak of the instantaneous unit hydrograph
UKFE	United Kingdom Flood Estimation (R package for implementing flood hydrology methods)
URBAN	Flood Studies Report index of fractional urban extent
URBEXT2000	revised index of urban extent
WINFAP	Windows Frequency Analysis Package (software that can be used for FEH Statistical method)

1 Summary of assessment

1.1 Summary

Catchment location:

The site of interest is located to the north of Llansanffraid Glan Conwy, North Wales (NGR: SH 80289 76787). The proposed works include the installation of a combined cycle and pedestrian path along the northern and eastern boundaries of the existing RSPB Conwy reserve and two new footbridges over the Afon Ganol and Conwy Valley Railway Line. A pedestrian ramp is also proposed on the RSPB side of the railway footbridge. The proposed combined cycle and pedestrian path follows the course of the Afon Ganal along a section to the east where the route runs approximately 30m to the west of the watercourse. To the south, one of the proposed footbridges crosses the Afon Ganol at NGR: SH 80299 76883. The site is also likely to be influenced by tides due to its coastal location, with the Afon Conwy estuary being located 0.2km to the south of site.

Purpose of study and complexity:

Conwy County Borough Council (CCBC) commissioned JBA Consulting to undertake this study in order to ascertain the impact of the proposed bridge over the Afon Ganol at SH 80299 76883. Peak flow estimates and hydrographs are required for six flow estimation points (FEP) for the Afon Ganol. Moderate complexity

Key catchment features:

The catchment is predominantly rural however the hydrology will be complicated by the presence of the splitter structure that regulates flow between the east and west Afon Ganol channels. The site is likely to also be influenced by tides due to its coastal location, with the Afon Conwy estuary being located 0.2km to the south of site.

Flooding mechanisms:

Along the upper reaches of the Afon Ganol to the southeast, flooding is likely to be related to peak flows but along the flatter Ganol West and Ganol East channels, flooding may be more volume driven as these sections are subject to tide locking.

Gauged / ungauged:

Ungauged

Final choice of method:

FEH Statistical method with REFH2 1%/0.1% AEP growth curve applied to the 0.1% AEP event.

Key limitations / uncertainties in results:

A significant limitation for this study is that there are no flow or level gauges or historic flood information on the watercourses and hence no data with which to improve estimates or verify model results.

1.2 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 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 use AEP; if required, this can be changed to return period.
- The table below is provided to enable quick conversion between return periods and annual exceedance probabilities.

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	0.013	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

2.1.1 Overview

The proposed site is located to the north of Llansanffraid Glan Conwy, North Wales (NGR: SH 80289 76787) and involves the installation of a combined cycle and pedestrian path and two new footbridges over the Afon Ganol and Conwy Valley Railway Line.

The site is located within Flood Zone 3 according to NRW Flood Map for Planning[1]. These Flood Zones are associated with the Afon Ganol, which flows approximately 30m to the east of the proposed path. To the south one of the proposed footbridges crosses the Afon Ganol at NGR: SH 80299 76883. The site is likely to also be influenced by tides due to its coastal location, with the Afon Conwy estuary being located 0.2km to the south of site.

Conwy County Borough Council (CCBC) commissioned JBA to undertake the study in order to ascertain the impact of the proposed bridge over the Afon Ganol at SH 80299 76883. As a result, hydrology estimates are required for input to a hydraulic model of the Afon Ganol. This document details the hydrological assessment undertaken to derive the hydraulic model inflows.

Peak flow estimates and hydrographs are required for six flow estimation points (FEP) for the Afon Ganol. Peak flow estimates and hydrographs have been derived for the following annual exceedance probabilities (AEP) events:

- 50%;
- 3.33%;
- 1%;
- 1% plus central climate change allowance;
- 1% plus higher climate change allowance;
- 0.1%;
- 0.1% plus central climate change allowance; and
- 0.1% plus higher climate change allowance.

Based on September 2021 Welsh Government climate change allowance guidance[2], the proposed development site is located within the West Wales Basin District. For the ‘2080’ scenario, the Central allowance climate change uplift is 30%. This has been

1 https://flood-map-for-planning.naturalresources.wales/
2 https://www.gov.wales/sites/default/files/publications/2021-09/climate-change-allowances-and-flood-consequence-assessments_0.pdf

applied to the 1% AEP event peak flows. Peak flows for the Higher allowance (75% uplift) have also been calculated. Peak flow estimates and hydrographs derived from the hydrological analysis will be incorporated into a 1D-2D hydraulic model capable of simulating flood extents, levels and flows through time in relation to the development site.

2.2 The catchment

Catchment description:

Maps showing key features and topography of the study catchment are given in Figure 2-1 and

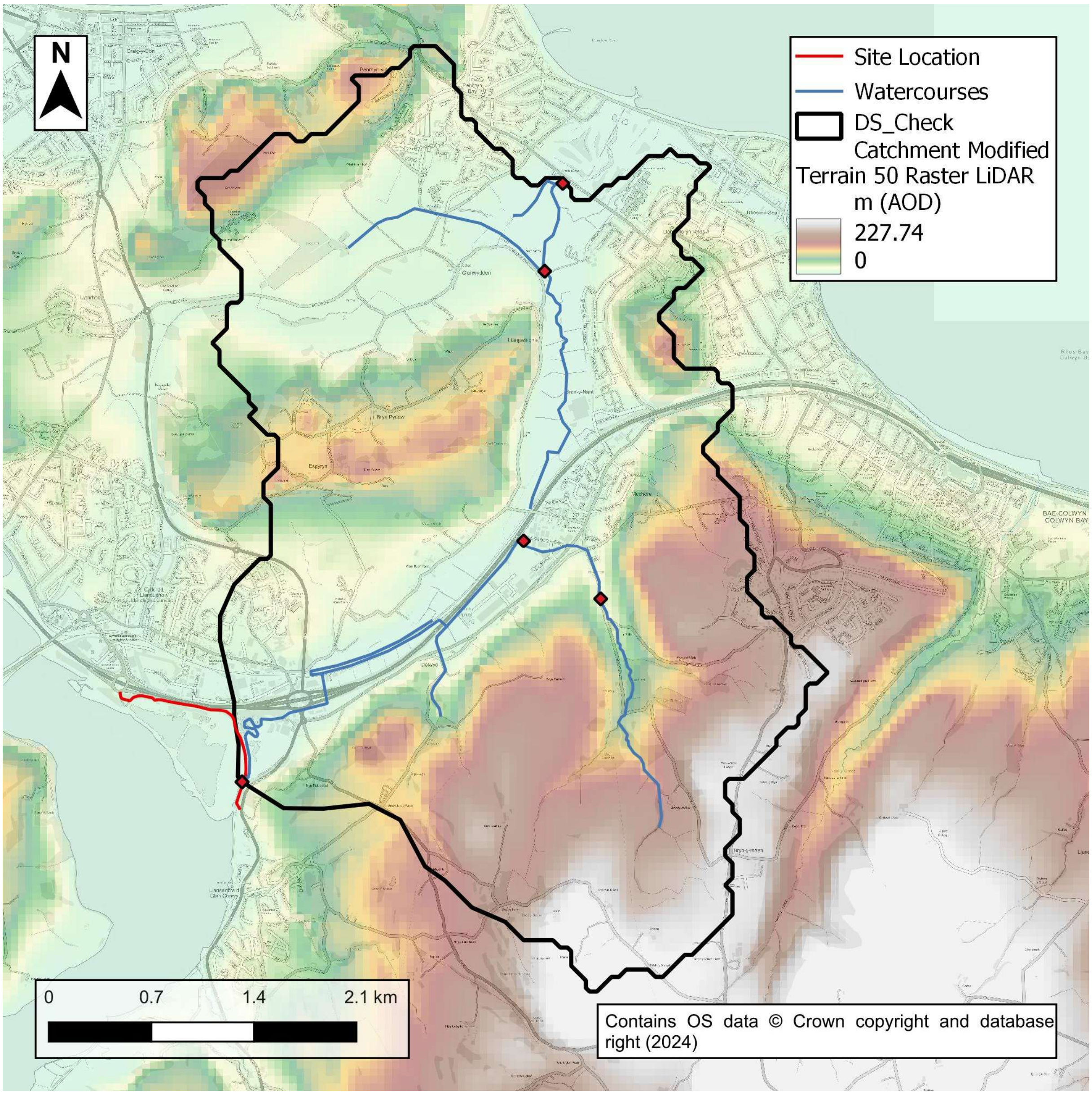


Figure 2-2.

The Afon Ganol, including contributing watercourses, drains an area of approximately 17.97km² at the downstream boundary of the hydraulic model. The general elevation trend of the study catchment is a decline from 227.4mAOD in the north, to 3.2mAOD in the southwest. The Afon Ganol catchment is located to the north of Llansanffraid Glan Conwy in North Wales. The catchment includes the town of Mochdre which is located, 2km east of Llansanffraid Glan Conwy. At the upstream extent of the town, the Afon Ganol drains a smaller catchment of 3.69km^2.

At SH 82200 78500 there is a bifurcation (splitter) structure which divides the river into two eastern and western channels (this is shown within the inset of Figure 2-1). The Ganol East flows northwards to drain into the Irish Sea at Penrhyn Bay. The Ganol West runs in a south-westerly direction towards the site and to meet the Afon Conwy at its estuary.

Data from the British Geological Survey (BGS) GeoIndex[3] shows that the underlying bedrock geology of the study catchment consists of the Elwy Formation - mudstone, siltstone and sandstone in the south and east. Both to the north and centrally within the catchment, the bedrock geology consists of the Gloddaeth Purple Sandstone Formation – sandstone and the Clwyd Limestone group – limestone. To the south and west the catchment is underlain by the Nantglyn Flags Formation - mudstone and siltstone and the Denbigh Grits Formation - mudstone, siltstone and sandstone. Superficial deposits consist predominantly of Till over higher elevations to the north, centrally and to the south of the catchment. Small pockets of glaciofluvial deposits - sand and gravel exist to the north in the upper reaches of the catchment, with tidal flat deposits - clay, silt and sand following the approximate course of the Afon Ganol.

Soils within the study catchment are shown to be varied[4]. At lower elevations to the north, soils are shown to be slightly acid loamy and clayey soils with impeded drainage. Bordering this region is an area of slowly permeable seasonally wet acid loamy and clayey soils. This soil type also occurs to the west of the catchment, to the north of Llandudno Junction. Following the approximate course of the Afon Ganol soils are shown to be loamy and clayey floodplain soils with naturally high groundwater. At higher elevations both centrally and to the south of the catchment, soils are freely draining slightly acid but base-rich soils and freely draining acid loamy soils over rock.

The underlying geology and soil types of the catchment indicate that the response to rainfall could be variable. In terms of the bedrock geology, the catchment is underlain by mudstones, siltstones and sandstones with some beds of limestones. The bedrock geology is overlain predominantly by superficial deposits of till. The varied and complex nature of the geology therefore indicates that there will be differing permeabilities and responses to rainfall across the catchment. The slowly permeable soils with those with impeded drainage within the lower elevations of the catchment

3 British Geological Survey (2024). BGS GeoIndex. [Source: https://mapapps2.bgs.ac.uk/geoindex/home.html].
4 British Geological Survey (2021). UK Soil Observatory Map Viewer. [Source: mapapps2.bgs.ac.uk/ukso/home.html].

would indicate that the fluvial response to rainfall based on the soil properties would likely be increased. At higher elevations the soils are more freely draining but are predominantly underlain by superficial deposits of till. However, the permeable nature of the underlying bedrock geology is likely to dampen the response of the catchment. The combination of these factors indicate that the Afon Ganol catchment is a complex system but will likely have a relatively slow response to rainfall.

The average annual rainfall (SAAR) for the period 1961 – 1990 was 863 mm, which is lower than the UK average annual rainfall of 1080mm.The catchment is located within Wales' regional climate[5] which can experience average annual rainfall (SAAR) exceeding 3000 mm. Rainfall in Wales varies widely and tends to have an uneven distribution through the year, with the highest rainfall experienced from October to January. This is due to the high frequency of winter Atlantic depressions and the relatively low frequency of summer thunderstorms.

5 https://www.metoffice.gov.uk/binaries/content/assets/metofficegovuk/pdf/weather/learn-about/weather/regional-climates/wales_-climate-met-office.pdf

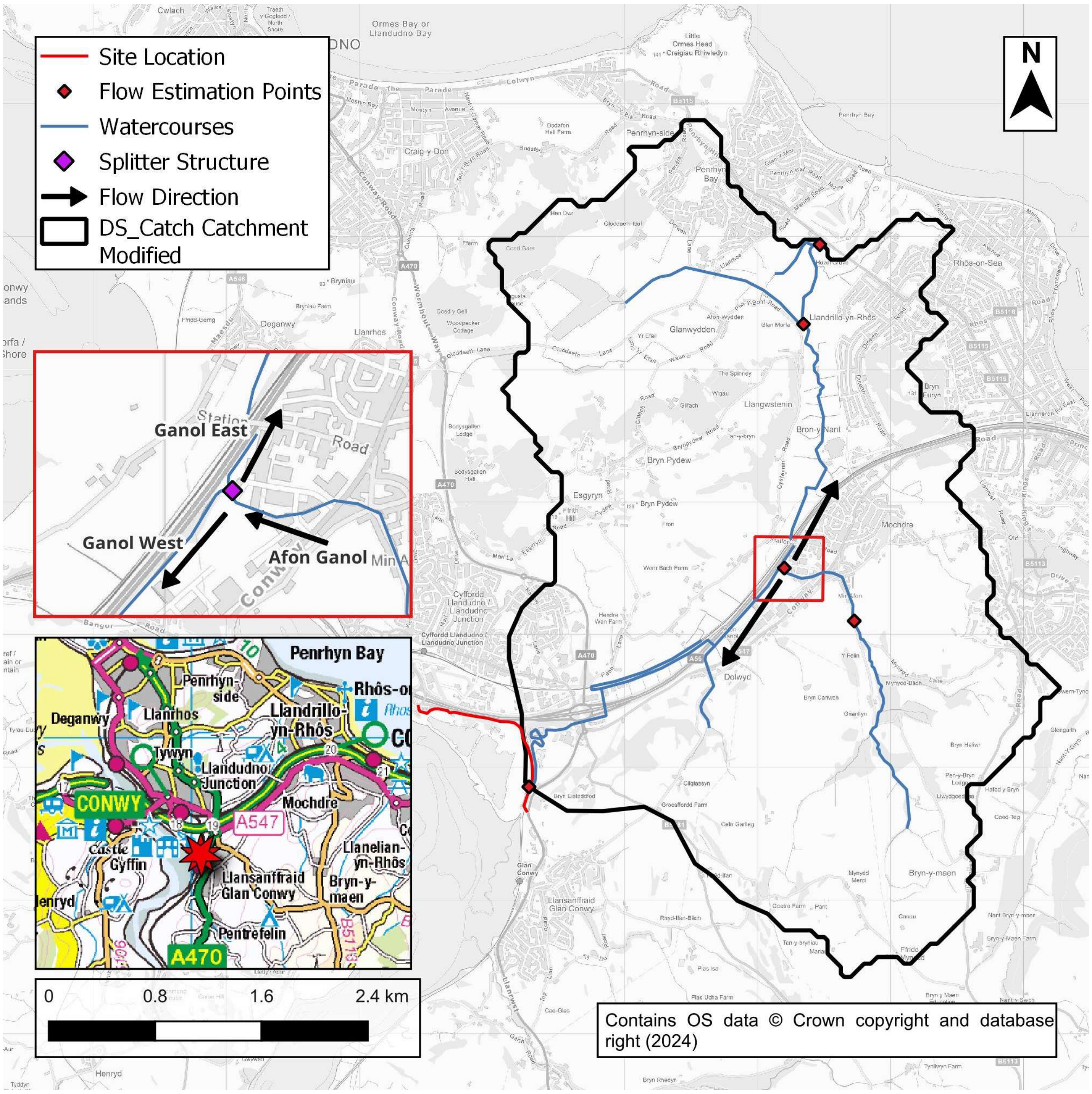


Figure 2-1: Catchment overview

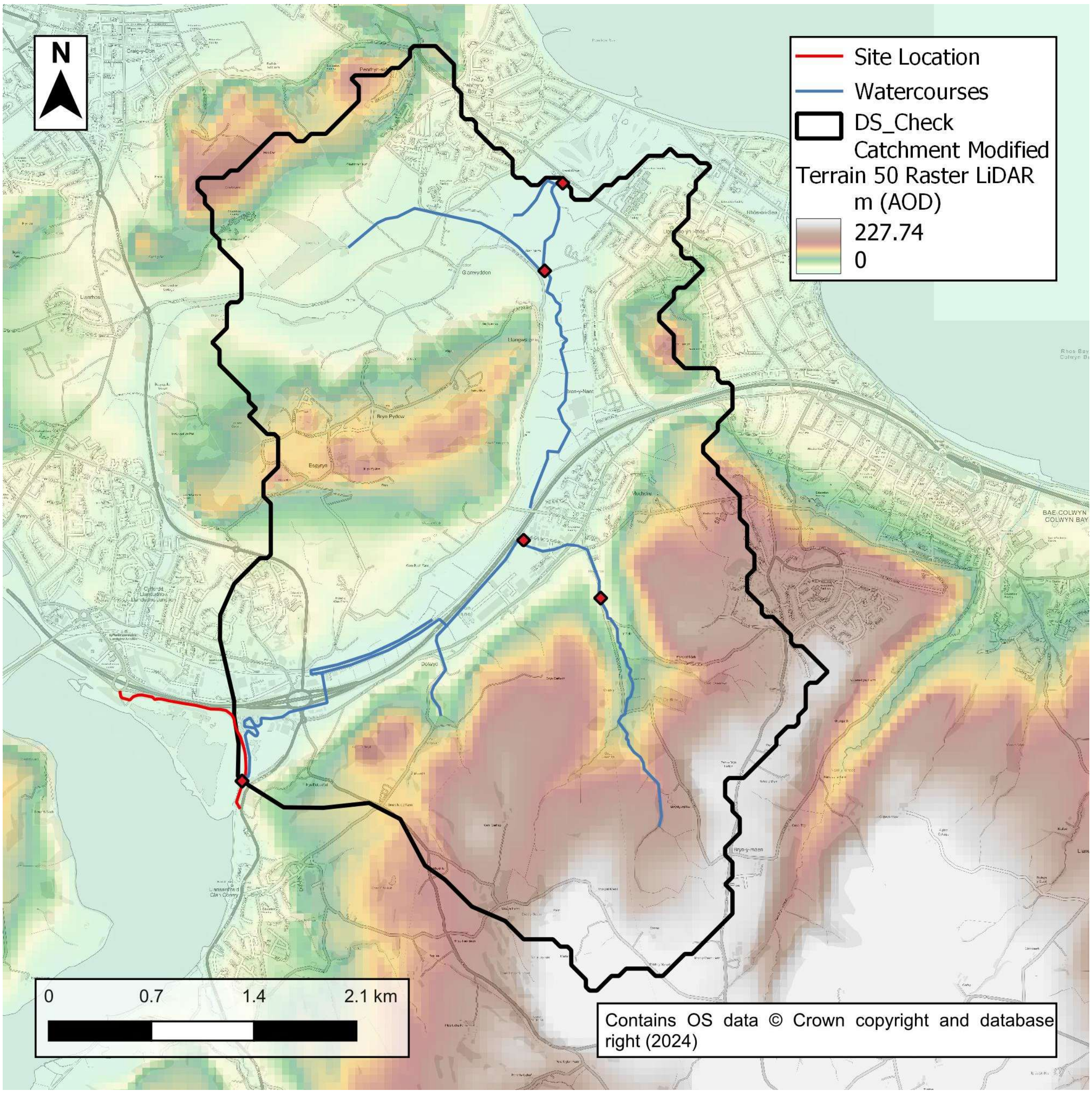


Figure 2-2: Catchment topography

2.3 Data review

The catchment is ungauged. A review of flood history has been carried out and is detailed in Section 2.3.1.

2.3.1 Flood history

Data available

Event date	Flooding source	Details
June 1st 1993	Pluvial	The Data Map Wales[6] shows one location within the catchment that has experienced a flood event. A very extreme event was experienced at Dolwyd whereby the channel capacity was exceeded (no raised defences). To the south of the catchment, but crucially outside of it, the railway embankment was breached at Glan Conwy Nurseries Feb/ March 1990.
N/A	N/A	There is no record of flooding when "Mochdre", 'Llandudno Junction" or "Llansanffraid Glan Conwy" is searched on the BHS Chronology of British Hydrological Events web site[7]. There are two records of flooding when "Llandudno" is searched on the BHS Chronology of British Hydrological Events web site, however, these relate to events further north (3km) outside the catchment in Llandudno.
October 20th /21st 2023 (Storm Babet)	Pluvial	An online google search for flooding and "'Llandudno Junction" yielded a few results; however, these again relate to Llandudno in the north and outside of the catchment. Results for "Mochdre" reveal that the area was affected by Storm Babet in 2023, with reports of minor flooding[8] and multiple blocked roads, including the A55 which runs east west through the catchment[9][10]. There were no relevant results for "Llansanffraid Glan Conwy".

6 https://datamap.gov.wales/maps/new?layer=inspire-nrw:NRW_HISTORIC_FLOODMAP#/
7 BHS Chronology of British Hydrological Events Available:https://www.cbhe.hydrology.org.uk/index.php
8 https://www.bbc.co.uk/news/uk-wales-59097578
9 https://www.northwalespioneer.co.uk/news/23870084.conwy-county-borough-council-tackles-flooding-issues/
10 https://www.dailypost.co.uk/news/north-wales-news/storm-babet-roads-blocked-flooding-27946031

2.3.2 Other relevant data

In 2012, the NRW (previously Environment Agency Wales) commissioned JBA to undertake a Flood Hazard Mapping Study on the Afon Ganol at Mochdre[11]. For this study an FEH Calculation record was produced. Five flow estimation points were chosen for the study and their locations have been matched by the approach of this current study in order to make a direct comparison. The chosen method for calculating peak flows was FEH Statistical, with the hybrid method used to derive peak flow estimates for the 0.1% AEP event.

Uses of the data for this study:

Peak flows derived within this study will be compared to the peak flows provided within the 2012 River Ganol Flood Hazard Mapping Study.

2.4 Hydrological understanding of the catchment

2.4.1 Conceptual model

The site of interest is located to the north of Llansanffraid Glan Conwy, North Wales (NGR: SH 80289 76787). The proposed combined cycle and pedestrian path follows the course of the Afon Ganal along a section to the west where the route runs approximately 30m to the west of the watercourse. To the south, one of the proposed footbridges crosses the Afon Ganol at NGR: SH 80299 76883.

Along the upper reaches of the Afon Ganol to the south east, flooding is likely to be related to peak flows but along the flatter Ganol West and Ganol East channels, flooding may be more volume driven as these sections are subject to tide locking.

2.4.2 Unusual catchment features

The catchment is predominantly rural however the hydrology will be complicated by the presence of the splitter structure that regulates flow between the east and west Afon Ganol channels. Therefore, the flow estimates produced by the hydrological analysis do not take into account the hydraulics of the system.

2.5 Initial choice of approach

Are FEH methods appropriate?: Yes

Initial choice of method(s) and reasons:

Peak flow estimates will be derived from application of FEH methods. ReFH2 methodology will be compared with FEH Statistical for estimating peak flows. The

11 JBA Consulting (2012), River Ganol at Mochdre Flood Hazard Mapping Study, Final Report.

favoured peak flow estimates are provided alongside justification for their adoption in subsequent sections.

The study catchments are small and ungauged and would benefit from local data which can be applied to the FEH Statistical method. The FEH Statistical method is considered suitable for peak flow estimation however, ReFH2 may be the more suitable as the FEH Statistical method peak flows can be more uncertain on small catchments[12].

There is no gauge data or historical flooding information against which to compare either hydrological or hydraulic modelling estimates, therefore there will be an inherent degree of uncertainty in the flow derived within this study.

How will hydrograph shapes be derived, if needed?:

Inflow hydrographs will be derived from ReFH2 and, depending on the final choice of method, either be applied to the hydraulic model directly or scaled to the FEH Statistical peak before being applied to the hydraulic model.

Will the catchment be split into sub-catchments? If so, how?:

The hydrology has been split into sub-catchments to obtain flow estimates for Ganol_W, Ganol_E and AfonG_SS; so no additional lateral flows are needed for these catchments.

Source of flood peak data & software to be used:

- NRFA peak flow dataset, v12.1 (November 2023)
- FEH Web Service[13]
- WINFAP 5.1[14]
- ReFH 2.3-FEH22 Calibrated

2.6 Selection of flood estimation locations

Flow estimates have been derived at five locations within the study area. These have been chosen to ensure peak flow estimates are available at the upstream and downstream extents of the model, at the splitter structure and where tributary inflows occur.

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

12 Environment Agency (2012) Estimating flood peaks and hydrographs for small catchments: Phase 1 and 2.

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

14 WINFAP 5.1 © Wallingford HydroSolutions Limited 2023.

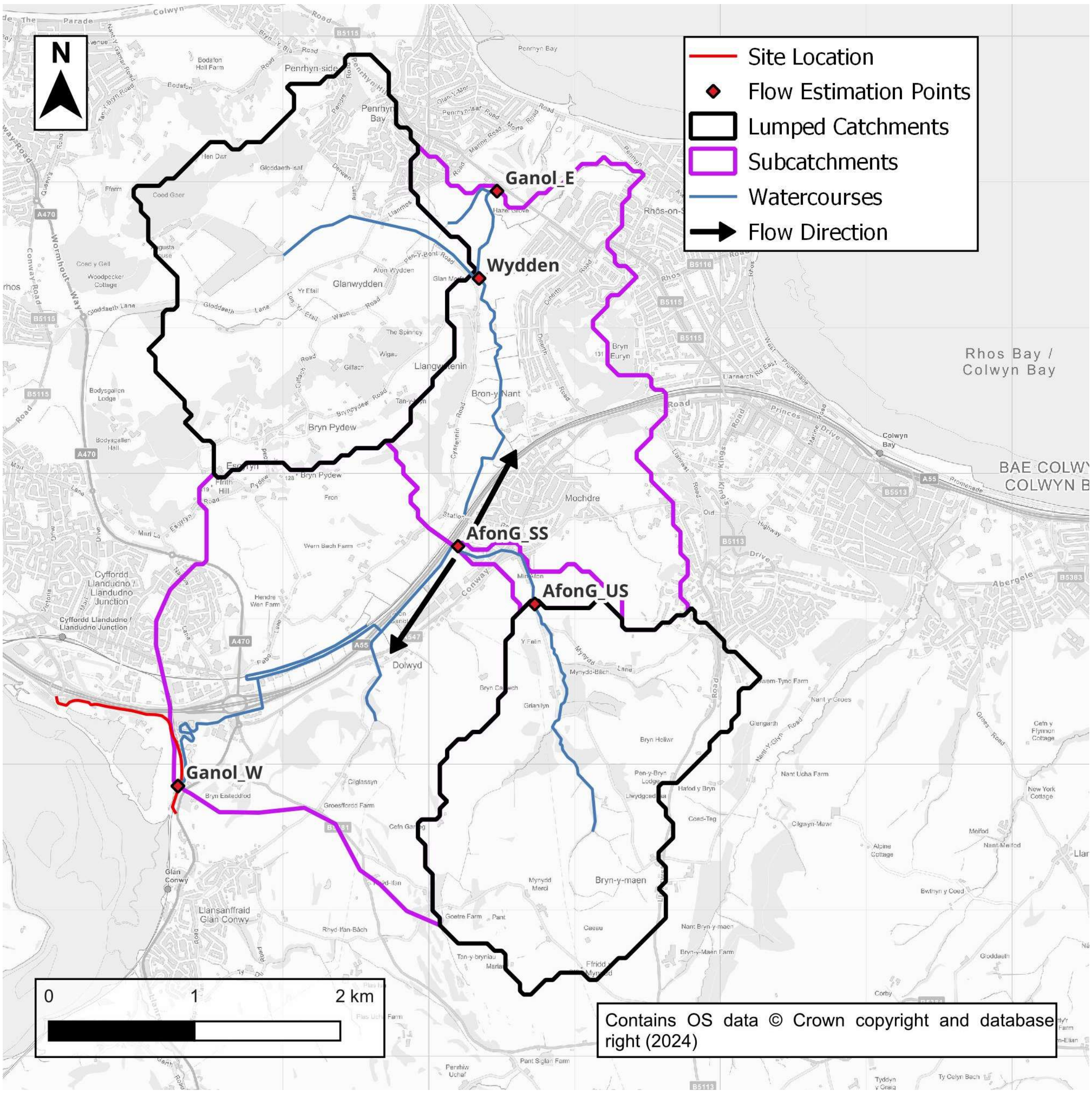


Figure 2-3: Flow estimation points

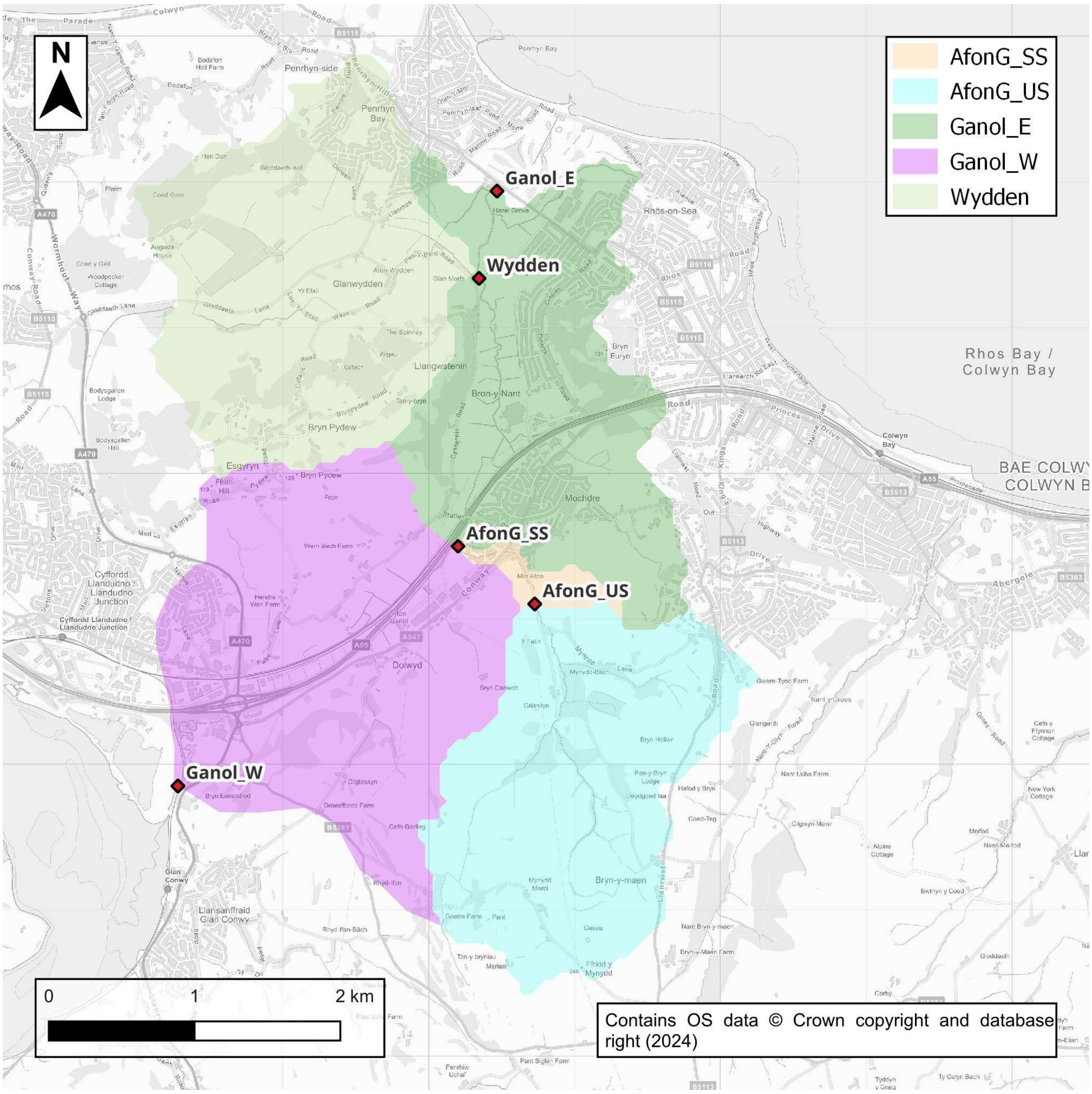


Figure 2-4: Study Area Catchments

Table 2-1: Flow estimation points

Site code	Type of estimate:	Watercourse	Site name / description	Easting	Northing
AfonG_US	L	Afon Ganol	Upstream Study Extent	282725	378102
AfonG_SS	S	Afon Ganol	Lateral flow between AfonG_US and the Afon Ganol splitter structure	282190	378495
Wydden	L	River Wydden	Wydden tributary catchment	282343	380339
Ganol_E	S	Afon Ganol East	Lateral flow between the Afon Ganol splitter structure and Ganol_E – flows to the north east	282466	380938
Ganol_W	S	Afon Ganol West	Lateral flow between the Afon Ganol splitter structure and Ganol_W – flows to the south west.	280281	376861

L = lumped catchment; S = sub-catchment

Further details on flood estimation location selection:

Both Wydden and Ganol_E flow estimation points are downstream of the splitter structure on the Ganol East. The flows from these will not directly impact the site, however they have been retained to allow for a direct comparison with the equivalent FEP's from the 2012 study.

3 Locations where flood estimates are required

3.1 Catchment boundary checks and revisions

The catchment boundaries were reviewed against both EA 1m DTM 2022 LiDAR data and Terrain 50m LiDAR data and modified to more accurately reflect the natural topographic elevations. Some of the catchments were modified to represent intervening areas/ lateral flows. The coverage of the EA 1m DTM 2022 LiDAR data did not extend to the entire catchment and so the lower resolution Terrain 50m LiDAR data has been used to demonstrate catchment extent revisions within Figure 3-1.

The exported FEH catchment for Wydden and AfonG_US were deemed to accurately reflect the drainage catchment and so no changes were made.

It should be noted that some of the catchments derived within this study differ significantly to the areas derived for the same node points within the 2012 study. Upon assessment of the catchment areas derived within the 2012 study, a number of observations were made which accounts for the differences between the two studies:

- Within the 2012 study the area for AfonG_SS includes the catchment area for AfonG_US whereas for AfonG_SS catchment area excludes the catchment area for AfonG_US within this study. Based on the existing model which shall be used within this study AfonG_US is to be applied as a model inflow whereas AfonG_SS will be applied as a lateral flow. As such, the AfonG_SS catchment area should exclude the catchment area for AfonG_US and the area derived within this study will be taken forward.
- The catchment for Ganol_E within the 2012 study includes the catchment area for Wydden. The model inflow point Ganol_E1 correlates with the location of the Wydden FEP and it is assumed that the model lateral point Ganol_E2 correlates to Ganol_E. As such, the Ganol_E lateral flow catchment area should exclude the catchment area for Wydden and the area derived within this study will be taken forward.
- In the 2012 report Ganol_W was calculated from Ganol_E as the catchment could not be obtained from the FEH CD. The catchment is available from the FEH Webservice and was modifed to exclude the catchment of Wydden then manually modified against LiDAR.

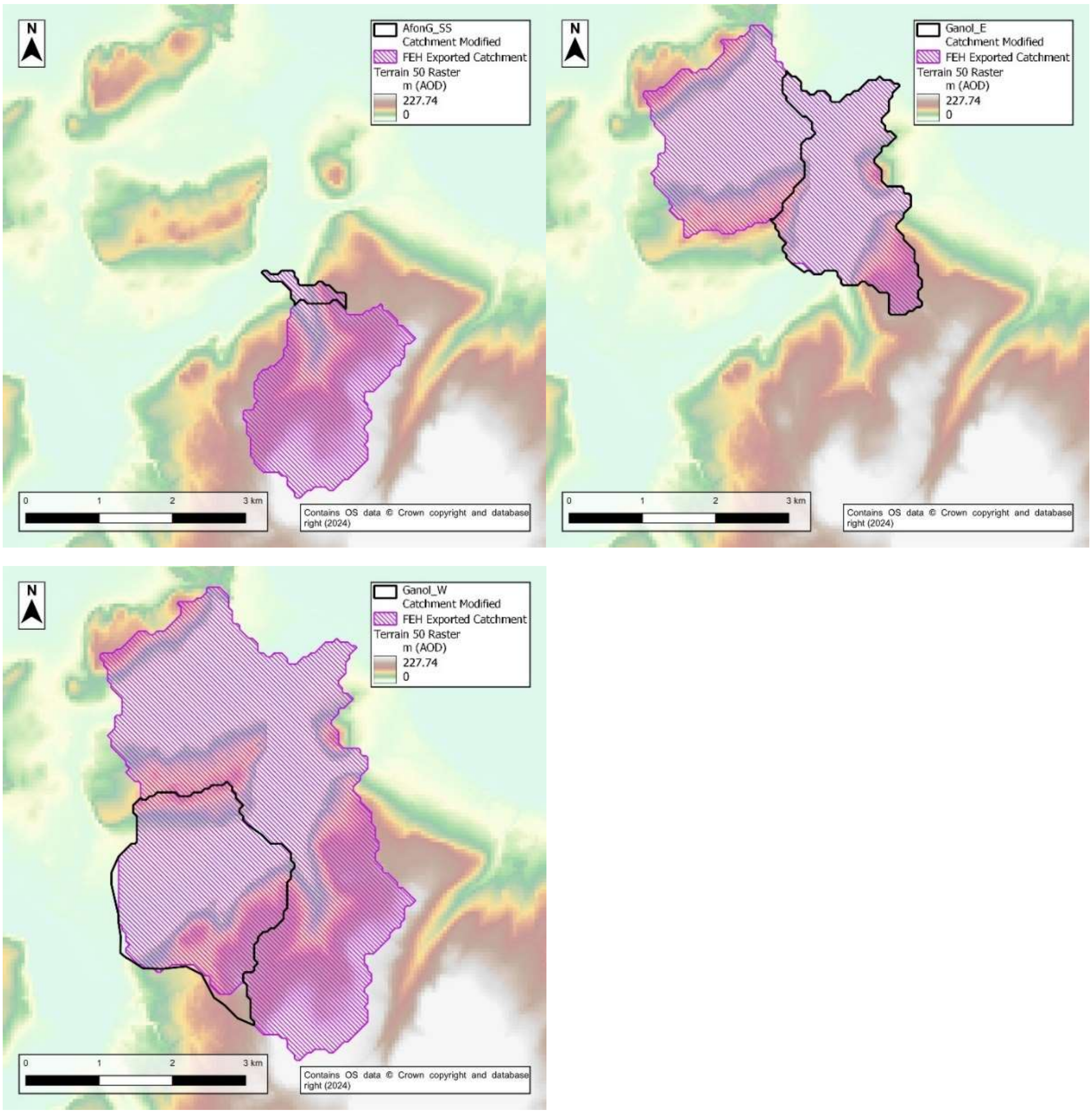


Figure 3-1: Catchment boundary revisions

3.2 Other catchment descriptor checks and revisions

The DPLBAR value was modified using an area ratio as the standard modification equation (Area^0.548). This can have uncertainty when applied to small catchments.

URBEXT:

A review of URBEXT was undertaken by recalculating URBEXT using OS50k mapping and equation 5.4 in Bayliss et al. (2006)[15].

URBEXT2000 = 0.629 URBAN

Site code	URBEXT 2000	Revised OS50K Mapping Urban Area Km^2	Revised URBEXT 2000
AfonG_US	0.015	0.00	**0.001**
AfonG_SS	0.006	0.03	**0.016**
Wydden	0.111	0.12	**0.078**
Ganol_E	0.067	0.03	**0.021**
Ganol_W	0.036	0.05	**0.149**

BFIHOST:

BFIHOST19 values were reviewed based on the online BGS GeoIndex[16] (See Section 2.2 for geological details) and were considered to reflect the geology of catchment so no changes were made.

FARL:

FARL value was reviewed based on online mapping/aerial imagery and against the 'Lakes and waterways' layer on the FEH Web Service. The catchment has a FARL value of 1.0 and no changes were considered necessary.

Version of URBEXT: URBEXT2000

Method for updating URBEXT: URBAN50k

Version of BFIHOST: BFIHOST19

15 Bayliss et al (2006) URBEXT2000 – A new FEH catchment descriptor. Available at: https://assets.publishing.service.gov.uk/media/602bb617d3bf7f0318a5ec3d/URBEXT2000_-_A_new_FEH_catchment_descriptor_-_SID5_technical_report.pdf

16 British Geological Survey (2024). BGS GeoIndex. [Source: https://mapapps2.bgs.ac.uk/geoindex/home.html]

3.3 Catchment descriptors

Final catchment descriptors at each subject site:

Values shown in bold denote that they have been manually adjusted.

Site code	AREA on FEH Web Service (km^2)	Revised AREA (km^2)	BFIHOST19	DPLBAR (km)	DPSBAR (m/km)	FARL	FPEXT	PROPWET	SAAR (mm)	URBEXT 2000
AfonG_SS	4.05	**0.23**	0.512	**0.13**	153	1	0.0105	0.59	927	**0.001**
AfonG_US	3.81	-	0.511	1.77	150.4	1	0.0039	0.59	931	**0.016**
Ganol_E	8.20	**3.90**	0.533	**2.14**	104.1	1	0.1404	0.59	825	**0.078**
Ganol_W	17.06	**5.07**	0.528	**2.78**	120.6	1	0.0974	0.59	864	**0.021**
Wydden	4.32	-	0.511	1.84	97.6	1	0.0892	0.59	831	**0.149**

4 Stationary statistical methods

4.1 Estimating QMED

4.1.1 QMED at ungauged subject sites

Site code	Method	Initial QMED (rural) from CDs (m^3/s)	Donors used (NRFA numbers)	Donor distance from subject centroid (km)	Moderation term (α) value	Final donor adjustment factor	Urban adjustment factor	Final QMED (m^3/s)
AfonG_SS	DT	0.1	66004	32.6	0.24	0.80	1.00	0.1
AfonG_US	DT	1.6	66004	32.6	0.24	0.80	1.02	1.3
Ganol_E	DT	1.1	66004	34.3	0.23	0.81	1.10	1.0
Ganol_W	DT	1.6	66004	33.9	0.23	0.81	1.03	1.3
Wydden	DT	1.4	66004	35.1	0.23	0.81	1.19	1.3

QMED estimation methods: **DT** - catchment descriptors with donor transfer

Donor distance weighting method:

Moderation term applied

Multiple donors:

N/A

Parameters used for WINFAP v4 urban adjustment:

Method for urban adjustment of QMED (subject site and donors): WINFAP v4[17] (first introduced for v4 of WINFAP and applied in v5 and UKFE)

Impervious fraction for built-up areas (IF): 0.3

Percentage runoff for impervious surfaces (PR_{imp}): 0.7

Method for calculating fractional urban cover (URBAN): From updated URBEXT2000

4.1.2 Search for donor sites

Discussion of selected donor sites / rejected donor sites:

The five closest donors (based on catchment centroids) 66002 (Elwy at Pant yr Onen), 66006 (Elwy at Pont-y-Gwyddel), 66011 (Conwy at Cwmlanerch), 66001 (Clwyd at Pont-y-Cambwll) and 66004 (Wheeler at Bodfari) were selected for assessment. As no donors exist within the wider catchment of the subject site, all potential donors are located outside the subject site catchment. All five stations are classed as suitable for QMED adjustment on the NRFA website.

Three other nearby donor stations were excluded for donor catchment consideration due to being unsuitable for QMED adjustment. These stations include 66012 (Lledr at Pont Gethin), 66025 (Clwyd at Pont Dafydd) and 67003 (Brenig at Llyn Brenig outflow).

Although the catchment areas of all five suitable donor catchments are larger than that of the subject site, they are considered to be within an acceptable range as to still reflect similar processes to that of the subject catchment. The small catchment research states that descriptors such as area are included in the regression equation for QMED.

[17] Wallingford HydroSolutions (2016). WINFAP 4 Urban adjustment procedures.

Donor adjustments therefore accounts for area differences between donor and subject catchments, and hence all five suitable donors can be used.

In terms of hydroclimatic similarities, donor 66001 has the closest BFIHOST19 (0.54) to the study catchments, with the two closest donors (66002, 66006) having slightly lower values of 0.43. Catchment 66004 has a slightly higher BFIHOST19 value of 0.61, whilst 66011 has a substantially lower value of 0.38. The three closest donors (66002, 66006 and 66001) are all hydromatically similar to each other and to the study catchment, with similar DPSBAR, FARL and PROPWET values.

Between the site, donor 66002 is the closest to the subject catchments (14.1-18.1km), with the next closest donor (66006) only being located 14.3 -18.2km to the south east; a difference of only 0.1-0.2km. The other three remaining sites are between 25-35km away from the catchment centroids. The Environment Agency Flood Estimation Guidelines LIT 11832 (2022) suggests that for small catchments it is advised to adjust QMED using a single donor catchment, usually chosen on the basis of proximity. However, an assessment of the record available for 66002 on NRFA showed that the gauge only has a AMAX record of 12 years (1962-1973). While the record is deemed acceptable on NRFA for QMED assessment it is felt that the record length is too short when 66004, even if it is further away, has a record length of 48 years.

Based on the above assessment, donor 66004 has therefore been chosen for QMED adjustment at the subject site due to a mixture of proximity, record length and hydroclimatical similarities.

Donor sites chosen and QMED adjustment factors:

NRFA no.	Method	Adjustment for climatic variation?	QMED from flow data (m^3/s)	Urban adjustment factor	De-urbanised QMED from flow data (m^3/s) (A)	Rural QMED from catchment descriptors (m^3/s) (B)	Adjustment ratio (A/B)
66004	AM	No	3.7	1.01	3.7	9.3	0.40

Methods: **AM** – Annual maxima; **POT** – Peaks over threshold; **LF** – Low flow (flow duration curve) statistics.

4.2 Estimating growth curves

4.2.1 Derivation of pooling groups

Several subject sites may use the same pooling group. LIT 11832 Flood Estimation Guidelines (2022) v4 states that it is good practice to apply one pooling group to multiple points along a watercourse to promote spatial consistency. AfonG_US and AfonG_SS FEP's will use the same pooling group, derived from the catchment descriptors for the AfonG_US FEP. Likewise, Ganol_W, Ganol_E and Wydden will use the same pooling group, derived from the catchment descriptors for the Ganol_W FEP. Catchment descriptors for the FEP's within each pooling group are relatively similar, and it is unlikely that a pooling group derived for AfonG_US would differ to a pooling group derived for the AfonG_SS .

In line with NRW Flood estimation – technical Guidance note, the pooling group urban threshold was changed from the default value of 0.03 to 0.3.

Name of group	Small catchment pooling procedure applied?	Site code from whose descriptors group was derived	Subject site treated as gauged? (ESS)	URBEXT2000 threshold applied to pooling group selection	L-moments deurbanised (including subject site for ESS)
AfonG_US Pooling	Yes	AfonG_US	No	0.30	L-CV: 0.245 L-Skew: 0.239
Ganol_W Pooling	Yes	Ganol_W	No	0.30	L-CV: 0.245 L-Skew: 0.215

Methods: Unless otherwise stated, pooling groups were derived using the procedures from Science Report SC050050 (2008). The small catchment pooling procedure is given in the report on Phase 2 of project SC090031 (2021) and implemented in WINFAP v5 / UKFE.

4.2.2 Pooling group composition

Name of group	Changes made to default pooling group	Weighted average L-moments	Weighted average L-moments with non-flood year adjustment
AfonG_US Pooling	**Removed**: 44008 - high % non-flood years **Added**: None	L-CV: 0.245 L-Skew: 0.239	N/A
Ganol_W Pooling	**Removed**: 44008 - high % non-flood years **Added**: 69047	L-CV: 0.245 L-Skew: 0.215	N/A

4.2.3 Derivation of growth curves at subject sites

Site code	Method	If P or ESS, name of pooling group	Distribution used and reason for choice	Any urban or non-flood years adjustments	Parameters of distribution (location, scale and shape after adjustments)	Growth factor for 1% AEP
AfonG_SS	P	AfonG_US Pooling	GEV, GL and KAP3 all give an acceptable fit to the data. GEV has the lowest absolute z-value (-0.44) indicating the best fit. GEV was therefore selected.	WINFAP-FEHV4 Urban adjustment applied. Guidelines states that non-flood years adjustment only applies to a GL distribution.	Location: 1.00 Scale: 0.353 Shape: -0.106	2.96
AfonG_US					Location: 1.00 Scale: 0.348 Shape: -0.109	2.95
Ganol_E		Ganol_W Pooling	GEV, GL and KAP3 all give an acceptable fit to the data. KAP3 has the lowest absolute z-value (0.09) indicating the best fit. KAP3 was therefore selected.		Location: 1.00 Scale: 0.281 Shape: -0.166	2.87
Ganol_W					Location: 1.00 Scale: 0.294 Shape: -0.154	2.90
Wydden					Location: 1.00 Scale: 0.265 Shape: -0.181	2.85

Methods: **P** - Pooled

Pooled and ESS growth curves were derived using the procedures from Science Report SC050050 (2008). Urban adjustments are carried out using the method of Kjeldsen (2010) which is used within the WINFAP v4 urban adjustment procedures using URBAN rather than URBEXT2000.

4.3 Final choice of QMED and growth curves

Site code	Final choice of QMED and reasons	Final choice of flood growth curve method and reasons
AfonG_SS	Donor catchment utilising 66004 – catchment considered to be suitable due to proximity and catchment characteristics.	Small Catchment Procedure using GEV distribution.
AfonG_US		
Ganol_E		Small Catchment Procedure using KAP3 distribution.
Ganol_W		
Wydden		

4.4 Final flood estimates from stationary statistical methods

Site code	50%	3.3%	1%	1% +30% Climate Change Allowance Central	1% +75% Climate Change Allowance Upper	0.1%	0.1% +30% Climate Change Allowance Central	0.1% +75% Climate Change Allowance Upper
AfonG_SS	0.1	0.3	0.3	0.4	0.6	0.5	0.7	0.9
AfonG_US	1.3	2.9	3.7	4.9	6.6	5.7	7.4	9.9
Ganol_E	1.0	2.2	2.9	3.8	5.1	4.6	6.0	8.1
Ganol_W	1.3	3.0	3.8	5.0	6.7	6.0	7.8	10.5
Wydden	1.3	2.8	3.7	4.8	6.5	6.0	7.8	10.5

Flood peak in m^3/s for the AEP (%) event

5 Revitalised Flood Hydrograph 2 (ReFH2) method

5.1 Model parameters

5.1.1 Summary of rural model parameters:

Site code	Method	Tp (hours) rural	Cmax (mm)	BL (hours)
AfonG_SS	CD	1.00	375.18	16.88
AfonG_US	CD	1.00	374.2	29.8
Ganol_E	CD	1.24	396.21	31.86
Ganol_W	CD	1.37	391.1	33.54
Wydden	CD	1.16	374.2	30.05

Methods: **CD**: Catchment descriptors,

5.2 Model inputs for design events

Design events for lumped catchments:

Site code	Default season of design event	Storm duration (hrs)	Initial soil moisture, Cini	Initial baseflow, BF0
AfonG_SS	Winter	05:45:00	85.72	0.01
AfonG_US			85.87	0.11
Ganol_E			82.72	0.08
Ganol_W			83.42	0.12
Wydden			85.87	0.10

Note: Design storm(s) to be applied to a hydraulic model are detailed in Section 6.3.

Is the catchment groundwater-dominated?:

No

Which rainfall DDF model has been used?:

FEH22

5.3 Final choice of ReFH2 flow estimates

Method choice and reasons:

Site code	Final choice of design inputs and model parameters
AfonG_SS	Rural design inputs used. Winter season design events used. The Critical Storm Duration (CSD) has been derived from the Ganol_W Flood Estimation Point (5.75hours) as it is the catchment closest to the study site. All FEP points were run to the ReFH2 Critical Storm Duration of Ganol_W to provide consistency through the study catchments. This and the ARF value (0.96) for Ganol_W has been adopted for all model inflows and sub-catchments for modelling.
AfonG_US	
Ganol_E	
Ganol_W	
Wydden	

Final flood estimates from ReFH2 method:

Site code	50%	3.3%	1%	1% +30% Climate Change Allowance Central	1% +75% Climate Change Allowance Upper	0.1%	0.1% +30% Climate Change Allowance Central	0.1% +75% Climate Change Allowance Upper
AfonG_SS	0.1	0.3	0.3	0.4	0.6	0.6	0.8	1.0
AfonG_US	1.9	3.9	5.2	6.8	9.2	8.9	11.5	15.5
Ganol_E	1.5	3.2	4.3	5.6	7.5	7.3	9.5	12.8
Ganol_W	1.9	4.2	5.6	7.3	9.8	9.5	12.3	16.6
Wydden	1.9	4.0	5.4	7.0	9.5	9.1	11.9	16.0

Flood peak in $m^{3/}s$ for AEP (%) even

6 Discussion and summary of results

6.1 Comparison of results from different methods

Site code	Method FEH Statistical (Y) peak flow (m^3/s), 50% AEP	Method ReFH2 (X) peak flow (m^3/s), 50% AEP	Method FEH Statistical (Y) peak flow (m^3/s), 1% AEP	Method ReFH2 peak (X) flow (m^3/s), 1% AEP
AfonG_SS	0.1	0.1	0.3	0.3
AfonG_US	1.3	1.9	3.7	5.2
Ganol_E	1.0	1.5	2.9	4.3
Ganol_W	1.3	1.9	3.8	5.6
Wydden	1.3	1.9	3.7	5.4

Site code	Ratio (X / Y), 50% AEP	Ratio (X / Y), 1% AEP
AfonG_SS	1.09	1.02
AfonG_US	1.49	1.40
Ganol_E	1.47	1.48
Ganol_W	1.47	1.46
Wydden	1.43	1.46

6.2 Final choice of method

Choice of method and reasons:

Flows derived through the application of the ReFH2 model were compared with those derived from the FEH statistical method. Results show that for the 50% and 1% AEP events, peak flow estimates from the FEH Statistical method are generally between 40-49% lower than the flows derived from ReFH2. Exceptions to this rule include AfonG_SS, where peak flow estimates are comparable. For the 50% AEP event, peak flow estimates from the FEH Statistical method are 9% lower than the flows derived from ReFH2, whilst estimates for the 1% AEP are only 2% lower from the FEH Statistical method than the flows derived from ReFH2.

Variation in results likely stems from the uncertainty associated with estimating peak flows in small and ungauged catchments. It is acknowledged that the Statistical Method benefits from use of a local gauge for donor adjustment, whereas ReFH2 estimates are just from catchment descriptors, so may be more uncertain.

The preferred method for peak flow estimation given in the technical guidance from NRW[18] is the FEH Statistical method, using the latest methodologies up to and including the 1% AEP. Peak flows for rarer events should be estimated using the flood growth curve from ReFH2 applied to the 1% AEP estimate from the FEH Statistical method. While flows derived within ReFH2 are higher than flows derived using Feh Statistical, NRW guidance is clear that choosing one methodology over another simply because it provides higher or lower estimates is not appropriate.

Therefore, in line with the preferred approach stated within the technical guidance from NRW, the preferred method is the FEH statistical method.

How will the 0.1% AEP flows be estimated?

Statistical method is valid for up to a 150-year AEP and is less certain for rarer events. Therefore, peak flows derived using the FEH Statistical method for the 1000-year event have been adjusted to apply the growth factor derived from ReFH2 flows (often referred to as the "Hybrid" approach).

6.3 Application of inflows to a hydraulic model

How will the flows be applied to a hydraulic model?

The model inflow will be distributed along the study reach at the location where flow points have been identified within Figure 2-3. Hydrographs obtained using the FEH statistical method will be taken forward for modelling purposes. ReFH2 design hydrographs will be scaled to FEH peak flows.

Final design storms applied in the hydraulic model:

Season of design event	Storm duration (hrs)	ARF	Reason for selecting storm
Summer	05:45:00	0.96	ReFH2 critical storm duration for Ganol_W (5.75hours) adopted for all model inflows and sub-catchments for modelling.

Hydrographs for modelling purposes are located within Appendix 7.2.1.

18 Natural Resource Wales 2021. Flood estimation – technical guidance. Guidance Note (GN 008)

6.4 Checks

Growth factor checks:

Site code	1% AEP growth factor	0.1% AEP / 1% AEP ratio	Comments
AfonG_SS	2.96	1.51	The 1% AEP Growth factor lies within the typical range.
AfonG_US	2.95	1.51	
Ganol_E	2.87	1.59	
Ganol_W	2.90	1.57	
Wydden	2.85	1.62	

The typical range is 2.1 to 4.0 (based on FSR regional growth curves) therefore the 1% AEP growth factor for all FEP's are inside the typical range for both flow estimation methodologies.

Spatial consistency of results:

Results are considered sensible in that they increase with downstream distance where applicable.

Frequency of notable historical floods:

No data is available in regard to flood events applicable to the site.

Compatibility with longer-term flood history:

This will be determined at the modelling stage

Comparisons with previous studies:

Peak flows were obtained from the JBA Consulting (2012) River Ganol Flood Hazard Mapping study. As the two lumped catchment flow estimation points from the 2012 study corresponds to the lumped flow estimation points derived for this study, they can therefore be directly compared.

Table 6-1 details a comparison between both the 2012 JBA Consulting study and this current study.

Table 6-1: Peak Flow Comparison

Site	50% AEP		1% AEP	
	JBA Consulting FEH Statistical (2024)	JBA Consulting FEH Statistical (2012)	JBA Consulting FEH Statistical (2024)	JBA Consulting FEH Statistical (2012)
AfonG_US	1.3	1.2	3.7	3.4
Wydden	1.3	1.0	3.7	2.8

Flows obtained from FEH Statistical for the current study vary against the flows derived from FEH Statistical in 2012. For AfonG_US, peak flows for the 50% and 1% AEP events are between 8-9% greater than those derived within the 2012 study. The difference in peak flows derived for Wydden is greater, with peak flows for the 50% and 1% AEP events being between 30-32% greater than those derived within the 2012 study.

Some of the differences between peak flow estimates will be because of the donor catchments used. The 2012 study does not apply a donor to either FEP, only to Ganol_E, which isn't in line with current day guidance. Another factor influencing the differences between the peak flows is the fact that 66002 was not considered for QMED adjustment within the 2012 study.

Further differences stem from the pooling groups which are detailed in Table 6-2. Bold red text highlights stations which appear in both study pooling groups.

Table 6-2: Pooling group comparison

JBA Consulting (2024) AfonG_US	JBA Consulting (2012) AfonG_US	JBA Consulting (2024) Ganol_W	JBA Consulting (2012) Ganol_E
27051	**27051**	**25019**	**25019**
76011	**76011**	**27051**	**27051**
45816	**45816**	**27010**	**27010**
28033	**28033**	**45816**	**45816**
25011	**25011**	**28033**	**28033**
25019	**25019**	27073	203046
27010	**27010**	23018	36009
27073	45817	26016	50009
49005	54091	49005	20002
23018	54062	68021	203049
26016	91802	76011	72014
84035	25003	84035	25011
68021	206006	27081	73015
69047	54022	39086	36010
47022	50009	69047	41020
-	27032	-	49003

As the current study utilises the latest datasets, methods and guidance, results derived for this study are preferred.

Checks on hydraulic model results:

Modelled flood levels and extents will be sense-checked to ensure that flow inputs produce realistic outputs.

6.5 Assumptions, limitations, and uncertainty

Assumptions:

Key assumptions for the study are:

- The selected donor adequately represents the subject catchment for QMED adjustment.
- The pooling group used to derive peak flow estimates is representative of the subject catchment.
- Use of GEV and KAP3 distributions in pooling group assessment is assumed to be preferable to the other distributions identified by WINFAP 5 due to its z value.
- The design peak flows derived are representative of those that would be observed during flood events.
- Design hydrographs generated using the ReFH2 model are representative of those that would be observed during typical flood events.

Limitations:

Limitations are generic to the methods used.

- The main limitation for this study is the absence of flow gauge data for the Afon Ganol with which to improve peak flow estimates.
- The catchments are considered to be small relative to the overall database of gauging station data used for calibration. Therefore, the use of FEH / ReFH is considered to be a primary limitation of the study.
- The flow estimates produced by the hydrological analysis do not take into account the hydraulics of the system including the setting of the splitter structure at the downstream extent of the Upper Ganol reach and the impact of tides at the downstream of both Ganol East and Ganol West channels which will result in ‘locking’.
- It has been recognised that the Statistical method is not appropriate to define the 0.1% AEP event because of the availability of flow data and an alternative (hybrid) method has been used.

Uncertainty:

No published methods of calculating confidence intervals exist for ReFH hydrological models; therefore, the uncertainty for each of these watercourses is difficult to quantify. The uncertainty will depend on many factors, for example, how unusual the study catchment is relative to the pooling group and donor catchment, and the uncertainty in flow measurement at other gauges. However, a UK average measure of uncertainty has been produced by Kjeldsen (2014). The 95% confidence limits for a 1% AEP flood estimate are:

Without donor adjustment of QMED: 0.42 – 2.37 times the best estimate.

With donor adjustment of QMED: 0.45 – 2.25 times the best estimate

A recently published R&D project into FEH, local data and uncertainty (Environment Agency funded consortium of JBA, CEH and others) established that the following range of a 95% confidence interval is to be expected per design flood for a rural site (numbers quoted are multipliers):

AEP	No donor	1 donor
50%	0.48 – 2.10	0.50 - 2.02
1%	0.45 – 2.33	0.47 – 2.12

6.6 Final results

Final method applied:

FEH Statistical method with REFH2 1%/0.1% AEP growth curve applied to the 0.1% AEP event.

Site code	50%	3.3%	1%	1% +30% Climate Change Allowance Central	1% +75% Climate Change Allowance Upper	0.1%	0.1% +30% Climate Change Allowance Central	0.1% +75% Climate Change Allowance Upper
AfonG_SS	0.1	0.3	0.3	0.4	0.6	0.6	0.7	1.0
AfonG_US	1.3	2.9	3.7	4.9	6.6	6.3	8.2	11.1
Ganol_E	1.0	2.2	2.9	3.8	5.1	4.9	6.4	8.7
Ganol_W	1.3	3.0	3.8	5.0	6.7	6.5	8.5	11.4
Wydden	1.3	2.8	3.7	4.8	6.5	6.3	8.1	10.9

Flood peak in m^3/s for the AEP (%) events

Climate change estimates:

Based on September 2021 Welsh Government climate change allowance guidance, the proposed development site is located within the West Wales Basin District. For the ‘2080’ scenario, the Central allowance climate change uplift is 30%. This has been applied to the 1% AEP event peak flows. Peak flows for the Higher allowance (75% uplift) have also been calculated. Peak flow estimates and hydrographs derived from the hydrological analysis will be incorporated into a 1D-2D hydraulic model capable of simulating flood extents, levels and flows through time in relation to the development site.

Suitability of results for future studies:

These flow estimates were derived specifically for this study. They should not be used elsewhere without at least being reviewed for suitability.

Recommendations for future work:

Confidence could be improved through installation of hydrometric monitoring and event hydrometric data.

7 Appendix

7.1 Digital files

Input data:

Catchment Descriptors: \\WAR-RDC05\Live Data\2024\Projects\2024s0854 - Conwy County Borough Council - RSPB Conwy FCA\1_WIP\HO\Non_Graphical\Catchment Descriptors

Shapefiles: \\WAR-RDC05\Live Data\2024\Projects\2024s0854 - Conwy County Borough Council - RSPB Conwy FCA\1_WIP\HO\Graphical\Shapefiles

Project or calculation files:

WINFAP:\\WAR-RDC05\Live Data\2024\Projects\2024s0854 - Conwy County Borough Council - RSPB Conwy FCA\1_WIP\HO\Non_Graphical\WINFAP

ReFH2: \\WAR-RDC05\Live Data\2024\Projects\2024s0854 - Conwy County Borough Council - RSPB Conwy FCA\1_WIP\HO\Non_Graphical\ReFH2

Output data:

Model Inflow Hydrographs: \\WAR-RDC05\Live Data\2024\Projects\2024s0854 - Conwy County Borough Council - RSPB Conwy FCA\1_WIP\HO\Non_Graphical\Hydrographs

7.2 Other supporting information

7.2.1 Model Hydrographs

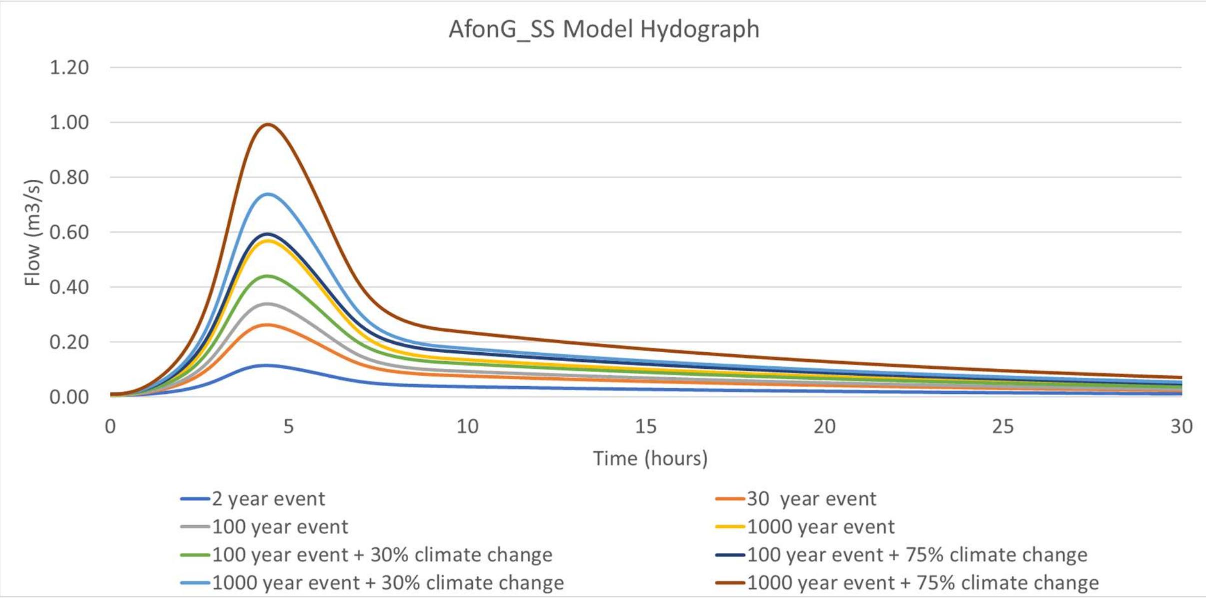


Figure 7-1: Model hydrograph for AfonG_SS

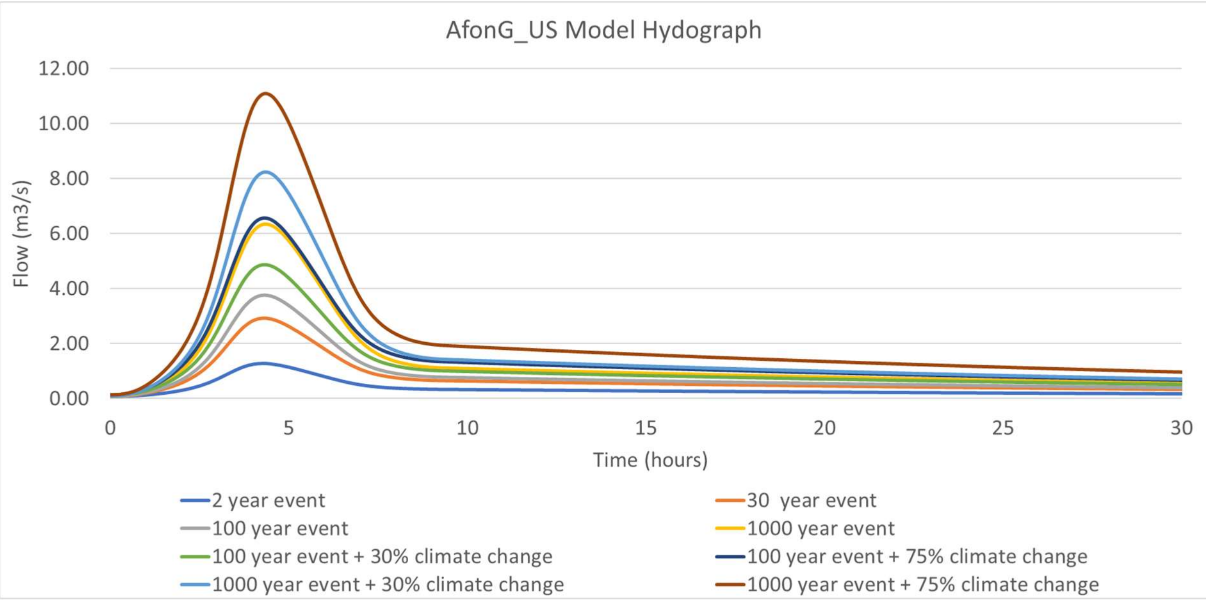


Figure 7-2: Model hydrograph for AfonG_US

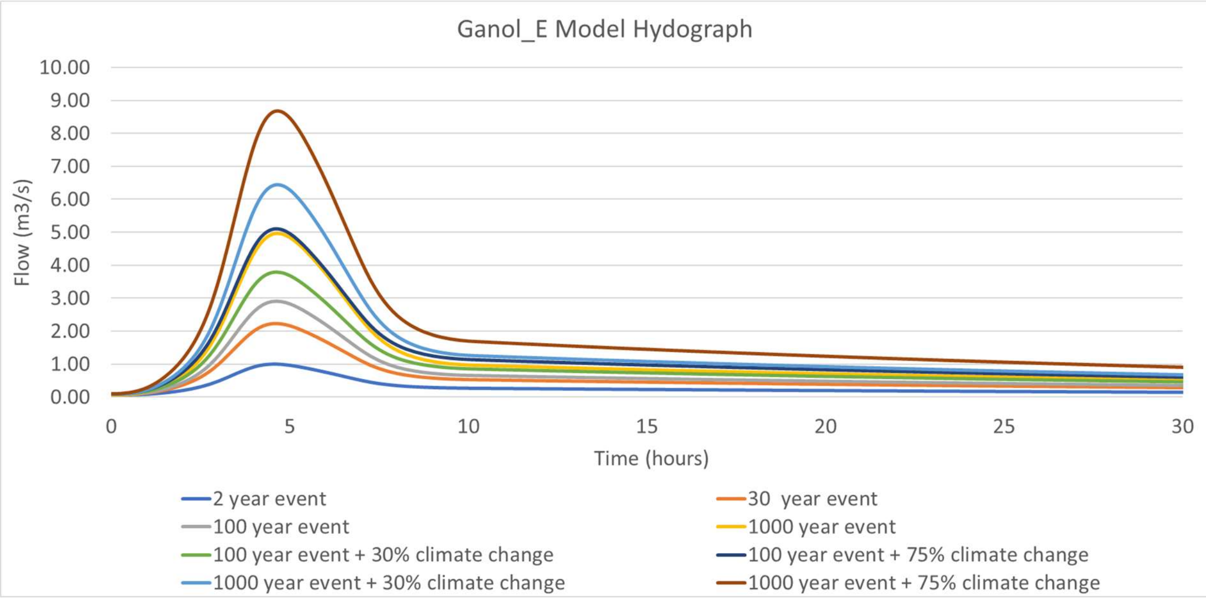


Figure 7-3: Model hydrograph for Ganol_E

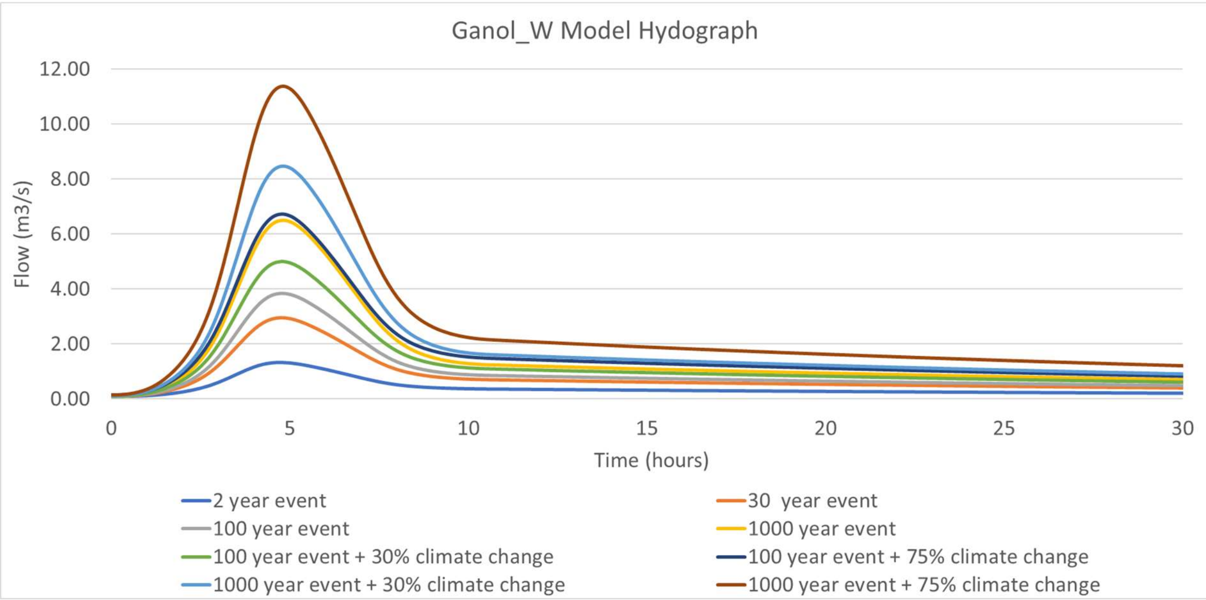


Figure 7-4: Model hydrograph for Ganol_W

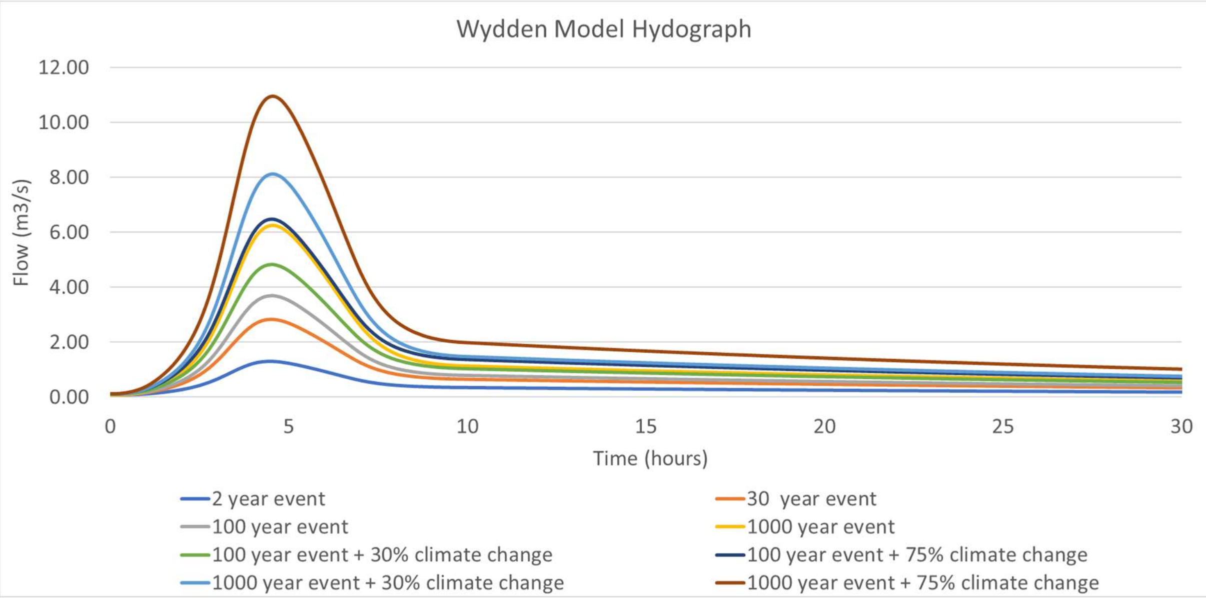


Figure 7-5: Model hydrograph for Wydden

7.2.2 Pooling groups

UK Design Flood Estimation

Summary of ESS/Pooled Estimation Analysis using the Flood Estimation Handbook Statistical Method

Date of creation:	26-06-2024 14:55:52
Software:	WINFAP Version: 5.1.8811 (23432)
Peak Flow dataset:	Peak Flow Dataset 12.1.1
Supplementary data used:	No

Site details

Site number:	376257749
Site name:	AfonG_US
Site location:	SH 82750 78100
Easting:	282750
Northing:	378100
Catchment area:	3.81 km^2
SAAR:	931 mm
BFIHOST19:	0.511
FPEXT:	0.004
FARL:	1.000
URBEXT2000:	0.0162

Site data

At-site data

At-site data present: No

UK Design Flood Estimation

Summary of ESS/Pooled Estimation Analysis using the Flood Estimation Handbook Statistical Method

Analysis settings

Urbanisation settings

User defined:	No
Urban area:	0.10 km²
PRimp:	70.00%
Impervious Factor:	0.300
UAF:	1.01931

Growth curve settings

Distance Measure Method:	Small catchment
Pooling group URBEXT2000 Threshold:	0.300
Deurbanise Pooling Group L-moments:	Yes

QMED settings

Use at-site data:	No
Method:	User Defined

Growth curve data and results

Pooling group AM data

Station	Distance	Years of data	QMED AM	L-CV Observed	L-CV Deurbanised	L-SKEW Observed	L-SKEW Deurbanised
27051 (Crimple @ Burn Bridge)	0.651	50	4.641	0.218	**0.218**	0.133	**0.133**
76011 (Coal Burn @ Coalburn)	0.819	45	1.840	0.171	**0.171**	0.292	**0.292**
45816 (Haddeo @ Upton)	0.880	29	3.248	0.289	**0.290**	0.432	**0.431**
27073 (Brompton Beck @ Snainton Ings)	0.942	42	0.816	0.212	**0.213**	0.020	**0.018**
25019 (Leven @ Easby)	1.137	44	5.384	0.340	**0.341**	0.367	**0.366**
49005 (Bolingey Stream @ Bolingey Cocks Bridge)	1.185	12	4.924	0.266	**0.267**	0.268	**0.267**
28033 (Dove @ Hollinsclough)	1.204	47	4.150	0.231	**0.231**	0.381	**0.381**
23018 (Ouse Burn @ Woolsington)	1.220	31	3.265	0.279	**0.296**	0.194	**0.177**
26016 (Gypsey Race @ Kirby Grindalythe)	1.274	25	0.101	0.309	**0.309**	0.249	**0.249**
27010 (Hodge Beck @ Bransdale Weir)	1.274	41	9.420	0.224	**0.224**	0.293	**0.293**
84035 (Kittoch Water @ Waterside)	1.361	31	20.128	0.130	**0.152**	0.049	**0.010**
68021 (Arrowe Brook @ Acton Lane)	1.370	16	3.997	0.259	**0.287**	0.456	**0.420**
69047 (Roch @ Littleborough)	1.515	26	9.742	0.226	**0.231**	0.127	**0.121**
47022 (Tory Brook @ Newnham Park)	1.541	27	6.176	0.246	**0.248**	0.151	**0.149**
25011 (Langdon Beck @ Langdon)	1.611	36	15.878	0.223	**0.223**	0.321	**0.320**
Total		**502**					

UK Design Flood Estimation

Summary of ESS/Pooled Estimation Analysis using the Flood Estimation Handbook Statistical Method

Pooling group suitability

Station	Suitability for QMED	Suitability for pooling	Years	Non-flood years	Percentage non-flood years	Mann Kendall (MK)	MK significance (%)	Discordancy	Comments
27051 (Crimple @ Burn Bridge)	Yes	Yes	50	4	8.00	1.51	None	0.335	
76011 (Coal Burn @ Coalburn)	Yes	Yes	45	0	0.00			1.139	
45816 (Haddeo @ Upton)	Yes	Yes	29	0	0.00	-0.83	None	0.766	
27073 (Brompton Beck @ Snainton Ings)	Yes	Yes	42	2	4.76	1.17	None	1.121	
25019 (Leven @ Easby)	Yes	Yes	44	3	6.82			1.524	
49005 (Bolingey Stream @ Bolingey Cocks Bridge)	Yes	Yes	12	0	0.00			2.963	
28033 (Dove @ Hollinsclough)	Yes	Yes	47	1	2.13			0.731	
23018 (Ouse Burn @ Woolsington)	Yes	Yes	31	4	12.90	0.71	None	0.569	
26016 (Gypsey Race @ Kirby Grindalythe)	Yes	Yes	25	3	12.00			1.013	
27010 (Hodge Beck @ Bransdale Weir)	Yes	Yes	41	1	2.44	-2.10	5	0.213	
84035 (Kittoch Water @ Waterside)	Yes	Yes	31	0	0.00	-1.38	None	1.910	
68021 (Arrowe Brook @ Acton Lane)	Yes	Yes	16	0	0.00			1.015	
69047 (Roch @ Littleborough)	Yes	Yes	26	2	7.69			0.594	
47022 (Tory Brook @ Newnham Park)	Yes	Yes	27	1	3.70			0.522	
25011 (Langdon Beck @ Langdon)	Yes	Yes	36	0	0.00			0.583	

Pooling group catchment descriptors

Station	Area	SAAR	FPEXT	FARL	URBEXT2000	BFIHOST19
27051 (Crimple @ Burn Bridge)	8.172	855	0.013	1.000	0.006	0.329
76011 (Coal Burn @ Coalburn)	1.630	1096	0.074	1.000	0.000	0.274
45816 (Haddeo @ Upton)	6.808	1210	0.011	1.000	0.005	0.535
27073 (Brompton Beck @ Snainton Ings)	8.060	721	0.237	1.000	0.008	0.811
25019 (Leven @ Easby)	15.088	830	0.019	1.000	0.004	0.495
49005 (Bolingey Stream @ Bolingey Cocks Bridge)	16.080	1044	0.023	0.991	0.006	0.562
28033 (Dove @ Hollinsclough)	7.915	1346	0.007	1.000	0.000	0.347
23018 (Ouse Burn @ Woolsington)	10.137	670	0.131	0.977	0.100	0.333
26016 (Gypsey Race @ Kirby Grindalythe)	15.850	757	0.030	1.000	0.000	0.927
27010 (Hodge Beck @ Bransdale Weir)	18.820	987	0.009	1.000	0.001	0.303
84035 (Kittoch Water @ Waterside)	16.812	1184	0.052	0.978	0.264	0.350
68021 (Arrowe Brook @ Acton Lane)	17.872	750	0.139	0.996	0.173	0.495
69047 (Roch @ Littleborough)	14.775	1353	0.038	0.890	0.034	0.467
47022 (Tory Brook @ Newnham Park)	13.432	1403	0.023	0.942	0.014	0.353
25011 (Langdon Beck @ Langdon)	12.787	1463	0.012	1.000	0.001	0.264

Pooling Group Rejected Stations

Station	Distance	Years of data	QMED AM	L-CV Observed	L-CV Deurbanised	L-SKEW Observed	L-SKEW Deurbanised	Comments
44008 (South Winterbourne @ Winterbourne Steepleton)	1.340	31	0.544	0.413	0.414	0.268	0.267	

UK Design Flood Estimation

Summary of ESS/Pooled Estimation Analysis using the Flood Estimation Handbook Statistical Method

Growth curve L-moments

Rural L-CV:	0.245	Urban L-CV:	0.243
Rural L-Skewness:	0.239	Urban L-Skewness:	0.242

Rural fitted parameters

Distribution	Location	Scale	Shape	H	Bound
GL	1.000	0.246	-0.239		-0.029
GEV	0.868	0.354	-0.105		-2.517
KAP3	0.933	0.293	-0.178	-0.400	-0.711

Urban fitted parameters

Distribution	Location	Scale	Shape	H	Bound
GL	1.000	0.243	-0.242		-0.005
GEV	0.870	0.349	-0.109		-2.337
KAP3	0.934	0.290	-0.182	-0.400	-0.657

Goodness of fit

GL:	1.0181 *
GEV:	-0.4408 *
P3:	-2.2215
GP:	-4.0101
KAP3:	0.5223 *

** Distribution gives an acceptable fit (absolute Z value < 1.645)*

Heterogeneity

Standardised test value H2: 3.0206

The pooling group is heterogeneous and a review of the pooling group is desirable.

Standardised growth curves

Rural

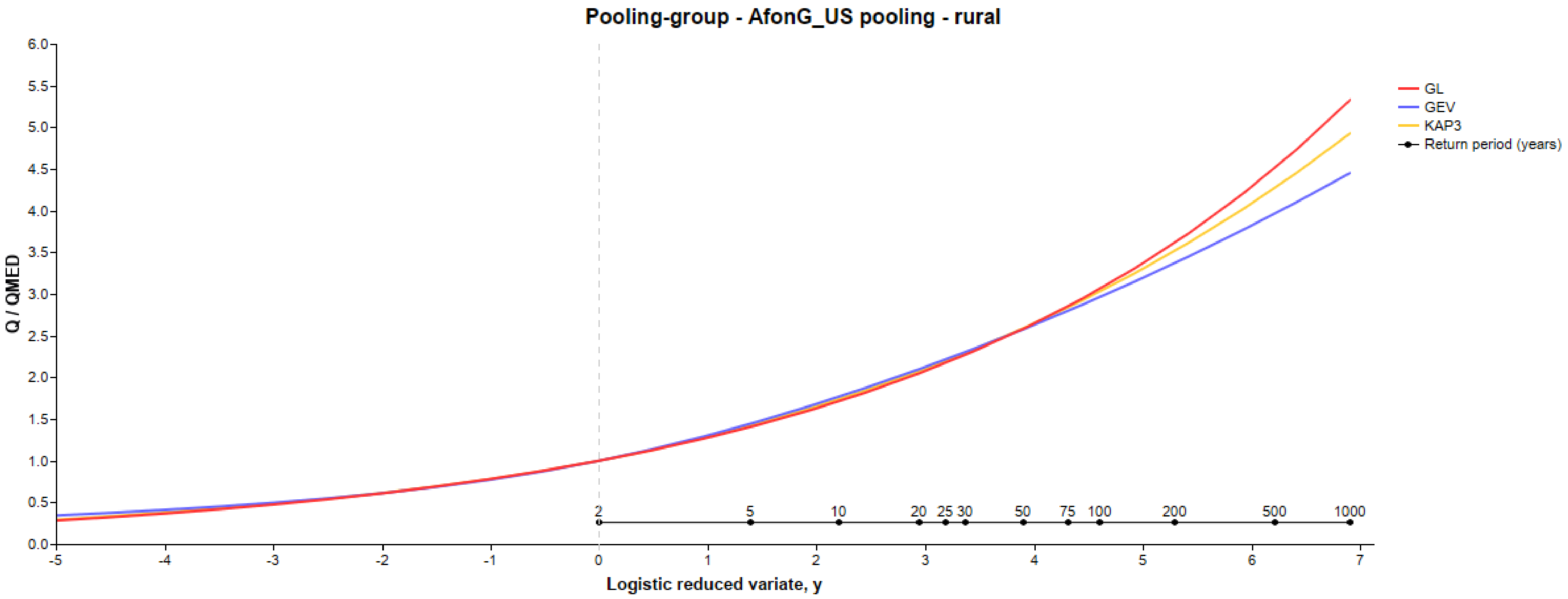
Return period	GL	GEV	KAP3
2	1.000	1.000	1.000
5	1.404	1.442	1.420
10	1.710	1.766	1.736
20	2.050	2.100	2.077
25	2.170	2.212	2.194
30	2.271	2.305	2.293
50	2.578	2.573	2.585
75	2.848	2.795	2.835
100	3.056	2.958	3.024
200	3.615	3.371	3.518
500	4.511	3.964	4.272
1000	5.329	4.452	4.928

Urban

Return period	GL	GEV	KAP3
2	1.000	1.000	1.000
5	1.400	1.438	1.416
10	1.705	1.759	1.730
20	2.043	2.093	2.069
25	2.162	2.204	2.186
30	2.263	2.297	2.285
50	2.570	2.566	2.577
75	2.840	2.789	2.828
100	3.047	2.952	3.017
200	3.609	3.368	3.513
500	4.508	3.968	4.272
1000	5.333	4.462	4.936

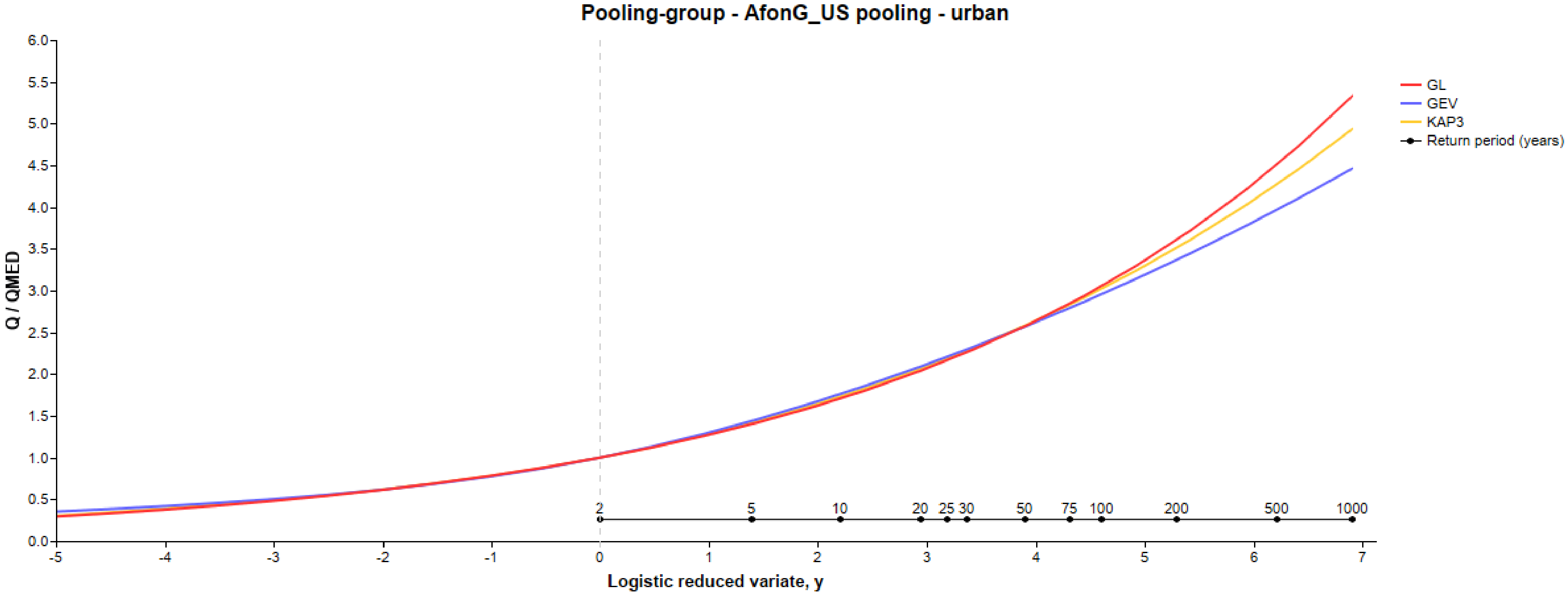
UK Design Flood Estimation

Summary of ESS/Pooled Estimation Analysis using the Flood Estimation Handbook Statistical Method



UK Design Flood Estimation

Summary of ESS/Pooled Estimation Analysis using the Flood Estimation Handbook Statistical Method



UK Design Flood Estimation

Summary of ESS/Pooled Estimation Analysis using the Flood Estimation Handbook Statistical Method

QMED data and results

QMED

Rural:	1.300 m³/s
Urban:	1.325 m³/s

UK Design Flood Estimation

Summary of ESS/Pooled Estimation Analysis using the Flood Estimation Handbook Statistical Method

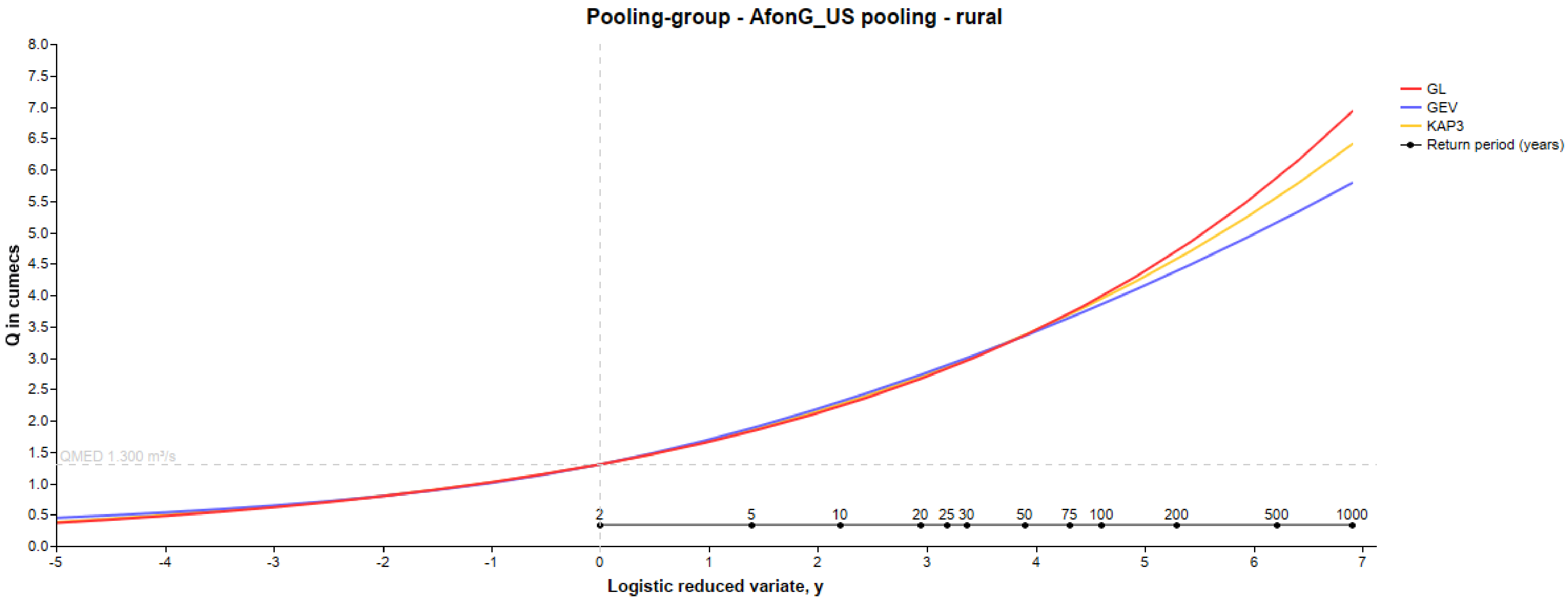
Flood Frequency Curve

Rural Flood Frequency Curve

Return period	GL (m³/s)	GEV (m³/s)	KAP3 (m³/s)
2	1.300	1.300	1.300
5	1.825	1.875	1.846
10	2.223	2.295	2.257
20	2.665	2.730	2.700
25	2.821	2.875	2.852
30	2.953	2.996	2.980
50	3.352	3.345	3.360
75	3.703	3.634	3.686
100	3.972	3.846	3.931
200	4.700	4.383	4.574
500	5.864	5.154	5.553
1000	6.928	5.787	6.407

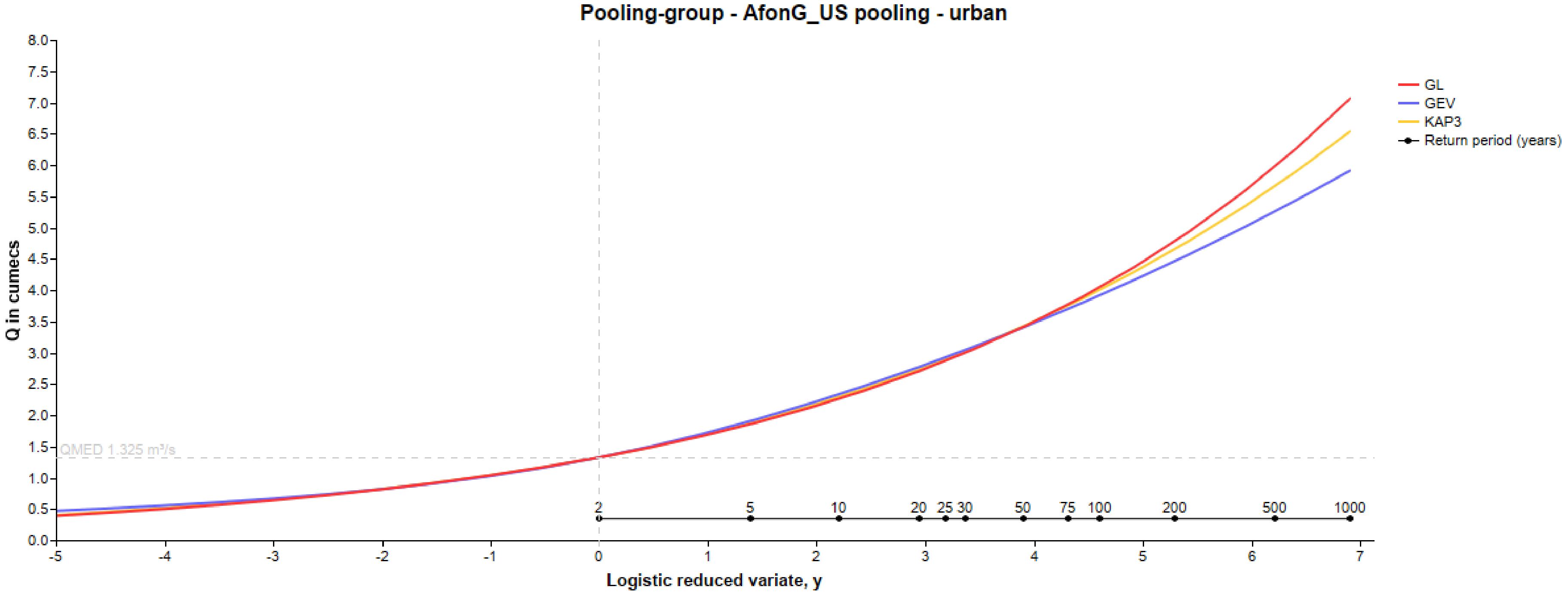
Urban Flood Frequency Curve

Return period	GL (m³/s)	GEV (m³/s)	KAP3 (m³/s)
2	1.325	1.325	1.325
5	1.855	1.905	1.876
10	2.259	2.331	2.292
20	2.707	2.773	2.742
25	2.865	2.921	2.897
30	2.999	3.044	3.027
50	3.406	3.400	3.415
75	3.763	3.695	3.747
100	4.038	3.912	3.997
200	4.782	4.463	4.656
500	5.974	5.257	5.661
1000	7.067	5.912	6.541



UK Design Flood Estimation

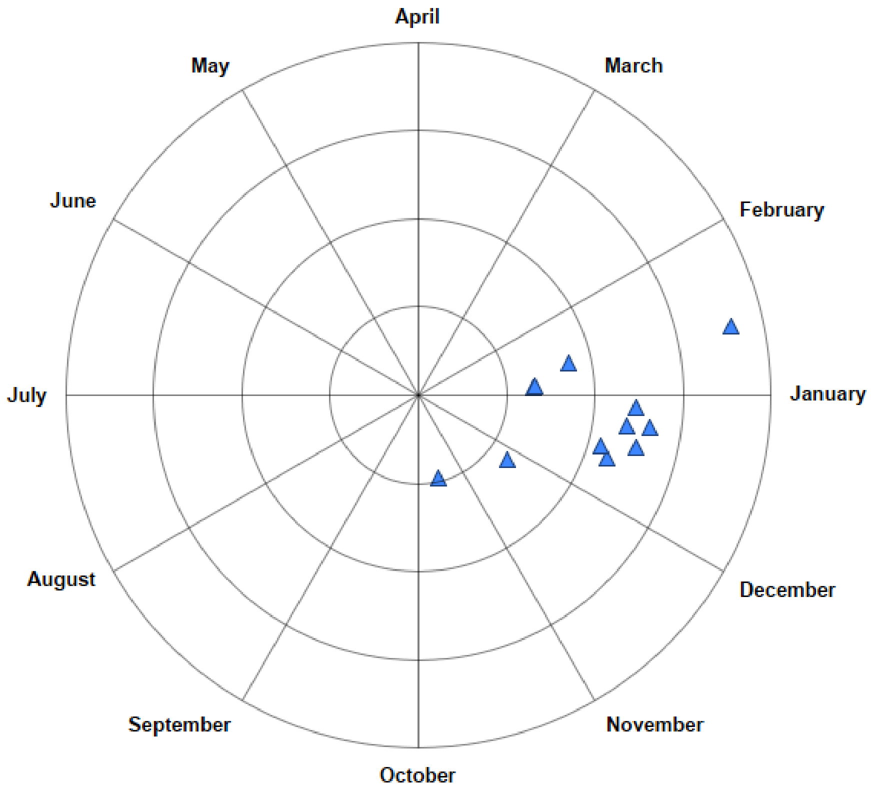
Summary of ESS/Pooled Estimation Analysis using the Flood Estimation Handbook Statistical Method



Appendix

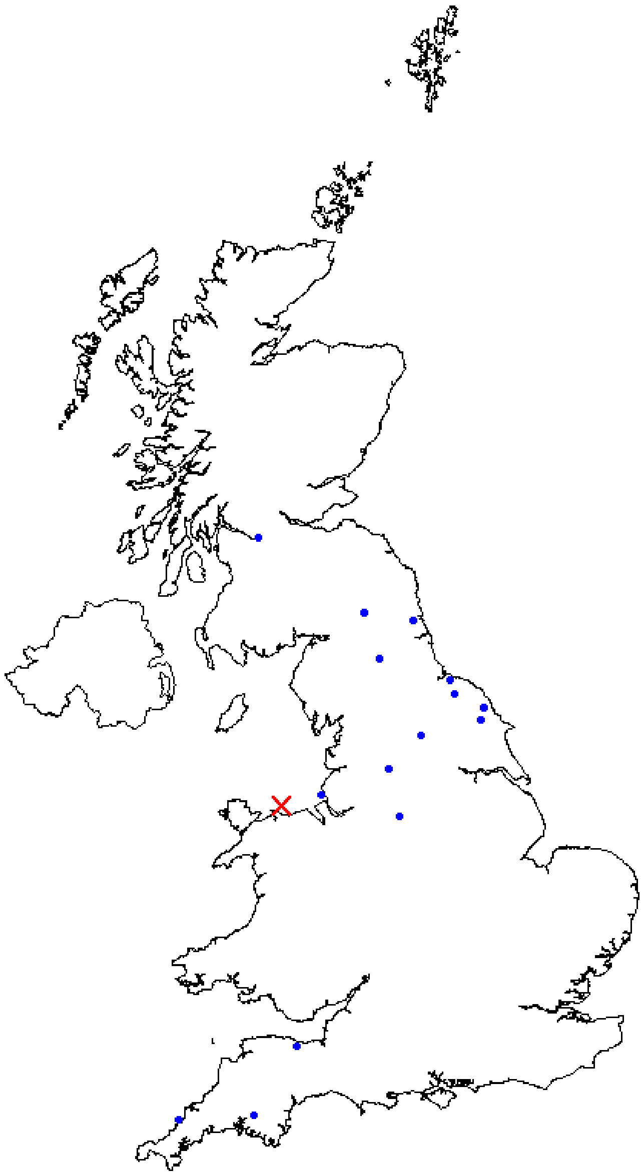
Station record parameters

Flood seasonality: AfonG_US pooling - rural



UK Design Flood Estimation

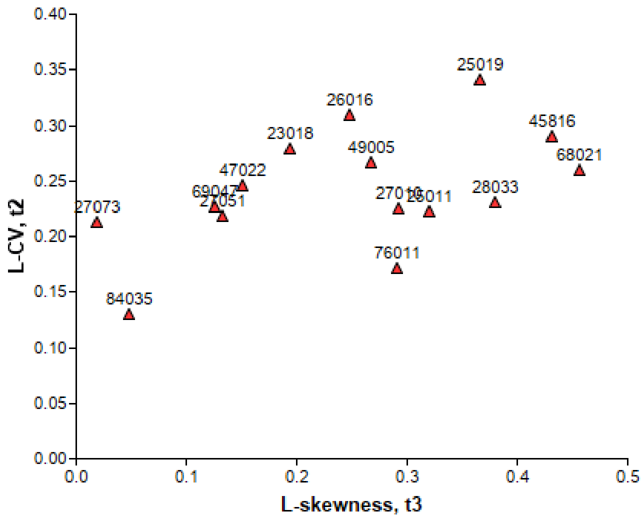
Summary of ESS/Pooled Estimation Analysis using the Flood Estimation Handbook Statistical Method

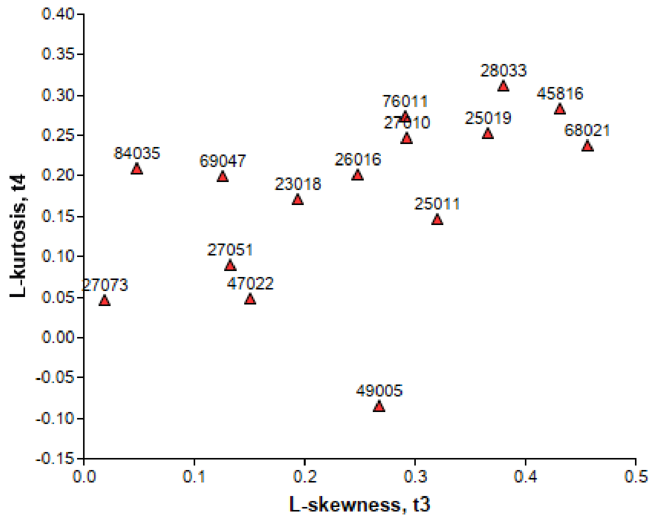


UK Design Flood Estimation

Summary of ESS/Pooled Estimation Analysis using the Flood Estimation Handbook Statistical Method

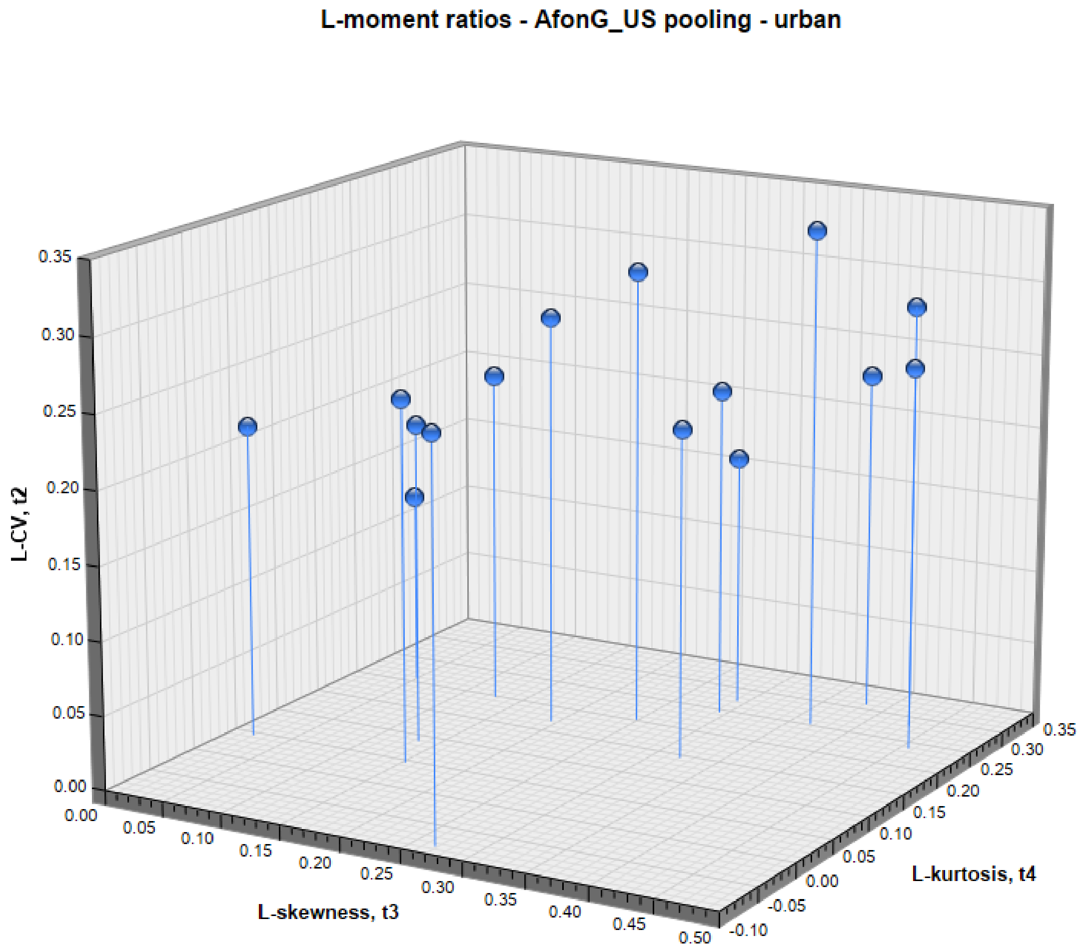
L-moment ratios - AfonG_US pooling - urban





UK Design Flood Estimation

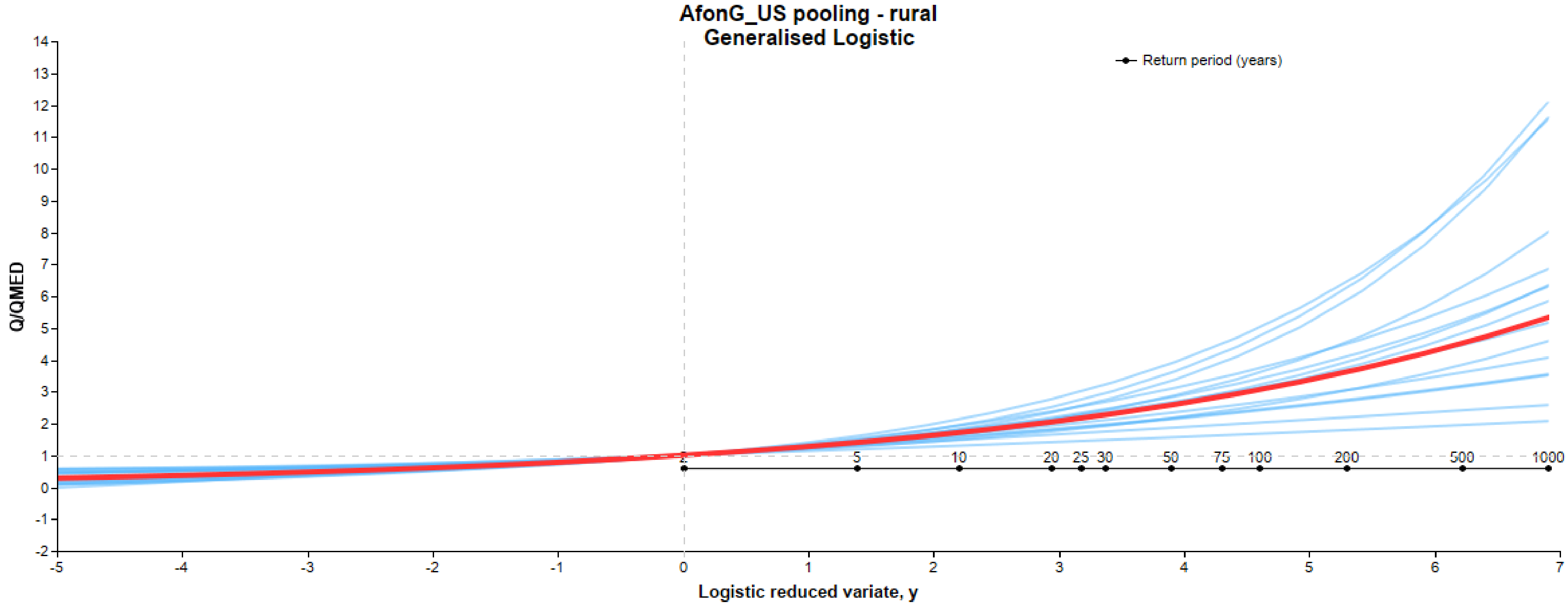
Summary of ESS/Pooled Estimation Analysis using the Flood Estimation Handbook Statistical Method



UK Design Flood Estimation

Summary of ESS/Pooled Estimation Analysis using the Flood Estimation Handbook Statistical Method

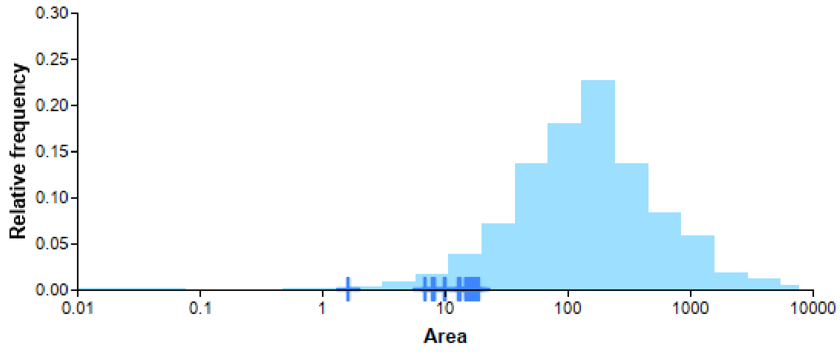
Pooling group growth curves

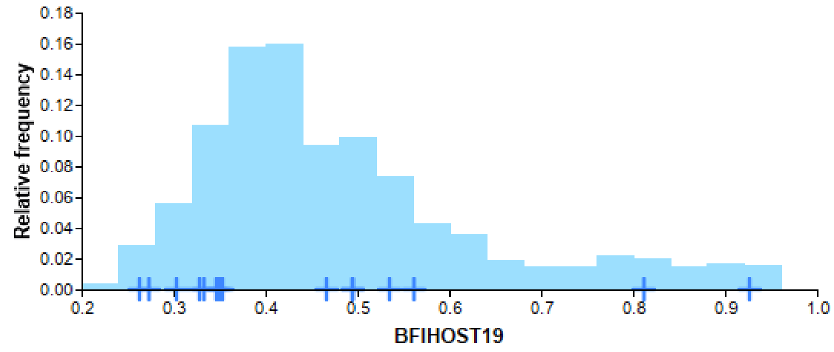


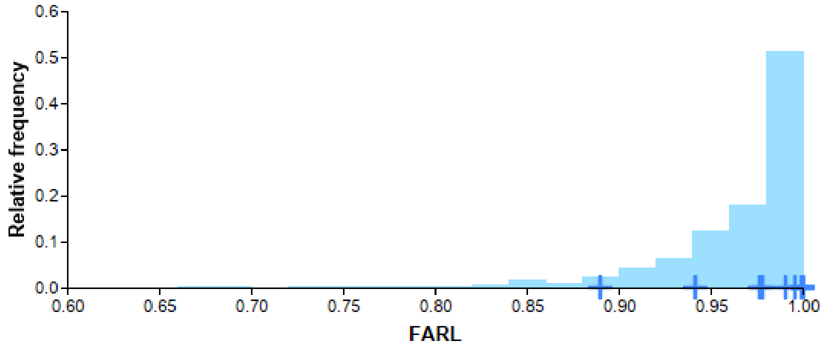
UK Design Flood Estimation

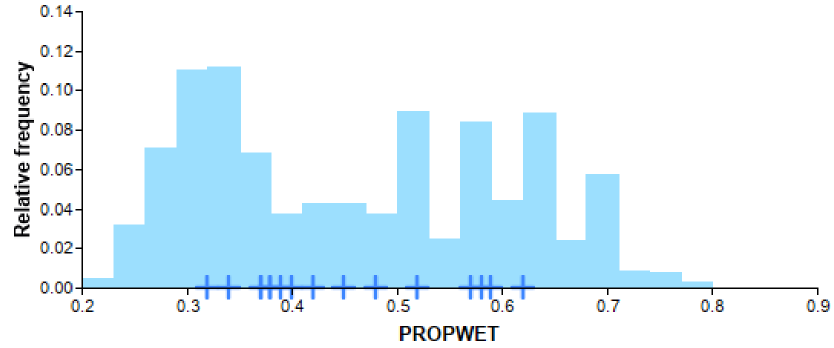
Summary of ESS/Pooled Estimation Analysis using the Flood Estimation Handbook Statistical Method

Catchment descriptors



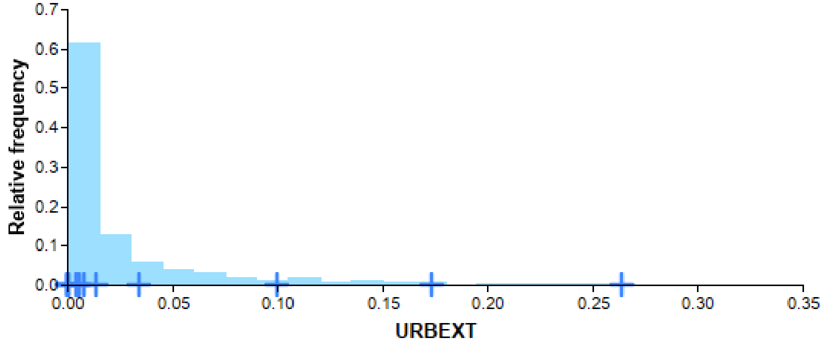


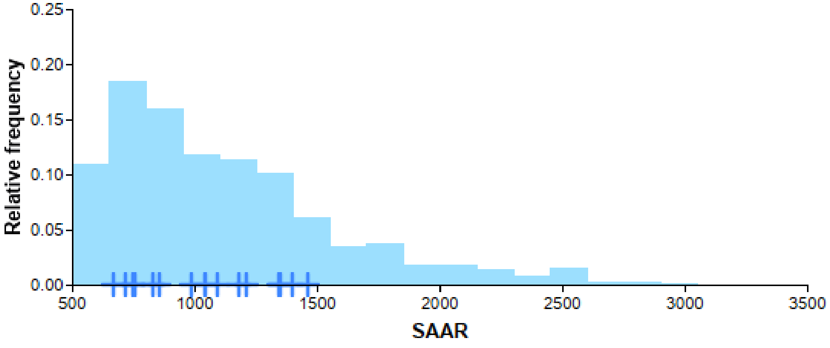


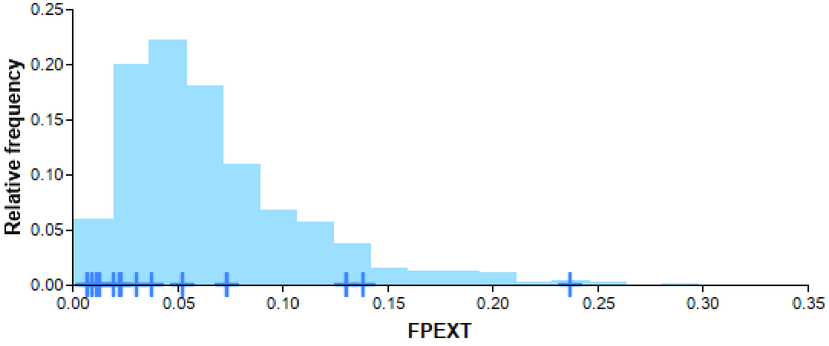


UK Design Flood Estimation

Summary of ESS/Pooled Estimation Analysis using the Flood Estimation Handbook Statistical Method







UK Design Flood Estimation

Summary of ESS/Pooled Estimation Analysis using the Flood Estimation Handbook Statistical Method

Date of creation:	26-06-2024 14:57:28
Software:	WINFAP Version: 5.1.8811 (23432)
Peak Flow dataset:	Peak Flow Dataset 12.1.1
Supplementary data used:	No

Site details

Site number:	3365154075
Site name:	Ganol_W
Site location:	SH 80350 76900
Easting:	280350
Northing:	376900
Catchment area:	5.07 km²
SAAR:	864 mm
BFIHOST19:	0.528
FPEXT:	0.097
FARL:	1.000
URBEXT2000:	0.0213

Site data

At-site data

At-site data present: No

UK Design Flood Estimation

Summary of ESS/Pooled Estimation Analysis using the Flood Estimation Handbook Statistical Method

Analysis settings

Urbanisation settings

User defined:	No
Urban area:	0.17 km²
PRimp:	70.00%
Impervious Factor:	0.300
UAF:	1.02629

Growth curve settings

Distance Measure Method:	Small catchment
Pooling group URBEXT2000 Threshold:	0.300
Deurbanise Pooling Group L-moments:	Yes

QMED settings

Use at-site data:	No
Method:	User Defined

Growth curve data and results

Pooling group AM data

Station	Distance	Years of data	QMED AM	L-CV Observed	L-CV Deurbanised	L-SKEW Observed	L-SKEW Deurbanised
27051 (Crimple @ Burn Bridge)	0.379	50	4.641	0.218	**0.218**	0.133	**0.133**
27073 (Brompton Beck @ Snainton Ings)	0.635	42	0.816	0.212	**0.213**	0.020	**0.018**
25019 (Leven @ Easby)	0.870	44	5.384	0.340	**0.341**	0.367	**0.366**
23018 (Ouse Burn @ Woolsington)	0.912	31	3.265	0.279	**0.296**	0.194	**0.177**
26016 (Gypsey Race @ Kirby Grindalythe)	0.978	25	0.101	0.309	**0.309**	0.249	**0.249**
45816 (Haddeo @ Upton)	0.993	29	3.248	0.289	**0.290**	0.432	**0.431**
49005 (Bolingey Stream @ Bolingey Cocks Bridge)	1.062	12	4.924	0.266	**0.267**	0.268	**0.267**
68021 (Arrowe Brook @ Acton Lane)	1.076	16	3.997	0.259	**0.287**	0.456	**0.420**
27010 (Hodge Beck @ Bransdale Weir)	1.106	41	9.420	0.224	**0.224**	0.293	**0.293**
76011 (Coal Burn @ Coalburn)	1.127	45	1.840	0.171	**0.171**	0.292	**0.292**
84035 (Kittoch Water @ Waterside)	1.309	31	20.128	0.130	**0.152**	0.049	**0.010**
28033 (Dove @ Hollinsclough)	1.318	47	4.150	0.231	**0.231**	0.381	**0.381**
27081 (Oulton Beck @ Oulton Farrer Lane)	1.446	36	2.545	0.253	**0.288**	0.236	**0.197**
39086 (Gatwick Stream @ Gatwick Link)	1.477	47	9.750	0.149	**0.166**	0.000	**-0.024**
69047 (Roch @ Littleborough)	1.539	26	9.742	0.226	**0.231**	0.127	**0.121**
Total		**522**					

UK Design Flood Estimation

Summary of ESS/Pooled Estimation Analysis using the Flood Estimation Handbook Statistical Method

Pooling group suitability

Station	Suitability for QMED	Suitability for pooling	Years	Non-flood years	Percentage non-flood years	Mann Kendall (MK)	MK significance (%)	Discordancy	Comments
27051 (Crimple @ Burn Bridge)	Yes	Yes	50	4	8.00	1.51	None	0.287	
27073 (Brompton Beck @ Snainton Ings)	Yes	Yes	42	2	4.76	1.17	None	0.963	
25019 (Leven @ Easby)	Yes	Yes	44	3	6.82			1.368	
23018 (Ouse Burn @ Woolsington)	Yes	Yes	31	4	12.90	0.71	None	0.570	
26016 (Gypsey Race @ Kirby Grindalythe)	Yes	Yes	25	3	12.00			1.001	
45816 (Haddeo @ Upton)	Yes	Yes	29	0	0.00	-0.83	None	0.710	
49005 (Bolingey Stream @ Bolingey Cocks Bridge)	Yes	Yes	12	0	0.00			3.627	
68021 (Arrowe Brook @ Acton Lane)	Yes	Yes	16	0	0.00			1.176	
27010 (Hodge Beck @ Bransdale Weir)	Yes	Yes	41	1	2.44	-2.10	5	0.226	
76011 (Coal Burn @ Coalburn)	Yes	Yes	45	0	0.00			1.197	
84035 (Kittoch Water @ Waterside)	Yes	Yes	31	0	0.00	-1.38	None	1.436	
28033 (Dove @ Hollinsclough)	Yes	Yes	47	1	2.13			0.794	
27081 (Oulton Beck @ Oulton Farrer Lane)	Yes	Yes	36	1	2.78	2.55	5	0.038	
39086 (Gatwick Stream @ Gatwick Link)	Yes	Yes	47	2	4.26	1.15	None	1.113	
69047 (Roch @ Littleborough)	Yes	Yes	26	2	7.69			0.494	

Pooling group catchment descriptors

Station	Area	SAAR	FPEXT	FARL	URBEXT2000	BFIHOST19
27051 (Crimple @ Burn Bridge)	8.172	855	0.013	1.000	0.006	0.329
27073 (Brompton Beck @ Snainton Ings)	8.060	721	0.237	1.000	0.008	0.811
25019 (Leven @ Easby)	15.088	830	0.019	1.000	0.004	0.495
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26016 (Gypsey Race @ Kirby Grindalythe)	15.850	757	0.030	1.000	0.000	0.927
45816 (Haddeo @ Upton)	6.808	1210	0.011	1.000	0.005	0.535
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84035 (Kittoch Water @ Waterside)	16.812	1184	0.052	0.978	0.264	0.350
28033 (Dove @ Hollinsclough)	7.915	1346	0.007	1.000	0.000	0.347
27081 (Oulton Beck @ Oulton Farrer Lane)	25.102	677	0.049	0.997	0.224	0.575
39086 (Gatwick Stream @ Gatwick Link)	32.623	830	0.103	0.946	0.174	0.504
69047 (Roch @ Littleborough)	14.775	1353	0.038	0.890	0.034	0.467

Pooling Group Rejected Stations

Station	Distance	Years of data	QMED AM	L-CV Observed	L-CV Deurbanised	L-SKEW Observed	L-SKEW Deurbanised	Comments
44008 (South Winterbourne @ Winterbourne Steepleton)	1.183	31	0.544	0.413	0.414	0.268	0.267	

UK Design Flood Estimation

Summary of ESS/Pooled Estimation Analysis using the Flood Estimation Handbook Statistical Method

Growth curve L-moments

Rural L-CV:	0.245	Urban L-CV:	0.242
Rural L-Skewness:	0.215	Urban L-Skewness:	0.219

Rural fitted parameters

Distribution	Location	Scale	Shape	H	Bound
GL	1.000	0.248	-0.215		-0.152
GEV	0.865	0.364	-0.069		-4.393
KAP3	0.932	0.299	-0.149	-0.400	-1.071

Urban fitted parameters

Distribution	Location	Scale	Shape	H	Bound
GL	1.000	0.244	-0.219		-0.116
GEV	0.867	0.358	-0.075		-3.910
KAP3	0.933	0.294	-0.154	-0.400	-0.978

Goodness of fit

GL:	0.6404 *
GEV:	-0.9149 *
P3:	-2.3680
GP:	-4.5794
KAP3:	0.0959 *

** Distribution gives an acceptable fit (absolute Z value < 1.645)*

Heterogeneity

Standardised test value H2: 3.6146

The pooling group is heterogeneous and a review of the pooling group is desirable.

Standardised growth curves

Rural

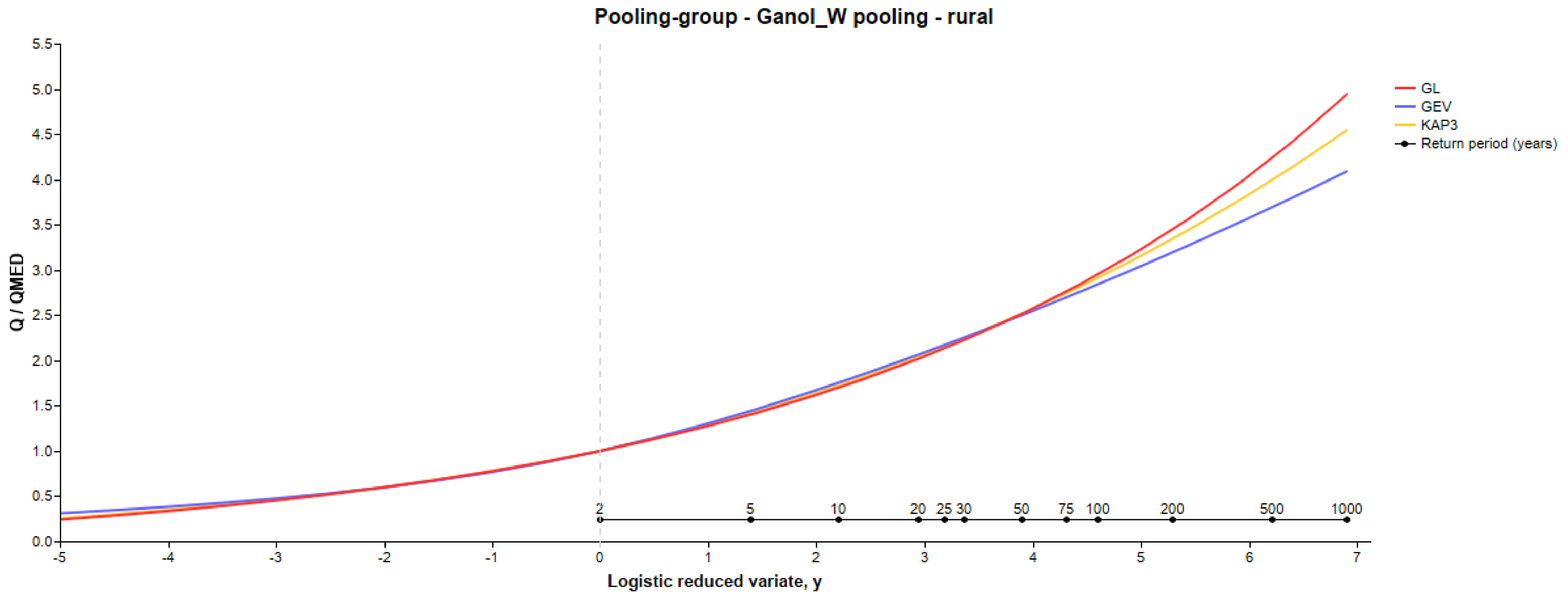
Return period	GL	GEV	KAP3
2	1.000	1.000	1.000
5	1.401	1.440	1.418
10	1.697	1.751	1.723
20	2.019	2.066	2.045
25	2.131	2.168	2.154
30	2.226	2.253	2.245
50	2.511	2.496	2.513
75	2.758	2.694	2.739
100	2.946	2.837	2.908
200	3.448	3.194	3.344
500	4.236	3.692	3.993
1000	4.943	4.090	4.546

Urban

Return period	GL	GEV	KAP3
2	1.000	1.000	1.000
5	1.396	1.435	1.412
10	1.689	1.743	1.715
20	2.010	2.056	2.035
25	2.122	2.159	2.144
30	2.217	2.244	2.235
50	2.500	2.487	2.503
75	2.748	2.686	2.730
100	2.936	2.830	2.900
200	3.440	3.191	3.338
500	4.233	3.696	3.994
1000	4.947	4.101	4.554

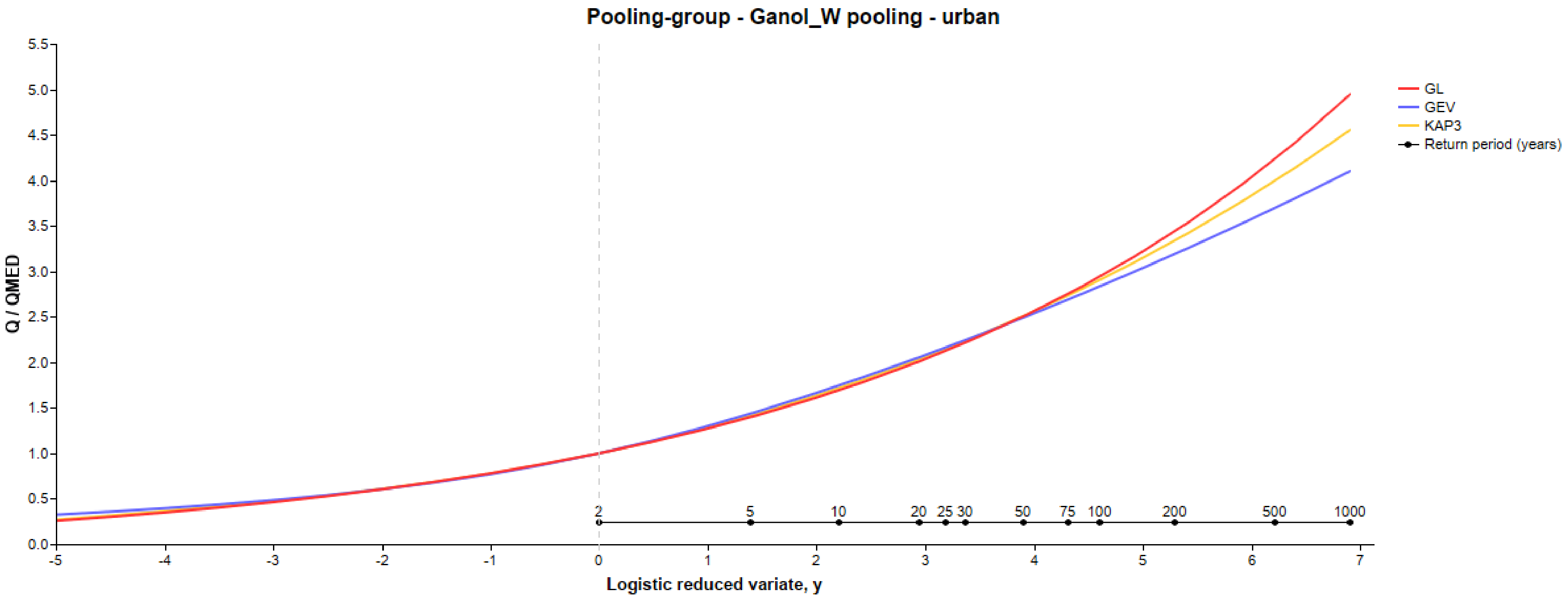
UK Design Flood Estimation

Summary of ESS/Pooled Estimation Analysis using the Flood Estimation Handbook Statistical Method



UK Design Flood Estimation

Summary of ESS/Pooled Estimation Analysis using the Flood Estimation Handbook Statistical Method



UK Design Flood Estimation

Summary of ESS/Pooled Estimation Analysis using the Flood Estimation Handbook Statistical Method

QMED data and results

QMED

Rural: 1.300 m³/s
Urban: 1.334 m³/s

UK Design Flood Estimation

Summary of ESS/Pooled Estimation Analysis using the Flood Estimation Handbook Statistical Method

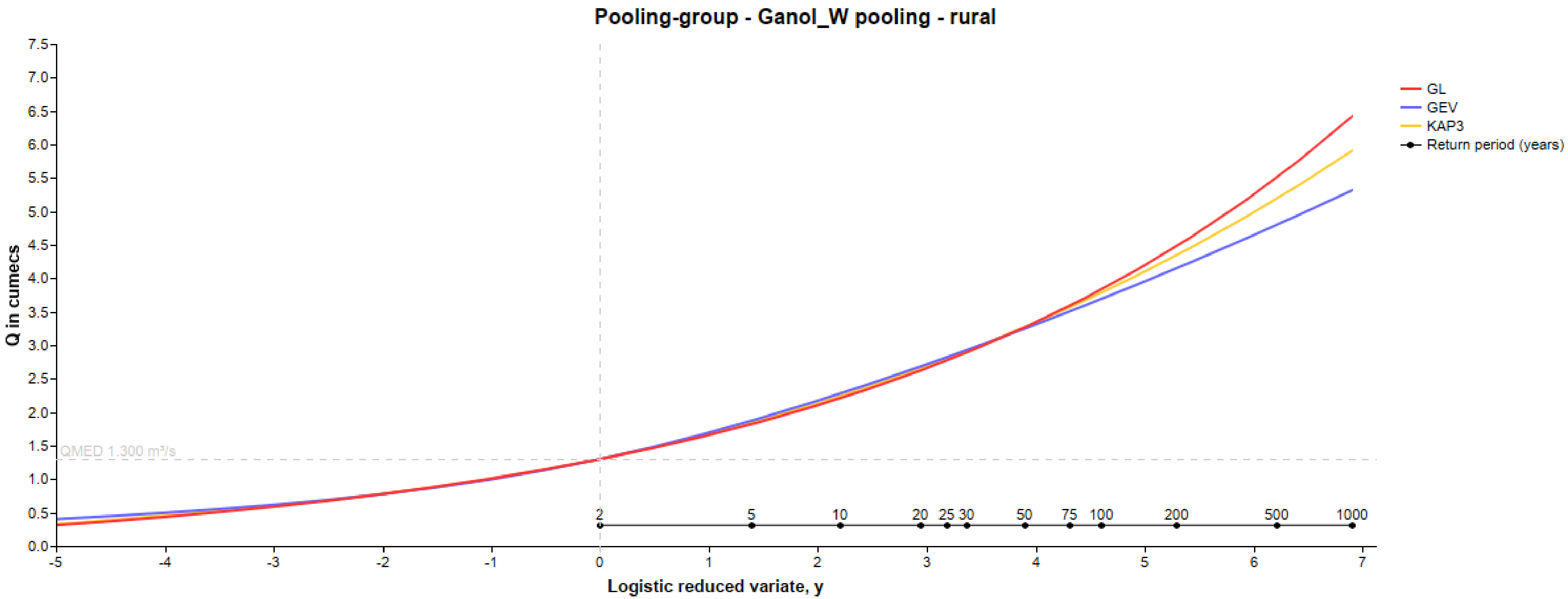
Flood Frequency Curve

Rural Flood Frequency Curve

Return period	GL (m³/s)	GEV (m³/s)	KAP3 (m³/s)
2	1.300	1.300	1.300
5	1.821	1.872	1.843
10	2.206	2.277	2.239
20	2.625	2.685	2.658
25	2.771	2.819	2.800
30	2.894	2.929	2.919
50	3.264	3.245	3.267
75	3.585	3.502	3.561
100	3.829	3.688	3.780
200	4.482	4.152	4.347
500	5.506	4.799	5.191
1000	6.425	5.317	5.909

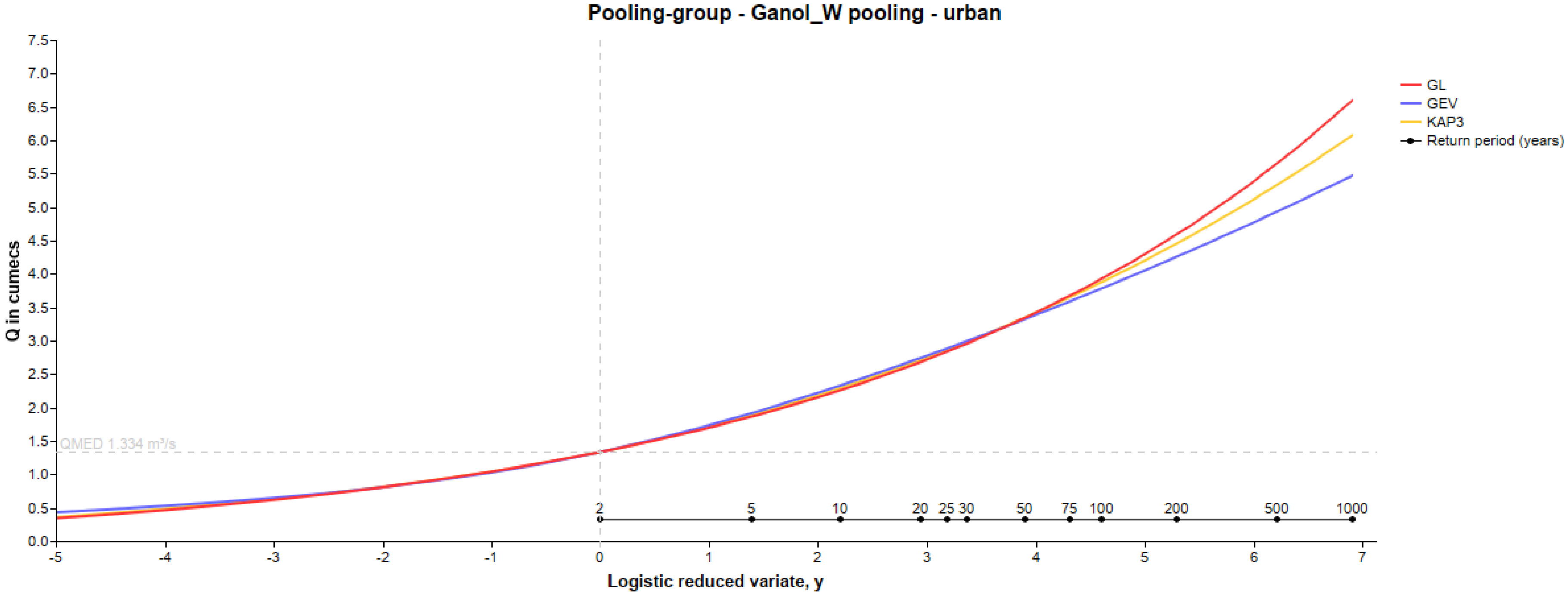
Urban Flood Frequency Curve

Return period	GL (m³/s)	GEV (m³/s)	KAP3 (m³/s)
2	1.334	1.334	1.334
5	1.862	1.914	1.884
10	2.254	2.326	2.288
20	2.682	2.744	2.716
25	2.831	2.881	2.861
30	2.957	2.994	2.982
50	3.336	3.318	3.340
75	3.666	3.584	3.643
100	3.917	3.776	3.869
200	4.590	4.257	4.454
500	5.647	4.931	5.328
1000	6.600	5.471	6.076



UK Design Flood Estimation

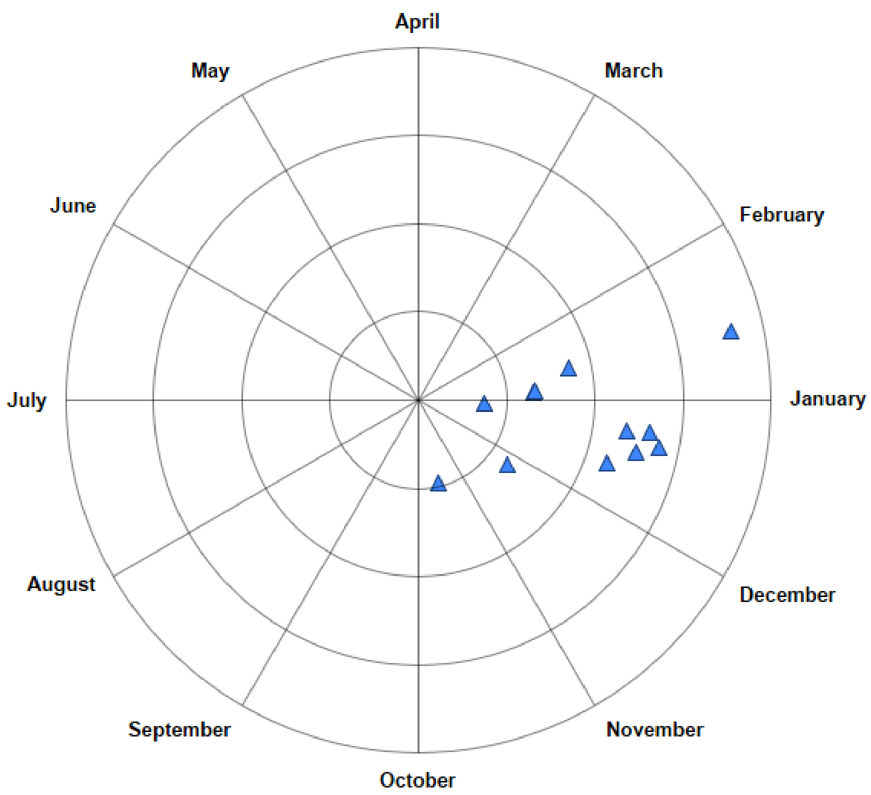
Summary of ESS/Pooled Estimation Analysis using the Flood Estimation Handbook Statistical Method



Appendix

Station record parameters

Flood seasonality: Ganol_W pooling - rural



UK Design Flood Estimation

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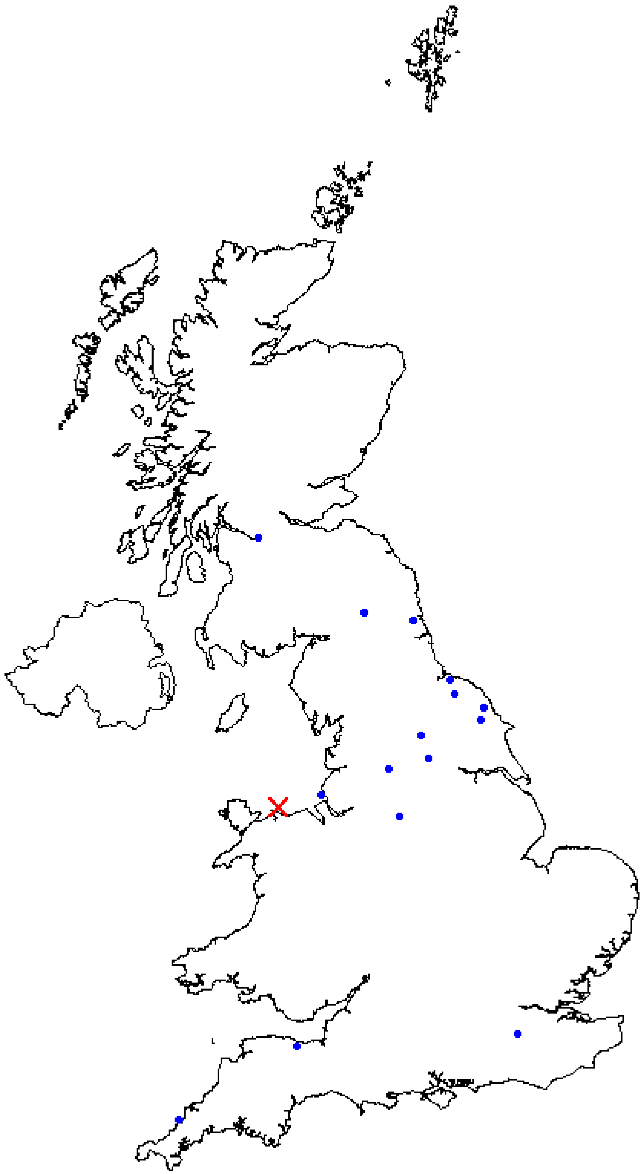
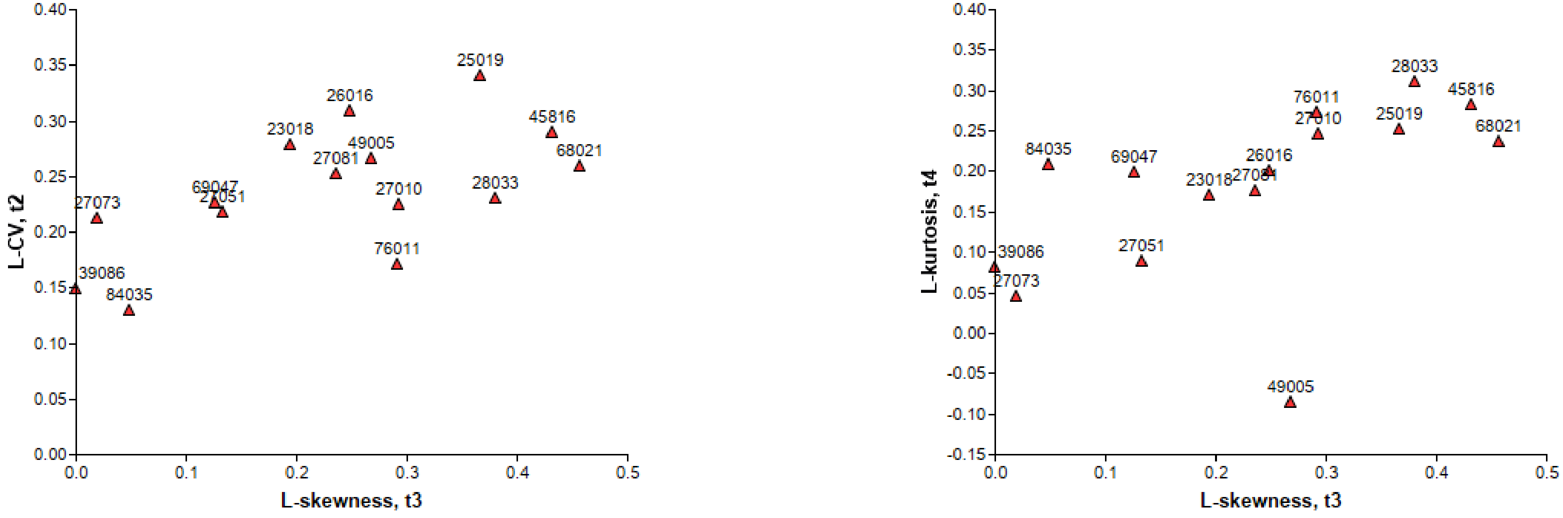


UK Design Flood Estimation

Summary of ESS/Pooled Estimation Analysis using the Flood Estimation Handbook Statistical Method

L-moment ratios - Ganol_W pooling - urban



UK Design Flood Estimation

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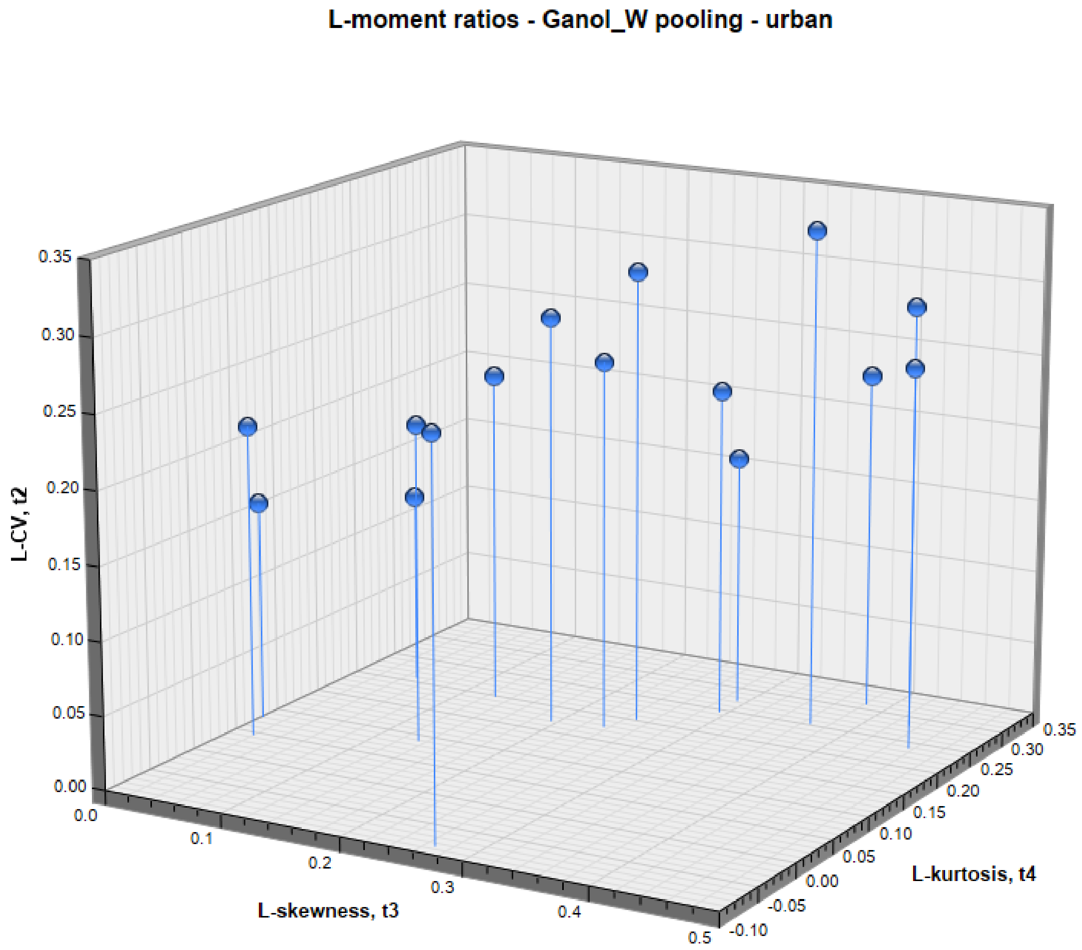

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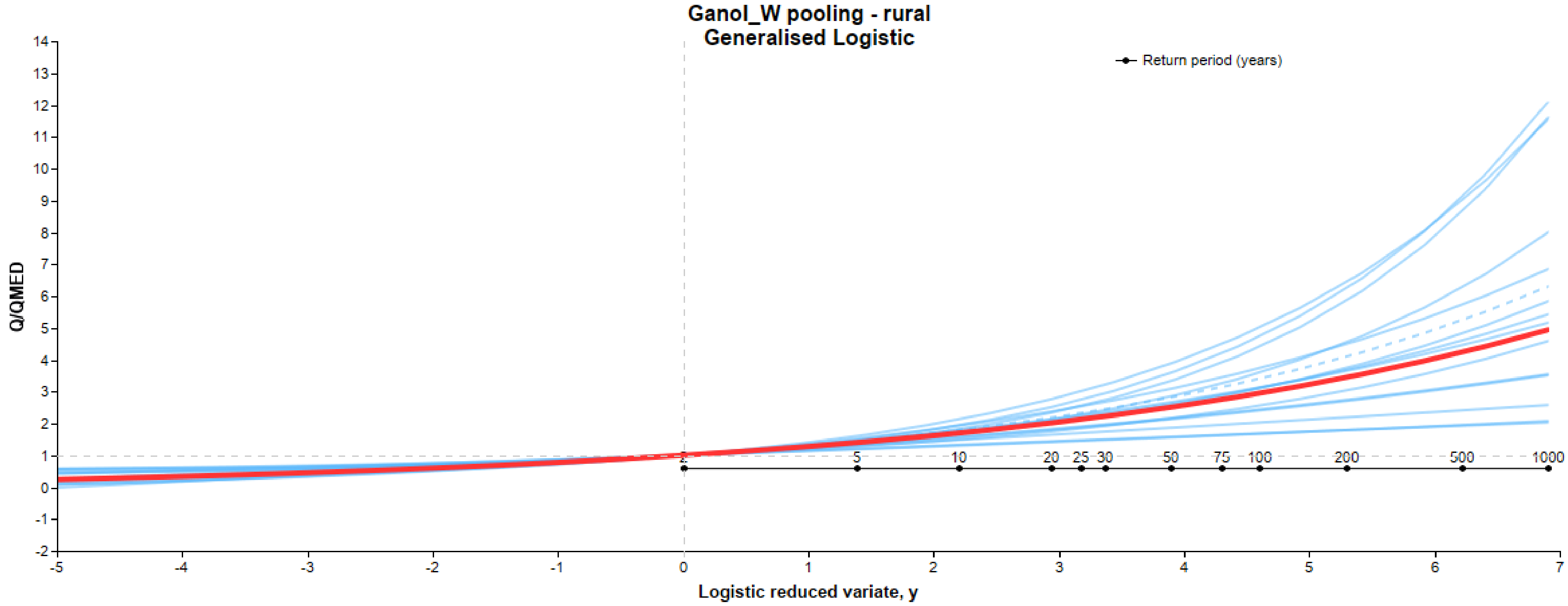
Pooling group growth curves



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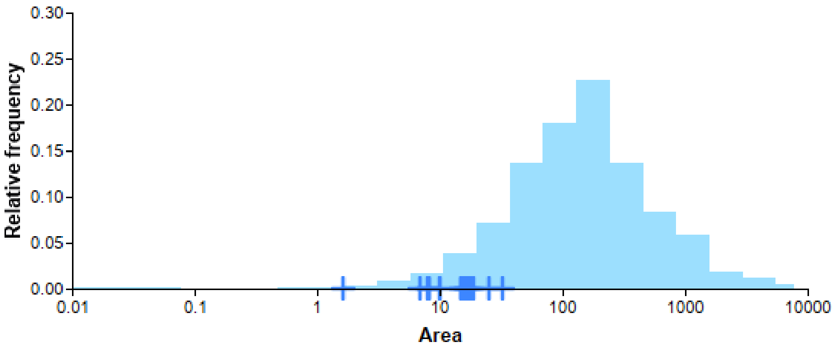
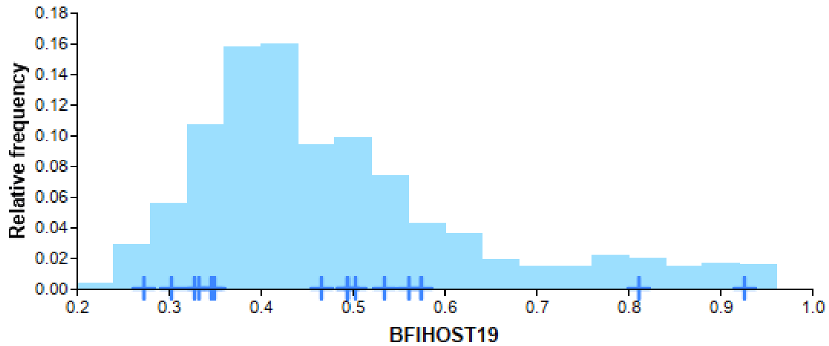
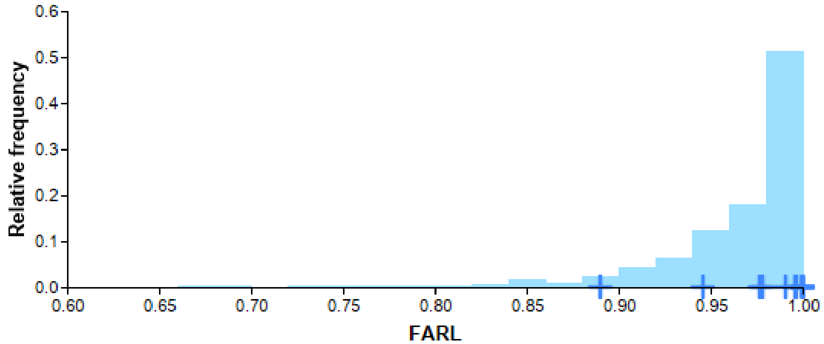
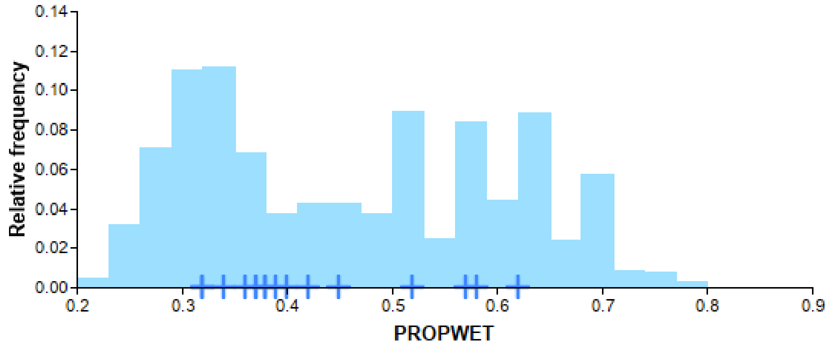
Summary of ESS/Pooled Estimation Analysis using the Flood Estimation Handbook Statistical Method

Catchment descriptors









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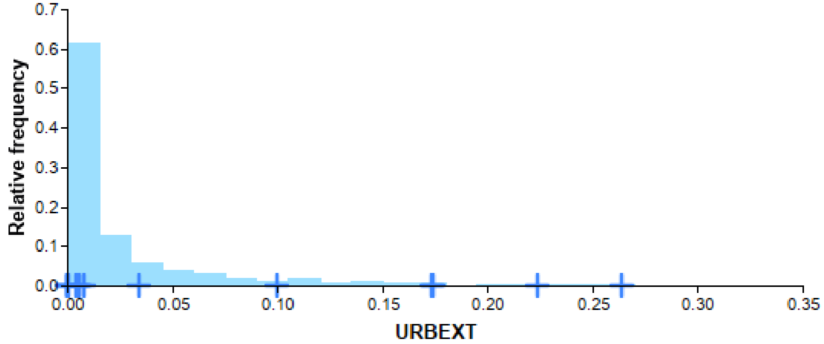

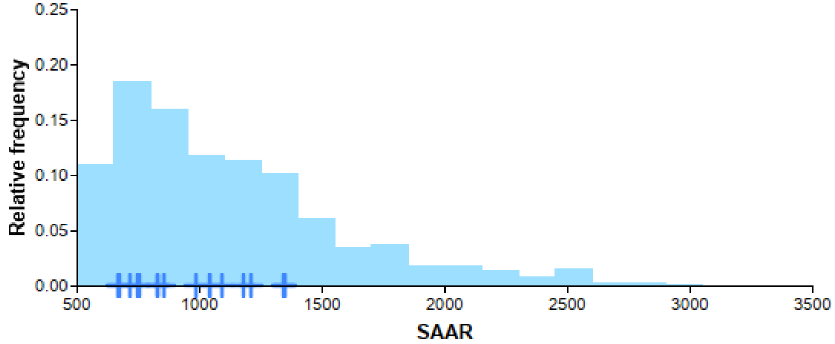

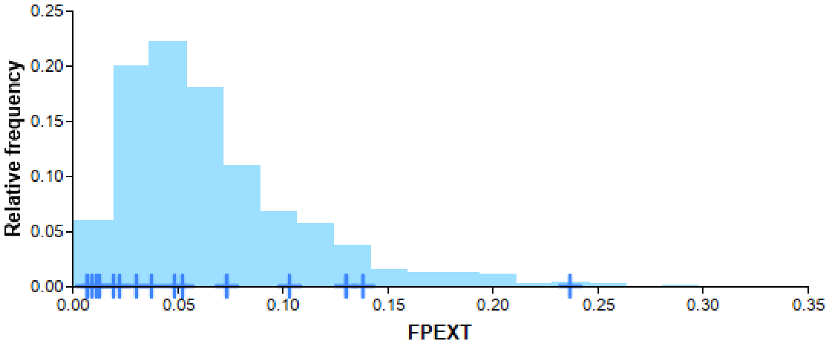

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