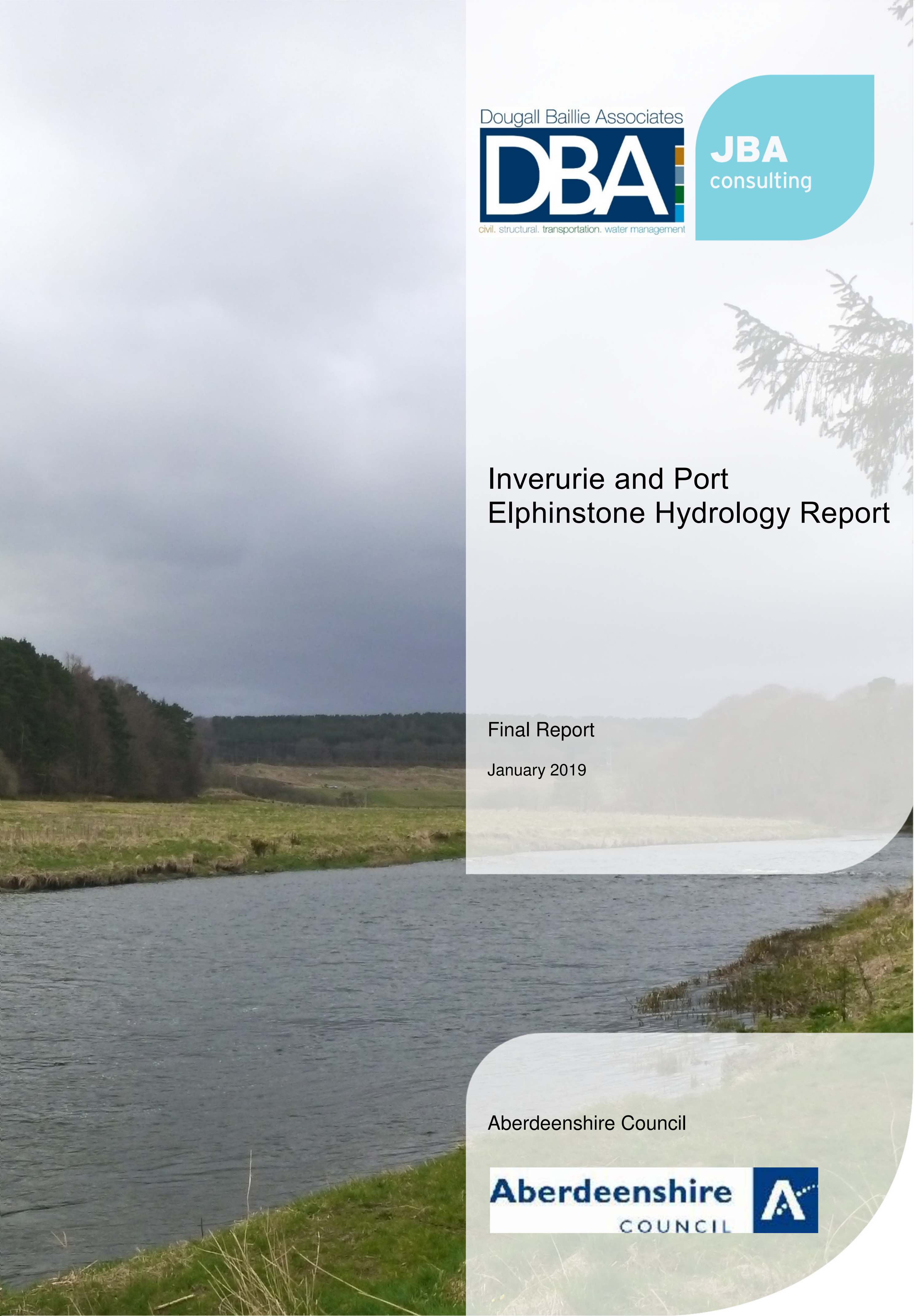

Inverurie and Port Elphinstone Hydrology Report

Final Report

January 2019

Aberdeenshire Council

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Revision History

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P01 / 13 June 2018	-	Alistair Scotland and Lee Watson, Aberdeenshire Council
P03 / 19 September 2018	SEPA and Aberdeenshire Council comments addressed. Parkhill peak flows added following SEPA rating approval.	Alistair Scotland and Lee Watson, Aberdeenshire Council
P04 / 07 November 2018	Pitcaple peak flows updated following SEPA rating review and provision of updated AMAX series.	Alistair Scotland and Lee Watson, Aberdeenshire Council
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Contract

This report describes work commissioned by Gavin Penman, on behalf of Aberdeenshire Council, on 10 October 2017 by Purchase Order Number 1095192. Dougall Baillie's representative for the contract was Scott Macphail and Aberdeenshire Council's representative for the contract was Alistair Scotland. Briony McIntosh and David Cameron of JBA Consulting carried out this work.

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Purpose

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Acknowledgements

JBA wishes to thank SEPA for supply of hydrometric and flooding information and Aberdeenshire Council for flooding information.

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Executive Summary

This report describes historical flooding and the input hydrology estimates developed for use in the hydraulic modelling for the Aberdeenshire Flood Prevention Studies. The River Don has a history of flooding dating back to at least 1786 and the main risk areas within the study reach (between Old Meldrum and Parkhill gauging station) are Inverurie, Port Elphinstone and Kintore. Flood risk at Inverurie and Port Elphinstone is from the River Don which flows in from the west, and from the River Urie which flows south along the eastern margin of Inverurie discharging into the Don at the southern extent of the town. The River Urie has been known to back up during high flows on the Don. Hydrology estimates were required as input into a linked 1D/2D hydraulic model of the River Urie between Old Rayne and its confluence with the River Don at Inverurie; and the River Don between Haughton gauging station and downstream of Parkhill gauging station for use in flood mapping. Overall, the hydrology estimates included the following:

- Extreme value estimates were required on the:
    - **River Urie at Pitcaple gauging station**. FEH statistical methods were investigated for peak flow estimation and the adopted method was Enhanced Single Site (ESS) analysis with a Generalised Logistic (GL) distribution. A new rating developed by SEPA based on a linked 1D/2D model was applied to the Pitcaple data prior to the analysis being undertaken. The 0.5% Annual Probability (AP, 200 year) flood was estimated to be circa 115.97 m^3/s for the Urie. Peak flows were also required north of Old Rayne (the upstream model extent) as a direct model input. For consistency, these were estimated using the ESS growth curve from Pitcaple with GL distribution and QMED was adjusted using Pitcaple.
    - **River Don at Haughton gauging station**. FEH statistical methods were investigated for peak flow estimation and the adopted method was Single Site (SS) analysis with a GL distribution. A new rating, agreed with SEPA for the JBA Consulting 'Upper Don to Inverurie Flood Mapping Study', was applied to the Haughton data prior to the analysis being undertaken, and the agreed peak flow estimates at Haughton are to be applied here for consistency. The 0.5% AP (200 year) flood was estimated to be circa 480.54 m^3/s for the Don.
    - **River Don at Parkhill gauging station.** FEH statistical methods were investigated for peak flow estimation and the adopted method was SS analysis with a GL distribution. A new rating, agreed with SEPA for use in this study, was applied to the Parkhill data, prior to the analysis being undertaken. The 0.5% AP (200 year) flood was estimated to be circa 687 m^3/s for the Don. These statistical estimates will be compared directly with model outputs at the modelling stage to assist in model calibration and design event runs. An additional check will also be made using water levels produced from the model at the gauging station location against those extreme water level estimates obtained using the FEH Statistical method. As Parkhill is understood to have a single high flow control throughout its period of record, it was possible to undertake a single site analysis of the AMAX stage recorded at the station. For example, the 0.5% AP (200 year) flood was estimated to have a stage of circa 6.03 m (38.38 metres above Ordnance Datum, mAOD) or 5.65 m (38.00 mAOD) for the Don at Parkhill using GL and GEV distributions, respectively.
- **Fluvial hydrographs and critical storm durations.** Although there are gauges at Haughton, Pitcaple and Parkhill, the upstream extents of the model are at ungauged locations on both the Urie and Don. A consistent approach was therefore required for hydrograph derivation and storm duration and this was achieved by using ReFH hydrographs at both upstream extents. As a check that this approach was appropriate prior to modelling, ReFH hydrographs were also derived at Haughton, Parkhill and Pitcaple gauging stations and were found to have a similar shapes to the largest events. The critical model duration to be modelled is 39 hours based on LAG analysis of the 2016 event at Parkhill (the downstream model extent) using Deskry Shiel rain gauge.

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Abbreviations

1D	One Dimensional (modelling)
2D	Two Dimensional (modelling)
ALTBAR	Mean catchment altitude (m above sea level)
AMAX	Annual Maximum
BFIHOST	Base Flow Index estimated from soil type
DPLBAR	Index describing catchment size and drainage path configuration
FARL	FEH index of flood attenuation due to reservoirs and lakes
FEH	Flood Estimation Handbook
FPEXT	FEH index describing floodplain extent
GEV	General Extreme Value Distribution
GL	General Logistic Distribution
LAG	Time between the centroid of the rainfall event and hydrograph
mAOD	metres Above Ordnance Datum
mOD	Metres above Ordnance Datum
OS	Ordnance Survey
QMED	Median Annual Flood (with return period 2 years)
ReFH	Revitalised Flood Hydrograph method
SAAR	Standard Average Annual Rainfall (mm)
SEPA	Scottish Environment Protection Agency
SPRHOST	Standard percentage runoff estimated from soil type
TBR	Tipping Bucket Raingauge
Tp	Time to Peak
URBEXT	FEH index of fractional urban extent
Z	Statistical significance measure

1 Introduction

1.1 Report objectives and approach

The purpose of this report is to provide details of the hydrology required to drive the hydraulic modelling and associated flood mapping of the River Urie between Old Rayne and its confluence with the River Don at Inverurie; and the River Don between Haughton gauging station and downstream of Parkhill gauging station. Extreme value estimates were required for the following watercourses:

- Peak flows for the River Urie at Pitcaple gauging station and north of Old Rayne (the upstream boundary of the model).
- Peak flows for the River Don at Haughton gauging station and upstream of the station for direct input at the upstream extent of the model.
- Peak flows for the River Don at Parkhill gauging station for comparison with model outputs at the modelling stage to assist in model calibration and design event runs.
- All lateral inflow tributaries > 3 km^2.

1.2 Catchment summary and relevant hydrometry

The catchment draining to Parkhill gauging station covers an area of approximately 1270 km^2. It is traversed by two primary watercourses: the River Don and the River Urie (a tributary of the Don). The River Don originates in the Grampian Mountains and flows east towards Inverurie through a predominantly rural catchment. At Inverurie it changes course to flow southeast towards Aberdeen. A number of tributaries discharge into the Don along both banks the key one being the River Urie. The River Urie originates in Gartly Moor north of Inverurie and flows through a similarly rural sub-catchment, with an area of approximately 305 km^2 at Inverurie, where it discharges into the Don. A number of additional smaller tributaries discharge into the Urie and Don along both banks. These include the Shevock Burn which affects the community of Insch[1], and the Bridgealehouse Burn and Tuach Burn which discharge into the Don at Kintore.

Catchment elevations range from approximately 800 metres above Ordnance Datum (mAOD) in the headwaters of the Don to approximately 40 mAOD at Parkhill gauging station. Average annual rainfall (SAAR) is c. 884 mm. The underlying bedrock geology is predominantly Ordovician to Silurian aged igneous and metamorphic rocks, overlain by superficial glacial deposits[2]. The catchment as a whole is therefore dominated by impervious bedrock but moderately pervious superficial deposits reflected in the catchment BFIHOST (Baseflow Index estimated from soil type) of 0.562 and SPRHOST (Standard Percentage Runoff estimated from soil type) of c. 32%. These indicate the catchment is likely to exhibit a moderate response hydrograph to rainfall.

Gauging station information is summarised in Table 1-2. HiFlows-UK gauging stations include the Don at Culfork (11006), Don at Alford (11003), Don at Haughton (11002), Don at Parkhill (11001) and the Urie at Pitcaple (11004). Other primary gauging stations in the catchment include the Don at Mill of Newe (11005; station closed in 1994), the Don at Inverurie and the Urie at Old Rayne (11007, a level only gauge upstream of Pitcaple, now closed). Telemetered tipping bucket raingauge (TBR) coverage is limited for such a large catchment and includes Alford, Westhill, the Lecht and Deskry Shiel. There is an additional raingauge at Old Mill of Newton. A summary of the catchment and its hydrometry is provided in Table 1-2.

1 Flood risk and hydrology at Insch will be covered in a separate independent report. JBA Consulting. Insch Hydrology Report. Final. May 2018.

2 British Geological Survey http://mapapps.bgs.ac.uk/geologyofbritain/home.html [Accessed: December 2017]

Table 1-1: Catchment Descriptors

Catchment Descriptor	River Don at Haughton Gauging Station	River Don at Parkhill Gauging Station	River Urie at Pitcaple Gauging Station	River Urie at upstream model boundary
AREA (km^2)	793.12 adjusted (792.65 default)	1270.56 adjusted (1269.11 default)	195.60 adjusted (195.44 default)	53.80 adjusted (53.59 default)
ALTBAR (m above sea level)	332	262	206	234
BFIHOST	0.573	0.584	0.562	0.587
DPLBAR (km)	51.23	59.69	15.36	8.08
FARL	0.997	0.996	0.996	0.987
FPEXT	0.0506	0.0587	0.0458	0.0251
FPDBAR	0.619	0.673	0.411	0.233
SAAR (mm)	916	884	870	902
SAAR4170 (mm)	1025	964	882	892
SPRHOST (%)	32.44	31.28	31.7	29.72
URBEXT 1990	0.0010 adjusted (0.0011 default FEH CD-ROM)	0.003 adjusted (0.0028 default FEH CD-ROM)	0.003 adjusted (0.0028 default FEH CD-ROM)	0.001 adjusted (0.001 default FEH CD-ROM)
URBEXT 2000	0.0017 adjusted (0.0016 default FEH CD-ROM)	0.004 adjusted (0.0041 default FEH CD-ROM t)	0.003 adjusted (0.0026 default FEH CD-ROM)	0.001 adjusted (0.001 default FEH CD-ROM)

Table 1-2: Gauging station summary information

Station number	Watercourse	Name	Type	Periods of record (water years)	Comments
11006	Don	Culfork	Primary	1997 - present	Not a HiFlows-UK station. The gauge at Culfork is located in an open channel section of the River Don downstream of a minor road bridge. There is no cableway and high flow gaugings are taken from the bridge. The bridge is not deemed to influence water levels at the gauge. The pressure transducer is located on the right bank and provides telemetered level data in real time. The level record dates from 1997. During floods, water is conveyed across the road and onto the left-hand floodplain. The gauging site was damaged and the channel geometry altered during storm Bertha on 11 August 2014.

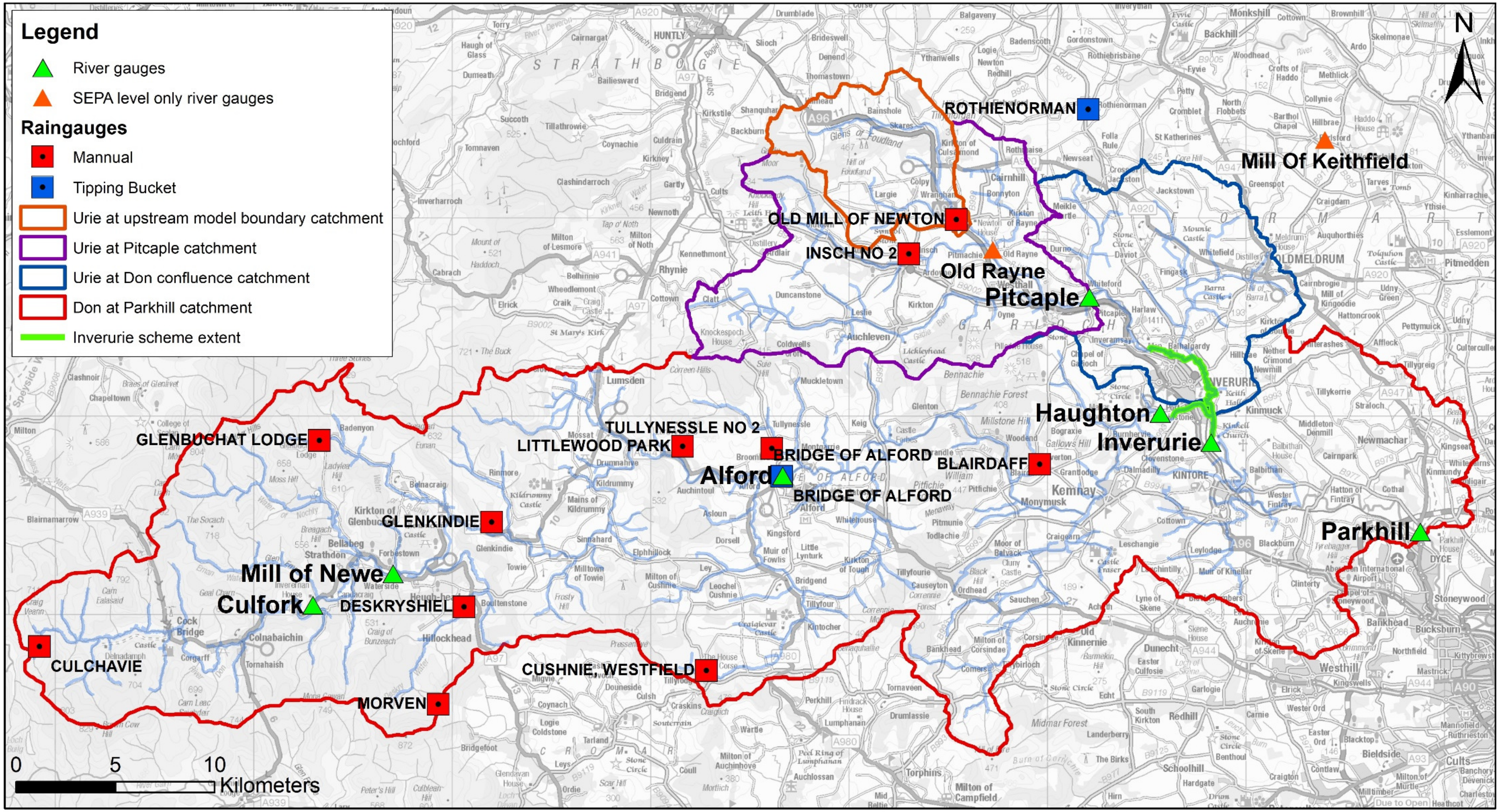
					A new rating was developed in 2018.
11003	Don	Bridge of Alford	Primary	1973 - present	The gauge at Bridge of Alford is located in an open channel section (with cableway) of the River Don c. 547 m downstream of the Bridge. The stilling well is located in the gauging hut on the right bank and provides telemetered level data in real time. The level record dates from 1973. A further bridge is located c. 1280 m downstream of the gauge. Both bridges are not deemed to influence water levels at the gauge. During floods, water is conveyed on the right-hand floodplain behind the gauging hut. Peak stages have been surveyed inside the gauging hut and the rain gauge was damaged during the 2015/16 high flows as water came through the fields. The new rating has been applied to the full AMAX record.
11002	Don	Haughton	Primary	1969 - present	The gauge at Haughton is located in an open channel section (with cableway) of the River Don. The stilling well is located in the gauging hut on the left bank and provides telemetered level data in real time. The level record dates from 1969. The A96 road bridge is located c. 2 km downstream of the gauge. The bridge is not deemed to influence water levels at the gauge. Ice can affect levels and minor bypassing occurred during the 2002 flood (AMAX stage of 5.07 m). The new rating has been applied to the full AMAX record for this study.
11001	Don	Parkhill	Primary	1969 - present	The gauge at Parkhill is located in an open channel section (with cableway) of the River Don c. 48 m upstream of a railway bridge. The stilling well is located in

					the gauging hut on the right bank and provides telemetered level data in real time. The level record dates from 1969. A further bridge (the A947 road bridge) is located c. 75 m downstream of the railway bridges. The bridges may have an influence during very large floods such as those of January 2016. During floods, water is conveyed on both the left bank and the right-hand floodplain behind the gauging hut. The site was damaged during the January 2016 event. A new rating was developed for Parkhill using hydraulic modelling in 2018. The new rating has been applied to the AMAX record above the gauged record i.e. a stage of 3.702 m for this study.
11004	Urie	Pitcaple	Primary	1984 - present	The gauge at Pitcaple is located in an open channel section (with cableway) of the River Urie c. 10 m upstream of a minor road bridge. A further two bridges are located c. 1.8 km downstream of the gauging station. The stilling well is located in the gauging hut on the left bank and provides telemetered level data in real time. The level record dates from 1984. The minor bridge is deemed to have a significant influence on water levels at the gauge. The two downstream bridges are not deemed to influence water levels. During floods, bypassing occurs where water cuts the meander upstream of the gauge flowing over the right-hand floodplain. It re-joins the river downstream of the gauging station. Gaugings pre-1988 referenced to a different datum. The new rating will be further explored using linked 1D/2D

					modelling being undertaken for this project.
11005	Don	Mill of Newe	Primary	1989 - 1994	Not a HiFlows station, primarily low flows. Closed 9 June 1964.
11007	Urie	Old Rayne	Level only	2009 - 2017	Non-cableway site. Minimal higher gaugings due to logistics of gauging. Short record suitable for use. Site closed due to issues with location[3].
		Bridge of Alford	Tipping bucket raingauge	1995 - present	15 minute recording rainfall. There are gaps in the data record but the data were largely used on an event basis for which data was available.
		Deskry Shiel	Manual raingauge	2008 - present	15 minute recording rainfall. There are gaps in the data record but the data were largely used on an event basis for LAG analysis for which data was available.
115233		Milton o Noth	Tipping bucket raingauge	1990 - 2010	To be used in model calibration for western Urie laterals. 15 minute recording rainfall. Data only available for the 2009 and 1995 events due to record length.
		Rhynie	Manual raingauge	2009 - 2017	To be used in model calibration for western Urie laterals for the 2016 event. 15 minute recording rainfall.
		Rothienorman	Tipping bucket raingauge	2001 - present	To be used in model calibration for eastern Urie laterals. 15 minute recording rainfall. No data available for calibration of the 1995 event due to record length.
115250		Westhill	Tipping bucket raingauge	1994 - 2017	To be used in model calibration for Don laterals south of Inverurie. 15 minute recording rainfall.

3 Email correspondence with Danni Murren of SEPA dated 9 January 2018.

Figure 1-1: Catchment and hydrometry



2 Flood History

2.1 Introduction

Both the River Don and River Urie are susceptible to fluvial flooding which has caused both localised and extensive flood inundation over the past few centuries. Inverurie, Port Elphinstone and Kintore lie within Potentially Vulnerable Area (PVA) 06/13 and all three communities have a history of flooding. Inverurie and Port Elphinstone are most susceptible to fluvial flooding in the area surrounding the confluence of the River Don and the River Urie.

A flood history review was carried out from data collected from the following: Aberdeenshire Council, Scottish Environment Protection Agency (SEPA), Chronology of British Hydrological Events (CBHE) and social media sources. The historical flood record for Inverurie, Port Elphinstone and Kintore is documented in the table below. The major events are summarised in Table 2-1.

The earliest recorded flooding on the River Don was in 1768. Prior to 2016, the most notable flood event occurred in 1829, causing widespread flood inundation and impacts on agriculture; infrastructure and residential dwellings. At the time, the event was described as follows: "In the flood of August 1829, it rose four inches higher than in that of 1768, and did much damage…0.1 m above 1768. Flooding 12-14 foot above ordinary level. Mill-house of Kemnay swept away"[4]. The most recent event occurred in 2016 also causing wide scale flood inundation to communities in: Port Elphinstone; Inverurie; Kemnay; Alford; Dyce; Cothal; Kildrummy; Burnhervie; Bellabeg; Glenkindie and Kintore. This flood was the largest recorded flow at the Parkhill gauging station (stage of 5.56 m) since records began in 1970.

Table 2-1: Flood History

Date	Description	Source
1768 1828 1838 1872 1903 1905	Most agricultural crops damaged and extensive flooding to agricultural land after the River Don breached its banks.	Aberdeenshire Council- North East Local Plan District: Local Flood Risk Management Plan [5]
1829	' …Several houses were flooded 4 or 5 feet deep, half the mill-house of Kemnay was swept away, and the wooden part of the machinery carried down to Inverurie and Kintore'	Muckle Spate, found online at: https://archive.org/stream/greatfloodsaugu00laudgoog#page/n250/mode/2up/search/Inverurie [assessed on 16.11.17]
1920	' Hundreds of Acres were inundated by the River Don bursting its banks; sheep, cattle and poultry perished.'	CBHE, found online at: < http://www.hydrology.org.uk/Chronology_of_British_Hydrological_Events.php> [accessed on 16.11.17]
1924	The Gas Burn flooded Blackhall Road in Inverurie.	Aberdeenshire Council- North East Local Plan District: Local Flood Risk Management Plan [5]
1928 1948 1951	Flooding to agricultural land after the River Don breached its banks.	Aberdeenshire Council- North East Local Plan District: Local Flood Risk Management Plan [5]
1995	Flooding to agricultural land from the Don breaching its banks. Flooding to Oldmeldrum Road and Souterford Road due to overtopping of the River Urie. Water levels of 4.74 m at Haughton gauging station.	Aberdeenshire Council- North East Local Plan District: Local Flood Risk Management Plan [5]

4 Lauder, T.D., (1830) The Great Floods of August 1829, In The Province of Moray and Adjoining Districts [Online]. Third edition. Elgin: R. Stewart. [Accessed 27/11/2017. Available from: https://archive.org/stream/greatfloodsaugu00laudgoog#page/n6/mode/2up]

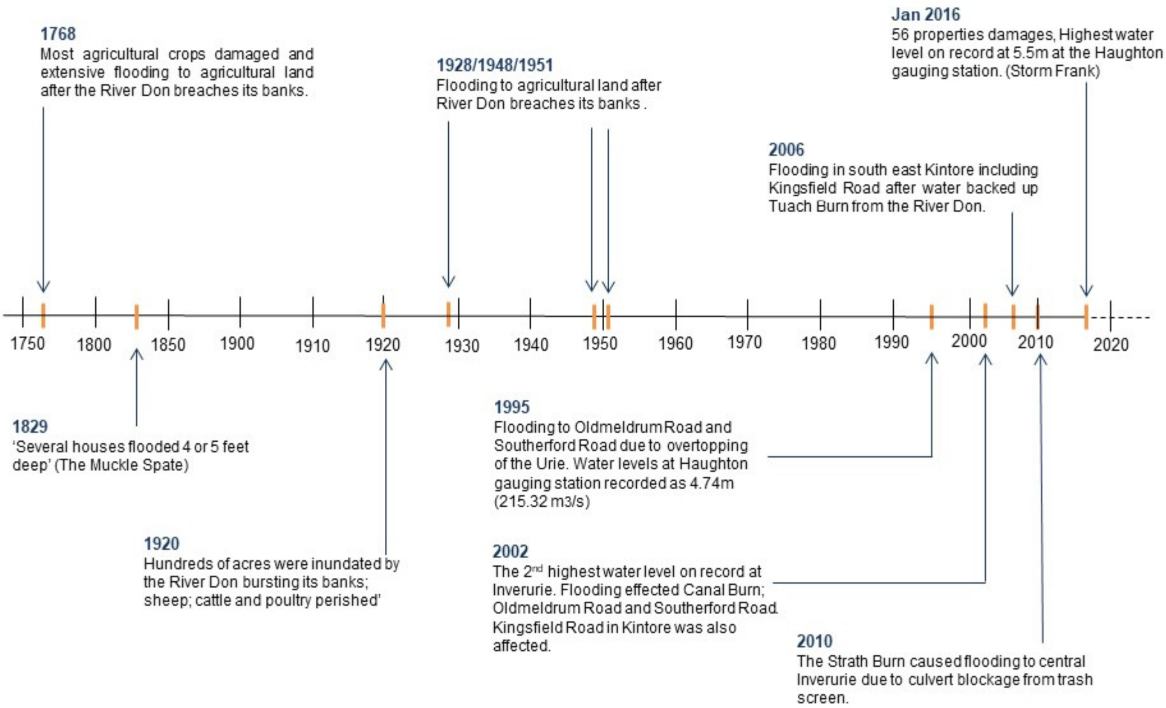
5 North East Local Plan District- Local Flood Risk Management Plan 2016-2022. Found online at: https://www.aberdeenshire.gov.uk/media/17174/north-east-local-flood-risk-management-plan-2016-2022-web-version.pdf [accessed on 24/10/17]

2000	Extensive flooding to Inverurie, Port Elphinstone and Kintore. A range of flooding photos showing flood extents. Flood outlines of the October flood event which shows flooding from both the River Don and the Urie in eastern Inverurie, covering the agricultural floodplains. Further flooding to the agricultural land east of Kintore and south of Kemnay.	Photos and flood outlines supplied by SEPA and JBA Consulting UK.
2002	The Bridge of Don had the highest water level on record and flooding affected Canal Road. The Strath Burn caused flooding to central Inverurie due to culvert blockage from a trash screen. Flooding in south east Kintore including Kingsfield Road after water backed up Tuach Burn from the River Don. Water levels backing up from the River Don caused flooding on Loch Burn in the eastern areas of Kintore affecting commercial property in the area between the two railway culverts and properties on Northern Road.	Aberdeenshire Council- North East Local Plan District: Local Flood Risk Management Plan [5]
2002	Aerial flooding photos of the area.	Photos supplied by SEPA
2002	Flooding photos at Inverurie	Photos supplied by SEPA
2003	The flood barrier at Keithhall Road, Inverurie was breached and residential properties were flooded. The Strath Burn caused flooding to central Inverurie due to culvert blockage from a trash screen. Flooding in south east Kintore including Kingsfield Road after water backed up the Tuach Burn from the River Don.	Aberdeenshire Council- North East Local Plan District: Local Flood Risk Management Plan [5]
2004	The River Don caused flooding after breaching its banks. The Strath Burn caused flooding to central Inverurie due to culvert blockage from a trash screen.	Aberdeenshire Council- North East Local Plan District: Local Flood Risk Management Plan[5]
2005	Water levels backing up from the River Don caused flooding on Loch Burn in the eastern areas of Kintore affecting commercial property in the area between the two railway culverts and properties on Northern Road.	Aberdeenshire Council- North East Local Plan District: Local Flood Risk Management Plan[5]
2006	Flooding in south east Kintore including Kingsfield Road after water backed up in the Tuach Burn from the River Don.	Aberdeenshire Council- North East Local Plan District: Local Flood Risk Management Plan[6]
2009	The River Don caused flooding after breaching its banks. The Strath Burn caused flooding to central Inverurie due to culvert blockage from a trash screen. Flooding to Oldmeldrum Road and Souterford Road due to overtopping of the River Urie. Flooding in south east Kintore including Kingsfield Road after water backed up the Tuach Burn from the River Don. Water levels backing up from the River Don caused flooding on Loch Burn in the eastern areas of Kintore affecting commercial property in the area between the two railway culverts and properties on Northern Road.	Aberdeenshire Council- North East Local Plan District: Local Flood Risk Management Plan[5]
2010	The Strath Burn caused flooding to central Inverurie due to culvert blockage from a trash screen.	Aberdeenshire Council- North East Local Plan District: Local Flood Risk Management Plan[5]
2016	56 properties damaged in Kintore and over 80 properties damaged in Inverurie. Emergency services were needed to rescue residents in Canal Road, Canal Crescent and Riverside Park which were inundated with several feet of water. The Port Elphinstone Bridge on Elphinstone Road was closed.	Aberdeenshire Council- North East Local Plan District: Local Flood Risk Management Plan[5].
2016	Canal Road and Riverside Park flooded, with homes needing evacuating. Flooding of up to 4ft	The Press and Journal, found online at: <

	into one living room. The fire service rescued 50 people in Port Elphinstone.	https://www.pressandjournal.co.uk/fp/news/aberdeenshire/799848/port-elphinstone-residents-tell-of-flooding/> [accessed on 16.11.17]
2016	'On Monday evening, residents in Canal Road in Inverurie were evacuated from their homes'……' Firefighters also rescued a woman who was trapped in her car by rising flood water in Inverurie…several householders in nearby Port Elphinstone were forced to leave their homes after water started coming through their floorboards'	BBC News, found online at: < http://www.bbc.co.uk/news/uk-scotland-35221823> [accessed on 16/11/17]
2016	'Dozens of homes were evacuated in Inverurie, Port Elphinstone and Ellon overnight as the swollen river sent flood waters racing down the streets'………' Gauge at Haughton measured the Don at 5.6 m - the highest level for 45 years. The level at the Parkhill gauge measured 4.84 m'.	The Sunday Post, found online at: < https://www.sundaypost.com/news/scottish-news/aberdeenshire-flooding-river-don-bursts-its-banks-with-homes-evacuated-in-inverurie-port-elphinstone-and-ellon/> [accessed on 16.11.17]
2016	Widespread flooding to Inverurie and Port Elphinstone. The highest water level on record at Haughton gauging station, 4.84 m	YouTube, found online at: https://www.youtube.com/watch?v=9HIZKrtV4p8 [accessed on 24/10/17]
2016	Flooding in Kintore. The highest water level on record at Haughton gauging station, 5.5 m.	YouTube, found online at: < https://www.youtube.com/watch?v=hOcRhiBT1YI> [accessed on 24/10/17]
2016	Flood photos from Aberdeenshire Council, See Appendix A	From Aberdeenshire Council, see Appendix A.

In summary the key events in which Inverurie, Port Elphinstone or Kintore experienced flooding were: 1829, 1924, 1995, 2002, 2003, 2004, 2005, 2006, 2009, 2010, 2015 and 2016. Key events are summarised below.

Figure 2-1: Summary timeline of flooding on the River Urie and Don at Inverurie, Port Elphinstone and Kintore



2.2 Previous Flood Estimates

CH2M were commissioned by Aberdeenshire Council in 2015 to update a Flood Study at Inverurie[6], previously undertaken by Halcrow in 2003 and then again in 2010. CH2M updated the peak flow estimates with a longer AMAX series using the Statistical single site methodology. The Halcrow and CH2M peak flows are given in the tables below. The ratings at Pitcaple and Parkhill were revised after the 2003 study reflected in the peak flow estimates between reports.

Table 2-2: Previous peak flow estimates for the Urie at Pitcaple

Annual Probability [AP] (%)	Return Period (years)	2003 Statistical single site analysis flow (m^3/s)	2010 Statistical pooling analysis flow (m^3/s)	2015 Statistical single site analysis flow (m^3/s)
50	2	25.0	27.1	27.9
10	10	46.9	56.4	61.9
2	50	72.7	98.5	117.0
0.1	100	86.6	124.0	152.7
0.5	200	102.7	155.8	199.3
0.5 +CC	200 +CC	123.2	187.0	239.1

Table 2-3: Previous peak flow estimates for the Don at Haughton

Annual Probability [AP] (%)	Return Period (years)	2003 Statistical single site analysis flow (m^3/s)	2010 Statistical pooling analysis flow (m^3/s)	2015 Statistical single site analysis flow (m^3/s)
50	2	112.4	112.4	124.8
10	10	187.5	176.7	196.2
2	50	279.5	247.3	277.8
0.1	100	330.3	283.7	320.8
0.5	200	389.9	324.8	370.0
0.5 +CC	200 +CC	467.9	389.8	443.9

Table 2-4: Previous peak flow estimates for the Don at Parkhill

Annual Probability [AP] (%)	Return Period (years)	2003 Statistical single site analysis flow (m^3/s)	2010 Statistical pooling analysis flow (m^3/s)	2015 Statistical single site analysis flow (m^3/s)
50	2	139.0	155.0	166.8
10	10	266.0	270.0	283.0
2	50	442.0	411.0	428.7
0.1	100	546.0	488.0	511.3
0.5	200	674.0	578.0	610.9
0.5 +CC	200 +CC	808.0	694.0	733.0

6 CH2M. July 2015. Inverurie Flood Study Update. Technical Note. v1.0. Project number 660541.

3 Flood Estimation: Overall Approach

3.1 Peak Flows: Overall approach

Important inputs into a flood study are the analysis of historic floods (where data are available), and estimation of flood flows for a range of annual probabilities or 'design' events. Flood estimates for catchments of this size and type are undertaken using the Flood Estimation Handbook (FEH). The FEH offers three methods for analysing design flood flows: the Statistical, the Rainfall Runoff, and hybrid methods. The Statistical method combines estimation of the median annual maximum flood (QMED) at the subject site with a growth curve, derived from one of three methods; (a) a pooling group of gauged catchments that are considered hydrologically similar to the subject site, (b) through single site analysis of a nearby gauge, or (c) a combination of the two through the use of enhanced single site. The Rainfall Runoff method combines design rainfall with a unit hydrograph derived for the subject site (the Rainfall Runoff method has recently been updated as ReFH2[7]). Hybrid methods involve a combination of the two. Both the Statistical and Rainfall Runoff procedures require the derivation of catchment descriptors (Table 1-1).

Adjustments were then made to catchment area (using OS background mapping) and URBEXT (using the national growth model through the year of study, 2018, per FEH Volume 5). The FEH CD-ROM BFIHOST values appeared reasonable in comparison to the available geological information[8].

The Statistical method was selected as the most appropriate choice of method of peak flow estimation for both the River Urie and River Don. This was because of the relatively large, rural nature of the catchments and that there are good gauged records available along both watercourses.

In addition to peak flow estimates, the hydraulic model also required the following information:

- Fluvial hydrographs for the Urie at the model upstream extent and the Don upstream of the Urie confluence.
- Appropriate storm durations for flood mapping. Storm durations were considered from observed data at Parkhill gauging station in addition to FEH Rainfall Runoff modelled durations.

These items are also discussed in the following sections.

7 Wallingford Hydro Solutions (WHS) The Revitalised Flood Hydrograph, ReFH2: Technical Guidance. 2015
8 http://mapapps.bgs.ac.uk/geologyofbritain/home.html

3.2 River Don Flood Estimation

3.2.1 River Don at Haughton

Peak flow estimates at Haughton were previously determined as part of the 2017 'Don to Inverurie Flood Mapping' project[9] being undertaken by JBA. These estimates have been approved by SEPA. A review of the methodology is given below.

There is a SEPA gauging station at Haughton (station number 11002) with 45 years of AMAX (spanning water years 1972 to 2016). JBA undertook a rating review of the gauging station and developed new high flow ratings using hydraulic modelling[10]. The new rating has been applied across the full record supplied by SEPA. The updated AMAX series used in calculation of peak flows is shown in Table 3-1.

Given the reasonable record length at Haughton and the rating review, both enhanced single site analysis (ESS) and single site (SS) analysis were considered as possible alternatives for obtaining flood estimates. SEPA gauges suitable for pooling analysis were updated through water year 2016 with the remaining sites being from the HiFlows database (v5.0)[11] with data up to 2014 for stations currently operating in England and Wales (the overall HiFlows dataset also includes data from stations closed prior to 2014). In both cases, a Generalised Logistic (GL) distribution was used for the growth curve, with additional tests using the Generalised Extreme Value (GEV) as described below. The results for Haughton are given in Table 3-2. Additional information on the ESS pooling approach is provided in Appendix A. In all cases, a QMED value of 111.7 m^3/s at Haughton as derived from the observed AMAX data was used.

In order to provide some historical context and inform the choice of method, the largest event on record at Haughton was considered (January 2016, a flow of circa 396 m^3/s). Historical flooding has occurred on the Don since at least 1829. If it is assumed that the flood of 1829[12] was higher than the 2016 flood (and disregarding any changes in the catchment since 1829), then, for the period 1829 to 2017 the AP value of the 2016 event was estimated to be circa 0.82% AP (121 years; as calculated using Gringorten plotting positions) and 1829 event, 0.30% AP (338 year) event. These estimates are broadly consistent with the frequency of flooding estimated using SS analysis (circa 1% AP, 100 year, to 0.91%, 110 year, event at Haughton, using the GL and GEV distributions respectively). The ESS results are slightly less consistent with the historical estimates with AP values of circa 0.59% AP (170 year) to greater than a 0.5% AP (200 year, using the GL and GEV distributions respectively). It was therefore concluded that the SS approach was more in keeping with the historical information available and was adopted. Of the two distributions considered within the SS approach, arguably either the GL or GEV distribution were applicable for Haughton. For the modelling of the upper Don the GL distribution was applied in order to provide consistency with Alford. A 24% climate change allowance upon the 0.5% AP (200 year) event was applied, per SEPA guidance for Local Authority studies for the North East of Scotland[13].

As in any SS analysis, the findings may be subject to change following large floods and extrapolation to large flood (e.g. the 0.1% AP, 1000 year) events may be more uncertain than under a pooled approach. In order to provide an indication of uncertainty, 95% confidence limits for the SS curves generated via high resampling through the bootstrapping method available in WINFAP are shown in Table 3-3, Figure 3-2 and Figure 3-3 (for the GL and GEV growth curves, respectively). The confidence band at Haughton is greater for the GEV distribution between the 20% AP (5 year) event and the 0.5% AP (200 year) event. For example, there is a range of 314 to 766 m^3/s for the 0.5% AP (200 year) using the GEV distribution compared to 339 to 790 m^3/s using the GL distribution. At the 50% AP (2 year), 0.2% AP (500 year) and 0.1 % AP (1000 year) events the confidence band at Haughton is greater with the GL distribution. The narrower confidence band for the GL distribution at Haughton for the majority of AP events supports the use of the SS GL growth curve at this site. Consideration of the 95% confidence range can be given during model sensitivity analysis.

9 JBA Consulting. 2017s6610. Don to Inverurie Flood Mapping. Don to Inverurie Hydrology Final Report v2.0.

10 JBA Consulting. 2018. 2017s6610 - Haughton Rating Review Final Report v2.0.

11 The HiFlows database was updated to v6.0 as of February 2018. ESS peak flow estimates stated have used v5.0 for consistency with the hydrology being used in the modelling of the upper Don.

12 An email from Claire Wheeler, SEPA, dated 22 November 2017, intimated that the 1829 event on the Don is thought to be larger than the 2016 event.

13 SEPA – Flood Modelling Guidance for Responsible Authorities, Version 1.0

Peak flow estimates were also required upstream of Haughton gauging station for input at the upstream model extent. These will be extracted from the JBA 'Upper Don to Inverurie' model currently being developed[9] when design flows are confirmed with SEPA.

Table 3-1: Haughton AMAX data series. New rating applied to the full record.

Date/Time	Stage (m)	Q (m^3/s)
25/11/1971 21:00	3.76	88.37
05/05/1973 06:00	3.38	59.47
12/01/1974 20:30	3.75	87.41
23/11/1974 05:15	3.95	105.85
01/10/1976 01:00	3.78	90.14
16/10/1976 11:45	4.70	203.66
11/12/1977 19:15	4.02	113.04
03/03/1979 10:30	4.12	124.72
05/10/1979 04:15	3.95	106.45
27/09/1981 08:15	3.92	103.17
03/10/1981 12:00	4.10	122.03
14/10/1982 00:00	4.81	222.56
27/03/1984 12:45	3.76	88.46
04/11/1984 09:00	4.53	177.17
02/12/1985 06:45	3.92	103.27
18/07/1987 23:00	3.56	72.04
25/01/1988 13:00	3.73	85.51
20/10/1988 02:30	3.84	95.70
01/07/1990 14:45	3.13	42.80
29/10/1990 09:15	3.99	110.33
19/11/1991 04:00	3.90	100.92
17/01/1993 14:00	3.65	79.17
08/10/1993 08:45	4.33	149.65
08/09/1995 19:15	4.74	210.21
10/02/1996 21:15	4.16	128.49
01/07/1997 22:45	3.80	92.21
05/04/1998 06:45	4.68	200.12
21/09/1999 11:00	3.87	98.62
27/04/2000 02:30	4.86	229.91
09/11/2000 01:30	4.36	153.83
20/07/2002 21:45	4.16	129.53
22/11/2002 07:00	5.07	273.93
19/08/2004 16:30	4.21	135.20
17/03/2005 02:45	3.68	81.38
03/12/2005 07:45	4.23	136.77
06/08/2007 14:00	3.94	105.75
22/11/2007 19:00	3.93	104.06
04/09/2009 15:15	4.21	134.36
22/10/2009 16:00	4.71	205.28
11/12/2010 11:45	4.36	153.30
26/04/2012 05:00	3.91	102.29
23/12/2012 08:15	4.43	162.85
11/08/2014 23:30	4.24	138.84
08/10/2014 02:30	4.20	133.89
08/01/2016 02:30	5.50	396.23
16/10/2016 01:00	3.73	86.20

Figure 3-1: AMAX series at Haughton

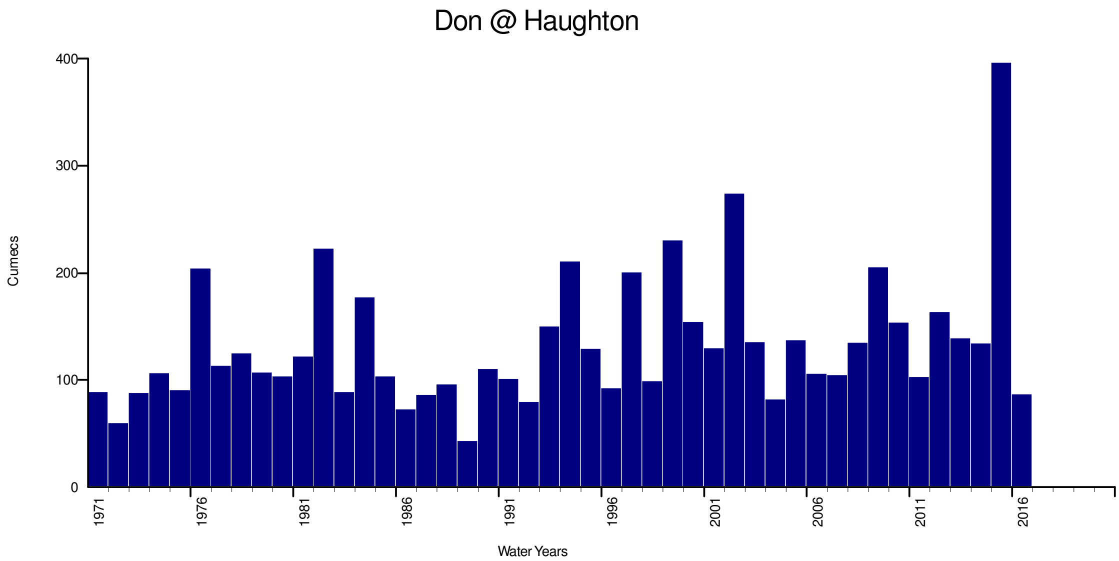


Table 3-2: Peak flow estimates: statistical estimates for the River Don at Haughton

Annual Probability [AP] (%)	Return Period (years)	River Don at Haughton Gauging Station. Single Site Statistical Method Flow: GL (m^3/s)	River Don at Haughton Gauging Station. Single Site Statistical Method Flow: GEV (m^3/s)	River Don at Haughton Gauging Station. Enhanced Single Site Statistical Flow: GL (m^3/s)	River Don at Haughton Gauging Station. Enhanced Single Site Statistical Flow: GEV (m^3/s)
50	2	111.69	116.45	111.71	111.70
20	5	158.07	166.07	154.42	158.16
10	10	196.42	206.46	187.96	193.63
4	25	258.29	268.08	239.78	244.64
3.33	30	272.62	281.74	251.47	255.52
2	50	317.22	322.90	287.20	287.52
1.33	75	357.91	358.91	319.09	314.64
1	100	390.06	386.43	343.85	334.88
0.5	200	480.54	460.26	411.90	387.33
0.2	500	635.11	576.77	523.67	465.59
0.1	1000	785.96	681.91	628.65	532.41
3.33 +CC	30 +CC	338.05	349.36	311.83	316.85
0.5 + CC	200 +CC	595.87	570.73	510.76	480.29
0.5 specific discharge ($l/s/km^2$)	200	0.61	0.58	0.52	0.49
0.5 growth factor	200	4.30	3.95	3.69	3.47

Figure 3-2: SS and ESS growth curves for Haughton SS GL 95% confidence limits

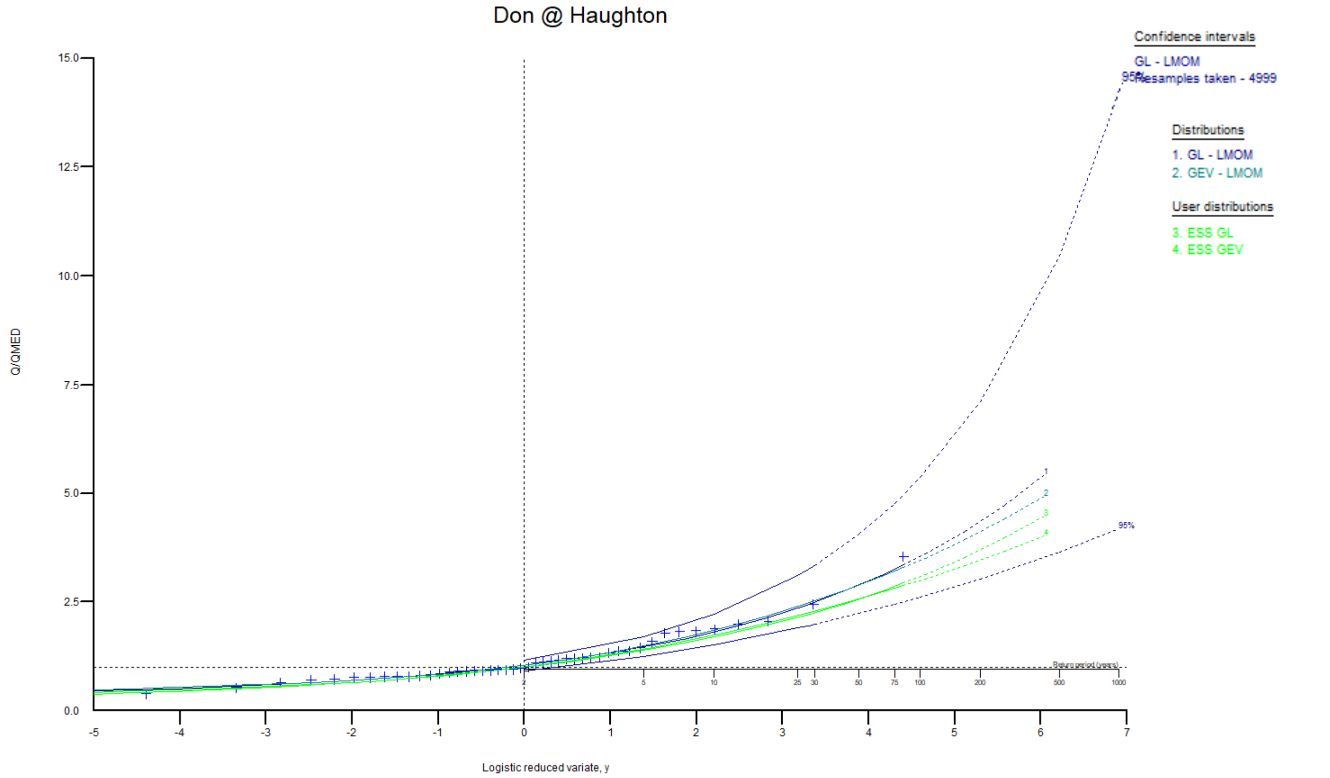


Figure 3-3: SS and ESS growth curves for Haughton SS GEV 95% confidence limits

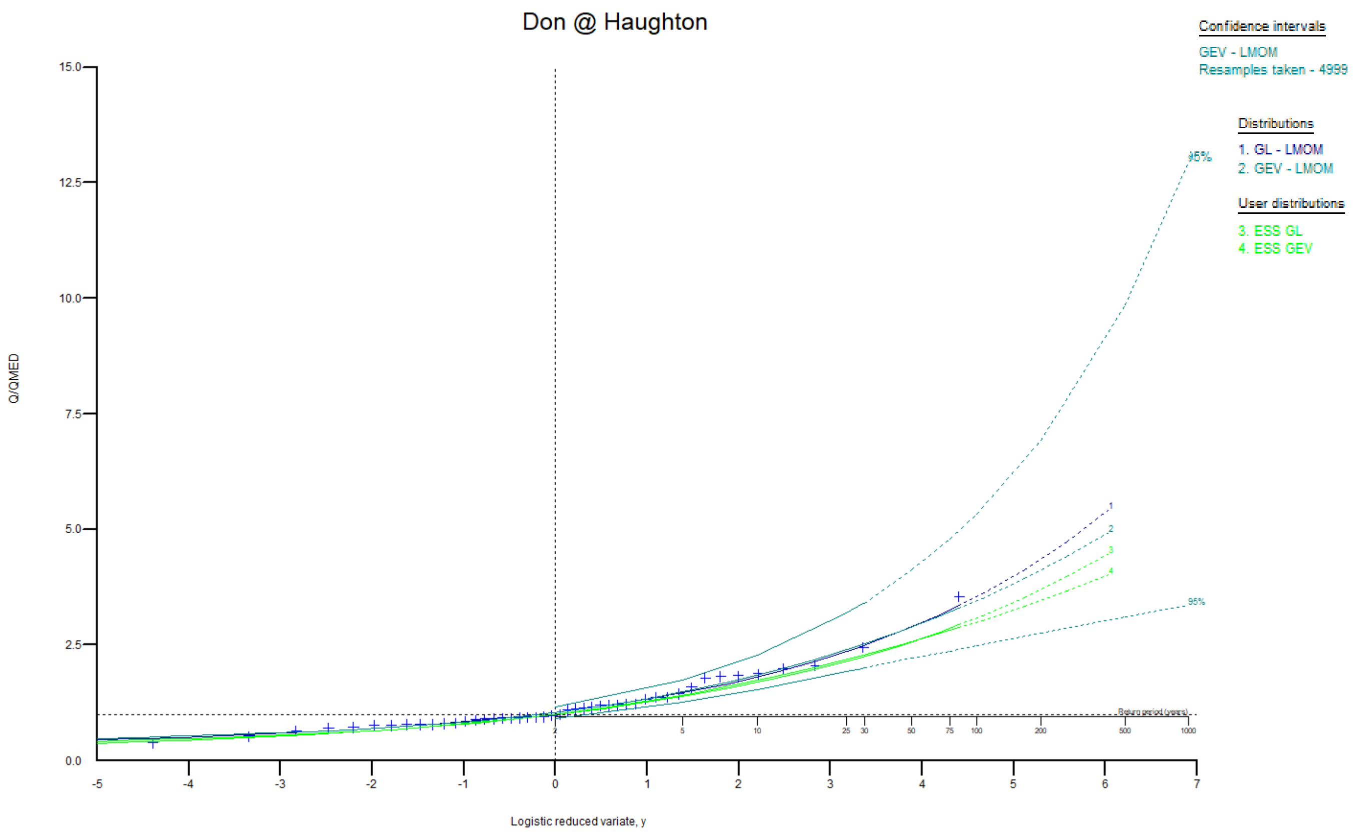


Table 3-3: Peak flow estimates: confidence limits for the Don at Haughton

Annual Probability [AP] (%)	Return Period (years)	Don at Haughton Single Site Statistical Method Flow: GL (m^3/s)	Don at Haughton Single Site Statistical Method Flow GL confidence limits (m^3/s)	Don at Haughton Single Site Statistical Method Flow: GEV (m^3/s)	Don at Haughton Single Site Statistical Method Flow GEV confidence limits (m^3/s)
50	2	111.69	102.199 - 131.504	116.45	101.417 - 129.938
20	5	158.07	139.403 - 191.811	166.07	140.995 - 193.927
10	10	196.42	168.908 - 246.729	206.46	172.455 - 252.568
4	25	258.29	212.439 - 345.686	268.08	215.410 - 352.451
3.33	30	272.62	221.823 - 370.557	281.74	223.745 - 376.918
2	50	317.22	249.799 - 451.776	322.90	248.751 - 454.502
1.33	75	357.91	274.741 - 529.783	358.91	268.727 - 528.252
1	100	390.06	293.348 - 595.039	386.43	281.506 - 587.535
0.5	200	480.54	339.421 - 790.477	460.26	313.579 - 766.139
0.2	500	635.11	413.149 - 1169.404	576.77	353.354 - 1090.626
0.1	1000	785.96	478.184 - 1583.385	681.91	383.421 - 1433.815

3.2.2 River Urie at Pitcaple

There is a SEPA gauging station at Pitcaple (station number 11004) with 29 years of AMAX data (spanning water years 1988 to 2017). SEPA undertook a rating review of the gauging station and developed a new high flow rating using a linked 1D/2D hydraulic model[14] to be used in this study. The updated AMAX series used in calculation of peak flows is shown in Table 3-4.

Both enhanced single site analysis (ESS) and single site (SS) analysis were considered as possible alternatives for obtaining flood estimates (Table 3-5). SEPA gauges suitable for pooling analysis were updated through water year 2016 with the remaining sites being from the most up-to-date HiFlows database (v6.0) with data up to 2016 for stations currently operating in England and Wales (the overall HiFlows dataset also includes data from stations closed prior to 2016). In both cases, a Generalised Logistic (GL) distribution was used for the growth curve, with additional tests using the Generalised Extreme Value (GEV) as described below. The results for Pitcaple are given in Table 3-5, and the SS confidence intervals given in Table 3-7. Growth curves are shown in Figure 3-5 and Figure 3-6. Additional information on the ESS pooling approach is provided in Appendix A. In all cases, a QMED value of 31.25 m^3/s at Pitcaple as derived from the observed AMAX data was used.

The SS and ESS growth curves both fit the AMAX data relatively well. The highest event on record (November 2009) falls between the SS and ESS growth curves. Whereas the majority of smaller events were better fit using either the SS or ESS growth curves with a GL distribution. The Z statistic within WINFAP indicated the GL distribution had a better fit than the GEV (0.5173 compared to -1.1519 respectively). In order to provide some historical context and inform the choice of method, the largest event on record at Pitcaple was considered (November 2009 with a flow of circa 94 m^3/s). Historical flooding has occurred on the Urie since at least 1829. If it is assumed that the flood of 1829 was higher than the 2009 flood (and disregarding any changes in the catchment since 1829), then, for the period 1829 to 2018 the AP value of the 2009 event was estimated to be circa 0.82% AP (122 years; as calculated using Gringorten plotting positions). This estimate is broadly consistent with the frequency of flooding estimated using ESS analysis (circa 1.22% AP, 82 years, for the 2009 event, using the GL distribution). The SS results are slightly less consistent with the historical estimates with AP values of circa 2.70% AP (37 year), using the GL distribution.

As the record at the gauge is relatively short (29 years) compared to Haughton; the 2009 event could have a large influence upon the frequency curve; and that the ESS GL approach is more in keeping with the historical information available, this method was therefore adopted. A 24% climate change allowance upon the 0.5% AP (200 year) event was applied, per SEPA guidance for Local Authority studies for the North East of Scotland[13].

Design peak flow estimates were also required at the upstream extent of the model, north of Old Rayne. For consistency, peak flows were derived using the Pitcaple ESS growth curve with GL distribution, and QMED adjusted using Pitcaple as the donor[15]. This gave a 0.5% AP (200 year) peak flow estimate of 36.92 m^3/s. A check was also made using the statistical pooling method. A pooling group of catchments deemed hydrologically similar to the catchment of interest upstream of Old Rayne was derived within WINFAP. Adjustments were made to the default pooling group to remove sites that were discordant or hydrologically dissimilar (e.g. those with a very high BFIHOST), or add sites until a suitable pooling group size was achieved. However, WINFAP indicated the final pooling group to be heterogenous and the Z statistic approach available indicated the GEV and Pearson Type III distributions to be acceptable. The GL and GEV distributions were considered for use for the growth curve, with the Urie at Pitcaple used to adjust QMED. The pooled growth curve with GEV distribution gave a 0.5% AP (200 year) peak flow estimate of 32.95 m^3/s. This is relatively similar to the peak flow derived using the Pitcaple growth curve.

14 Email correspondence with Claire Wheeler (SEPA) dated 11 October 2018 and Danni Murren dated 2 November 2018.

15 As part of the Ellon, Inverurie and Insch Flood Prevention Studies peak flow estimates were also required for the Shevock at Insch. The Shevock is a tributary of the Urie, but is more responsive in nature than the Urie at Pitcaple. In addition, the Shevock headwaters are close to the headwaters of the Deveron catchment. For the Shevock study, it was therefore judged more appropriate to use the Deveron at Avochie (9001) as a QMED donor for the Shevock. In this present (Inverurie study), the catchment descriptors for Pitcaple were found to be similar to the upstream model extent of the Urie, and Pitcaple was therefore used for QMED adjustment and for other aspects of the flood frequency analysis. The Pitcaple rating will be further checked using the 1D/2D model being developed for the Urie and Don for this study. Further details of the Shevock study are provided in: JBA Consulting, Insch Hydrology Report, Final Report, May 2018.

Table 3-4: Pitcaple AMAX data series.

Date/Time	Stage (m)	Q (m^3/s)
20/10/1988 02:15	1.31	21.86
01/07/1990 05:00	0.83	6.79
05/03/1991 03:15	1.44	25.05
04/11/1991 14:00	1.41	24.48
29/10/1992 08:15	1.13	17.63
08/10/1993 03:15	1.81	34.77
12/09/1995 08:15	2.80	76.78
10/02/1996 12:00	2.06	42.42
01/07/1997 19:45	1.49	26.32
05/04/1998 03:30	1.86	35.93
25/10/1998 10:00	1.36	23.14
27/04/2000 02:00	2.51	63.19
09/11/2000 04:00	1.78	33.64
20/07/2002 18:00	1.62	29.48
22/11/2002 01:30	2.64	69.41
19/08/2004 08:15	1.23	20.00
16/10/2004 04:45	1.06	15.86
03/12/2005 04:45	1.46	25.68
06/08/2007 13:30	1.76	32.43
22/11/2007 13:00	2.05	42.42
04/09/2009 11:15	2.25	51.36
02/11/2009 01:15	3.17	93.79
11/12/2010 04:30	1.90	37.07
22/06/2012 10:15	1.14	17.70
15/12/2012 06:15	1.90	37.07
29/01/2014 12:45	1.71	31.25
08/10/2014 00:45	1.71	31.25
07/01/2016 22:15	2.88	79.98
15/09/2017 23:15	1.13	17.65
21/11/2017 20:45	1.237	20.20

Figure 3-4: AMAX series at Pitcaple

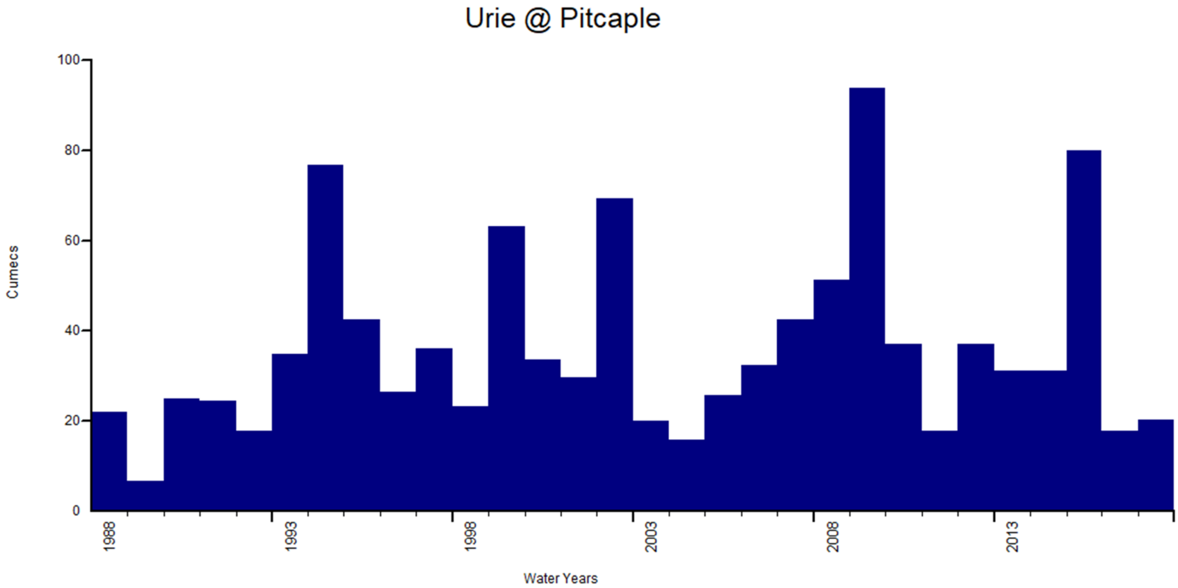


Table 3-5: Peak flow estimates: statistical estimates for the River Urie at Pitcaple

Annual Probability [AP] (%)	Return Period (years)	River Urie at Pitcaple Gauging Station. Single Site Statistical Method Flow: GL (m^3/s)	River Urie at Pitcaple Gauging Station. Single Site Statistical Method Flow: GEV (m^3/s)	River Urie at Pitcaple Gauging Station. Enhanced Single Site Statistical Flow: GL (m^3/s)	River Urie at Pitcaple Gauging Station. Enhanced Single Site Statistical Flow: GEV (m^3/s)
50	2	31.25	30.42	31.25	31.23
20	5	47.59	47.99	44.85	46.17
10	10	60.97	62.11	55.00	56.85
4	25	82.34	83.39	69.98	71.30
3.33	30	87.27	88.07	73.27	74.26
2	50	102.54	102.11	83.15	82.76
1.33	75	116.41	114.31	91.76	89.73
1	100	127.32	123.59	98.34	94.80
0.5	200	157.89	148.31	115.97	107.49
0.2	500	209.69	186.88	143.79	125.37
0.1	1000	259.84	221.30	168.91	139.79
3.33 +CC	30 +CC	108.22	109.21	90.86	92.09
0.5 + CC	200 +CC	195.79	183.91	143.80	133.29
0.5 specific discharge ($l/s/km^2$)	200	0.81	0.76	0.59	0.55
0.5 growth factor	200	4.07	3.95	3.15	3.03

Table 3-6: Peak flow estimates: statistical estimates for the River Urie north of Old Rayne (the upstream model boundary)

Annual Probability [AP] (%)	Return Period (years)	River Urie north of Old Rayne. Enhanced Single Site GL parameters from Pitcaple flow (m^3/s)	River Urie north of Old Rayne. Pooling Statistical Method Flow: GL (m^3/s)	River Urie north of Old Rayne. Pooling Statistical Method Flow: GEV (m^3/s)
50	2	9.95	9.95	9.95
20	5	14.28	14.35	14.81
10	10	17.51	17.54	18.16
4	25	22.28	22.16	22.55
3.33	30	23.32	23.15	23.43
2	50	26.47	26.12	25.93
1.33	75	29.21	28.68	27.95
1	100	31.30	30.62	29.39
0.5	200	36.92	35.75	32.95
0.2	500	45.77	43.68	37.81
0.1	1000	53.77	50.70	41.62
3.33 +CC	30 +CC	28.92	31.26	31.64
0.5 + CC	200 +CC	45.77	44.33	40.86
0.5 specific discharge ($l/s/km^2$)	200	0.69	0.67	0.61
0.5 growth factor	200	3.71	3.08	2.95

Figure 3-5: SS and ESS growth curves for Pitcaple: SS GL 95% confidence limits

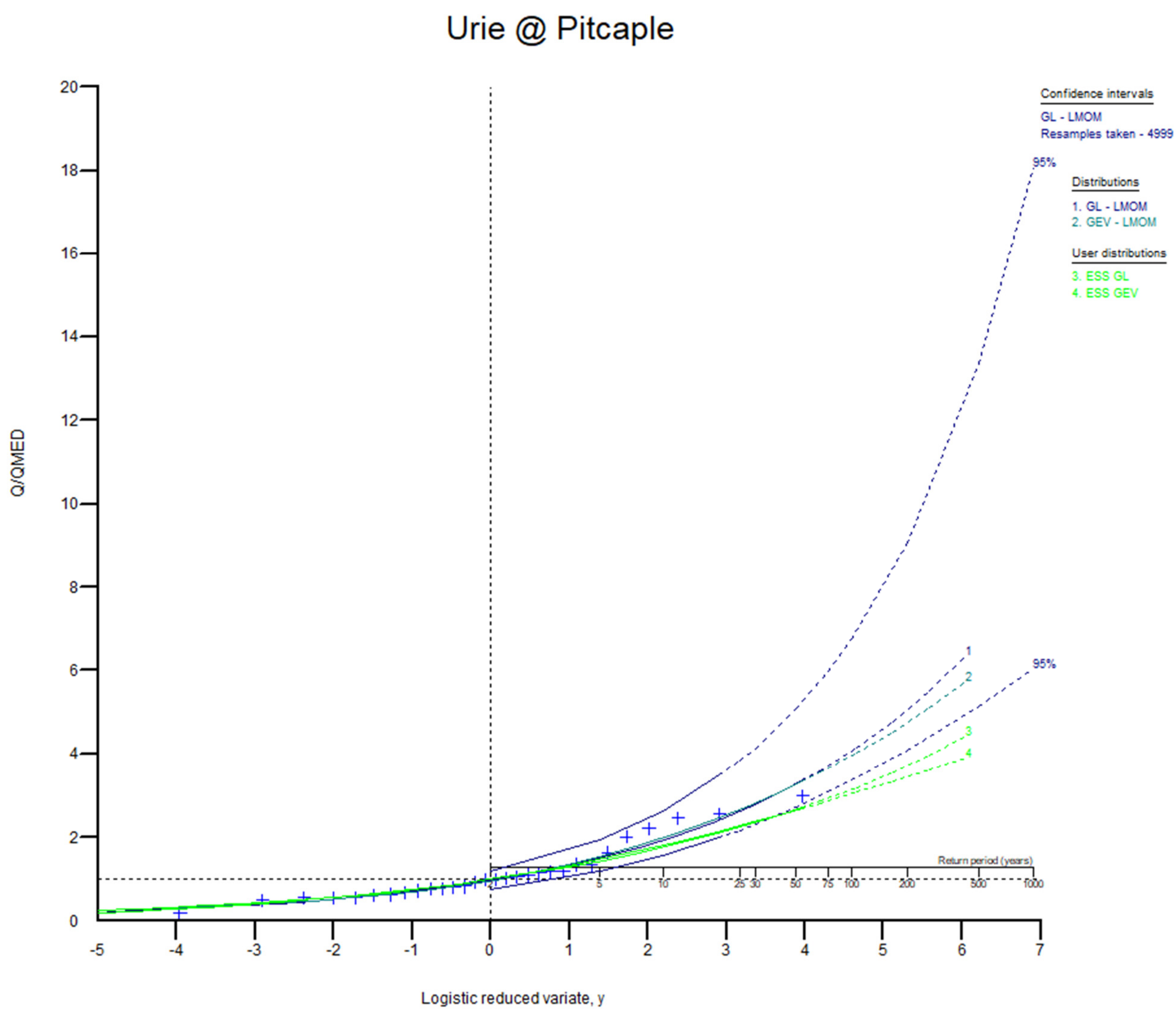


Figure 3-6: SS and ESS growth curves for Pitcaple: SS GEV 95% confidence limits

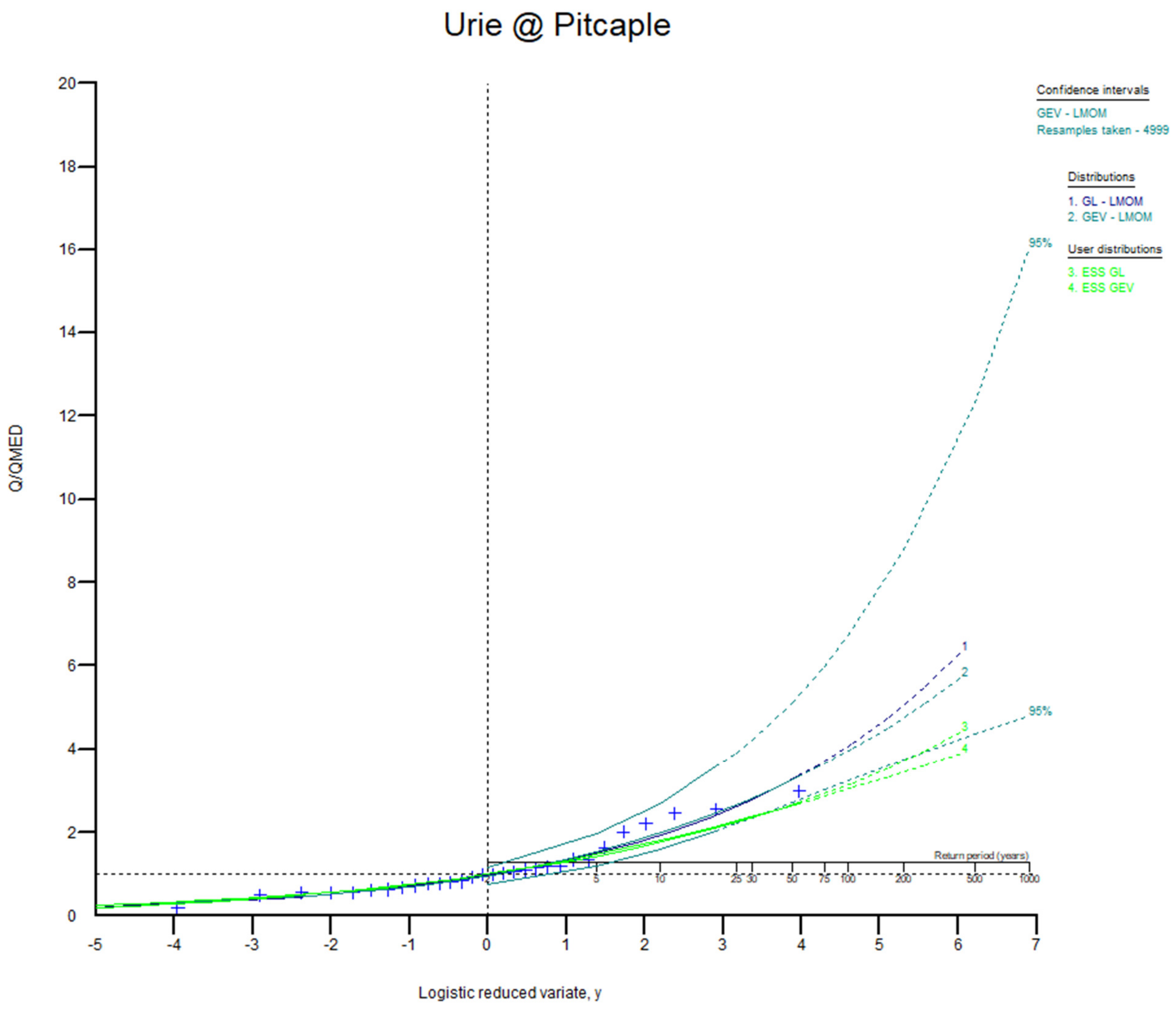


Table 3-7: Peak flow estimates: SS confidence limits for the Urie at Pitcaple

Annual Probability [AP] (%)	Return Period (years)	Urie at Pitcaple Single Site Statistical Method Flow: GL (m^3/s)	Urie at Pitcaple Single Site Statistical Method Flow GL confidence limits (m^3/s)	Urie at Pitcaple Single Site Statistical Method Flow: GEV (m^3/s)	Urie at Pitcaple Single Site Statistical Method Flow GEV confidence limits (m^3/s)
50	2	30.73	23.994 - 37.145	30.4	23.765 - 36.851
20	5	47.11	37.029 - 60.189	47.96	37.653 - 61.830
10	10	60.51	48.487 - 80.669	62.08	49.855 - 83.664
4	25	81.94	67.545 - 117.684	83.37	69.053 - 121.859
3.33	30	86.89	71.924 - 126.515	88.05	73.199 - 130.782
2	50	102.2	85.129 - 155.284	102.1	85.087 - 159.556
1.33	75	116.11	96.431 - 184.053	114.31	94.580 - 185.853
1	100	127.07	104.869 - 207.051	123.6	101.415 - 206.991
0.5	200	157.75	126.365 - 273.660	148.36	117.461 - 268.161
0.2	500	209.75	158.171 - 397.703	187	137.489 - 377.599
0.1	1000	260.12	186.212 - 533.978	221.49	152.280 - 486.525

3.2.3 River Don at Parkhill

There is a SEPA gauging station at Parkhill (station number 11001) with 49 years of AMAX (spanning water years 1969 to 2018). As part of the recent update to the Parkhill rating, SEPA commissioned additional survey work on the River Don at locations upstream and downstream of the gauging station at Parkhill and a 1D/2D model including the Parkhill reach developed for rating work using this survey. It is therefore anticipated that the Inverurie 1D/2D hydraulic model will be consistent with the Parkhill model and will therefore extend to the cross section furthest downstream of Parkhill and minimise the influence of downstream boundary conditions on simulated water levels at the gauging station.

A new high flow rating was developed using the Parkhill 1D/2D hydraulic model. The new rating has been applied only to the SEPA AMAX series above the gauged range (i.e. stage of 3.702 m and flow of 307.11 m^3/s). The updated AMAX series used in calculation of peak flows are shown Table 3-8..

Given the reasonable record length at Parkhill and the rating review, both enhanced single site analysis (ESS) and single site (SS) analysis were considered as possible alternatives for obtaining flood estimates. SEPA gauges suitable for pooling analysis were updated through water year 2016 with the remaining sites being from the most up-to-date HiFlows database (v6.0) with data up to 2016 for stations currently operating in England and Wales (the overall HiFlows dataset also includes data from stations closed prior to 2016). In both cases, a Generalised Logistic (GL) distribution was used for the growth curve, with additional tests using the Generalised Extreme Value (GEV) as described below. The results for Parkhill are given in Table 3-9. Additional information on the ESS pooling approach is provided in Appendix A. In all cases, a QMED value of 153 m^3/s at Parkhill as derived from the observed AMAX data was used.

In order to provide some historical context and inform the choice of method, the largest event on record at Parkhill was considered (January 2016, a flow of circa 576 m^3/s). Historical flooding has occurred on the Don since at least 1829. If it is assumed that the flood of 1829[16] was higher than the 2016 flood (and disregarding any changes in the catchment since 1829), then, for the period 1829 to 2018 the AP value of the 2016 event was estimated to be circa 0.82% AP (122 years; as calculated using Gringorten plotting positions) and 1829 event, 0.29% AP (340 year) event. The frequency of flooding for the 2016 event estimated using non-standardised SS analysis within WINFAP was circa 0.94% AP (106 years) to 0.81% (124 years) at Parkhill, using the GL and GEV distributions respectively. The ESS results are less consistent with the historical estimates with AP values of circa 0.25% AP (408 years) to greater than a 0.1% AP (1000 year) using the GL and GEV distributions respectively. It was therefore concluded that the SS approach was more in keeping with the historical information available and was adopted. Of the two distributions considered within the SS approach, arguably either the GL or GEV distribution were applicable for Parkhill. The SS GL growth curve fits the observed AMAX data well (Appendix A) and for consistency with the modelling of the upper Don[9] the GL distribution was applied. A 24% climate change allowance upon the 0.5% AP (200 year) event was applied, per SEPA guidance for Local Authority studies for the North East of Scotland[17].

As in any SS analysis, the findings may be subject to change following large floods and extrapolation to large flood (e.g. the 0.1% AP, 1000 year) events may be more uncertain than under a pooled approach. In order to provide an indication of uncertainty, 95% confidence limits for the SS curves generated via high resampling through the bootstrapping method available in WINFAP are shown in Figure 3-8, Figure 3-9 (for the GL and GEV growth curves, respectively) and Table 3-10. The confidence band at Parkhill is greater for the GEV distribution between the 20% AP (5 year) event and the 1% AP (100 year) event. For example, there is a range of 399 to 802 m^3/s for the 1% AP (100 year) using the GEV distribution compared to 420 to 818 m^3/s using the GL distribution. At the 50% AP (2 year), 0.5% AP (200 year), 0.2% AP (500 year) and 0.1 % AP (1000 year) events the confidence band at Parkhill is greater with the GL distribution. The narrower confidence band for the GL distribution at Parkhill for the majority of AP events supports the use of the SS GL growth curve at this site. Consideration of the 95% confidence range can be given during model sensitivity analysis.

The water levels produced from the model at the gauging station location can also be checked against those obtained using the FEH Statistical method. As Parkhill is understood to have a single

16 An email from Claire Wheeler, SEPA, dated 22 November 2017, intimated that the 1829 event on the Don is thought to be larger than the 2016 event.

17 SEPA – Flood Modelling Guidance for Responsible Authorities, Version 1.0

high flow control throughout its period of record, it was possible to undertake a single site analysis of the AMAX stage recorded at the station.

FEH Statistical single site analysis using the stage AMAX series with GL and GEV distributions were explored. The stage AMAX series is given in Table 3-11 and Figure 3-10 (for reference, level data to mAOD are also shown using the station datum of 32.35 mAOD[18]). Results are shown in Table 3-12 and Figure 3-11 and confidence limits in Table 3-13, Figure 3-12 and Figure 3-13. The 0.5% AP (200 year) flood was estimated to have a stage of circa 6.03 m (38.38 metres above Ordnance Datum, mAOD) or 5.65 m (38.00 mAOD) for the Don at Parkhill using GL and GEV distributions, respectively. The 2016 event of 5.56 m is estimated to have an AP value of 0.79% (127 years) and 0.56% (177 years) using the GL and GEV distributions, respectively which is broadly consistent with the single site analysis of flow described above.

18 Surveyed by Six West. JBA Consulting. 2018. 2017s6610 - Parkhill Rating Review Final Report v3.0.

Table 3-8: Parkhill AMAX data series. New rating has been applied to the AMAX series above the gauged record (stage of 3.702 m)

Date/Time	Stage (m)	Q (m^3/s)
24/03/1971 21:00	1.89	71.04
04/02/1972 21:00	2.29	112.67
05/05/1973 21:00	1.73	56.54
18/01/1974 21:00	2.31	115.58
23/11/1974 21:00	2.41	127.26
30/09/1976 21:00	2.24	106.96
16/10/1976 21:00	3.37	265.11
23/02/1978 21:00	2.50	138.53
09/12/1978 21:00	2.69	163.09
05/10/1979 21:00	2.56	146.18
02/12/1980 21:00	2.34	118.04
03/10/1981 21:00	2.62	153.48
13/10/1982 21:00	3.45	279.55
27/03/1984 21:00	2.61	151.91
04/11/1984 21:00	3.10	222.08
02/12/1985 21:00	2.66	158.39
18/07/1987 21:00	2.13	94.51
25/01/1988 21:00	2.70	164.03
19/10/1988 21:00	2.53	142.34
01/07/1990 20:00	1.72	53.27
29/10/1990 16:15	2.35	119.58
19/11/1991 12:30	2.37	122.67
17/01/1993 18:45	2.04	85.58
08/10/1993 17:15	2.95	200.24
12/09/1995 16:30	3.61	306.01
11/02/1996 01:30	3.35	262.63
02/07/1997 08:45	2.43	128.97
05/04/1998 14:00	3.53	291.88
15/11/1998 04:15	2.40	125.92
27/04/2000 09:45	3.82	327.26
11/10/2000 15:30	3.02	209.76
21/07/2002 06:45	2.62	152.96
22/11/2002 14:15	4.17	375.13
19/08/2004 23:30	2.57	146.70
16/10/2004 21:30	2.20	102.26
03/12/2005 17:30	2.83	181.76
06/08/2007 23:45	2.51	139.29
23/11/2007 00:45	2.79	176.00
05/09/2009 00:00	3.10	221.44
02/11/2009 12:30	3.74	315.50
11/12/2010 17:45	3.29	252.31
26/04/2012 12:15	2.49	137.27
23/12/2012 12:00	3.52	291.53
30/01/2014 00:15	2.95	198.91
08/10/2014 12:30	2.80	178.37
08/01/2016 07:00	5.56	576.16
16/10/2016 07:45	2.19	100.93

Figure 3-7: AMAX series at Parkhill

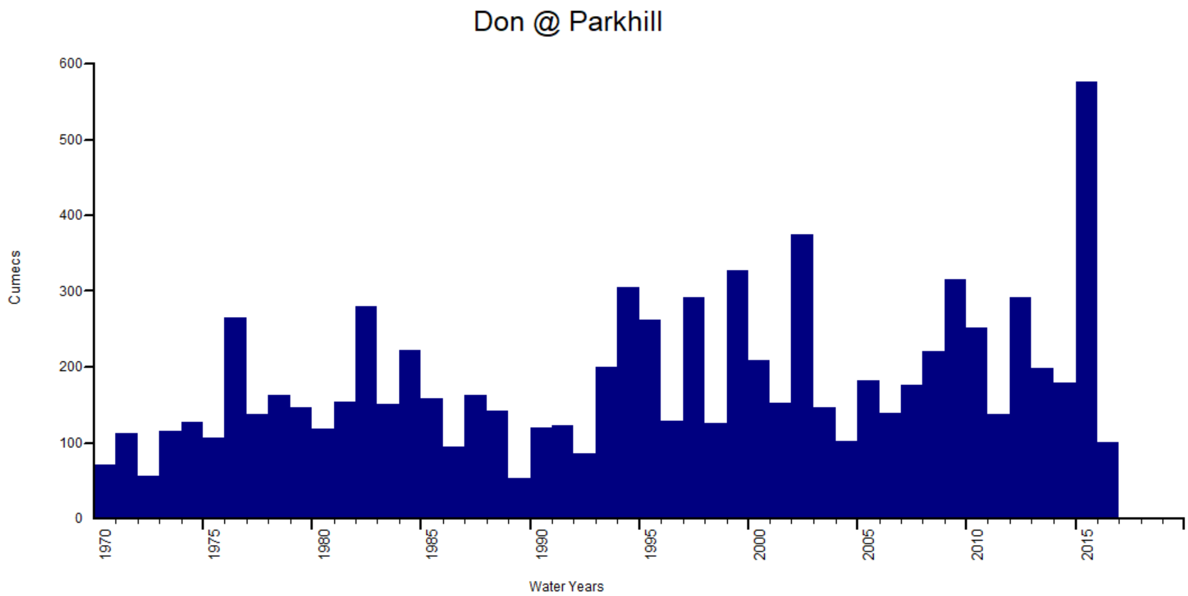


Table 3-9: Peak flow estimates: statistical estimates for the River Don at Parkhill

Annual Probability [AP] (%)	Return Period (years)	River Don at Parkhill Gauging Station. Single Site Statistical Method Flow: GL (m^3/s)	River Don at Parkhill Gauging Station. Single Site Statistical Method Flow: GEV (m^3/s)	River Don at Parkhill Gauging Station. Enhanced Single Site Statistical Flow: GL (m^3/s)	River Don at Parkhill Gauging Station. Enhanced Single Site Statistical Flow: GEV (m^3/s)
50	2	160.40	158.90	153.11	153.14
20	5	234.30	238.60	214.78	221.18
10	10	292.70	300.00	258.62	266.83
4	25	383.30	388.90	320.90	325.20
3.33	30	403.90	407.90	334.23	336.72
2	50	466.70	464.20	373.61	369.00
1.33	75	522.90	512.00	407.27	394.66
1	100	566.60	547.80	432.57	412.91
0.5	200	687.10	641.00	498.92	457.09
0.2	500	885.90	781.00	599.94	516.03
0.1	1000	1073.40	901.40	688.03	561.09
3.33 +CC	30 +CC	500.84	505.80	414.44	417.54
0.5 + CC	200 +CC	852.00	794.84	618.66	566.79
0.5 specific discharge (l/s/km^2)	200	0.54	0.50	0.39	0.36
0.5 growth factor	200	4.28	4.03	4.03	3.26

Figure 3-8: SS and ESS growth curves for Parkhill SS GL 95% confidence limits

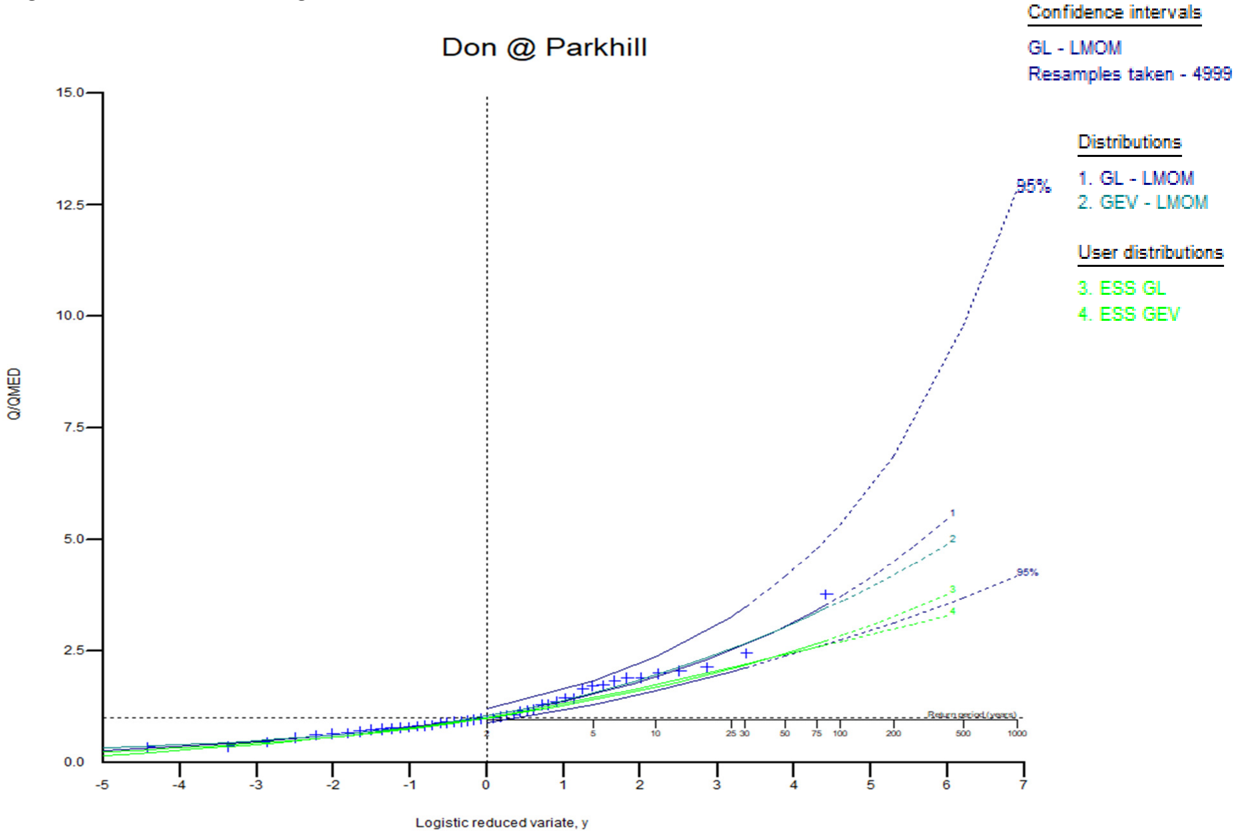


Figure 3-9: SS and ESS growth curves for Parkhill SS GEV 95% confidence limits

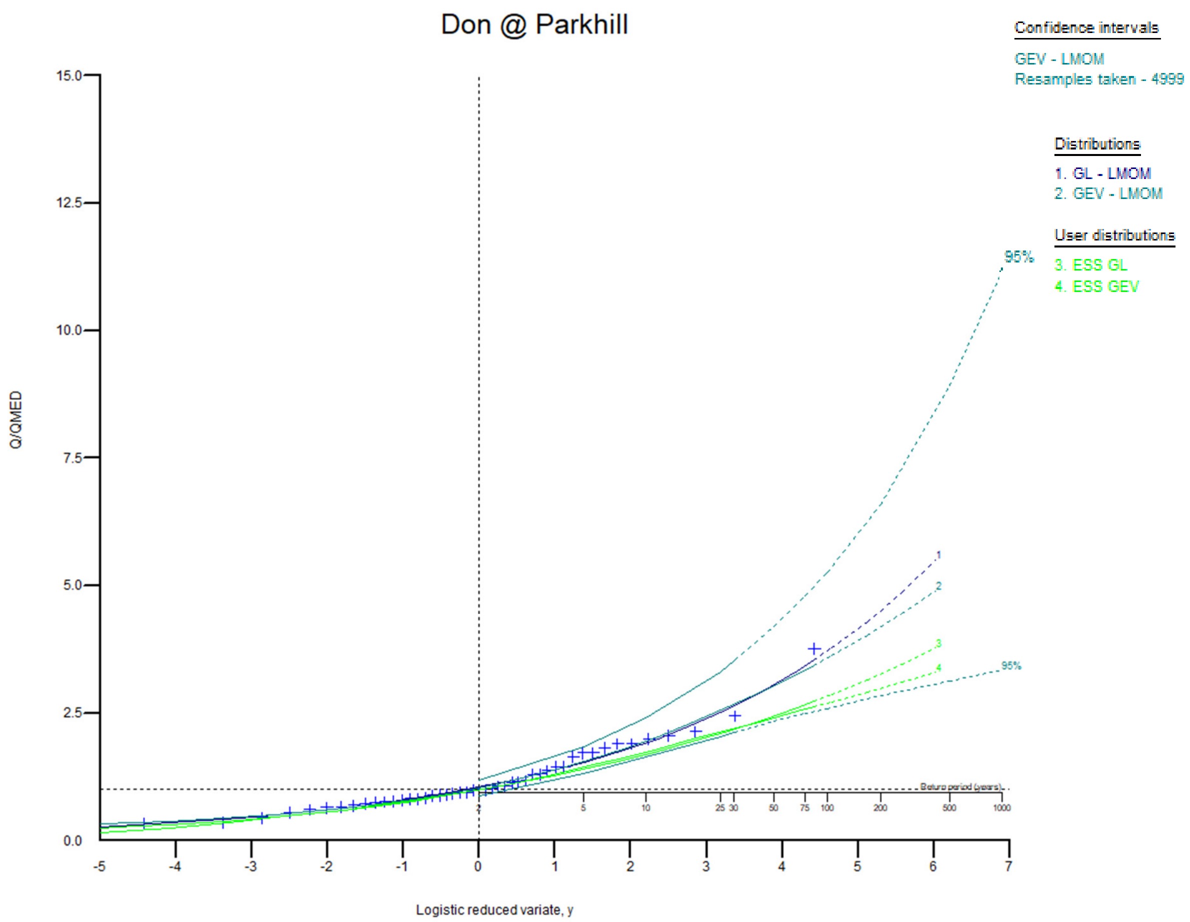


Table 3-10: Peak flow estimates: confidence limits for the Don at Parkhill

Annual Probability [AP] (%)	Return Period (years)	Don at Parkhill Single Site Statistical Method Flow: GL (m^3/s)	Don at Parkhill Single Site Statistical Method Flow GL confidence limits (m^3/s)	Don at Parkhill Single Site Statistical Method Flow: GEV (m^3/s)	Don at Parkhill Single Site Statistical Method Flow GEV confidence limits (m^3/s)
50	2	160.40	136.690 - 184.118	158.90	135.334 - 182.335
20	5	234.30	198.863 - 278.571	238.60	203.010 - 284.606
10	10	292.70	244.025 - 358.709	300.00	252.547 - 370.141
4	25	383.30	310.845 - 497.199	388.90	314.420 - 508.567
3.33	30	403.90	324.828 - 530.437	407.90	326.550 - 540.771
2	50	466.70	363.069 - 637.310	464.20	359.413 - 639.073
1.33	75	522.90	396.613 - 736.427	512.00	383.376 - 727.388
1	100	566.60	420.605 - 818.672	547.80	399.419 - 802.040
0.5	200	687.10	479.773 - 1055.008	641.00	434.838 - 1004.098
0.2	500	885.90	566.259 - 1506.709	781.00	480.818 - 1360.860
0.1	1000	1073.40	639.270 - 1991.962	901.40	505.130 - 1712.680

Table 3-11: Parkhill stage AMAX data series.

Date	Stage (m)	Level (mOD)
24/03/1971	1.89	34.24
04/02/1972	2.29	34.64
05/05/1973	1.73	34.08
18/01/1974	2.31	34.66
23/11/1974	2.41	34.76
30/09/1976	2.24	34.59
16/10/1976	3.37	35.72
23/02/1978	2.50	34.85
09/12/1978	2.69	35.04
05/10/1979	2.56	34.91
02/12/1980	2.34	34.69
03/10/1981	2.62	34.97
13/10/1982	3.45	35.80
27/03/1984	2.61	34.96
04/11/1984	3.10	35.45
02/12/1985	2.66	35.01
18/07/1987	2.13	34.48
25/01/1988	2.70	35.05
19/10/1988	2.53	34.88
01/07/1990	1.72	34.07
29/10/1990	2.35	34.70
19/11/1991	2.37	34.72
17/01/1993	2.04	34.39
08/10/1993	2.95	35.30
12/09/1995	3.61	35.96
11/02/1996	3.35	35.70
02/07/1997	2.43	34.78
05/04/1998	3.53	35.88
15/11/1998	2.40	34.75
27/04/2000	3.82	36.17
11/10/2000	3.02	35.37
21/07/2002	2.62	34.97
22/11/2002	4.17	36.52
19/08/2004	2.57	34.92
16/10/2004	2.20	34.55
03/12/2005	2.83	35.18
06/08/2007	2.51	34.86
23/11/2007	2.79	35.14
05/09/2009	3.10	35.45
02/11/2009	3.74	36.09
11/12/2010	3.29	35.64
26/04/2012	2.49	34.84
23/12/2012	3.52	35.87
30/01/2014	2.95	35.30
08/10/2014	2.80	35.15
08/01/2016	5.56	37.91
16/10/2016	2.19	34.54

Figure 3-10: AMAX series at Parkhill

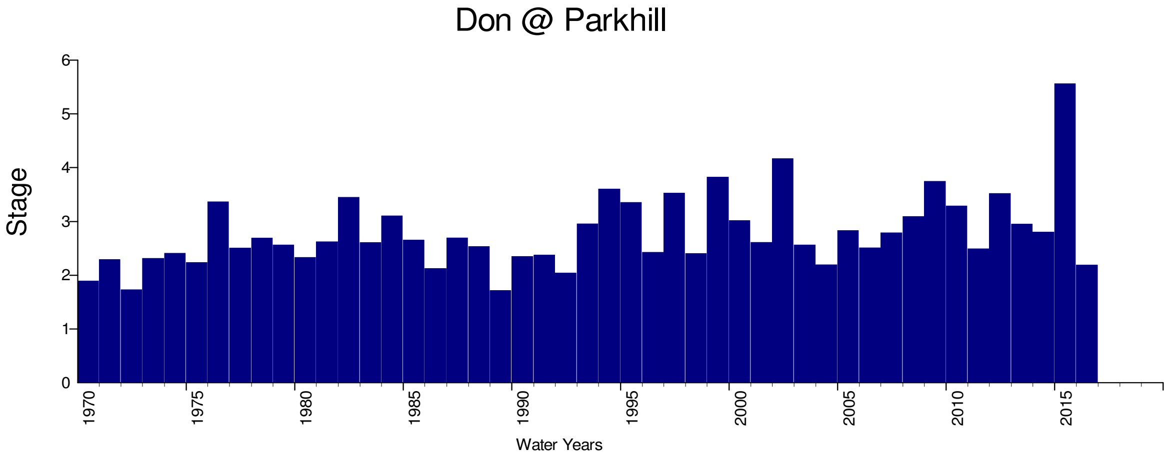


Table 3-12: Peak stage estimates: statistical estimates for the River Don at Parkhill

Annual Probability [AP] (%)	Return Period (years)	River Don at Parkhill Single Site Statistical Method Stage: GL (m)	River Don at Parkhill Single Site Statistical Method Stage: GEV (m)	River Don at Parkhill Single Site Statistical Method Level: GL (mAOD)	River Don at Parkhill Single Site Statistical Method Level: GEV (mAOD)
50	2	2.66	2.65	35.01	35.00
20	5	3.20	3.24	35.55	35.59
10	10	3.61	3.66	35.96	36.01
4	25	4.20	4.23	36.55	36.58
3.33	30	4.33	4.35	36.68	36.70
2	50	4.73	4.68	37.08	37.03
1.33	75	5.07	4.95	37.42	37.30
1	100	5.33	5.15	37.68	37.50
0.5	200	6.03	5.65	38.38	38.00
0.2	500	7.13	6.35	39.48	38.70
0.1	1000	8.12	6.91	40.47	39.26

Figure 3-11: SS growth curves for Don at Parkhill

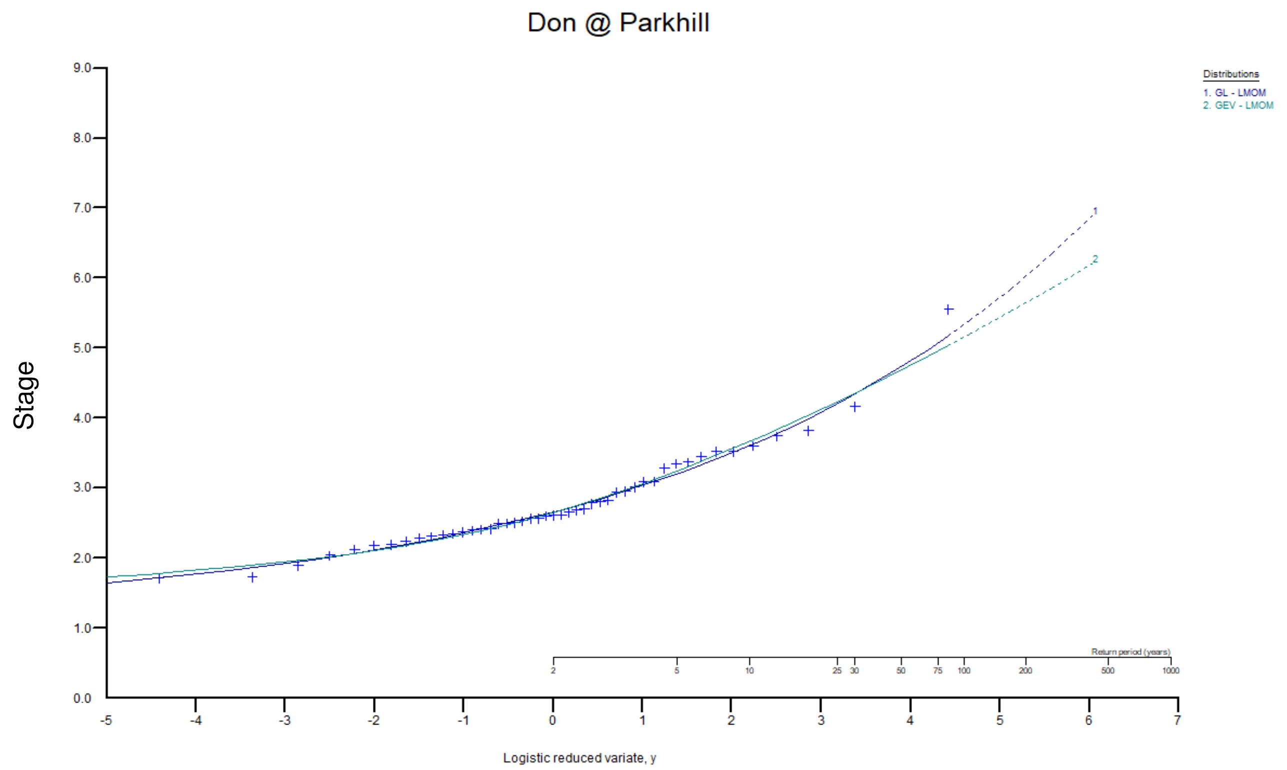


Figure 3-12: SS GL growth curve for Don at Parkhill with 95% confidence limits

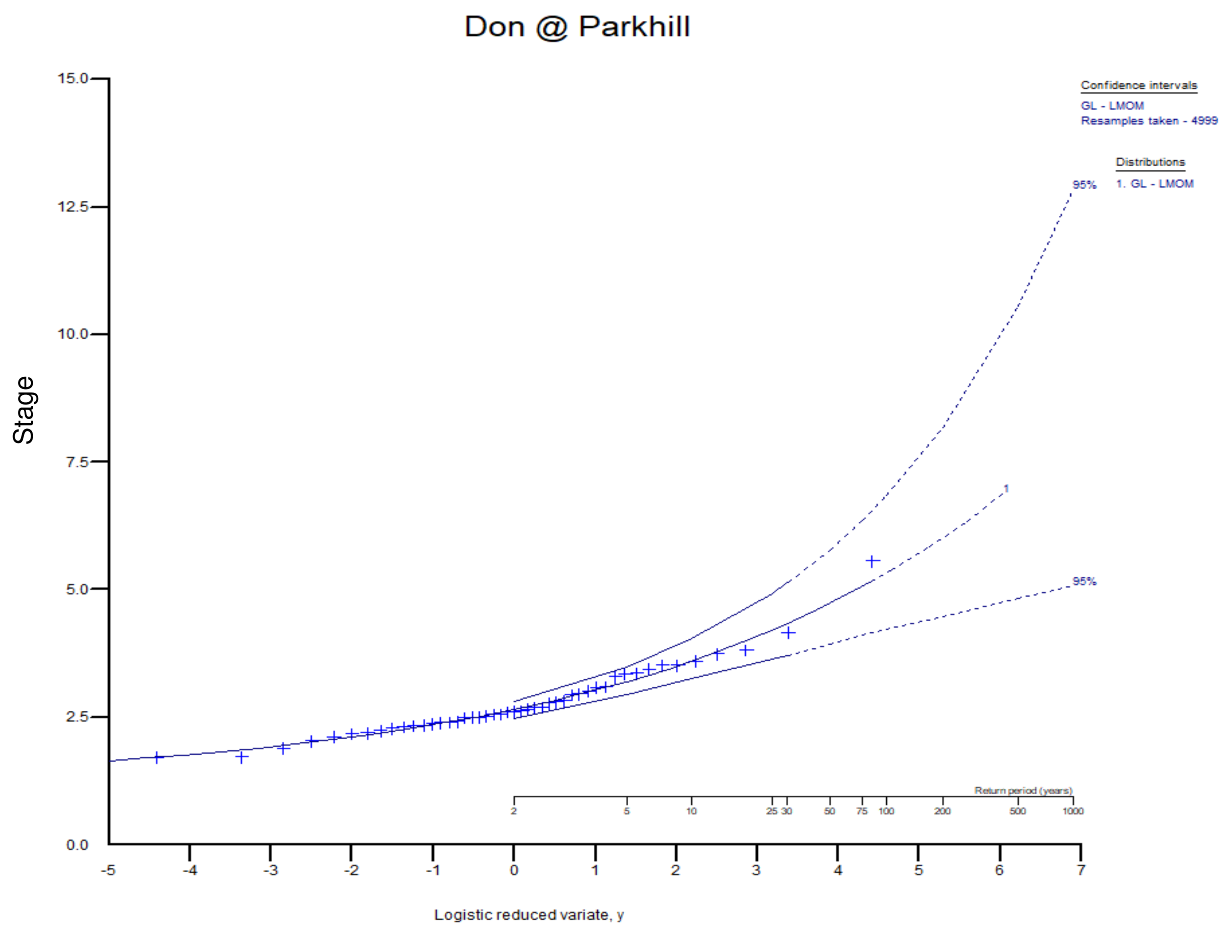


Figure 3-13: SS GEV growth curve for Don at Parkhill with 95% confidence limit

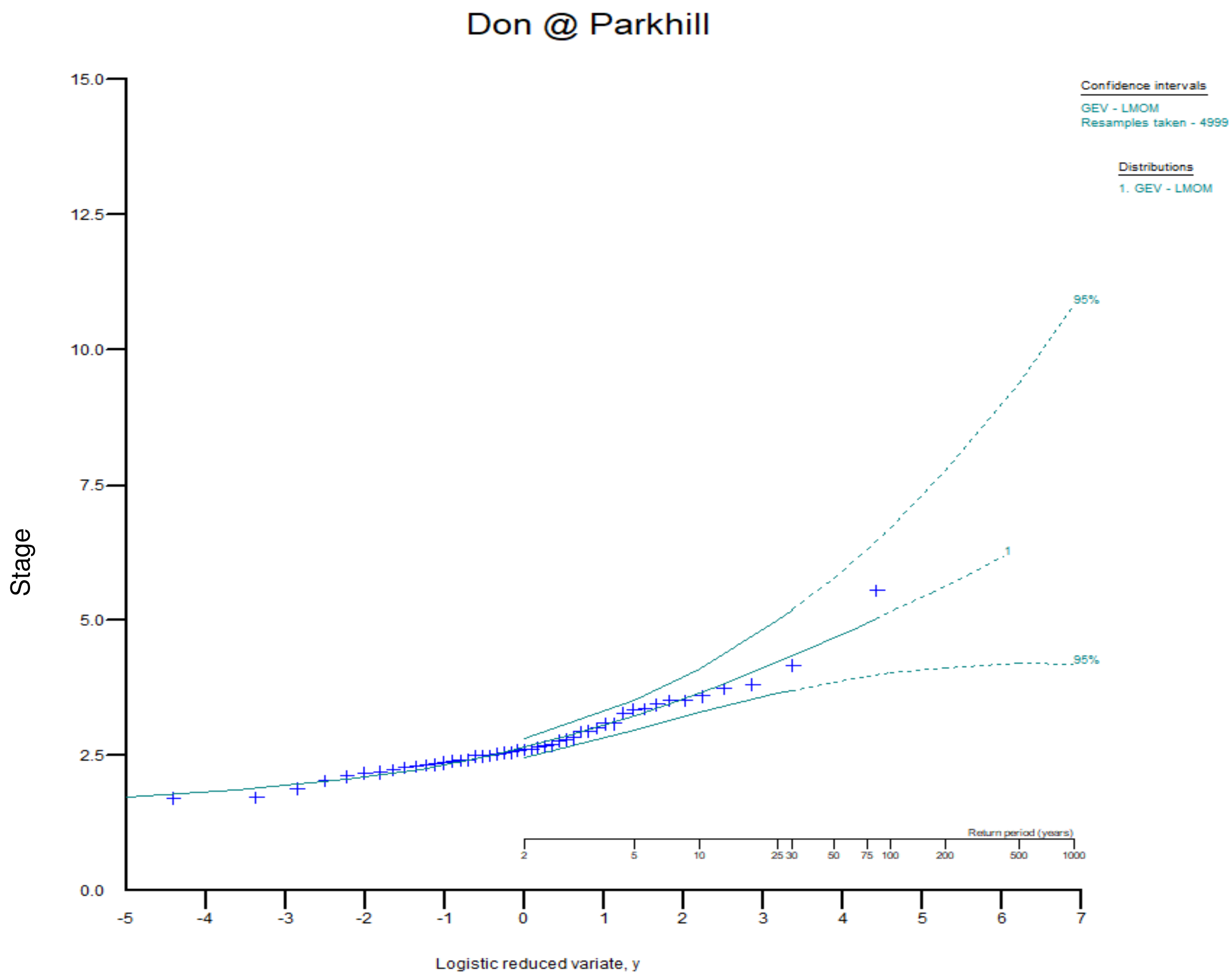


Table 3-13: Peak stage estimates: confidence limits for the River Don at Parkhill

Annual Probability [AP] (%)	Return Period (years)	River Don at Parkhill Single Site Statistical Method Stage: GL (m)	River Don at Parkhill Single Site Statistical Method Stage: GL confidence limits (m)	River Don at Parkhill Single Site Statistical Method Stage: GEV(m)	River Don at Parkhill Single Site Statistical Method Stage: GEV confidence limits (m)
50	2	2.66	2.464 - 2.833	2.65	2.433 - 2.821
20	5	3.20	2.914 - 3.528	3.24	2.950 - 3.546
10	10	3.61	3.220 - 4.101	3.66	3.274 - 4.147
4	25	4.20	3.638 - 4.984	4.23	3.652 - 5.021
3.33	30	4.33	3.709 - 5.184	4.35	3.717 - 5.209
2	50	4.73	3.917 - 5.848	4.68	3.868 - 5.814
1.33	75	5.07	4.130 - 6.449	4.95	3.954 - 6.309
1	100	5.33	4.265 - 6.921	5.15	3.953 - 6.675
0.5	200	6.03	4.558 - 8.240	5.65	4.008 - 7.649
0.2	500	7.13	4.924 - 10.439	6.35	4.093 - 9.154
0.1	1000	8.12	5.017 - 12.633	6.91	3.993 - 10.612

3.3 Timings of peak flows on the River Urie and River Don

Although Inverurie is at risk of flooding from both the Rivers Urie and Don, historically, flooding has generally been generated from the same catchment wide storm event which affects both rivers. As an example, a comparison of the timing of the peak flow on the Urie (at Pitcaple) and the Don (at Haughton) for three AMAX events is shown in Table 3-14 and graphically in the following figures. It can be seen that, in general, the shape and timing of peak flow on the Urie and Don are broadly similar for these events. It was therefore concluded that use of a single, consistent storm duration across the catchment (39 h, Section 3.5.2) was sufficient for the purpose of estimating flood risk at Inverurie and that separate Urie and Don based runs were not required.

Table 3-14: Comparison of peak flow timings on the River Urie and River Don

Date	Time of peak at Pitcaple	Time of Peak at Haughton	Difference (hours)
7-8 Jan 2016	22:15	02:30	4.25
22 Nov 2002	01:30	07:00	5.50
27 Apr 2000	02:00	02:30	0.50

Figure 3-14: Comparison of peak timings on the Urie and Don - January 2016

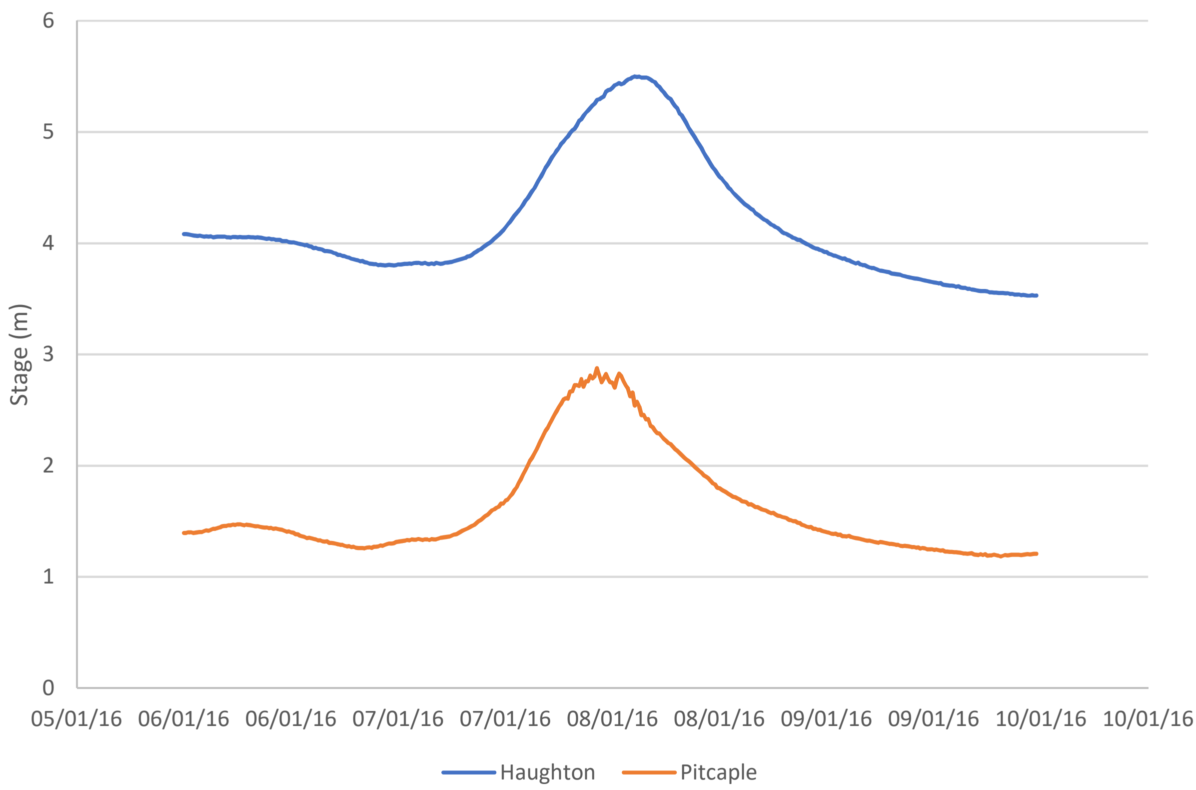


Figure 3-15: Comparison of peak timings on the Urie and Don - November 2002

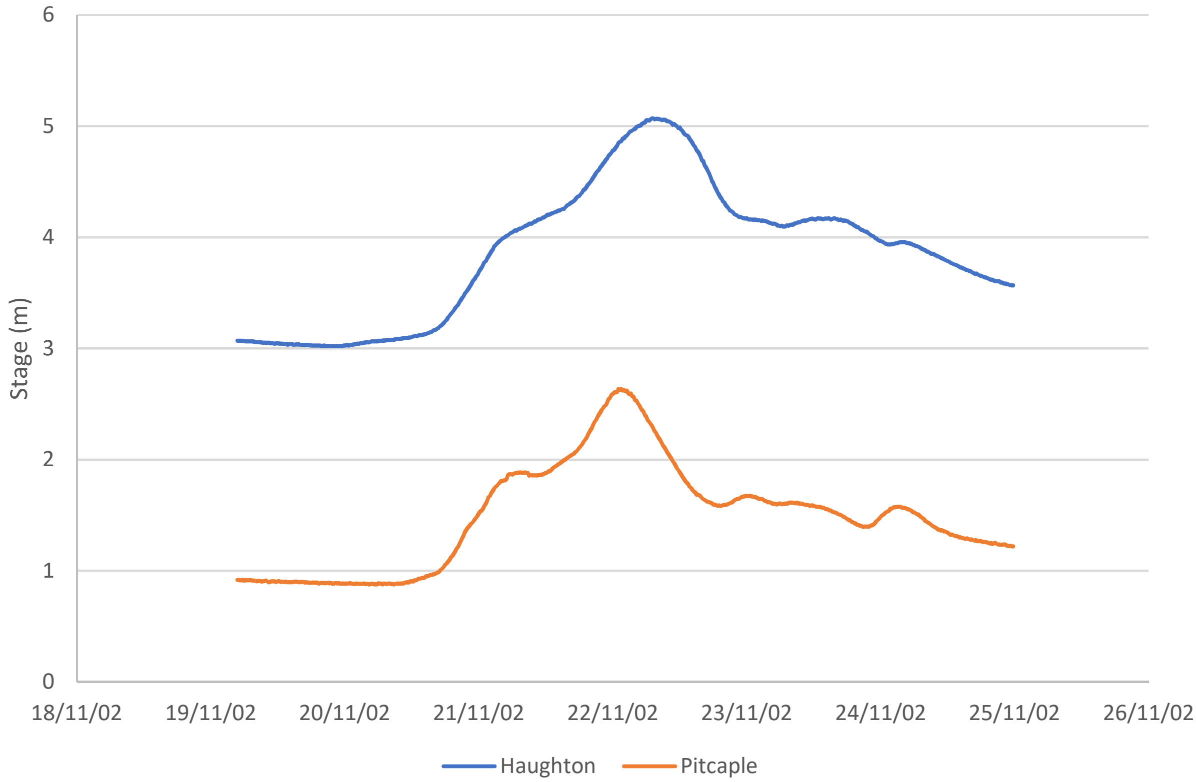
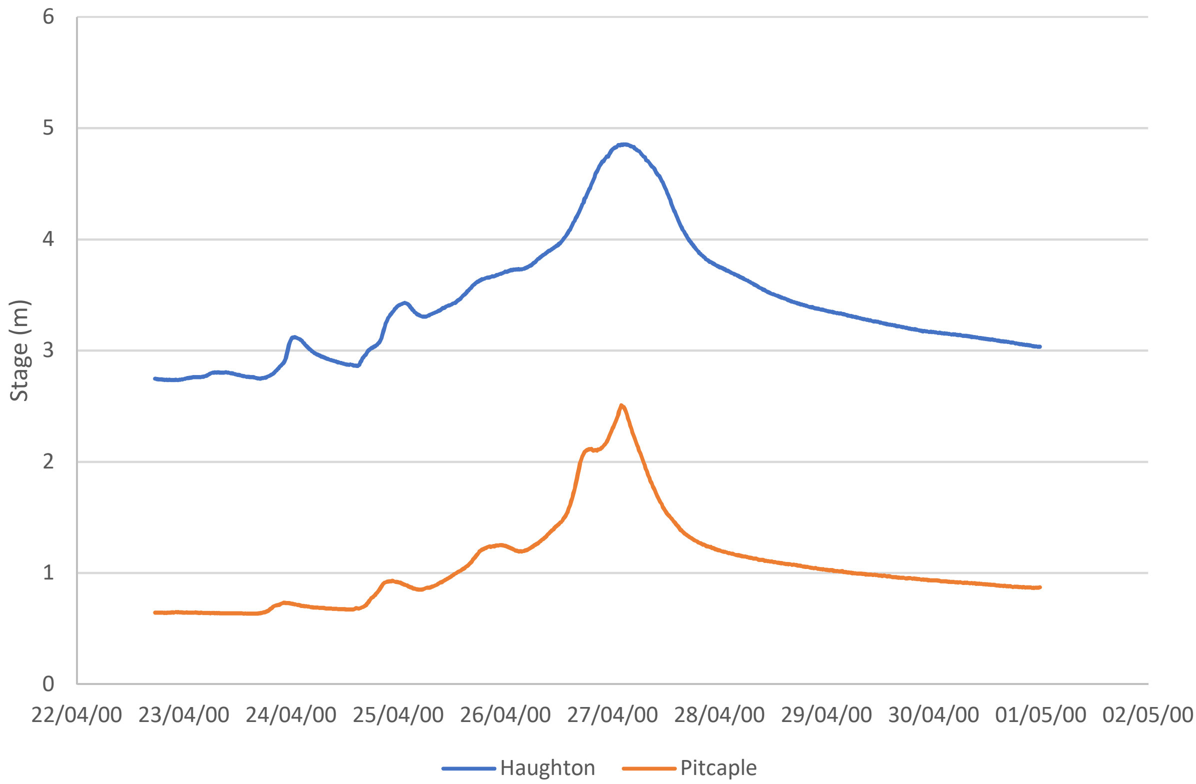


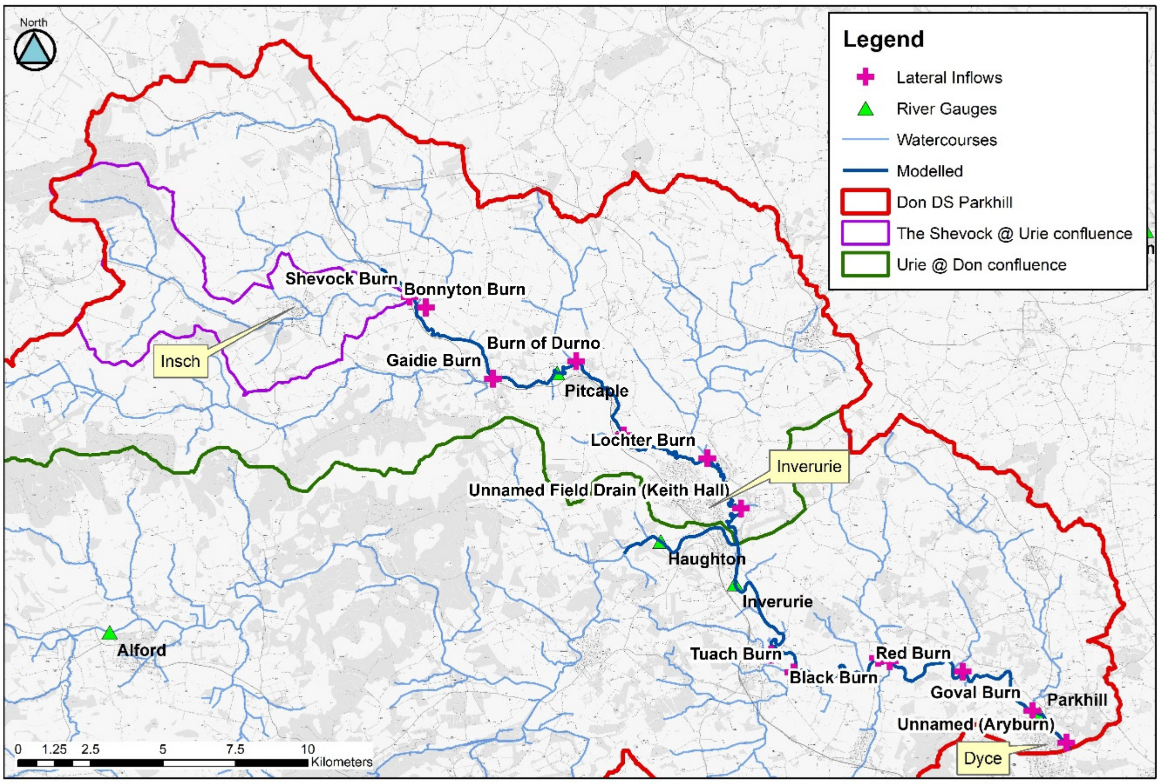
Figure 3-16: Comparison of peak timings on the Urie and Don - April 2000



3.4 Lateral inflows for modelling

Peak flow estimates and hydrographs for the River Don and River Urie tributaries were also required for the hydraulic model. The major lateral inflows will be represented using ReFH units, with catchment areas increased to account for any additional inflows located between the major laterals (Table 3-15 and Table 3-16)[19]. For the calibration model runs, the ReFH units will be driven by data from appropriate raingauges. It is anticipated that the Milton o Noth and / or Rhynie raingauge will be used for the western Urie laterals, Rothienorman for the eastern Urie laterals and Westhill for tributaries downstream of Inverurie. For the design runs, the peaks of the ReFH estimates will be scaled to ReFH2 with FEH13 rainfall estimates based on a storm duration of 39 h (Table 3-17 and Table 3-18). Of the available rainfall runoff methods, ReFH2 with FEH13 rainfall is considered more appropriate for scaling lateral inflows than the FEH Rainfall Runoff method due to the lateral catchment sizes e.g. the Lochter Burn at Inverurie has a catchment area of approximately 66 km^2 (the FEH Rainfall Runoff method is generally better suited to small catchments). The Shevock Burn inflow will be scaled to the Statistical pooling peak flow estimate for consistency with the Insch flood study[20].

Figure 3-17: Model extent and lateral inflow locations



19 Significant increases in catchment area are noted at the Strathnaterick, Keith Hall, Bridgealehouse, Red and Tuach Burn's. It is anticipated resulting higher flows from these tributaries will not affect flood risk at key communities. For example, the Bridgealehouse Burn at Kintore enters the Don downstream of the railway which is likely to limit flooding to Kintore itself.

20 JBA Consulting. Insch Hydrology Report. Final Report. May 2018.

Table 3-15: Catchment descriptors for Urie lateral inflows

Catchment Descriptor	The Shevock	Bonnyton burn	Gaidie Burn	Burn of Durno	Strathnaterick Burn	Lochter Burn	Keith Hall
AREA (km^2)	40.25 adjusted (39.62 default)	21.52 adjusted for modelling (19.16 default)	74.09 adjusted for modelling (65.63 default)	26.85 adjusted for modelling (20.02 default)	11.00 adjusted for modelling (5.55 default)	65.74 adjusted for modelling (60.51 default)	10.54 adjusted for modelling (3.40 default)
ALTBAR (m above sea level)	204	150	226	117	45	115	107
BFIHOST	0.569	0.551	0.534	0.551	0.511	0.574	0.692
DPLBAR (km)	9.74	5.72	12.29	45.4	2.59	8.01	1.81
FARL	1	1	0.998	1	1	0.998	1
FPEXT	0.0417	0.0902	0.046	0.054	0.026	0.038	0.032
FPDBAR	0.446	0.555	0.401	0.36	0.236	0.522	0.265
SAAR (mm)	868	841	872	815	816	827	789
SAAR4170 (mm)	867	822	924	800	829	830	836
SPRHOST (%)	32.32	30.61	33.49	32.99	31.84	30.55	26.06
URBEXT 1990	0.007 adjusted (0.0068 default)	0.0022 default	0.0011 default	0.0024 default	0.0018 default	0.0053 default	0.0007 default
URBEXT 2000	0.008 adjusted (0.0077 default)	0.0015 default	0.0013 default	0.0014 default	0.0000 default	0.0063 default	0.0000 default

Table 3-16: Catchment descriptors for Don lateral inflows

Catchment Descriptor	Bridgealehouse Burn	Tuach Burn	Newmill Burn	Black Burn	Red Burn	Goval Burn	Ayrburn
AREA (km^2)	20.12 adjusted for modelling (6.21 default)	28.93 adjusted for modelling (28.06 default)	34.58 adjusted for modelling (25.43 default)	27.16 adjusted for modelling (26.85 default)	11.44 adjusted for modelling (6.80 default)	48.37 adjusted for modelling (39.99 default)	5.46 adjusted for modelling (0.70 default)
ALTBAR (m above sea level)	88	98	108	124	97	106	64
BFIHOST	0.608	0.604	0.686	0.622	0.745	0.739	0.725
DPLBAR (km)	3.59	6.48	5.88	6.73	3.7	42.2	1.02
FARL	0.995	1	1	0.999	1	0.983	1
FPEXT	0.054	0.093	0.061	0.067	0.073	0.065	0.036
FPDBAR	0.606	0.646	0.473	0.486	0.518	0.534	0.179
SAAR (mm)	764	784	797	811	787	812	775
SAAR4170 (mm)	797	851	873	886	877	914	894
SPRHOST (%)	29.03	27.62	22.01	29.68	20.08	20.07	23.08
URBEXT 1990	0.0183 default	0.004 default	0.0008 default	0.005 default	0.0002 default	0.0046 default	0.0000 default
URBEXT 2000	0.0322 default	0.0067 default	0.0002 default	0.0135 default	0.0018 default	0.0072 default	0.0000 default

Table 3-17: Peak flow estimates: Urie laterals (ReFH2 with FEH13, storm duration 39 h)

Annual Probability [AP] (%)	Return Period (years)	The Shevock (Statistical pooling GEV flow m^3/s)	Bonnyton Burn (m^3/s)	Gaidie Burn (m^3/s)	Burn of Durno (m^3/s)	Strathnaterick Burn (m^3/s)	Lochter Burn (m^3/s)	Keith Hall (m^3/s)
50	2	9.04	4.21	15.64	5.14	2.63	10.88	1.22
20	5	12.76	5.31	19.80	6.49	3.33	13.76	1.59
10	10	15.15	6.20	23.19	7.59	3.91	16.15	1.90
4	25	18.12	7.59	28.37	9.31	4.79	19.81	2.37
3.33	30	18.69	7.90	29.49	9.68	4.98	20.61	2.48
2	50	20.27	8.80	32.78	10.79	5.54	22.97	2.77
1.33	75	21.50	9.55	35.49	11.72	6.02	24.93	3.02
1	100	22.36	10.10	37.46	12.40	6.36	26.38	3.20
0.5	200	24.42	11.49	42.44	14.11	7.22	30.00	3.66
0.2	500	27.07	13.43	49.39	16.50	8.43	35.05	4.29
0.1	1000	29.03	14.96	54.88	18.40	9.39	39.05	4.80
3.33 +CC	30 +CC	23.17	9.79	36.56	12.01	6.17	25.56	3.07
0.5 + CC	200 +CC	30.28	14.25	52.62	17.50	8.96	37.20	4.54

Table 3-18: Peak flow estimates: Urie laterals (ReFH2 with FEH13, storm duration 39 h)

Annual Probability [AP] (%)	Return Period (years)	Bridgealehouse Burn (m^3/s)	Tuach Burn (m^3/s)	Newmill Burn (m^3/s)	Black Burn (m^3/s)	Red Burn (m^3/s)	Goval Burn (m^3/s)	Ayrburn (m^3/s)
50	2	3.07	4.44	3.36	3.74	0.91	3.68	0.52
20	5	4.01	5.90	4.42	4.96	1.23	4.89	0.71
10	10	4.77	7.07	5.29	5.96	1.48	5.88	0.86
4	25	5.90	8.83	6.58	7.39	1.86	7.36	1.08
3.33	30	6.14	9.22	6.85	7.69	1.94	7.68	1.13
2	50	6.85	10.39	7.66	8.55	2.18	8.58	1.26
1.33	75	7.43	11.38	8.33	9.25	2.37	9.32	1.37
1	100	7.86	12.13	8.82	9.75	2.51	9.87	1.45
0.5	200	8.92	14.05	10.03	11.02	2.86	11.23	1.64
0.2	500	10.41	16.80	11.73	12.76	3.34	13.12	1.91
0.1	1000	11.59	19.05	13.08	14.15	3.73	14.63	2.13
3.33 +CC	30 +CC	7.62	11.43	8.50	9.54	2.41	9.52	1.40
0.5 + CC	200 +CC	11.07	17.42	12.44	13.67	3.54	13.92	2.04

3.5 Design hydrographs and storm durations

In addition to peak flow estimates, the hydraulic model also required the following information:

- Two fluvial hydrographs at the upstream extents on the Don and Urie.
- Appropriate storm durations for flood mapping.

3.5.1 Fluvial hydrographs

Although there are gauges at Haughton, Pitcaple and Parkhill, the upstream extents of the model are at ungauged locations on both the Urie and Don. A consistent approach was therefore required for hydrograph derivation and storm duration and this was achieved by using ReFH hydrographs at both upstream extents. As a check that this approach was appropriate, the available observed data close to the upstream extent of the Don reach of the model were considered. Specifically, a 0.5% AP (200 year) ReFH unit hydrograph was generated for the River Don at Haughton and then scaled to the 2016 AMAX peak flow of 396.23 m^3/s. This was compared to the observed 2016 hydrograph and was found to be very similar in shape (Figure 3-18) therefore supporting the use of the ReFH hydrograph. A consideration of other events at Haughton was also made (Figure 3-19, hydrographs have been normalised by peak stage in order to bring them to a common scale; note that the x-axis of this figure shows a longer duration than that of Figure 3-18 and the January 2016 event displays slightly differently as a result). This analysis identified that a number of the observed hydrographs have multiple peaks on both the rising and falling limbs making them less suitable for use in the hydraulic model.

The upstream extent of the model on the River Urie is ungauged and it was therefore not possible to compare a ReFH hydrograph with observed data at this location. For reference purposes only (Pitcaple is located circa 8 km downstream of the model's upstream extent), a ReFH hydrograph was generated for Pitcaple and compared with the observed data. This is shown in Figure 3-20, where it can be seen that there are some differences in shape between the ReFH and observed hydrographs, notably with respect to the duration of the peak. It is possible that the shape at Pitcaple is in part related to the influence of the bridge downstream of the gauging station and this would not be representative of the hydrograph at the upstream extent of the Urie. The hydraulic modelling approach will not apply a ReFH hydrograph directly at Pitcaple but will instead utilise a ReFH hydrograph at the upstream end of the Urie which will then, together with the ungauged lateral inflows, be routed to the confluence of the Don. Calibration runs using the hydraulic model with observed rainfall to drive the ReFH units for the 2002, 2009 and 2016 flood events suggest that the observed hydrograph shape at Pitcaple can be adequately simulated for those events using this approach[21].

Also for reference purposes only, a comparison of a ReFH hydrograph with observed data at Parkhill is shown in Figure 3-21. The ReFH hydrograph is broadly similar to the observed data although, similar to Pitcaple, there are some differences with respect to the duration of the peak.

21 JBA Consulting, Inverurie, Aberdeenshire Model Calibration Report. Draft Report. November 2018.

Figure 3-18: Comparison of the observed 2016 and scaled ReFH hydrographs

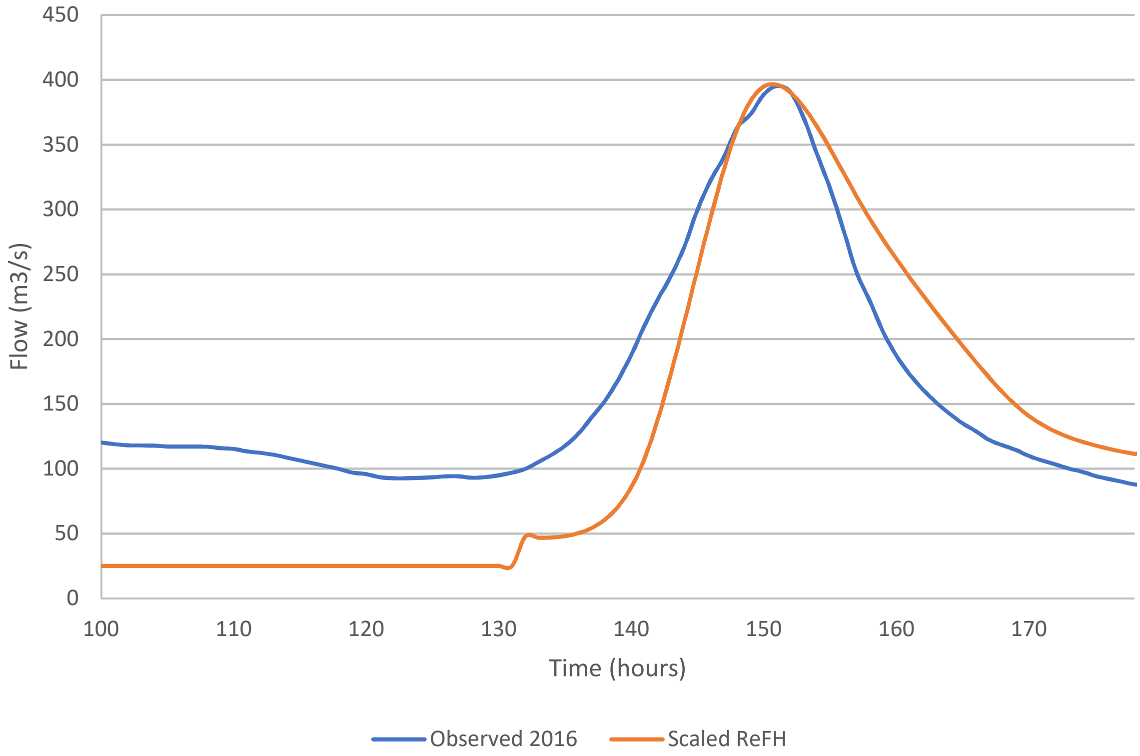


Figure 3-19: Observed and ReFH hydrograph comparison on the River Don at Haughton

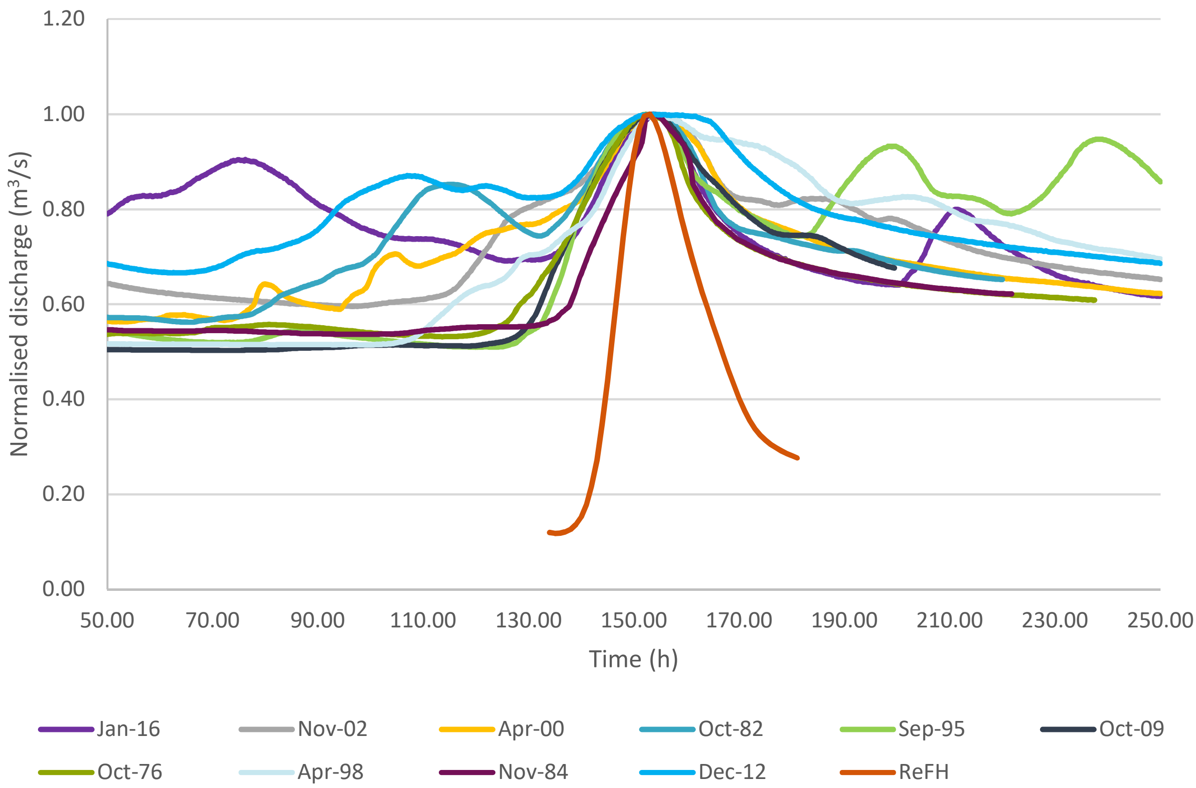


Figure 3-20: Observed and ReFH hydrograph comparison on the River Urie at Pitcaple

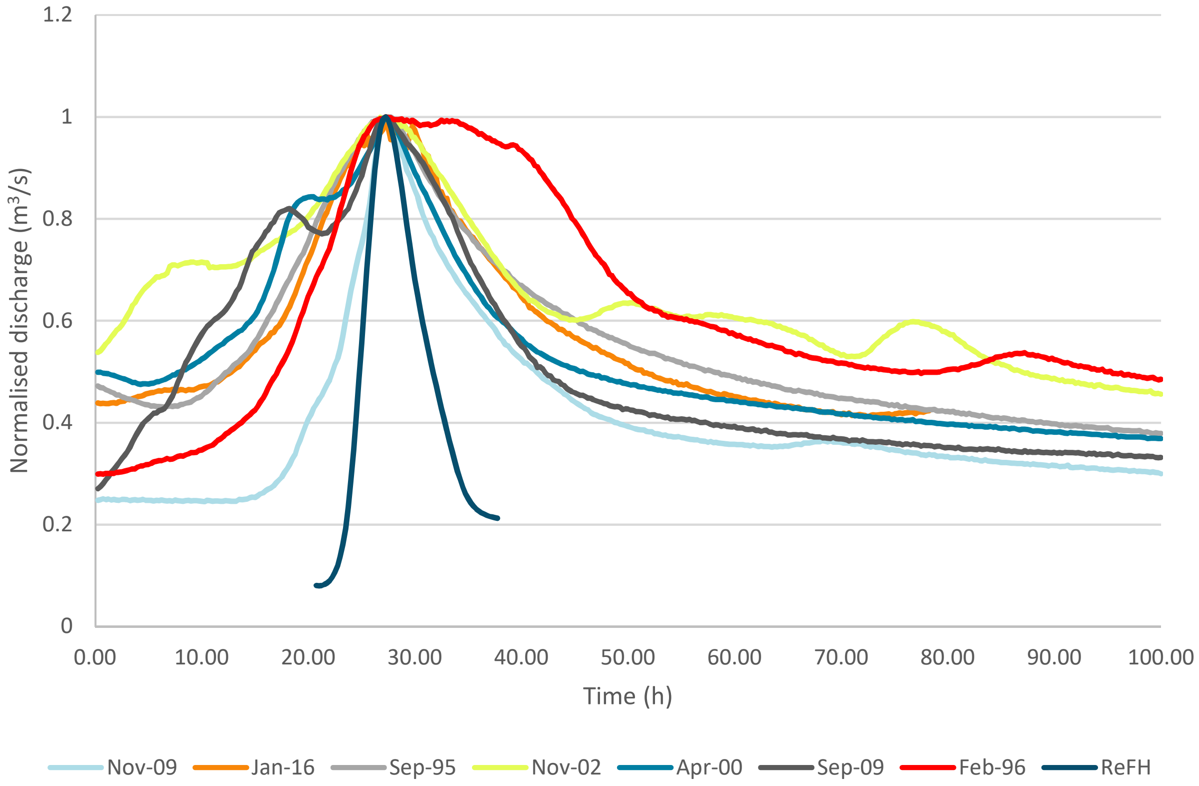
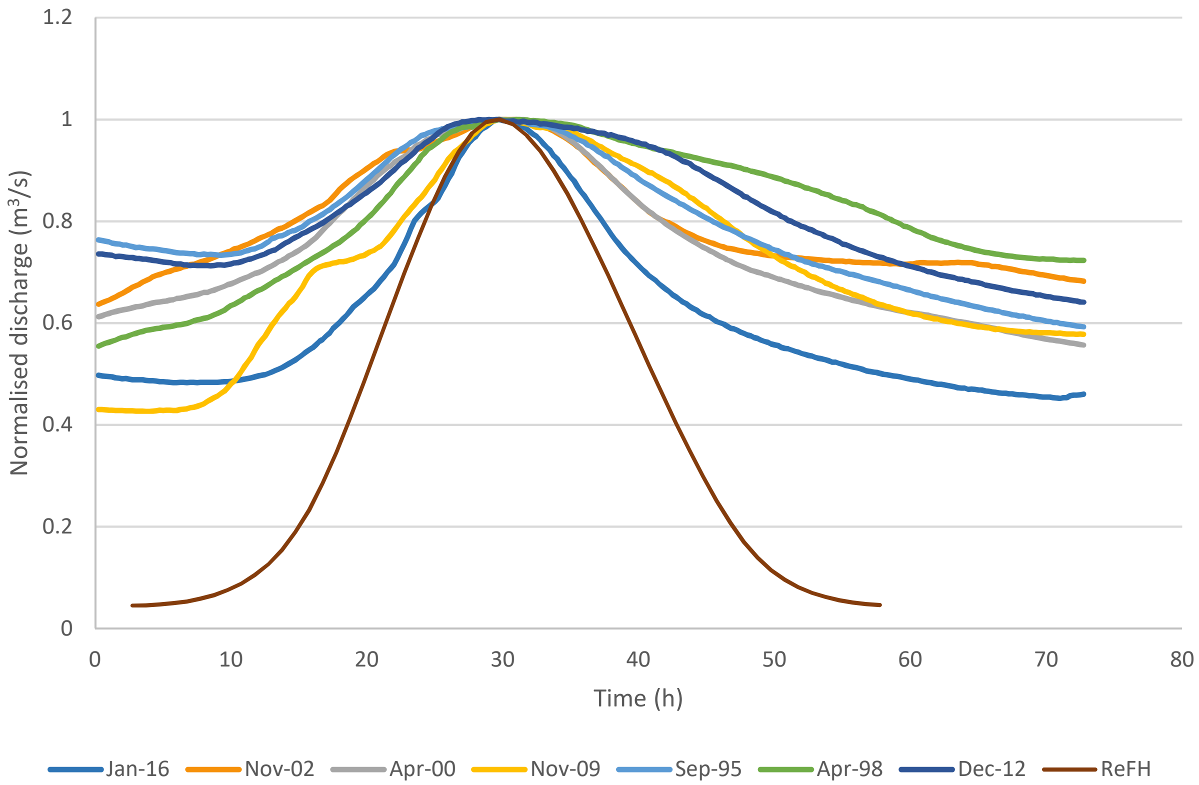


Figure 3-21: Observed and ReFH hydrograph comparison on the River Don at Parkhill



3.5.2 Storm durations

Observed hydrograph information was also considered together with rainfall data from the Deskry Shiel raingauge in order to provide an estimate of lag time (LAG) at Parkhill (the downstream point of the model) and therefore guide an appropriate catchment wide storm duration. LAG analysis at Parkhill for the 2016 event, the largest recorded flood on the Don, yielded a LAG of 21 h, Tp of 16 h and critical storm duration of 39 h[22]. This is consistent with the 'Don to Inverurie Flood Mapping' project[9] which yielded a critical storm duration of 30 h at Haughton gauging station.

Further storm duration analysis was undertaken for the top 7 flood events at the Parkhill gauging station within the period of record at Deskry Shiel (2008 - present): January 2016; November 2009; December 2012; December 2010; September 2009 and January 2014 and October 2014. This suite of events provided a suitably representative sample of flood events for calculating LAG, ranging from the top event with a stage of 5.6 m (January 2016) to the 18th ranked event with a stage of 2.8 m (October 2014). Combined analysis of the top 7 events yielded a geometric mean LAG value of 22.98 h with a range of 15 h for the November 2009 event to 33.5 h for the September 2009 event. Back-calculation from this LAG value yielded a Tp of 17.32 hours and storm duration of approximately 33 hours. Analysis of the top 3 AMAX events only within the period of record (January 2016, November 2009 and December 2012) gave a shorter average storm duration of 25 h. Calculation of storm duration at Parkhill using the FEH Rainfall Runoff method with catchment descriptors also yielded a storm duration of 25 h with Tp of 12.38 h.

On the basis that the 2016 event is the largest event on record, and for consistency with the 'Don to Inverurie Flood Mapping' project it was concluded the final storm duration to be modelled in the design runs for this project was 39 h.

22 Per equations 2.9 and 3.1 of FEH Volume 4.

4 Comparison with Previous Studies

CH2M in 2015 updated peak flow estimates on the River Urie at Pitcaple and River Don at Haughton using a Statistical SS approach[6]. Previous estimates by Halcrow in 2003 and then again in 2010, along with the CH2M estimates are compared with peak flows from this study in the tables below. It should be noted the ratings at Pitcaple and Parkhill were revised after the 2003 study, and again for this study, there is a longer period of record at each gauge and the most up-to-date HiFlows database (v6.0 February 2018), which undergoes frequent revision, was used in this study explaining the differences in peak flow estimates. In summary, the differences are as follows:

- QMED at Pitcaple increased by approximately 12% between the 2003 and 2015 studies, and by a further 10% in 2018.
- The 0.5% AP (200 year) peak flow at Pitcaple was 102.7 m^3/s, 199.3 m^3/s and 116.0 m^3/s in 2003, 2015 and 2018 respectively. The design flows calculated for this study are relatively similar to those obtained in 2003.
- QMED at Haughton increased approximately 4% between the 2003 and 2015 reports but was approximately 5% lower in this study compared to 2015.
- The 0.5% AP (200 year) peak flow was 389.9 m^3/s, 370.0 m^3/s and 480.54 m^3/s in 2003, 2015 and 2018 respectively.
- QMED at Parkhill increased by approximately 9% between the 2003 and 2015 studies with an additional 11 years of AMAX data, but remained approximately the same between 2015 and 2018 despite the rating review undertaken as part of this study (152.43 m^3/s compared to 152.96 m^3/s respectively). The AMAX record only increased by 3 years between the 2015 and 2018 studies, and the new rating was applied to the AMAX series above a stage of 3.702 m affecting only 4 records which explains the minimal impact on QMED.
- The 0.5% AP (200 year) peak flow at Parkhill was 674.0 m^3/s, 610.9 m^3/s and 679.99 m^3/s in 2003, 2015 and 2018 respectively. Similarly to Pitcaple the design flows calculated in this study were relatively similar to those obtained in 2003. Differences in the rating applied and influence of the length of the AMAX series may explain this.

Table 4-1: Peak flow estimate comparison for the Urie at Pitcaple

Gauging Station	2003 QMED (m^3/s)	2010 QMED (m^3/s)	2015 QMED (m^3/s)	2018 QMED (m^3/s)	Difference 2003 - 2015 (%)	Difference 2015 - 2018 (%)
Pitcaple	25.02	27.21	28.35	31.25	12	10
Haughton	112.40	112.40	117.10	111.70	4	-5
Parkhill	138.84	149.30	152.43	153.00	9	0

Table 4-2: Peak flow estimate comparison for the Urie at Pitcaple

Annual Probability [AP] (%)	Return Period (years)	2003 Statistical single site analysis flow (m^3/s)	2010 Statistical pooling analysis flow (m^3/s)	2015 Statistical single site analysis flow (m^3/s)	2018 JBA Statistical enhanced single site GL analysis flow (m^3/s)
50	2	25.0	27.1	27.9	31.3
10	10	46.9	56.4	61.9	55.0
2	50	72.7	98.5	117.0	83.2
0.1	100	86.6	124.0	152.7	98.34
0.5	200	102.7	155.8	199.3	116.0
0.5 +CC	200 +CC	123.2	187.0	239.1	143.8

Table 4-3: Peak flow estimate comparison for the Don at Haughton

Annual Probability [AP] (%)	Return Period (years)	2003 Statistical single site analysis flow (m^3/s)	2010 Statistical pooling analysis flow (m^3/s)	2015 Statistical single site analysis flow (m^3/s)	2018 JBA Statistical single site GL analysis flow (m^3/s)
50	2	112.4	112.4	124.8	111.69
10	10	187.5	176.7	196.2	196.42
2	50	279.5	247.3	277.8	317.22
0.1	100	330.3	283.7	320.8	390.06
0.5	200	389.9	324.8	370.0	480.54
0.5 +CC	200 +CC	467.9	389.8	443.9	595.87

Table 4-4: Peak flow estimate comparison for the Don at Parkhill

Annual Probability [AP] (%)	Return Period (years)	2003 Statistical single site analysis flow (m^3/s)	2010 Statistical pooling analysis flow (m^3/s)	2015 Statistical single site analysis flow (m^3/s)	2018 JBA Statistical single site GL analysis flow (m^3/s)
50	2	139.0	155.0	166.8	160.40
10	10	266.0	270.0	283.0	234.30
2	50	442.0	411.0	428.7	466.70
0.1	100	546.0	488.0	511.3	566.60
0.5	200	674.0	578.0	610.9	687.10
0.5 +CC	200 +CC	808.0	694.0	733.0	852.00

5 Conclusions

The River Don and River Urie have a history of flooding dating back to at least 1768 and the main risk areas within the modelled reach are at Inverurie, Port Elphinstone and Kintore. Direct flood risk to Inverurie and Port Elphinstone is from the fluvial Don and Urie. The River Urie has been known to back up during high flows on the Don. Hydrology estimates were required as input to a linked 1D/2D hydraulic model of the Don and Urie for use in flood mapping. Those estimates included the following.

- Extreme value estimates were required on the:
    - **River Urie at the Pitcaple** gauging station. FEH statistical methods were investigated for peak flow estimation and the adopted method was Enhanced Single Site (ESS) analysis with a Generalised Logistic (GL) distribution. A new rating developed by SEPA for use in this study was applied to the Pitcaple data prior to the analysis being undertaken. The 0.5% Annual Probability (AP, 200 year) flood was estimated to be circa 115.97 m^3/s for the Urie. Peak flows were also required north of Old Rayne (the upstream model extent) as a direct model input. For consistency, these were estimated using the ESS growth curve from Pitcaple with GL distribution and QMED adjusted using Pitcaple.
    - **River Don at the Haughton gauging station**. FEH statistical methods were investigated for peak flow estimation and the adopted method was Single Site (SS) analysis with a GL distribution. A new rating, agreed with SEPA for the JBA Consulting 'Upper Don to Inverurie Flood Mapping Study' was applied to the Haughton data, prior to the analysis being undertaken, and the agreed peak flow estimates at Haughton are to be applied here for consistency. The 0.5% AP (200 year) flood was estimated to be circa 480.54 m^3/s for the Don.
    - **River Don at Parkhill gauging station.** FEH statistical methods were investigated for peak flow estimation and the adopted method was SS analysis with a GL distribution. A new rating, agreed with SEPA for use in this study, was applied to the Parkhill data, prior to the analysis being undertaken. The 0.5% AP (200 year) flood was estimated to be circa 687.10 m^3/s for the Don. These statistical estimates will be compared directly with model outputs at the modelling stage to assist in model calibration and design event runs. An additional check will also be made using water levels produced from the model at the gauging station location against those extreme water level estimates obtained using the FEH Statistical method. As Parkhill is understood to have a single high flow control throughout its period of record, it was possible to undertake a single site analysis of the AMAX stage recorded at the station. For example, the 0.5% AP (200 year) flood was estimated to have a stage of circa 6.03 m (38.38 metres above Ordnance Datum, mAOD) or 5.65 m (38.00 mAOD) for the Don at Parkhill using GL and GEV distributions, respectively.

- **Fluvial hydrographs and critical storm durations.** Although there are gauges at Haughton, Pitcaple and Parkhill, the upstream extents of the model are at ungauged locations on both the Urie and Don. A consistent approach was therefore required for hydrograph derivation and storm duration and this was achieved by using ReFH hydrographs at both upstream extents. As a check that this approach was appropriate prior to modelling, ReFH hydrographs were also derived at Haughton, Parkhill and Pitcaple gauging stations and were found to have a similar shapes to the largest events. The critical model duration to be modelled is 39 hours based on LAG analysis of the 2016 event at Parkhill (the downstream model extent) using Deskry Shiel rain gauge.

Table 5-1: Summary of design peak estimates

Annual Probability [AP] (%)	Return Period (years)	River Don at Haughton Gauging Station. Single Site Statistical Method Flow: GL (m^3/s)	River Urie at Pitcaple Gauging Station. Enhanced Single Site Statistical Flow: GL (m^3/s)	River Don at Parkhill Gauging Station. Single Site Statistical Flow: GL (m^3/s)	River Don at Parkhill Single Site Statistical Method Stage: GL (m)	River Don at Parkhill Single Site Statistical Method Stage: GEV (m)
50	2	111.69	31.25	160.40	2.66	2.65
20	5	158.07	44.85	234.30	3.20	3.24
10	10	196.42	55.00	292.70	3.61	3.66
4	25	258.29	69.98	383.30	4.20	4.23
3.33	30	272.62	73.27	403.90	4.33	4.35
2	50	317.22	83.15	466.70	4.73	4.68
1.33	75	357.91	91.76	522.90	5.07	4.95
1	100	390.06	98.34	566.60	5.33	5.15
0.5	200	480.54	115.97	687.10	6.03	5.65
0.2	500	635.11	143.79	885.90	7.13	6.35
0.1	1000	785.96	168.91	1073.40	8.12	6.91
3.33 +CC	30 +CC	338.05	90.86	500.84	5.37	5.39
0.5 +CC	200 +CC	595.87	143.80	852.00	7.47	7.01
0.5 specific discharge	200	0.61	0.59	0.54		
Critical duration for modelling (h)		39	39	39		

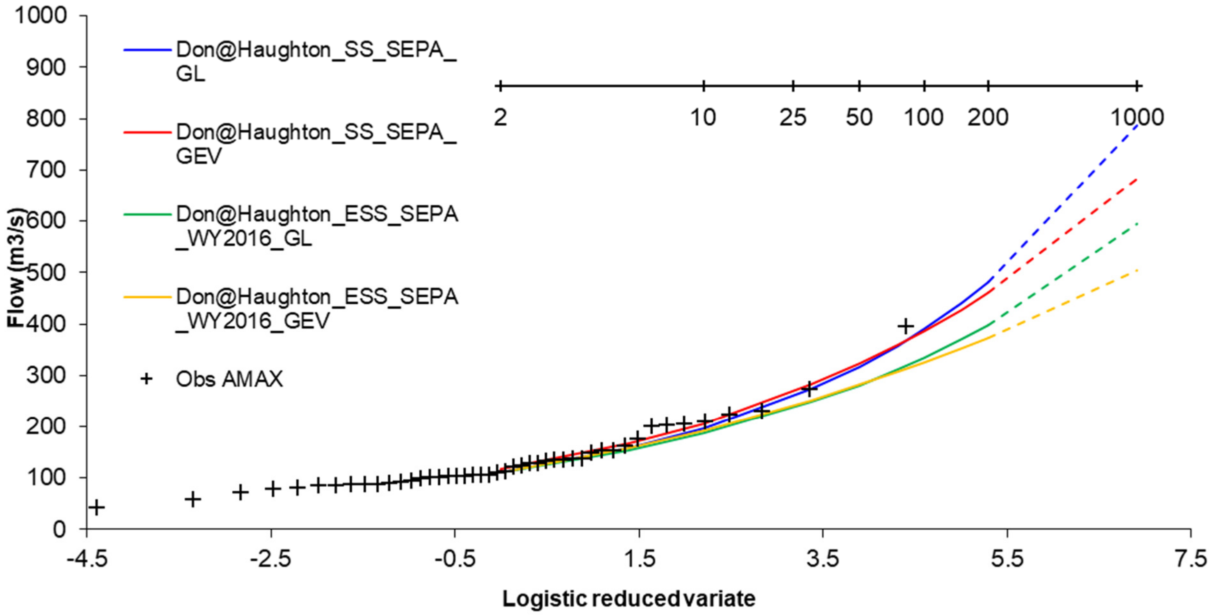
Appendices

A Statistical Method - Additional Outputs

This section provides further information on the statistical method. The sheets below show estimates using JBA's internal software, where single site analysis is standardised by QMED.

A.1.1 Don at Haughton

FEH STATISTICAL FLOOD ESTIMATION SUMMARY SHEET			
Site	Haughton		
NGR	NJ756201		
Type of problem/objective of	Peak Flows for Flood Mapping Study		
Type of catchment	Rural		
QMED $_{site\ cd}$	113.8	m^3/s	
Donor/ Analogue Sites Considered			
Site name	Don@Haughton		
Station number	11002		
NGR	NJ756201		
Proximity (km)	0.00		
Adjustment	0.9818		
Site Chosen	Y		
QMED $_{site}$ adjusted by data transfer (m^3/s)	111.7	**Specific Q (l/s/ha)**	1.4
Q_{100} growth curve factor	3.49	**Q100/ area (l/s/ha)**	4.9
Q_{100} (m^3/s)	**390.1**		
Summary Data			
FEH catchment area	792.65		km^2
Adjusted catchment area	792.65		km^2
URBEXT 1990	0.001		
URBEXT 2010	0.002		
URBEXT Adjustment Method	Urbext2000		
SAAR	916		
Method Used	FEH Statistical Method		
Variation from Chosen Method			
Index Used	BFIHOST		
QMED	111.69		m^3/s
5	158.07		m^3/s
10	196.42		m^3/s
30	272.62		m^3/s
50	317.22		m^3/s
75	357.92		m^3/s
100	390.06		m^3/s
200	480.54		m^3/s
1000	785.96		m^3/s
Climate Change Region	Eastern Scotland		
Climate change adjustment	24.0%		
200 + cc	595.9		m^3/s
Donor/ Analogues Used			
Calcs by:	Danni Murren and Briony McIntosh	Date:	02/02/2018
Checked by:	David Cameron	Date:	05/02/2018



POOLING GROUP DETAILS

Original Default Pooling Group

Station	Distance	Years of data	QMED AM	L-CV	L-SKEW	Discordancy
11002 (Don @ Haughton)	0.000	46	111.687	0.237	0.320	0.618
7002 (Findhorn @ Forres)	0.327	59	328.722	0.224	0.223	0.190
24001 (Wear @ Sunderland Bridge)	0.334	58	185.838	0.189	0.239	1.881
28018 (Dove @ Marston on Dove)	0.339	54	112.978	0.129	0.061	2.262
21806 (Till @ Heaton Mill)	0.385	13	124.000	0.348	0.332	1.934
21031 (Till @ Etal)	0.412	28	82.895	0.273	0.282	0.384
23015 (North Tyne @ Barrasford)	0.440	22	422.680	0.152	0.183	0.757
23004 (South Tyne @ Haydon Bridge)	0.446	56	452.241	0.138	0.175	1.340
50001 (Taw @ Umberleigh)	0.469	57	235.790	0.207	0.286	0.454
21003 (Tweed @ Peebles)	0.477	57	175.735	0.214	0.309	0.911
22001 (Coquet @ Morwick)	0.478	52	149.909	0.268	0.284	0.270
Total		502				
Weighted means				0.230	0.257	

Default Pooling Group Catchment Descriptors

Station	Distance SDM	AREA	SAAR	FPEXT	FARL	URBEXT 2000
11002 (Don @ Haughton)	0.000	792.670	916.000	0.051	0.997	0.002
7002 (Findhorn @ Forres)	0.327	781.780	1065.000	0.048	0.973	0.000
24001 (Wear @ Sunderland Bridge)	0.334	661.170	932.000	0.035	0.978	0.019
28018 (Dove @ Marston on Dove)	0.339	884.070	935.000	0.075	0.976	0.014
21806 (Till @ Heaton Mill)	0.385	655.540	822.000	0.067	0.992	0.002
21031 (Till @ Etal)	0.412	634.680	827.000	0.067	0.992	0.002
23015 (North Tyne @ Barrasford)	0.440	1049.630	1013.000	0.049	0.989	0.001
23004 (South Tyne @ Haydon Bridge)	0.446	749.900	1147.000	0.044	0.989	0.002
50001 (Taw @ Umberleigh)	0.469	832.970	1153.000	0.037	0.997	0.004
21003 (Tweed @ Peebles)	0.477	698.120	1140.000	0.051	0.974	0.003
22001 (Coquet @ Morwick)	0.478	578.250	850.000	0.040	0.993	0.002

Final Pooling Group

Station	Distance	Years of data	QMED AM	L-CV	L-SKEW	Discordancy
11002 (Don @ Haughton)	0	46	111.687	0.237	0.32	0.892
7002 (Findhorn @ Forres)	0.327	59	328.722	0.224	0.223	0.771
24001 (Wear @ Sunderland Bridge)	0.334	58	185.838	0.189	0.239	2.272
21806 (Till @ Heaton Mill)	0.385	13	124	0.348	0.332	1.945
21031 (Till @ Etal)	0.412	28	82.895	0.273	0.282	0.385
23015 (North Tyne @ Barrasford)	0.44	22	422.68	0.152	0.183	0.908
23004 (South Tyne @ Haydon Bridge)	0.446	56	452.241	0.138	0.175	1.357
50001 (Taw @ Umberleigh)	0.469	57	235.79	0.207	0.286	0.502
21003 (Tweed @ Peebles)	0.477	57	175.735	0.214	0.309	1.479
22001 (Coquet @ Morwick)	0.478	52	149.909	0.268	0.284	0.292
27007 (Ure @ Westwick Lock)	0.481	60	281.504	0.187	0.232	0.196
Total		508				
Weighted means				0.232	0.271	

Final Pooling Group

Station	Distance SDM	AREA	SAAR	FPEXT	FARL	URBEXT 2000
11002 (Don @ Haughton)	0.000	792.67	916.000	0.051	0.997	0.002
7002 (Findhorn @ Forres)	0.327	781.78	1065.000	0.048	0.973	0.000
24001 (Wear @ Sunderland Bridge)	0.334	661.17	932.000	0.035	0.978	0.019
21806 (Till @ Heaton Mill)	0.385	655.54	822.000	0.067	0.992	0.002
21031 (Till @ Etal)	0.412	634.68	827.000	0.067	0.992	0.002
23015 (North Tyne @ Barrasford)	0.440	1049.63	1013.000	0.049	0.989	0.001
23004 (South Tyne @ Haydon Bridge)	0.446	749.9	1147.000	0.044	0.989	0.002
50001 (Taw @ Umberleigh)	0.469	832.97	1153.000	0.037	0.997	0.004
21003 (Tweed @ Peebles)	0.477	698.12	1140.000	0.051	0.974	0.003
22001 (Coquet @ Morwick)	0.478	578.25	850.000	0.040	0.993	0.002
27007 (Ure @ Westwick Lock)	0.481	912.58	1120.000	0.067	0.981	0.008

DERIVING A POOLED GROWTH CURVE			
Site	Haughton		Ungauged site
NGR	3756 82011	√	Gauged site

Attached Printouts

	WINFAP-FEH station details
	WINFAP-FEH summary information if gauged site

Initial Pooling Group Details

Name	ess_sepa_Haughton_default
Site of interest	Don@Haughton
Return period of interest	200 years
Other information	SEPA data updated through WY2016, All other sites from HiFlows v5.0 Till@Heaton Mill (2001-present) Till@Etal (1955-1981)
Version of WIN-FAP FEH	Version 3.0
Data Files	Other
If 'Other' chosen in Data Files enter file path here	HiFlows v5.0

Adjustment/ Changes made to Default Pooling Group.
Also note sites that were investigated but retained in the group (i.e. for discordancy)

Station number	Name	Addition/ Deletion/ Move/ Investigate	Reason
21018	Dove@Marston on Dove	D	Discordant
27007	Ure@WestwickLock	A	Increase record length

Final Pooling Group Details

Heterogeneity Measure

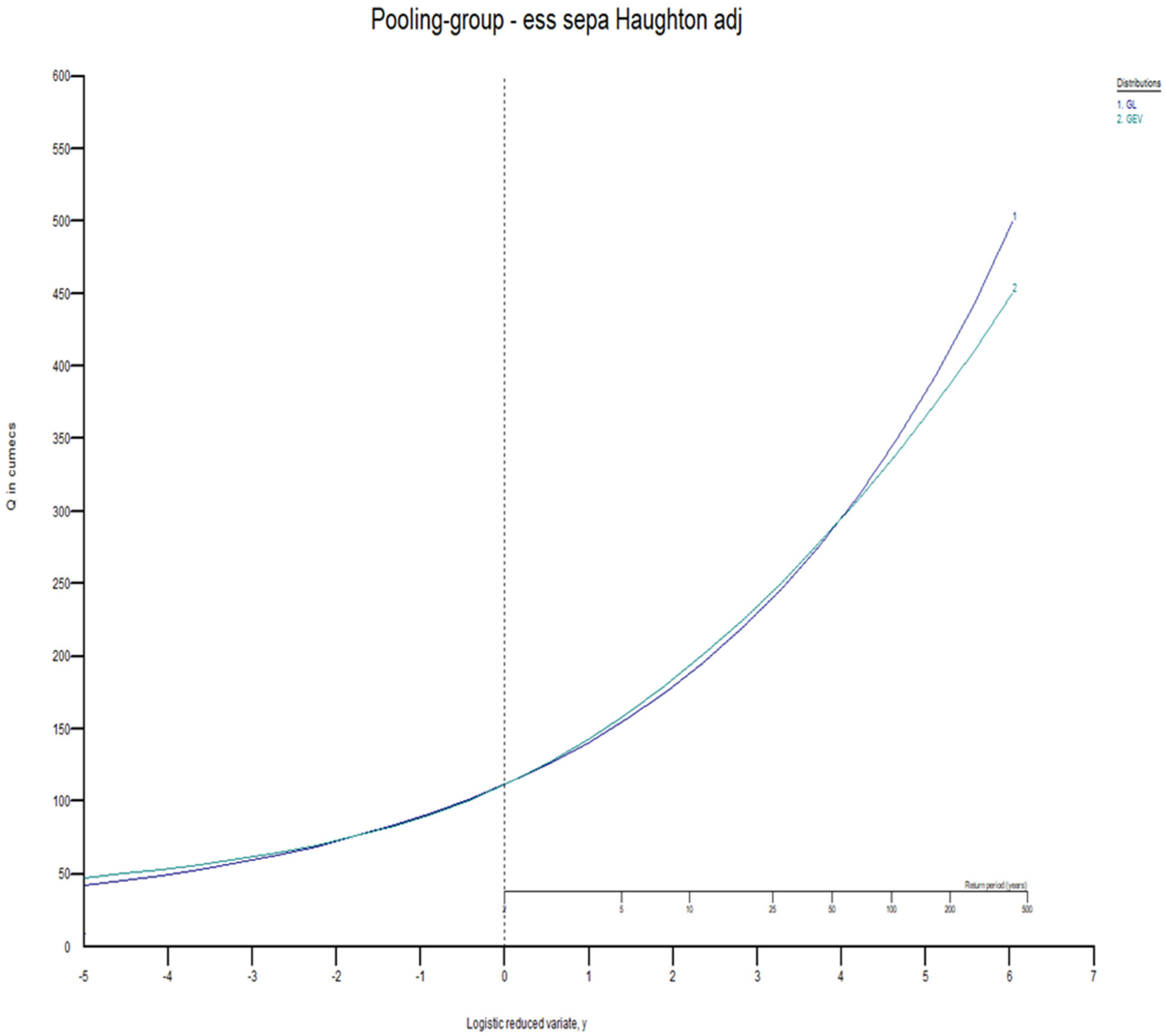
H1	Heterogeneous
H2	Acceptably Homogeneous

Goodness of Fit

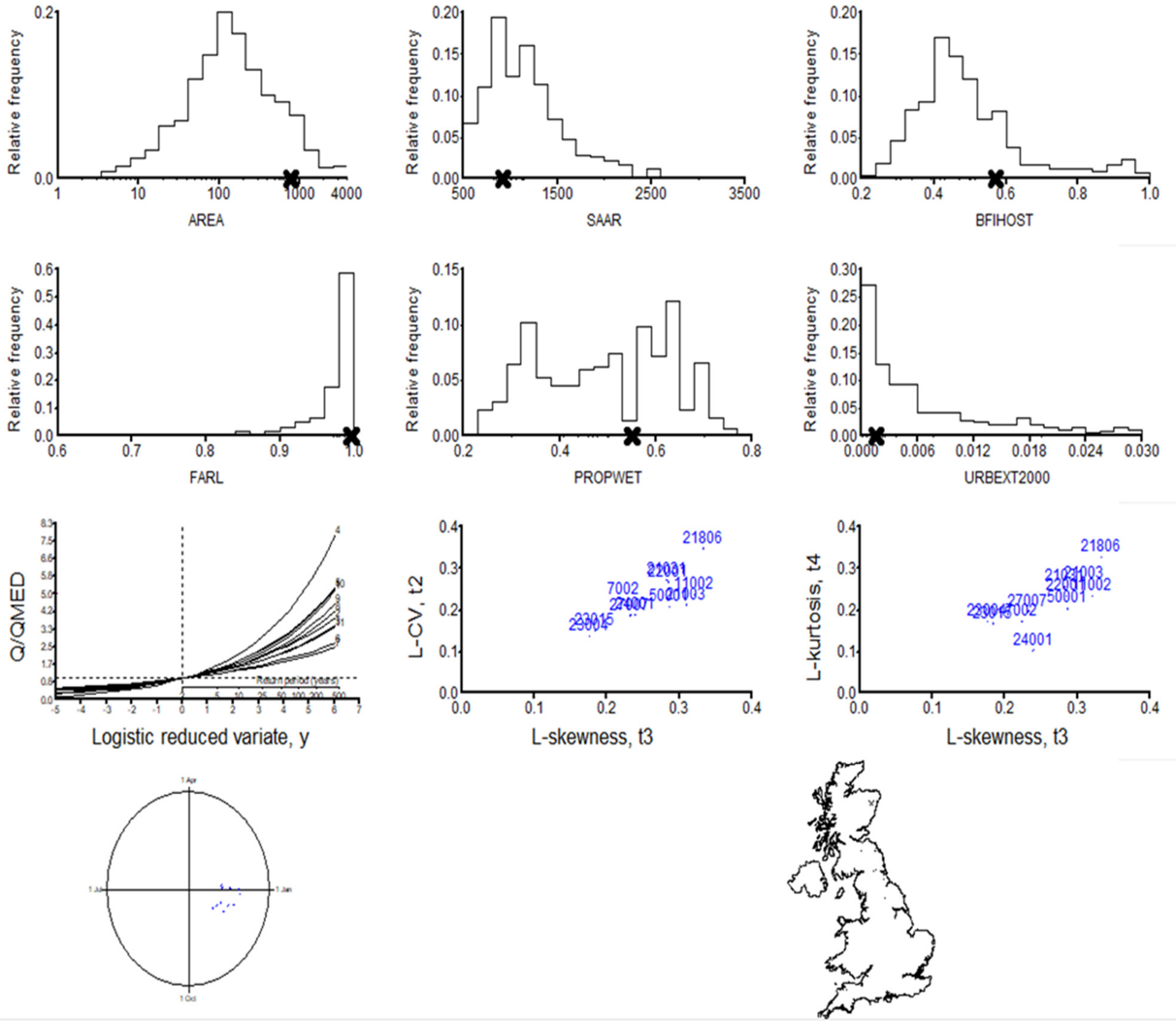
Acceptable Fit	Distribution
√	Generalised Logistic
√	Generalised Extreme Value
	Pearson Type iii
	Generalised Pareto

Growth Curve Fittings

Attached print outs	√	WINFAP-FEH growth curve fittings
	√	WINFAP-FEH growth curve
Name of Final Pooling Group		ess_sepa_Haughton_adj

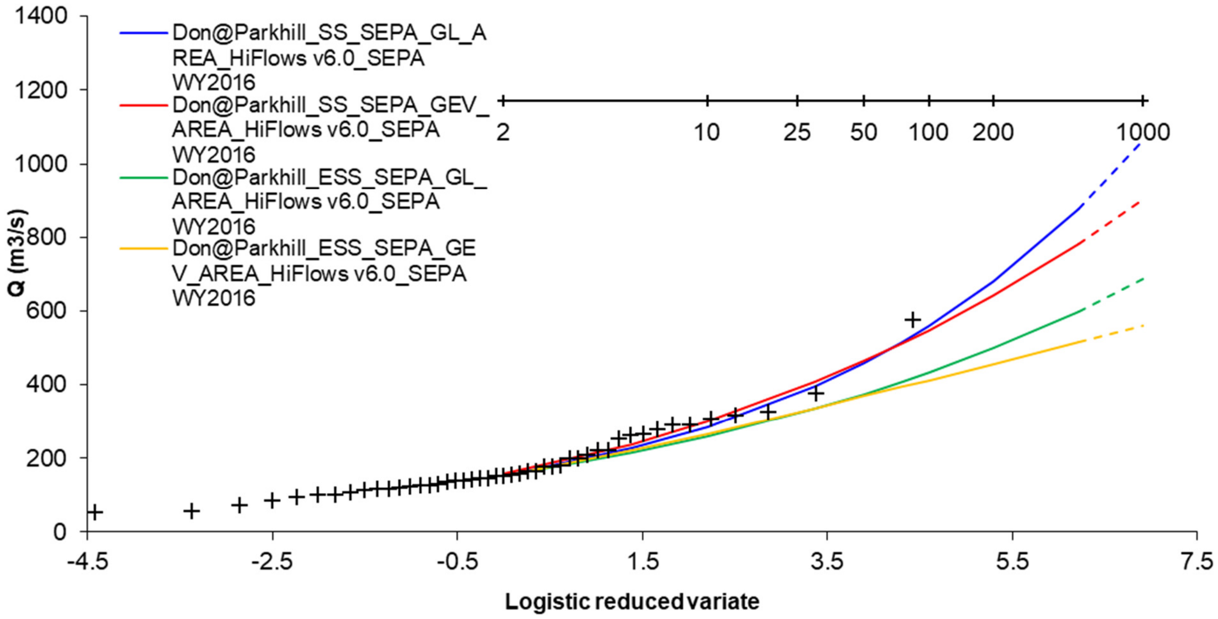


Pooling-group - ess sepa Haughton adj
Distributions
1. GL
2. GEV
Q in cumecs
Return period (years)
Logistic reduced variate, y


Relative frequency
AREA
SAAR
BFIHOST
FARL
PROPWET
URBEXT2000
Q/QMED
Logistic reduced variate, y
L-CV, t2
L-skewness, t3
L-kurtosis, t4
21806
24001
7002
1 Apr
1 Jul
1 Jan
1 Oct

A.1.2 Don at Parkhill

FEH STATISTICAL FLOOD ESTIMATION SUMMARY SHEET			
Site	Don @ Parkhill		
NGR	NJ 887 141		
Type of problem/objective of	Peak flows for comparison to model outputs at downstream boundary for calibration purposes		
Type of catchment	Rural		
QMED $_{site\ cd}$	151.8	m^3/s	
Donor/ Analogue Sites Considered			
Site name	Don @ Parkhill		
Station number	11001		
NGR	NJ 887 141		
Proximity (km)	0.00		
Adjustment	1.0075		
Site Chosen	Y		
QMED $_{site}$ adjusted by data transfer (m^3/s)	153.0	**Specific Q (l/s/ha)**	1.2
Q_{100} growth curve factor	3.65	**Q100/ area (l/s/ha)**	4.4
Q_{100} (m^3/s)	**559.0**		
Summary Data			
FEH catchment area	1269.11		km^2
Adjusted catchment area	1270.56		km^2
URBEXT 1990	0.003		
URBEXT 2010	0.004		
URBEXT Adjustment Method	Urbext2000		
SAAR	884		
Method Used	FEH Statistical Method		
Variation from Chosen Method			
Index Used	BFIHOST		
QMED	152.96		m^3/s
5	226.89		m^3/s
10	285.29		m^3/s
30	396.40		m^3/s
50	459.17		m^3/s
75	515.32		m^3/s
100	559.00		m^3/s
200	679.33		m^3/s
1000	1064.93		m^3/s
Climate Change Region	Eastern Scotland		
Climate change adjustment	24.0%		
200 + cc	842.4		m^3/s
Donor/ Analogues Used			
Calcs by:	Briony McIntosh	Date:	12/09/2018
Checked by:	David Cameron	Date:	13/09/2018



POOLING GROUP DETAILS

Original Default Pooling Group

Station	Distance	Years of data	QMED AM	L-CV	L-SKEW	Discordancy
11001 (Don @ Parkhill)	0.000	47	152.957	0.280	0.302	2.226
54008 (Teme @ Tenbury)	0.202	60	139.355	0.183	0.133	1.159
21008 (Teviot @ Ormiston Mill)	0.253	57	351.082	0.188	0.166	0.225
54029 (Teme @ Knightsford Bridge)	0.266	46	171.314	0.152	0.070	0.280
43003 (Avon @ East Mills Total)	0.296	45	47.500	0.200	0.109	0.812
25009 (Tees @ Low Moor)	0.367	46	410.178	0.182	-0.041	2.216
23015 (North Tyne @ Barrasford)	0.390	22	422.680	0.152	0.183	1.176
12001 (Dee @ Woodend)	0.483	88	442.724	0.215	0.151	1.041
39016 (Kennet @ Theale)	0.502	54	37.624	0.188	0.099	0.127
53018 (Avon @ Bathford)	0.539	47	167.223	0.134	0.074	0.738
Total		512				
Weighted means				0.254	0.163	

Default Pooling Group Catchment Descriptors

Station	Distance SDM	AREA	SAAR	FPEXT	FARL	URBEXT 2000
11001 (Don @ Parkhill)	0.000	1269.150	884.000	0.059	0.996	0.004
54008 (Teme @ Tenbury)	0.202	1124.620	841.000	0.064	0.994	0.006
21008 (Teviot @ Ormiston Mill)	0.253	1121.550	936.000	0.046	0.987	0.004
54029 (Teme @ Knightsford Bridge)	0.266	1483.650	818.000	0.062	0.994	0.006
43003 (Avon @ East Mills Total)	0.296	1459.450	807.000	0.069	0.985	0.016
25009 (Tees @ Low Moor)	0.367	1267.120	966.000	0.078	0.958	0.022
23015 (North Tyne @ Barrasford)	0.390	1049.630	1013.000	0.049	0.989	0.001
12001 (Dee @ Woodend)	0.483	1380.060	1108.000	0.047	0.976	0.001
39016 (Kennet @ Theale)	0.502	1037.390	758.000	0.078	0.965	0.017
53018 (Avon @ Bathford)	0.539	1569.350	817.000	0.096	0.985	0.030

Final Pooling Group

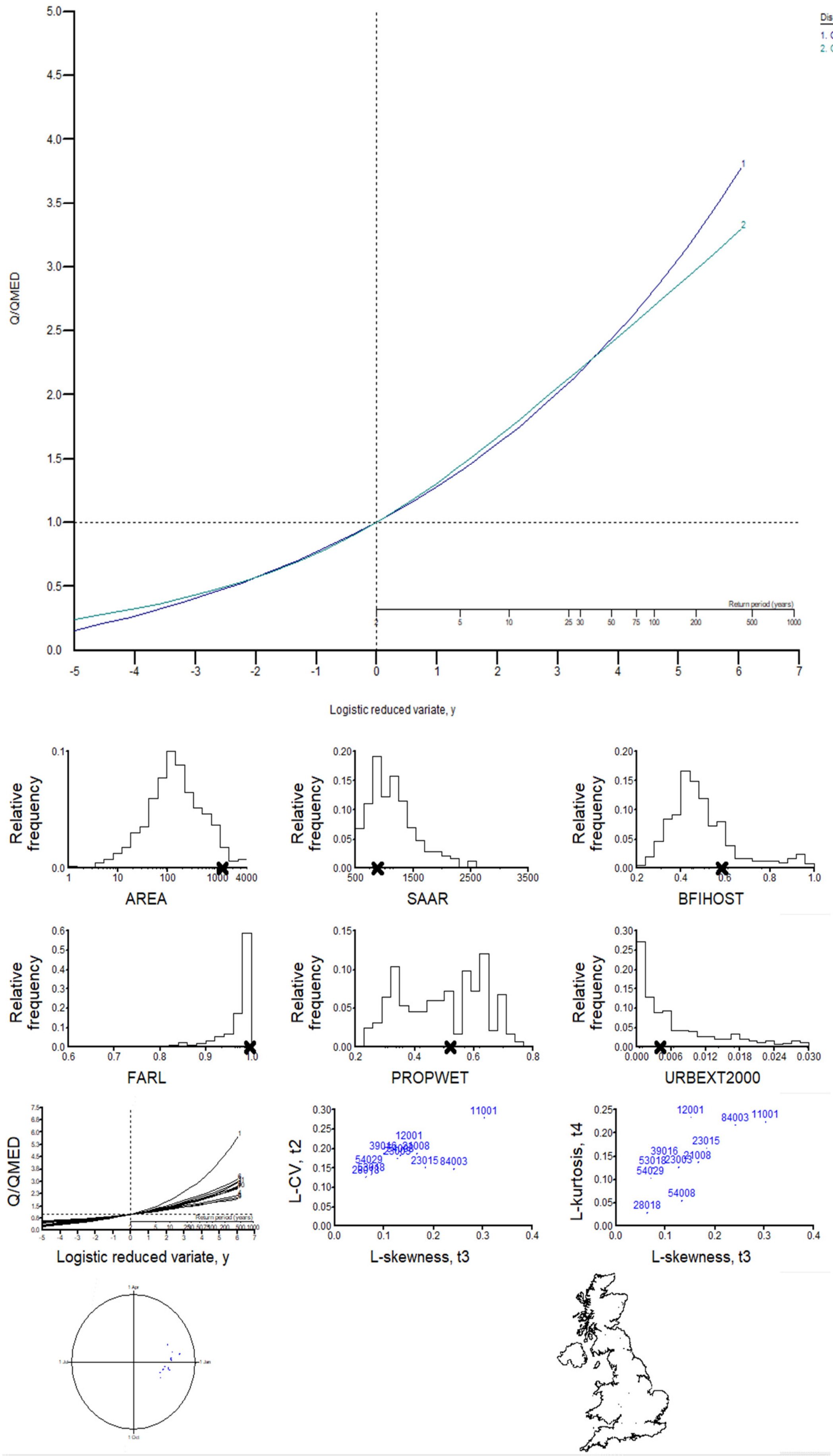
Station	Distance	Years of data	QMED AM	L-CV	L-SKEW	Discordancy
11001 (Don @ Parkhill)	0.000	47	152.957	0.280	0.302	2.402
54008 (Teme @ Tenbury)	0.202	60	139.355	0.183	0.133	1.258
21008 (Teviot @ Ormiston Mill)	0.253	57	351.082	0.188	0.166	0.093
54029 (Teme @ Knightsford Bridge)	0.266	46	171.314	0.152	0.070	0.408
23015 (North Tyne @ Barrasford)	0.390	22	422.680	0.152	0.183	0.637
12001 (Dee @ Woodend)	0.483	88	442.724	0.215	0.151	1.666
39016 (Kennet @ Theale)	0.502	54	37.624	0.188	0.099	0.598
53018 (Avon @ Bathford)	0.539	47	167.223	0.134	0.074	0.607
28018 (Dove @ Marston on Dove)	0.561	55	112.737	0.128	0.063	1.124
23003 (North Tyne @ Reaverhill)	0.581	21	403.997	0.175	0.127	0.041
84003 (Clyde @ Hazelbank)	0.594	62	283.779	0.148	0.240	2.165
Total		559				
Weighted means				0.251	0.178	

Final Pooling Group

Station	Distance SDM	AREA	SAAR	FPEXT	FARL	URBEXT 2000
11001 (Don @ Parkhill)	0.000	1269.150	884.000	0.059	0.996	0.004
54008 (Teme @ Tenbury)	0.202	1124.620	841.000	0.064	0.994	0.006
21008 (Teviot @ Ormiston Mill)	0.253	1121.550	936.000	0.046	0.987	0.004
54029 (Teme @ Knightsford Bridge)	0.266	1483.650	818.000	0.062	0.994	0.006
23015 (North Tyne @ Barrasford)	0.390	1049.630	1013.000	0.049	0.989	0.001
12001 (Dee @ Woodend)	0.483	1380.060	1108.000	0.047	0.976	0.001
39016 (Kennet @ Theale)	0.502	1037.390	758.000	0.078	0.965	0.017
53018 (Avon @ Bathford)	0.539	1569.350	817.000	0.096	0.985	0.030
28018 (Dove @ Marston on Dove)	0.561	884.070	935.000	0.075	0.976	0.014
23003 (North Tyne @ Reaverhill)	0.581	1012.980	1023.000	0.047	0.936	0.001
84003 (Clyde @ Hazelbank)	0.594	1093.100	1165.000	0.065	0.970	0.004

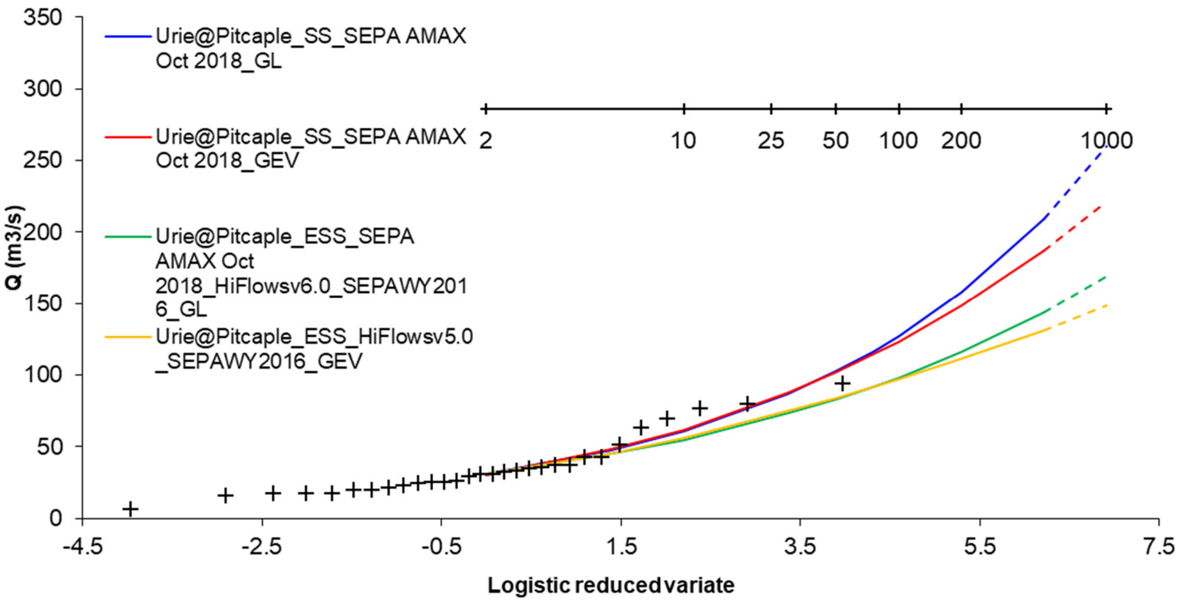
DERIVING A POOLED GROWTH CURVE			
Site	Don @ Parkhill		Ungauged site
NGR	NJ887141	√	Gauged site
Attached Printouts			
	WINFAP-FEH station details		
	WINFAP-FEH summary information if gauged site		
Initial Pooling Group Details			
Name	sepa_ess_parkhill		
Site of interest	Don @ Parkhill		
Return period of interest	2, 5, 10, 25, 30, 50, 75, 100, 200, 500, 1000, 30 +CC, 200 +CC years		
Other information			
Version of WIN-FAP FEH	Version 3.0		
Data Files	Other		
If 'Other' chosen in Data Files enter file path here	HiFlows v6.0 with SEPA stations through WY2016		
Adjustment/ Changes made to Default Pooling Group. Also note sites that were investigated but retained in the group (i.e. for discordancy)			
Station number	**Name**	**Addition/ Deletion/ Move/ Investigate**	**Reason**
43003	Avon@EastMillsTotal	D	High BFIHOST >0.85
25009	Tees@LowMoor	D	Discordant
28018	Dove@Marston on Dove	A	Increase record length
23003	NorthTyne@Reaverhill	A	Increase record length
84003	Clyde@Hazelbank	A	Increase record length
Final Pooling Group Details			
Heterogeneity Measure			
H1	Strongly Heterogeneous		
H2	Acceptably Homogeneous		
Goodness of Fit			
Acceptable Fit	**Distribution**		
	Generalised Logistic		
√	Generalised Extreme Value		
√	Pearson Type iii		
	Generalised Pareto		
Growth Curve Fittings			
Attached print outs	√	WINFAP-FEH growth curve fittings	
	√	WINFAP-FEH growth curve	
Name of Final Pooling Group	sepa_ess_Parkhill_adj		

Pooling-group - sepa ess Parkhill adj



A.1.3 Urie at Pitcaple - ESS outputs

FEH STATISTICAL FLOOD ESTIMATION SUMMARY SHEET			
Site	Picaple		
NGR	NJ721259		
Type of problem/objective of	Peak Flow s for Flood Mapping Study		
Type of catchment	Rural		
QMED site cd	32.2	m^3/s	
Donor/ Analogue Sites Considered			
Site name	Urie@Pitcaple		
Station number	11004		
NGR	NJ721259		
Proximity (km)	0.00		
Adjustment	0.9714		
Site Chosen	Y		
QMED site adjusted by data transfer (m^3/s)	31.3	Specific Q (l/s/ha)	1.6
Q_{100} growth curve factor	3.15	Q100/ area (l/s/ha)	5.0
Q_{100} (m^3/s)	**98.3**		
Summary Data			
FEH catchment area	195.44		km^2
Adjusted catchment area	195.44		km^2
URBEXT 1990	0.003		
URBEXT 2010	0.003		
URBEXT Adjustment Method	Urbext2000		
SAAR	870		
Method Used	FEH Statistical Method		
Variation from Chosen Method			
Index Used	BFIHOST		
QMED	31.25		m^3/s
5	44.85		m^3/s
10	55.00		m^3/s
30	73.27		m^3/s
50	83.15		m^3/s
75	91.76		m^3/s
100	98.34		m^3/s
200	115.97		m^3/s
1000	168.91		m^3/s
Climate Change Region	Eastern Scotland		
Climate change adjustment	24.0%		
200 + cc	143.8		m^3/s
Donor/ Analogues Used			
Calcs by:	Briony McIntosh	Date:	02/11/2018
Checked by:	David Cameron	Date:	02/11/2018



POOLING GROUP DETAILS

Original Default Pooling Group

Station	Distance	Years of data	QMED AM	L-CV	L-SKEW	Discordancy
11004 (Urie @ Pitcaple)	0.000	29	30.563	0.277	0.207	0.699
21032 (Glen @ Kirknewton)	0.097	44	44.450	0.267	0.236	0.225
9003 (Isla @ Grange)	0.147	58	54.883	0.239	0.148	1.034
43006 (Nadder @ Wilton)	0.188	49	15.647	0.223	0.285	0.305
21013 (Gala Water @ Galashiels)	0.191	54	51.252	0.235	0.243	0.185
45005 (Otter @ Dotton)	0.222	54	68.255	0.290	0.410	1.574
67008 (Alyn @ Pont-y-capel)	0.229	51	22.028	0.175	0.289	1.585
52005 (Tone @ Bishops Hull)	0.253	55	44.756	0.200	0.078	1.103
9004 (Bogie @ Redcraig)	0.260	37	29.514	0.252	0.235	0.283
43018 (Allen @ Walford Mill)	0.325	42	7.026	0.242	0.127	1.600
203024 (Cusher @ Gamble's Bridge)	0.349	40	50.194	0.111	0.122	2.407
Total		513				
Weighted means				0.259	0.220	

Default Pooling Group Catchment Descriptors

Station	Distance SDM	AREA	SAAR	FPEXT	FARL	URBEXT2000
11004 (Urie @ Pitcaple)	0.000	195.440	870.000	0.046	0.996	0.003
21032 (Glen @ Kirknewton)	0.097	196.050	877.000	0.039	0.986	0.001
9003 (Isla @ Grange)	0.147	179.980	900.000	0.040	0.994	0.005
43006 (Nadder @ Wilton)	0.188	215.630	875.000	0.047	0.976	0.009
21013 (Gala Water @ Galashiels)	0.191	205.450	930.000	0.035	0.999	0.001
45005 (Otter @ Dotton)	0.222	202.830	971.000	0.050	0.996	0.024
67008 (Alyn @ Pont-y-capel)	0.229	225.650	917.000	0.048	0.990	0.029
52005 (Tone @ Bishops Hull)	0.253	203.660	964.000	0.054	0.977	0.016
9004 (Bogie @ Redcraig)	0.260	182.430	955.000	0.031	0.998	0.001
43018 (Allen @ Walford Mill)	0.325	170.880	860.000	0.067	0.979	0.005
203024 (Cusher @ Gamble's Bridge)	0.349	170.890	996.000	0.058	0.992	0.004

Final Pooling Group

Station	Distance	Years of data	QMED AM	L-CV	L-SKEW	Discordancy
11004 (Urie @ Pitcaple)	0.000	29	30.563	0.277	0.207	1.322
21032 (Glen @ Kirknewton)	0.097	44	44.450	0.267	0.236	0.548
9003 (Isla @ Grange)	0.147	58	54.883	0.239	0.148	1.263
43006 (Nadder @ Wilton)	0.188	49	15.647	0.223	0.285	1.778
21013 (Gala Water @ Galashiels)	0.191	54	51.252	0.235	0.243	0.487
45005 (Otter @ Dotton)	0.222	54	68.255	0.290	0.410	1.497
52005 (Tone @ Bishops Hull)	0.253	55	44.756	0.200	0.078	1.193
9004 (Bogie @ Redcraig)	0.260	37	29.514	0.252	0.235	0.185
45003 (Culm @ Woodmill)	0.373	54	70.500	0.226	0.178	0.857
21025 (Ale Water @ Ancrum)	0.400	44	50.748	0.197	0.083	1.041
45012 (Creedy @ Cowley)	0.432	44	89.115	0.277	0.337	0.828
Total		522				
Weighted means				0.264	0.223	

Final Pooling Group

Station	Distance SDM	AREA	SAAR	FPEXT	FARL	URBEXT2000
11004 (Urie @ Pitcaple)	0.000	195.440	870.000	0.046	0.996	0.003
21032 (Glen @ Kirknewton)	0.097	196.050	877.000	0.039	0.986	0.001
9003 (Isla @ Grange)	0.147	179.980	900.000	0.040	0.994	0.005
43006 (Nadder @ Wilton)	0.188	215.630	875.000	0.047	0.976	0.009
21013 (Gala Water @ Galashiels)	0.191	205.450	930.000	0.035	0.999	0.001
45005 (Otter @ Dotton)	0.222	202.830	971.000	0.050	0.996	0.024
52005 (Tone @ Bishops Hull)	0.253	203.660	964.000	0.054	0.977	0.016
9004 (Bogie @ Redcraig)	0.260	182.430	955.000	0.031	0.998	0.001
45003 (Culm @ Woodmill)	0.373	228.910	971.000	0.065	0.993	0.014
21025 (Ale Water @ Ancrum)	0.400	173.790	926.000	0.060	0.948	0.000
45012 (Creedy @ Cowley)	0.432	263.630	909.000	0.040	0.993	0.009

DERIVING A POOLED GROWTH CURVE			
Site	Pitcaple GS		Ungauged site
NGR	NJ721259	√	Gauged site

Attached Printouts

	WINFAP-FEH station details
	WINFAP-FEH summary information if gauged site

Initial Pooling Group Details

Name	ess_sepa_Pitcaple_default
Site of interest	Pitcaple GS
Return period of interest	200 years
Other information	
Version of WIN-FAP FEH	Version 3.0
Data Files	Other
If 'Other' chosen in Data Files enter file path here	HiFlows v6.0 with SEPA WY2016

Adjustment/ Changes made to Default Pooling Group.
Also note sites that were investigated but retained in the group (i.e. for discordancy)

Station number	Name	Addition/ Deletion/ Move/ Investigate	Reason
43018	Allen@WalfordMill	D	BFI host >0.85
67008	Alyn@Pont-y-Capel	D	URBEXT > 0.025 (0.029)
45003	Culum@WoodMill	A	increase data record
21025	AleWater@Ancrum	A	increase data record
203024	Cusher@Gambles Bridge	D	Discordant
45012	Creedy@Cowley	A	increase data record

Final Pooling Group Details

Heterogeneity Measure

H1	Acceptably Homogeneous
H2	Acceptably Homogeneous

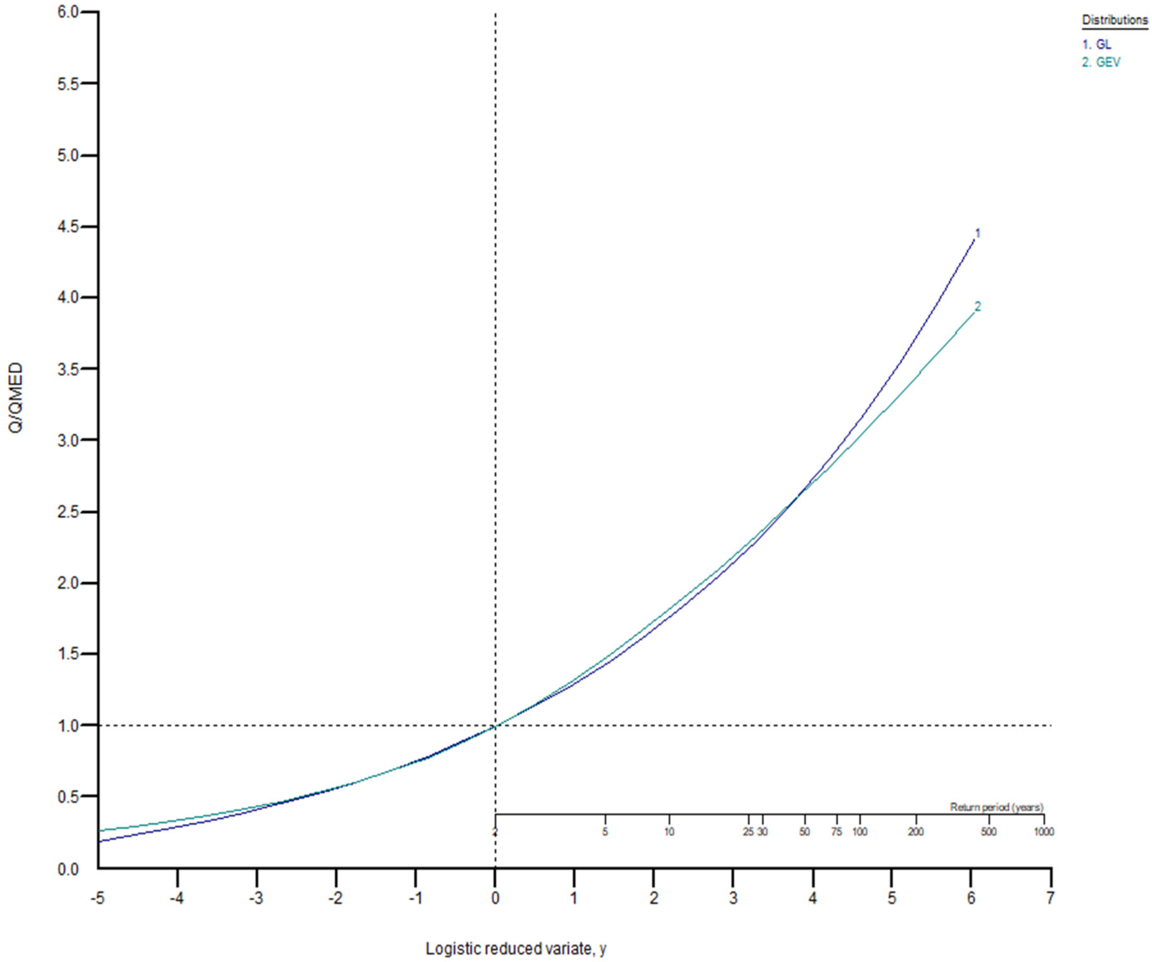
Goodness of Fit

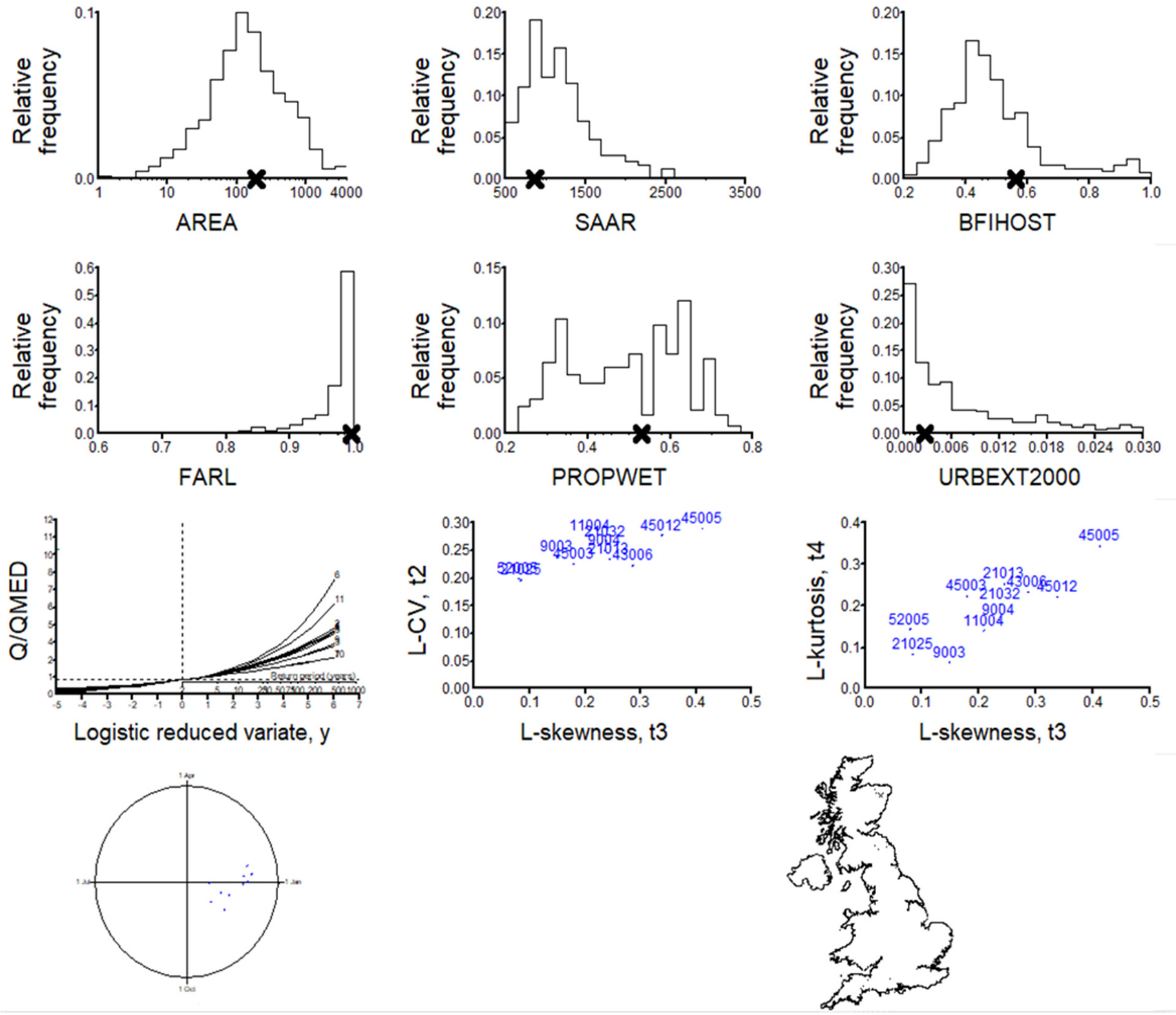
Acceptable Fit	Distribution
√	Generalised Logistic
√	Generalised Extreme Value
	Pearson Type iii
	Generalised Pareto

Growth Curve Fittings

Attached print outs	√	WINFAP-FEH growth curve fittings
	√	WINFAP-FEH growth curve
Name of Final Pooling Group		ess_sepa_Pitcaple_adj

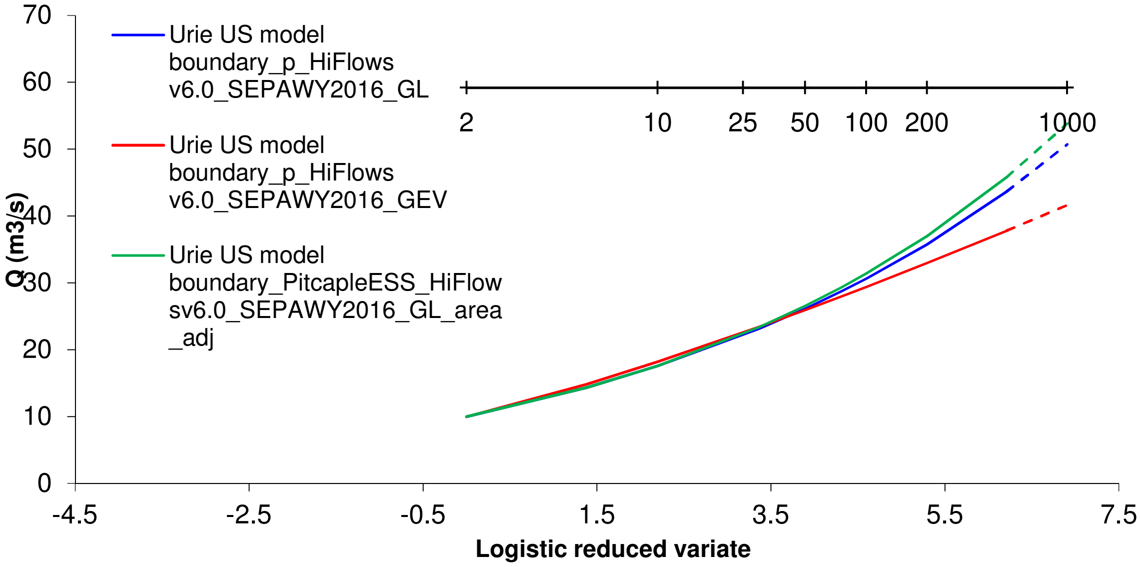
Pooling-group - ess sepa Pitcaple adj




Relative frequency
AREA
SAAR
BFIHOST
FARL
PROPWET
URBEXT2000
Q/QMED
Logistic reduced variate, y
Return period (years)
L-CV, t2
L-skewness, t3
L-kurtosis, t4
45005
45012
11004
21032
9004
9003
45003
21013
43006
52005
21025
1 Apr
1 Jan
1 Jul
1 Oct

A.1.4 Urie north of Old Rayne - Pooling outputs

FEH STATISTICAL FLOOD ESTIMATION SUMMARY SHEET			
Site	Urie north of Old Rayne (US model boundary)		
NGR	NJ 660 295		
Type of problem/objective of	Peak flow estimates for input into hydraulic model		
Type of catchment	Rural		
QMED site cd	10.2	m^3/s	
Donor/ Analogue Sites Considered			
Site name	11004		
Station number	Urie@Pitcaple		
NGR	NJ 721 259		
Proximity (km)	4.35		
Adjustment	0.9859		
Site Chosen	Y		
QMED site adjusted by data transfer (m^3/s)	9.9	Specific Q (l/s/ha)	1.8
Q_{100} growth curve factor	3.15	Q100/ area (l/s/ha)	5.8
Q_{100} (m^3/s)	**31.3**		
Summary Data			
FEH catchment area	53.59		km^2
Adjusted catchment area	53.80		km^2
URBEXT 1990	0.001		
URBEXT 2010	0.001		
URBEXT Adjustment Method	Urbext2000		
SAAR	902		
Method Used	FEH Statistical Method		
Variation from Chosen Method			
Index Used	BFIHOST		
QMED	9.95		m^3/s
5	14.28		m^3/s
10	17.51		m^3/s
30	23.32		m^3/s
50	26.47		m^3/s
75	29.21		m^3/s
100	31.30		m^3/s
200	36.92		m^3/s
1000	53.77		m^3/s
Climate Change Region	Eastern Scotland		
Climate change adjustment	24.0%		
200 + cc	45.8		m^3/s
Donor/ Analogues Used	Picaple		
Calcs by:	Briony McIntosh	Date:	07/11/2018
Checked by:	David Cameron	Date:	07/11/2018



70
60
50
40
30
20
10
0
Q (m3/s)
Urie US model boundary_p_HiFlows v6.0_SEPAWY2016_GL
Urie US model boundary_p_HiFlows v6.0_SEPAWY2016_GEV
Urie US model boundary_PitcapleESS_HiFlowsv6.0_SEPAWY2016_GL_area_adj
2
10
25
50
100
200
1000
-4.5
-2.5
-0.5
1.5
3.5
5.5
7.5
Logistic reduced variate

POOLING GROUP DETAILS

Original Default Pooling Group

Station	Distance	Years of data	QMED AM	L-CV	L-SKEW	Discordancy
44003 (Asker @ Bridport)	0.153	14	12.354	0.224	0.170	1.900
44011 (Asker @ East Bridge Bridport)	0.153	21	16.800	0.239	0.112	0.318
43806 (Wylye @ Brixton Deverill)	0.226	25	2.080	0.376	0.211	1.119
42011 (Hamble @ Frogmill)	0.260	44	8.282	0.167	0.073	1.514
49002 (Hayle @ st Erth)	0.370	59	4.649	0.234	0.202	0.360
24007 (Browney @ Lanchester)	0.375	15	10.981	0.222	0.212	1.469
20006 (Biel Water @ Belton House)	0.395	28	11.748	0.375	0.128	1.769
53017 (Boyd @ Bitton)	0.396	43	13.820	0.247	0.106	0.135
20007 (Gifford Water @ Lennoxlove)	0.453	44	16.895	0.321	0.191	0.296
28058 (Henmore Brook @ Ashbourne)	0.470	12	9.006	0.155	-0.064	1.801
41022 (Lod @ Halfway Bridge)	0.475	46	16.260	0.288	0.181	0.192
51001 (Doniford Stream @ Swill Bridge)	0.479	50	11.980	0.325	0.385	1.787
49004 (Gannel @ Gwills)	0.480	47	15.022	0.258	0.105	0.316
24004 (Bedburn Beck @ Bedburn)	0.488	56	25.342	0.275	0.311	1.022
Total		504				
Weighted means				0.266	0.172	

Default Pooling Group Catchment Descriptors

Station	Distance SDM	AREA	SAAR	FPEXT	FARL	URBEXT 2000
44003 (Asker @ Bridport)	0.153	48.520	924.000	0.025	0.994	0.015
44011 (Asker @ East Bridge Bridport)	0.153	48.520	924.000	0.025	0.994	0.015
43806 (Wylye @ Brixton Deverill)	0.226	50.040	968.000	0.037	1.000	0.003
42011 (Hamble @ Frogmill)	0.260	55.250	838.000	0.044	0.991	0.029
49002 (Hayle @ st Erth)	0.370	48.580	1076.000	0.027	0.977	0.008
24007 (Browney @ Lanchester)	0.375	44.670	797.000	0.015	1.000	0.001
20006 (Biel Water @ Belton House)	0.395	57.550	742.000	0.019	0.981	0.001
53017 (Boyd @ Bitton)	0.396	47.580	807.000	0.050	0.998	0.016
20007 (Gifford Water @ Lennoxlove)	0.453	67.780	770.000	0.029	0.977	0.000
28058 (Henmore Brook @ Ashbourne)	0.470	38.520	895.000	0.030	0.977	0.021
41022 (Lod @ Halfway Bridge)	0.475	52.440	857.000	0.061	0.951	0.009
51001 (Doniford Stream @ Swill Bridge)	0.479	74.230	911.000	0.038	0.988	0.011
49004 (Gannel @ Gwills)	0.48	40.83	1046	0.025	0.999	0.007
24004 (Bedburn Beck @ Bedburn)	0.488	74.120	895.000	0.011	0.999	0.001

Final Pooling Group

Station	Distance	Years of data	QMED AM	L-CV	L-SKEW	Discordancy
44003 (Asker @ Bridport)	0.153	48.52	924.000	0.025	0.994	0.015
44011 (Asker @ East Bridge Bridport)	0.153	48.52	924.000	0.025	0.994	0.015
43806 (Wylye @ Brixton Deverill)	0.226	50.04	968.000	0.037	1.000	0.003
42011 (Hamble @ Frogmill)	0.260	55.25	838.000	0.044	0.991	0.029
49002 (Hayle @ st Erth)	0.370	48.58	1076.000	0.027	0.977	0.008
24007 (Browney @ Lanchester)	0.375	44.67	797.000	0.015	1.000	0.001
20006 (Biel Water @ Belton House)	0.395	57.55	742.000	0.019	0.981	0.001
53017 (Boyd @ Bitton)	0.396	47.58	807.000	0.050	0.998	0.016
20007 (Gifford Water @ Lennoxlove)	0.453	67.78	770.000	0.029	0.977	0.000
28058 (Henmore Brook @ Ashbourne)	0.470	38.52	895.000	0.030	0.977	0.021
41022 (Lod @ Halfway Bridge)	0.475	52.44	857.000	0.061	0.951	0.009
51001 (Doniford Stream @ Swill Bridge)	0.479	74.23	911.000	0.038	0.988	0.011
49004 (Gannel @ Gwills)	0.480	40.83	1046.000	0.025	0.999	0.007
24004 (Bedburn Beck @ Bedburn)	0.488	74.12	895.000	0.011	0.999	0.001

Final Pooling Group

Station	Distance SDM	AREA	SAAR	FPEXT	FARL	URBEXT 2000
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49004 (Gannel @ Gwills)	0.480	40.830	1046.000	0.025	0.999	0.007
24004 (Bedburn Beck @ Bedburn)	0.488	74.120	895.000	0.011	0.999	0.001
39033 (Winterbourne Stream @ Bagnor	0.511	45.310	717.000	0.033	1.000	0.001
23011 (Kielder Burn @ Kielder)	0.567	58.59	1199	0.02	1	0

DERIVING A POOLED GROWTH CURVE

Site	Urie US Old Rayne	√	Ungauged site
NGR			Gauged site

Attached Printouts

	WINFAP-FEH station details
	WINFAP-FEH summary information if gauged site

Initial Pooling Group Details

Name	p_sepa_Urie US Old Rayne_default
Site of interest	
Return period of interest	200 years
Other information	
Version of WIN-FAP FEH	Version 3.0
Data Files	Other
If 'Other' chosen in Data Files enter file path here	HiFlows v6.0, SEPA WY 2016

Adjustment/ Changes made to Default Pooling Group.
Also note sites that were investigated but retained in the group (i.e. for discordancy)

Station number	Name	Addition/ Deletion/ Move/ Investigate	Reason
43806	Wylye@Brixton Deverill	D	High BFIHOST (0.931)
42011	Hamble@Frogmill	D	High URBEXT (0.0285)
39033	WinterbourneStream@Bangor	A	Increase record length
23011	KiederBurn@Kieder	A	Increase record length
28058	HenmoreBrook@Ashbourne	D	Discordant

Final Pooling Group Details

Heterogeneity Measure

H1	Strongly Heterogeneous
H2	Heterogeneous

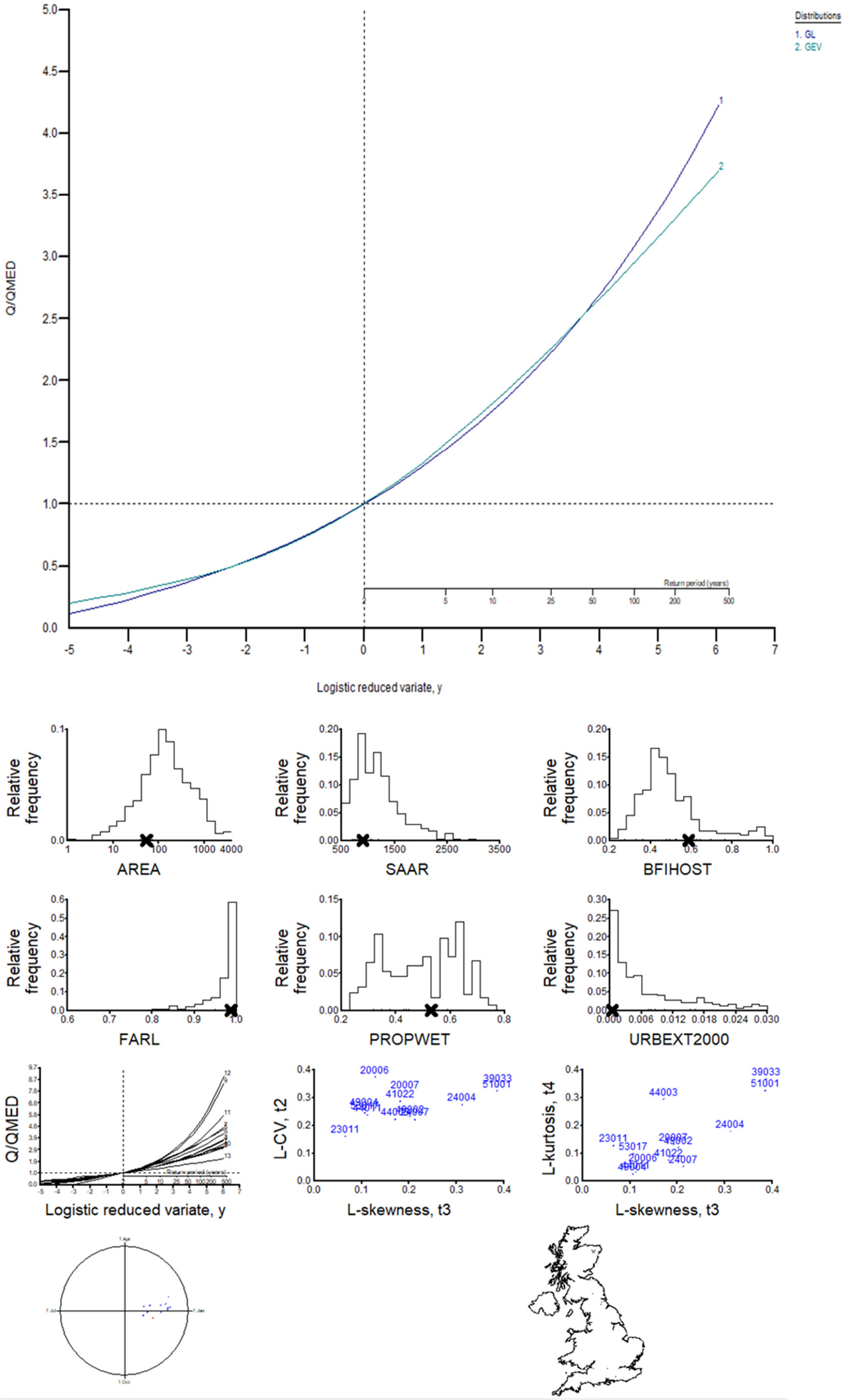
Goodness of Fit

Acceptable Fit	Distribution
	Generalised Logistic
√	Generalised Extreme Value
√	Pearson Type iii
	Generalised Pareto

Growth Curve Fittings

Attached print outs	√	WINFAP-FEH growth curve fittings
	√	WINFAP-FEH growth curve
Name of Final Pooling Group		p_sepa_US Old Rayne_adj

Pooling-group - p sepa US Old Rayne adj



B Technical Review Certificate

Technical Review Certificate

Project Name	Ellon, Inverurie and Insch FPS
Project Number	2017s6743
Project Manager	David Cameron
Work Carried Out by	Briony McIntosh
Reviewer	David Cameron
Subject of Review	Peak estimates for the River Don at 3 gauging stations
Date	4 June 2018
Revision	1.0
Documents used in Review	..\4.Statistical\2017s6743 FEH_Spreadsheet_v3.2.6 SCO Pitcaple_2017s6610_adj.xlsm ..\..\Calculations\1. Hydrology\2. FEH\1. Statistical\2017s6610 FEH_Spreadsheet_v3.2.6 SCO Haughton.xlsm ..\..\..\..\..\..\2017s6610 - SEPA - Don to Inverurie Flood Mapping\Calculations\1. Hydrology\2. FEH\1. Statistical\2017s6610 FEH_Spreadsheet_v3.2.6 SCO Parkhill.xlsm
Applicable Standards or Guidance	

Use the following colour scheme to record recommendations:

Green – suggestion for improved / good practice but which is unlikely to change the project outcomes.

Amber – non-standard method or method not following guidance but unlikely to have impacted on results

Red – omission that could make the findings subject to challenge and which requires correction/further work.

SCOPE OF REVIEW:

Review estimates from the FEH Statistical method for the Don catchment at the following gauging stations: Haughton and the Urie at Pitcaple (Haughton previously reviewed under 2017s6610 and remains acceptable); single site analysis of AMAX stage at Parkhill.

DETAILED REVIEW COMMENTS:

Suitable approach comparing 2 FEH Statistical methods (Single site, SS and Enhanced Single Site, ESS) at Haughton and Pitcaple; suitable approach at Parkhill for providing information for hydraulic model checking.

RECOMMENDATIONS:

The recommended approaches (SS for Haughton and ESS for Pitcaple) are suitable. ESS for Pitcaple is preferred given the shorter record length, although SS provides similar results.

ESS and SS to be carried out on Parkhill flows once rating has been finalised with SEPA.

PRELIMINARY CERTIFICATE (only required when comments are raised).

In respect of the project design described above, I have carried out a Review and consider the technical output sound, subject to the comments and recommendations listed above. Please inform me when you have considered these comments so that I may complete the Final Certificate.

Signature of Reviewer	

This document is classified as Commercial

Name of Reviewer	
Date	

	Aspect	**Y/N**	**Comments**
General	Has the appropriate calculation record been completed?	Y	Calculation record produced for Statistical method
	Has a method statement been produced?	N	Will be included in main report
	Does the analysis (or an accompanying report) include a description of the catchment and its flooding processes?	Y	In main report.
	Are there any unusual features of the catchment and how they will be taken into account?	N	
	Aspect	**Revision required? (Y,N,N/A)**	**Comments**
Data Review & Choice of Method	Has a review of existing data been carried out?	N	As part of the flood mapping study 2017s6610, the gauging station ratings have been reviewed and new ratings developed using hydraulic modelling and implemented.
	Are flow and level stations present, and closed stations as well as current ones?	N	Yes.
	Have stations outside the HiFlows-UK dataset been considered, e.g. temporary loggers?	N	N/A
	Is it appropriate to update the flood peak series from those in HiFlows-UK, if so has this been done?	N	Yes, data updated through year of study.
	Is there a potential donor site? Within / outside the reach?	N	Each gauging station.
	Is the data quality reviewed – at a minimum HiFlows-UK classification	N	Hiflows stations with updated data and ratings reviewed.
	Is more detailed review of data and ratings appropriate for this study, has this been carried out?	N	Rating review for these stations being carried out elsewhere in the project and re-rated flows used here. Parkhill stage only as rating not yet finalised.
	Has a historical review of data been carried out?	N	Yes as part of the overall project.
	Does the report include plots and interpretation of flood peak time series and flood event data?	N	Yes.
	Appropriate choice of flow calculation point?	N	At gauging stations.
	Has catchment boundary been checked and area revised?	N	Boundaries checked against OS mapping.
	What other catchment descriptors have been checked - is this appropriate?	N	URBEXT updated using national growth equation.
	What method has been chosen?	N	Single site statistical for Haughton with comparison to enhanced single site. Enhanced single site for Pitcaple with comparison to single site. Single site AMAX stage at Parkhill.
	Is chosen method appropriate?	N	Method appropriate given record lengths and data. Pitcaple SS and ESS very similar.
Statistical Method	Has the standard methodology been adjusted?	N	
	QMED checked? Has the revised QMED equation been used (CEH, 2008)?	N	Revised QMED used.
	Has the revised method of data transfer (CEH, 2008) been used?	N	Revised method used.
	Choice of donor appropriate?	N	Gauged sites.

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	Choice of adjustment factor appropriate?	N	Standard approach.
	Have QMED estimates been checked for consistency with upstream and downstream gauges?	N	QMED and peak flows have been compared at Alford and Haughton in 2017s6610.
	Local data being used to full potential?	N	Gauged data used.
	Choice of adjustment factor appropriate?	N	Standard approach.
	Estimation of growth factor appropriate?	N	Appropriate
	Growth factor Q2-Q100 is 1.8-3.0	N	3.49 for Haughton 3.14 for Pitcaple Values greater than 3 can occur on Scottish rivers.
	Pooling group reviewed and details given?	N	Included within excel files.
	Has the removal and retention of sites in the pooling group been justified?	N	Yes
	Are there any flood peak records suitable for the derivation of single site growth curves?	N	Yes, used.
	Has enhanced single site analysis been carried out? (rural sites)	N	Yes, used
	Has a comparison of the pooled, single site and enhanced growth curves been undertaken?	N	Yes, SS and ESS compared. Appropriate comparison for this location.
	Climate change considered?	N	24%
Rainfall Runoff	Has the standard methodology been adjusted?	N/A	
	Has FEH rainfall runoff method been used or ReFH?	N/A	
	Have any parameters been adjusted?	N/A	
	Has lag analysis been undertaken?	N/A	
	Climate change considered?	N/A	
Small Catchments or Unusual Catchments	Have non FEH methods been used for small catchment estimates? If so have these been justified and limitations acknowledged?	N	Catchment is large.
	If the catchment is heavily urbanised ($URBEXT_{2000}$>0.150)	N	Catchment is not heavily urbanised.
	If there is a significant reservoir influence (FARL<0.9, with reservoirs not kept permanently full), and there is inadequate flood peak data available downstream of the reservoirs	N	FARL not < 0.9.
	If the catchment is permeable (SPRHOST<20%), has the statistical method been used, with growth curves adjusted to remove non-flood annual maximum flows?	N	SPRHOST > 20%.
	Is the catchment is pumped?	N	Not pumped.
Final Checks	Have results for all methods been summarised for comparison?	N	Summarised in excel sheet.
	Is choice of method justified?	N	Yes.
	Have the design flows been checked for spatial consistency, e.g. at confluences and along reaches?	N	At gauging stations only at this stage.
	Have they been checked against flood peaks in the gauged record, and any longer-term flood history?	N	Longer term history has been consider using Gringorten plotting positions to 1829.
	Have the specific runoff rates been checked for spatial consistency?	N	At gauging stations only at this stage.
	Have the results been compared with any from other studies	N	To be included in main report
	Does the report comment on uncertainty in the design flows?	N	To be included in main report
	Are the assumptions and limitations of the methods acknowledged?	N	To be included in main report

RESPONSE (only required when a Preliminary Certificate is raised)	
I have addressed the comments raised under the Preliminary Certificate.	
Signature	
Name	Briony McIntosh
Date	04 June 2018

FINAL CERTIFICATE	
In respect of the project design described above, I have carried out a Review and consider the technical output sound, and any comments raised under a Preliminary Certificate have been satisfactorily addressed.	
Signature of Reviewer	
Name of Reviewer	David Cameron
Date	04 June 2018

JBA consulting

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