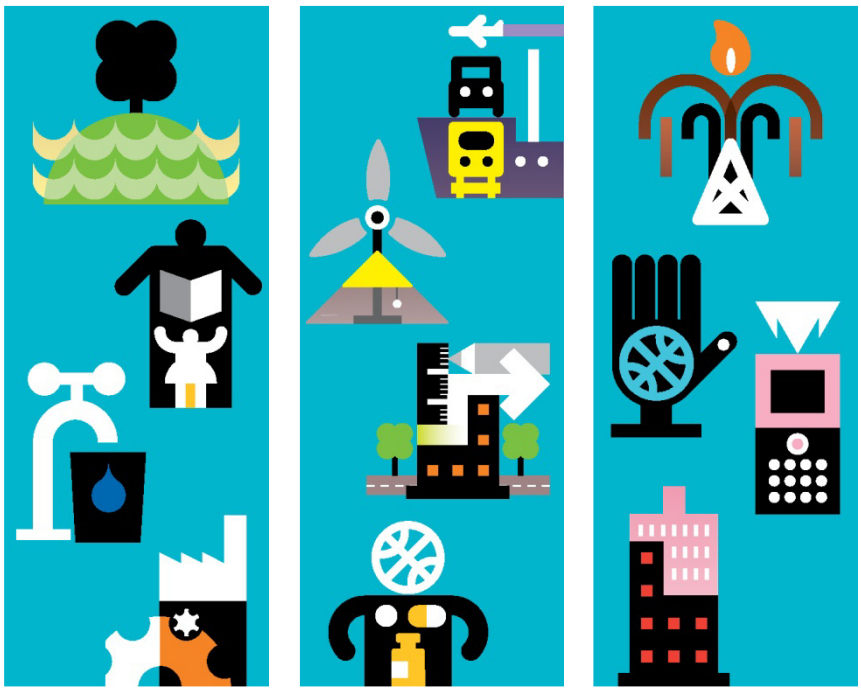

River Almond - Structural Examination and Silt Surveys

Level 3 Flood Risk Assessment - Hydrological Analysis

August 2014

Rivers and Fisheries Trusts of Scotland

RIVERS & FISHERIES TRUSTS OF SCOTLAND
Safeguarding Scotland's Rivers & Lochs

Mott MacDonald

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Contents

Executive Summary

This report details the hydrological assessments undertaken for three locations on the River Almond, in the Lothian Region of Scotland: Howden Bridge Weir in Livingston; and the Peggies Mill and Dowies Mill Weirs in Cramond.

A Flood Risk Assessment (FRA) is required at these locations to assess the impact of the proposed removal of the weir structures. The FRA considers the flood extents for the existing, 'baseline' conditions at these structures and a scenario with the structures removed. The analysis for the FRA has been completed using 1D-2D hydraulic models and the purpose of this report is to document the hydrological calculations that have been completed to determine inflows into these models.

The two weirs at Cramond are assessed in the FRA using one hydraulic model and therefore design event peak flows have been derived in this report for the target sites of the River Almond at Howden Bridge and the River Almond at Peggies Mill Weir only.

The hydrological assessment has been undertaken following current best practice as defined within the *Flood Estimation Handbook* (Institute of Hydrology, 1999) in combination with subsequent updated guidance. The final peak flood flows calculated in this study are presented in Table S.1.

Table S.1: Design Event Peak Flows Derived for the River Almond at Howden Bridge and Peggies Mill

Return period (years)	Howden Bridge (m^3/s)	Peggies Mill (m^3/s)
2	72.8	125.2
5	96.6	168.6
10	114.5	198.6
25	141.2	240.0
50	164.8	274.2
100	192.3	311.7
200	224.5	353.1

1 Introduction

1.1 Background and Context

Mott MacDonald (MM) has been commissioned to undertake Flood Risk Assessments (FRA) at three locations on the River Almond:

- Howden Bridge Weir (NGR NT 06077, 67207)
- Dowies Mill Weir (NGR NT 17920, 75630)
- Peggies Mill Weir (NGR NT 18309, 76420)

The FRA assesses the impact of removal of the weir structures on flood risk to receptors upstream and downstream in each case. The assessment involves the development of 1D-2D linked hydraulic models of the watercourse and the floodplain areas around each of these structures, comparing baseline conditions with the existing structure configuration, to a scenario with the weirs removed. The models show the impact of the structure removal on peak flood depths, extent and velocities.

The hydrological analysis has been undertaken to support the flood analysis documented in the following two reports (Mott MacDonald, 2014):

- *'River Almond, Level 3 Flood Risk Assessments – Cramond Weirs'* and;
- *'River Almond, Level 3 Flood Risk Assessments – Howden Bridge Weir'.*

1.2 Design Events and Methodology

The upstream inflows to each of these models require hydrological analysis of the catchment to determine design event hydrographs and peak flow estimates. Hydrology has been assessed for the following return period events:

- 2 year
- 5 year
- 10 year
- 25 year
- 50 year
- 100 year
- 200 year
- 200 year plus climate change

The hydrological assessment has been undertaken following current UK best practice as defined within *Flood Estimation Handbook* (Institute of Hydrology, 1999) (FEH). Following current best practice guidance, the statistical method, using hydrological 'pooling groups', was judged to be the most suitable approach for calculating peak flows in the

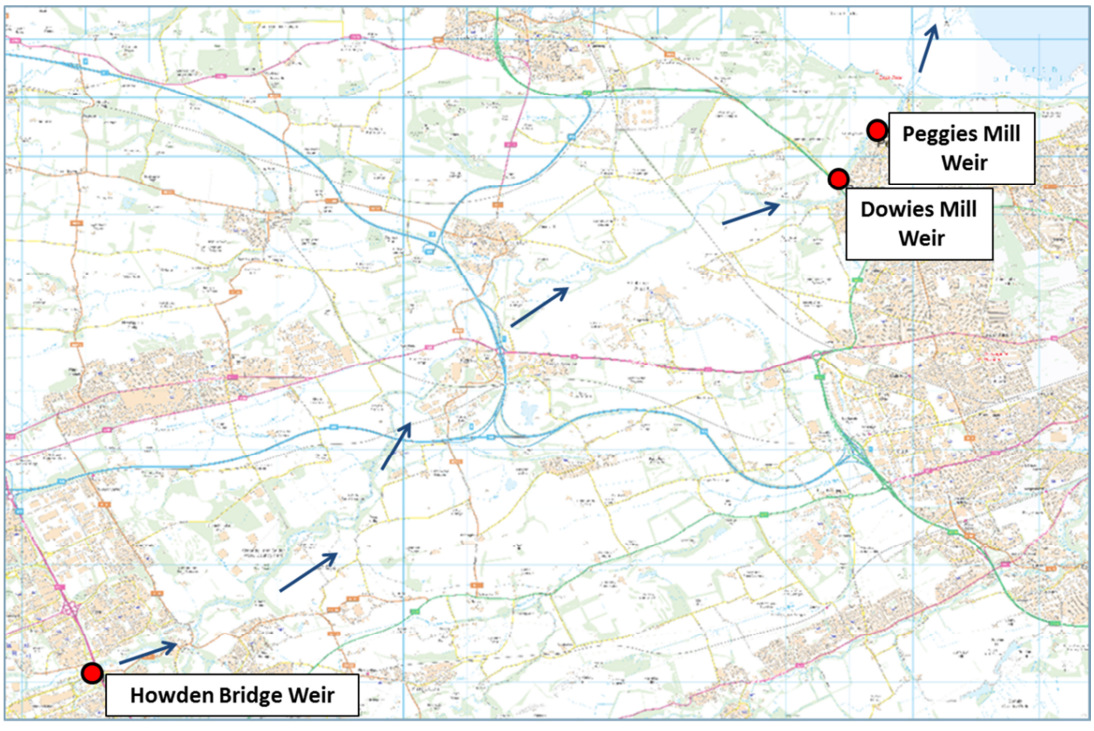
catchment, particularly for higher return period events. The statistical assessment has been undertaken using the industry-standard FEH-WINFAP software package, applying the methods outlined for peak flow estimation in the '*Flood Estimation Handbook: Statistical methods and subsequent scientific advances; User Guide'* (Wallingford HydroSolutions Ltd, 2009). The HiFlows data set v3.3.2 was utilised for the study, as the latest update from SEPA and the Environment Agency for annual maximum flow records at selected UK gauging stations.

1.3 Cramond Weirs (Peggies and Dowies Weir Structures)

The Peggies Mill and Dowies Mill weirs are located in close proximity to Cramond village near the downstream extent of the River Almond at the Firth of Forth.

Peggies Mill Weir is located approximately 900m downstream of Dowies Mill Weir with no significant inflows between the two locations. Figure 1.1 shows the locations of the three weir structures.

Figure 1.1: Location of the Weir Structures Assessed for Hydrology (arrows show approximate route of downstream reaches of the River Almond)



Source: Contains Ordnance Survey Data (c) Crown copyright and database right 2014

The hydrological analysis has been completed for Peggies Mill Weir, the downstream structure at Cramond and the resultant design hydrographs will also be used for the hydraulic modelling of Dowies Mill Weir. With a very small variation in catchment area between the two structures, the differences in the peak flows will be negligible and transferring the peak flow calculated at Peggies Mill Weir upstream to Dowies Mill Weir is considered conservative for the purposes of the flood risk analysis.

The hydrological analysis has therefore only been completed for two locations, Howden Bridge Weir and Peggies Mill Weir.

1.4 Subject Sites

The catchment descriptors of the target sites for the hydrological analysis are shown in Table 1.1.

It is noted that the catchment area at Peggies Mill is significantly larger than Howden Bridge due a number of large contributing catchments flowing into the River Almond between the two sites.

However, the annual average rainfall (SAAR) and the BFIHOST values are reasonably similar and show that the catchments do not experience particularly high annual average rainfall and have only moderately permeable soils.

Table 1.1: Subject Site Catchment Descriptors

Catchment	Howden Bridge	Peggies Mill
AREA (km^2)	162.42	387.35
SAAR (mm)	976	888
BFIHOST	0.356	0.402
URBEXT1990	0.0273	0.0365
URBEXT2000	0.0532	0.0634

Source: FEH CDROMv3

2 Local Hydrometric Data Review

2.1 Review of Local Observed River Flow Records

The target sites for the hydrological analysis are not located at hydrometric river gauging stations and are therefore regarded hydrologically as 'ungauged'.

A key stage of flood hydrology analysis for ungauged sites is to review observed flow records at gauging sites on the target watercourse or in nearby hydrologically similar catchments. The FEH statistical method for ungauged sites relies on a 'pooling group' approach where flow records for UK gauged catchments that are hydrologically similar to the target catchment are used to derive flood growth curves at the target site (peak flow estimates according to flood event probabilities). The growth curve is then multiplied by the median annual maximum flow (QMED) estimate to derive the flood frequency curve.

An initial review identified a number of gauging stations located on the main River Almond, as well as a few additional stations in nearby catchments that were considered for inclusion in the estimation of the QMED values and flood growth curves at the target sites.

The Scottish Environment Protection Agency (SEPA) was contacted for local information regarding the quality of the level-flow rating at each station, in addition to any recorded Annual Maximum flow data and equivalent levels. Confidence in the ratings is important to ensure that flows are accurately translated from observed water level records at high flows.

The HiFlows database is administered by SEPA and the Environment Agency and contains updated flow records together with assessments of whether specific gauging stations should be used for QMED and pooling group analysis. The latest version of the HiFlows database was used in the pooling group analysis in WINFAP.

A summary of the suitability of each gauge for inclusion in the pooling group is shown in Table 2.1. The table provides information regarding the quality of the flow data for inclusion in assessment of the QMED index flow and in the pooling group. The spatial location of the gauges is also shown in Figure 2.1.

The review of the gauged data incorporating the information from SEPA on data quality resulted in the following conclusions:

- Stations where SEPA have concerns over the quality of the data (shaded orange) were immediately disregarded from the hydrological analysis.
- Those stations suitable for QMED only (shaded blue) were not considered for pooling but were revisited when assessing the QMED values.
- Those stations which were identified as being suitable for QMED and pooling but are not included in the HiFlows database (shaded green) are highlighted in Table 2.1.
- This left five potential 'donor' gauging sites: 19005 Almond at Almondell, 19001 Almond at Craigiehall, 19006 Water of Leith at Murrayfield, 19007 River Esk at Musselburgh and 17005 Avon at Polmonthill, shown in white in Table 2.1.

Table 2.1: Gauging Stations within the Almond catchment and surrounding area (SEPA has expressed that stations shaded orange are not suitable; stations in blue are only suitable for QMED; stations in green are suitable for QMED and use in pooling groups, but are not included in the HiFlows database)

Station Number	Station Name	Comment	Usage
19002	River Almond at Almond Weir	Low confidence in extrapolation	QMED Only
19005	Almond at Almondell	Confident in extrapolation	QMED and Pooling
19012	Water of Leith at Colinton	Halcrow Modelled Rating - Confident in extrapolation	QMED and Pooling
19021	South Esk at Cowbridge	Confident in extrapolation	QMED and Pooling
19001	Almond at Craigiehall	Confident in extrapolation	QMED and Pooling
19006	Water of Leith at Murrayfield	Confident in extrapolation though catchment response changed since 2011 due to Water of Leith flood defences	QMED and Pooling
19007	River Esk at Musselburgh	Confident in extrapolation	QMED and Pooling
17005	Avon at Polmonthill	Confident in extrapolation	QMED and Pooling
19017	Gogar Burn at Turnhouse	Confident in extrapolation	QMED and Pooling
19020	River Almond at Whitburn	Low confidence in extrapolation	QMED Only
19003	Breich Weir	Closed 1981 - SEPA hold no data	Not to be used
19008	Prestonholm	Closed 1990 - SEPA hold no data	Not to be used
19011	Dalkeith Palace	Poor quality station	Not to be used

Figure 2.1: Local flow gauging stations

Source: Contains Ordnance Survey Data (c) Crown copyright and database right 2014

The catchment descriptors of the subject sites were compared against the potential SEPA donor sites (Table 2.2) to assess whether they would be suitable for inclusion in either pooling group. It is not surprising that the two gauges with most similar catchment characteristics to the target sites were those located on the River Almond between Howden Bridge and Dowies Mill: 19005 Almond at Almondell, and 19001 Almond at Craigiehall.

Table 2.2: Comparison of the Target Sites and SEPA Gauging Stations

	Howden Bridge	Peggies Mill	19005 (Almond)	19001 (Almond)	19006 (Leith)	19007 (Esk)	17005 (Avon)
AREA (km^2)[1]	162.42	387.35	233	380	102	323	195
SAAR (mm)	976	888	964	892	867	837	990
BFIHOST (%)	0.356	0.402	0.361	0.399	0.428	0.567	0.411
URBEXT1990	0.0273	0.0365	0.0275	0.0339	0.0993	0.0236	0.0188
URBEXT2000	0.0532	0.0634	0.0464	0.0609	0.1095	0.0325	0.0362
Review:			Good similarity to Howden Bridge despite slightly larger area	Very good similarity to Peggies Mill and within close proximity	Moderate similarity to Peggies Mill though area is smaller and URBEXT is higher	Moderate similarity to Peggies Mill though lower URBEXT value and located on a different watercourse	Moderate similarity to Howden Bridge though lower URBEXT value and located on a different watercourse

[1] National River Archive IH DTM Area

2.2 Use of Local Observed River Flow Records to Derive Flood Frequency Curves at the Target Sites

The FEH software requires that gauges selected for use in pooling groups are required to be classed as 'essentially rural' with URBEXT2000 parameter values, indicating the proportion of urban and sub-urban land use in the catchment, of less than 0.03. Analysis of design events for more 'urban' target catchments in WINFAP requires urban adjustments to the QMED and growth curves after the pooling group has been established from 'rural' gauged catchments.

All of the local SEPA gauging stations identified in the River Almond and surrounding catchments are classified as 'urban' and therefore should not be directly incorporated into a pooling group analysis. However, a number of the local stations have been identified as having good quality records and their proximity to the target sites suggests that these observed records should be used in the analysis where possible.

Two of the SEPA gauging stations are located in the same catchment as the target sites on the River Almond. These stations were taken forward in the analysis to test the use of this local observed data in the hydrological analysis. Single site flood frequency analysis was also undertaken at these gauged sites as a comparison with the pooling group results for the target sites.

3 Statistical Assessment of Flood Flows

3.1 Introduction

As the target sites are ungauged and peak flow estimates up to the 200-year return period event, the FEH pooling group was deemed to be the most appropriate approach to derive flood frequency curves at both the Howden Bridge and Peggies Mill target sites.

Initially it was hoped that the pooling group would be made up of a number of gauging stations within the target catchment. However, as identified in Section 2.2, the characteristics of the gauged catchments prevented their inclusion in the pooling groups. Data from the local gauges on the River Almond was used for QMED transfer.

The statistical frequency analysis for the target sites at Howden Bridge and Peggies Mill will be considered separately in this section.

3.2 Howden Bridge

3.2.1 Pooling group formation

An initial pooling group was automatically generated by WINFAP based on the target site catchment characteristics compared to records from gauging stations across the UK.

The target length of record for the pooling of hydrologically similar gauged catchments was set to 500 years in line with current guidance. The WINFAP software reviews the similarity of the individual growth curves from the selected stations in the pooling group and overall there was no discordancy between these stations. However, as per standard practice, all stations were manually compared across the key catchment characteristics including AREA, SAAR[2] and BFIHOST[3] to check hydrological similarity with the target catchments.

In general most stations have reasonable similarity with the subject site and only one station was identified as unsuitable due to a high BFIHOST value of 0.914 (SEPA Gauge 43018 Allen at Walford Mill). This station was removed from the pooling group and replaced by a gauge at Kilmore Bridge (SEPA Gauge 205011 Annacloy at Kilmore Birdge) to maintain the total number of record years.

[2] SAAR: Standard Average Annual Rainfall

[3] Base Flow Index, a measure of the proportion of the watercourse flow resulting from base flow and is used as a measure of the permeability of soils in the catchment

The final pooling group is shown in Table 3.1. The WINFAP H2 parameter value, measuring pooling group similarity / discordancy, was 3.89 and the General Logistics distribution for the flood frequency curve was shown to be the most appropriate in this case. No urban expansion adjustment was made to the URBEXT value.

Table 3.1: Revised Pooling Group for Howden Bridge

Station	Distance (an indexed measure of the similarity with the target site on the basis of Area, Rainfall and the presence of lakes/reservoirs)	Years of data in flow record	QMED from Annual Maxima record (m^3/s)	L-CV (frequency curve distribution parameter)	L-SKEW (frequency curve distribution parameter)	Discordancy (measure of the similarity of the growth curves for the gauged records with the overall pooing group)
76010 (Petteril @ Harraby Green)	0.166	39	31.5	0.226	0.339	0.241
203024 (Cusher @ Gamble's Bridge)	0.200	38	48.0	0.13	-0.002	2.358
21025 (Ale Water @ Ancrum)	0.239	33	51.7	0.214	0.097	0.662
55014 (Lugg @ Byton)	0.348	41	27.3	0.252	0.263	0.559
96001 (Halladale @ Halladale)	0.353	31	105.5	0.174	0.186	0.176
68018 (Dane @ Congleton Park)	0.366	56	41.0	0.183	0.444	1.293
52005 (Tone @ Bishops Hull)	0.371	48	44.3	0.191	0.062	0.908
52010 (Brue @ Lovington)	0.378	45	36.3	0.279	0.37	0.801
203022 (Blackwater @ Derrymeen Bridge)	0.387	18	57.3	0.083	0.295	2.037
7005 (Divie @ Dunphail)	0.407	24	67.2	0.228	0.177	0.246
45005 (Otter @ Dotton)	0.412	47	69.7	0.279	0.409	2.056
9003 (Isla @ Grange)	0.423	47	49.3	0.218	0.148	0.615
205011 (Annacloy @ Kilmore Bridge)	0.43	30	35.5	0.151	0.261	1.048

3.2.2 QMED estimation

3.2.2.1 Catchment Descriptors

The QMED value was initially generated using the standard FEH equation based on the catchment descriptors of the target catchment. Applying this method the QMED value is 57.1m^3/s.

3.2.2.2 QMED Adjustment Using Local Hydrometric Data

There are two gauging stations with observed data upstream and downstream of Howden Bridge (19002 and 19005) which SEPA have confirmed are suitable for estimating QMED.

The upstream gauging station, River Almond at Almond Weir (19002), is upstream of a significant tributary and the gauged catchment (44km^2) is significantly smaller than the target catchment (162km^2). With such a large difference in catchment area and the presence of the large urban catchment of Livingston between the gauging station and the subject site it was dismissed as a potential QMED donor gauge.

The downstream gauging station, River Almond at Almondell (19005), has a catchment area slightly larger than the target site at 233km^2. However the level of catchment urbanisation is similar to the target site due to its close proximity to Howden Bridge (the gauging station is located approximately 3km downstream of the target site).

The QMED at the downstream gauge is 88.8m^3/s calculated as the median of recorded AMAX values from 52 years of data (1962-2013). Whilst it is acknowledged that using QMED transfer on urban catchments is not recommended, in this instance it was judged reasonable to apply a QMED adjustment from a good quality gauged record so close to the target site. A sense check has been made on the results to assess whether they are providing representative peak flows for this location.

The adjusted QMED value at the target site using the Almondell record was 72.8m^3/s, a decrease of 16.0m^3/s on the QMED value at the Almondell gauge. This appears a plausible QMED adjustment considering the target site has a 30% smaller catchment.

It is acknowledged that the latest guidance recommends the adjustment ratio for the transfer of QMED is factored according to the geographical distance between the centroid of the gauged catchment and centroid of the target catchment.

Initially this equation was applied but results in an adjusted QMED of 65.1m^3/s compared to 72.8m^3/s at the target site and 88.8m^3/s at the downstream gauged site. It was thought that the factor was having a disproportionate effect on the adjusted QMED, an issue that was even more evident at Peggies Mill, as described in Section 3.3. It was

concluded that this distance weighting factor would not be applied to the QMED adjustment equation and QMED was adopted as 72.8m^3/s.

3.2.3 Flood frequency curves

The calculations for the QMED flow and flood growth curves presented in the previous sections have been used to generate two flood frequency curves:

- Pooling based flood growth curve with QMED by catchment descriptors - Section 3.2.3.1
- Pooling based flood growth curve with QMED updated using local data - Section 3.2.3.2

A Single Site analysis of the gauged record downstream at the River Almond at Almondell site (19005) is also presented in Section 3.2.4 for comparison.

3.2.3.1 Pooling based flood growth curve with QMED from catchment descriptors

An urban adjustment was made to the QMED rural value to reflect the urbanised nature of the catchment. The Generalised Logistic distribution was applied and fitted by L-moments in WINFAP. The growth curve values (flow standardised by QMED) and the final peak flows from the flood frequency curve) are shown in Table 3.2.

Table 3.2: Growth Curve and Peak Flows based on QMED from catchment descriptors - Howden Bridge

Return Period (years)	Growth Curve (Q / QMED)	Flood Frequency Curve, Peak Flows (m^3/s)
2	1	59.8
5	1.316	78.7
10	1.557	93.1
25	1.919	114.8
50	2.242	134.1
100	2.62	156.8
200	**3.066**	**183.4**

3.2.3.2 Pooling based flood growth curve with QMED updated using local data

The growth curve and peak flows based on the locally adjusted QMED value of 72.8m^3/s are shown in Table 3.3. No urban adjustment was

applied as the gauged QMED used in the adjustment is from the same urbanised catchment.

Table 3.3: Growth Curve and Peak Flows with QMED adjusted using local gauged data - Howden Bridge

Return Period (years)	Growth Curve (Q / QMED)	Flood Frequency Curve, Peak Flows (m^3/s)
2	1	72.8
5	1.326	96.6
10	1.572	114.5
25	1.939	141.2
50	2.264	164.8
100	2.641	192.3
200	**3.083**	**224.5**

3.2.4 Single Site Analysis Comparison

A single site analysis has been undertaken for comparative purposes on the Almond at Almondell SEPA gauge (19005), the same gauge used in the QMED transfer. SEPA are confident that the rating curve is accurate at this station for all flood flows.

The observed QMED value is 88.8m^3/s based on the median of the annual maximum flow values over a 52 year period. The growth curve and peak flows from the single site analysis are shown in Table 3.4. The short length of recorded data available at the site means it should not be used for long return periods as the growth curve would need to be extrapolated, but results can be compared to the flows derived from the pooling group analysis at lower return periods.

Table 3.4: Howden Bridge Single Site Growth Curve and Flood Frequency Curve

Return Period (years)	Growth Curve (Q / QMED)	Flood Frequency Curve, Peak Flows (m^3/s)
2	1.000	88.8
5	1.276	113.4
10	1.492	132.5
25	1.793	159.3
50	2.044	181.6
100	2.321	206.2
200	2.629	233.6

3.2.5 Design Event Flow Estimates for Howden Bridge

The peak flows calculated from all three methods are shown in Table 3.5.

The flood frequency curve for the pooling group with the adjusted value of QMED from local hydrometric data (Section 3.2.3.2), has been adopted for the design event flow estimates at Howden Bridge (highlighted values in bold in Table 3.5). These values compare well with the Single Site Analysis results for the gauged site at Almondell.

The results for the pooling group analysis applying the QMED value from catchment descriptors are significantly lower than the results for the single site and the adjusted QMED approach.

It is thought that the urban adjustment in the catchment descriptor method may not provide realistic results and it is generally preferable to apply observed flow data (of sufficient quality) as far as possible in flow estimation calculations.

The highlighted design peak flow values have been taken forward to be used in the hydraulic modelling at Howden Bridge.

Table 3.5: Summary Table of Calculated Peak Flows at Howden Bridge, River Almond

	Growth Curve			Peak Flows (m^3/s)		
Return period (years)	Pooling Group, QMED from catchment descriptors	Pooling Group, adjusted QMED from local gauged data (Adopted)	Single Site (SEPA Gauge 19005)	Pooling Group, QMED from catchment descriptors	Pooling Group, adjusted QMED from local gauged data (Adopted)	Single Site (SEPA Gauge 19005)
2	1.000	**1.000**	1.000	59.8	**72.8**	88.8
5	1.316	**1.326**	1.276	78.7	**96.6**	113.4
10	1.557	**1.572**	1.492	93.1	**114.5**	132.5
25	1.919	**1.939**	1.793	114.8	**141.2**	159.3
50	2.242	**2.264**	2.044	134.1	**164.8**	181.6
100	2.62	**2.641**	2.321	156.8	**192.3**	206.2
200	3.066	**3.083**	2.629	183.4	**224.5**	233.6

3.3 Peggies Mill

3.3.1 Pooling group formation

An initial pooling group was automatically generated using the FEH-WINFAP software for the Peggies Mill site.

The pooling group did not identify any initial significant discordancy between the growth curves for the selected sites. However, as per standard practice, all stations were manually compared across the key catchment characteristics including AREA, SAAR and BFIHOST to check hydrological similarity with the target catchments.

A number of the stations were identified as having high BFIHOST values and were removed from the pooling group and substituted by sites from the Environment Agency / SEPA list of approved gauging records for pooling analysis (HiFlows data set). The final pooling group is shown in Table 3.6.

The WINFAP H2 parameter value, measuring pooling group similarity / discordancy was 1.544 and the General Logistic distribution for the flood frequency curve was shown to be the most appropriate in this case. As with the Howden Bridge analysis, no urban expansion adjustment was made to the URBEXT value.

Table 3.6: Peggies Mill Pooling Group

Station	Distance (an indexed measure of the similarity with the target site on the basis of Area, Rainfall and the presence of lakes/reservoirs)	Years of data in flow record	QMED from Annual Maxima record (m^3/s)	L-CV (frequency curve distribution parameter)	L-SKEW (frequency curve distribution parameter)	Discordancy (measure of the similarity of the growth curves for the gauged records with the overall pooing group)
55021 (Lugg @ Butts Bridge)	0.188	38	44.8	0.162	0.037	0.779
41014 (Arun @ Pallingham Quay)	0.197	35	76.5	0.175	0.058	0.705
55029 (Monnow @ Grosmont)	0.301	36	157.4	0.146	0.07	2.228
10002 (Ugie @ Inverugie)	0.334	35	45.9	0.291	0.243	0.432
53008 (Avon @ Great Somerford)	0.416	46	36.7	0.257	0.195	0.113
14001 (Eden @ Kemback)	0.458	39	40.4	0.176	0.032	0.851
7004 (Nairn @ Firhall)	0.487	25	95.8	0.312	0.325	1.205
23008 (Rede @ Rede Bridge)	**0.535**	**41**	**137**	**0.172**	**0.195**	**1.633**
10001 (Ythan @ Ardlethen)	**0.560**	**46**	**50.1**	**0.179**	**0.116**	**1.871**
22009 (Coquet @ Rothbury)	**0.597**	**34**	**131.5**	**0.258**	**0.26**	**0.613**
9001 (Deveron @ Avochie)	**0.663**	**47**	**129.3**	**0.217**	**0.157**	**0.537**
20001 (Tyne @ East Linton)	**0.668**	**47**	**57.8**	**0.32**	**0.193**	**1.751**
45012 (Creedy @ Cowley)	**0.755**	**45**	**74.1**	**0.26**	**0.177**	**0.282**

3.3.2 QMED estimation

3.3.2.1 Catchment Descriptors

The QMED value was initially generated using the standard FEH equation based on the catchment descriptors of the target catchment. Applying this method the estimated QMED value is 86.9m^3/s.

3.3.2.2 QMED Adjustment Using Local Gauge Data

A gauging station exists approximately 3km upstream of the site (SEPA Gauge 19001 Almond at Craigiehall) with a catchment only 2% smaller in area than the catchment for the target site. Although the gauged catchment is classified as 'essentially urban' in FEH, the close proximity of the gauge to the target site and the similarity of the respective upstream catchments supports the use of a data transfer to the target site to improve the estimation of QMED.

As with the Howden Bridge site, the results have been compared to peak flows using catchment descriptors to derive QMED and a single site analysis at the gauging station to provide a sense check on the results.

The gauged record at Craigiehall has been confirmed by SEPA as being reliable and the QMED has been calculated from the median of 57 years of AMAX data (1956-2013). The gauged QMED at the upstream station is 124.7m^3/s.

The adjusted QMED value is 125.2m^3/s, an increase of 0.5m^3/s on the upstream gauged site. This appears to be a feasible adjustment to the QMED value.

As for the Howden Bridge analysis, it is acknowledged that the latest guidance recommends the adjustment ratio above is factored to a value dependent on the distance between the centroid of the gauged catchment and centroid of the subject catchment.

Initially this equation was applied but it results in an adjusted QMED of 121.9m^3/s which is lower than the gauged record located upstream. On this basis it appears that the distance weighting factor is not applicable at this location and as such was not applied to the QMED adjustment.

It was concluded that this distance weighting factor should not be applied to the QMED adjustment equation and QMED was adopted as 125.2m^3/s.

3.3.3 Flood frequency curves

The calculations for the QMED flow and flood growth curves presented in the previous sections have been used to generate two flood frequency curves:

- Pooling based flood growth curve with QMED by catchment descriptors - Section 3.3.3.1
- Pooling based flood growth curve with QMED updated using local data - Section 3.3.3.2

A Single Site analysis of the Almond at Craigiehall SEPA gauge (19001) is also presented in Section 3.3.4 for comparison.

3.3.3.1 Pooling based flood growth curve with QMED by catchment descriptors

The Generalised Logistic distribution was applied and fitted by the L-moments method in WINFAP. The growth curve values (flow standardised by QMED) and the final peak flows are shown in Table 3.7.

Table 3.7: Pooling based flood growth curve with QMED by catchment descriptors - Peggies Mill

Return Period (years)	Growth Curve (Q / QMED)	Flood Frequency Curve, Peak Flows (m^3/s)
2	1.000	92.3
5	1.335	123.2
10	1.569	144.8
25	1.895	174.9
50	2.167	200.0
100	2.468	227.8
200	2.802	258.6

3.3.3.2 Pooling based flood growth curve with QMED updated using local data

The growth curve and peak flows based on the locally updated QMED value of 125.2m^3/s are presented in Table 3.8. No urban adjustment was applied as the gauged QMED used in the adjustment is from the same urbanised catchment.

Table 3.8: Pooling based flood growth curve with QMED updated using local data - Peggies Mill

Return Period (years)	Growth Curve (Q / QMED)	Flood Frequency Curve, Peak Flows (m^3/s)
2	1.000	125.2
5	1.347	168.6
10	1.585	198.6
25	1.916	240.0
50	2.189	274.2
100	2.489	311.7
200	2.819	353.1

3.3.4 Single Site Analysis Comparison

A single site analysis has been undertaken for comparative purposes on the Almond at Craigiehall SEPA gauge (19001), the same gauge

used in the QMED transfer. SEPA are confident that the station's rating is reliable for all flood flows.

The observed QMED value is 124.7m^3/s based on the median of the AMAX values over a 57 year period. The growth curve and peak flows from the single site analysis are shown in Table 3.9.

The length of recorded data available at the site means the single site assessment is unreliable for large return periods as the growth curve would be extrapolated from a relatively short data series, but results can be compared to the pooling group analysis at the lower return periods.

Table 3.9: Peggies Mill Single Site Growth Curve and Flood Frequency Curve

Return Period (years)	Growth Curve	Peak Flows (m^3/s)
2	0.999	124.7
5	1.284	160.1
10	1.463	182.4
25	1.692	211.1
50	1.869	233.1
100	2.052	255.9
200	2.242	279.7

3.3.5 Conclusion

The peak flows derived for the design events using the three methods have been collated in Table 3.10.

The flood frequency curve for the pooling group with the adjusted value of QMED from local hydrometric data (Section 3.3.3.2), has been adopted for the design event flow estimates at Peggies Mill (highlighted values in bold in Table 3.10).

Although these flow values are relatively high, they compare well with the results of the Single Site Analysis at low return periods where there is more confidence in the Single Site results given the length of the gauged record.

The results for the pooling group analysis applying the QMED value from catchment descriptors are significantly lower than the results for the single site and the adjusted QMED approach. It is thought that the urban adjustment in the catchment descriptor method may not provide

realistic results and it is generally preferable to apply local and reliable observed flow data as far as possible in flow calculations.

The highlighted design peak flow values have been taken forward to be used in the hydraulic modelling at Peggies Mill (and Dowies Mill) in Cramond.

Table 3.10: Summary Table of Calculated Peak Flows at Peggies Mill, River Almond

	Growth Curve			Peak Flows		
Return period (years)	Pooling Group, QMED from catchment descriptors	Pooling Group, adjusted QMED from local gauged data (Adopted)	Single Site (SEPA Gauge 19005)	Pooling Group, QMED from catchment descriptors	Pooling Group, adjusted QMED from local gauged data (Adopted)	Single Site (SEPA Gauge 19005)
2	1.000	**1.000**	1.000	92.3	**125.2**	124.7
5	1.335	**1.347**	1.284	123.2	**168.6**	160.1
10	1.569	**1.585**	1.463	144.8	**198.6**	182.4
25	1.895	**1.916**	1.692	174.9	**240.0**	211.1
50	2.167	**2.189**	1.869	200.0	**274.2**	233.1
100	2.468	**2.489**	2.052	227.8	**311.7**	255.9
200	2.802	**2.819**	2.242	258.6	**353.1**	279.7