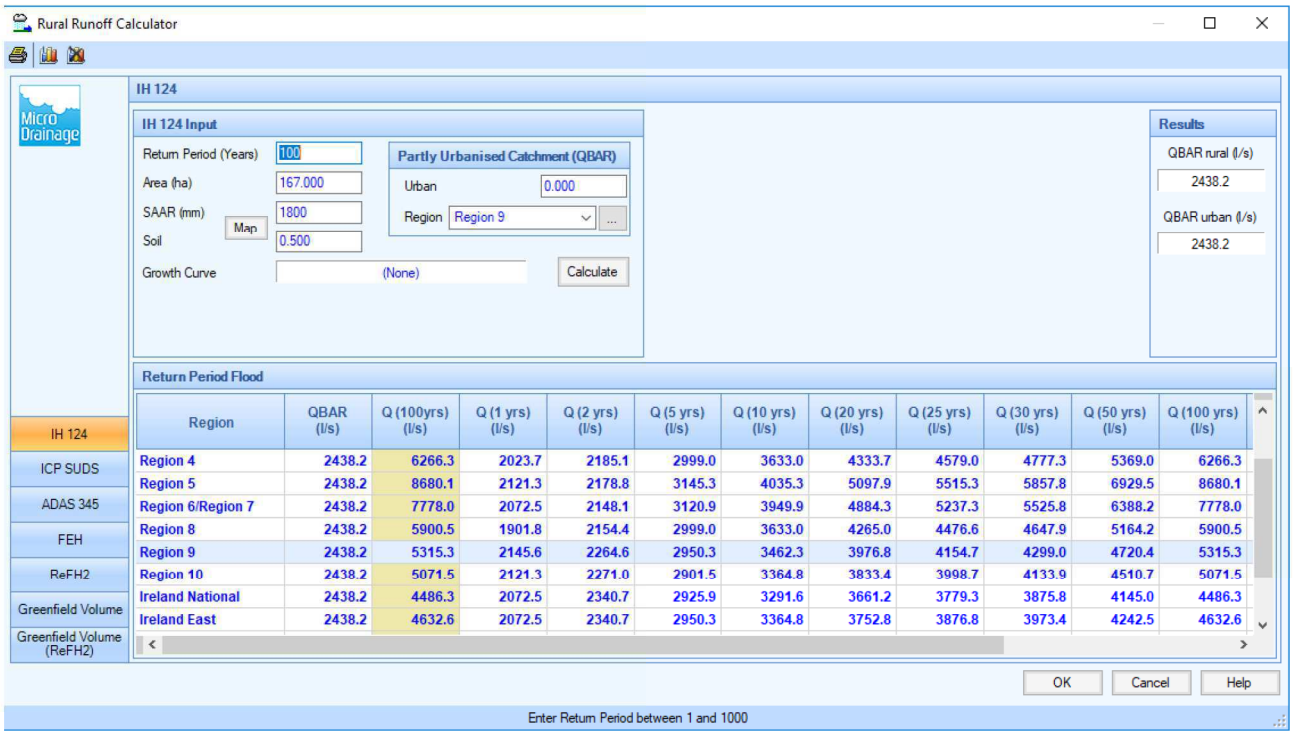


Region	QBAR (l/s)	Q (100yrs) (l/s)	Q (1 yrs) (l/s)	Q (2 yrs) (l/s)	Q (5 yrs) (l/s)	Q (10 yrs) (l/s)	Q (20 yrs) (l/s)	Q (25 yrs) (l/s)	Q (30 yrs) (l/s)	Q (50 yrs) (l/s)	Q (100 yrs) (l/s)
Region 4	2438.2	6266.3	2023.7	2185.1	2999.0	3633.0	4333.7	4579.0	4777.3	5369.0	6266.3
Region 5	2438.2	8680.1	2121.3	2178.8	3145.3	4035.3	5097.9	5515.3	5857.8	6929.5	8680.1
Region 6/Region 7	2438.2	7778.0	2072.5	2148.1	3120.9	3949.9	4884.3	5237.3	5525.8	6388.2	7778.0
Region 8	2438.2	5900.5	1901.8	2154.4	2999.0	3633.0	4265.0	4476.6	4647.9	5164.2	5900.5
Region 9	2438.2	5315.3	2145.6	2264.6	2950.3	3462.3	3976.8	4154.7	4299.0	4720.4	5315.3
Region 10	2438.2	5071.5	2121.3	2271.0	2901.5	3364.8	3833.4	3998.7	4133.9	4510.7	5071.5
Ireland National	2438.2	4486.3	2072.5	2340.7	2925.9	3291.6	3661.2	3779.3	3875.8	4145.0	4486.3
Ireland East	2438.2	4632.6	2072.5	2340.7	2950.3	3364.8	3752.8	3876.8	3973.4	4242.5	4632.6

Figure 1: IH124 Calculation undertaken within Microdrainage for the River Dulais Catchment

3.1.2 ReFH Version 2.2

The catchment descriptors purchased from the FEH Online service were imported into the ReFH2 software (version 2.2). Within the software, the FEH13 DDF rainfall model was applied as this updated method removes the need to derive an alpha correctional factor. This factor was used to modify the initial soil moisture content (C_{ini}) of the model and was often derived using results from the FEH Statistical Method.

By removing the alpha factor, the peak flows estimated by the ReFH2 method are independent of those generated using the FEH Statistical Method, resulting in improved decision making and higher flexibility when selecting the appropriate GRR (ReFH2 Technical Report).

The default storm duration recommended by ReFH2 was used to calculate the GRR. This corresponded to the 2 hour 54 minute storm event. A timestep of 6 minutes was applied.

The 1, 30 and 100-year peak flow outputs were scaled by the subject catchment area to obtain GRR per hectare and are shown in Table 2 below. Both the winter and summer seasonal values have been provided:

Table 2 – Derived GRR from the ReFH2 Analysis for the River Dulais		
Return Period	**Winter (l/s/ha)**	**Summer (l/s/ha)**
1:1 Year	18.4	19.8
QMED	20.7	22.4
1:30 Year	42.2	46.3
1:100 Year	52.7	57.9

The proposed scheme predominantly involves sizing cut-off ditches, culverts, cascades and attenuation features which are suitable for conveying and attenuating predominantly undeveloped land. It is important that the critical storm event is used to size these features to ensure they have sufficient capacity. Since the GRR was calculated to be higher for the summer seasonality, these values will be applied in the design, to ensure adequate sizing of proposed drainage features.

3.1.3 FEH Statistical Method

To undertake the FEH Statistical analysis, the WINFAP4 software was used. Within the software, the latest version of the HiFlows UK data set was applied (version 8), to ensure the latest available station data was utilised.

DEFRA/EA Science Report SC090031 provides guidance and best practice on estimating peak flows and hydrographs for small catchments. The report recommends that for ungauged catchments, the QMED obtained from catchment descriptors should be modified using data transfer from a local donor station with annual maxima data.

The use of a geographically close catchment prevents introducing uncertainties from local flooding factors that may not be contained within catchment descriptors. The QMED adjustment factor in the data transfer equation is moderated based on distance between catchment centroids, so only geographically close stations will have a larger influence.

Using the WINFAP Donor Adjustment method provided a list of the ten closest catchments, and selected the nearest 6 of these by default:

- Station 58008: Dulais at Cilfrew
- Station 59001: Tawe @ Ynystanglws
- Station 58002: Neath @ Resolven
- Station 58006: Mellte @ Pontneddfechan
- Station 60009: Sawdde @ Felin-Y-Cwm
- Station 58012: Afan @ Marcroft Weir

A review of the catchment descriptors for these donor sites was undertaken. Stations 59001, 60009 and 58012 were all removed due to the difference of the SPRHOST, BFIHOST and AREA with the subject catchment. Station 58002 was also removed due to the large AREA difference and the noted combined effect on observed flows from reservoirs, water abstraction and effluent returns.

The donor catchments used for the QMED adjustment were therefore:

- Station 58008: Dulais at Cilfrew
- Station 58006: Mellte @ Pontneddfechan

Station 58006 provided the closest correlation with the target sites catchment descriptors. Station 58008 also provided a good correlation and is downstream of the site in the River Dulais. Given this station includes the area within the site catchment, it is likely to give a reasonable representation of the QMED adjustment required. It was noted that the observed flows for both stations are affected by effluent, but since they are suitable for QMED this was deemed to be acceptable.

A comparison of QMED was undertaken between the calculated value using catchment descriptors and the measured value observed from annual maxima data. This comparison is shown in Table 3 below.

Table 3 – Comparison of calculated and observed QMED values for donor sites

Station	Observed QMED (m3/s)	Calculated QMED (m3/s)	Difference ($QMED_{calc}/QMED_{obs}$)
River Dulais (From FEH Online)	N/A	2.4	N/A
58008 (Dulais @ Cilfrew)	56.4	46.9	1.20
58006 (Mellte @ Pentneddfechan)	87.4	75.3	1.16

The use of data transfer from these donor sites results in an uplift of the GRR from 23.0 l/s/ha (using the QMED catchment descriptor equation) to 25.7 l/s/ha.

The default pooling group contained 16 stations with a total of 515 years of data. This pooling group had a standardised test value (H2) of 1.36, indicating that the pooling group was possibly heterogeneous and a review of the group was optional.

A review of the pooling group was undertaken and the following stations removed:

- Station 49005 – Bollingey Stream at Bollingey Cocks Bridge. Rationale: Short records, only 8 years. Different seasonality of flooding. Negative L-kurtosis. High BFIHOST (0.627) compared to target site. High discordancy value of 2.803.
- Station 69047 – Roch @ Littleborough. Rationale: Low FARL value (0.890)

It was also noted that Station 45816 (Haddeo at Upton) had a steeper growth curve than other stations and a high BFIHOST (0.590). However, a review of the site showed that it has had two relatively large annual maxima events during its recording period. These signify extreme events which have occurred and offer an important contribution to the pooled growth curve. Therefore, it was decided that this station should be included within the group.

The resulting pooling group consisted of 14 stations with a total of 466 years of data. One station was added to achieve the required 500 years:

- Station 21017 – Ettrick Water @ Brockhoperig

This brings the total years of data within the group to 507 years. The modifications to the pooling group resulted in a reduced H2 value of 1.10. The group therefore remained possibly heterogeneous, but there were no obvious justifications to make further amendments.

The goodness of fit test was used which recommended the Generalised Logistic fit. This was applied to produce peak flow estimates for the QMED, 30 and 100-year return period events. These were then scaled by the catchment area to determine the GRR.

The modified pooling group was used to produce peak flow estimate for the QMED, 30 and 100 year return period events. These were then scaled by the catchment area to determine the GRR.

The derived Greenfield Runoff Rate is shown below:

- QMED (1:2 year) rainfall event – 25.7 l/s/ha
- 1:30 year rainfall event – 52.2 l/s/ha
- 1:100 year rainfall event – 67.9 l/s/ha

3.2 Afon Pyrddin Catchment

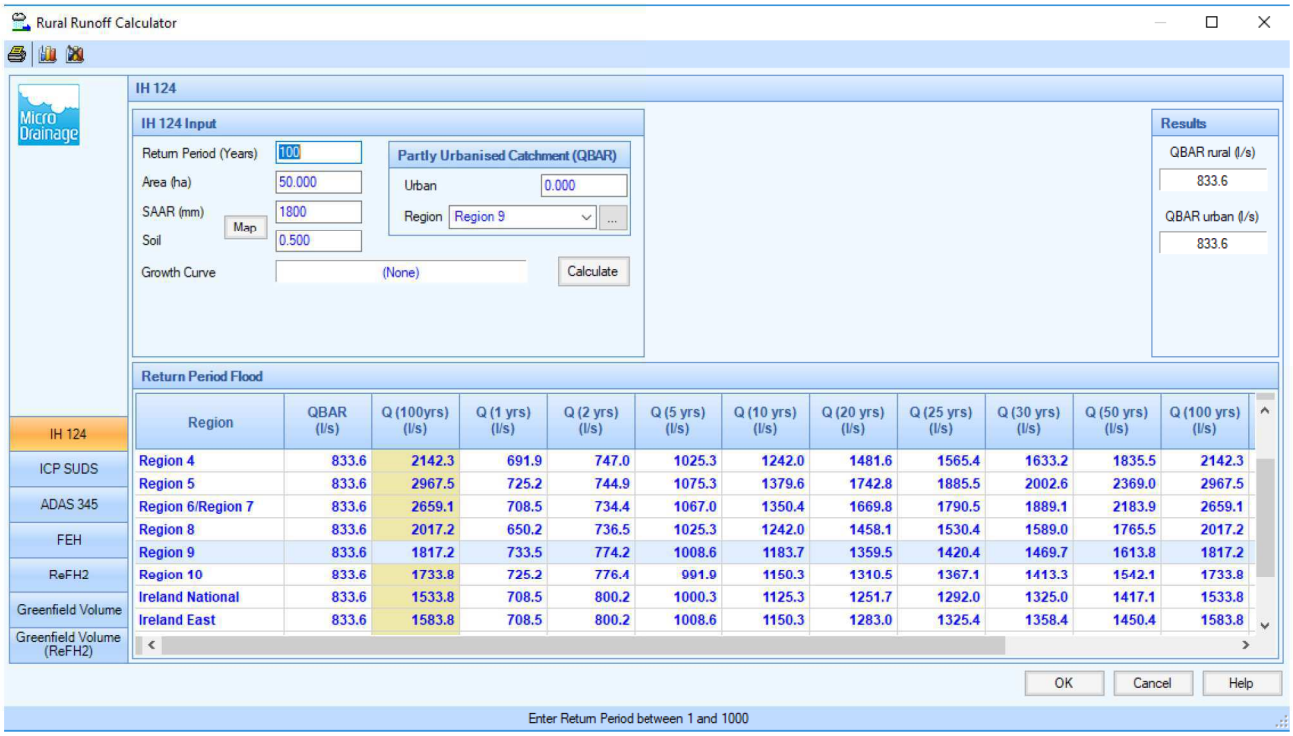
3.2.1 IH124 Method

The IH124 Method was applied within Microdrainage as described for the River Dulais catchment (see Section 3.1.1). The area of the Afon Pyrddin catchment within the planning application boundary was measured to be 33Ha. The point SAAR value of 1800mm was applied.

As the IH124 method was derived for sites over 50ha, it is common practice to undertake the calculation based on an area of 50ha and then linearly interpolate this down for the catchment area. This has been shown in Table 4 below. The results from Microdrainage are shown in Figure 2:

Table 4 – Derived GRR from the IH124 Analysis for the Afon Pyrddin

Return Period	Total GRR for 50ha (l/s)	Scaled Catchment (33ha) GRR (l/s)	GRR per ha (l/s/ha)
1:1 Year	733.5	484.1	14.7
1:30 Year	1469.7	970.0	29.4
1:100 Year	1817.2	1199.4	36.3



Region	QBAR (l/s)	Q (100yrs) (l/s)	Q (1 yrs) (l/s)	Q (2 yrs) (l/s)	Q (5 yrs) (l/s)	Q (10 yrs) (l/s)	Q (20 yrs) (l/s)	Q (25 yrs) (l/s)	Q (30 yrs) (l/s)	Q (50 yrs) (l/s)	Q (100 yrs) (l/s)
Region 4	833.6	2142.3	691.9	747.0	1025.3	1242.0	1481.6	1565.4	1633.2	1835.5	2142.3
Region 5	833.6	2967.5	725.2	744.9	1075.3	1379.6	1742.8	1885.5	2002.6	2369.0	2967.5
Region 6/Region 7	833.6	2659.1	708.5	734.4	1067.0	1350.4	1669.8	1790.5	1889.1	2183.9	2659.1
Region 8	833.6	2017.2	650.2	736.5	1025.3	1242.0	1458.1	1530.4	1589.0	1765.5	2017.2
Region 9	833.6	1817.2	733.5	774.2	1008.6	1183.7	1359.5	1420.4	1469.7	1613.8	1817.2
Region 10	833.6	1733.8	725.2	776.4	991.9	1150.3	1310.5	1367.1	1413.3	1542.1	1733.8
Ireland National	833.6	1533.8	708.5	800.2	1000.3	1125.3	1251.7	1292.0	1325.0	1417.1	1533.8
Ireland East	833.6	1583.8	708.5	800.2	1008.6	1150.3	1283.0	1325.4	1358.4	1450.4	1583.8

Figure 2: *IH124 Calculation undertaken within Microdrainage for the Afon Pyrddin Catchment*

3.2.2 ReFH Version 2.2

The ReFH2 method was applied as described for the River Dulais catchment (see section 3.1.2). Catchment descriptors were exported from FEH Online and analysed for both winter and summer seasonality. The default recommended storm duration of 2 hours, 42 minutes with 6-minute intervals was used.

The 1, 30 and 100-year peak flows from the analysis were scaled by the subject catchment area to obtain GRR per hectare estimates. These are shown in Table 5 below.

Table 5 - Derived GRR using the ReFH2 Analysis for the Afon Pyrddin

Return Period	Winter Seasonality (l/s/ha)	Summer Seasonality (l/s/ha)
1:1 Year	15.6	16.9
QMED	17.5	19.2
1:30 Year	36.6	40.5
1:100 Year	45.9	51.0

As with the River Dulais catchment, the summer seasonality has been applied due to the proposed use of the GRR to size culverts and ditches from predominantly undeveloped areas.

3.2.3 FEH Statistical Method

As per the River Dulais analysis, the latest HiFlows UK data set was used (version 8).

The data transfer method from donor catchments was used to estimate QMED. Applying the donor adjustment method within the WINFAP software provided a list of the ten geographically closest catchments, selecting the closest six of these by default. These are listed below in order of proximity, as well as whether they were included for data transfer:

- Station 58008: Dulais at Cilfrew - Included
- Station 58002: Neath @ Resolven – Discounted
- Station 59001: Tawe @ Ynystanglws – Discounted
- Station 58006: Mellte @ Pontneddfechan - Included
- Station 57017: Rhondda Fawr @ Tynewydd – Discounted
- Station 58012: Afan @ Marcroft Weir - Discounted

The catchment descriptors for these are shown in Table 4 below. Stations 58002 and 59001 were discounted owing to the significantly larger catchment area (more than 200 times larger than the target catchment). Station 58012 was discounted as it has a significantly higher BFIHOST value than the target site. Station 57017 was discounted owing to its much higher SAAR value than the target site.

The two remaining donor catchments are larger than the subject site but are similar from a hydrological perspective. For the selected donor site, a comparison was undertaken between QMED calculated using catchment descriptors and the measured values observed from annual maxima data. This comparison is shown in Table 6 below.

Table 6 – Comparison of calculated and observed QMED values for Afon Pyrddin donor sites

Station	Observed QMED (m3/s)	Calculated QMED (m3/s)	Difference ($QMED_{calc}/QMED_{obs}$)
River Dulais (From FEH Online)	N/A	2.388	N/A
58008 (Dulais @ Cilfrew)	56.3	46.9	1.20
58006 (Mellte @ Pentneddfechan)	87.4	75.3	1.16

The data transfer from the selected donor sites resulted in an uplift to the QMED value from 1.399m^3/s to 1.551m^3/s.

The default pooling group consisted of 14 stations with a total of 516 years of data. This pooling group had a standardised test value (H2) of 1.48, indicating that it was possibly heterogeneous and a review of the group was optional.

A review of the pooling group was subsequently undertaken and the following stations removed:

- Station 69047 – Roch at Littleborough: Low FARL value (0.890) relative to target catchment (1.000).

- Station 47022 – Tory Brook at Newnham Park: Low FARL value (0.942) relative to target catchment (1.000).
- Station 27073 – Brompton Beck at Snainton Ings: High FPEXT (0.2373) and BFIHOST (0.887) compared to the target site (0.0776 and 0.319 respectively).

The resulting pooling group consisted of 11 stations with a total of 416 years of data. Two stations were added to achieve the required 500 years:

- Station 46005 – East Dart @ Bellever
- Station 21017 – Ettrick Water @ Brockhoperig

This brings the total data within the group to 511 years. The modifications to the pooling group resulted in a reduced H2 value of 1.29. This means it remains possibly heterogeneous, however there are no obvious justifications to make further changes.

The goodness of fit test was used which recommended the Generalised Logistic fit. This was applied to produce peak flow estimates for the QMED, 30 and 100-year return period events. These were then scaled by the catchment area to determine the GRR.

The derived Greenfield Runoff Rate is shown below:

- QMED (1:2 year)– 25.3 l/s/ha
- 1:30 year– 52.0 l/s/ha
- 1:100 year– 68.6 l/s/ha

3.3 River Tawe Catchment

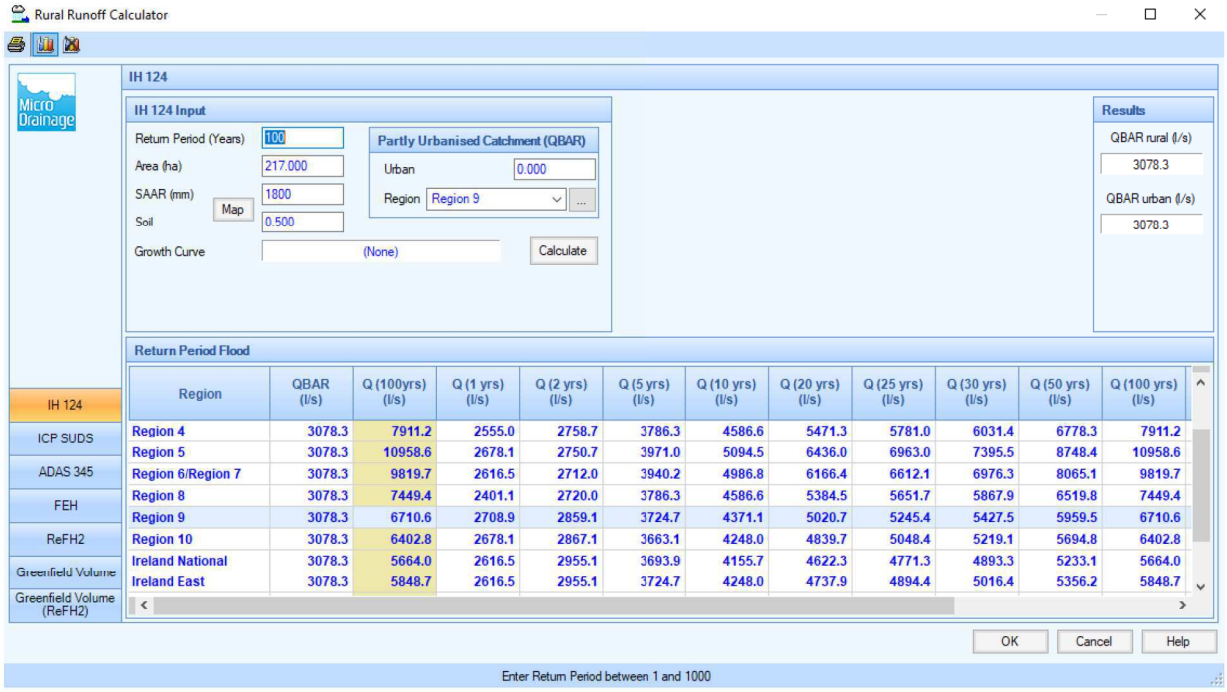
3.3.1 IH 124 Method

The IH124 Method was applied within Microdrainage as described for the River Dulais catchment.

The area of the River Tawe catchment contained within the planning application boundary was measured to be 217Ha. This area was applied within the software to determine the peak GRR for the total site. The peak GRR was been calculated for the 1 year, 30 year and 100-year return period events and was subsequently scaled by the area to give the GRR per hectare:

- 1:1 year rainfall event – 12.4l/s/ha
- 1:30 year rainfall event – 25.0l/s/ha
- 1:100 year rainfall event – 30.9l/s/ha

The results from the Microdrainage analysis are shown in Figure 3.



Region	QBAR (l/s)	Q (100yrs) (l/s)	Q (1 yrs) (l/s)	Q (2 yrs) (l/s)	Q (5 yrs) (l/s)	Q (10 yrs) (l/s)	Q (20 yrs) (l/s)	Q (25 yrs) (l/s)	Q (30 yrs) (l/s)	Q (50 yrs) (l/s)	Q (100 yrs) (l/s)
Region 4	3078.3	7911.2	2555.0	2758.7	3786.3	4586.6	5471.3	5781.0	6031.4	6778.3	7911.2
Region 5	3078.3	10958.6	2678.1	2750.7	3971.0	5094.5	6436.0	6963.0	7395.5	8748.4	10958.6
Region 6/Region 7	3078.3	9819.7	2616.5	2712.0	3940.2	4986.8	6166.4	6612.1	6976.3	8065.1	9819.7
Region 8	3078.3	7449.4	2401.1	2720.0	3786.3	4586.6	5384.5	5651.7	5867.9	6519.8	7449.4
Region 9	3078.3	6710.6	2708.9	2859.1	3724.7	4371.1	5020.7	5245.4	5427.5	5959.5	6710.6
Region 10	3078.3	6402.8	2678.1	2867.1	3663.1	4248.0	4839.7	5048.4	5219.1	5694.8	6402.8
Ireland National	3078.3	5664.0	2616.5	2955.1	3693.9	4155.7	4622.3	4771.3	4893.3	5233.1	5664.0
Ireland East	3078.3	5848.7	2616.5	2955.1	3724.7	4248.0	4737.9	4894.4	5016.4	5356.2	5848.7

Figure 3: IH124 Calculation undertaken within Microdrainage for the River Tawe Catchment

3.3.2 ReFH2

Similarly, the ReFH2 method was applied as described for the River Dulais catchment (see section 3.1.2). The default recommended storm duration of 2 hours, 42 minutes with a 6-minute time step was used to calculate the GRR.

The 1, 30 and 100-year peak flows from the analysis were scaled by the subject catchment area to obtain GRR per hectare estimates. These are shown in Table 7 below.

Table 7 - Derived GRR using the ReFH2 Analysis for the River Tawe

Return Period	Winter Seasonality (l/s/ha)	Summer Seasonality (l/s/ha)
1:1 Year	16.3	17.8
QMED	18.5	20.2
1:30 Year	38.0	42.2
1:100 Year	47.6	53.0

As with the other catchments, the larger summer seasonality values will be adopted.

3.3.3 FEH Statistical Assessment – Pooled Analysis

Reviewing the FEH Statistical Method for the Afon Pyrddin and River Dulais catchments highlighted that the pooling groups and donor stations were very similar for the two catchments, resulting in very similar discharge rates.

The catchment descriptors between the River Tawe and River Dulais/Afon Pyrddin are very similar. As such, it is presumed that an FEH pooled analysis would result in very similar results for the River Tawe Catchment. As such, the values derived from the River Dulais catchment have been adopted for the scheme.

4 Conclusion

4.1 Results and Comparison

A hydrological study of the River Tawe, River Dulais and Afon Pyrddin catchments have been undertaken using the IH124, ReFH2 and FEH Statistical methods. The statistical method was not undertaken for the River Tawe catchment due to the similarities between the catchment descriptors, and as such the outputs from the River Dulais catchment have been adopted for the River Tawe. A summary of the results has been included in Table 8:

Table 8 – Summary of Hydrological Analysis for the GCRE Project

Catchment	Return Period (yr)	IH124 Peak Flows (l/s/ha)	ReFH2 Peak Flows (l/s/ha)	WINFAP Peak Flows (l/s/ha)
River Tawe	1	12.4	17.8	N/A
River Dulais		12.8	19.8	N/A
Afon Pyrrdin		14.7	16.9	N/A
River Tawe	QMED (2 year)	N/A	20.2	25.7
River Dulais		N/A	22.4	25.7
Afon Pyrrdin		N/A	19.2	25.3
River Tawe	30	25.0	42.2	52.2
River Dulais		25.7	46.3	52.2
Afon Pyrrdin		29.4	40.5	52.0
River Tawe	100	30.9	53.0	67.9
River Dulais		31.8	57.9	67.9
Afon Pyrrdin		36.3	51.0	68.6

The results of the IH124 method are shown to correlate well between the three catchments. However, this is due to the only variable within the equation within the three catchments being the catchment area. The IH124 QBAR equation contains a factor of $(0.01 \times AREA)^{0.89}$. Therefore, a larger area such as the River Tawe catchment will have a reduced discharge rate when compared to a smaller area such as the Afon Pyrddin catchment.

The GRR estimate provided using the FEH Statistical and ReFH2 methods are significantly higher than the estimate provided by the IH 124 method. IH124 is a relatively coarse method based on regional growth curves, which utilises no site-specific information. In addition to this, NRW Guidance Note GN008 provides a preference for the FEH Statistical and ReFH2 methods. Given this, the results of the IH124 method has been discounted.

The ReFH2 discharge rates show a reasonable correlation between the three catchments. The results from the WINFAP4 method show a better correlation, with less than 1 l/s/ha difference between the two catchments. This is due to the similarity between the pooling groups, initial QMED estimate from catchment descriptors and the suitable donor catchments based on Geographical distance. Therefore, the closer correlation of the FEH method does not in this instance indicate that it is more accurate. There is a large difference between the results generated by the two methods, particularly when comparing the QMED values.

As mentioned previously, there is a station downstream in the River Dulais. The QMED value measured from this station is 56.4m^3/s, which equates to 13.1 l/s/ha. As this is downstream and serves a larger area, a larger GRR would be expected when analysing a smaller area owing to the longer time of concentration and catchment losses through infiltration and evapotranspiration. However, the values estimated using the WINFAP method are almost double the observed QMED, which is significantly higher than would be expected.

The WINFAP method uses a catchment descriptor equation to estimate QMED which was derived from regression analysis and based on observed information from gauging stations. However, most of the gauged catchments used to compare the equations are between 50km^2 and 500km^2, whilst the target catchments are 1km^2 or less. A smaller area used within the derived FEH QMED equation results in higher peak flow rates, which explains why using this method would result in a significantly higher QMED value. Owing to the small catchment sizes, it is likely that this equation is overestimating QMED.

ReFH2.2 is widely accepted for use on plot-scale sites, as it uses sire specific catchment descriptors with updated FEH13 DDF curves. ReFH2.2 is also used on the plot scale, which is more appropriate for the catchment sizes being reviewed. Given the smaller catchment areas, since the ReFH2 provides a reasonably consistent GRR for the catchments that is slightly higher than the observed downstream QMED in the River Dulais, this method has been chosen as the preferred method.

Therefore, it is recommended that the GRR applied to the Nant Helen Complementary Earthworks scheme should be as shown in Table 9:

Table 9 – GRR to be Applied for the Nant Helen Complementary Earthworks Scheme

Catchment	Return Period (yr)	ReFH2 Peak Flows (l/s/ha)
River Tawe	1	17.8
River Dulais		19.8
Afon Pyrrdin		16.9
River Tawe	30	42.2
River Dulais		46.3
Afon Pyrrdin		40.5
River Tawe	100	53.0
River Dulais		57.9
Afon Pyrrdin		51.0

Technical Note

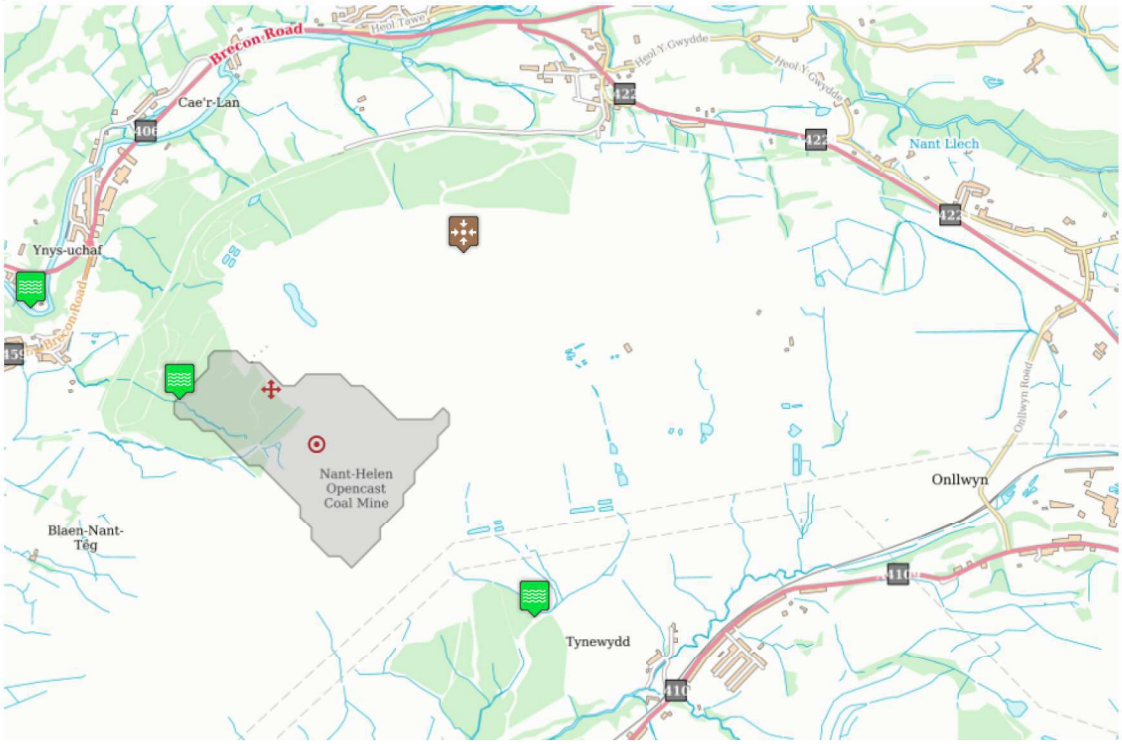
264904 04 December 2019

DOCUMENT CHECKING (not mandatory for File Note)

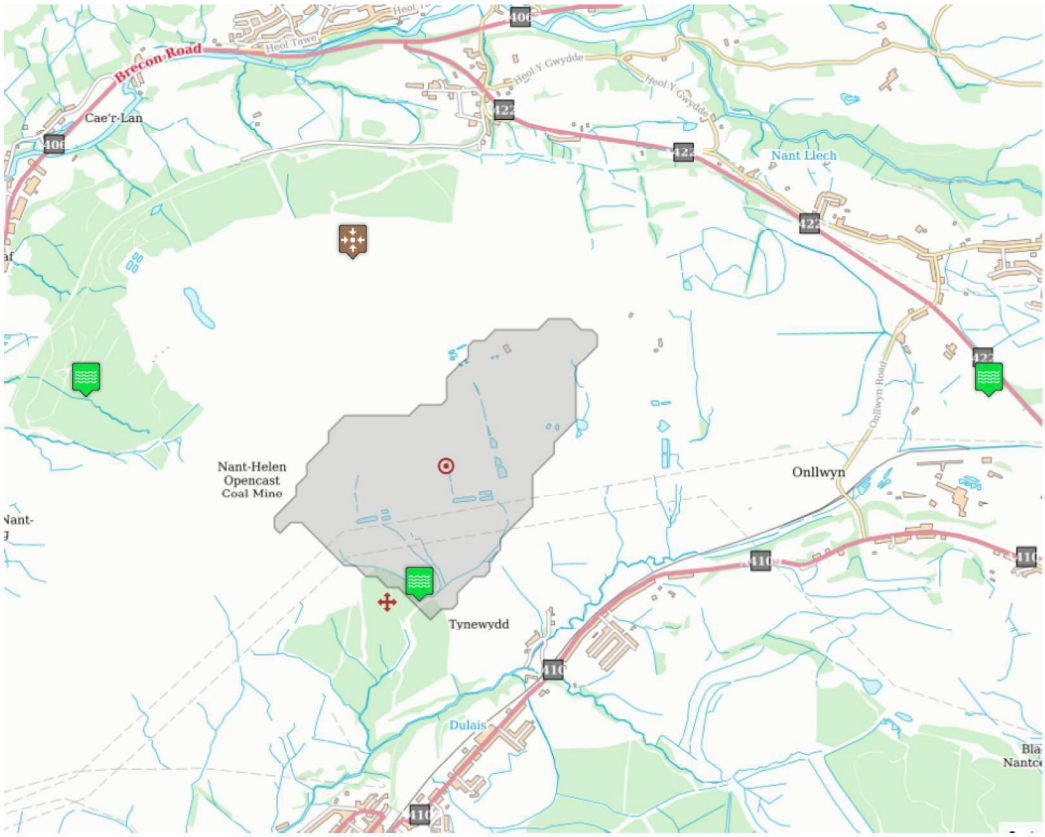
	Prepared by	Checked by	Approved by
Name	Rob Varley	Miguel Piedra	John Smith
Signature			

Appendix A – FEH Catchment Downloads

River Tawe Catchment from FEH Online



River Dulais Catchment from FEH Online



Afon Pyrddin Catchment from FEH Online