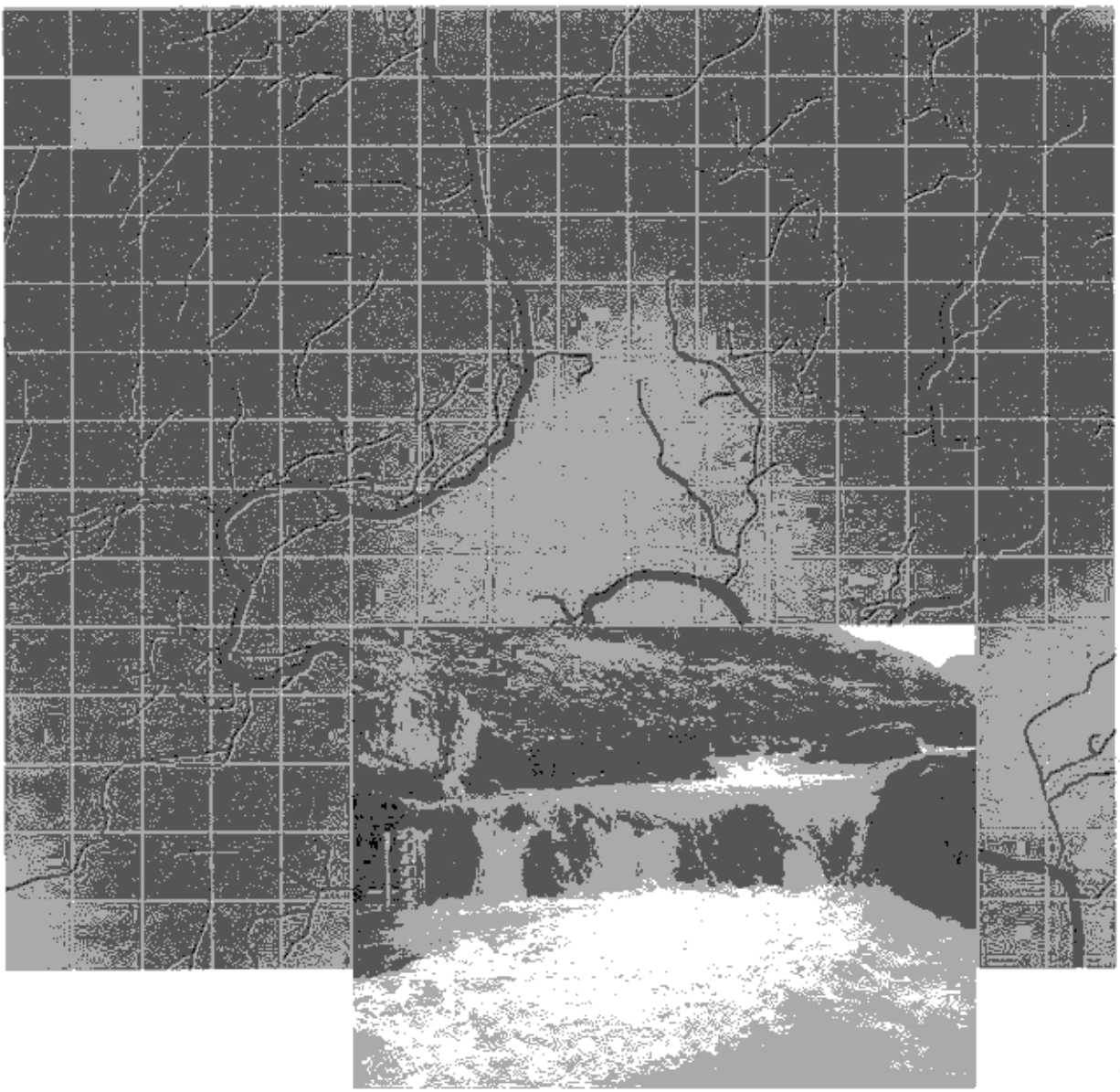
LowFlows Report 02/12

16 January 2012

Flow estimate for Snowdonia Hydro



WHS Wallingford HydroSolutions Limited

For and on behalf of Wallingford HydroSolutions Ltd

Client	Amanda Forman on behalf of Snowdonia Hydro
Prepared by	Gwyneth Cole
Approved by	Jude Jeans
Position	*Senior Consultant*
Invoice value	£175 (excl. VAT)

This report has been produced in accordance with the WHS Quality Management system which is certified as meeting the requirements of ISO 9001:2008.

WHS

Registered Office Maclean Building, Benson Lane, Wallingford OX10 8BB
www.hydrosolutions.co.uk

Contents

1 Introduction

This report presents the annual and seasonal flow statistics for the site(s) requested using the LowFlows Enterprise model. The site location(s) have been confirmed using a digital map and copies of the correspondence are contained within Annex 1.

The LowFlows software system is the standard software system used by the Environment Agency, the Scottish Environment Protection Agency and the Northern Ireland Environment Agency for providing estimates of river flows within ungauged catchments. The software and underpinning science have been widely published in the scientific literature. The LowFlows software system is available for purchase as two versions; LowFlows 2 and LowFlows Enterprise. Wallingford HydroSolutions (WHS) is the sole appointed developer and distributor of the LowFlows software system.

Section 2 of the report provides an overview of our consultancy services; specifically our hydrometry services for supplementing the flow statistics presented within this report with at site measurements and flood event estimation services. We also provide a range of software products ranging from the Flood Estimation Handbook (FEH) software through to Hydra 2 to support hydropower design.

Section 3 presents the methods for the derivation of catchment characteristics and the annual and monthly flow estimates. Following the results for each site, Sections 5 and 6 present the assumptions and uncertainties within the flow estimates, followed by the consideration for use in section 7 and the warranty and liability in section 8.

2 WHS Consultancy Services

WHS was founded by the Natural Environment Research Council (NERC) to deliver high quality consultancy services and environmental software systems. WHS has a team of experienced technical staff including leading UK scientists and specialists. We have a proven track record in provision of flood risk, water resources and Environmental (including EIA) consultancy services across the whole of the UK.

WHS has extensive project experience and can offer a service that meets any of your water resources requirements. Water resources and the estimation of river flows is a core WHS capability and we continue to develop methodologies for estimation of flow statistics within ungauged catchments. Our staff have authored all recognised design methods for estimating flow duration curves within the UK since the 1980s.

WHS also has a strong background of working directly with our clients to meet their requirements for field services. Our in-house field team is well equipped to undertake a wide range of field measurement services, ranging from hydrometric, topographic and geomorphological surveys through to aquatic habitat mapping. We provide hydrometric measurements for resource assessment (to include improving the estimation of flood risk) and WHS has substantial experience undertaking both continuous river flow gauging and event driven gauging at remote, rural and urban locations. We are currently operating hydrometric installations at over thirty sites on behalf of our private and public sector clients. Installations can include additional security measures and/or discrete installations to meet the specific requirements of your site. We offer telemetered data transfer and management to ensure data continuity and fast response to vandalism or

equipment problems. Our expertise also includes ecology surveys and water quality measurement and analysis.

WHS is committed to continuously improving company performance and customer satisfaction. We are proud of our ISO 9001 certification for the provision of environmental consultancy services, development of hydrological software and associated training. For further information on all of our services and software, please visit our website www.hydrosolutions.co.uk.

3 Derivation of the LowFlows Results

Section 3.1 presents the methods used to define the catchment characteristics, and section 3.2 provides an overview of the long term annual and monthly flow statistics provided for the site(s). The flow statistic estimates contained in this report have been produced by LowFlows Enterprise[1] using models and relationships that relate these flow statistics to the climatic and hydrological characteristics of the catchment of interest. All flow statistics provided in this report are for natural flows, thus do not contain any artificial influences such as abstractions, discharges or impounding reservoirs.

3.1 Catchment Characteristics

The following catchment characteristics are provided in the results section of this report:

- **Catchment Area:** The catchment boundary may be derived using either a digital terrain model or an analogue river network based method. The digital method is the default option used in preference to the analogue method but may be misleading or not possible in some areas. The estimation method used to estimate the catchment boundary is identified within the results section for the site(s).
  - The digital method uses a Digital Terrain Model (DTM) to determine the topographic boundaries of the catchment.
  - The analogue method associates grid squares (200 m resolution) to the nearest stretch of river and defines the boundary by selecting grid squares which are assigned to river reaches upstream of the ungauged point.
- **Base-Flow Index (BFI):** The proportion of a hydrograph occurring as base flow, hence varying between zero and unity. BFI is indicative of catchment permeability with values approaching unity associated with highly permeable systems. BFI is estimated from a revised form of the HOSTBFI multivariate linear regression equation [2].

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[1] Young A. R., Grew R. and Holmes M.G.R. 2003. Low Flows 2000: A national water resources assessment and decision support. Water Science and Technology, 48 (10).
[2] Boorman, D.B., Hollis, J.M. and Lilly, A. 1994. Hydrology of Soil Types: a Hydrologically-based Classification of the Soils of the United Kingdom. IH Report 126.

3.2 Long Term Natural Flow Statistics

The following long term flow statistics are provided in the results section of this report.

- **Annual Mean Flow (MF):** The estimation of Mean Flow is based on a grid of long term average annual runoff developed by the Centre for Ecology and Hydrology (CEH). This was derived using the outputs from a deterministic water balance model using observed data from over 500 gauged catchments[3].
- **Mean Monthly Flows (MMF):** The MMF for each month are derived from the natural MF estimate by distributing the total average flow volume for the year between the months of this year. This distribution is based upon observed data from hydrologically similar gauged catchments.
- **Annual Flow Duration Curve (FDC) statistics:** The flow duration curve statistics are estimated using a procedure based on measured flow data from hydrologically similar gauged catchments[4]. This methodology was further updated by WHS in 2009. Flows are provided for the following exceedence percentiles: 5, 10, 20, 30, 40, 50, 60, 70, 80, 90, 95, 99.
- **Mean Monthly Flow Duration Curves (MFDC):** The MFDC for each month is estimated using gauged MFDCs from hydrologically and climatologically similar catchments and the estimate of MMF for that month. The MFDC statistics are presented, by month for the following exceedence percentiles: 5, 10, 20, 30, 40, 50, 60, 70, 80, 90, 95, 99.

If these long term natural flow statistics were calculated directly from a gauged flow record the annual statistics would be equivalent to those calculated using all of the daily flow data from all years of record and the monthly statistics for a month equivalent to those calculated from the gauged data for that month from all years.

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[3] Holmes, M.G.R., Young, A.R., Gustard, A.G. and Grew, R. 2002. A new approach to estimating Mean Flow in the United Kingdom. Hydrology and Earth System Sciences. 6(4) 709-720.
[4] Holmes, M.G.R., Young, A.R., Gustard, A.G. and Grew, R. 2002. A Region of Influence approach to predicting Flow Duration Curves within ungauged catchments. Hydrology and Earth System Sciences. 6(4) 721-731.

4 LowFlows Results for catchment 1 at 272844,322792

4.1 Catchment Characteristics

The catchment characteristics and map for this catchment are presented in the table and figure below. 80% of this catchment is covered by mineral soils which mainly overlie impermeable bedrock (68% of catchment area) or permeable hard fissured sandstone. The remainder of the catchment comprises peat soils overlying permeable substrates (15% of catchment area) and slowly permeable shales. This is a very small catchment less than 0.5 km^2 in area – please refer to the limitations of modelling flows in small catchments as outlined in Section 7.

Monthly flows for May to September inclusive are presented to 4 decimal places which improves the definition of very low flows.

Table 4.1 Catchment Characteristics

Basin Details	
Outlet grid reference	272849, 322794
Hydrometric area	64 (Northern)
Catchment definition method	Digital
Basin area (km^2)	0.345
Base-Flow Index	0.52

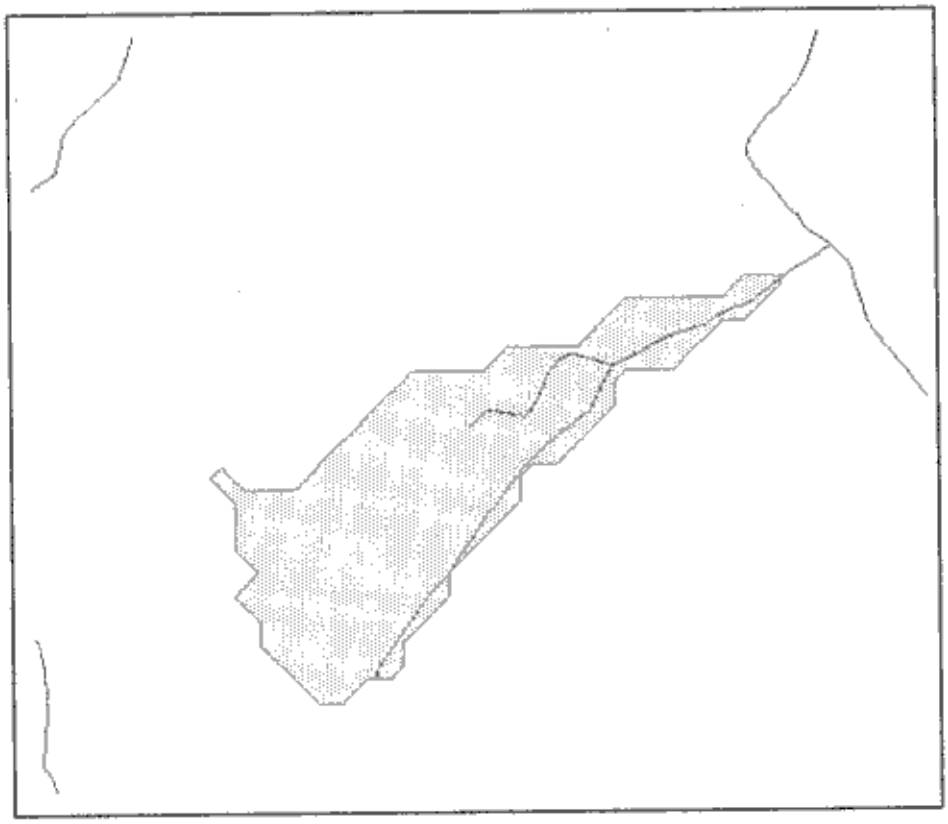

Figure 4.1 Catchment Boundary

4.2 Long Term Natural Flow Statistics

This section presents the long term natural flow statistics. The table below presents both the monthly mean flows and the annual flow duration statistics. The annual flow duration curve is also presented in the figure below, followed by a table displaying the monthly flow duration statistics.

Table 4.2 Mean Flows and Annual Flow Duration Curve Statistics

Mean Flows	Flow (m³/s)
Annual	**0.016**
January	0.027
February	0.022
March	0.021
April	0.011
May	0.007
June	0.006
July	0.007
August	0.009
September	0.013
October	0.023
November	0.023
December	0.026

Percentile	Flow (m³/s)
5	0.0554
10	0.0388
20	0.0244
30	0.0170
40	0.0120
50	0.0087
60	0.0063
70	0.0046
80	0.0034
90	0.0022
95	0.0016
98	0.0013
99	0.0009

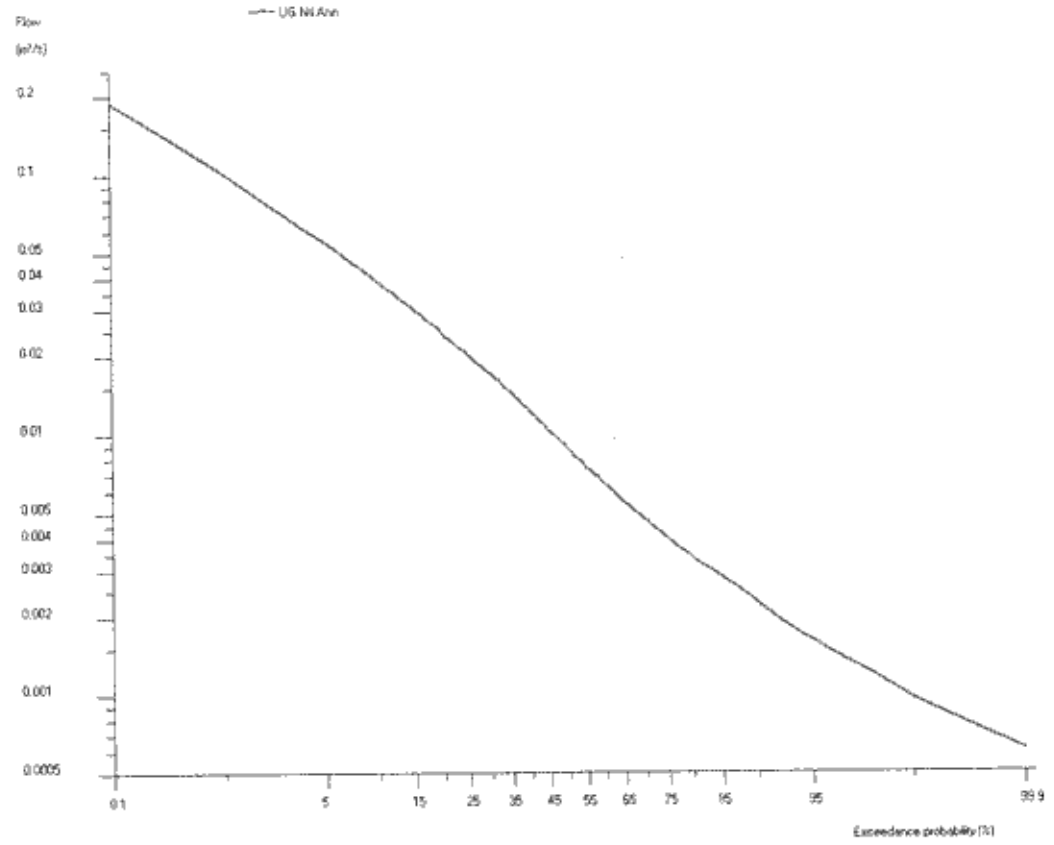

Figure 4.2 Annual Flow Duration Curve

Table 4.3 Monthly Flow Duration Curve Statistics

January		February		March		April	
Percentile	**Q (m^3/s)**	**Percentile**	**Q (m^3/s)**	**Percentile**	**Q (m^3/s)**	**Percentile**	**Q (m^3/s)**
5	0.065	5	0.068	5	0.058	5	0.030
10	0.052	10	0.052	10	0.044	10	0.022
20	0.036	20	0.034	20	0.028	20	0.015
30	0.029	30	0.023	30	0.022	30	0.012
40	0.024	40	0.017	40	0.017	40	0.009
50	0.019	50	0.013	50	0.013	50	0.007
60	0.015	60	0.009	60	0.010	60	0.006
70	0.011	70	0.007	70	0.008	70	0.005
80	0.008	80	0.005	80	0.006	80	0.004
90	0.005	90	0.004	90	0.005	90	0.003
95	0.004	95	0.003	95	0.004	95	0.002
99	0.003	99	0.003	99	0.003	99	0.002

May		June		July		August	
Percentile	**Q (m^3/s)**	**Percentile**	**Q (m^3/s)**	**Percentile**	**Q (m^3/s)**	**Percentile**	**Q (m^3/s)**
5	0.0240	5	0.0213	5	0.0227	5	0.0319
10	0.0164	10	0.0144	10	0.0157	10	0.0231
20	0.0102	20	0.0085	20	0.0093	20	0.0142
30	0.0071	30	0.0063	30	0.0063	30	0.0096
40	0.0052	40	0.0049	40	0.0046	40	0.0067
50	0.0040	50	0.0040	50	0.0036	50	0.0050
60	0.0032	60	0.0033	60	0.0030	60	0.0037
70	0.0027	70	0.0026	70	0.0025	70	0.0028
80	0.0022	80	0.0021	80	0.0019	80	0.0020
90	0.0016	90	0.0016	90	0.0015	90	0.0014
95	0.0014	95	0.0013	95	0.0012	95	0.0011
99	0.0010	99	0.0009	99	0.0009	99	0.0008

September		October		November		December	
Percentile	**Q (m^3/s)**	**Percentile**	**Q (m^3/s)**	**Percentile**	**Q (m^3/s)**	**Percentile**	**Q (m^3/s)**
5	0.0447	5	0.067	5	0.061	5	0.071
10	0.0305	10	0.051	10	0.048	10	0.056
20	0.0194	20	0.034	20	0.034	20	0.038
30	0.0123	30	0.024	30	0.027	30	0.029
40	0.0085	40	0.018	40	0.021	40	0.022
50	0.0064	50	0.014	50	0.017	50	0.017
60	0.0049	60	0.011	60	0.013	60	0.013
70	0.0037	70	0.008	70	0.009	70	0.010
80	0.0027	80	0.005	80	0.007	80	0.008
90	0.0017	90	0.003	90	0.004	90	0.005
95	0.0012	95	0.003	95	0.003	95	0.004
99	0.0008	99	0.002	99	0.002	99	0.003