Derivation of daily outflows from Hydrometric Areas

National River Flow Archive

CEH Wallingford

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Outflow Assessments for Great Britain[1]

Client requirement

As part of a wider study to characterise runoff outflow patterns, the Proudman Oceanographic Laboratory required aggregated outflows for river basins throughout Great Britain ; the initial focus of interest were daily outflows for 2001.

Background and general approach

Unlike many countries, where total outflows to the surrounding seas are dominated by the runoff from relatively few major basins, Great Britain has a long (and indented) coastline and a dense drainage network. In all there are around 200,000 km of watercourses in almost 1500 discrete river systems draining to the sea through over 100 estuaries. Correspondingly, Britain maintains a dense network of gauging stations – currently around 1400. However, the network density varies considerably from region to region reflecting technical difficulties in continuously measuring river flows (e.g. in the flat terrain of East Anglia) and a limited perceived need for dense monitoring networks (e.g. in much of western Scotland).

Reflecting climatic differences, outflows vary substantially from region to region – mean annual runoff from parts of the western Highlands of Scotland is around two orders of magnitude greater than for catchments in the driest parts of the English Lowlands. More details relating to the hydrological characteristics of Britain are given in given in Appendix 1.

The gauging station network provides direct measurement of the outflow from over 65% of Great Britain. To assess regional and sub-regional river outflows, some estimate therefore needs to be made of the contribution from the ungauged areas. These contributions may include major rivers in ungauged basins, minor streams draining directly to the sea and groundwater outflows (by springs and seepages close to, or below, the tidal limits); in a few areas (e.g. the Thames estuary) sewage effluent may constitute a significant proportion of the total outflow. Fortunately for estimation purposes, there is generally a strong association between river flow and catchment size. Knowledge of the catchment area to the gauging station and the overall catchment area of the target region enables a first-order estimate to be made of the total outflow. Such estimates can be refined by weighting according to the average rainfall over the ungauged area (relative to the gauged component). This approach has been widely used in national and regional studies but a more rigourous treatment requires that the weighting factor be based on the relation between mean runoff from the gauged and ungauged areas; the latter approach has been used here.

Hydrometric Areas

For this study, the basic areal unit for which outflows need to be aggregated is the Hydrometric Area. Originally delineated by the Surface Water Survey in the 1930s, Hydrometric Areas (HAs) are either integral river catchments having one or more outlets to the sea or tidal estuary or, for convenience, they may include several contiguous river catchments having topographical similarity with separate tidal outlets (e.g. in south-west England). In mainland Britain, the Hydrometric Areas are numbered from 1 to 97 in clockwise order around the coast commencing in north-east Scotland - see Figure 1.

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[1] Report prepared by T J Marsh and F J Sanderson

Method used

The approach adopted involved, firstly, the identification of one or more representative index catchments within each Hydrometric Area[2] and, thence, the derivation of a weighting factor to allow for those outflows which are not measured.

Identifying a selection of gauged catchments within each HA which, together, may be expected to fairly represent the volume and variability of outflows from the HA as a whole is relatively straightforward where the rainfall and geological characteristics of river basins within a HA are similar and where patterns of water use do not substantially influence outflow regimes. More judgement is required in circumstances where neighbouring rivers have very different hydrological characteristics (as is the case for streams draining the chalk downlands and clay vales of the English Lowlands) or where major water transfers routinely cross catchment divides (this is common in the Scottish Highlands in basins developed for hydro-power purposes).

The hydrometric performance of the individual gauging stations, data continuity and record length were also important selection criteria (it is expected that outflows will be required for periods prior to 2001). The index catchments used in this study are listed in Table 1 together with their catchment area, average rainfall and mean flow for the individual gauging stations; for a few HAs no suitable gauging stations were available. The first three digits of the station number correspond to the HA in which the station is located. Also listed is the Base Flow Index which provides a measure of regime similarity (the BFI may be considered to be the proportion of the total flow from a catchment which originates from stored sources – soil water, groundwater, natural and artificial water bodies).

River flow data

The daily river flow data required for this study were abstracted from the UK National River Flow Archive maintained by CEH Wallingford. Data for this archive are routinely submitted by measuring authorities throughout the UK. The primary measuring authorities in Great Britain are the Environment Agency (including EA Wales) and the Scottish Environment Protection Agency; all the gauging stations featured in Table 1 fall under their aegis.

Weighting factor

The following formula was used to calculate the Weighting Factor (WF) to apply, where necessary, to the combined flows of the index catchment(s) within each Hydrometric Area in order to assess the total HA outflow:

$$\frac{\textit{Area of Hydrometric Area x (1961-90 HA rainfall – Av. annual actual evaporation)}}{\textit{Area of catchment(s) x (1961-90 Catchment rainfall – Av. annual actual evaporation)}}$$

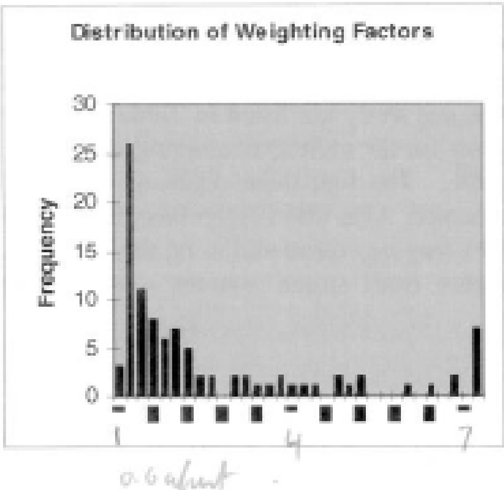
The HA and catchment areas were generally derived using a digital terrain model and a digital characterisation (using a 1km grid) was used to derive the rainfall averages. Estimates of average actual evaporation were based on the MORECS methodology[3] and the balance between long term catchment rainfall and runoff averages.

[2] For a few HAs – those without any direct flow monitoring, the index gauging stations were selected from neighbouring HAs – see particular problems.
[3] See: Hough, M. N. and Jones, R. J. A. 1997. The United Kingdom Meteorological Office rainfall and evaporation calculation system: MORECS version 2 – an overview. Hydrol. Earth Sci. Syst. 1 (2), 227-239.

The WF would not necessarily apply under all circumstances – for instance, in extreme droughts the assumption that flows increase downstream may no longer be valid. Equally, unusual synoptic conditions may produce rainfall patterns across Hydrometric Areas which are also inconsistent with this assumption. Nonetheless under most circumstances the assumption is practical and valid.

Table 2 lists the Weighting Factor to be applied in order to assess total outflows for each HA. The utility of the HA outflow figures is grounded in the high proportion of the outflow which is directly measured. Over 40% of the Weighting Factors are less 1.5 and more than 60% less than 2.0 (see Figure 3).

Figure 3



Particular problems

For some HAs (e.g. 26 and 88) the measured component is, however, very small and the weighting factors are correspondingly large. In these circumstances, and particularly where the WF had to be based on index catchments outwith the target hydrometric area (check the Station Numbers in Table 2), the computed outflows will be of a lesser precision.

Caution also needs to be exercised where the index catchments for any given HA have substantially different flow regimes – this is often the case in the Scottish Highlands where the degree of loch storage in each catchment greatly influences river flow patterns, or in parts of the English Lowlands where clay catchments respond to rainfall much more rapidly than neighbouring chalk catchments. Where possible, judgement has been exercised to provide an appropriate balance between catchments types in each Hydrometric Area but where the BFIs of the selected index catchments exhibit a wide spread, possible differences in the response times of the gauged and ungauged components within the HA may imply that monthly outflow data will have considerably greater credibility than the individual daily outflows.

Missing data

For over 90% of the index gauging stations daily flows are complete for 2001 and in only a few cases do record gaps extend beyond a single month. In some instances the relevant measuring authority may be able to provide infill values but some synthesising of daily flows is likely to be required. Linear interpolation or the substitution of runs of long term average flows should be avoided if possible. A more robust approach involves the use of flow percentiles – the assumption being that the daily flow in a 'target' river will be similar the corresponding n-percentile flow measured in a nearby (and analogous) 'donor' river. The Base Flow Index provides a means of selecting suitable 'donor' rivers.

The percentile method also provides a mean of extending flow records, e.g. at index gauging stations that were not commissioned until the late 1970s. The utility of this approach obviously diminishes as the number of operational 'donor' gauging stations decreases.

Figure 1 UK Hydrometric Areas

Figure 2 Index Gauging Stations used in the derivation of HA outflows

Table 1 Index catchment details

Station Number	River Name	Station Name	Grid Ref East	North	Catchment Area (Sq km)	Base Flow Index	Av Rain 1961-90 (mm)
1001	Wick	Tarroul	3262	9549	161.9	0.38	934
2001	Helmsdale	Kilphedir	2997	9181	551.4	0.47	1117
2002	Brora	Bruachrobie	2892	9039	434.4	0.30	1217
3003	Oykel	Easter Turnaig	2403	9001	330.7	0.23	1900
4003	Alness	Alness	2654	8695	201.0	0.44	1373
4005	Meig	Glenmeannie	2286	8528	120.5	0.25	2145
5002	Farrar	Struy	2390	8405	311.3	0.56	2300
5003	Glass	Kerrow Wood	2354	8321	481.8	0.55	2450
6007	Ness	Ness-side	2645	8427	1839.1	0.61	1764
7002	Findhorn	Forres	3018	8583	781.9	0.40	1064
8006	Spey	Boat o Brig	3318	8518	2861.2	0.60	1120
9002	Deveron	Muiresk	3705	8498	954.9	0.57	928
10003	Ythan	Ellon	3947	8303	523.0	0.73	820
10002	Ugie	Inverugie	4101	8485	325.0	0.64	812
11001	Don	Parkhill	3887	8141	1273.0	0.69	885
12002	Dee	Park	3798	7983	1844.0	0.53	1081
13007	North Esk	Logie Mill	3699	7640	732.0	0.52	1074
13008	South Esk	Brechin	3600	7596	488.0	0.55	1069
14001	Eden	Kemback	3415	7158	307.4	0.62	799
14002	Dighty Water	Balmossie Mill	3477	7324	126.9	0.59	798
15006	Tay	Ballathie	3147	7367	4587.1	0.64	1425
16004	Earn	Forteviot Bridge	3044	7183	782.2	0.52	1397
17001	Carron	Headswood	2832	6820	122.3	0.35	1529
17002	Leven	Leven	3369	7006	424.0	0.67	948
17005	Avon	Polmonthill	2952	6797	195.3	0.41	989
18002	Devon	Glenochil	2858	6960	181.0	0.54	1327
18011	Forth	Craigforth	2775	6955	1036.0	0.40	1767
19001	Almond	Craigiehall	3165	6752	369.0	0.39	896
19006	Water of Leith	Murrayfield	3228	6732	107.0	0.49	854
19007	Esk	Musselburgh	3339	6723	330.0	0.53	835
20001	Tyne	East Linton	3591	6768	307.0	0.53	713
21009	Tweed	Norham	3898	6477	4390.0	0.53	955
21022	Whiteadder Water	Hutton Castle	3881	6550	503.0	0.53	813
22001	Coquet	Morwick	4234	6044	569.8	0.44	850
22007	Wansbeck	Mitford	4175	5858	287.3	0.37	793
23001	Tyne	Bywell	4038	5617	2175.6	0.38	1015
23007	Derwent	Rowlands Gill	4168	5581	242.1	0.57	849
24009	Wear	Chester le Street	4283	5512	1008.3	0.47	855
25005	Leven	Leven Bridge	4445	5122	196.3	0.44	725
25009	Tees	Low Moor	4364	5105	1264.0	0.36	969
26003	Foston Beck	Foston Mill	5093	4548	57.2	0.96	699
26008	Mires Beck	north Cave	4890	4316	41.9	0.86	650
27003	Aire	Beal Weir	4535	4255	1932.1	0.52	979
27009	Ouse	Skelton	4568	4554	3315.0	0.46	900
27021	Don	Doncaster	4570	4040	1256.2	0.55	799
27041	Derwent	Buttercrambe	4731	4587	1586.0	0.68	765
27089	Wharfe	Tadcaster	4477	4441	818.0	0.41	1131

27092 Esk	Briggswath	4873	5082	325.4	0.29	884
28015 Idle	Mattersey	4690	3895	529.0	0.79	650
28022 Trent	North Muskham	4801	3601	8231.0	0.65	747
29002 Great Eau	Claythorpe Mill	5416	3793	77.4	0.89	692
29003 Lud	Louth	5337	3879	55.2	0.90	699
30001 Witham	Claypole Mill	4842	3480	297.9	0.68	614
30003 Bain	Fulsby Lock	5241	3611	197.1	0.58	668
30006 Slea	Leasingham Mill	5088	3485	48.4	0.89	601
31002 Glen	Kates Br and King St Br	5106	3149	341.9	0.60	608
31004 Welland	Tallington	5095	3078	717.4	0.52	634
32002 Willow Brook	Fotheringhay	5067	2933	89.6	0.73	601
32003 Harpers Brook	Old Mill Bridge	4983	2799	74.3	0.49	623
32004 Ise Brook	Harrowden Old Mill	4898	2715	194.0	0.54	635
33007 Nar	Marham	5723	3119	153.3	0.91	682
33021 Rhee	Burnt Mill	5415	2523	303.0	0.74	559
33039 Bedford Ouse	Roxton	5160	2535	1660.0	0.56	628
34004 Wensum	Costessey Mill	6177	3128	570.9	0.74	672
34006 Waveney	Needham Mill	6229	2811	370.0	0.47	594
35003 Alde	Farnham	6360	2601	63.9	0.37	592
35010 Gipping	Bramford	6127	2465	298.0	0.51	580
35013 Blyth	Holton	6406	2769	92.9	0.36	591
36005 Brett	Hadleigh	6025	2429	156.0	0.47	580
36006 Stour	Langham	6020	2344	578.0	0.53	580
37001 Roding	Redbridge	5415	1884	303.3	0.39	606
37002 Chelmer	Rushes Lock	5794	2090	533.9	0.45	583
37005 Colne	Lexden	5962	2261	238.2	0.52	566
37010 Blackwater	Appleford Bridge	5845	2158	247.3	0.57	572
38001 Lee	Feildes Weir	5390	2092	1036.0	0.57	630
39001 Thames	Kingston	5177	1698	9948.0	0.64	706
40003 Medway	Teston	5708	1530	1256.1	0.41	744
40004 Rother	Udiam	5773	1245	206.0	0.35	857
40011 Great Stour	Horton	6116	1554	345.0	0.70	747
41003 Cuckmere	Sherman Bridge	5533	1051	134.7	0.28	814
41005 Ouse	Gold Bridge	5429	1214	180.9	0.51	835
41011 Rother	Iping Mill	4852	1229	154.0	0.61	920
41014 Arun	Pallingham Quay	5047	1229	379.0	0.30	805
41023 Lavant	Graylingwell	4871	1064	87.2	0.86	922
42001 Wallington	North Fareham	4587	1075	111.0	0.41	820
42003 Lymington	Brockenhurst	4318	1019	98.9	0.36	854
42004 Test	Broadlands	4354	1189	1040.0	0.94	790
42010 Itchen	Highbridge+Allbrook	4467	1213	360.0	0.96	833
43007 Stour	Throop	4113	958	1073.0	0.65	861
43021 Avon	Knapp Mill	4156	943	1706.0	0.90	810
44001 Frome	East Stoke Total	3866	867	414.4	0.85	968
44002 Piddle	Baggs Mill	3913	876	183.1	0.89	943
44003 Asker	Bridport	3470	928	49.1	0.63	922
45001 Exe	Thorverton	2936	1016	600.9	0.50	1248
45005 Otter	Dotton	3087	885	202.5	0.53	976
46002 Teign	Preston	2856	746	381.0	0.55	1230
46003 Dart	Austins Bridge	2751	659	247.6	0.52	1765
46008 Avon	Loddiswell	2719	476	102.3	0.52	1560
47001 Tamar	Gunnislake	2426	725	916.9	0.46	1216
47004 Lynher	Pillaton Mill	2369	626	135.5	0.60	1423

48011 Fowey	Restormel one	2108	613	169.1	0.65	1450
48003 Fal	Tregony	1921	447	87.0	0.66	1210
49001 Camel	Denby	2017	682	208.8	0.62	1336
49002 Hayle	St Erth	1549	341	47.6	0.83	1077
50001 Taw	Umberleigh	2608	1237	826.2	0.43	1155
50002 Torridge	Torrington	2500	1185	663.0	0.38	1186
51002 Horner Water	West Luccombe	2898	1458	20.8	0.60	1480
51003 Washford	Beggearn Huish	3040	1395	36.3	0.62	1156
52005 Tone	Bishops Hull	3206	1250	202.0	0.58	966
52007 Parrett	Chiselborough	3461	1144	74.8	0.41	887
52010 Brue	Lovington	3590	1318	135.2	0.47	867
53006 Frome(Bristol)	Frenchay	3637	1772	148.9	0.39	792
53018 Avon	Bathford	3785	1670	1552.0	0.59	817
54002 Avon	Evesham	4040	2438	2210.0	0.52	654
54032 Severn	Saxons Lode	3863	2390	6850.0	0.58	856
55023 Wye	Redbrook	3528	2110	4010.0	0.54	1011
56001 Usk	Chain Bridge	3345	2056	911.7	0.52	1363
56002 Ebbw	Rhiwderyn	3259	1889	216.5	0.57	1456
57005 Taff	Pontypridd	3079	1897	454.8	0.47	1830
57008 Rhymney	Llanedeyrn	3225	1821	178.7	0.48	1405
57009 Ely	St Fagans	3121	1770	145.0	0.48	1350
58001 Ogmore	Bridgend	2904	1794	158.0	0.48	1773
58002 Neath	Resolven	2815	2017	190.9	0.35	1949
58008 Dulais	Cilfrew	2778	2008	43.0	0.39	1808
59001 Tawe	Ynystanglws	2685	1998	227.7	0.37	1892
59002 Loughor	Tir-y-dail	2623	2127	46.4	0.44	1500
60003 Taf	Clog-y-Fran	2238	2160	217.3	0.56	1420
60010 Tywi	Nantgaredig	2485	2206	1090.4	0.46	1534
61001 Western Cleddau	Prendergast Mill	1954	2177	197.6	0.63	1275
61002 Eastern Cleddau	Canaston Bridge	2072	2153	183.1	0.55	1437
62001 Teifi	Glan Teifi	2244	2416	893.6	0.54	1382
63001 Ystwyth	Pont Llolwyn	2591	2774	169.6	0.41	1443
63002 Rheidol	Llanbadarn Fawr	2601	2804	182.1	0.49	1787
64001 Dyfi	Dyfi Bridge	2745	3019	471.3	0.39	1834
64002 Dysynni	Pont-y-Garth	2632	3066	75.1	0.48	2164
65005 Erch	Pencaenewydd	2400	3404	18.1	0.55	1470
65006 Seiont	Peblig Mill	2493	3623	74.4	0.41	2278
65007 Dwyfawr	Garndolbenmaen	2500	3429	52.4	0.39	2047
66001 Clwyd	Pont-y-Cambwll	3069	3709	404.0	0.60	911
66006 Elwy	Pont-y-Gwyddel	2952	3718	194.0	0.45	1189
67008 Alyn	Pont-y-Capel	3336	3541	227.1	0.57	916
67015 Dee	Manley Hall	3348	3415	1019.3	0.52	1369
68001 Weaver	Ashbrook	3670	3633	622.0	0.53	731
68003 Dane	Rudheath	3668	3718	407.1	0.54	854
68007 Wincham Brook	Lostock Gralam	3697	3757	148.0	0.51	819
69002 Irwell	Adelphi Weir	3824	3987	559.4	0.50	1257
69007 Mersey	Ashton Weir	3772	3936	660.0	0.53	1129
69030 Sankey Brook	Causey Bridge	3588	3922	154.0	0.56	903
70002 Douglas	Wanes Blades Bridge	3476	4126	196.0	0.53	1037
70005 Lostock	Littlewood Bridge	3497	4197	56.0	0.48	1020
71001 Ribble	Samlesbury	3587	4314	1145.0	0.34	1353
72002 Wyre	St Michaels	3463	4411	275.0	0.33	1245
72004 Lune	Caton	3529	4653	983.0	0.32	1523

73005 Kent	Sedgwick	3509	4874	209.0	0.42	1732
73010 Leven	Newby Bridge FMS	3367	4863	247.0	0.50	2167
74005 Ehen	Braystones	3009	5061	125.5	0.42	1758
75002 Derwent	Camerton	3038	5305	663.0	0.49	1811
75017 Ellen	Bullgill	3096	5384	96.0	0.50	1110
76007 Eden	Sheepmount	3390	5571	2286.5	0.49	1183
77001 Esk	Netherby	3390	5718	841.7	0.38	1358
78003 Annan	Brydekirk	3191	5704	925.0	0.44	1351
79002 Nith	Friars Carse	2923	5851	799.0	0.39	1460
79005 Cluden Water	Fiddlers Ford	2928	5795	238.0	0.38	1422
80001 Urr	Dalbeattie	2822	5610	199.0	0.36	1340
80002 Dee	Glenlochar	2733	5641	809.0	0.41	1754
81002 Cree	Newton Stewart	2412	5653	368.0	0.28	1760
81003 Luce	Airyhemming	2180	5599	171.0	0.23	1504
81004 Bladnoch	Low Malzie	2382	5545	334.0	0.34	1344
82001 Girvan	Robstone	2217	5997	245.5	0.34	1373
82002 Doon	Auchendrane	2338	6160	323.8	0.57	1581
82003 Stinchar	Balnowlart	2108	5832	341.0	0.32	1507
83005 Irvine	Shewalton	2345	6369	380.7	0.27	1228
83006 Ayr	Mainholm	2361	6216	574.0	0.30	1214
83009 Garnock	Kilwinning	2307	6424	183.8	0.23	1554
84001 Kelvin	Killermont	2558	6705	335.1	0.43	1257
84005 Clyde	Blairston	2704	6579	1704.2	0.45	1140
84012 White Cart Water	Hawkhead	2499	6629	234.9	0.35	1314
85001 Leven	Linnbrane	2394	6803	784.3	0.76	2025
85003 Falloch	Glen Falloch	2321	7197	80.3	0.16	3000
86001 Little Eachaig	Dalinlongart	2143	6821	30.8	0.23	2337
89005 Lochy	Inverlochy	2197	7274	47.7	0.25	2884
89006 Avich	Barnaline	1971	7139	32.1	0.54	2600
89007 Abhainn	Braevallich	1957	7076	24.1	0.23	2850
90003 Nevis	Claggan	2116	7742	76.8	0.26	2912
91002 Lochy	Camisky	2145	7805	1252.0	0.39	2188
92001 Shiel	Shielfoot	1666	7702	256.0	0.60	2769
93001 Carron	New Kelso	1942	8429	137.8	0.26	2620
94001 Ewe	Poolewe	1859	8803	441.1	0.64	2273
95001 Inver	Little Assynt	2147	9250	137.5	0.64	2211
96001 Halladale	Halladale	2891	9561	204.6	0.26	1102
96002 Naver	Apigill	2713	9568	477.0	0.43	1384
97002 Thurso	Halkirk	3131	9595	412.8	0.46	1057

Table 2 Hydrometric Areas, Index Gauging Stations and Weighting Factors

Hydrometric Area Number	Area (Sq km)	Mean Rainfall (mm)	Mean Evaporation (mm)	Index Gauging Stations	No. of Stations	Combined Area (Sq km)	Mean Rainfall (mm)	Weighting Factor
1	873	971	450	1001	1	161.9	934	5.81
2	1354	1110	450	2001, 2002	2	965.8	1161	1.27
3	1929	1527	460	3003	1	434.4	1217	6.26
4	2189	1345	460	4003, 4005	2	321.5	1662	5.01
5	1078	1882	450	5002, 5003	2	793.1	2391	1
6	1990	1664	470	6007	1	1839.1	1750	1.01
7	1820	911	480	7002	1	781.9	1064	1.72
8	2969	1087	480	8006	1	2861.2	1110	1.01
9	1555	874	500	9002	1	954.9	928	1.42
10	1413	799	510	10002, 10003	2	848.0	817	1.57
11	1324	878	480	11001	1	1273.0	885	1.02
12	2112	1032	470	12002	1	1844.0	1081	1.05
13	2020	963	490	13007, 13008	2	1220.0	1080	1.33
14	1037	758	490	14001, 14002	2	434.3	799	2.07
15	5079	1364	450	15006	1	4587.1	1425	1.04
16	962	1293	450	16004	1	782.2	1397	1.12
17	1497	943	500	17001, 17002, 17005	3	741.6	1055	1.61
18	1601	1560	480	18002, 18011	2	1217.0	1702	1.16
19	926	846	490	19001, 19006, 19007	3	806.0	865	1.09
20	661	683	500	20001	1	307.0	713	1.85
21	5320	917	480	21009, 21022	2	4893.0	940	1.03
22	2022	755	500	22001, 22007	2	857.1	831	1.82
23	2933	938	480	23001, 23007	2	2417.7	998	1.07
24	1194	825	490	24009	1	1008.3	855	1.09
25	2210	840	500	25005, 25009	2	1460.3	936	1.18
26	2148	663	520	26003, 26008	2	99.1	678	19.57
27	11330	850	520	27003, 27009, 27021 27041, 27089, 27092	6	9232.7	900	1.07
28	10432	718	510	28015, 28022	2	8760.0	741	1.07
29	1932	642	520	29002, 29003	2	132.6	695	10.17
30	3371	600	520	30001, 30003, 30006	3	543.4	632	4.39
31	1602	606	510	31002, 31004	2	1059.3	626	1.26
32	2362	598	520	32002, 32003, 32004	3	357.9	624	4.95
33	8564	594	520	33007, 33021, 33039	3	2116.3	622	2.93
34	3738	628	520	34004, 34006	2	940.9	641	3.53
35	1583	589	510	35003, 35010, 35013	3	454.8	584	3.73
36	1039	578	490	36005, 36006	2	734.0	580	1.39
37	3127	567	490	37001, 37002, 37005 37010	4	1322.7	583	1.94
38	1413	634	500	38001	1	1036.0	630	1.41
39	10951	704	520	39001	1	9948.0	706	1.09
40	4773	717	500	40003, 40004, 40011	3	1807.1	757	2.23
41	3110	824	490	41003, 41005, 41011 41014, 41023	5	935.8	842	3.15
42	2748	811	510	42001, 42003, 42004 42010	4	1609.9	806	1.74
43	2999	829	520	43007, 43021	2	2779.0	830	1.08
44	1308	907	520	44001, 44002, 44003	3	646.6	957	1.79
45	2253	1015	520	45001, 45005	2	803.4	1179	2.11
46	1512	1291	530	46002, 46003, 46008	3	730.9	1457	1.7

47	1819	1277	540	47001, 47004		2	1052.4	1243	1.81
48	1572	1179	550	48003, 48011		2	256.1	1368	4.72
49	1228	1115	550	49001, 49002		2	256.4	1288	3.66
50	2158	1148	550	50001, 50002		2	1489.2	1169	1.4
51	512	1172	550	51002, 51003		2	57.1	1274	7.7
52	2780	823	540	52005, 52007, 52010		3	412.0	919	5.03
53	2213	828	550	53006, 53018		2	1700.9	815	1.36
54	11430	788	510	54002, 54032		2	9060.0	807	1.18
55	4181	1010	520	55023		1	4010	1011	1.04
56	1753	1268	530	56001, 56002		2	1128.2	1381	1.35
57	922	1580	530	57005, 57008, 57009		3	778.5	1643	1.12
58	1045	1510	540	58001, 58002, 58008		3	391.9	1863	1.96
59	864	1535	550	59001, 59002		2	274.1	1826	2.43
60	2059	1477	550	60003, 60010		2	1307.7	1515	1.51
61	1440	1209	560	61001, 61002		2	380.7	1353	3.09
62	1006	1339	550	62001		1	893.6	1382	1.07
63	860	1338	530	63001, 63002		2	351.7	1621	1.81
64	1360	1782	510	64001, 64002		2	546.4	1879	2.31
65	1332	1679	540	65005, 65006, 65007		3	144.9	2094	6.74
66	1522	1288	540	66001, 66006		2	596.0	1001	4.13
67	2126	1049	510	67015, 67008		2	1246.4	1286	1.19
68	1875	776	560	68001, 68003, 68007		3	1177.1	785	1.53
69	2711	1020	560	69002, 69007, 69030		3	1373.4	1156	1.53
70	620	962	560	70002, 70005		2	254.0	1033	2.07
71	1489	1281	530	71001		1	1145.0	1353	1.19
72	1643	1366	510	72002, 72004		2	1258.0	1462	1.17
73	1206	1611	490	73005, 73010		2	456.0	1968	2.01
74	910	1647	490	74005		1	125.5	1758	6.62
75	1254	1404	500	75002, 75017		2	759.0	1722	1.22
76	2398	1162	470	76007		1	2286.5	1183	1.02
77	1366	1252	500	77001		1	841.7	1358	1.42
78	964	1330	470	78003		1	925.0	1351	1.02
79	1461	1352	470	79002, 79005		2	1037.0	1451	1.28
80	1535	1537	500	80001, 80002		2	1008.0	1672	1.35
81	2062	1380	520	81002, 81003, 81004		3	873.0	1551	1.97
82	1085	1426	520	82001, 82002, 82003		3	910.3	1497	1.1
83	1537	1273	500	83005, 83006, 83009		3	1138.5	1274	1.35
84	3022	1201	490	84001, 84005, 84012		3	2274.2	1175	1.38
85	832	1982	500	85001		1	784.3	2025	1.03
86	1051	2077	510	86001		1	30.8	2337	29.26
87	722	2264	510	85003, 89006	2*		112.4	2886	4.74
88	1567	1697	520	83005, 89006	2*		412.8	1335	5.55
89	1411	2497	480	89005, 89006, 89007		3	103.9	2788	11.87
90	1194	2540	470	89006, 90003	1+1*		108.9	2820	9.66
91	1339	2174	460	90003, 91002	1+1*		1328.8	2180	1
92	1155	2339	480	92001, 93001	1+1*		393.8	2717	2.44
93	1649	2581	440	92001, 93001	1+1*		393.8	2717	3.94
94	1070	2143	460	93001, 94001	1+1*		578.9	2356	1.64
95	2200	1815	450	94001, 95001	1+1*		578.6	2258	2.87
96	1964	1426	460	96001, 96002		2	681.6	1299	3.31
97	920	998	470	97002		1	412.8	1057	2.01

* Indicates stations located outside the target Hydrometric Area

Appendix 1 HYDROLOGICAL BACKGROUND

Precipitation

Average annual precipitation totals vary by more than an order of magnitude across Great Britain. The higher precipitation totals are associated with the maritime west - average annual rainfall exceeds 4000 mm in the mountains of the Scottish Highlands, Lake District and Snowdonia. These uplands apart, snowfall constitutes a very minor proportion of total precipitation. To the east, much of which is within the rain-shadow of the western hills and less frequently in the path of rain-bearing depressions, average annual rainfall totals become progressively smaller with decreasing elevation. Mean annual totals of less than 600 mm characterise large parts of the English lowlands with totals falling below 500 mm around the Thames estuary.

Whilst in global terms rainfall in the GB may be considered to be evenly distributed throughout the year, seasonal contrasts are appreciable, especially in the west where a distinct tendency towards a late autumn/early winter maximum may be recognised. Partly as a result of convective rainfall over the summer half-year, the contrasts are less strong in the drier regions – August and November are typically the wettest months and spring the driest season.

Evaporation

A substantial proportion of GB precipitation is accounted for by evaporative losses – around half on a nationwide basis. Evaporation demands are very seasonal, the summer half year (April-September) accounting for approximately 80% of the annual total. Modelled annual potential evaporation losses (PE), which assume that water is readily available at all times for plant transpiration, typically range from 400 mm to 650 mm, being greatest in the south and east of the country, especially in coastal areas where windspeed is an important factor. In much of the English lowlands average PE losses are equivalent to more than three-quarters of the average annual rainfall. PE decreases northwards and with increasing altitude; 350 mm being typical over the Scottish mountains although substantially higher annual totals are known to occur where aspect and land use favour higher rates of evaporative loss.

Actual evaporation (AE) losses are of more direct relevance in water balance terms. AE is a conservative variable that displays a large measure of spatial consistency and limited year on year variability. Average annual AE totals are mostly in the 350-500 mm range across GB and are similar to the corresponding PE totals in most western and northern regions. Total evaporation losses can exceed the modelled AE (and PE) totals, e.g. in wet upland afforested catchments where interception losses are substantial. Throughout much of the east and south of the country transpiration rates are significantly restricted by the dryness of soils during the summer. As a consequence annual AE totals can be considerably lower than the corresponding PE totals, especially during dry years.

Runoff

As a result of evaporation losses, the north-west to south-east gradient in runoff across the UK is markedly steeper than that for rainfall. This reflects the non-linear relationship between rainfall and runoff (and groundwater recharge also); in the driest English catchments a reduction of 20% in annual rainfall can correspond to a reduction of greater than 50% in runoff. Mean annual runoff varies from >3500 mm in the western highlands of Scotland to <150 mm over substantial parts of the English lowlands.

The variation in evaporation rates through the year imposes a strong seasonal imprint upon rates of river flow (aquifer recharge also). However, where groundwater makes a major contribution to river flow – substantially enhancing summer and autumn flow rates - the contrast between winter and summer flows is considerably moderated. In the English Lowlands minimum river flows usually occur in the autumn whereas in the more maritime western catchments – which are generally impervious and relatively steep – river flows are, on average, lowest in the summer; during freezing conditions notably low flows may also occur in the winter.