UK Hydrological Review 1996

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Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

1996

UK HYDROLOGICAL REVIEW

This Hydrological Review, which also provides an overview of water resources status throughout 1996, is a reformatted version of the original commentary released as a web report in 1997. Some of the data featured in this report, particularly the more extreme flows, may have been subsequently revised.

The annual Hydrological Reviews are components in the National Hydrological Monitoring Programme (NHMP) which was instigated in 1988 and is undertaken jointly by the Centre for Ecology & Hydrology (CEH) and the British Geological Survey (BGS) – both are component bodies of the Natural Environment Research Council (NERC). The National River Flow Archive (maintained by CEH) and the National Groundwater Level Archive (maintained by BGS) provide the historical perspective within which to examine contemporary hydrological conditions.

A primary source of information for this review is the series of monthly UK Hydrological Summaries (for further details please visit: http://www.ceh.ac.uk/data/nrfa/nhmp/nhmp.html). The river flow and groundwater level data featured in the Hydrological Summaries – and utilised by many NHMP activities – have been provided by the Environment Agency (EA), Natural Resources Wales - Cyfoeth Naturiol Cymru, the Scottish Environment Protection Agency (SEPA) and their precursor organisations. For Northern Ireland, the hydrological data were sourced from the Rivers Agency and the Northern Ireland Environment Agency. The great majority of the reservoir level information has been provided by the Water Service Companies, the EA, Scottish Water and Northern Ireland Water (formerly Water Service). The generality of meteorological data, including the modelled assessments of evaporation and soil moisture deficits featured in the report, has been provided by the Met Office. To allow better spatial differentiation the monthly rainfall data for Britain are presented for the regional divisions of the precursor organisations of the EA and SEPA. The Met Office monthly rainfall series are Crown Copyright and may not be passed on to, or published by, any unauthorised person or organisation. The provision of the basic data, which provides the foundation both of this report and the wider activities of the NHMP, is gratefully acknowledged.

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For further information about the National Hydrological Monitoring Programme please visit: http://www.ceh.ac.uk/data/nrfa/nhmp/nhmp.html

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UK Hydrological Review of 1996

1996 Summary

Although extreme weather conditions were relatively rare in 1996 - and it was a quiet year in terms of flooding - the notable climatic volatility of the last decade continued. The intense drought experienced during the summer of 1995 heralded the development of a very protracted rainfall deficiency which by the end of 1996, had produced significant concern for the water resources outlook. Through the year the focus of the drought, which extended over 20 months by December 1996, shifted from north-west England to the English lowlands.

The 1996 rainfall total for the UK was 940mm - 86% of the 1961-90 average and ranking tenth driest this century. Scotland, where rainfall over the ten years beginning in 1986, was around 15% above average, recorded only its second year with below average rainfall since 1978. On a nationwide basis, the June-September period was especially dry, the second driest (over that timespan) in more than 80 years. Fortunately, in a water resources context, 1996 was also the coolest year since 1987 and evaporative demands were generally lower than those which have typified much of the recent past. This helped to moderate water demand and, despite very modest rainfall through the early summer, there was no repetition of the water resources stress of the previous year. Nonetheless, the June-August period added to the recent cluster of dry summers and the autumn recovery in runoff and aquifer recharge rates was patchy and, in most regions, weak. New minimum annual runoff totals were registered at around 20% of the gauging stations in the national network and, by year-end, both river flows and, in particular, groundwater levels were depressed over wide areas.

The relatively dry summer of 1996 and the associated depressed river flows, together with the large soil moisture deficits which were maintained well into the autumn in the lowlands, is consistent with a number of favoured climate change scenarios. However, the limited 1995/96 winter rainfall and the dry cold early winter of 1996/97 emphasise the variability of winters over the last decade rather than reinforcing the recent tendency for winters to be considerably milder and wetter than average. The natural variability of the UK climate is such that any apparent short term trends need to be treated with considerable caution. Nonetheless, the river flow and aquifer recharge conditions experienced since the mid-1980s have been characterised by very wide and protracted departures from the seasonal average. Initial analyses of rainfall and evaporation data, together with evidence from the relatively few hydrometric series extending over 50 years, suggest that there is no close modern parallels to the recent past.

Rainfall

The 1996 rainfall total for Northen Ireland was a little above average but Scotland recorded its lowest annual total for 20 years. England and Wales registered its driest year since 1973, and the fifth lowest rainfall total in the last 110 years. The spatial distribution of the rainfall was also notable - wide regional and local variations characterising most of the country (Figure 1). Significantly above average rainfall was recorded in a number of more maritime locations e.g. parts of Cornwall and coastal districts in Scotland. By contrast, annual totals of less 85% of the 1961-90 average typified most regions (Table 1), less than 65% of average was recorded for a few locations in the Scottish Highlands (remarkable in the context of the wetness of the recent past); near Harlech in North Wales, and in several parts of the English lowlands (Figure 2). 1996 rainfall totals below 400mm covered extensive areas adjacent to the Thames estuary, and in Essex and Cambridgeshire - in an average year very few raingauges report totals below 500mm.

Although the ratio of the October-March rainfall to that of the ensuing six months was above the long term average, the recent tendency for a more distinct partitioning of rainfall between the winter and summer half-years was less evident in 1995/96 than in most of the preceding decade. In large part this reflects the relatively modest rainfall over the October 1995-March 1996 period. For Britain as a whole it was the driest winter half-year in twenty years. December-February rainfall totals were also well below average in large parts of northern Britain. The largest negative anomalies generally coincided with what, on average, are the wettest regions - e.g. the Scottish Highlands, Lake District and North Wales, substantial parts of which registered only around half of the 1961-90 average. Scotland recorded its driest winter for 32 years - precipitation totals in many areas being very modest by comparison with those of the preceding 15 years. By contrast, December-February rainfall totals were well above average in parts of southern England and were typically in the 90-120% range over most of the Chalk outcrop. Eastern parts of Northern Ireland and Britain's north-eastern seaboard also experienced a wet winter, the Grampian Region particularly.

Rainfall through the spring (March-May) signalled the beginning of a gradual move in the drought's focus towards the English lowlands. Most eastern areas of England recorded less than 55% of average rainfall and it was the driest spring in some catchments for 20 years. Above average spring rainfall characterised

Table 1 *1996 Rainfall in mm as a % of the 1961-90 average.*
Note: To allow better spatial differentiation the rainfall figures are presented for the major administrative divisions of the water industry prior to the creation of the Environment Agency and the Scottish Environment Protection Agency.

Data source: UK Met Office.

1996		**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**	**Year**	**Oct-Mar 1995/96**	**Apr-Sep 1996**
United Kingdom	mm	75	103	49	73	66	42	55	78	44	138	149	68	940	521	358
	%	68	136	54	112	92	58	75	87	44	125	135	60	87	86	76
England and Wales	mm	63	83	43	51	57	30	41	80	34	91	128	54	755	414	293
	%	72	132	60	85	89	46	66	105	44	107	142	57	84	84	73
Scotland	mm	89	141	60	108	78	65	78	67	64	227	193	97	1267	699	460
	%	59	138	48	142	91	76	83	57	45	146	128	64	88	84	77
Northern Ireland	mm	120	100	56	133	88	46	71	113	38	149	127	64	1085	633	469
	%	108	128	64	177	124	65	106	124	39	132	123	62	102	111	102
North West	mm	53	105	36	77	62	49	65	88	61	149	143	68	956	417	402
	%	44	135	38	108	83	60	76	82	53	116	116	55	79	62	75
Northumbrian	mm	46	89	31	63	53	22	53	67	31	69	110	90	724	420	289
	%	55	151	44	113	85	37	82	83	42	91	128	111	85	92	73
Severn Trent	mm	44	67	41	50	48	30	33	68	20	72	94	54	621	337	249
	%	63	124	67	91	81	51	62	101	31	113	132	70	82	85	70
Yorkshire	mm	46	78	31	41	52	35	41	74	31	57	113	97	696	319	274
	%	58	134	46	69	87	58	69	100	46	78	141	117	85	72	72
Anglian	mm	33	50	20	15	23	18	40	76	16	46	92	43	472	229	188
	%	66	135	43	33	48	35	82	138	33	90	159	78	79	77	63
Thames	mm	50	64	35	36	35	16	39	61	20	47	108	24	535	343	207
	%	78	142	63	72	63	29	80	105	34	76	166	34	78	95	63
Southern	mm	67	68	40	23	51	16	34	80	33	57	143	32	644	368	237
	%	84	126	63	43	94	30	71	140	48	71	168	39	83	83	71
Wessex	mm	76	85	68	58	60	29	27	86	33	84	146	31	782	525	293
	%	87	131	97	109	98	51	52	130	46	106	175	33	92	110	81
South West	mm	156	119	72	79	100	34	31	98	50	135	203	52	1129	711	392
	%	113	118	73	114	139	49	45	117	54	116	162	37	96	99	86
Welsh	mm	102	127	73	87	106	47	47	103	58	180	170	53	1153	653	448
	%	71	131	68	109	129	59	61	102	50	131	120	35	88	84	84
Highland	mm	58	153	55	111	84	79	91	73	85	263	255	107	1413	719	523
	%	31	120	34	122	91	81	86	57	50	133	126	54	80	67	76
North East	mm	69	114	59	63	67	33	66	64	32	136	113	88	904	515	325
	%	70	175	76	105	97	50	90	74	37	140	114	95	93	97	74
Tay	mm	136	116	76	103	67	44	53	64	52	194	147	71	1123	736	383
	%	94	122	70	166	81	60	69	68	46	149	121	56	91	101	76
Forth	mm	72	86	53	86	68	44	55	61	47	174	150	85	981	554	361
	%	61	109	56	146	92	64	73	65	43	151	134	77	88	88	75
Clyde	mm	119	180	62	142	90	88	99	66	78	284	220	96	1524	851	563
	%	63	153	42	169	99	95	91	49	44	147	122	54	90	85	82
Tweed	mm	68	103	30	79	63	30	53	63	29	133	137	119	907	496	317
	%	68	154	38	139	89	46	73	72	33	140	147	128	94	94	72
Solway	mm	135	160	74	133	80	78	69	66	58	261	162	106	1382	783	484
	%	87	158	63	173	94	93	77	55	41	166	113	72	97	95	81
Western Isles; Orkney and Shetland	mm	82	125	54	87	72	75	87	85	85	223	217	98	1290	676	491
	%	65	149	53	140	122	123	124	99	71	166	164	77	111	96	107

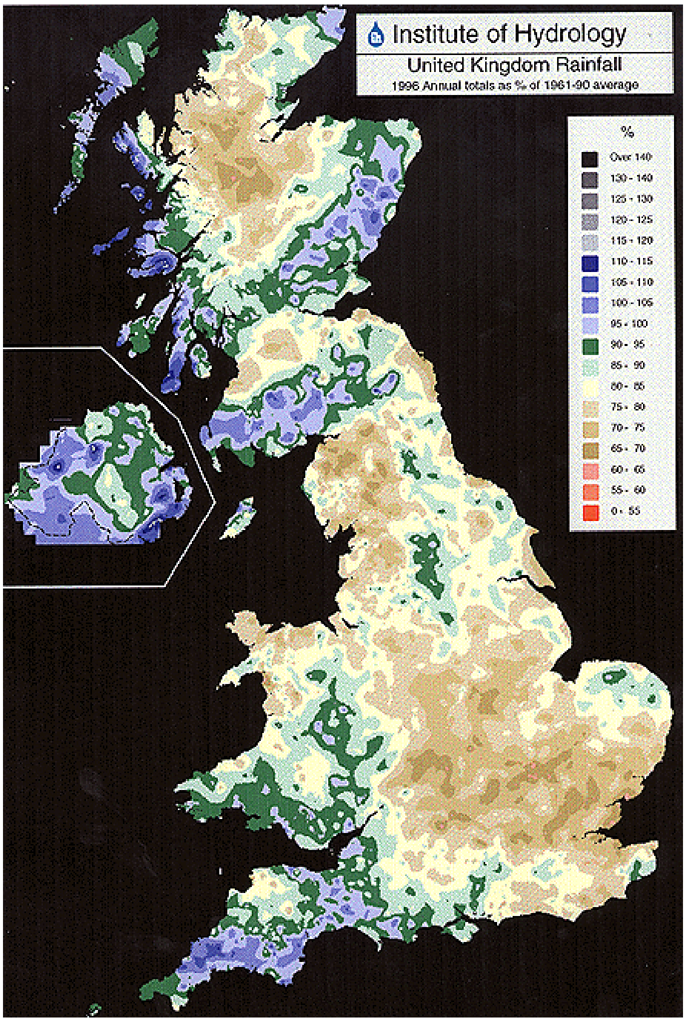

Figure 1 *Annual rainfall for 1996 as a % of the 1961-90 average.*
Note: For Northern Ireland, the percentages are based on the 1941-70 average.
Data source: UK Met Office.

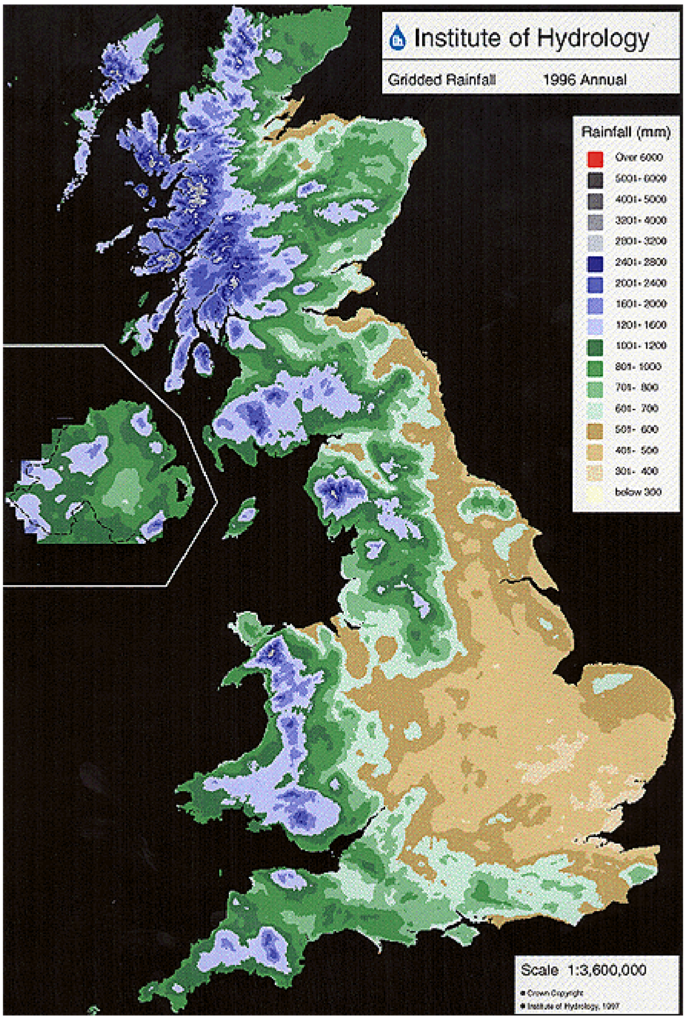

Figure 2 *Annual rainfall for 1996.*
Data source: UK Met Office.

much of south-western Britain, usefully delaying the onset of reservoir drawdown. A few districts in north-west England registered above average rainfall but in parts of the Lake District and the southern Pennines rainfall deficiencies continued to build; a number of raingauges reported unprecedented 12-month rainfall totals - some with records exceeding 100 years. The summer was generally wetter than in 1995 and, partly as a result of thunderstorms, rainfall totals exhibited wide spatial variability. A few areas (e.g. Norfolk and parts of the Pennines) were relatively wet but away from East Anglia most regions recorded well below average rainfall; large parts of Scotland and central England registered only around half the 1961-90 average.

Dry conditions continued into the autumn especially in central southern England where rainfall deficiencies from the early spring were notable; the March to October period was the fifth driest in a series from 1883 for the Thames basin - the rainfall total was very similar to that for the corresponding period in 1995. Weather patterns changed in November which was very unsettled and the wettest month of the year, by a considerable margin throughout much of England and Wales. Nonetheless, autumn (September-November) rainfall totals were well below average in most of north-eastern Britain and the Midlands. The driest December for 20 years then ensured that widespread and severe drought conditions would continue into 1997.

The rainfall deficiencies for 1996 assume a greater water resources significance when considered together with the rainfall patterns over the spring, summer and autumn of 1995. Over large parts of the country, drought conditions developed during the exceptionally dry spring of 1995. Although above average rainfall in September 1995 provided some respite the drought then reintensified, especially in northern and western Britain. Well above average rainfall in February 1996 produced substantial and much needed reservoir and groundwater replenishment but the dry March heralded a further phase of the drought. By year-end long term rainfall deficiencies were outstanding over wide areas. For England and Wales as a whole, the period April 1995-December 1996 is the driest such period in the entire England and Wales rainfall series (which begins in 1767). Considering any start month, drier 21-month periods have been restricted to the droughts of 1975/76, 1933/34 and, marginally, 1802/03. Over the droughts full compass (to December 1996), the rainfall deficiencies were greatest in eastern, central and northern England - for some areas, the shortfall was the equivalent of more than 5-months average rainfall.

Notable Rainfall Events in 1996

Relatively few exceptionally wet interludes or intense storm events occurred in 1996; notable daily rainfall totals were also relatively rare - see Table 2. Widespread heavy rainfall on the 9th February in the Grampian Region - with rain-day (09.00-09.00) totals up to 105.6mm at Bogmore (in the Dee catchment) - generated very notable runoff rates in the affected catchments (see 'River Flows' section). In Northern Ireland, a substantial area reported rain-day totals in excess of 60mm on the 5th August, at Omagh (Tyrone) a total of 100.3mm corresponded with a return period of greater than 700 years. For rain-day totals this was the most notable rainfall event in 1996. However, the storm total was matched by a remarkable downpour in Folkestone - almost 100mm in four hours (incuding 90mm in two) - which produced severe local flooding on the 12th of August. A number of 24-hour rainfall totals of 100mm or more were reported for raingauges in the mountains of North Wales and the Lake District (e.g. in September) but in such wet areas these were not rare events. The highest rain-day total of the year, 147mm for the 11th October was reported, from the headwaters of the River Dee (Dumfries and Galloway). The associated return period exceeded 300 years but, with modest antecedent flows in the local rivers the hydrological impact was modest.

Evaporation and Soil Moisture Deficits

The mean temperature in 1996 was below the long term average, albeit marginally, for the first time since 1987; March, May and December were particularly cold - and considerably below the respective monthly averages for the 1990s thus far. Despite such cool interludes, the last decade remains the warmest ten-year sequence in the 331-year Central England Temperature series; average temperatures over the twenty years to 1996 are around 0.4 above the preceding average. Although temperatures were not exceptional for 1996 as a whole, sunshine hours were appreciably above average for Britain, notably from June to December. With temperatures also above average in each month from June to September, summer evaporative demands were high, this accentuated the normally marked seasonality in potential evaporation (PE) losses.

Annual potential evaporation totals were close to record levels in parts of northern Scotland and notably above average in the South-West (Figure 3). Above average annual totals characterised much of eastern, central and southern England also but generally fell considerably short of the outstanding totals registered in 1995, 1990 and 1989. Nationally, PE totals were around 120% of the 1961-90 average. In western Britain actual evaporation (AE) losses were also well above average and often close to the highest on record. This reflects the limited periods during which soil moisture deficits (smds) were sufficiently high to materially restrict transpiration rates. By contrast, in the English lowlands smds remained above 100mm for a protracted period - from late May to late October in parts of Cambridgeshire. The very dry soils inhibited transpiration and moderated actual evaporation losses which, for the year, were well within the normal range (Figure 4).

Soil moisture deficits began to build in the spring and increased rapidly from late May. By the end of July they were above average throughout much of the English lowlands. The wet August avoided a repeat of the extremely arid soil conditions experienced during the late summer in 1995 but smds increased again during September, when normally a seasonal decline is established. At month-end smds (Figure 5) were the equivalent of around 10 weeks residual rainfall (rainfall-actual evaporation) in much of eastern and southern England. In the west and north, deficits were generally satisfied in October but substantial deficits persisted in the lowlands (Figure 6); these were maintained well into November over some eastern areas. Similarly dry late autumn soil conditions have been a feature of most of the last ten years. They are of considerable hydrological significance, delaying the onset of the seasonal recovery in runoff and recharge rates. This is particularly important in relation to groundwater - reducing the window of opportunity for aquifer recharge from several months (in a typical year) to, in exceptional years, a few weeks in eastern England - if these weeks turn out dry aquifer replenishment can be minimal.

Table 2 *Daily Rainfalls in 1996 with Return Periods equal to or exceeding 50 years.*
Note The return periods are based on the methods and findings of the Flood Studies Report, as implemented by the Met Office, whereby a return period can be assigned to a catch at a particular raingauge. The return periods in Table 2 have been rounded to the nearest 10 years.
Data source: UK Met Office.

Date (Rain-day)	Raingauge Number	Raingauge Name	County/Region	Grid Reference	Amount (mm)	Return Period*
09.02.96	847657	Bogmore	Grampian	NO607903	105.6	220
09.02.96	848741	Durris	Grampian	NO755931	87.8	80
07.06.96	261041	Wantage, Kitford Gardens	Oxfordshire	SU428867	73.9	90
05.08.96	925309	Boom Hall	Londonderry	445194	60.8	60
05.08.96	926409	Killyclogher Filter House	Tyrone	473746	78.3	160
05.08.96	926641	Dromore S. Works No 2	Tyrone	366649	72.0E	80
05.08.96	927679	Edenfel	Tyrone	466719	80.5	220
05.08.96	927736	Omagh S. Works	Tyrone	441737	100.3	720
05.08.96	928030	Lough Bradan W Works	Tyrone	258723	96.0E	210
05.08.96	932222	Baron's Court	Tyrone	373833	80	270
05.08.96	938112	Cloghole P. Station	Londonderry	489200	69.8	140
05.08.96	938308	Carmoney W.Works	Londonderry	503197	72.3	140
05.08.96	938594	Ballykelly SAMOS	Londonderry	634238	60.6E	60
05.08.96	939063	Banagher, Caugh Hill	Londonderry	663047	72.2	50
05.08.96	939114	Dungiven, Lackagh	Londonderry	691099	70.7E	60
05.08.96	932592	Strebane Grammar School	Tyrone	353964	74.7	160
05.08.96	945218	Ballygawley Primary School	Tyrone	626578	67.8	70
05.08.96	987860	Killyfole W. Works	Fermanagh	468315	85.6	150
05.08.96	990798	Crom Castle	Fermanagh	356240	72.2	90
05.08.96	991622	Altaveedan W. Works	Tyrone	487451	87.8	150
05.08.96	992442	Lisnaskea Creamery	Fermanagh	341351	81	270
05.08.96	992556	Glasdrumman Reservoir	Fermanagh	390340	92.6E	410
05.08.96	995613	St Angelo B	Fermanagh	230498	64.7E	50
05.08.96	996082	Ballinamallard S. Works	Fermanagh	261528	66.1	70
05.08.96	996134	Irvinestown S. Works	Fermanagh	241581	66.3	60
11.08.96	188730	Stanton	Suffolk	TL969730	84.7	200
11.08.96	301985	Ashford, Hythe Road	Kent	TR018425	78.4E	110
12.08.96	305106	Folkstone	Kent	TR214369	98.4	220
12.08.96	305110	Folkestone, Upper Cherry Garden P S	Kent	TR210380	89.3E	130
29.08.96	213939	Hevingham	Norfolk	TG172204	69.7	80
11.10.96	627056	Upper Black Laggan Logger Station	Dumfries & Galloway	NX476769	147	330
11.10.96	627059	Black Laggan Logger Station	Dumfries & Galloway	NX469777	125.2	110
11.10.96	627258	Craigencallie	Dumfries & Galloway	NX504779	128.7E	140
01.11.96	682776	Blaran	Strathclyde	NM859172	98.2	60
01.12.96	663926	Burncrooks Reservoir	Central	NS490796	93.4	90
03.12.96	903637	Nunraw Abbey	Lothian	NT594700	74.5	60
03.12.96	910529	Bowhill	Borders	NT428278	75.3	70
03.12.96	912526	Blythe	Borders	NT585495	81.1	120
03.12.96	922302	Hungry Snout No 2	Lothian	NT663633	101.4	120
03.12.96	922931	Nother Monynut	Lothian	NT728645	86.4	80

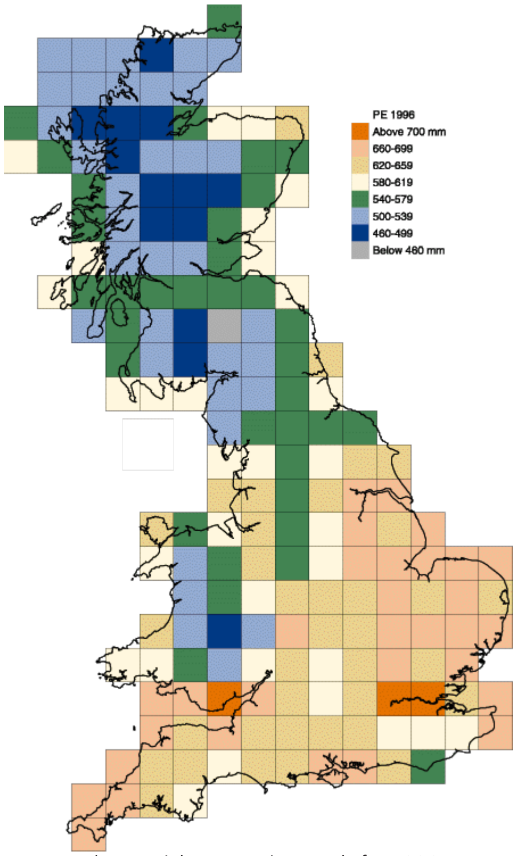

Figure 3 *Annual Potential Evaporation totals for 1996.*

Note: *Potential evaporation (PE) is the maximum evaporation which would occur from a continuous vegative cover amply supplied with moisture. PE depends principally on solar radiation, temperature, windspeed and humidity. The data presented here are for a grass cover.*

Data source: MORECS..

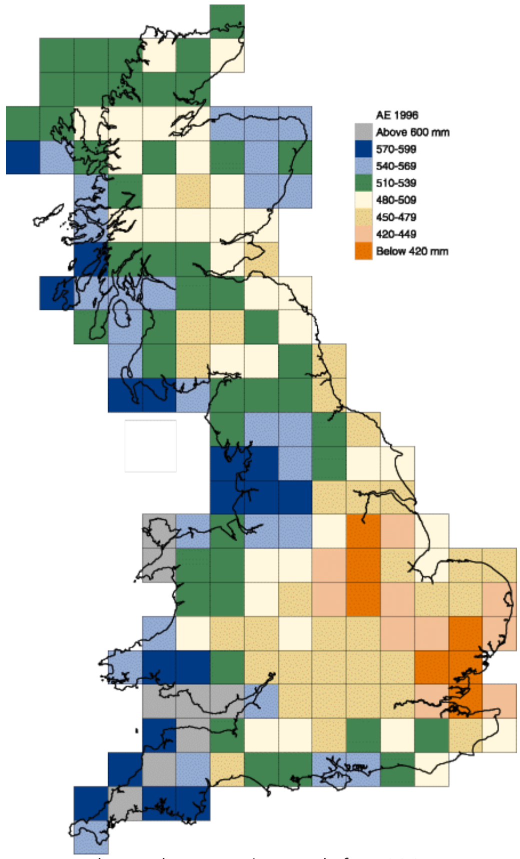

Figure 4 *Annual Actual Evaporation totals for 1996.*

Note: *From the late spring (typically), Actual evaporation rates fall below the potential value as, with increasingly dry soils, the ability of vegetation to loss moisture by transpiration is reduced. In a warm dry year AE totals may be 150 mm, or more, less than the corresponding PE total. The data presented here are for a grass cover.*

Data source: MORECS.

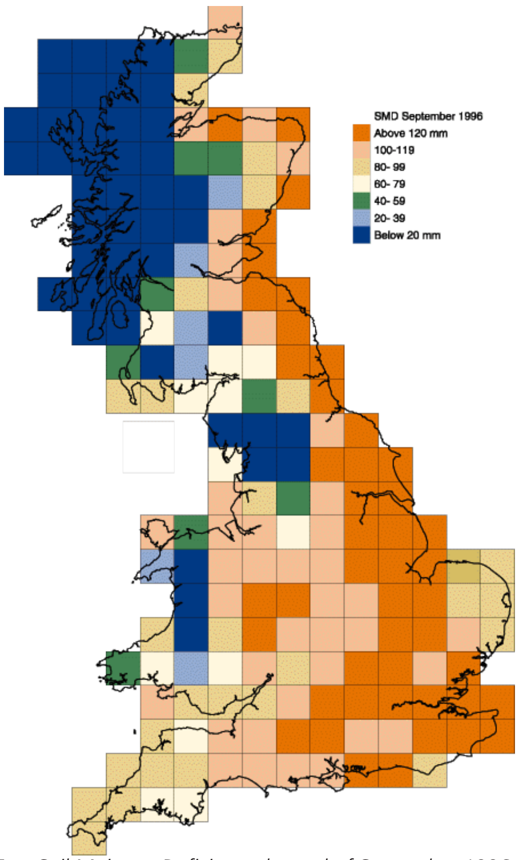

Figure 5 *Soil Moisture Deficits at the end of September 1996.*

Note: *Given normal rainfall, accelerating evaporative demands through the spring leads to a progressive drying of the soil profile and the creation of what is termed a Soil Moisture Deficit (SMD). This is equivalent to the amount of rainfall (evaporation losses aside) required to restore the soil to Field Capacity (when soil moisture is at a maximum). Following a particularly dry summer the SMD may be the equivalent of around three months average rainfall in parts of the eastern lowlands of England.*

Data source: MORECS.

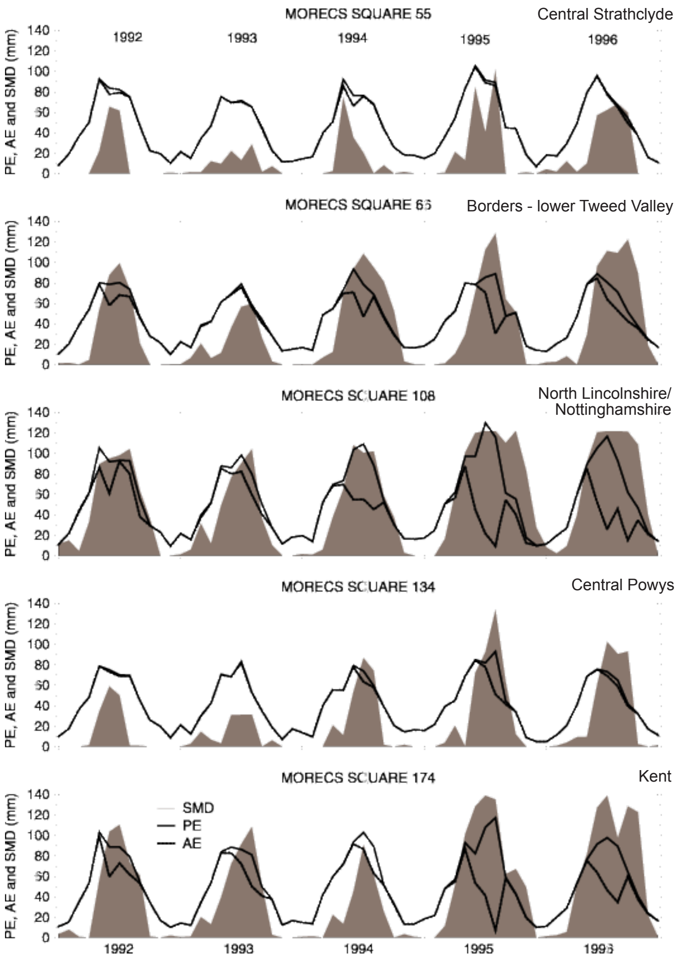

Figure 6a *The variation in potential evaporation, actual evaporation and soil moisture deficits for five MORECS squares.*
Note: The data are monthly figures for a grass cover.

Data source: MORECS.

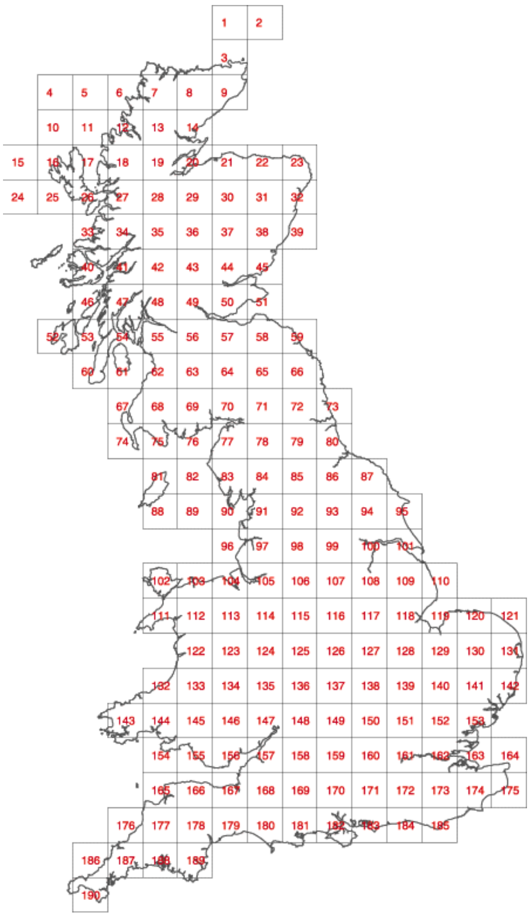

Figure 6b *MORECS Location Map: the location of the 40km squares and their associated reference numbers.*

Data source: MORECS.

River Flows

As in the previous year the main feature of the runoff pattern in 1996 was the depressed flows throughout the late summer and early autumn, and the weakness of the seasonal recovery over the last quarter. The monthly hydrographs featured in Figure 8 illustrate the very large seasonal variations in runoff rates over the recent past and confirm that low flows were dominant in 1996 - many new low flow records were established (Tables 3-7).

Existing minimum monthly mean flows were widely eclipsed in February and March and again throughout the autumn. Notably low daily flows were also recorded in July - mostly in western catchments and at Year-end. With very few exceptional high flow episodes to compensate, annual runoff totals were in the lowest

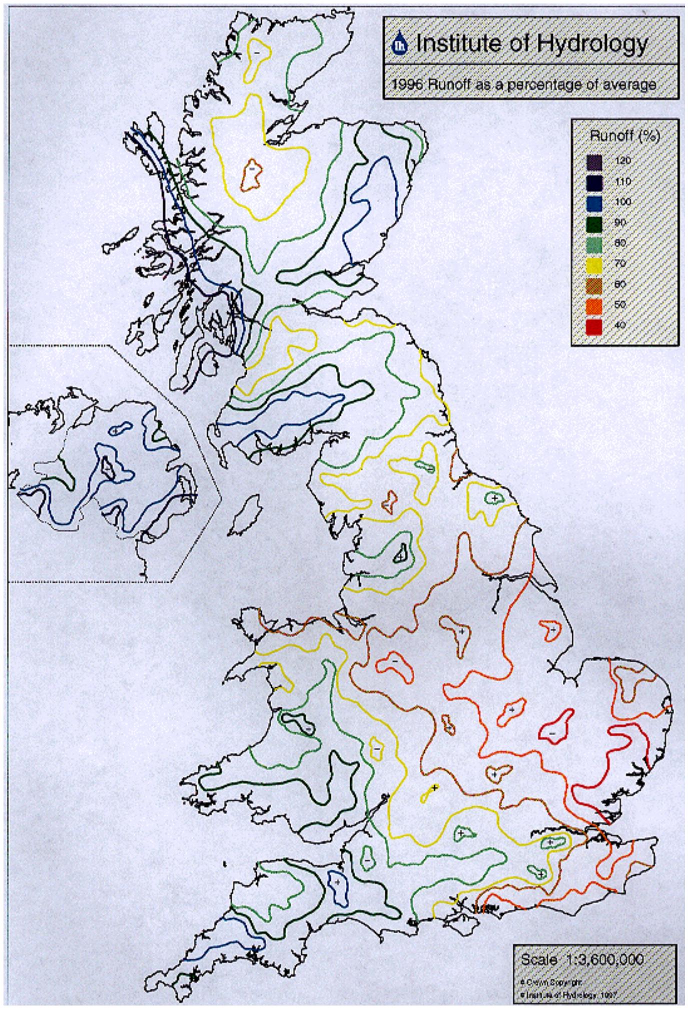

Figure 7 *A guide to 1996 runoff expressed as a percentage of the 1961-90 average.*

Note: The gauging station network in the UK is being steadily extended but areas remain where the available flow data is insufficient to properly delineate spatial variations in runoff. Uncertainties associated with the annual runoff totals are greatest in parts of of north-western Scotland, the Welsh mountains and the coastal lowlands of eastern England. In such areas, and in Northern Ireland,estimates of residual rainfall(rainfall-actual evaporation) were used to help delineate the runoff isopleths. No attempt has been made to draw isopleths in areas such as the Orkneys and Shetlands or Anglesey where little or no flow data have been provided for 1996.

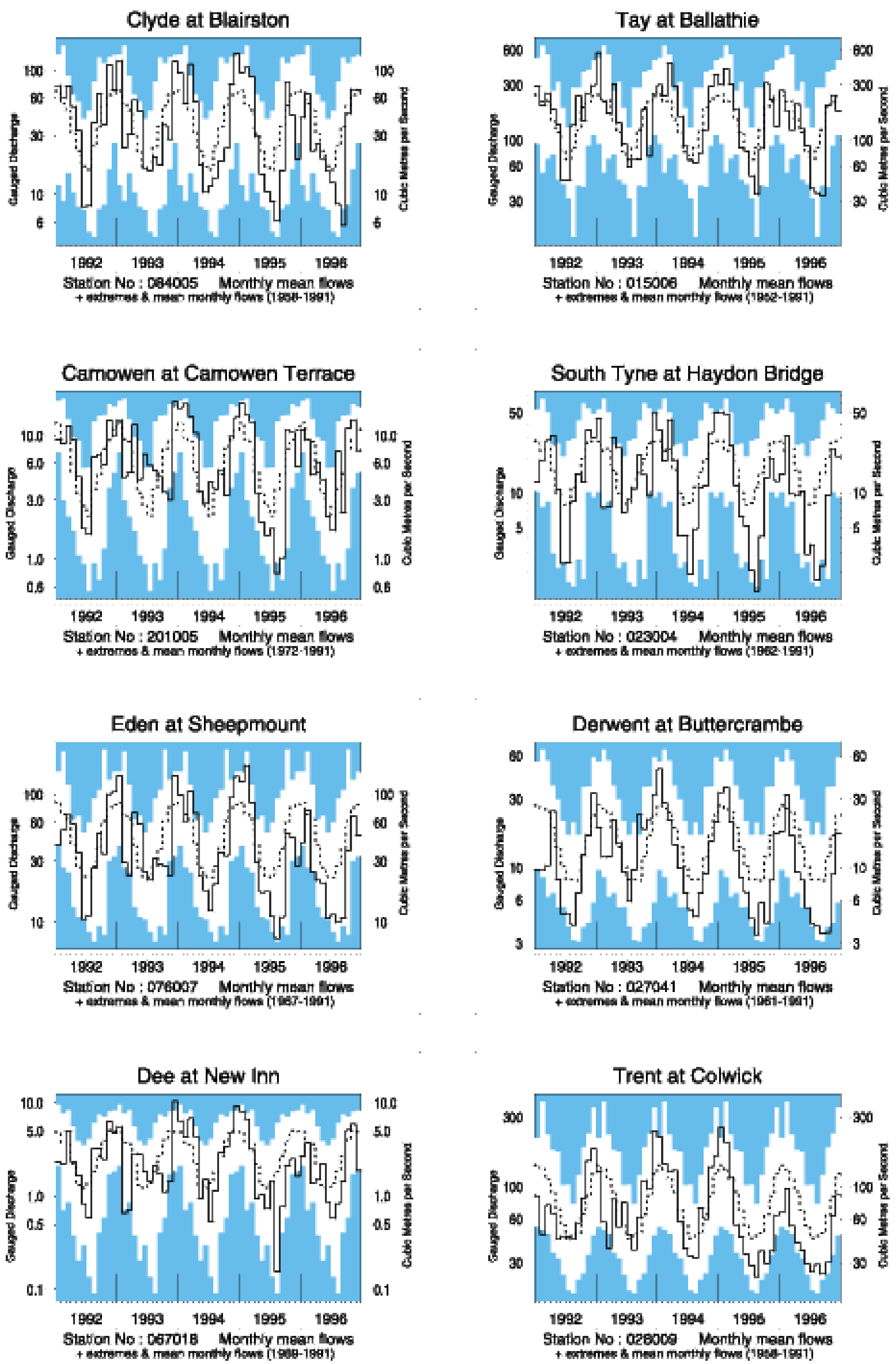

Figure 8 *1992-96 monthly river flow hydrographs.*

Note: The monthly mean flows (black trace) over the 1992-96 period are shown together with the pre-1992 monthly average (dotted blue trace) and the pre-1992 maximum and minimum monthly flows - the latter are indicated by the shaded envelopes. The flows for the River Thames at Kingston are naturalised - that is, adjusted to take account of the major upstream abstractions for London's water supply.

Data sources: Environment Agency/Scottish Environment Protection Agency/DoENI.

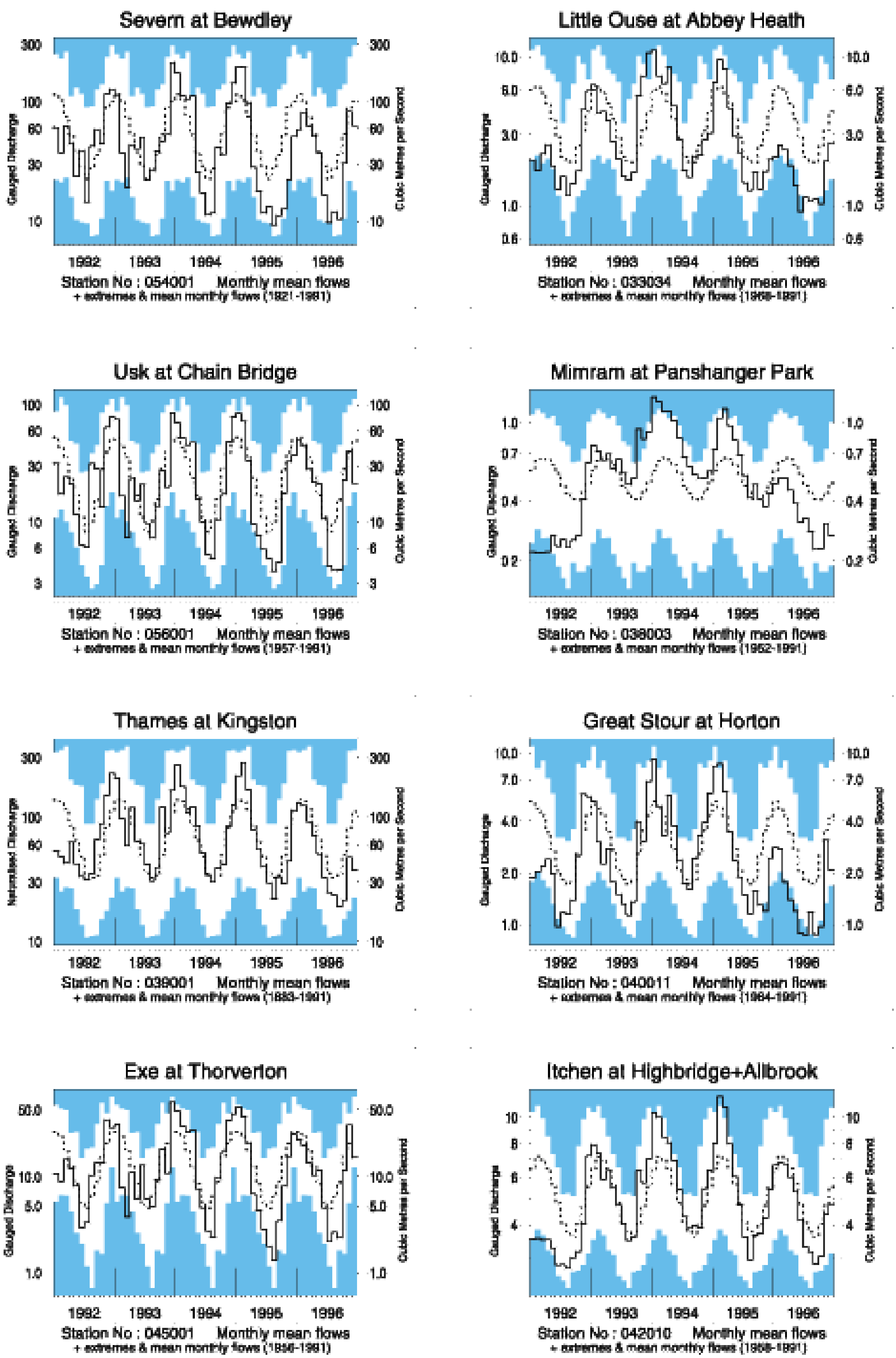

Figure 8 *(Contd.)*

Table 3 *Lowest annual gauged runoff records established in 1996.*

Note: Gauging stations are featured only where there are at least 20 years of flow data on the National River Flow Archive. The data are, for the most part, provisional and subject to review as the flow rates in the extreme ranges are examined in the light of recent current meter gaugings and other evidence.

Station Number	River	Station Name	First year of record	New record (mm)	Pre-1996 record (mm)	Year
3002	Carron	Sgodachail	1974	789	895	1976
3003	Oykel	Easter Turnaig	1977	1087	1237	1987
6007	Ness	Ness-side	1973	919	1191	1976
8010	Spey	Grantown	1953	478	494	1969
15012	Tummel	Pitlochry	1973	1025	1036	1973
15016	Tay	Kenmore	1974	1842	1904	1987
17003	Bonny Water	Bonnybridge	1971	495	550	1975
23004	South Tyne	Haydon Bridge	1962	489	490	1973
23006	South Tyne	Featherstone	1966	704	747	1971
25012	Harwood Beck	Harwood	1969	875	889	1973
25023	Tees	Cow Green Reservoir	1971	903	1173	1976
27002	Wharfe	Flint Mill Weir	1955	434	474	1975
27029	Calder	Elland	1961	517	561	1964
27031	Colne	Colne Bridge	1964	318	319	1975
27043	Wharfe	Addingham	1973	664	730	1995
27047	Snaizeholme Beck	Low Houses	1972	1137	1316	1976
27052	Whitting	Sheepbridge	1976	333	353	1985
27053	Nidd	Birstwith	1975	423	504	1989
28001	Derwent	Yorkshire Bridge	1933	222	244	1964
28003	Tame	Water Orton	1955	271	310	1956
28007	Trent	Shardlow	1957	213	259	1964
28015	Idle	Mattersey	1965	83	107	1992
28018	Dove	Marston on Dove	1961	275	280	1976
28019	Trent	Drakelow Park	1966	222	234	1976
28032	Meden	Church Warsop	1965	169	216	1992
28039	Rea	Calthorpe Park	1967	216	256	1973
28040	Trent	Stoke on Trent	1968	195	242	1991
28052	Sow	Great Bridgford	1971	117	138	1976
28053	Penk	Penkridge	1976	138	183	1991
28058	Henmore Brook	Ashbourne	1974	195	211	1976
28061	Churnet	Basford Bridge	1975	207	242	1991
28066	Cole	Coleshill	1973	152	173	1975
28085	Derwent	St Marys Bridge	1935	275	288	1976
28086	Sence	South Wigston	1971	128	138	1976
29009	Ancholme	Toft Newton	1974	50	65	1989
30002	Barlings Eau	Langworth Bridge	1960	65	70	1976
30015	Cringle Brook	Stoke Rochford	1976	85	102	1991
31007	Welland	Barrowden	1968	76	79	1976
33011	Little Ouse	County Bridge Euston	1968	30	37	1973
33034	Little Ouse	Abbey Heath	1968	75	78	1991
33057	Ouzel	Leighton Buzzard	1976	120	145	1989
34011	Wensum	Fakenham	1967	79	86	1973
37001	Roding	Redbridge	1950	73	83	1985
37031	Crouch	Wickford	1976	80	116	1973
37034	Mardyke	Stifford	1974	64	73	1990
38024	Small River Lee	Ordnance Road	1973	132	163	1991

Table 3 *(Contd.)*

Station Number	River	Station Name	First year of record	New record (mm)	Pre-1996 record (mm)	Year
38026	Pincey Brook	Sheering Hall	1974	61	72	1976
39049	Silk Stream	Colindeep Lane	1973	175	193	1985
39076	Windrush	Worsham	1942	184	202	1989
40003	Medway	Teston	1956	150	152	1989
40005	Beult	Stile Bridge	1958	91	127	1962
40006	Bourne	Hadlow	1959	152	167	1972
40011	Great Stour	Horton	1964	151	165	1973
41010	Adur W Branch	Hatterell Bridge	1961	132	188	1991
47008	Thrushel	Tinhay	1969	448	459	1975
47010	Tamar	Crowford Bridge	1972	540	601	1985
54011	Salwarpe	Harford Hill	1961	142	145	1964
54040	Meese	Tibberton	1973	129	155	1976
54041	Tern	Eaton On Tern	1972	145	201	1976
54044	Tern	Ternhill	1972	188	211	1991
54046	Worfe	Cosford	1975	43	54	1991
54048	Dene	Wellesbourne	1976	77	99	1991
54052	Bailey Brook	Ternhill	1970	166	194	1975
54060	Potford Brook	Sandyford Bridge	1972	94	98	1976
55028	Fromw	Bishops Frome	1971	152	173	1973
60012	Twrch	Ddol Las	1970	701	716	1976
65004	Gwyrfai	Bontnewydd	1970	981	1134	1995
66006	Elwy	Pont-y-Gwyddel	1973	447	472	1975
67001	Dee	Bala	1957	1080	1088	1976
67025	Clywedog	Bowling Bank	1976	296	346	1992
68004	Wistaston Brook	Marshfield Bridge	1957	133	176	1991
68007	Wincham Brook	Lostock Gralam	1962	167	191	1991
69007	Mersey	Ashton Weir	1976	402	403	1985
69008	Dean	Stanneylands	1976	248	276	1991
69012	Bollin	Wilmslow	1976	333	379	1976
69013	Sinderland Brook	Partington	1976	246	261	1991
69017	Goyt	Marple Bridge	1969	388	419	1976
71001	Ribble	Samlesbury	1960	598	607	1971
72004	Lune	Caton	1959	733	794	1976
73009	Sprint	Sprint Mill	1976	1221	1328	1976
73010	Leven	Newby Bridge FMS	1939	1177	1178	1973
73013	Rothay	Miller Bridge House	1976	1498	1808	1984
73014	Brathay	Jeffy Knotts	1976	1728	1895	1984
74006	Calder	Calder Hall	1964	1004	1052	1995
74007	Esk	Cropple How	1976	1602	1628	1976
76011	Coal Burn	Coalburn	1967	610	654	1971
83003	Ayr	Catrine	1970	678	685	1971
83005	Irvine	Shewalton	1972	523	554	1973
83006	Ayr	Mainholm	1976	563	648	1989
84014	Avon Water	Fairholm	1964	584	588	1969
84029	Cander Water	Candermill	1975	445	495	1976
201008	Derg	Castlederg	1976	1061	1069	1984

Table 4 *Lowest gauged daily mean flow records established in 1996.*

Note: Gauging stations are featured only where there are at least 20 years of flow data on the National River Flow Archive. The data are, for the most part, provisional and subject to review as the flow rates in the extreme ranges are examined in the light of recent current meter gaugings and other evidence.

Station Number	River	Station Name	First year of record	New record m^3s^{-1}	Day	Month	Pre-1996 Record m^3s^{-1}	Day	Month	Year
19010	Braid Burn	Liberton	1969	0.015	23	10	0.016	12	10	1989
27021	Don	Doncaster	1959	3.066	19	8	3.145	20	6	1960
27058	Riccal	Crook House Farm	1974	0.147	2	10	0.158	31	8	1976
28015	Idle	Mattersey	1965	0.187	21	7	0.459	6	8	1992
28039	Rea	Calthorpe Park	1967	0.167	20	9	0.17	5	9	1991
28049	Ryton	Worksop	1970	0.037	18	8	0.04	22	8	1976
28053	Penk	Penkridge	1976	0.419	18	9	0.463	28	8	1995
28061	Chrunet	Basford Bridge	1975	0.266	15	9	0.272	15	9	1990
31016	North Brook	Empingham	1969	0.018	31	10	0.025	26	8	1976
33014	Lark	Temple	1960	0.258	22	7	0.282	14	8	1990
33040	Rhee	Ashwell	1965	0.013	9	10	0.017	30	7	1973
33062	Guilden Brook	Fowlmere Two	1964	0.016	9	11	0.019	22	8	1989
34011	Wensum	Fakenham	1967	0.125	21	8	0.13	25	8	1976
35002	Deben	Naunton Hall	1964	0.024	22	8	0.029	25	5	1980
39090	Cole	Inglesham	1976	0.081	5	9	0.085	22	8	1995
40011	Great Stour	Horton	1964	0.559	8	8	0.658	19	9	1990
54041	Tern	Eaton On Tern	1972	0.337	5	8	0.343	2	7	1976
68003	Dane	Rudheath	1949	0.406	20	7	0.473	20	8	1995
68004	Wistaston Brook	Marshfield Bridge	1957	0.053	22	7	0.075	21	8	1995
69012	Bollin	Wilmslow	1976	0.286	5	8	0.287	21	8	1976
69020	Medlock	London Road	1975	0.133	27	7	0.138	30	6	1984
77003	Liddel Water	Rowanburnfoot	1973	0.523	20	9	0.625	26	7	1984
85004	Luss Water	Luss	1976	0.043	19	9	0.062	21	8	1995

Table 5 *Lowest monthly naturalised runoff records established in 1996.*

Note: Gauging stations are featured only where there are at least 20 years of flow data on the National River Flow Archive. The data are, for the most part, provisional and subject to review as the flow rates in the extreme ranges are examined in the light of recent current meter gaugings and other evidence.

Station Number	River	Station Name	First year of record	New record (mm)	Month	Pre-1996 record (mm)	Month	Year
21018	Lyne Water	Lyne Station	1962	7.58	9	7.65	8	1995
21020	Yarrow Water	Gordon Arms	1968	3.73	8	4.01	7	1989
21022	Whiteadder Water	Hutton Castle	1969	4.04	9	4.69	8	1995
26002	Hull	Hempholme Lock	1965	2.28	10	2.56	3	1992

Table 6 *Lowest monthly gauged runoff records established in 1996.*

Note: Gauging stations are featured only where there are at least 20 years of flow data on the National River Flow Archive. The data are, for the most part, provisional and subject to review as the flow rates in the extreme ranges are examined in the light of recent current meter gaugings and other evidence.

Station Number	River	Station Name	First year of record	New record (mm)	Month	Pre-1996 record (mm)	Month	Year
19002	Almond	Almond Weir	1962	6.08	9	7.19	5	1980
19010	Braid Burn	Liberton	1969	3.01	9	3.86	10	1969
19011	North Esk	Dalkeith Palace	1963	8.88	9	9.21	9	1973
27006	Don	Hadfields Weir	1965	6.11	9	7.33	8	1976
27058	Riccal	Crook House Farm	1974	7.09	9	7.97	9	1990
28015	Idle	Mattersey	1965	1.75	7	3.08	7	1995
28036	Poulter	Twyford Bridge	1969	2.36	7	3.6	8	1995
28039	Rea	Calthorpe Park	1967	7.39	9	9.32	7	1976
28061	Chrunet	Basford Bridge	1975	6.74	9	7.19	9	1991
28066	Cole	Coleshill	1973	3.5	9	3.59	8	1995
30011	Bain	Goulceby Bridge	1971	1.56	19	1.65	8	1991
38028	Stansted Brook	Gypsy Lane	1972	1.01	7	1.17	8	1973
39036	Law Brook	Albury	1968	7.85	6	8.04	9	1993
40014	Wingham	Durlock	1971	0.04	7	0.06	7	1974
41001	Nunningham Stream	Tilley Bridge	1950	1.19	9	1.26	8	1976
43010	Allen	Loverley Mill	1970	3.13	10	3.16	9	1976
47013	Withey Brook	Bastreet	1972	9.83	9	10.37	8	1989
68004	Wistaston Brook	Marshfield Bridge	1957	4.06	9	4.33	8	1995
76009	Caldew	Holm Hill	1968	6.22	9	10.67	8	1995
84003	Clyde	Hazelbank	1956	6.93	9	8.03	8	1995
84004	Clyde	Sills	1957	7.23	9	8.09	8	1995
84007	South Calder Water	Forgewood	1965	15.37	9	18.51	8	1995
84013	Clyde	Daldowie	1963	11.74	9	12.07	8	1984
84016	Luggie Water	Condorrat	1966	9.39	9	9.53	9	1972

Table 7 *Highest instantaneous flows records established in 1996.*

Note: Gauging stations are featured only where there are at least 20 years of flow data on the National River Flow Archive. The data are, for the most part, provisional and subject to review as the flow rates in the extreme ranges are examined in the light of recent current meter gaugings and other evidence.

Station Number	River	Station Name	First year of record	New record m^3s^{-1}	Day	Month	Pre-1996 Record m^3s^{-1}	Day	Month	Year
31014	Grimsthorpe Brook	Grimsthorpe Park	1969	1.992	12	2	0.673	17	3	1969
38003	Mimram	Panshanger Park	1952	5.83	23	7	3.82	12	10	1993
55003	Lugg	Lugwardine	1939	81.48	26	3	81.22	8	12	1972
201007	Burn Dennet	Burndennet Bridge	1975	123.7	5	8	110.8	21	10	1987

three or four on record in many river basins. Rivers registering new minimum annual runoff totals showed a very wide distribution from the Naver (in northern Scotland) to the Great Stour (Kent); for some, including the Soar (Leicestershire) and Wharfe (Yorkshire), the previous minimum had been established in 1995. A substantial proportion of East Anglian rivers registered 1996 runoff totals of less than 50% of the 1961-90 average and, largely as a result of low baseflows, the majority of catchments throughout the English lowlands registered annual totals of less than 70% (Figure 7). Corresponding deficiencies characterised parts of the Pennines and the Lake District. Even more notably, particularly in the context of the recent past, runoff totals were similarly depressed over large parts of the Scottish Highlands. Very low summer and early autumn flows were even more extensive than in 1995 principally as a consequence of much lower groundwater levels - see below. Nationwide runoff totals in August were close to the long term minimum and the low flow regimes of a number of Highland rivers, with records commencing in the last 20 years, were largely redefined.

Although 1996 was a quite year for flood events a few notable spates occurred, and some new peak flows were established on several rivers. January produced notably low runoff totals over much of southern Britain but flows generally picked up rapidly in February. In eastern Scotland the peak flow on the Ython at Ellen on the 10th was the highest in a record from 1983. Recessions were again dominant in March when new monthly minima were widespread e.g. on the Gt Stour (Kent) and Carron (north-west Scotland). Most Pennine rivers recorded flows more typical of the summer and the depressed runoff rates were a matter of concern to the hydro-power industry, in the Scottish Highlands especially.

The Great Stour again registered a new minimum monthly flow in April as did the Little Ouse (Norfolk/ Suffolk) and flows were in the lowest quartile, for the month, throughout much of the UK. Away from north-west Scotland, the seasonal recessions gathered momentum in May when unprecedented monthly runoff totals were reported from responsive catchment in nort-west England (e.g. the Eden) and more widely in groundwater-fed lowland rivers. With very modest groundwater contributions to most lowland rivers, May runoff totals were typically between 30-60% of average. Flows rates were generally meagre entering the summer and many rivers recorded their lowest June runoff since 1976. Accumulated runoff totals in the 3-, 6- and 9-month timeframes were also notably low. In most regions July was the fifth successive month with below average rainfall but localised thunderstorms produced some steep but short-lived runoff increases, even in largely permeable catchments. On the 23rd, the peak flow in the Mimram (Hertfordshire) comfortably exceeded the previous maximum in a series from 1952. Monthly runoff rates, however, remained depressed; only during the intense drought of 1976 have lower July runoff totals been recorded for many catchments in eastern England.

August rainfall totals were boosted by frequent thunderstorms and localised flooding was relatively common, in urban areas particularly. The very severe local flooding in Folkestone on the 12th was followed by further flooding on the 28/29th - when convectional storms affected large parts of England, 80mm was recorded at Norwich over the two days. But such droughtbreaks were very shortlived and localised. Despite above average rainfall, August runoff totals were depressed over wide areas, in Chalk catchments and parts of the Pennines especially. Absolute daily minimum flows, mostly established during the 1976 drought, were eclipsed in several basins including the Chelmer (Essex) and Tern (Shropshire).

In late September heavy frontal rainfall totals in parts of North Wales and the Lake District generated some seasonally notable spates but many central areas of England reported three virtually rainless weeks; the summer recessions continued in most regions. New September monthly minimum runoff totals were common and in a few rivers - including the Clyde, Dove (Derbyshire) and Tame (W. Midlands) - absolute monthly minima were established. In northern and much of western Britain flow recoveries gathered momentum during October and triggered minor flood warnings in a number of catchments around month-end, e.g. on the Tay. By contrast, monthly runoff totals in England were still well below average in most catchments and many rivers eclipsed their previous October minimum. The Thames registered its lowest October flow since 1934.

November saw large spatial and temporal variations in flow rates. Early November flows were exceptionally low in many eastern rivers but picked-up significantly towards month-end. In the west and north spates were common in the first week; on the 4th the Yarrow Water (Borders) exceeded its previous maximum flow rate in a 27-year record; on the 5/6th minor flooding affected a number of catchments especially in the South-West. The belated seasonal recovery continued into December - minor flood warnings were issued (e.g. in the Midlands) during spate conditions around the 18/19th - but then stalled in most regions. Generally, rivers were in steep recession over the latter half of the month, particularly low daily flow rates were reported from some frozen Scottish catchments. The Thames reported its second lowest December flow for 50 years and at year-end long term runoff deficiencies testified to a protracted, widespread and severe drought.

The depressed nature of runoff conditions throughout most of 1996 is confirmed by a comparison of the flow duration curves for 1996 with the corresponding curve for the preceding record (Figure 9). Low flows were especially depressed in some Scottish catchments particularly those draining the Highlands. The flow exceeded 95% of the time during 1996 for the Tay was only around 60% of the corresponding figure for 1952-95. In smaller catchments to the west the 95% exceedance flow for 1996 was considerably more outstanding. For many lowland catchments in England the 1996 duration curves plot well below that for the preceding record throughout the flow range (see, for instance, the curves for the Gt. Stour). In Chalk catchments the lack of high flows during 1996 is most evident; in the drought range 1996 flows, though notably low, were typically greater than those recorded during the very intense drought of 1976. Only in Northern Ireland, and in a few catchments in south-west Britain was 1996 flow regime similar to that for the preceding period of record.

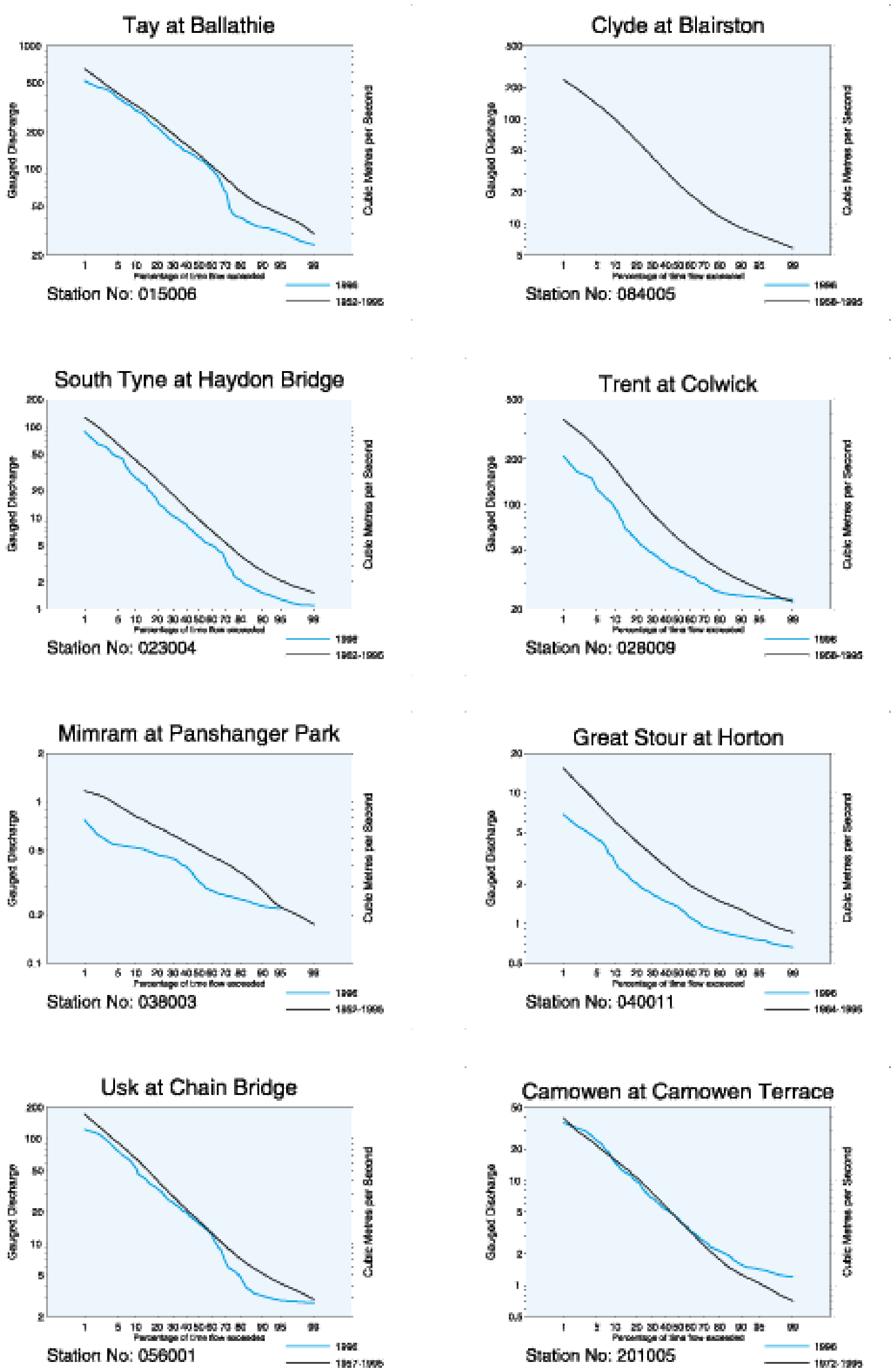

Figure 9 *Flow duration curves for 1996 and the preceding record.*

Note: Flow duration curves enable the proportion of time that flows fall above or below a given threshold to be identified - they also provide a ready means of comparing the regime in a particular year with that for the previous record.

Data sources: Environment Agency/Scottish Environment Protection Agency/ DoENI.

Groundwater

Following the near-record high groundwater levels registered over wide areas in the late winter of 1994/95 levels declined steeply throughout the spring and summer of 1995. The extremely high soil moisture deficits in the late autumn of 1995 delayed the onset of any sustained recovery and, in the east, water-tables continued to fall until year-end. Over the 1995 calendar year the decline in groundwater levels was exceptional - more than twice the annual range in parts of the Chalk - but levels generally remained above drought minima. However, the dry last quarter of 1995 served to considerably foreshorten the recharge season and only patchy recoveries e.g. in the Permo-Triassic sandstones of the South-West, followed the limited rainfall in January 1996. Fortunately, February rainfall was well above average in most outcrop areas. This triggered a surge of infiltration and significant water-table response in all areas - the Lincolnshire and Carboniferous Limestones especially. The particular value of the recharge was underlined by a relatively dry March and brisk increases in soil moisture deficits during early April - signalling an early end to the recharge season in the East. In some eastern aquifer units three-quarters of the 1995/96 recharge occurred over the six weeks from the beginning of February. Overall recharge over the winter was below average in almost all aquifer outcrop areas - replenishment was typically 50-90% of the long term average but much

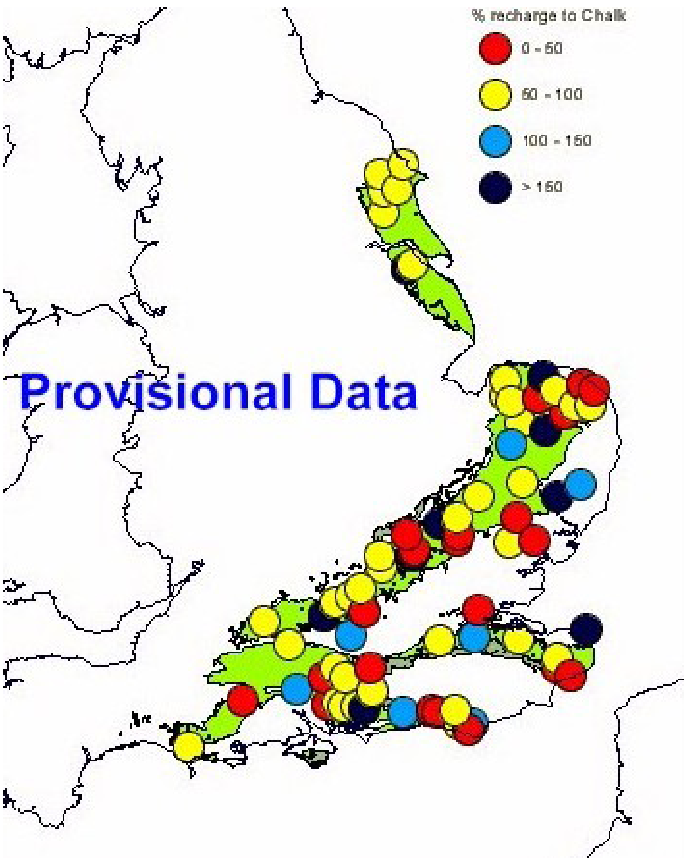

Figure 10 *Generalised percentage of the mean annual replenishment to the main outcrops of the Chalk aquifer 1995/96.*

lower in some parts of the eastern Chalk where little or no water-table rise was reported through the winter half-year (Figure 10).

In parts of Kent the 1996 recession began at near record seasonal minima and spring groundwater levels were substantially below average in all regions apart from the South-West (where winter rainfall had been well within the normal range). By late May, the 1996 groundwater level recessions were well established and, entering the summer, groundwater levels were at, or close, to seasonal minima in much of the eastern Chalk. Levels were also exceptionally depressed in the northern Permo-Triassic sandstones outcrops. In June many springs failed and winterbournes were dry well below their headwater reaches. New minimum groundwater levels for June characterised many of the more northerly Permo-Triassic sandstones outcrops. This was true of the the Chalk in Kent also and continuing recessions produced very depressed levels by the late summer throughout most of England. New record minima were recorded at a number of Permo-Triassic sites in northern England southern Scotland and north Wales. The failure of some shallow wells, mostly in minor aquifers was reported.

Soils were considerably less parched in the late summer than in 1995 but late-August smds were still well above average in most outcrop areas. Despite substantial September rainfall the smds proved notably persistent - by mid-October they remained around twice the seasonal average delaying the recommencement of infiltration and narrowing the window of opportunity for recharge over the 1996/97 winter. With only very modest infiltration in most areas during October, groundwater levels were close to drought minima throughout most of Britain away from the South-West. In a zone stretching from the Yorkshire Wolds to Kent early autumn levels in the Chalk were, typically, close to those recorded during the terminal phase of the 1976 and 1988-92 droughts. In the Permo-Triassic of North Wales and the Eden Valley, levels were at or below preceding minima (albeit in relatively short records). Falling groundwater levels and the consequent failure of springs led to a substantial contraction in the river network and with it the temporary loss of aquatic habitat.

The distribution of rainfall throughout a wet November favoured the outcrop areas of the major aquifers and generated some brisk recoveries in western and northern areas (e.g. Alstonefield, Derbyshire) but only a sluggish response in the Chalk - the most important aquifer for water supply purposes. Upturns in groundwater levels were reported throughout most of the aquifer by the end of November but the seasonal recovery needed to be generated from an exceptionally low base - at Dalton Holme in Yorkshire, for example, the November levels established new autumn minima in a record from 1889.

Soils were approaching saturation even in the eastern lowlands by early December providing the opportunity for substantial recharge late in the year. In the event, December rainfall was below half the 1961-90 average in many outcrop areas, and rises in groundwater levels were faltering. At year-end levels in parts of the South Downs were around 30 metres below the 1995 peak and well below average throughout all areas with the exception of the South-West. Preliminary analyses indicates that overall stocks in the Chalk at year-end were similar to 1991/92 and rank about fourth lowest since 1950. Entering 1997 the groundwater resources outlook was fragile.

The majority of observation boreholes for which data are held on the National Groundwater Level Archive monitor the natural variation in levels. However in parts of the UK levels have been influenced, sometimes over long periods, by pumping for water supply or other purposes which exceeds the natural rate of replenishment. As a consequence the regional water-table may become substantially depressed. For instance, levels in the Permo-Triassic sandstones of the Midlands are indicative of a significant regional decline. By contrast, in the 1990s levels at Rushyford (Northumbria) have been substantially higher than those for 10 years previously. This reflects, in part, the rundown in the coal indusry and the cessation of continuous pumping for mine dewatering. A more protracted recovery is evident for the Trafalgar Square borehole which penetrates the confined Chalk below central London. As a result of increasingly heavy abstraction groundwater levels declined by around 70 metres between the early nineteenth century to the 1950s. Subsequently much reduced abstraction rates have allowed groundwater levels to rise, latterly by about two matres a year.

Rising groundwater levels have also been reported from other conurbations in Britain. These again are linked to reduced abstraction rates but leakage from water mains may be a factor in some cases. The implications of rising groundwaterlevels extend beyond the potential improvement in resources that the rise represents. Groundwater quality may be adversely affected as levels approach the surface and a number of geotechnical problems may result, for instance the flooding of tunnels and foundations.

Location Map

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