UK Hydrological Review 2004

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Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

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NATURAL ENVIRONMENT RESEARCH COUNCIL

2004

UK HYDROLOGICAL REVIEW

This Hydrological Review, which also provides an overview of water resources status throughout 2004, is a reformatted version of the original commentary released as a web report in 2005. 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

CONTENTS

Hydrological Review of 2004

2004 Summary

In contrast to the previous year, when drought conditions extended across much of the country, rainfall totals for 2004 were appreciably above average in almost all regions of the UK with the highest anomalies in northern and eastern Britain - Scotland added a further year to a notably wet cluster. The inherent variability of the UK climate tends to produce substantial month by month rainfall variations but rainfall patterns in 2004 were particularly volatile. A very wet January helped reinforce the water resources recovery following the 2003 drought and well above average April rainfall ensured that reservoir stocks were generally close to capacity before the onset of the summer drawdown. May was relatively dry but very little water resources stress was experienced during the ensuing summer which was very unsettled. The June-August rainfall total was the 2nd highest (for the UK) since 1958, largely due to an exceptionally wet August. Countrywide, it was the wettest August for 48 years, causing significant crop damage and delays in harvesting. Severe but mostly localised flooding was also widely reported and several extreme events, the most notable at Boscastle (north Cornwall), underlined the UK's continuing vulnerability to very intense rainfall events. October was also wet, with further flooding, but the sustained rainfall initiated a substantial seasonal recovery in most reservoir stocks and some unusually early recharge to a few eastern aquifers. Thereafter however the water resources outlook deteriorated considerably during the driest November/December for England and Wales since 1953. Regional rainfall deficiencies of 40% or more over the two months heralded a notable winter/spring drought across southern Britain - foreshadowing considerable water resources and environmental stress in the summer of 2005.

Mean temperatures for 2004 were only modestly below those in 2003 and, once again, well above average. The mean Central England Temperature[1] for 2004 was around 1.0°C above the 1961-90 average, ranking among the warmest 10 years on record in a series from 1659. The late winter (of 2003/04) was especially mild and July was alone in registering a below average monthly temperature. In most areas, the warm conditions contributed to moderately above average potential evaporation losses for 2004 as a whole. Due to the relatively moist late summer soils transpiration rates in most areas were inhibited for only short periods. Correspondingly, annual (MORECS) actual evaporation losses were >15% above average throughout much of the English Lowlands and established a new annual maximum for England and Wales as a whole - in a series from 1961. Soil moisture deficits varied rather erratically through the year, particularly during the late summer and autumn. Following an unusual decline in August, and contrary to the normal seasonal trend, deficits increased again through September, exceeding the average across much of the Chalk outcrop at month end. A steep fall in October then facilitated the onset of groundwater recharge across most northern and western aquifers. By contrast, infiltration was limited across much of the English Lowlands where modest soil moisture deficits remained at year end in some eastern areas.

Figure 1 provides a guide to overall reservoir stocks for England and Wales for the 1988-2004 period, based on a representative network of major reservoirs. Reservoir stocks were generally very healthy throughout the 1998-2003 period but during the latter stages of the 2003 drought they fell well below the seasonal average across much of the UK. In southern England stocks in a few reservoirs (including Ardingly and Clatworthy) were still below 30% of capacity in early December. Fortunately, stocks recovered very briskly over the late autumn and winter of 2003/04. Overall stocks for England and Wales increased by 40% from early November 2003 to early February 2004 - the largest increase in any 3-month period in a series from 1988. Replenishment declined substantially during the late winter but, by early April, stocks were close to capacity in most major reservoirs - exceptions included Colliford and Roadford in the South West, and Silent Valley in Northern Ireland. For England and Wales as a whole, stocks were modestly above average at the onset of the seasonal decline in May (see Figure 2). However, despite significant replenishment to pumped storages in the English Lowlands, stocks generally fell more rapidly than normal through the early summer and overall stocks were a little below average entering August. Very unusually, overall stocks increased appreciably over the month (the last such occurrence was in 1992) mainly reflecting healthy inflows to western and northern reservoirs and a moderation in the rate of decline in many southern impoundments. Further

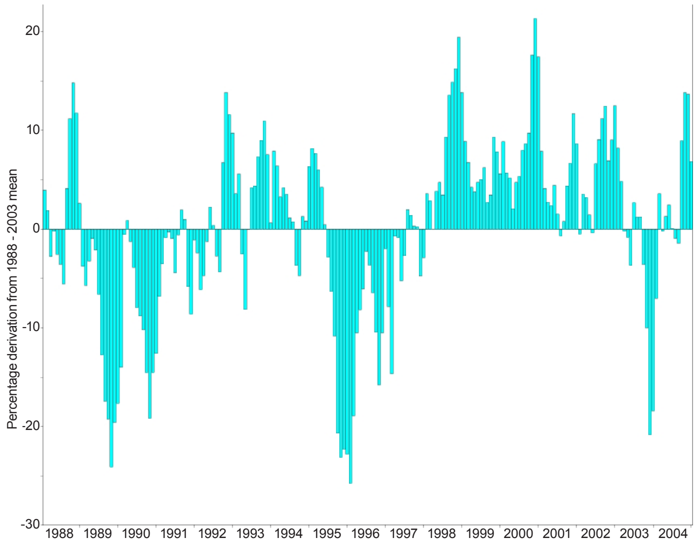


Figure 1 *A guide to England and Wales reservoir stocks 1988-2004.*

Data sources: Water Services Companies and the Environment Agency.

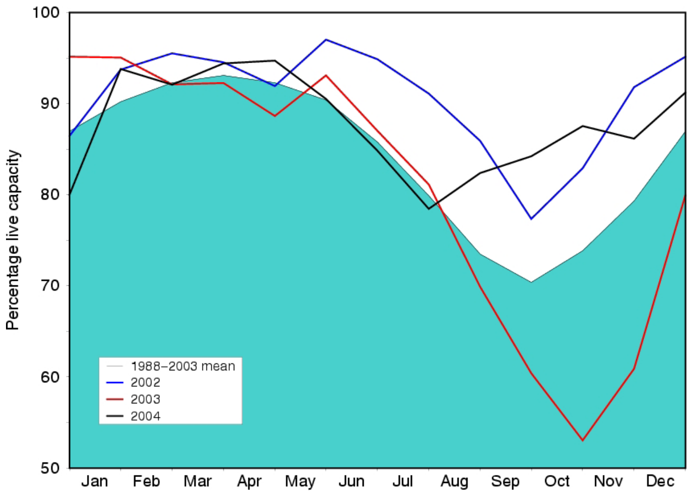


Figure 2 *Variation in overall reservoir stocks for England and Wales.*
Data sources: Water Services Companies and the Environment Agency.

increases in reservoir levels during October left overall stocks at their 3rd highest on record by early November. The atypical replenishment pattern continued with an appreciable decline of stocks into December but, by year end, overall stocks were still appreciably above average at the national scale. Significantly however, water levels were considerably below average in a number of important southern reservoirs (e.g. Bewl and Colliford).

Due in part to seasonally very healthy runoff over the August-October period, total outflows from the UK were modestly above average in 2004. A guide to the variation in annual runoff for England and Wales, Scotland and Northern Ireland - expressed as percentage departures from the long term mean - is shown on Figure 3. The runoff assessments are based on representative networks of gauging stations monitoring outflows from major river basins. The estimates for the first few years featured on each plot are less reliable due to the relatively sparse monitoring network at the time (prior to 1981 there were too few operational gauging stations to monitor total outflows from Northern Ireland). After a notably low runoff year (2003 which registered the lowest total since 1973) and a cluster of years with abundant outflows (1998, 1999, 2000 and 2003) each rank in the highest five in a series from 1961), runoff totals for Great Britain returned to well within the normal range. England and Wales reported outflows around 3% above average, the first time since 1995 that they have been within 15% of the long term average. The total for Scotland was about 16% above average and Northern Ireland registered a similar percentage below - the third time in four years that runoff has fallen well below average (but the 2001 and 2003 totals were considerably lower than 2004).

Seasonally typical river flows at the beginning of 2004 were in sharp contrast to the floods in early January 2003 and heralded a year when flows in most rivers remained within the normal range. Seasonal contrasts were also more muted than normal. Although annual runoff totals were generally not exceptional, flow patterns displayed considerable spatial and temporal variations through the year. River flows approached long term monthly minima in many responsive catchments during April, and again in June, but recessions in most rivers were reversed during the late summer. Widespread moderate flooding occurred in late January and early February, and again in October, but the events with the greatest impact were concentrated in August when extreme rainfall (over a range of timespans) generated a number of very damaging floods and landslides (from Cornwall to the Scottish Highlands). The estimated peak flows associated with the most outstanding events (at Boscastle[2] and Loch Ogle[3] in Perthshire) have important implications for understanding flood generating processes, flood management and the development of improved engineering design procedures. As a consequence of the exceptional

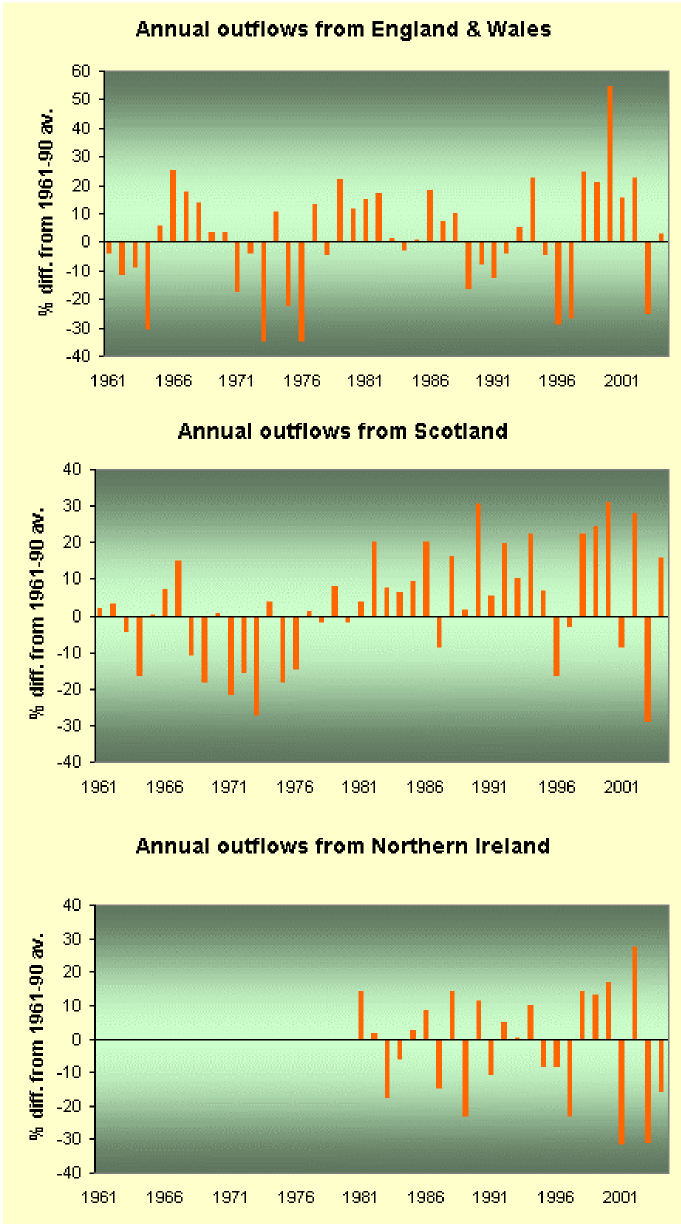


Figure 3 *Index of total runoff 1961-2004.*

late-summer runoff, most 2004 daily minimum flows were well above drought mimima. Seasonal runoff recoveries were generally strong in October in western and northern Britain, but relatively weak in the English Lowlands. This was particularly notable in spring-fed streams and rivers which exhibited remarkably stable flows over the latter half of 2004, implying well below average flow rates by the end of the year. The very limited November and December rainfall also resulted in seasonally low flows in most responsive catchments across the rest of the country.

Aquifer recharge patterns and groundwater level variations in 2004 were substantially different from those in a more typical year. Generally the rainfall distribution through the year was unfavourable in relation to groundwater recharge, with a number of the wettest episodes occurring in the April-October period - when evaporation losses are at their greatest. Infiltration was erratic throughout much of 2004 but seasonal contrasts in recharge, which were exaggerated in 2003, were less evident and contrasted with infiltration patterns which have typified much of the post-1997 period. In 2004, abundant infiltration characterised January and October (in many areas); much more unusually, significant and widespread infiltration was reported during late August. Recharge was very modest in the late winter/early spring (2003/04) and, particularly, during the last two months of the year when soil moisture deficits lingered in the outcrop areas of many eastern and southern aquifers. As a consequence, groundwater levels were at their lowest for seven or eight years over wide areas by the end of 2004. More generally, groundwater resources, which had provided an important buttress against drought conditions in the previous year, were, by year end, much more poorly placed to counterbalance the impact of any substantial rainfall deficiencies in 2005.

The Recent Past

2004 followed a period with very notable seasonal - and longer term - variations in river flows and rates of aquifer recharge. The preceding decade saw widespread drought conditions in 1995-97, in northern Britain and Northern Ireland during 2001, and again across much of the country in the summer of 2003. By contrast, severe floods were a feature of the spring of 1998 (across the Midlands), throughout most of southern Britain in 2000/01, and again in early 2003. Existing maximum recorded flows were widely eclipsed, although mostly by modest margins, and groundwater levels - responding to unprecedented rates of aquifer recharge (especially in the winter of 2000/01) - exceeded previous maxima for extended periods in many outcrop areas.

Figure 4 shows 5-year running means of annual rainfall for the 1914-2004 period for England and Wales, Scotland and Northern Ireland. Overall, the relative dryness of much of the 1970s has served to exaggerate the apparent increasing trend over the last 40 years; when considered within the context of rainfall records extending back to the late 18th century the main features may be seen as perturbations about a relatively stable mean. Nonethless, the recent past has been notably wet. The 1998-2002 period is the wettest 5-year sequence on record for England and Wales. As notably, the last 15 years have been, on average, 9% wetter in Scotland than the preceding average (4% wetter for Northern Ireland). North-western Britain has been especially wet over this timespan with winters contributing most to the additional rainfall. However a proportion of this increase may be attributable to a reduction in snowfall as a proportion of total precipitation (snowfall is normally underestimated). As winter rainfall has increased, there has also been a tendency towards a clearer partitioning between winter and summer rainfall across much of the UK. This is in marked contrast to the 19th century when many summer half-year rainfalls totals exceeded those for the preceding winter half-year.

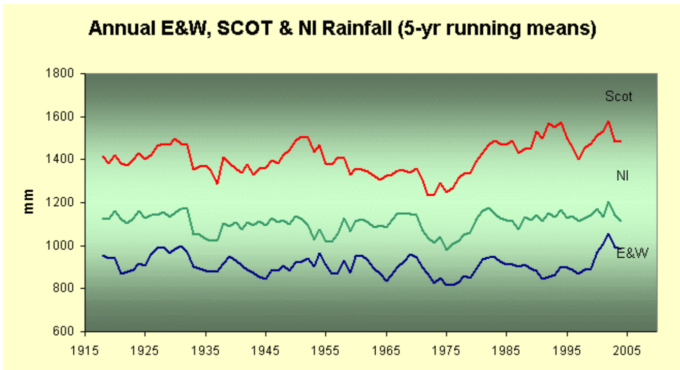


Figure 4 *National rainfall series 1914-2004.*
Data source: UK Met Office.

A common climatological feature of the recent past has been the notably warmth, over the last decade particularly. The annual average Central England Temperature has, with the exception of 1996, been above the long term mean for every year since 1987 and the 1995-2004 mean is around 1.0°C greater than temperatures of a century ago. This very appreciable warming is evident in Figure 5 which illustrates winter and summer temperature and rainfall anomalies (relative to the 1845-1974 average) for England and Wales. The red diamonds show the plotting positions for the most recent 30-years; a high proportion have registered positive temperature anomalies. The winter (November-April) and summer (May-October) periods for 2003/04 both plot in warm/wet quadrant, as do most years since 1997; for the preceding eight years the summers tend to group in the warm/dry quadrant.

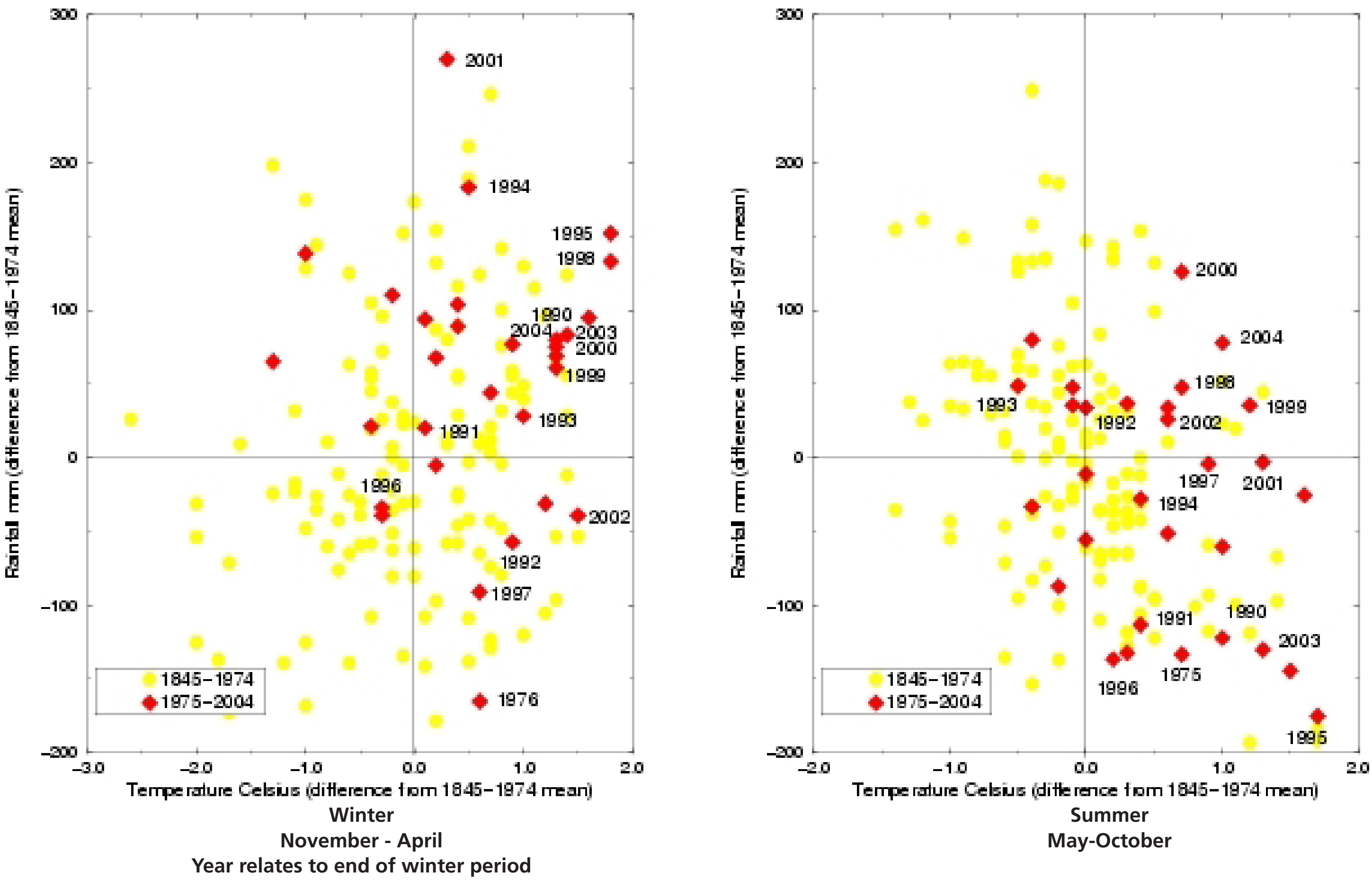


Figure 5 *England and Wales rainfall and temperature anomalies 1845-2004.*
Data sources: Central England Temperature series/Hadley Centre.

The warm conditions have encouraged increasing evaporation demands over the last 40 years. Figure 6 shows the 5-year running mean annual (MORECS) Potential (PE) and Actual Evaporation (AE) losses for England and Wales and for Scotland. PE losses for England and Wales have increased erratically but recent annual totals have been around 30mm greater than in the 1960s. AE losses, however, exhibit less of a trend. This is largely due the warmer (and, often, drier) summers with correspondingly very dry soil conditions, inhibiting transpiration rates and moderating overall AE losses in the English Lowlands especially. As a result, changing evaporative demands have had only a limited impact on the water balances of most catchments. For Scotland, transpiration rates are normally restricted for only very short periods across most of the country. As a consequence, countrywide annual AE losses closely approach PE totals in most years. Evaporation losses have increased by a similar margin to those for England and Wales since the 1960s but the impact on water balances in most areas has been more than counterbalanced by a larger increase in annual precipitation totals.

Rivers, reservoirs and groundwater reserves are sustained and replenished not by rainfall directly but that proportion which remains after allowing for

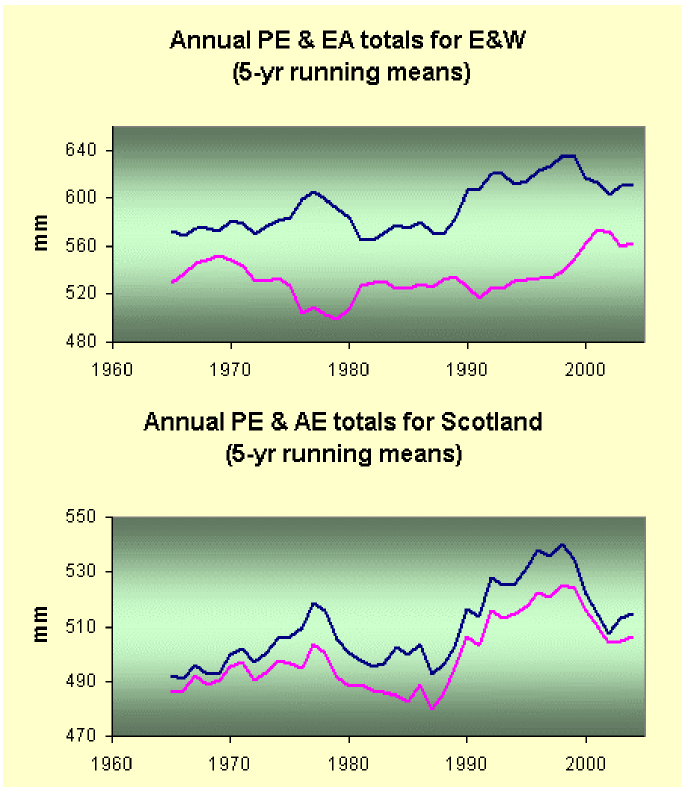


Figure 6 *Annual potential evaporation and actual evaporation totals 1961-2004.*
Data source: MORECS.

evaporative demands. Runoff therefore provides the best index of the health of water resources. Figure 3 provides evidence of substantially greater runoff from Scotland over the post-1980 period than in the preceding 20 years. Notwithstanding the enhanced evaporative demands, total runoff over the 1998-2002 period for England and Wales matched rainfall as being unprecedented over the post-1960 period and, very probably, throughout the instrumented era. A common feature of the annual histogram plots is the notable variability over the last decade with wide departures from the preceding average; seasonal departures have also been substantial in recent years also. Statistically significant increases in runoff and flood magnitude have been identified for some rivers (mostly in Scotland) and examples of both positive and negative trends in low flows can readily be found. However, given the natural range of hydrological variability and the pervasive impact of artificial influences (e.g. abstractions, river regulation, inter-basin transfers), any attribution to climatic change can be only tentative. Of particular significance in the UK is the fact that the great majority of UK river flow and groundwater level data has been collected over the last 40 years. In relative terms, the early part of this period can be broadly characterised as quiescent - with below average runoff and a low frequency of major flood events across much of the UK. As with many hydrological series the timeframe over which any trend analysis is undertaken can be very influential in determining the sign and magnitude of any apparent trend. When considered in the context of available long river flow records and curatorially appraised historical material, most apparent trends appear as perturbations about a relatively stable mean. Compelling evidence for an increase in the frequency or magnitude of UK hydrological extremes is still awaited. However, there are few modern parallels for the volatility of the recent past and this enhanced variability has substantial implications for water and environmental management.

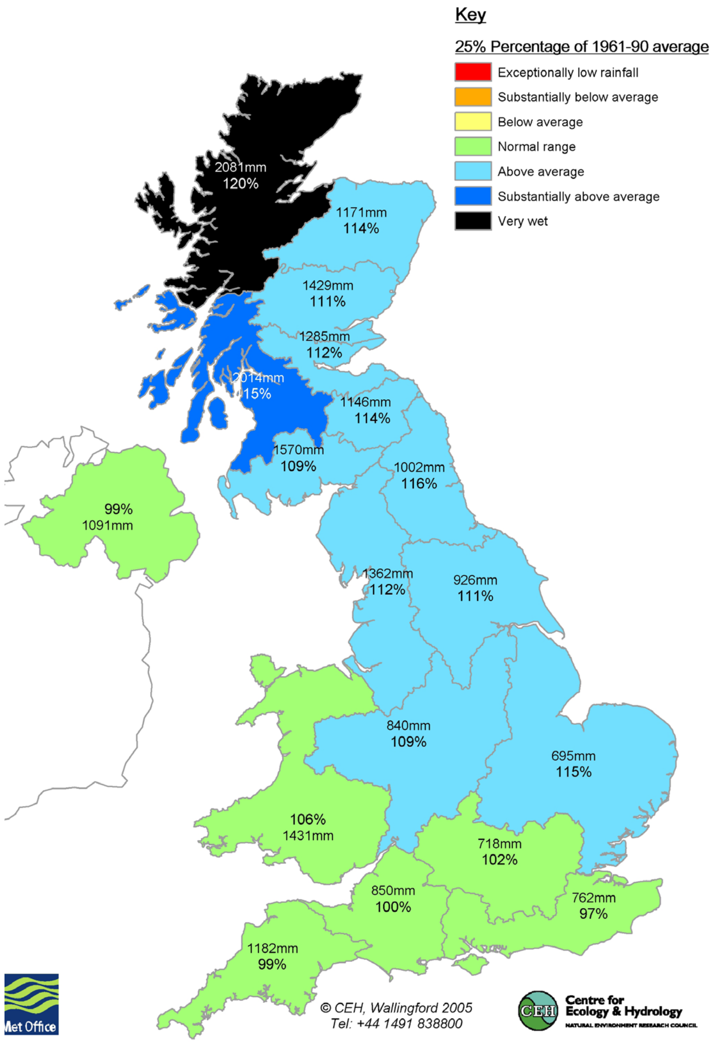


Figure 7 *Annual rainfall for 2004 in mm and as a percentage of the 1961-90 average.*

Data source: UK Met Office.

Rainfall

The year in brief

2004 national and regional rainfall totals for the UK, together with the corresponding percentages of the 1961-90 average, are shown on Figure 7, individual monthly and half-yearly figures are given in Table 1. At the national scale, rainfall for 2004 was approximately 10% above average adding to a recent cluster of notably wet years - five of the last seven years rank among the 10 wettest in a series from 1914. The 2004 total for Scotland is the 4th highest annual total in a series from 1869 (1990 was considerably wetter). Northern Ireland registered a near-average annual rainfall total whilst the England and Wales total moderately exceeded the 1961-90 average but the regional totals for the Southern and the South-West regions fell marginally below average.

Although most regions of the country were relatively wet, the rainfall distribution through the year was generally unfavourable from a water resources perspective. January, April, August and October were wet months across most of the country but a relatively dry late winter (2003/04) and early spring across the entire country (see Figure 8) raised some concern about possible hydrological stress in the summer of 2004. In the event, a extremely unsettled August (equalling the wettest since 1917) contributed to the 2nd highest June-August rainfall since 1958 for the UK as a whole. Some regional rainfall totals for the summer were outstanding (see Figure 9). Much of the Northumbrian region reported considerably above average rainfall for each of the summer months and the accumulated total eclipsed the previous maximum (in a series from 1961) by a substantial margin. Much of eastern Scotland also had an exceptionally wet summer with only 1985 producing broadly similar totals in the last 45 years at

Table 1 *2004 Rainfall in mm and as a % of the 1961-90 average.*

Data source: UK Met Office.

2004		**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**	**Year**	**Oct-Mar 2003/04**	**Apr-Sep 2004**
United	mm	152	74	70	93	51	85	71	160	103	165	75	111	1210	603	562
Kingdom	%	135	94	76	138	72	119	96	176	103	148	66	96	110	96	118
England and	mm	124	59	54	79	46	58	68	149	66	149	53	69	973	495	466
Wales	%	137	91	74	131	72	92	110	194	84	172	57	72	107	99	115
Scotland	mm	208	108	98	123	62	131	76	188	175	204	121	192	1686	821	754
	%	134	102	77	152	71	152	79	161	121	128	77	123	115	95	124
Northern	mm	133	51	87	78	49	109	63	114	106	133	61	107	1091	535	519
Ireland	%	115	63	96	118	67	149	88	120	106	116	57	98	99	86	108
North West	mm	169	89	69	76	46	92	76	229	138	165	83	131	1362	651	655
	%	142	112	72	106	61	112	87	208	118	128	66	104	112	97	121
Northumbrian	mm	127	64	54	69	29	97	72	199	45	152	37	57	1002	450	511
	%	151	107	75	119	47	157	109	240	61	198	43	69	116	98	126
Severn Trent	mm	95	41	41	87	43	52	61	153	58	121	46	41	840	380	454
	%	134	75	68	156	72	87	111	221	88	185	65	52	109	94	124
Yorkshire	mm	118	57	43	99	31	72	72	182	38	128	39	47	926	410	494
	%	148	97	63	167	51	117	116	240	54	173	48	57	111	92	127
Anglian	mm	82	37	32	67	42	41	79	122	32	92	44	26	695	328	383
	%	160	97	69	143	86	79	157	220	64	180	75	46	115	109	126
Thames	mm	89	30	43	76	50	32	49	114	30	119	41	45	718	391	351
	%	135	65	75	149	89	58	99	194	51	187	62	64	102	106	106
Southern	mm	110	32	41	74	55	32	54	105	36	127	34	62	762	488	356
	%	135	59	65	141	102	58	112	181	51	158	40	75	97	109	106
Wessex	mm	116	46	55	81	40	47	59	91	52	153	35	73	850	504	370
	%	129	70	78	151	65	82	111	135	71	189	42	77	100	103	101
South West	mm	177	71	89	76	47	64	70	151	68	201	56	110	1182	672	476
	%	127	70	89	109	63	92	99	174	72	172	44	78	99	92	103
Welsh	mm	185	114	86	82	65	72	76	152	138	249	87	126	1431	765	584
	%	128	113	79	99	77	88	93	143	117	179	60	81	106	97	106
Highland	mm	264	168	117	142	73	149	86	167	244	212	180	282	2081	1044	859
	%	145	133	74	151	77	150	80	129	145	110	91	146	120	100	124
North East	mm	129	72	62	114	44	128	55	164	67	182	74	81	1171	541	573
	%	125	103	75	167	60	186	71	181	73	177	71	83	114	97	122
Tay	mm	145	66	76	119	67	113	70	239	126	223	65	120	1429	600	734
	%	100	67	67	174	77	149	85	239	104	165	51	90	111	79	137
Forth	mm	138	62	72	97	52	134	62	185	111	195	60	117	1285	543	642
	%	116	76	73	157	68	186	80	190	98	163	52	102	112	84	129
Clyde	mm	272	93	119	137	72	152	96	221	236	221	143	252	2014	983	913
	%	144	76	79	153	75	156	84	156	129	112	77	136	115	95	127
Tweed	mm	133	64	75	85	37	109	60	207	70	194	45	67	1146	536	568
	%	132	91	91	141	51	161	80	231	76	197	46	69	114	98	124
Solway	mm	190	89	116	111	55	102	71	223	164	202	86	161	1570	798	726
	%	125	87	97	141	63	120	76	183	114	128	59	107	109	97	119
Western Isles;	mm	193	119	86	94	48	85	60	106	151	151	139	173	1406	806	545
Orkney and Shetland	%	133	120	72	121	69	117	70	107	110	98	91	116	103	99	100

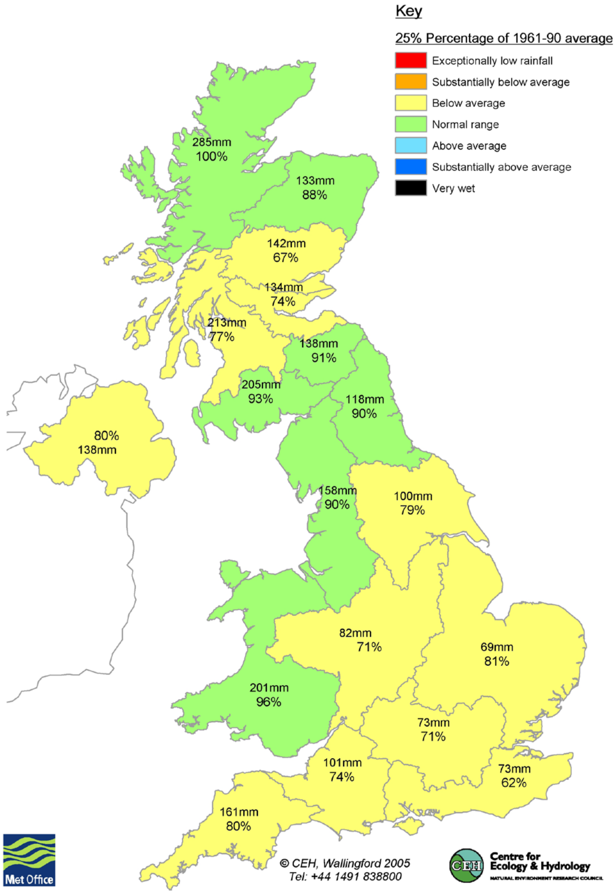


Figure 8 *February-March 2004 rainfall in mm and as a percentage of the 1961-90 average.*

Data source: UK Met Office.

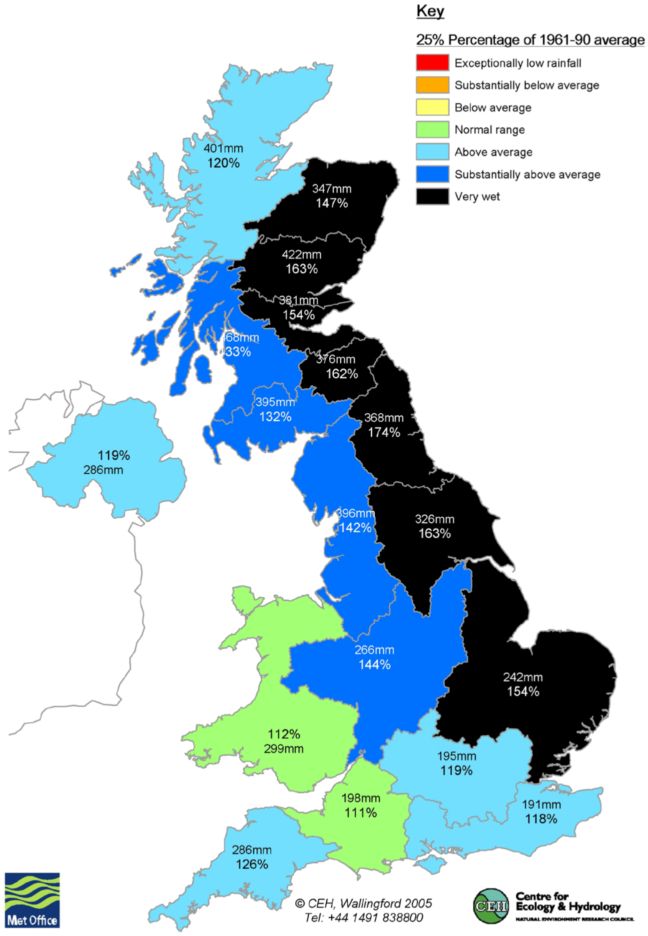


Figure 9 *June-August 2004 rainfall in mm and as a percentage of the 1961-90 average.*

Data source: UK Met Office.

least. Apart from western Scotland and the Islands (much of Northern Ireland also) October rainfall totals exceeded 120% of average but, thereafter, frontal systems mostly followed northerly tracks. As a result the normal north-west/south-east rainfall gradient across the UK was accentuated and significant rainfall deficiencies became established across southern and eastern Britain. Seasonal recoveries in water resources normally gather momentum in November and December but in 2004, the two-month rainfall totals were <60% of average across large parts of eastern, central and southern England (see Figure 10) and for England and Wales as a whole it was the third driest end to the year since 1953.

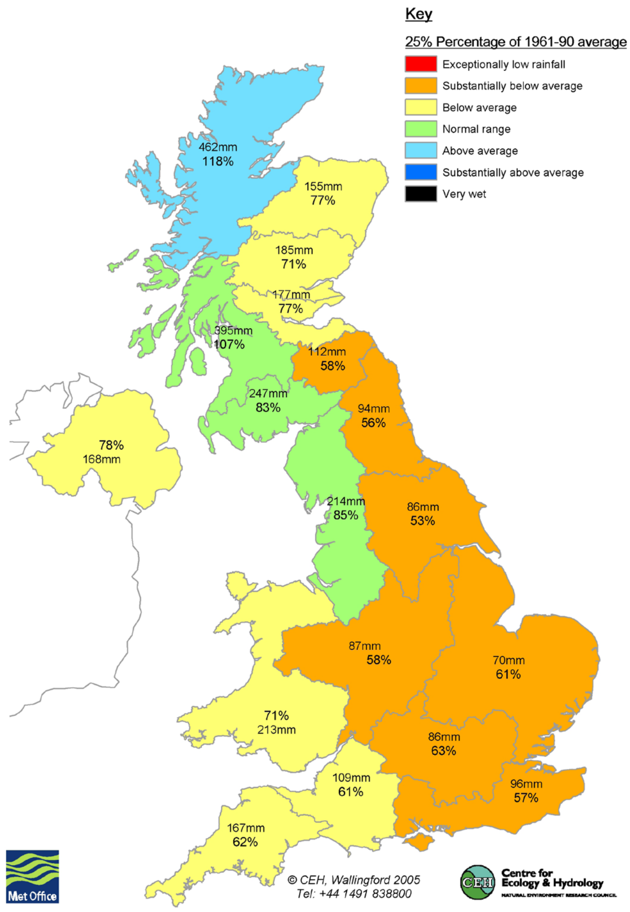


Figure 10 *November-December 2004 rainfall in mm and as a percentage of the 1961-90 average.*

Data source: UK Met Office.

Rainfall - through the year

January

January was a generally mild and unsettled month but with a freezing interlude late in the month, as an Arctic airflow brought widespread snowfall across much of the UK late in the month. Gales and blizzards were common in northern Scotland but, to the south, mild and damp conditions predominated. Many areas reported only 3 or 4 dry days in the month and vigorous frontal systems produced significant precipitation totals on a number of occasions. Precipitation totals over the last few days of the month were especially impressive (Eskdalemuir reported 62mm on the 28th and parts of Northern Ireland received almost half their January total in the last couple of days); substantial accumulations of snow were also reported (e.g. around 30cm at Fylingdales and Glenlivit on the 28th) - initiating an exceptionally wet spell that continued into February. A few areas, mostly in eastern Scotland, reported slightly below average January rainfall totals but much of Britain exceeded 120% with a few areas (e.g. the North York Moors) approaching 200%. For the UK as a whole, January was the wettest month since October 2002 and all regions registered above average rainfall for the Nov-Jan period (only marginally so in the South West). Given the low evaporation demands, the positive rainfall anomalies, during what is on average the wettest period of the year, resulted in substantial improvements in water resources notwithstanding appreciable long term rainfall deficiencies (from February 2003) remaining in parts of north-east Britain especially.

February

A sequence of vigorous frontal systems brought substantial rainfall to most regions in early February but a decisive change in synoptic patterns heralded colder and mostly dry conditions over the ensuing four weeks. In the context of the recent past, snowfall constituted a substantial proportion of total precipitation, in Scotland especially, but blizzard conditions were also experienced in coastal areas of England (e.g. at Bournemouth on the 27th). A slow-moving frontal system produced a remarkable 260mm rainfall total over 48 hours (4/5th Feb) at Capel Curig in North Wales - the corresponding return period exceeds 100 years. Substantial rainfall occurred across much of the UK on the 5th but, subsequently, some localities in central southern England reported only 2mm over the three weeks up to 2nd March. Monthly precipitation totals for February exhibited wide spatial variations; North Wales was exceptionally wet and parts of northern Scotland reported >150% of the monthly average also. By contrast, parts of southern England (coastal areas particularly) registered <30% and Northern Ireland recorded its 2nd lowest February rainfall in 20 years. Despite its dry conclusion, rainfall totals for the winter (December-February) were close to, or above, average in all regions but long term deficiencies remained significant, particularly in the 13-month timeframe; the February-February rainfall total for the UK as a whole was the lowest since 1975/76.

March

March was, at turns, balmy and boisterous with precipitation mostly concentrated in the first three weeks. Gales produced significant rainfall and some wind damage on the 8th (e.g. on the Isle of Wight) and substantial rainfall totals were registered in northern Britain on the 19th (e.g. 60mm at Loch Glascarnoch, Highland Region). However, many rain-bearing depressions passed to the north of the British Isles and most frontal incursions produced only modest rainfall totals. As a consequence, March rainfall was below average across the UK with the exception of a zone from the Cheviots to Northern Ireland (plus a few other localities). Large parts of eastern Britain registered less than 70% of the March average, the southern Pennines and Cheshire Plain being particularly dry. Regional February-March rainfall totals were generally higher than in 2003 but still well below average in most regions, notably so in the South East. For England and Wales it was the 4th driest such period since 1976. Rainfall over the winter half-year (October-March) was typified by large month-on-month variability but all regions of Britain registered half-year totals in the normal range; Northern Ireland was its driest since 1986 in this timeframe. Longer term deficiencies remained large across much of the UK with a few eastern catchments reporting below average rainfall in 10 of the 12 months since February 2003.

April

April was very unsettled across much the greater part of the UK and the proverbial April showers were decidely more vigorous than usual. Widespread frontal rainfall also contributed to the well above average rainfall reported in most regions. The 18th was especially wet with much of eastern England and the Borders registering rainfall totals >20mm. Intense localised downpours were especially common over the final week - triggering localized, mostly urban, flooding. Following a short heat-wave, thunderstorms on the 26th and 27th resulted in some exceptional storm totals e.g. 43mm in 2 hours at Bromsgrove (26th); 33mm in an hour near Sheffield (27th). Further vigorous thunderstorms affected much of southern England as warm, moist air pushed up from France on the 27th. The showery nature of much of the April rainfall made for substantial local variability in the monthly totals but only a few areas - mostly in Wales and North West England - reported less than 75% of average; Anglesey was especially dry. By contrast, much of the Scottish Highlands registered around twice the April average, with similar percentages characterising parts of the Midlands and the North East. Regional rainfall deficiencies over the post-January 2003 period remain very substantial but the above average rainfall over the six months since October 2003 has largely banished the spectre of drought.

May

The sequence of low pressure systems which brought plentiful rain in late April continued into May with many areas reporting only one dry day in the first week; the 3rd was especially wet. Thereafter, anticyclonic conditions dominated synoptic patterns, producing warm and dry weather with notable sequences of dry days, in the West particularly - a number of localities from North Wales to Cornwall registered 22 consecutive dry days. Elsewhere, intense local thunderstorms - on the 19th and 20th especially - contributed to above average May rainfall totals in South East England (and a few other areas). However, generally, regional rainfall totals were in the 45-90% range with a few areas registering only about a third of average (e.g in parts of the Vale of York and north-east Scotland). The modest UK total added to a cluster of dry Mays in the last 15 years - six being substantially below average. From a water resources viewpoint, medium and longer term deficiencies are of more significance. Some catchments (e.g. in the South West) have reported below average rainfall in 9 of the last 10 months with notable accumulated deficiencies over the August-May period. In this timeframe Northern Ireland and the Tay basin both registered their lowest rainfall since 1973; the South West was almost as deficient.

June

June was a month of contrasting weather patterns. The unsettled weather of late May continued with significant rainfall in northern Britain - Tain Range (Highland Region) reported 38mm on the 11th - but rainfall amounts were very modest in the South and, with high pressure dominating, some localities (e.g. in south Oxfordshire) reported <1mm of rainfall up to the 19th. This very warm and dry spell brought an arid complexion to the landscape and generated some local concern for the water resources outlook (e.g. in parts of Northern Ireland). Stress on farmers, growers and gardeners was relieved locally by thunderstorms and, more generally, on the 22/23rd when an unusually vigorous summer depression generated rainfall totals of 15-25mm across much of the UK - triggering local flooding and landslides (e.g. in Cornwall); Lough Fea (Northern Ireland) reported 45mm and Buxton 46mm on the following day. The showery nature of much of the rainfall made for imprecise areal assessments but a notable north-south contrast in June rainfall totals was clearly evident. A few localities near the Moray coast reached 300% of average and the above average rainfall in Northern Ireland was particularly welcome. Much of the English Lowlands, however, reported less than half the June average with several coastal pockets being extremely dry (e.g. Portsmouth and Southend). In some regions this arid interlude appreciably increased medium term rainfall deficiencies. The February-June period was the 2nd driest in the last 20 years in parts of the South West, and, for a few southern catchments (e.g. in the Thames basin), above average rainfall has been registered in only three or four of the 17 months ending with June.

July

July began in autumnal mode across much of the UK with boisterous, cool, wet and cloudy conditions as a sequence of westerly frontal systems brought high winds and significant pulses of rain, often with thunderstorms in their wake. This very unsettled interlude culminated on the 7th when a particularly vigorous depression moved north across the UK. Daily rainfall totals exceeded 15mm over wide areas and convective activity generated some extreme storm totals: Wittering (Cambs) reported a remarkable 107.4mm in 19 hours on the 7/8th; an event with a return period exceeding 100 years. Thereafter, thunderstorms remained common (Scampton in Lincolnshire reported 28.6mm in an hour on the 22nd) but rainfall totals were modest at the regional scale and many areas registered <5mm over the final three weeks of the month. July rainfall totals showed an unusual consistency across much of the country (mostly in the 40-70mm range) - this translates into well above average rainfall across much of eastern England but generally below average throughout most of the rest of the UK. Parts of eastern and northern Scotland were particularly dry as were catchments to the south of Lough Neagh in Northern Ireland. Regional rainfall totals for the January-July period were all relatively close to the long term average but some short term deficiencies were notable (e.g. May-July for parts of Wales). Many regions had 10-15% deficiencies over the period since July 2003; in this timeframe the Tay and South West regions registered their 2nd and 3rd lowest rainfalls in series from 1960.

August

Many new local and catchment rainfall records were established (particularly for high intensity events) when a combination of humid sub-tropical air masses, slow-moving frontal systems and several hurricane remnants made for exceptional precipitation conditions. Much of the precipitation was convective and downpours of near-tropical intensity affected many parts of the country (their impact exacerbated in some cases by hail - a 45mm diameter hailstone was reported at Bracknell on the 5th). Convective storms produced many notable precipitation totals including: 42mm in 38 minutes at High Wycombe (3rd) and an unconfirmed 67mm in 45 minutes near Huddersfield (12th) and a slow-moving front generated exceptional storm totals on the 9/10th. Many areas exceeded 50mm with Skipton registering

96mm in 36 hours and 24hr totals of 73mm (Wheatley, Oxen), 77mm (Sheffield) and 91mm (Wittering, Cambs). In the lower Trent basin a single raingauge reported an exceptional 6-hour total of 86mm. However, the most outstanding August event was a 200mm storm total in around 4 hours at Otterham, north Cornwall on the 16th (return period estimate >>1000 years). Rainfall accumulations were also exceptional over much longer timespans - in Dumfries and Galloway, Boreland recorded a 16-day total of 248mm (RP >200 years) and many localities reported record August totals (e.g. Wittering in an 80-year series). For the UK, the rainfall was the highest since 1956; only 1912 has been appreciably wetter in the 105-year national series. Much of eastern Britain reported more than twice the monthly average rainfall and totals for many gauged catchments were amongst the three highest on record for any month. By contrast, a few areas reported monthly totals of <70% (e.g. the north-eastern tip of Scotland, parts of Fermanagh). Such localities aside, the abundant August rainfall contributed to the 2nd wettest summer (June-August) in 47 years for the UK; rainfall totals were well above average in all regions and longer term deficiencies (e.g. from February 2003) were substantially reduced.

September

In contrast to much of August, Indian Summer conditions characterised early September with predominately anticyclonic synoptic patterns and exceptional high temperatures characterising the first nine days. During this period precipitation was restricted to fog- drip throughout much of the English Lowlands. Thereafter, incursions of low pressure systems were more common - particularly in northern Britain where frontal rainfall produced some notable storm totals (e.g. Lusa 51mm on the 14th, Sloy 77mm on the 20th, Capel Curig 56mm in 12 hrs - also on the 20th), and many catchments in Northern Ireland registered 15-25mm on the 29/30th. The preferred tracks of frontal systems were clearly reflected in the September rainfall totals. Above average rainfall was reported for the uplands of western Britain with parts of the Scottish Highlands reaching twice the average. By contrast, low-lying eastern and southern catchments were much drier with large areas of eastern Britain registering less than half the 1961-90 average; a few, mostly coastal, districts (e.g. in Kent) recording less than 30%. Rainfall throughout the summer half-year (April-September) was erratic but all regional totals exceeded the average. Since 1968, the total for Anglian region has been appreciably exceeded only in 2000 - and for some catchments it was the 7th above average summer half-year in the last eight. The summer half-year total only marginally exceeded the average for the Southern region where, for some localities (e.g. Havant), five of the six months were below average. Appreciable long term deficiencies remained (e.g. in the South West from Jan 2003) but accumulated rainfall totals for the first nine months of 2004 were close to, or above, average for all regions.

October

October was a very cyclonic month with an almost unbroken sequence of vigorous frontal systems producing significant pulses of frontal rainfall. The more notable rainfall totals included 48mm at Lusa (Skye) on the 5th and 24-hr totals of 91mm at Llansadwarn (Anglesey) on the 22/23rd and 78mm at Capel Curig (North Wales), the latter contributing to an exceptional 9-day total of 250mm. October rainfall totals were modestly below average in parts of northern and western Scotland (Allnabad, Highland Region reported 80%) and Northern Ireland (e.g. parts of the Sperrin Mountains) but elsewhere totals generally exceeded the average by a substantial margin. Large parts of eastern and central southern Britain reported more than twice the average and Leuchars (Fife) exceeded 300%. For England and Wales it was the 3rd wettest October in the last 37 years, adding to a cluster of recent wet Octobers. More significantly, the July-October period was the 3rd wettest since 1927 (2000 was similar); in this timeframe much of eastern Britain has been exceptionally wet. Unsurprisingly, rainfall accumulations for the May-October period were well above average in all regions and, for the year to the end of October. Northern Ireland and the Western Isles aside, most regional anomalies in this timeframe exceeded 15% - sufficient to eliminate, or greatly reduce, the large regional rainfall deficiencies built up through the 2003 drought.

November

Despite a cold snap in mid-month, November was generally mild and cloudy. The damp complexion to the weather (fog and drizzle were common) provided a misleading perception; significant storm events were rare, being largely confined to mid-month in many regions. On the 18th, a 33mm rainfall total was recorded at Grimsbury (Oxon) and significant snowfall was reported as far south as East Anglia. Three days later an active frontal system produced 2-day totals of >50mm in parts of the Western Highlands. Thereafter, November precipitation was largely limited to fog-drip in many areas, and the dry spell continued into December. Rainfall totals of only around 5mm were recorded in parts of central southern Britain over the 21 days from the 21st November. November rainfall totals modestly exceeded the average in parts of western Scotland and in a few parts of central England (e.g. Woburn, Bedfordshire) but most index raingauges registered only 40-80% of average; the lowest totals clustered in north-east England, and in a zone from Cornwall to Sussex. The UK total of 75mm ranks as the lowest since 1993. Nationally, monthly rainfall totals have alternated between below and above average for the last nine months but in some regions there has been less counterbalancing; autumn (September-November) rainfall totals were particularly low in Southern Region. All regional rainfall accumulations were above average in the June-Nov timeframe and for the January-November period only Southern Region and Northern Ireland had below average totals.

December

December began with high pressure - which dominated the latter half of November - still acting as the most influential synoptic feature. The associated very dry spell extended to 25-30 days in much of eastern Britain. A vigorous frontal system on the 14th proved pivotal - bringing significant rainfall to much of Britain (a 75mm daily total was reported from Lussa, Kintyre) and heralding a sequence of deep Atlantic depressions; importantly, however, most followed tracks relatively remote from southern England. A cold snap was associated with significant snowfall (as far south as Dorset) around Christmas. December rainfall totals reflected the dominant synoptic patterns - with rain-shadow effects particularly influential in the east. In parts of the Scottish Highlands, precipitation totals approached 200% of the monthly mean, some western catchments in Wales and Northern Ireland were also notably wet. By contrast, much of eastern Britain reported less than half the average rainfall with December totals of <30% in parts of the Midlands. More significantly, England and Wales registered its third lowest November-December rainfall since 1953 and regional rainfall deficiencies in this timeframe were very substantial across much of the UK. The dry end to 2004 was especially notable in a zone from Kent to Northumbria; in the south these deficiencies continued to build well into January 2005. January-December rainfall totals testified to a notably wet year for Scotland as a whole whilst rainfall totals for Northern Ireland and England and Wales were near average. Although most regions of England reported above average rainfall, its distribution through the year was unfavourable in relation to the water resources outlook.

Evaporation and Soil Moisture Deficits

Background

On average, evaporation losses account for over 40% of UK rainfall - but the proportion varies greatly from region to region, reaching around 80% in the driest parts of the English Lowlands. Evaporation may occur directly from open water surfaces, from the soil or as transpiration from plants. Potential evaporation (PE) is the maximum evaporation which would occur from a continuous vegetative cover amply supplied with moisture. PE losses exhibit a strong annual cycle, peaking normally in June or July; typically, only 10-20% of the annual PE loss occurs during the October-March period. Given normal rainfall, the increasing temperatures and accelerating evaporative demands through the spring lead to a progressive drying of the soil profile and the creation of what is termed a Soil Moisture Deficit (SMD). Eventually, the ability of transpiration to proceed at the potential rate is reduced as a result of the drying soil conditions, the associated reduced capability of plants to take up water, and the measures plants take to restrict transpiration under such conditions. Thus in the absence of favourable soil moisture conditions actual evaporation (AE) rates will fall below the corresponding PE rates, appreciably so during dry summers. When plant activity and evaporation rates slacken in the autumn, rainfall wets-up the soil profile once more - allowing runoff rates to increase and infiltration to groundwater to re-commence. Knowledge of the soil moisture status and evaporation rates are essential factors in understanding water resource variability. The following commentary on evaporation patterns and soil moisture deficits during 2004 relies, in large part, on monthly figures derived by the Met Office Rainfall and Evaporation Calculation System (MORECS)[4].

Potential and actual evaporation losses

2004 was another warm year; the average Central England Temperature (CET)[1] was close to 10.5°C, approximately one degree above the 1961-90 average. An average of 10.2°C has now been exceeded in 11 years over the post-1988 period, compared with only nine in the preceding 328 years of the CET series. In 2004 mean temperatures were above average in all months apart from July and, relative to the seasonal norm, the late winter (January and February) was notably mild. May and June were warm and the summer half-year (April-September) ranks 25th warmest in the CET series, albeit appreciably cooler than in recent notably warm summers (e.g. 2003 and 1995). Evaporation losses reflect other factors as well as temperatures (e.g. windspeed, humidity and land use) but the, generally, warm conditions through the late spring and early autumn of 2004 were associated with well above average evaporation demands. Figure 11 shows annual potential evaporation (MORECS) losses for 2004 in mm and as percentage of the preceding average. The annual total for England and Wales was around 6% above the 1961-90 average but unremarkable in the context of the preceding 15 years, around half of which had higher annual losses. Potential evaporation (PE) totals ranged from a little above 400mm in the Scottish Highlands to around 700mm in a few, mostly coastal, locations (where wind is particularly influential) in southern Britain. PE totals were 5-15% above average across much of Britain with below average evaporative demands mostly confined to Scotland and south-west Wales. Considering England and Wales as a whole, PE losses for 2004 were above average in the late winter (but still modest in absolute terms) and much more significantly during the summer half year.

Open water evaporation losses were high also in 2004 with daily totals exceeding 5mm during the early summer heat-waves. As notably in a water resources context, the damp summer resulted in transpiration rates being constrained for a much shorter period than normal and contributed to the highest annual Actual Evaporation total for England and Wales in the MORECS series (which begins in 1961). Annual AE totals exceeded the average by more than 20% in many eastern areas (see Figure 12) and the notable contrast with 2003 is evident in Figure 13 - the annual shortfall of AE relative to PE across much of the English Lowlands in 2004 was only 15-30% of that for the preceding year. For Scotland both PE and AE totals for 2004 were, as usual, considerably below the figures for England and Wales and the shortfall of AE relative to PE was narrow - only a couple of millimeters at the national scale. 2004 PE totals exceeded AE losses by a considerably wider (though still modest) margin in the drier eastern catchments.

Soil moisture deficits

The development and decay of soil moisture deficits (SMDs) over the 2000-2004 period is illustrated in Figure 13 for six representative MORECS squares; the SMD values relate to the end of each month and assume a grass cover. Monthly PE and AE totals are also shown together with the differences in the annual PE and AE totals. 2004 contrasted markedly with the exceptionally arid soil conditions experienced through the summer and early autumn of the preceding year. After a faltering beginning in the early spring, soil moisture deficit increase followed a relatively normal pattern through much of the summer but from late July soil moisture variations were atypical in most areas. A notable feature was the substantial decline in SMDs during August. Late August deficits were below average over wide areas with soils close to saturation throughout most of northern and western Britain (see Figure 14). However in September - when a seasonal increase in soil moisture is normally gathering momentum - deficits increased once more in much of southern and eastern Britain (Figure 15). The erratic pattern continued as the sustained October rainfall then caused a brisk increase in soil moisture. Generally, SMDs were very modest by late autumn but the dry end to the year allowed modest deficits to carry over into 2005 in a few, mostly coastal, areas of eastern England.

River Flows

The year in brief

Apart from a few catchments, drained mostly by spring-fed streams in southern England, mean river flows in 2004 were unexceptional but runoff patterns through the year showed wide departures from normal. River flows were seasonally very low in the late winter, early summer and during much of November and December. By contrast, flows were seasonally very high in many impermeable catchments during the late summer, helping to ensure that annual minima were relatively healthy. Widespread floodplain inundations were relatively uncommon in 2004, particularly by comparison with the preceding five years. However, the heavy August rainfall, much of it convective, produced many flash floods which were especially disruptive in urban areas; transport disruption was very substantial. Storm runoff and sewage overflows also depleted oxygen levels in many rivers; in London, a large fish kill occurred on the Thames Tideway on the 3/4th. Many new maximum August flows were registered and some new period-of-record maxima were established in northern England and eastern Scotland. The exceptional runoff rates achieved an extreme expression in mid-month. On the 16th in north Cornwall when a rainfall total of 200mm was recorded in just over four hours at Otterham - generating remarkable flow rates in a number of steep streams which drain to the coast. At Boscastle, below the confluence of the Jordan and Valency rivers the peak flow was estimated at around 180 m^3s^{-1}; a major rescue operation was needed to prevent fatalities. Two days later, a similar peak runoff rate was estimated for Glen Ogle in west Perthshire (120 m^3s^{-1} from a catchment of 11.4 km^2).

In water resources terms the most significant features of runoff patterns in 2004 were the unusually high runoff, and corresponding reservoir replenishment, over the August-October period, and the ensuing sustained river flow recessions. These resulted in substantial accumulated runoff deficiencies over the final two months of the year, heralding drought conditions in 2005. Annual catchment runoff totals for 2004 were mostly within the normal range (see Figure 16) but with a clear tendency for above average runoff across much of north-western Scotland - the Ewe and Carron both registered their third highest annual runoff on record - and below average runoff in southern England, where many rivers registered less than 75% of the annual average. Runoff was particularly meagre in parts of Sussex, Kent and Devon.

Figure 17 shows 1999-2004 hydrographs representing the total outflows from Great Britain, England and Wales, Scotland, and Northern Ireland - the hydrographs are based on flows for a network of large rivers which, taken together, provide a convincing guide to runoff patterns at the national scale. The hydrograph for

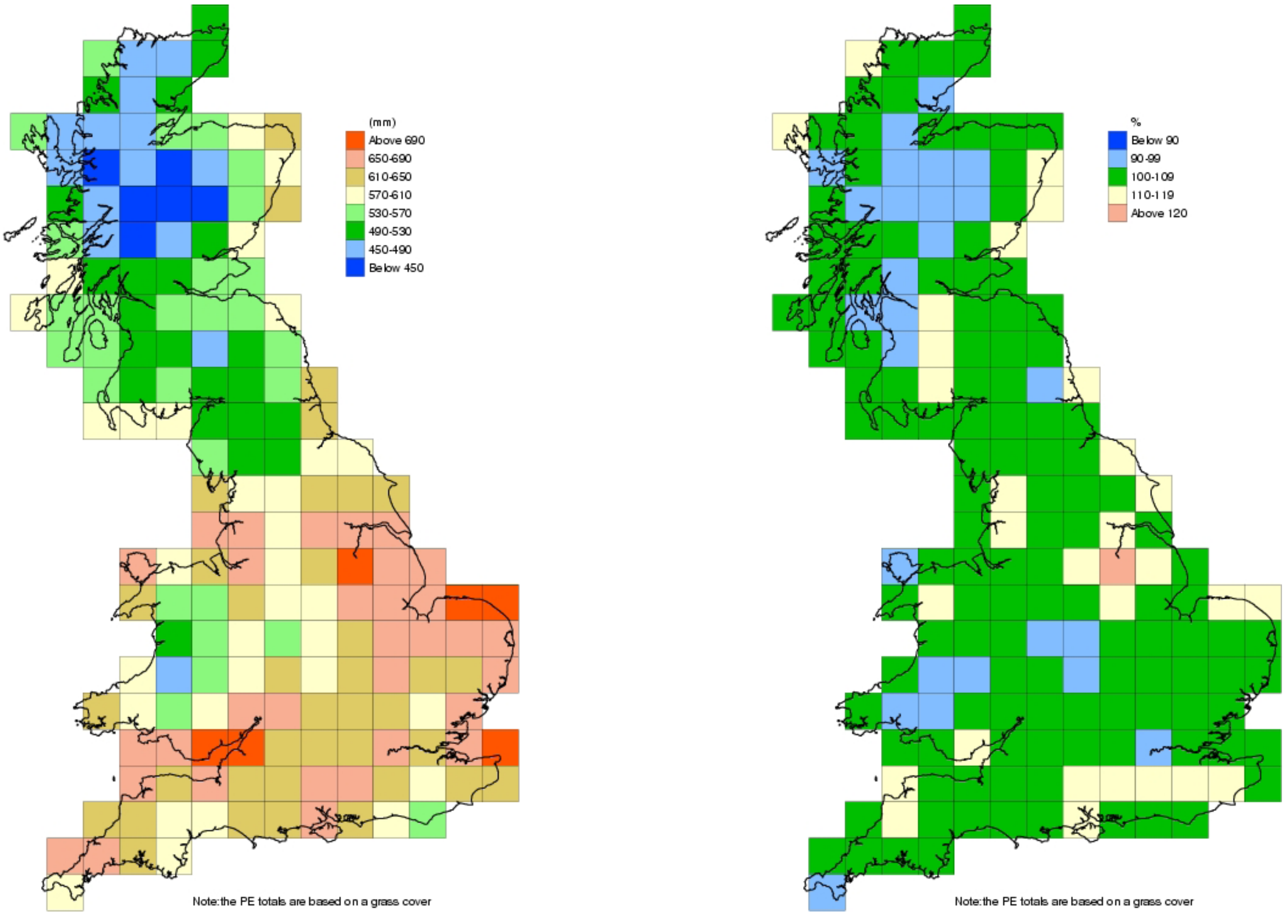


Figure 11 *Potential evaporation totals for 2004 in mm and as a percentage of the 1961-90 average.*

Data source: MORECS.

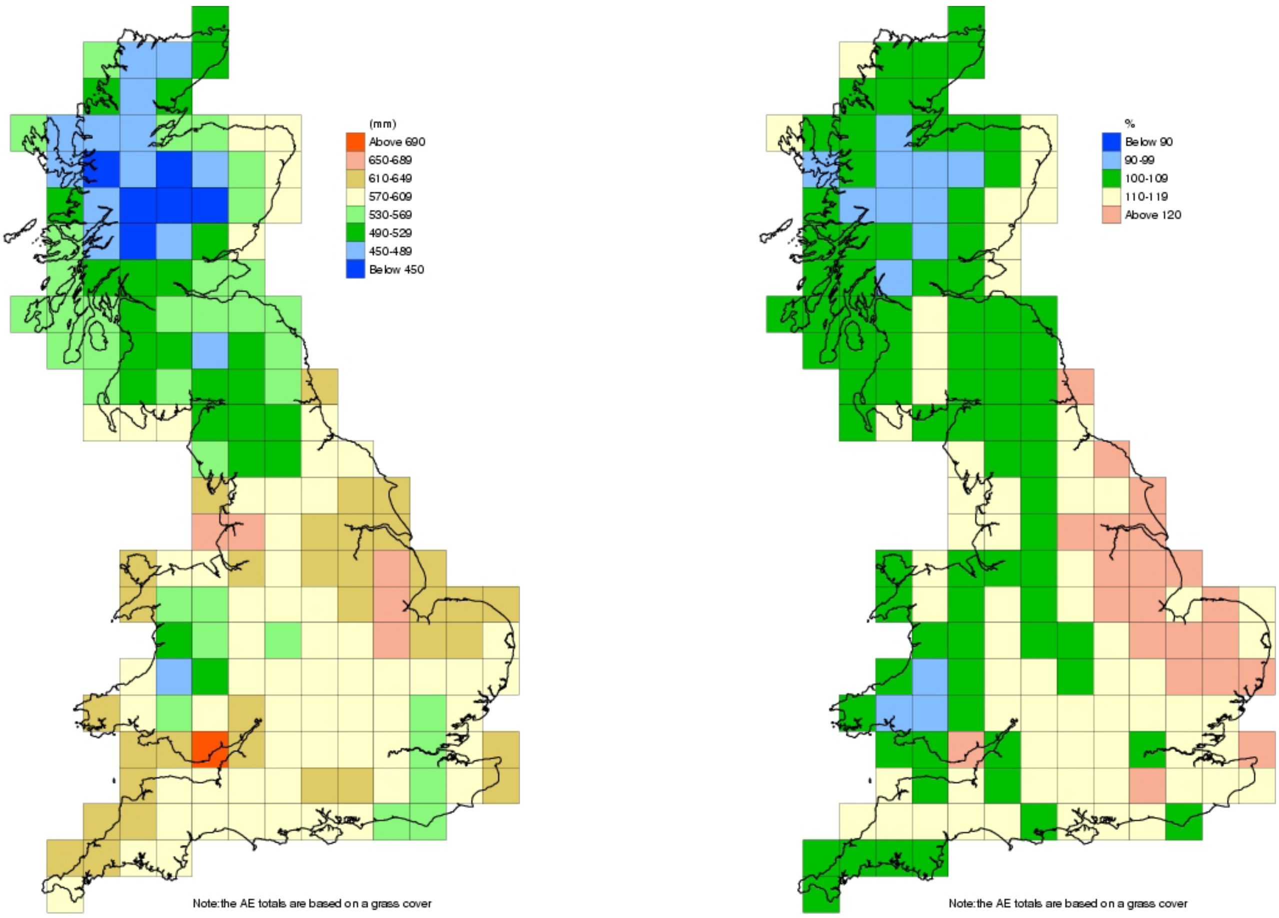


Figure 12 *Actual evaporation totals for 2004 in mm and as a percentage of the 1961-90 average.*

Data source: MORECS.

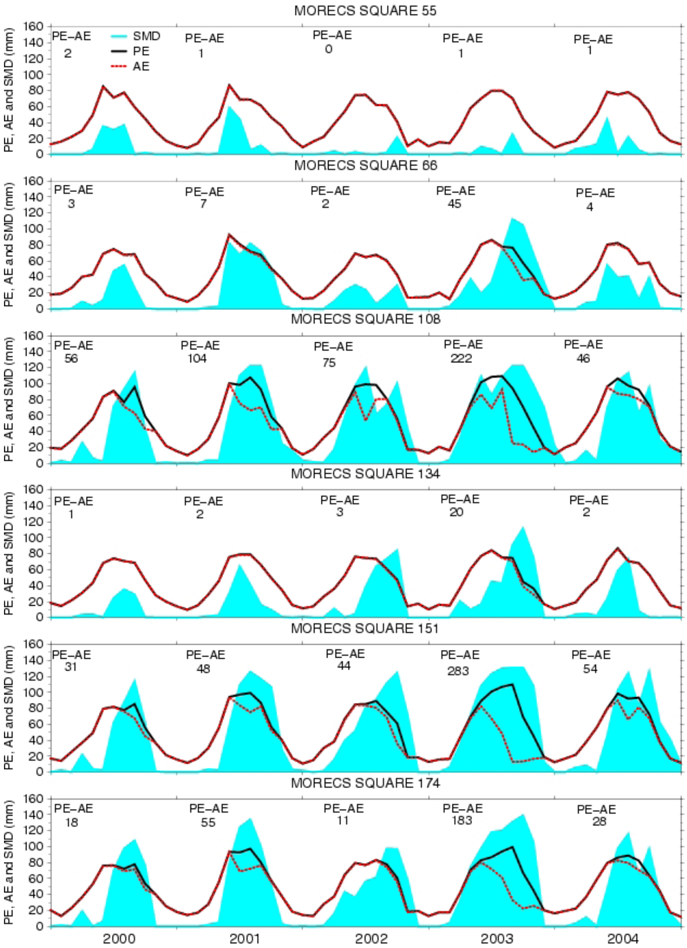


Figure 13a *Monthly variation in potential evaporation, actual evaporation and soil moisture deficits for six MORECS squares 2001-2004.*

Data source: MORECS.

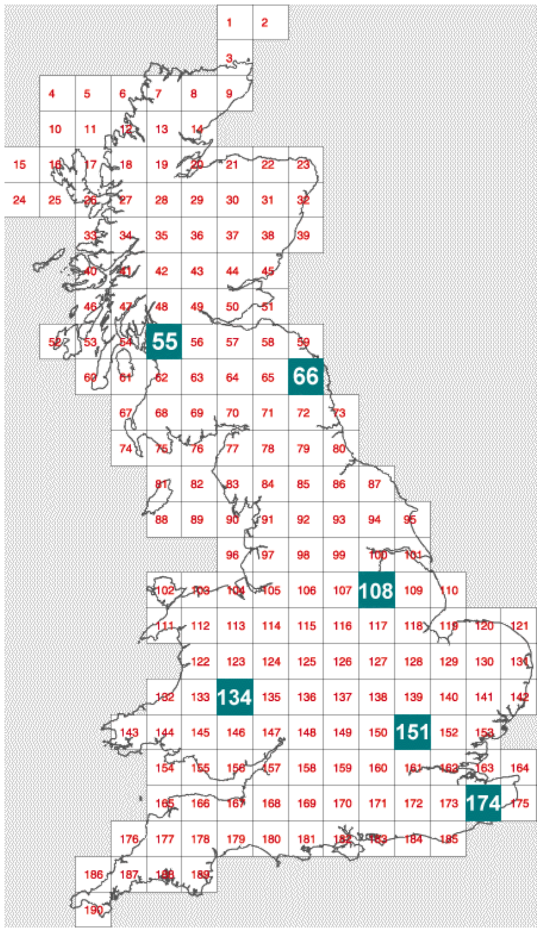


Figure 13b *MORECS Location Map: the location of the 40km squares and their associated reference numbers.*

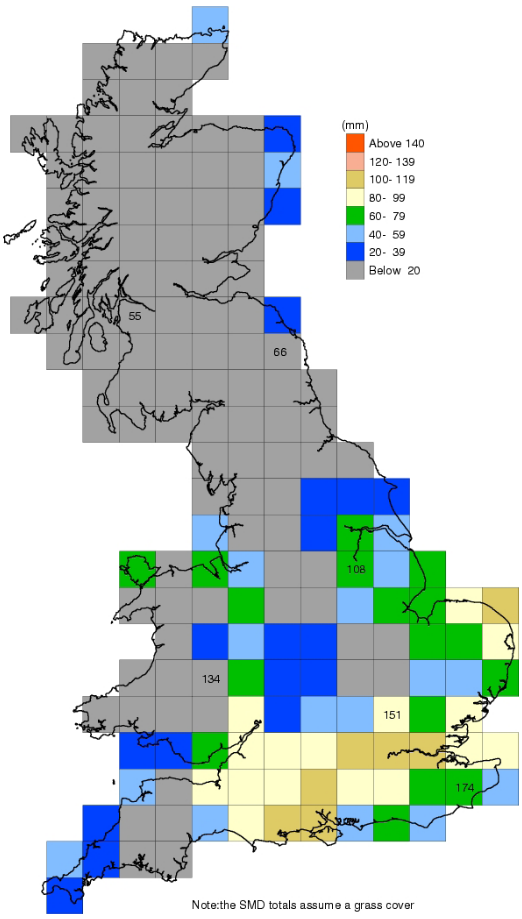


Figure 14 *Soil Moisture Deficits at the end of August 2004.*

Data source: MORECS.

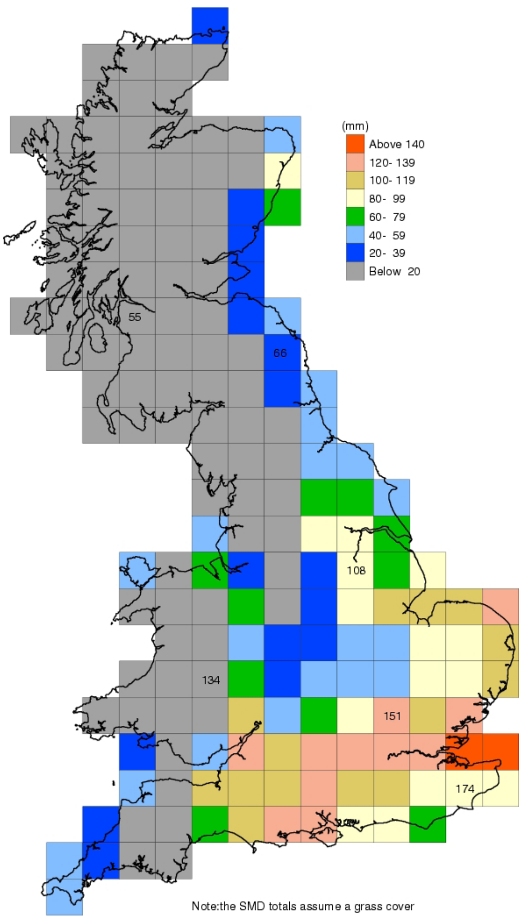
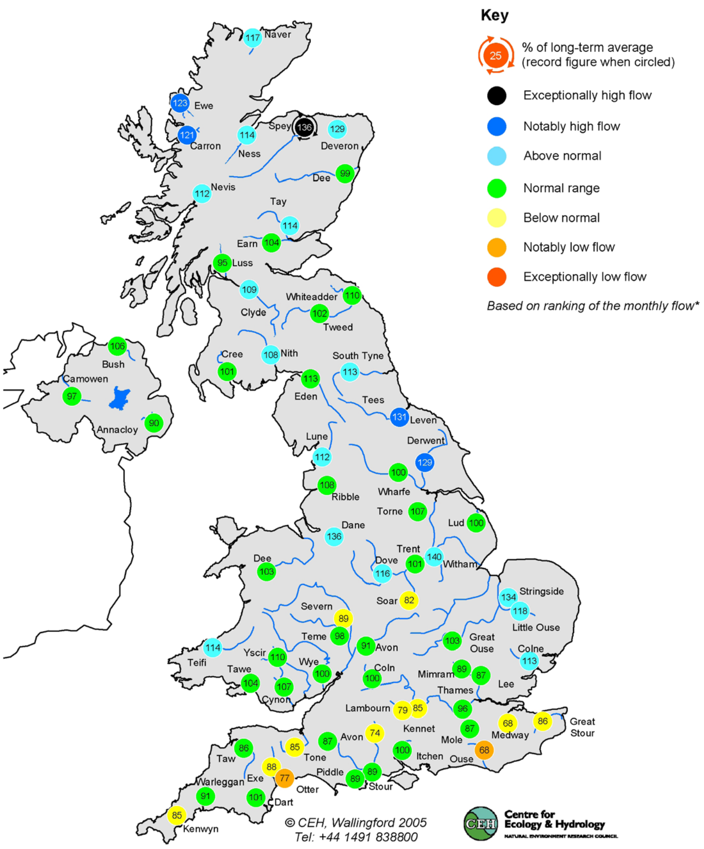


Figure 15 *Soil Moisture Deficits at the end of September 2004.*

Data source: MORECS.



*Comparisons based on percentage flows alone can be misleading. A given percentage flow can represent extreme drought conditions in permeable catchments where flows patterns are relatively stable but well within the normal range in impermeable catchments where the natural variation in flows is much greater. Note: the period of record on which these percentages are based varies from station to station.

Figure 16 *2004 runoff totals as a percentage of the previous average.*

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

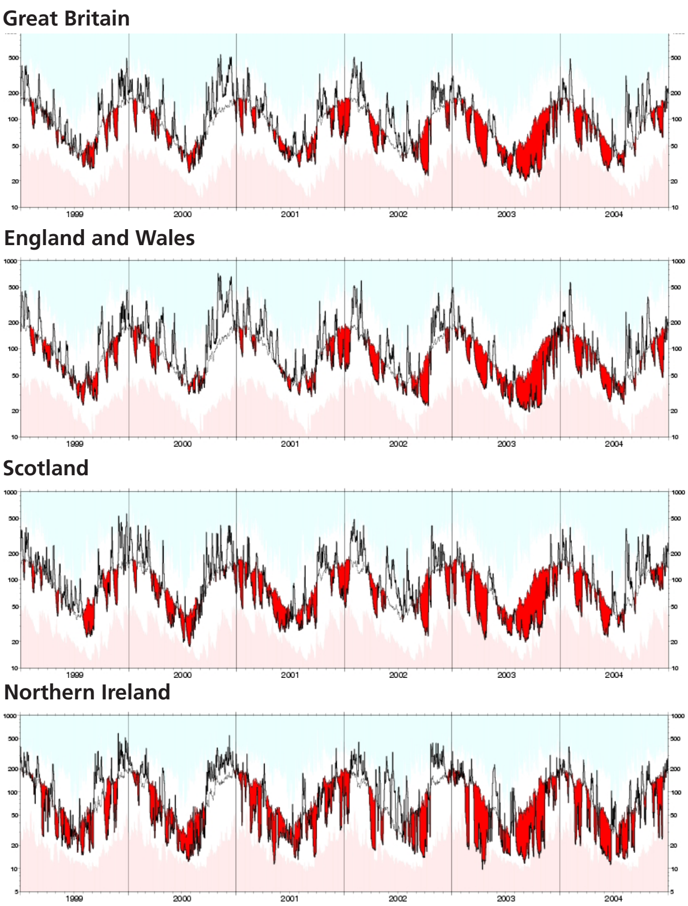


Figure 17 *A guide to total daily outflows (in cumecs) 1999-2004.*

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

Northern Ireland reflects, in part, the controlled flow releases from Lough Neagh into the Lower Bann - these constitute more than a third of the total outflows from Northern Ireland. The daily outflows are shown as a bold trace and a red infill is used to emphasise periods of below average flow; the use of a logarithmic scale also gives greater prominence to low flow episodes. The long term daily maximum and minimum flows are also shown - represented by the pink and blue envelopes. Generally outflows were abundant in January, with significant flooding around the turn of the month. Outflows then declined steeply and were notably low across much of the UK in the early spring, and again in the early summer but recovered dramatically in August when many rivers draining impermeable catchments registered new maximum monthly runoff totals (see Figure 18). Outflows were again exceptionally high in October when, with most catchments saturated by the third week, the risk of flooding was high. In the event, a dramatic decline in the frequency of Atlantic frontal systems contributed to November and December runoff totals which were substantially below average across most of the country. Figure 19 confirms that the December runoff totals were substantially below average across large parts of eastern and southern Britain; the Kenwyn (Cornwall) recorded its second lowest December runoff in a 38-yr series.

A spatially more detailed breakdown of flow patterns in 2004 is provided by Figure 20 which shows 2004 hydrographs for 20 index rivers across the UK. Whilst flow variability was considerable, significant extensions to the low and high flow envelopes were relatively rare. The Ness and Tay (in Scotland), Annacloy (Northern Ireland) and Lune (England) are among a number of rivers where monthly minima were approached or eclipsed in June. In relation to the typical seasonal pattern, flows in August were the most exceptional. The Tay and Tweed (not featured) were among a number of Scottish rivers reporting their highest August daily flow on record; as notably, the August daily maxima were the highest flows in the year on these rivers - an unprecedented circumstance in records of around 50 years.

The seasonally high late summer runoff was a primary factor in ensuring that, in most areas, annual minima flows for 2004 were relatively healthy and well above drought minima. Pre-2004 daily minimum flows were eclipsed only in a few isolated cases, mostly urban rivers in the early autumn (e.g. in south London). However, in southern England especially, the August spates failed to herald any sustained recovery of runoff rates through the autumn. This was especially evident in spring-fed streams and rivers (e.g. the Lambourn and Itchen) where flows remained remarkably stable over the latter half of the year. This stability represents a transformation from very healthy late summer flows to well below average flows approaching year-end.

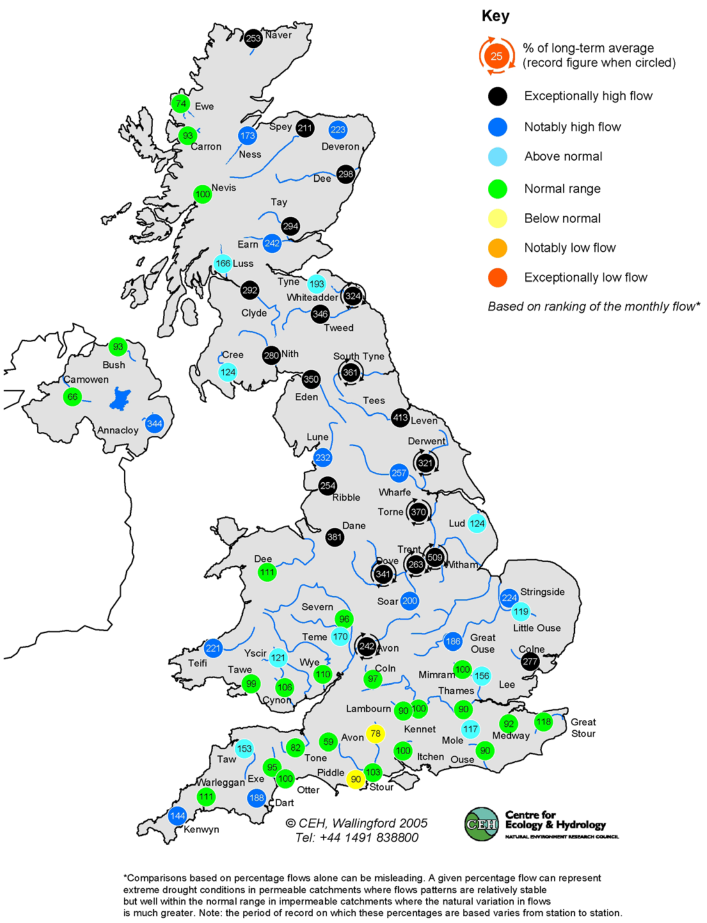


Figure 18 *August 2004 runoff totals as a percentage of the preceding average.*

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

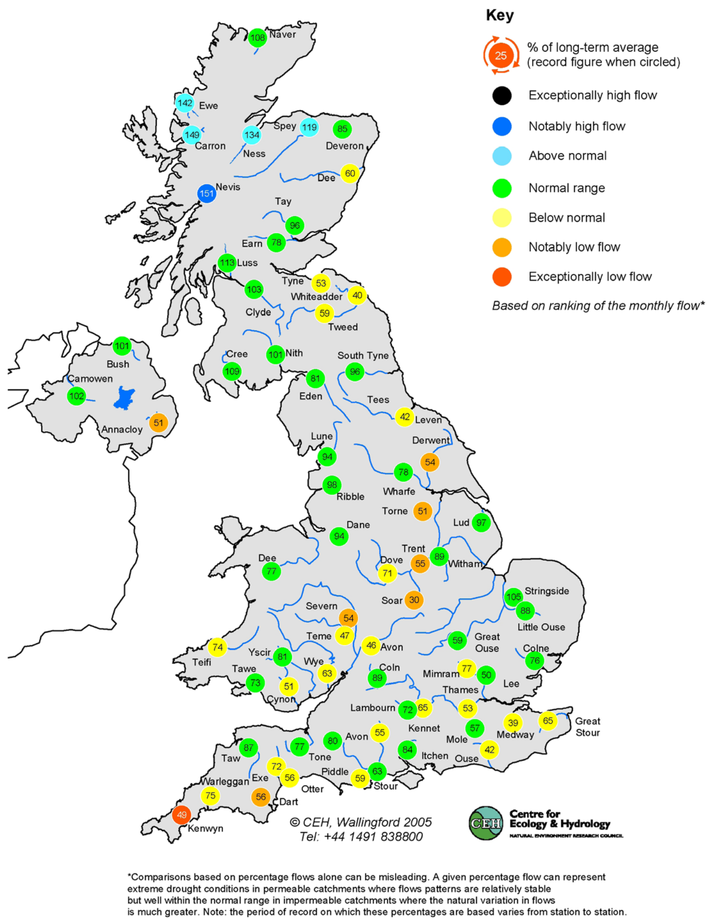


Figure 19 *December 2004 runoff totals as a percentage of the preceding average.*

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

Flow duration curves provide a means of comparing the regime for a particular year with that for the previous record. They allow the proportion of time that river flows are above, or below, any given threshold to be identified. The 2004 duration curves for Britain, England and Wales, Scotland and Northern Ireland are similar to those for the preceding record (Figure 21). A greater measure of disparity is evident for a number of individual rivers (see Figure 22). In northern Scotland, the 2004 duration curves for the Ewe and Ness both plot above that for the preceding record throughout the full flow range. The most revealing departures are found in spring-fed rivers in the English Lowlands where the relatively high late summer flows, and the failure of the seasonal recovery late in year, made for a narrow flow range throughout 2004. As a consequence, the flow duration curves for some rivers draining permeable catchments were remarkably flat (see, for example, the Mimram). For many more in southern Britain the absence of sustained high flows during 2004 is confirmed by the degree to which the 5%ile flow fell below the corresponding long term average - see the Thames, for example.

River flows - through the year

January

Most rivers experienced a wide range of flows in January but the overall runoff pattern was in marked contrast to the depressed flows which characterised most catchments through the autumn of 2003. By the second week of January, the focus of hydrological concern had switched decisively to the risk of flooding. Flood Alerts and Warnings were common in January and snowmelt at month end, together with heavy rainfall, triggered notable spates in many catchments. The peak flow on the Alconbury Brook in East Anglia was the highest in a 42-year record and the Dee (North Wales) closely approached its highest January flow on record - heralding severe flooding in early February. In north west Scotland, the River Ewe registered its second highest flow in the last 10 years and, generally, the late-January spates boosted runoff totals to well above average in the great majority of index catchments. Flows in some, mostly eastern, spring-fed rivers remained below average but a belated seasonal recovery gathered momentum over the latter half of the month. In many areas the January runoff terminated lengthy sequences of below average monthly flows - extending back to February 2003 on the Thames, and

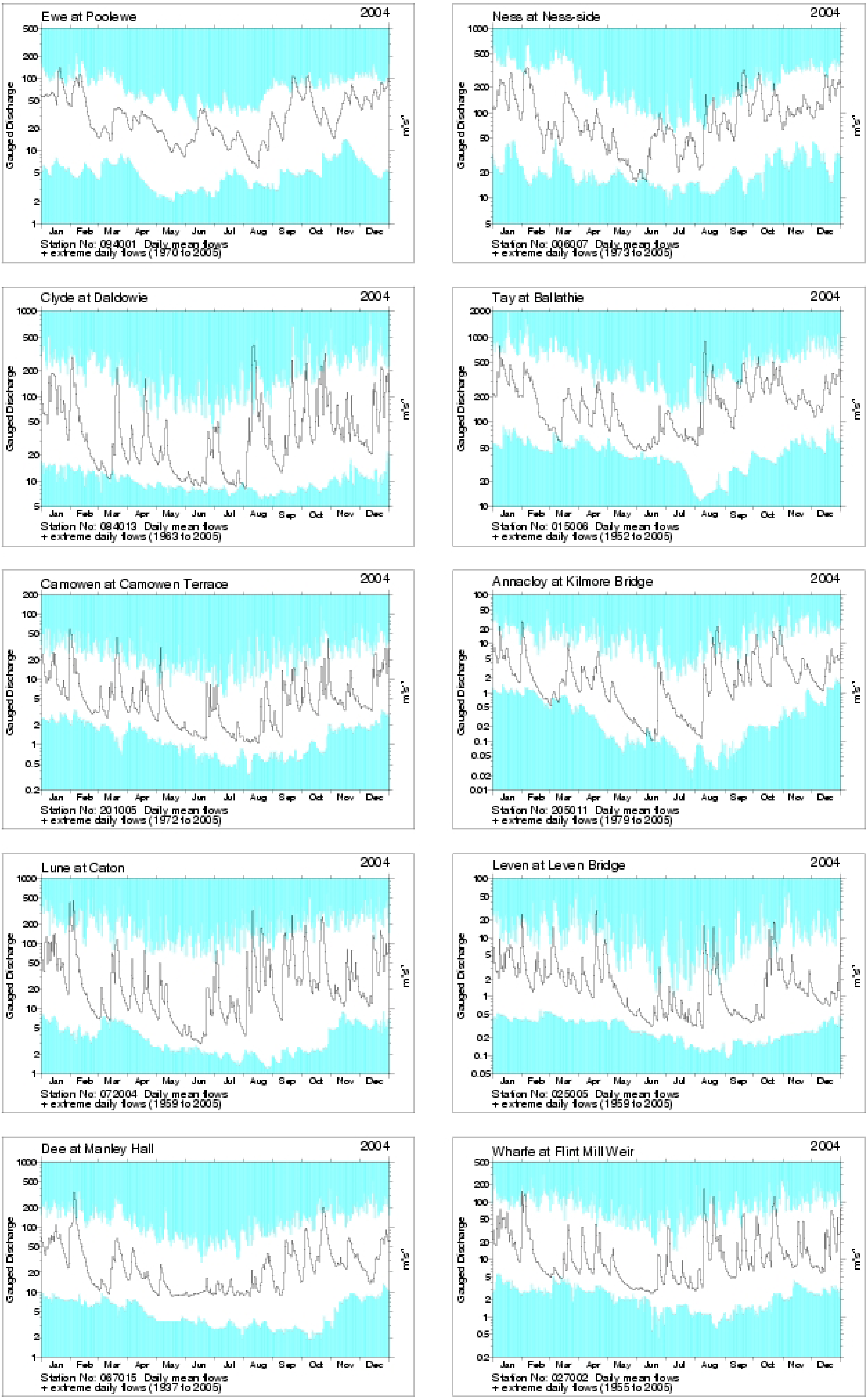


Figure 20 *Daily flow hydrographs for 2004 for a selection of index stations.*

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

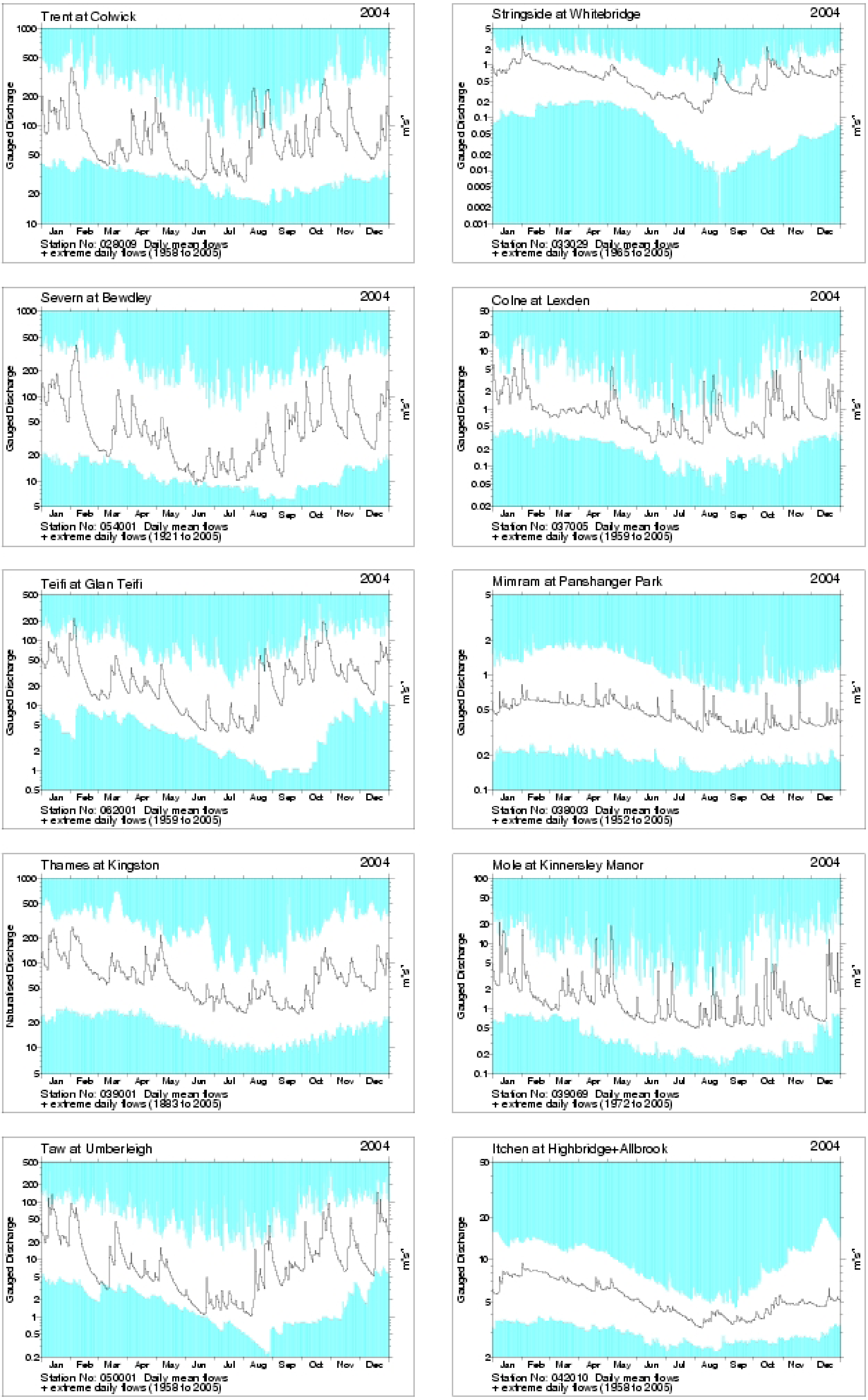


Figure 20 *(Contd.)*

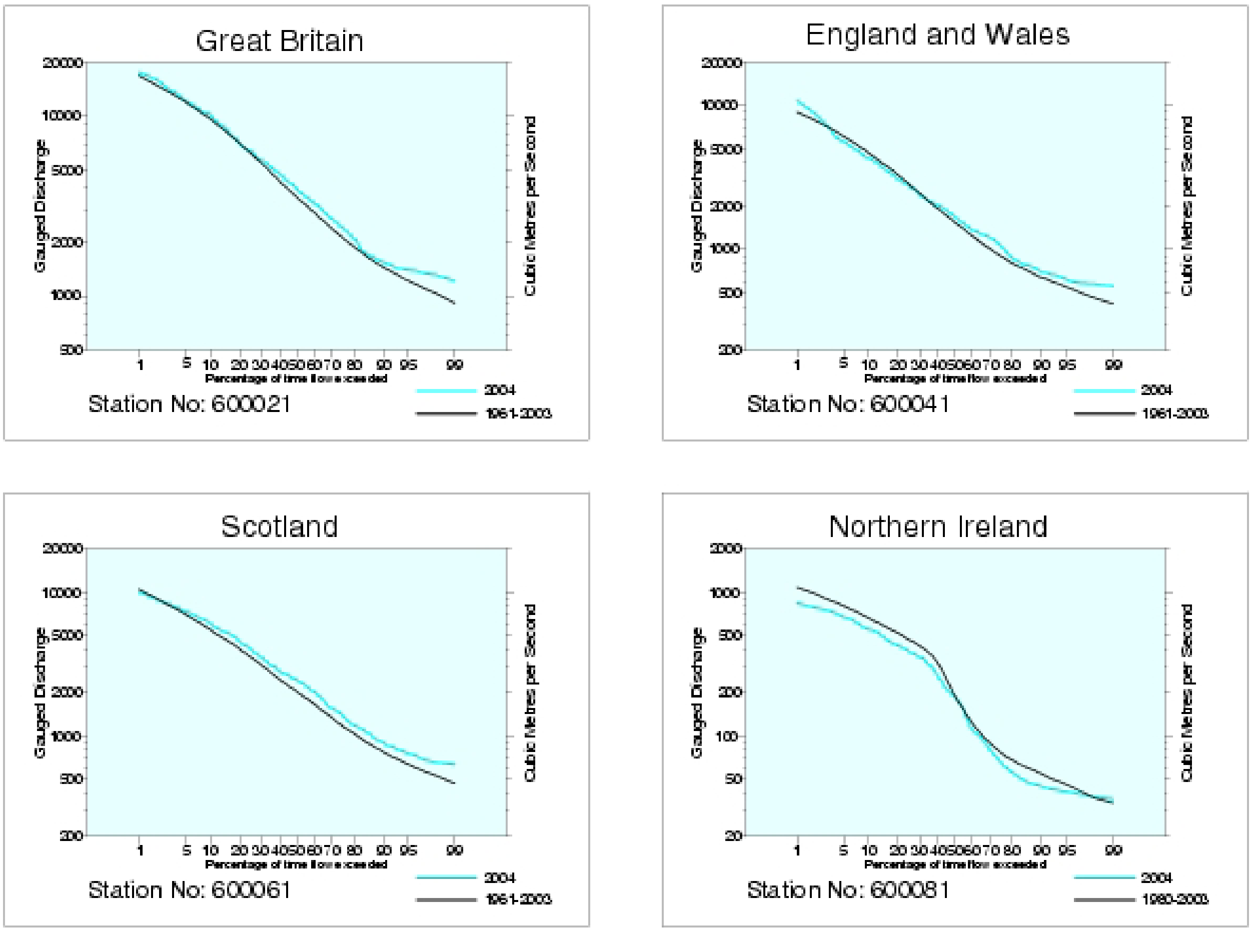


Figure 21 *Indicative flow duration curves for 2004 national outflows (blue trace) and the preceding record.*

longer in many Scottish catchments. A measure of the contrast with antecedent flow patterns is provided by the Aberdeenshire Dee where above average January flows followed its lowest annual runoff total in a series from 1929.

February

With catchments saturated and snowmelt an exacerbating factor in northern Britain, February began with a high flood risk over wide areas. Flood Warnings were very common during the first week when extreme runoff rates characterised a number of western rivers. In North Wales, new maximum daily flow were established on the Dee (at New Inn) on the 3rd and on the Alwen (4th); the associated flooding was particularly severe in the Conwy Valley (e.g. at Llanwrst and Trefriw). The Kent (Lake District) was among several rivers in north-west England which exceeded previous maximum recorded flows; a larger number of western rivers (including the Wye and Severn) eclipsed previous February peaks. Thereafter, river flow recessions were exceptionally steep in many impermeable catchments. In some, mostly Scottish, catchments (including the Nith and Forth), period-of-record February minima were approached around month-end. The counterbalancing effect of these contrasting flow episodes resulted in monthly runoff totals that were well within the normal range throughout most of the UK. This was true of most winter (December-February) runoff totals also, but longer term runoff deficiencies remained large in many areas - in eastern Scotland especially. The belated seasonal recovery of flows in groundwater-fed streams in the English Lowlands continued in February, but flows remained well below average across most of southern England.

March

During the first week of March the continuation of the steep February recessions produced depressed flows in impermeable catchments across northern Britain; the Forth, Tweed, Ribble and Nith were amongst many index rivers eclipsing previous daily minimum flows for mid-March. A sharp recovery in runoff rates then produced significant spates around the 19th when localised flooding was reported in the Scottish Highlands. Steep recessions resumed thereafter and many rivers were again approaching seasonal minima by early April. March runoff totals were well below average (typically, < 70%) at almost all index gauging stations. The Tay reported its second lowest March flow in the last 20 years and, in England, the Trent registered its 3rd lowest March flow in a 47-year record. Many rivers (including the Sussex Ouse) reported their lowest March runoff since 1993. Flows in rivers draining permeable catchments are less responsive to a paucity of early spring rainfall, but seasonal recessions had

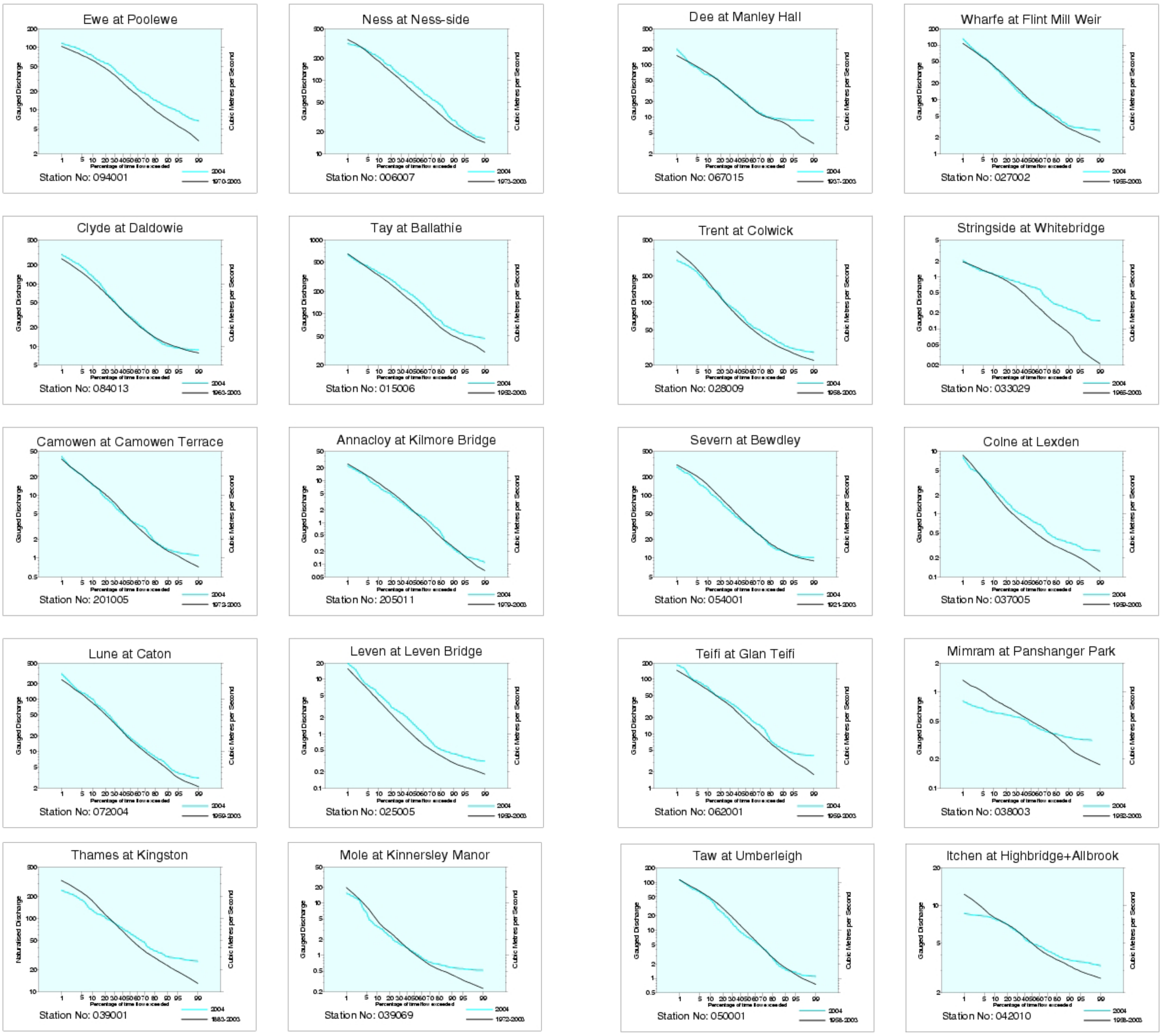


Figure 22 *Flow duration curves for 2004 (blue trace) and the preceding record.*

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

begun in many Chalk streams by late March, typically from well below average spring peaks. This increased the expectation of low flows by the late summer. Importantly however, for most spring-fed rivers, the March flows were substantially above corresponding values in recent drought years (e.g. 1997, 1992, 1991 and 1976).

April

River flows in most catchments were seasonally depressed and in brisk recession entering April, but - contrary to the normal seasonal trend - they increased over the month. In a few areas modest floodplain inundations occurred during the latter half of April. Heavy runoff from the North York Moors on the 18/19th triggered Flood Warnings on the Derwent and contributed to notably high runoff in north-east England. Localized, mostly urban, flooding was common on the 26/27th (e.g. in Worcester, Sheffield and London) as convective storms overwhelmed local drainage systems. Flow patterns in the Thames typified many rivers with runoff rates increasing from considerably below to appreciably above average through April. Correspondingly, April runoff totals were mostly well within the normal range but with significant variations reflecting both regional rainfall patterns and catchment geology. Local contrasts where particularly evident in the English Lowlands where rivers draining impermeable catchments responded much more quickly to the April rainfall than spring-fed rivers and streams. Runoff over the Nov-April period was appreciably below average across almost all of the UK and longer term accumulations - reflecting the impact of the 2003 drought - remained depressed over wide areas. In the period from February 2003, many rivers (including the Trent, Exe and Medway) registered only a single month with above average flows; in this timeframe, the 15-month accumulations for the Exe and Medway rank as the 2nd and 3rd lowest, respectively, in records of almost 50 years. The late-spring return to more typical flow rates was therefore particularly welcome.

May

In many regions, the recovery of runoff rates during April continued into May. After the first week however steep recessions became established in most index rivers draining impermeable catchments. By month-end, long term daily minima (for May) were being closely approached in many western and northern rivers, including the Ness, Nith and, in Northern Ireland, the Mourne. In parts of the English Lowlands, localised flooding was reported in response to thunderstorms (e.g. at Haywards Heath on the 19th) but the general pattern was epitomised more effectively by the Thames which mirrored the April flow pattern; flows were appreciably below the long term daily average by late May. Runoff totals for the month were above average in a few responsive eastern catchments and a larger proportion of spring-fed rivers in the English Lowlands. Elsewhere, runoff totals were mostly well below average - typically in the 50-90% range - and the Lower Bann (which flows from Lough Neagh) registered its second lowest May runoff since 1984. The modest May runoff served to increase long term runoff deficiencies over wide areas. Amongst the rivers which established new 16-month minimum runoff totals (for sequences ending in May) were the Aberdeenshire Dee, Luss Water, Naver, Faughan and Annacloy.

June

Exceptionally dry soil conditions greatly limited the effectiveness of the early June rainfall and flows in most rivers exhibited steep recessions - a new minimum June flow was recorded for the Ribble (on the 15th) contributed to outflows from Great Britain as a whole falling marginally below previous minima (in a series from 1961) during the second week of June. The depressed runoff resulted in a number of flow augmentation schemes being activated (e.g. in south Wessex). By contrast, some localised - mostly urban - flooding was reported and more notable flow recoveries characterised the final week of the month. The River Whiteadder eclipsed its previous maximum June flow on the 24th having closely approached its minimum in the second week. South of the Moray Firth, a 48-hr rainfall total of 80.4mm (at Torwinny) triggered severe flooding in Elgin and Rothes on the 23/24th - precautionary evacuations were organized. The Isla at Grange reported its 3rd highest level in a 44-year record and the main Inverness-Aberdeen railway was closed. June runoff totals showed very wide regional and more local variations. In northern Scotland, the River Naver registered its highest June runoff in a 27-yr record whilst notably low runoff characterised much of south-western Britain; in South Wales, the River Tawe reported its lowest June runoff since 1975. In the English Lowlands the generality of runoff totals were in the 50-85% range but mostly well above drought minima. Geological control on flows rates were very evident; flows in many Chalk catchments were near-average whilst neighbouring streams draining impermeable catchments reported <35% of the June average.

July

Significant late-June and early-July flow recoveries in rivers draining impermeable catchments were soon reversed as brisk recessions again became established - by month-end these had produced very depressed runoff rates in a few western rivers, including the Clyde, Eden, Ribble and Yscir, the latter registered its lowest July daily flow since the 1984 drought. Most rivers, however, followed a normal summer recession punctuated locally by short-lived spates (often thunderstorm generated) - a few were notable; the Soar reported its highest recorded July peak on the 24th. Natural groundwater support through springs and seepages, though declining, helped ensure that flows in rivers draining permeable catchments in the English Lowlands remained well within the normal range. Monthly runoff totals for a few index gauging stations were notable - the lowest July runoff for 20 years on the Yscir - but the generality of index stations reported typical July runoff totals, albeit mostly below average. Longer term accumulations testified to notable deficiencies, in the West and North especially. The August-July runoff for the Annacloy was the lowest for any 12-month sequence in a series from 1979 and a significant minority of other rivers in Northern Ireland - northern and eastern Scotland also - closely approached previous August-July minima.

August

August was an exceptional month in runoff terms - the second highest (after 1985) in the 45 year series of Great Britain outflows. Following sustained July recessions, flows in most rivers were considerably below the monthly average at the beginning of August. Widespread thundery activity produced many locally intense runoff events on the 2-4th - triggering severe urban flooding and generating massive transport disruption (e.g. in north-west London on the 3rd). Storm runoff and sewage overflows also depleted river oxygen levels; a large fish kill occurred on the Thames Tideway on the 3/4th. Notable urban flooding continued throughout the month (e.g. in Londonderry, Wycombe, Redruth, Sheffield and London, where the peak on the Wandle on the 18th was close to the period-of-record maxima). Widespread fluvial flooding is rare in August (some parallels can be drawn with 1961 and 1931) but, with rainfall intensities exceeding infiltration capacities and catchment headwaters becoming saturated, flood risk increased rapidly. Bankfull flows were exceeded in many rivers in eastern Scotland and northern England during the second week. The Braan was among a number of rivers in the lower Tay basin recording new maximum flows and, on the 11th, the Tay itself reported its highest August flow (>1000 m^3s^{-1}) in a 52-year record; other rivers establishing new August maxima included the Earn, Trent and Ribble. On the 16th, extreme runoff in the Valency and Jordan - estimated at around 180 m^3s^{-1} below the confluence - resulted in severe structural damage at Boscastle on the north Cornwall coast (where there is a history of significant flooding - its location and topography make it particularly vulnerable to high-intensity storms). Many flood warnings (and Flood Watches) were in operation in mid-month; on the 18th the Bedburn Beck (Durham) exceeded its previous maximum flow, in a 45-year record, by a substantial margin. Surface runoff and mudslides were widely reported. Many vehicles were trapped on the A85 near Lochearnhead when a combination of intense rainfall, saturated ground and steep slopes generated several damaging landslides; peak flows in Glen Ogle and Glen Ample were extreme - and had substantial geomorphological impacts. Despite the very modest flows at the beginning of the month, gauging stations which closely approaching, or exceeded, their August runoff maxima showed a wide distribution - from the Midlands to northern Scotland. Runoff totals for the Summer (June-August) were mostly in the normal range but 12-month accumulations remained well below average for many rivers across the UK.

September

The normal north-west/south-east contrast in runoff rates across the UK was strongly accentuated in September. Heavy rainfall and near-saturated catchments promoted spate conditions in western Scotland whilst limited rainfall, mostly dry catchments and (in most areas) declining baseflow contributions resulted in modest flows in much of eastern and southern England especially in southern catchments. Notable high flows were common in rivers draining the hills of northern Britain on the 19-21st; the Strae eclipsed its previous maximum flow in a 26-year record and the Ness reported its highest September flow in a series from 1973. September runoff totals exceeded the average in most catchments from Wales to northern Scotland where both the Ness and Nevis eclipsed previous September maxima. In the English Lowlands September runoff totals reflected the balance between flows which were initially appreciably above average but ended the month appreciably below, albeit well within the normal range. Recessions were most persistent in the more southerly catchments where runoff totals were commonly less than 70% of the September average. The Otter registered its 2nd lowest September runoff in a series from 1962 whilst, more notably, the Medway (at Chafford) and the Ravensbourne (south London) both established new minima for any month. Accumulated runoff totals in the six-month timeframe broadly reflected the September pattern with April-September totals falling in the lower quartile for a few catchments in central, southern and south-west England (the Lower Bann in Northern Ireland also).

October

The brisk elimination of soil moisture deficits allowed flow recoveries to gain momentum in most catchments during October. As catchments approached saturation, the threat of flooding increased - this was mitigated somewhat by high windspeeds which ensured a relatively rapid passage of most frontal systems (moderating storm rainfall totals and the magnitude of the resulting spates). Nonetheless, moderate floodplain inundations were common (e.g. on the 4/5th in the west). In the Lake District, the River Ellen reported a new maximum flow (in a series from 1976) on the 4th and the flood threat culminated around the 23rd when more than 50 Flood Warnings were in operation across England and Wales. Around half related to Wales where severe flooding was experienced in the North (e.g. at Beaumaris, Carnarvon and on Anglesey). To the South, the estimated peak on the Tawe ranks 5th highest in a 47-year record and. In coastal areas of southern England the flood risk was exacerbated by a combination of high tides and strong south-westerly winds - a number of tidal defences were overtopped (e.g. at Bournemouth). Away from the English Lowlands, October runoff totals were mostly well above average; a number of index rivers (including the Tweed, Witham, Tawe and Clyde - each with records >45 years) registered their 2nd highest October runoff. By contrast, runoff was appreciably below average in a few southern catchments and seasonal recoveries had yet to begin in some spring-fed rivers in the South East. The Lambourn reported its 18th successive month with below average flow but, more typically, runoff accumulations over periods of 3-9 months were generally above average.

November

Contrary to the normal seasonal pattern, flows in most rivers declined substantially through November. Most recessions were interrupted in mid month as spates triggered a few Flood Warnings (e.g. on the Great Ouse) but, thereafter, they continued well into December. Index gauging stations reporting above average monthly runoff totals were mainly confined to the East Midlands and East Anglia. Elsewhere, runoff was below normal, notably so in a number of impermeable catchments - mostly in the West. In Wales, a very steep recession on the Tawe produced its lowest November flow since 1970 and, in Northern Ireland, the Faughan registered its second lowest in the last 22 years. In many spring-fed rivers and streams, November flows were similar to those in late August and a sustained seasonal recovery was still awaited. Autumn (September-November) runoff totals - boosted by the very healthy October flows - were well above average in most western and northern catchments, the Ness reported its second highest on record, but moderately depressed in parts of southern England (e.g. the Mole). For the year to November, runoff totals showed wide spatial variability - mostly above average but runoff deficiencies exceeded 20% for a number of, mostly southern, catchments including the Otter and Wallington.

December

Unusually steep recessions characterised the first half of December, resulting in flows in a number of index rivers (including the Taw, Great Stour and Faughan) approaching their mid-December minima. Thereafter, a spatially uneven recovery gained momentum. By year-end, flows were generally within the normal range (in much of northern Britain this recovery heralded exceptionally high flows in early January 2005). The recoveries were sufficient to produce above average December flows in a few, mostly north-western, catchments but, generally, runoff totals were appreciably below average - typically in the 40-80% range across England. Flows were particularly depressed in some sheltered eastern catchments - the Whiteadder and Soar reported their second lowest December runoff in the last 30 years. Runoff deficiencies for the November-December period were also substantial in many responsive catchments across southern England; the healthy autumn runoff being succeeded by sustained below average flows - raising concern regarding the resources outlook for 2005. Flows in many rivers draining permeable catchments remained more than usually stable over the latter half of 2004, confirming the limited groundwater recharge. In contrast to the regional rainfall figures, catchment runoff totals for 2004 as a whole were - northern Scotland apart - mostly below average (notably so for the Medway) reflecting, in large part, the notably high actual evaporation losses - across the English Lowlands especially.

Groundwater

Background

Most major aquifer outcrop areas are in the driest parts of the country - predominately the English Lowlands where groundwater is the principal source of public water supply. In water supply terms the Chalk, which outcrops in eastern and southern England, is the major aquifer; the Permo-Triassic sandstones are regionally important - in the Midlands and North-West especially. Limestone aquifers are also regionally significant and a number of minor aquifers (e.g. the Norfolk Crag) are of local water supply importance.

Away from the more westerly aquifer outcrop areas groundwater replenishment (or recharge) in a typical year ranges from 500mm to less than 100mm in the most easterly outcrops. Evaporation losses result in a non-linear relationship between rainfall and aquifer recharge; a 20% reduction in annual rainfall can result in a reduction of 50% or more in groundwater replenishment. Consequently year-on-year variations in recharge tend to be much greater than for rainfall. This volatility has been well illustrated over the last decade. Depressed groundwater levels in the 1995-97 period contrasted with remarkably healthy groundwater resources (and sustained groundwater flooding) during the winter and spring of 2000/01. The generally high groundwater levels over the first three years of the 21st century and, particularly, the abundant resources in January of 2003 helped limit the impact of the drought conditions in the ensuing summer but except in the slowest responding aquifers, groundwater levels had returned to the normal range by early 2004.

The year in brief

Rainfall over the outcrop areas of most major aquifers during 2004 was within 10% of the 1961-90 average with significant positive anomalies over much of the eastern Chalk. However, the distribution of rainfall throughout the year was generally unhelpful for groundwater resources. The very limited rainfall in February and March, and then more notably in November and December, restricted recharge during what are normally four of the most productive months for infiltration. Recharge during 2004 was more than usually episodic with good replenishment in January and (in most areas) October. In addition, the appreciable April/early May infiltration was particularly beneficial in many areas, providing a late pulse of recharge at a time when the seasonal decline in groundwater levels is normally well established, at least in most eastern and southern outcrop areas. Despite this, total infiltration in 2004 was appreciably below average across most major aquifers. By year-end, groundwater levels had generally declined to well below average over wide areas, albeit substantially above drought minima.

The behaviour of groundwater levels throughout the year is shown in Figure 23 which features 2000-2004 hydrographs for a selection of index wells and boreholes throughout the UK. Five-year plots have been used because groundwater levels in many areas show considerable persistence - reflecting groundwater replenishment over a number of recharge seasons. The groundwater level trace is shown together with the

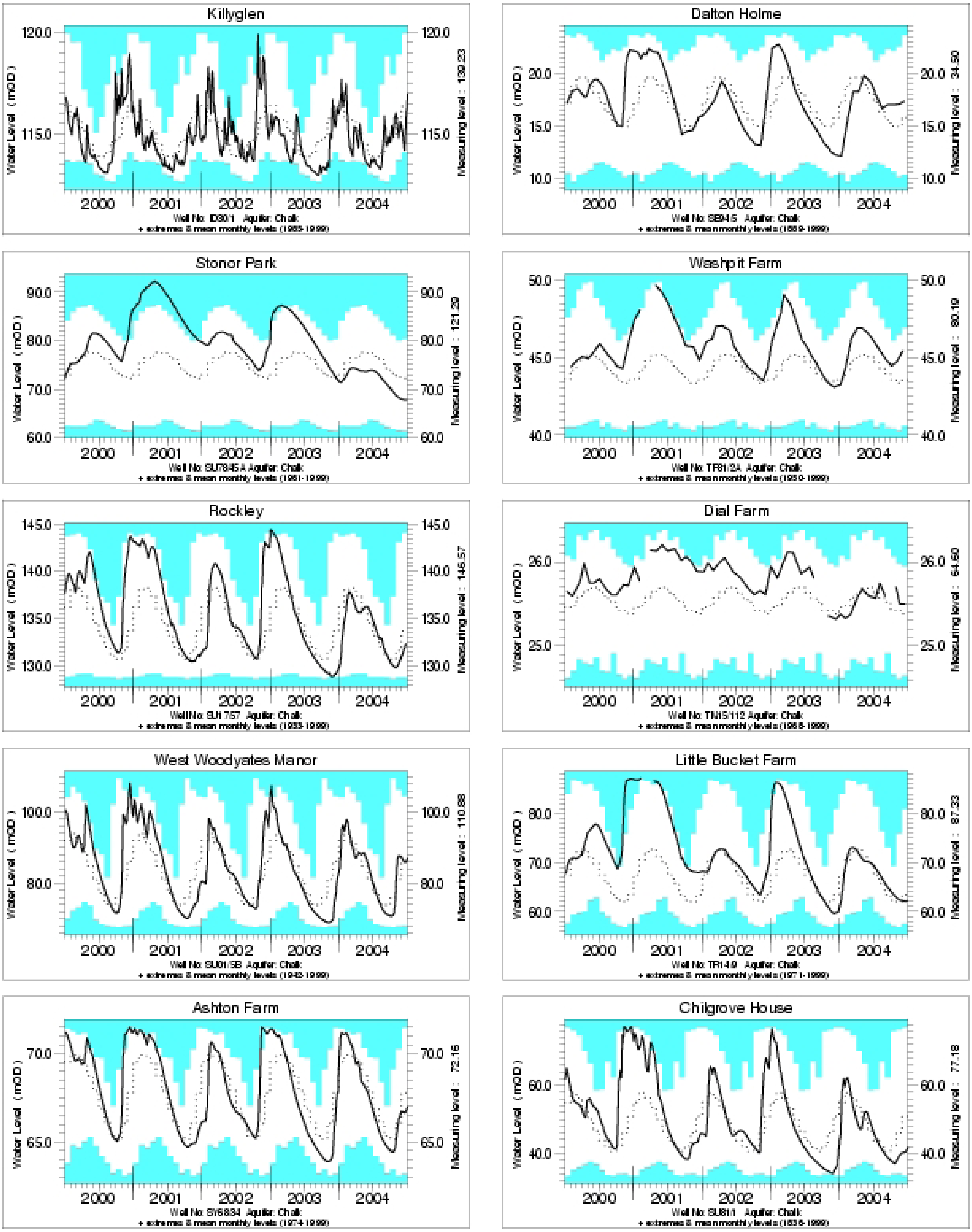


Figure 23 *Groundwater level hydrographs 2000-2004.*

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

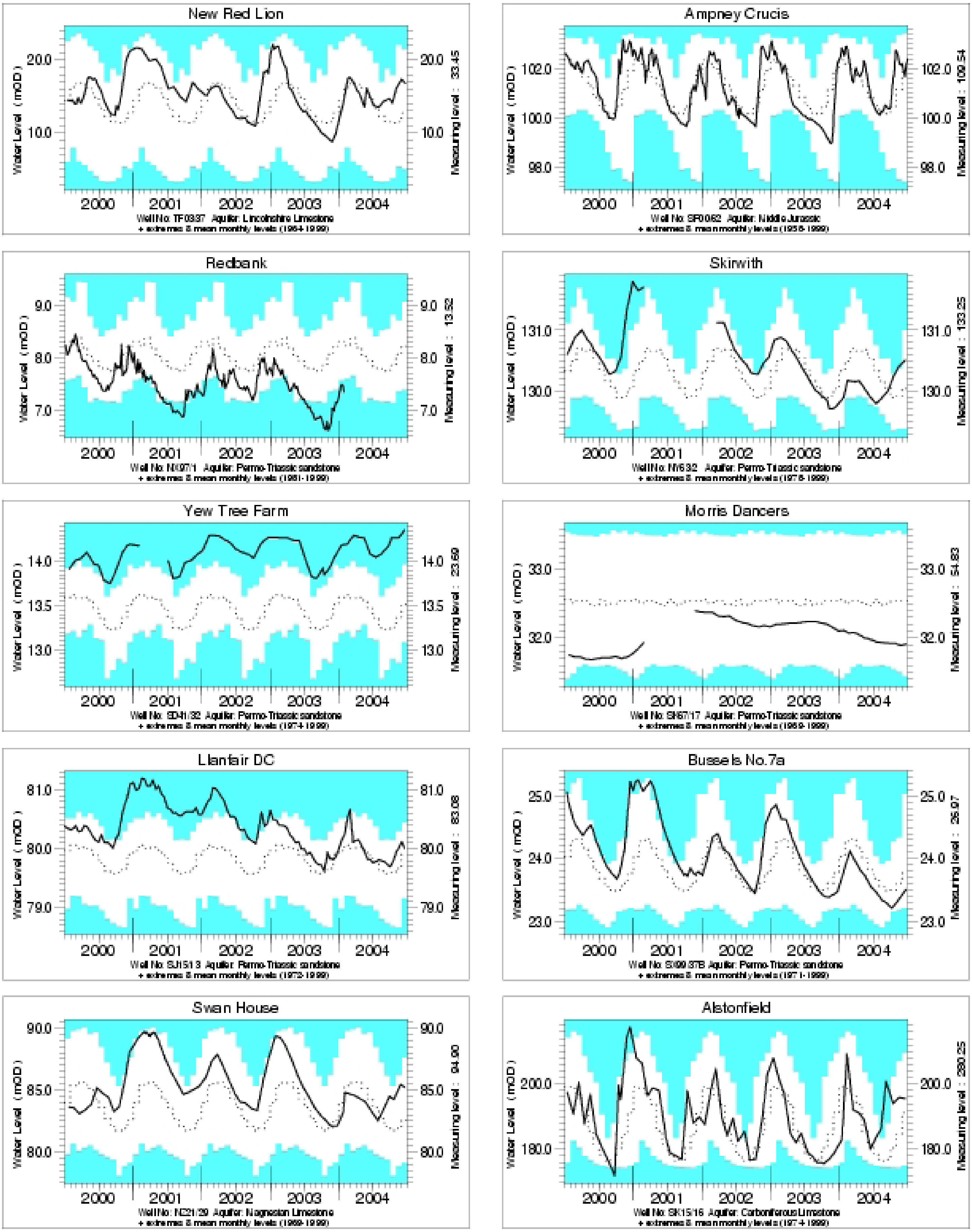


Figure 23 *(Contd.)*

monthly maximum and minimum levels for the pre-2000 record. For 2004, the hydrographs confirm the rather erratic recharge pattern and provide a guide to the spatial variations in total replenishment to individual aquifer units.

Following notable declines in groundwater levels across most major aquifers during the 2003 drought, the 2003/04 winter recoveries needed to be generated from well below average autumn minima in many outcrop areas. In such circumstances the lag between infiltration and water-table response can be considerable but the sustained rainfall in December 2003 helped initiate recoveries in most aquifers, the recoveries did, however, vary considerably in their strength and persistence. In the southern Chalk (the Yorkshire Wolds also), recoveries were of a typical magnitude but in the Chilterns (e.g. at Stonor) they were much more faltering. With total winter recharge falling below average in most outcrop areas, the 2004 seasonal groundwater level recessions began from moderate spring maxima - April groundwater levels were mostly below average (Figure 24) and in the Chilterns the seasonal recession began at its lowest spring peak since 1998. Some compensation was provided by sustained April/early May rainfall which fuelled a modest upturn in groundwater levels during the late spring (e.g. at Chilgrove). Thereafter, groundwater levels mostly followed normal recessions through until the late summer when the impact of significant, and unusual, August infiltration was evident in the more responsive aquifers (e.g. the Carboniferous Limestone and Middle Jurassic outcrops; in the former - at Alstonefield - groundwater levels reached their highest early autumn level in a series from 1974 - see Figure 25).

The occurrence of groundwater level minima during 2004 showed limited spatial or temporal coherence but they were mostly within the normal range. However, the dry end to the year meant that no appreciable seasonal rises in groundwater levels were evident in some aquifer units in eastern, central and southern England. For some index sites (e.g. Nuttall's Farm) groundwater levels declined steadily throughout 2004 and the absence of an autumn/early winter recovery was especially notable in the eastern Chalk. By year-end levels at Stonor in the Chilterns levels had declined to their lowest since the end of the 1995-97 drought. Entering 2005, groundwater levels were mostly within the normal winter range (see Figure 26) but the lack

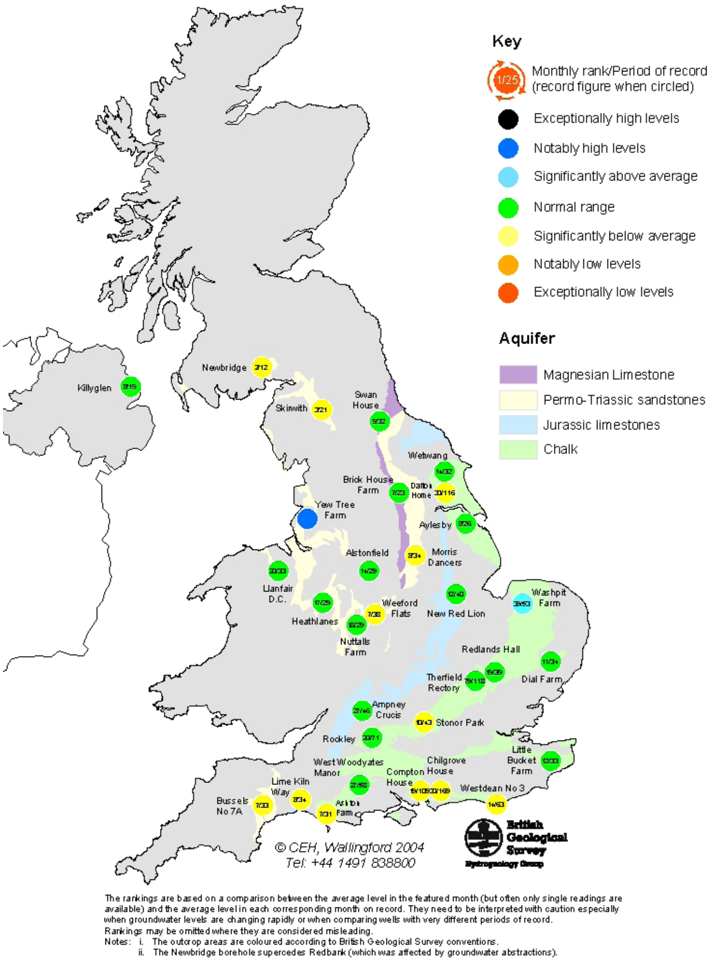


Figure 24 *April 2004 groundwater levels.*

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

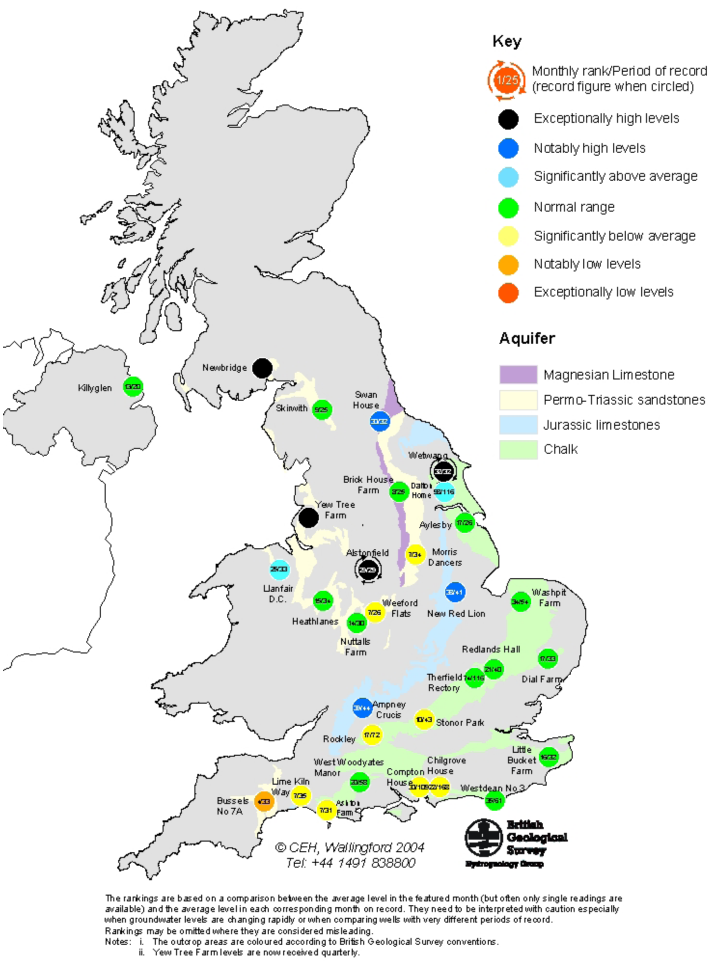


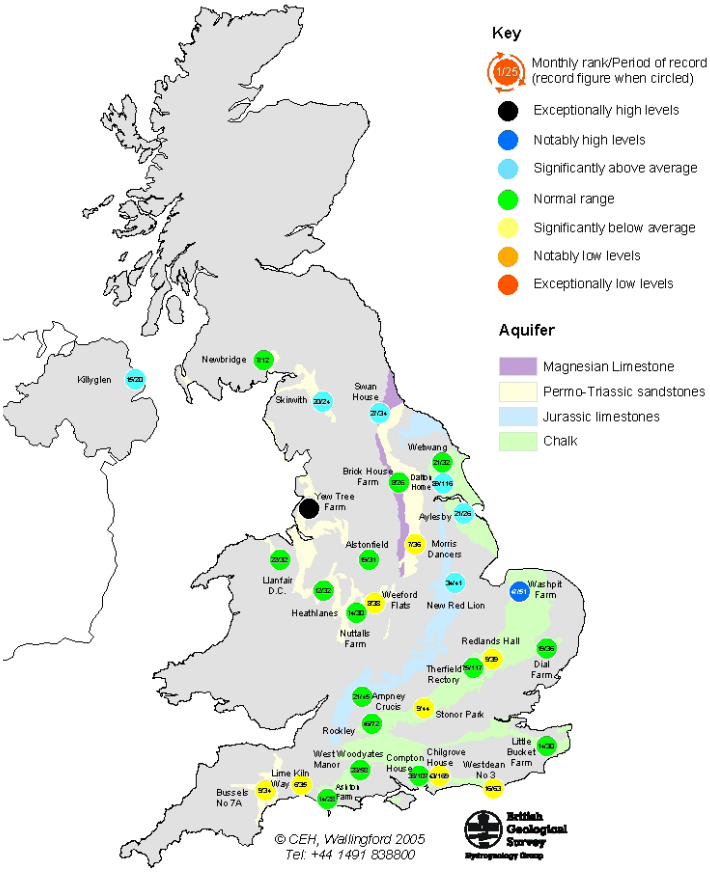
Figure 25 *September 2004 groundwater levels.*

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

of substantial infiltration in late 2004 implied that the normal January-February rise in groundwater levels would be considerably weaker than normal, and the groundwater resources outlook less healthy than in any of the previous seven or eight years.

The majority of observation wells and boreholes for which data are held on the National Groundwater Level Archive monitor the natural variation in levels. However, in parts of the UK groundwater levels have been influenced, sometimes over very long periods, by pumping for water supply or other purposes. As a consequence, some local or regional water-tables have become substantially depressed. For instance, contemporary levels at a number of boreholes in the Permo-Triassic sandstones of the Midlands are indicative of a significant regional decline. In contrast, rising groundwater levels have been reported from a number of conurbations; leakage from water mains is considered a significant factor in some cases. The implications of rising groundwater levels extend beyond the potential improvement in water 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.

Artificial influence on groundwater levels have been particularly pervasive in London where increasing groundwater abstraction through the nineteenth and the first half of the twentieth centuries led to a 70-metre decline in groundwater levels in the Trafalgar Square borehole. Since the 1950s, a much reduced abstraction rate has resulted in a recovery of around 40 metres with levels rising by 1-2 metres a year through the early 1990s (see Figure 27). The potential disruption and damage (e.g. to the stability of buildings) which would result from a continuation of this rise stimulated the development of a strategy to control rising groundwaters below London. Implementation of this strategy has resulted in a modest decline in levels at Trafalgar Square over the post-2000 period.



The rankings are based on a comparison between the average level in the featured month (but often only single readings are available) and the average level in each corresponding month on record. They need to be interpreted with caution especially when groundwater levels are changing rapidly or when comparing wells with very different periods of record.
Rankings may be omitted where they are considered misleading.
Notes: i. The outcrop areas are coloured according to British Geological Survey conventions.
ii. Yew Tree Farm levels are now received quarterly.

Figure 26 *December 2004 groundwater levels.*

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

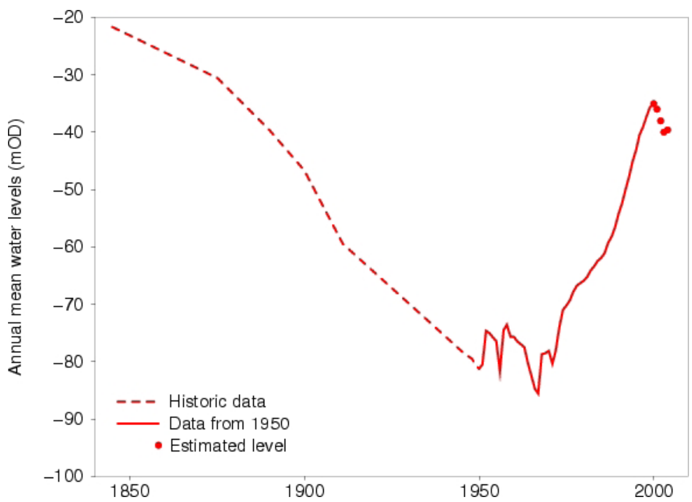


Figure 27 *Annual mean groundwater levels for the Trafalgar Square borehole.*

Data source: Environment Agency.

Groundwater levels - through the year

January

Soils remained at, or very close to, saturation throughout January and with modest evaporative demands, infiltration rates were well above average throughout most aquifer units - exceeding 150% of the January average in parts of the Chalk. January 2004 levels confirmed that a strong, if belated, recovery was underway in almost all outcrop areas. In the southern Chalk (e.g. at Chilgrove and West Woodyates) levels had risen by 30 metres or more since the minima recorded during the terminal phase of the 2003 drought. Levels remained below average, but generally within the normal range, in the slower-responding eastern outcrops where the recovery had only recently been initiated. Steep winter recoveries characterised most limestone aquifers; in the Jurassic Limestone of the Cotswolds, levels at Ampney Crucis, which had been at their lowest since 1996 in the autumn of 2003 rose to above the January average. In contrast to the limestone and Chalk aquifers, the delayed recovery in most of the Permo-Triassic sandstones outcrops (the Bussels index borehole, in the South West, was an exception) began from relatively healthy levels - a reflection of recharge patterns over several years. Generally, the 2003/04 groundwater level recovery gathered momentum in January and levels in most index boreholes were appreciably above average at month-end; heavy late-January infiltration implied that groundwater levels would rise further in February.

February

The February rainfall distribution was unfavourable for groundwater replenishment, in both spatial and temporal terms. Most aquifer outcrop areas reported significantly below average monthly rainfall and, although infiltration rates remained high in the first week, the subsequent dry spell saw modest soil moisture deficits develop across southern England. Groundwater levels for index boreholes which reported in early February reflected the heavy antecedent recharge but some of those reporting around month end confirmed a continuing late-winter recession (e.g. at Ampney Crucis and Chilgrove). Nonetheless, February levels across almost the entirety of the Chalk aquifer were within the normal late winter range (Killyglen in Northern Ireland was an exception). Similarly, levels in most index wells in the limestone aquifers were around the seasonal norm. In the Permo-Triassic sandstones, below average February levels typified most of the more responsive wells (Llanfair DC in North Wales excepted) but healthy levels still characterised the slowest responding aquifer units, including most outcrops in the Midlands. Levels in the minor aquifers of eastern England were also typical for the time of year. The early 2004 recharge resulted in much healthier overall groundwater resources than at the corresponding time in many recent groundwater drought years (e.g. 1992, 1996 and 1997).

March

Although very moist soil moisture conditions were helpful for groundwater replenishment in March, rainfall across most outcrop areas was < 75% of the average and infiltration rates less than half the long term mean. As importantly, winter half-year (October-March) recharge totals were well below average across almost all aquifer outcrop areas. This implied that, in the absence of further significant recharge, the spring maxima in 2004 would be the lowest for seven years over wide areas, with most recessions commencing from below average levels (but see below). Recessions were well established in late March across much of the southern Chalk (e.g. at Chilgrove and Rockley) but levels continued to rise at the deep Therfield well (near Royston). Levels were also falling in the Limestone aquifers but rising slowly in the slowest responding Permo-Triassic sandstones outcrops. Overall groundwater resources for the early spring were substantially lower than at the corresponding time in 2003 (and in the preceding five years). Nonetheless, most March 2004 groundwater levels were within the normal spring range; generally below average but well above the levels which characterised the droughts of the early and mid-1990s, and much of the 1970s.

April

April began with soil moisture deficits building across many eastern aquifer outcrop areas and, with evaporation losses accelerating, the prospect for further significant recharge was poor. In the event, the April rainfall was generally well distributed through the month and 30%, or more, above average across most major aquifer units; in the east, the frontal rainfall on the 18th was especially beneficial. The substantial late-spring rainfall was sufficient to re-initiate infiltration and provide a seasonally late pulse of recharge which generated an upturn in groundwater levels (e.g. at Ampney Crucis in the Jurassic Limestone and Rockley in the Chalk). Evidence of a recovery is lacking in the slower-responding Chalk outcrops but April groundwater levels were well within the normal range for almost all index sites. Despite steep groundwater level declines in the late winter and early spring, this was also true across most of the limestone aquifers. Spatial variation was much more evident in the Permo-Triassic sandstones where notably high levels at Yew Tree Farm contrasted with the relatively depressed water-table in southern Scotland. Nonetheless, most Permo-Triassic sandstones index sites registered typical spring levels. Overall groundwater resources were only a little below average at month- end with, in some areas, the likelihood of further modest recoveries before the summer recessions become firmly entrenched.

May

The first week of May saw some modest, but very useful, infiltration before aquifer recharge was curtailed as soil moisture deficits increased rapidly over the rest of the month. Importantly, the early May rainfall succeeded in postponing the full onset of the summer recession in groundwater levels across most major aquifers (see the Chilgrove hydrograph for example). As a consequence, May levels remained above the monthly average in almost half the index wells and boreholes. Notwithstanding the erratic recharge patterns through the spring, groundwater levels across much the greater part of the Chalk outcrop were well within the normal range - exceptions included Northern Ireland where the very responsive Killyglen borehole registered its lowest May level in a 20-year record. Levels were also relatively depressed in the Permo-Triassic sandstones of the North West (see Skirwith) but near-average levels characterised most of the outcrop; in the west

Midlands, levels had fallen close the average for the first time in five years. Levels in the limestone and minor aquifers were also generally around the normal level for late spring.

June

Soil moisture deficits increased rapidly in the first half of June and, notwithstanding an unsettled final week, end-of-month values remained considerably above average in southern Britain. Consequently, little or no infiltration occurred in the major aquifer outcrop areas. After the modest late spring infiltration moderated the seasonal decline in the more responsive aquifers, groundwater level recessions re-established themselves in June. By month-end levels were in decline in all but the slowest-responding aquifer units. June levels in the Chalk were close to the early summer mean in many index wells and boreholes but regional regional differences were appreciable (levels remained low at Killyglen in Northern Ireland). Groundwater levels within the normal June range also typified the major limestone and Permo-Triassic sandstones outcrops, but levels in the latter were relatively depressed in the Midlands (e.g. at Weeford Flats) and in the most northerly outcrops. Levels remained a little above average in the minor aquifers of eastern England.

July

As usual in mid-summer, very dry soil conditions across the major aquifer outcrop areas generally restricted infiltration to very localised events associated with convective storms. However, the impact of the exceptional early July rainfall in a zone from Cambridgeshire to the Humber was reflected in the (very modest) increase in levels in the Chalk at Aylesby and an inflection the recession for the New Red Lion borehole (in the Lincolnshire Limestone). Elsewhere, groundwater levels in the great majority of index boreholes were in well established seasonal recessions. In the Chalk, levels were relatively low in the more south-westerly outcrops (and in parts of the Chilterns) but levels closely followed the mean seasonal trace in most areas. This situation was broadly replicated in the limestone aquifers but the Permo-Triassic sandstones displayed much less geographical coherence. Levels were notably low in the most northerly outcrops but still very high in some of slowest responding aquifer units. Again however, levels at most index sites were in the normal range. The overall 'near-average' groundwater resources picture had remained fairly stable through the late spring and most of the summer.

August

August rainfall totals were 130-200% of average over most (but not all) major aquifer outcrop areas but local variability was large. In marked contrast to the normal seasonal pattern, soil moisture deficits declined in August - dramatically in some outcrop areas (e.g. parts of Cambridgeshire). Generally however, substantial deficits remained at month-end, and were above average in parts of the south-western Chalk outcrop. Infiltration rates were high relative to the August average (which is negligible for most outcrop areas) but very modest in absolute terms. Many reporting dates were too early to capture any impact of the August rainfall but groundwater hydrographs for some of the more responsive aquifer units provide evidence of a very early seasonal upturn in groundwater levels e.g. at Ampney Crucis, Killyglen, Newbridge and Alstonfield where levels increased by over 10 metres. Elsewhere, the August levels confirmed the continuation of a typical summer recession in the Chalk. Late summer levels were close to average in the Lincolnshire Limestone also and remained within the normal range for most index wells in the Permo-Triassic Triassic sandstones (albeit with significant regional variations). The main benefit of the abundant August rainfall was the increase in soil moisture and the corresponding increased likelihood of a relatively early onset of the seasonal recovery in recharge rates (a notable contrast with 2003).

September

Most frontal systems followed tracks remote from the English Lowlands during September; as a consequence, rainfall across many major aquifers was less than 50% of average. In addition, evaporative demands were seasonally high throughout most of the UK - 20-30% above average across much of the southern Chalk outcrop. Thus, contrary to the normal seasonal pattern, soil moisture deficits increased in much of southern and eastern Britain; by month-end they exceeded the average across the greater part of the Chalk outcrop. Recharge opportunities were therefore modest but early groundwater level recoveries (heralded by the exceptional August downpours) continued in some responsive aquifer units - notably in the Carboniferous Limestone where the September level at Alstonfield was the highest, by a considerable margin, in a 30-year record. Less dramatic recoveries were reported for other limestone index wells (e.g. in the Lincolnshire Limestone and the northern Chalk). Elsewhere in the Chalk, levels remained within the normal autumn range - but relatively depressed in the south-western outcrops. Levels in most of the Permo-Triassic sandstones outcrop areas were also healthy, notably so in some of the more northerly outcrops (Yew Tree Farm especially). More modest exceedance of the September average characterised most of the minor aquifers in East Anglia (e.g. the Norfolk Drift and Essex Gravels).

October

October rainfall totals were in the 150-200% range across many major outcrop areas and, by month-end, significant (but generally below average) soil moisture deficits were restricted to the drier parts of eastern and southern England - encompassing a large part of the Chalk outcrop. Infiltration was substantial over the latter half of the month but at many index wells and boreholes the major proportion remained in the unsaturated zone when the October levels were measured. Nonetheless, recoveries were firmly established in parts of the Chalk aquifer (e.g. West Woodyates) and autumn levels were generally well within the normal range across the outcrop - and notably high in the Yorkshire Wolds. Steep recoveries since mid August left levels in most limestone index wells considerably above average and, as has been the case for much of the preceding two years, levels in the Permo-Triassic sandstones outcrop displayed large spatial variations; mostly above average (exceptionally so in some of the more north-westerly outcrops) but modestly depressed in a few areas. October groundwater levels in most minor aquifers were healthy and, with most outcrop areas close to saturation, the prospects for further substantial late autumn recharge were very good.

November

November rainfall totals exceeded the average across a modest proportion of the central Chalk outcrop but elsewhere many aquifer units received less than half the 1961-90 average. Correspondingly, some areas registered little or no infiltration (e.g. parts of the North Downs). The patchiness of the autumn recharge patterns also reflected the large spatial variations in late autumn soil moisture deficits across the English Lowlands where, at the end of November, significant deficits remained in the east. November groundwater levels in many aquifer outcrops showed little change from those in October (the late autumn is normally a time of brisk recoveries). Levels in the Chalk were generally well within the normal range but a distinction could be drawn between those where recoveries were underway (e.g. in the south-western and north-eastern extremities) and those slower responding units where the summer decline had yet to be arrested (see, for instance, Stonor). The generally heavy October recharge ensured that levels in most index wells in the limestone aquifers were above average entering the winter of 2004/05. Late autumn groundwater levels in the Permo-Triassic sandstones reflected the wide distribution of the outcrop areas and the substantial variations in response rates - nonetheless all were within the normal range.

December

Despite the low rainfall across most aquifer outcrop areas, residual soil moisture deficits were sensibly eliminated in all but a few parts of eastern England by the end of the year. However, infiltration totals for December were well below the monthly average, declining to less than 20% in much of the eastern Chalk. As a consequence, the 2004 groundwater level recessions for the eastern Chalk extended into the new year. Groundwater levels in parts of the Chalk (e.g. Stonor, Redlands) were at their lowest since 1998. However, the residual benefit of abundant recharge to the Chalk over previous winters can still be identified - thus levels remained substantially above winter drought minima (e.g. those for 1991, 1992 and 1997). Groundwater levels in the limestone aquifers had generally declined from very healthy early autumn levels but remained in the normal end-of-year range. This was true of levels in most Permo-Triassic sandstones outcrops also although levels in many index wells began 2005 at their lowest January level for around seven years. Overall groundwater resources for England and Wales remained close to average but the barely discernible seasonal recovery in the eastern (and parts of the southern) Chalk implied a need for substantial late winter and spring recharge to avoid depressed groundwater levels in the summer of 2005.

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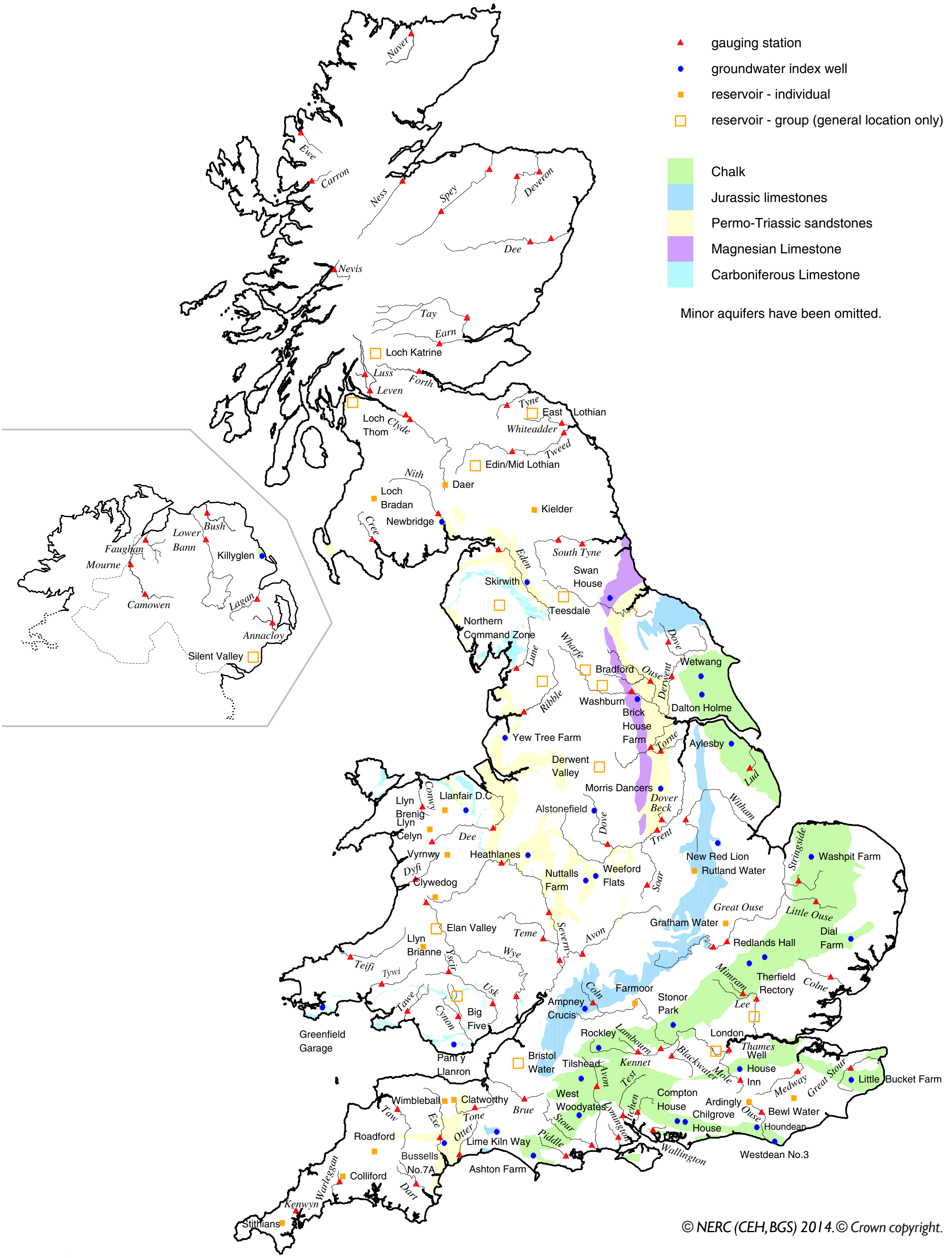
Location Map



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