UK Hydrological Review 2010

Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

2010

UK HYDROLOGICAL REVIEW

This hydrological review, which also provides an overview of water resources status throughout 2010, was undertaken as part of the National Hydrological Monitoring Programme (NHMP). The NHMP was set up in 1988 to document hydrological and water resources variability across the UK. It is a collaborative programme between the Centre for Ecology & Hydrology, which maintains the National River Flow Archive and the British Geological Survey which maintains the National Groundwater Level Archive. Both organisations are component bodies of the Natural Environment Research Council.

This report has been compiled with the active cooperation of the principal measuring authorities in the UK: the Environment Agency[a], the Scottish Environment Protection Agency and, in the Northern Ireland, the Rivers Agency. These organisations provided the great majority of the required river flow and groundwater level data. The Met Office provided almost all of the rainfall and climatological information featured in the report and the reservoir stocks information derive from the Water Service Companies, Scottish Water and Northern Ireland Water. Groundwater level data for Northern Ireland were provided by the Northern Ireland Environment Agency. The provision of the basic data, which provides the foundation both of this report and the wider activities of the NHMP, is gratefully acknowledged.

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).

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Cover photo

River Dee (Grampian) January 2010 (Photo credit: SEPA - Derek Fraser).

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[a] Including the Environment Agency Wales which is both an Assembly Public Body (obtaining a proportion of its funding and direction from the Welsh Assembly) and part of the corporate Environment Agency for England & Wales.

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Note: the Location Map gives the location of many of the rivers, reservoirs, aquifer outcrop areas and wells and boreholes mentioned in the Hydrological Review.

UK Hydrological Review of 2010

2010 Summary

In the context of the recent past 2010 was an unusual year climatologically. After four successive years with well above average rainfall, it was the UK's third driest year in the last 35. Rainfall deficiencies were particularly notable over the first half of the year – at the national scale, the January-June rainfall was the equal 2nd lowest in a series from 1910[a]. 2010 was also the coolest year since 1986, largely because of Arctic conditions in January and December, the latter being the coldest in the UK temperature series. With catchments frozen for the majority of both months, runoff and aquifer recharge conditions in southern Britain were of a type not experienced for around 30 years.

Snowmelt contributed to especially high river flows in mid-January but the year as a whole was characterised by a low frequency of significant flood events. Sustained recessions and very moderate reservoir inflows were a particular feature of the spring and early summer when the spatial extent and severity of drought conditions was most evident. This is underlined by the estimated overall June outflows from Great Britain – the lowest in a series from 1961.

The lack of rainfall caused moderate agricultural stress and a brisk decline in reservoir stocks through the spring and early summer, heralding the introduction of a hosepipe ban in north-west England. However, a decisive change in synoptic patterns then resulted in an exceptionally wet late summer and autumn. The focus of hydrological attention shifted, albeit briefly, from drought towards the risk of flooding during September, and reservoir stocks recovered smartly in most areas. However, sustained freezing conditions during December greatly restricted runoff and aquifer recharge rates. Burst pipes caused widespread local water supply difficulties and a more general threat in parts of Northern Ireland where the rapid depletion of stocks in a number of service reservoirs resulted in restricted water supplies to around 40,000 properties. Rota cuts were introduced, bowsers deployed and bottled water was also made available in some areas.

End-of-year reservoir stocks were mostly within 10% of the early-winter average but seasonally depressed in a number of major western and southern impoundments although generally above drought minima for the early winter. Groundwater levels were also considerably below average across many aquifer outcrop areas. This, together with the persistence of moderate long term rainfall deficiencies, made parts of the country more vulnerable than usual to drought conditions in 2011.

a Unless otherwise stated all comparisons are based on the National Climate Information Centre (Met Office) figures.

Rainfall

Eastern Britain apart, almost all areas recorded below average annual rainfall totals for 2010 (see Figure 1). Many areas registered only two months with above average rainfall during the year and the most exceptional annual rainfall deficiencies were found in the western uplands, and particularly in Scotland where some catchments in the western Highlands recorded their lowest annual rainfall totals in at least 50 years.

The temporal distribution of the 2010 rainfall was also unusual (see Table 1). At the national scale, rainfall totals were below average in each of the first six months of 2010 with exceptional accumulated deficiencies in most western regions (Figure 2); the North West Region recorded its driest January-June since 1929. Fortunately, in a drought context, a continuing sequence of active Atlantic low pressure systems crossed most of the country in July. Although much of the English Lowlands remained relatively dry, Northern Ireland reported its wettest July in 50 years and Scotland its 2nd wettest since 1940. The majority of the country registered >150% of the 1971-2000 average and, nationally, it was the fourth successive notably wet July. August was also very wet across eastern and southern Britain ensuring that summer (June-August) rainfall totals exceeded the average for the 9th time in 14 years. Unsettled weather patterns continued into the early autumn and July-September rainfall totals were more than 30% above average across most of the UK; generally, the highest anomalies coincided with those regions which had the

Table 1 2010 rainfall in mm and as a % of the 1971-2000[a] average — Data source: Met Office

2010		J	F	M	A	M	J	J	A	S	O	N	D	Year	Oct-Mar 2009/10	Apr-Sep 2010
United	mm	80	75	79	48	39	39	108	98	114	101	123	48	951	658	445
Kingdom	%	68	89	86	72	62	56	163	121	118	90	107	40	88	103	101
England &	mm	72	72	64	27	33	37	75	98	89	80	98	38	783	578	359
Wales	%	78	110	89	46	57	58	135	141	114	88	107	38	87	113	93
England	mm	68	74	59	25	30	37	61	97	79	73	91	35	727	532	328
	%	82	126	90	44	54	59	117	150	110	90	112	40	89	116	91
Scotland	mm	93	82	103	87	50	40	166	103	154	149	167	63	1255	810	599
	%	56	70	78	108	69	50	192	103	116	97	105	39	87	91	109
Wales	mm	100	61	99	43	54	42	159	105	153	119	140	53	1128	862	555
	%	66	56	87	53	70	51	216	104	130	81	92	32	82	102	104
Northern	mm	88	62	107	57	43	46	138	63	162	65	147	69	1047	670	509
Ireland	%	74	72	115	81	64	64	185	69	173	57	133	59	94	104	109
North West	mm	67	57	82	32	29	36	159	84	156	106	141	38	987	712	497
	%	55	66	82	48	43	46	204	88	152	84	113	29	84	103	102
Northumbrian	mm	75	75	92	20	31	40	92	73	87	72	167	47	870	601	341
	%	91	128	134	33	54	65	160	103	124	95	201	55	105	132	91
Severn Trent	mm	62	50	46	27	32	46	53	93	66	67	66	28	636	420	317
	%	83	92	78	50	60	73	108	148	98	95	93	35	84	103	91
Yorkshire	mm	71	70	65	23	19	44	66	60	95	74	118	38	740	535	306
	%	87	121	96	39	34	70	125	90	138	96	149	42	91	119	84
Anglian	mm	51	76	35	17	24	35	31	119	61	55	54	26	586	378	288
	%	96	206	78	38	52	64	70	231	112	96	95	46	97	124	97
Thames	mm	65	80	47	21	34	25	23	115	47	67	52	31	607	478	266
	%	94	169	88	42	64	44	54	212	75	94	79	43	87	126	83
Southern	mm	76	110	64	21	30	38	26	99	50	87	86	51	738	654	263
	%	93	207	108	40	59	69	57	186	70	98	104	58	94	144	81
Wessex	mm	69	79	57	32	31	30	39	102	63	65	86	36	688	579	297
	%	75	117	81	58	56	49	83	155	82	75	100	35	79	115	82
South West	mm	106	95	90	35	44	33	99	106	107	94	142	47	997	779	423
	%	75	90	93	49	64	45	160	129	108	75	107	31	83	104	93
Welsh	mm	98	60	97	42	53	41	151	107	146	114	133	51	1093	831	541
	%	67	58	88	53	71	52	212	109	128	81	91	32	83	103	105
Highland	mm	91	83	117	106	59	43	181	125	173	168	138	80	1363	841	686
	%	45	56	72	114	75	48	191	114	109	93	68	40	79	77	110
North East	mm	111	99	80	54	64	41	133	102	135	94	160	61	1132	740	528
	%	114	149	103	84	102	62	200	145	153	93	160	67	119	139	127
Tay	mm	103	77	73	77	43	44	165	80	143	143	202	39	1189	766	552
	%	66	72	62	114	59	63	224	97	127	106	153	27	94	97	115
Forth	mm	68	91	92	69	35	37	146	73	126	120	171	50	1079	667	487
	%	53	101	90	111	53	54	206	89	120	101	149	41	95	99	107
Clyde	mm	89	83	113	108	37	40	197	113	179	195	199	61	1413	919	674
	%	44	58	71	119	47	45	184	90	109	103	106	31	82	85	103
Tweed	mm	85	78	122	34	35	25	125	66	107	82	171	51	979	695	390
	%	84	111	152	56	53	38	193	88	132	86	183	49	103	128	95
Solway	mm	88	56	124	84	48	38	168	85	150	151	196	50	1238	877	573
	%	57	50	101	104	64	49	193	80	121	97	132	31	88	102	104
Western Isles,	mm	92	87	78	86	58	36	125	92	120	132	119	65	1092	721	518
Orkney and	%	57	75	60	111	93	52	154	97	90	86	71	41	78	81	100

a — The 1971-2000 averages are the mean of monthly, half-yearly and annual averages stored on the National River Flow Archive (and supplied by the Met Office) for the 30-year standard period. They may differ slightly from averages derived using different analytical procedures.

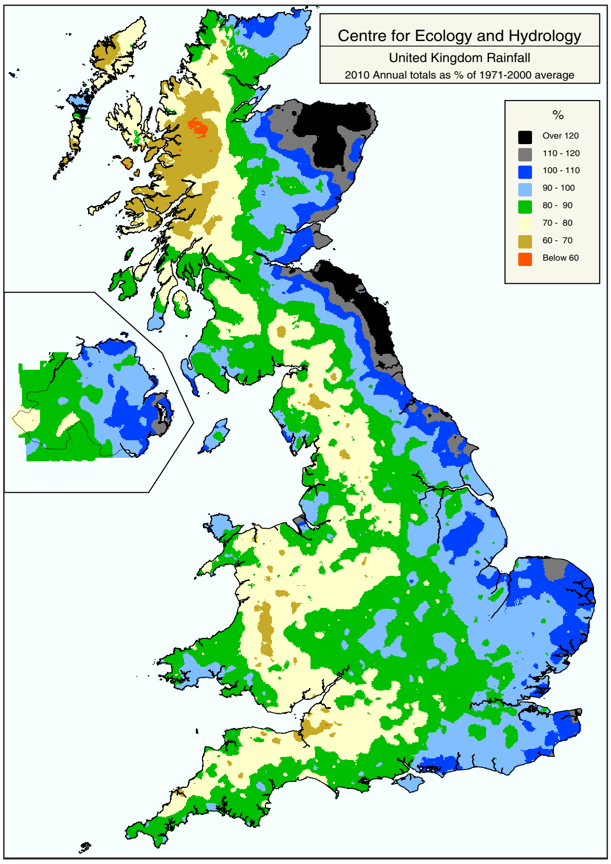


Figure 1 *2010 annual rainfall totals as a % of the 1971-2000 average.*
Data source: Met Office

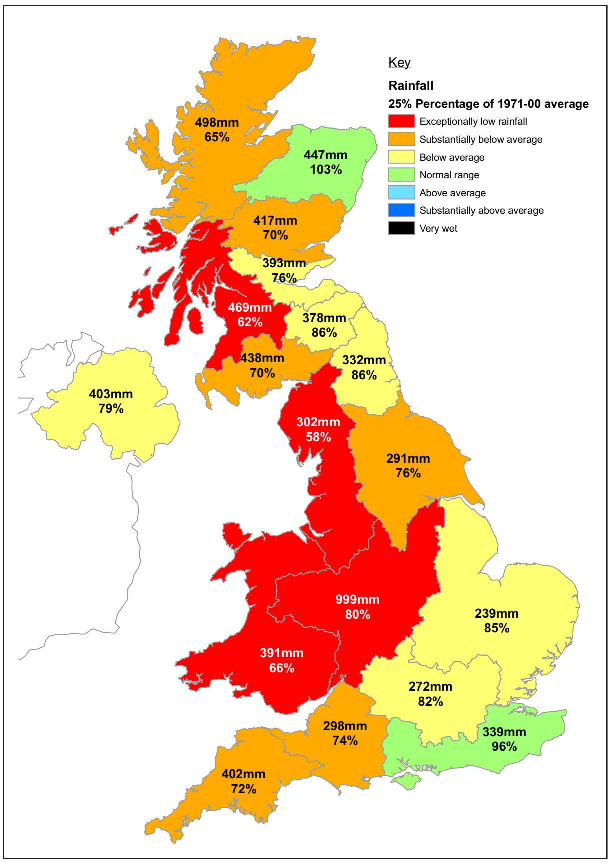


Figure 2 *January - June 2010 rainfall in mm and as a % of the 1971-00 average*
Data source: Met Office

highest rainfall deficiencies in the early summer.

Autumn rainfall totals were well within the normal range across most of the UK but deficiencies again began to build in central and southern Britain; the Thames region recorded its 2nd lowest September-November rainfall since 1997. After a very mild spell in November, an airflow from the north-eastern quadrant during the last ten days of the month brought unusually early Arctic conditions to the UK, with exceptionally low temperatures and the earliest widespread snowfall in 17 years. Significant falls were recorded across much of eastern Britain. A large proportion of the December precipitation also fell as snow (accumulations locally exceeded 50cm) but regional precipitation totals were well below average and the UK as a whole registered its driest December since 1963. By year-end, significant rainfall deficiencies had become re-established across large parts of southern Britain.

Evaporation and Soil Moisture Deficits

On average, over 40% of UK rainfall is accounted for by **evaporation losses** – but the proportion varies greatly from region to region, reaching around 80% in the driest parts of the English Lowlands. Given normal rainfall, the increasing temperatures and accelerating evaporative demands through the spring and early summer lead to a progressive drying of the soil and the creation of what is termed a **soil moisture deficit (SMD)**. Knowledge of evaporation rates and soil moisture status are essential for understanding catchment responses to rainfall and water resource variability.

Exceptionally low temperatures early and late in 2010 contributed to the lowest annual mean temperature for 24 years. However in most regions, temperatures from April to September (when the bulk of the evaporation losses occur) were modestly above the 1971-2000 average. Potential Evaporation (PE) losses for 2010 were within 10% of the average across almost all of the UK (see Figure 3) but appreciably above average in parts of eastern England. For the country as a whole, annual Actual Evaporation (AE) losses were a little below average but within 10% of the mean in almost all regions (Figure 4).

The normal seasonal cycle in evaporation losses in 2010 is clearly evident in Figure 5 which features areally averaged PE, AE and SMD totals for England, the English Lowlands, Scotland and Wales. As usual, AE losses fell below those for PE in all but the wettest parts of the country when dry soil conditions limited the ability of plants to

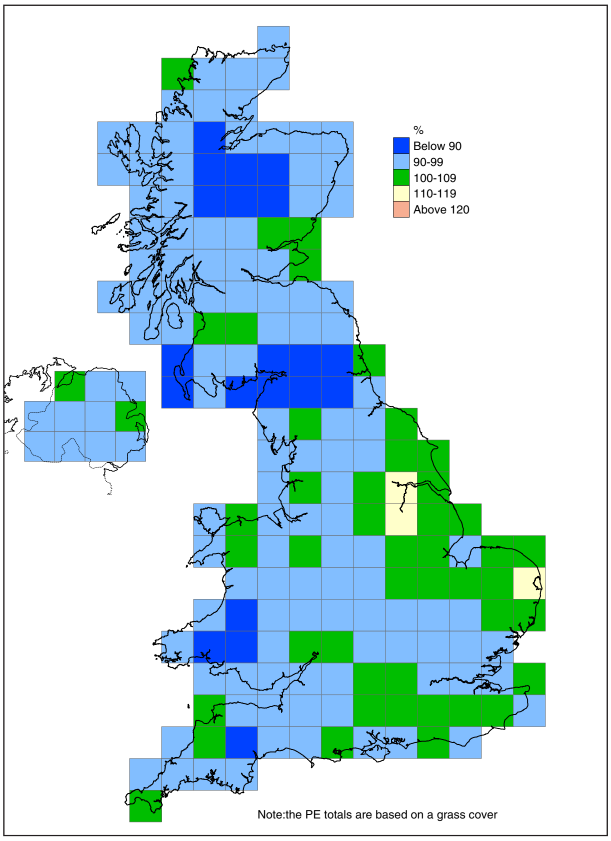


Figure 3 *Potential Evaporation totals for 2010 as a % of the 1971-2000 average*
Data source: MORECS [a]

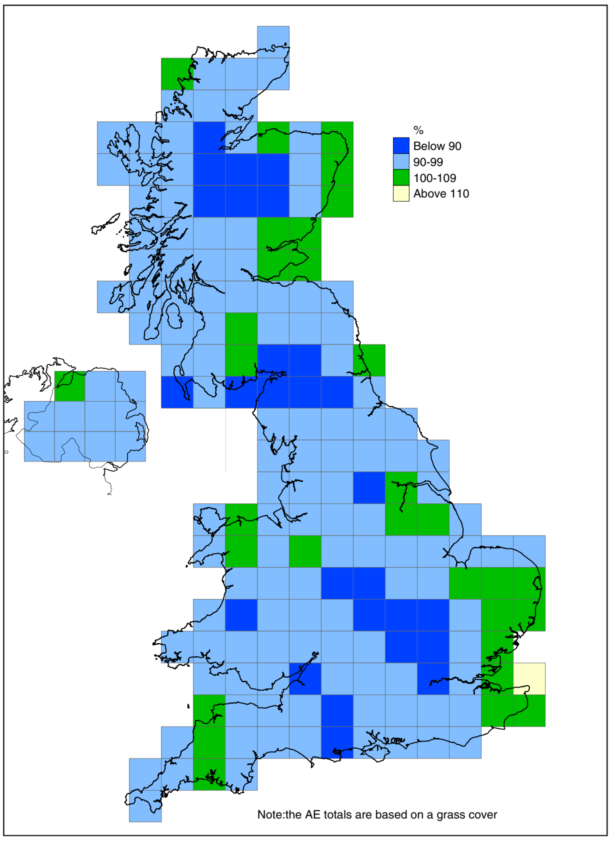


Figure 4 *Actual Evaporation totals for 2010 as a % of the 1971-2000 average*
Data source: MORECS [a]

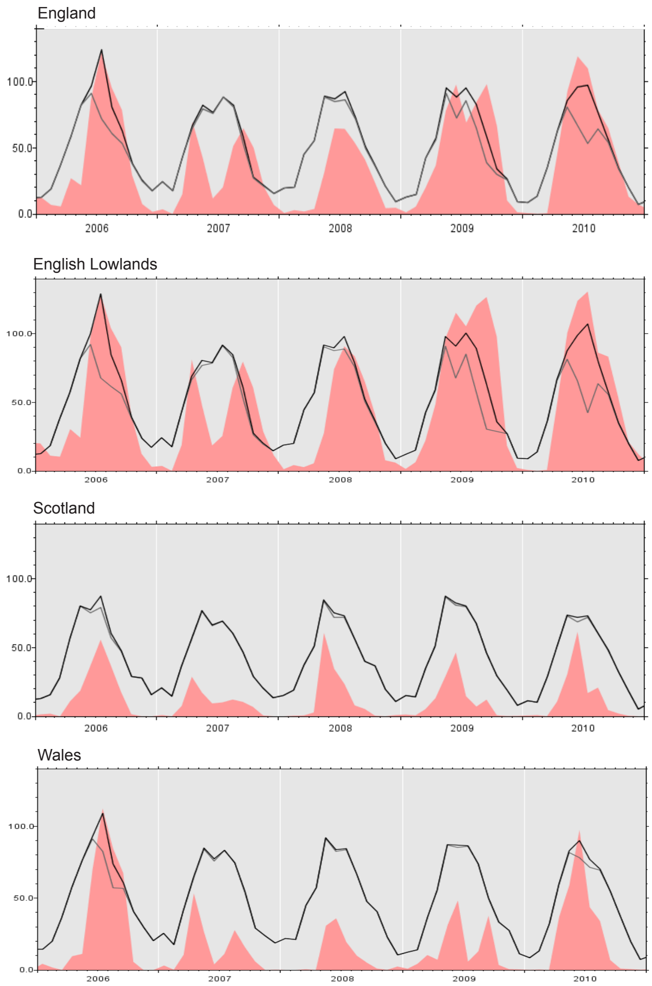


Figure 5 *The variation in monthly Potential Evaporation (black trace), Actual Evaporation (grey trace) and SMDs (pink shading) for 2006-2010*
Data source: MORECS [a]

transpire through the late spring and summer. The deficiencies were particularly notable in June and July, and for the English Lowlands, the annual shortfall of AE relative to PE was the 2nd largest since 1996; in some areas the deficiency exceeded 120mm.

Following record November rainfall in 2009, soils generally remained close to saturation throughout the ensuing winter but soil moisture deficits (SMDs) increased briskly through the spring and end-of-May deficiencies were marginally the highest on record for the English Lowlands as a whole (see Figure 6). They increased further through June but then declined steeply during the late summer. Nonetheless, average SMDs through the April-August growing season (a good indicator of agricultural stress[b]) were the highest since 1995.

In most northern and western areas of the UK above average rainfall throughout much of the autumn of 2010 ensured that soils were close to saturation by late November but in much of England modest SMDs remained and the very limited December precipitation resulted in appreciable deficiencies (>20mm) being carried over into 2011. For the English Lowlands, the

a MORECS is the generic name for the Met Office services involving the routine calculation of evaporation and soil moisture throughout the United Kingdom[1].
b In the absence of irrigation

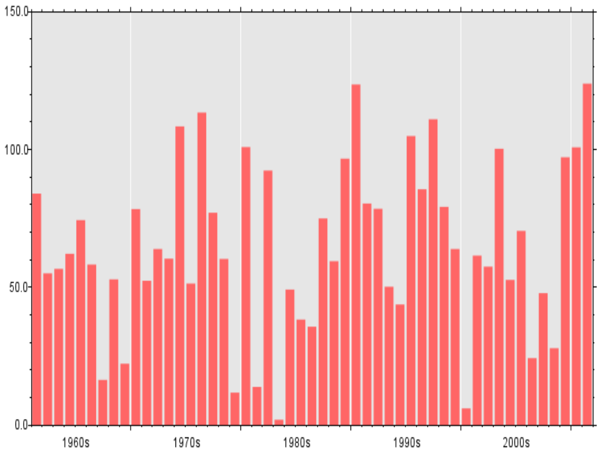


Figure 6 *Average end-of-May soil moisture deficits (in mm) for the English Lowlands.*
Data source: MORECS [a]

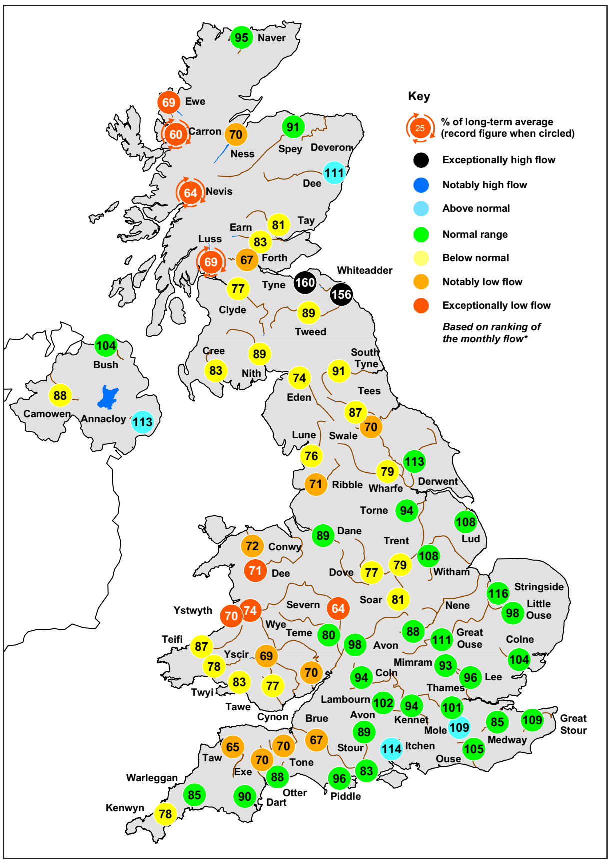


Figure 7 *Annual runoff in 2010 as a percentage of the long term average.*

average end-of-year SMD was the highest since 2005 – but substantially drier early winter soil conditions occurred regularly in the 1970s and 1980s; and in December 1964 SMDs were around four times those experienced at the end of 2010.

River flows

The below average rainfall, together with the concentration of the wettest months during the summer half-year (when evaporation demands are at their greatest) ensured that annual catchment runoff totals for 2010 were generally below average. There were exceptions, mostly in rivers draining to the north-eastern seaboard, but estimated outflows from mainland Great Britain were the 2nd lowest since 1997 with particularly modest runoff in parts of western Britain. Many rivers draining west from the Scottish Highlands established new annual runoff minima (see Figure 7). By contrast, runoff in permeable catchments in the English Lowlands remained within the normal range, reflecting less exceptional rainfall deficiencies and healthy natural groundwater contributions, particularly over the first half of the year.

The normal seasonal contrasts in flows could readily be identified (Figure 8) but the overall range of flows was relatively muted by comparison to most years. A defining characteristic of runoff patterns in 2010, was the dearth of major flood events. An absence of exceptional spates was especially widespread at the beginning and end of the year when many headwater catchments were frozen and runoff rates generally depressed. In mid-January however a vigorous frontal system brought sustained rainfall and, with a significant snowmelt component in most catchments, flows increased steeply and Flood Alerts were widespread. Notable spates were also common in March but thereafter floodplain inundations were uncommon as very steep recessions became established and, in most areas, extended into the early summer. By late June, flows were approaching their long term minima (for the time of year) in many responsive rivers across the UK. Existing June daily flow minima were eclipsed in, for example, the Ness, Clyde and Lune, and estimated outflows from Britain as a whole fell marginally below the previous June minima at month end – see Figure 8. The early summer drought stress is underlined by runoff totals over first half of the year. Throughout much of western Britain January-June runoff totals were very depressed – and a significant proportion of, mostly westward draining, rivers from north Wales to Wester Ross eclipsed previously recorded runoff minima for this six-month period (Figure 9). Correspondingly, there was a substantial contraction in the headwater stream network with an associated, albeit temporary, loss of aquatic habitat.

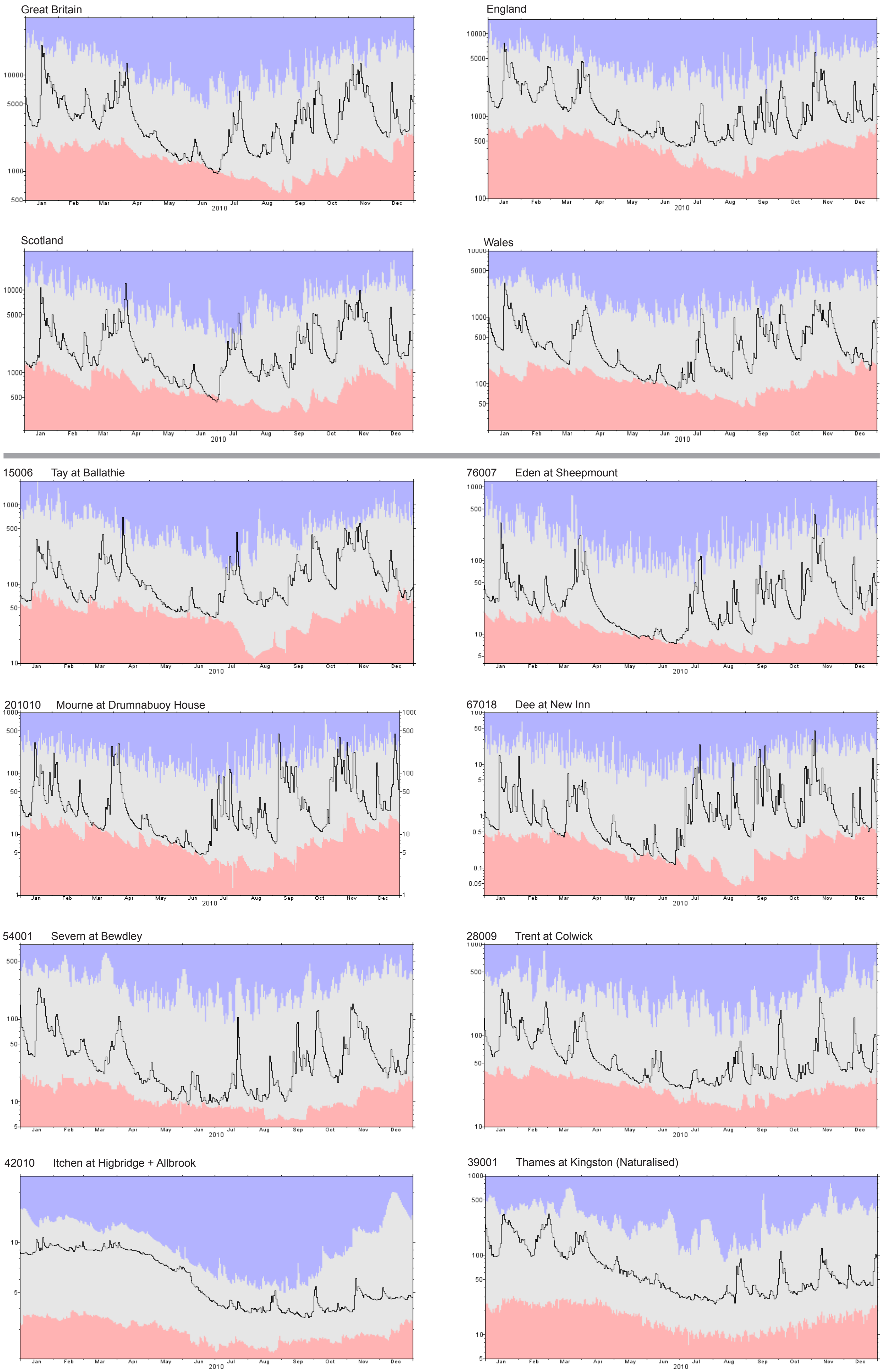


Figure 8 *2010 daily flow hydrographs of estimated outflows at the national scale and for a selection of index catchments (flows in m^3s^{-1}). The blue and pink envelopes show the highest and lowest daily flows on record (up to 2009).*

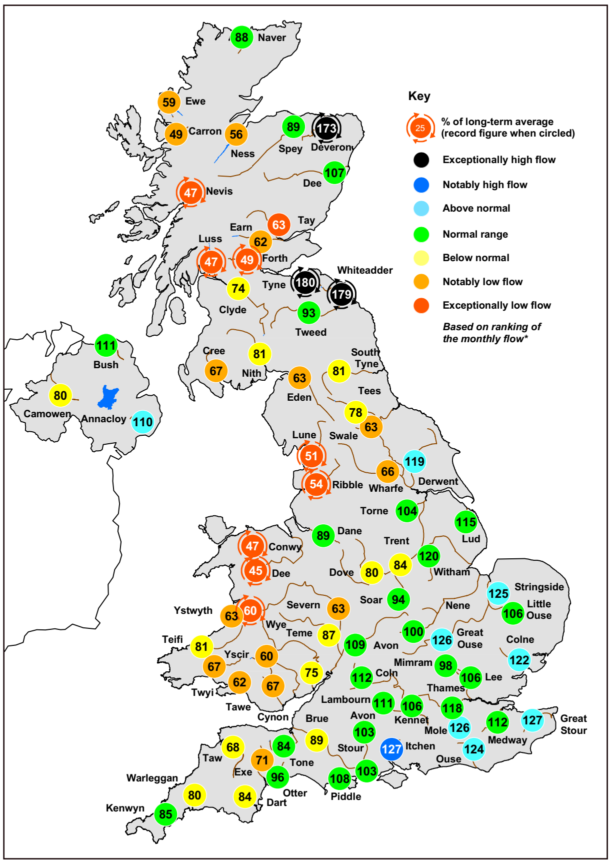


Figure 9 *Runoff accumulations January-June 2010 as a percentage of the long term average.*

An exceptionally wet July then generated a notable recovery in flows in many responsive catchments. In most regions this recovery was reinforced during August and Flood Alerts were relatively common (for the late summer) during the fourth week. One result of this seasonally very early recovery in flow rates, was that minimum flows recorded during 2010 were generally close to the long term average. At a national scale, the Q_{95} flow was well within the normal range, a contrast to the Q_5 and mean flows. Generally, river flows remained within the normal range through the autumn but spate conditions were common in early November. On the 16th an extremely intense storm, with rainfall totals approaching 40mm in an hour at some localities, resulted in outstanding runoff rates in parts of Cornwall. For several rivers draining from Bodmin Moor, the peak flows had estimated return periods of between 10 and 50 years. Concurrent high tides were an exacerbating factor in coastal settlements – contributing to particularly severe flood damage in Mevagissey, St Blazey and Lostwithiel. Generally river flows then declined rapidly once more and frozen catchment conditions in mid-December saw runoff rates approach seasonal minima. A brief return to more maritime weather patterns triggered a recovery of river flows during the final week of 2010; nonetheless UK outflows were the lowest for December since 1975.

Groundwater

Groundwater is a major source of public supply across much of eastern and southern England and, via springs and seepages, provides an important component of river flows in permeable catchments.

Across most aquifer outcrop areas annual rainfall for 2010 was below average – most outcrops receiving between 80% and 95% of the 1971-2000 average. Importantly however, rainfall deficiencies were substantially greater through the winter and early spring when most groundwater recharge normally occurs. Generally, aquifer recharge was both limited and erratic through the 2009/10 winter half-year (October-March) with particularly meagre groundwater replenishment in December and January. Fortunately however, this was largely counterbalanced by exceptional infiltration rates during November 2009 and above average recharge in February 2010. As a consequence, groundwater levels in most index wells and boreholes began their seasonal decline from levels a little above the normal spring maxima.

A brisk rise in soil moisture deficits through April signalled an early end to the 2009/10 recharge season in most aquifer outcrop areas. Thereafter, groundwater hydrograph traces for most index boreholes exhibited the normal seasonal pattern through the late spring and early summer (Figure 10). Over this period, the importance of groundwater was well demonstrated; despite the developing drought, levels in most index wells remained in the normal range, and continued to do so throughout much of the summer. However, the exceptionally dry soil conditions precluded anything but very local infiltration through the summer and considerably delayed the seasonal onset of recharge during the autumn. Correspondingly, groundwater levels continued to fall and by late-September levels were moderately depressed over wide areas, particularly in the more responsive chalk outcrops in southern England (see Figure 11).

In most index wells and boreholes minimum levels in 2010 were recorded later in the year than usual and were mostly below the average annual minima. Generally however, they were above those registered in drought years – for example during the early- and middle-1990s.

The sustained November rainfall initiated seasonal groundwater level recoveries in most western and northern outcrop areas but in southern England natural base levels were being approached in a few index wells (see, for example, the Tilshead hydrograph in Figure 10). Most recoveries stalled during December due to a combination of limited precipitation and frozen ground conditions. Levels in most index boreholes remained below the early winter average and were particularly depressed in some central and southern aquifer outcrop areas where recessions continued through the early winter. At year-end groundwater levels were still in decline in many slow-responding aquifer units (see the hydrograph trace for Heathlanes in Figure 10).

Reservoir stocks

Overall reservoir stocks for most of the UK were healthy throughout almost all of the 2007-09 period and, thanks in part to exceptional inflows during November 2009, stocks in the great majority of index reservoirs were within 10% of capacity entering 2010. Limited rainfall, and frozen headwaters, restricted inflows to many reservoirs during January but with stocks already close to capacity (in almost all areas) at the turn of the year, the limited inflows through the late winter had only a modest impact on the water resources outlook.

Thereafter however, the arid nature of the spring, particularly in western gathering grounds, translated into a steep decline in

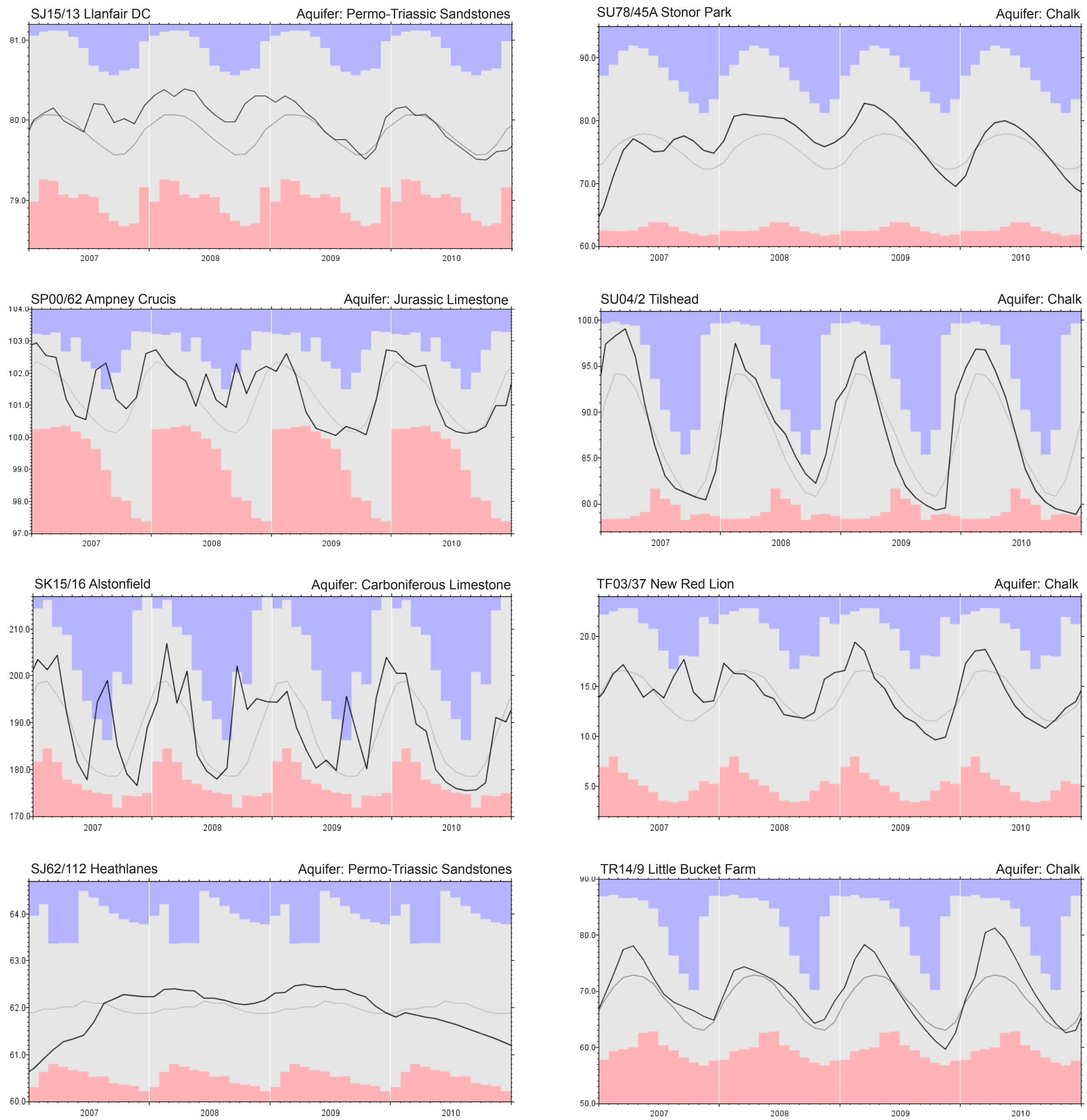


Figure 10 *2007-2010 groundwater level hydrographs (levels in metres above Ordnance Datum). Pre-2010 monthly max and min levels are coloured and the grey trace is the long term average.*

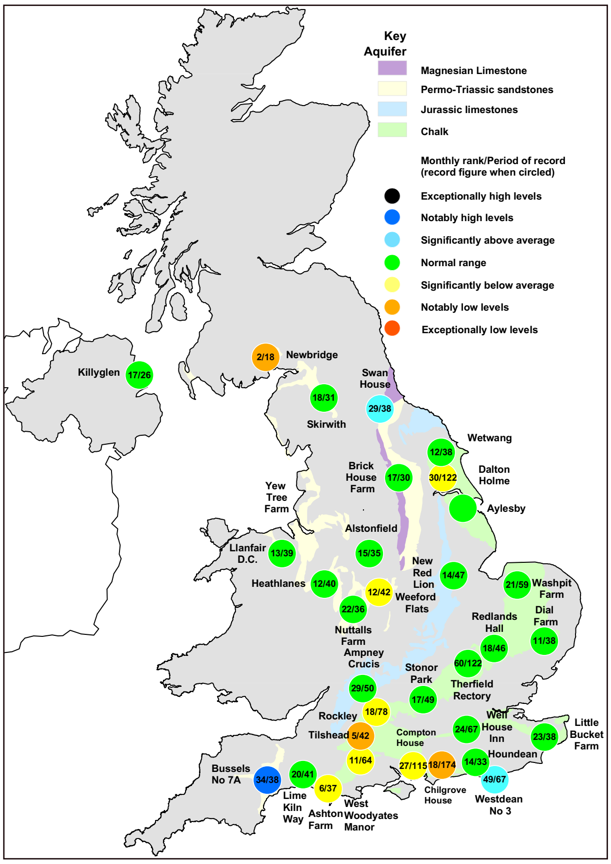


Figure 11 *Groundwater levels in September 2010*

reservoir stocks. Through the late spring and early summer stocks in many large reservoirs fell by more than 30% and, entering July, estimated overall stocks for England & Wales had fallen to their lowest (for the time of year) since 1990 (see Figure 12). Particularly depressed levels were recorded in some major reservoirs in western Britain. In Scotland, Loch Katrine reported its lowest early July stocks in a series from 1994 and in north-west England the combined stocks in a group of large reservoirs were the lowest since the 1984 drought. With some major impoundments only a little over half full, a hosepipe ban affecting 6.5 million consumers was introduced in north-west England; at the same time Scottish Water applied for a Drought Order covering part of Dumfries and Galloway.

The relative wetness of the July-September period (England & Wales registered its 5th highest rainfall since 1968 in this timeframe) was particularly welcome in water resources terms. Aided by the steepness and thin soil cover of most upland gathering grounds, most reservoir stocks had returned to the seasonal average by the early autumn. As usual, the summer rainfall had a much more modest impact in the English Lowlands where stocks in many gravity-fed reservoirs continued to decline. Stocks in most pumped-storage reservoirs held up well but overall reservoir stocks for England & Wales for early August were still the 2nd lowest since 1996.

September was a pivotal month in relation the water resources outlook. Substantial increases in reservoir levels characterised Scotland and Northern Ireland, and England & Wales registered its largest increase (for the month) on record. In southern England however, the relatively modest rainfall failed to reverse the seasonal decline in reservoir stocks.

Rainfall patterns in the late autumn reinforced the regional contrasts in reservoir stocks. At the end of November stocks exceeded 90% of capacity in the majority of index reservoirs in Scotland, Wales and Northern Ireland but had fallen considerably below the seasonal average elsewhere. The very dry December resulted in a decline in stocks in most gravity-fed reservoirs and, entering 2011, overall stocks for England & Wales were the lowest since 1997 (for early January). Stocks were particularly depressed, for the early winter, in parts of southern England At Bewl Water for example, stocks had fallen to marginally above 50% of capacity and were the equal 2nd lowest for the year-end since 1990; stocks were seasonally low in north-west England also.

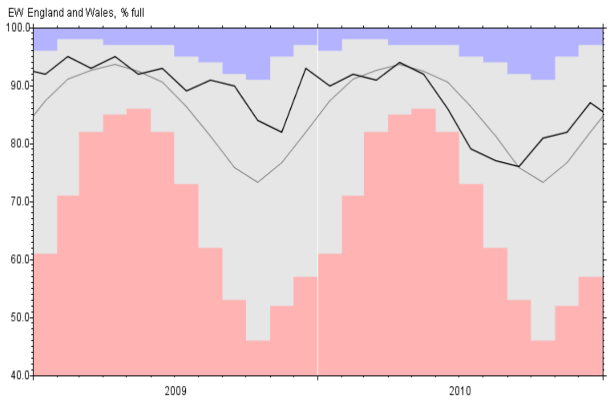
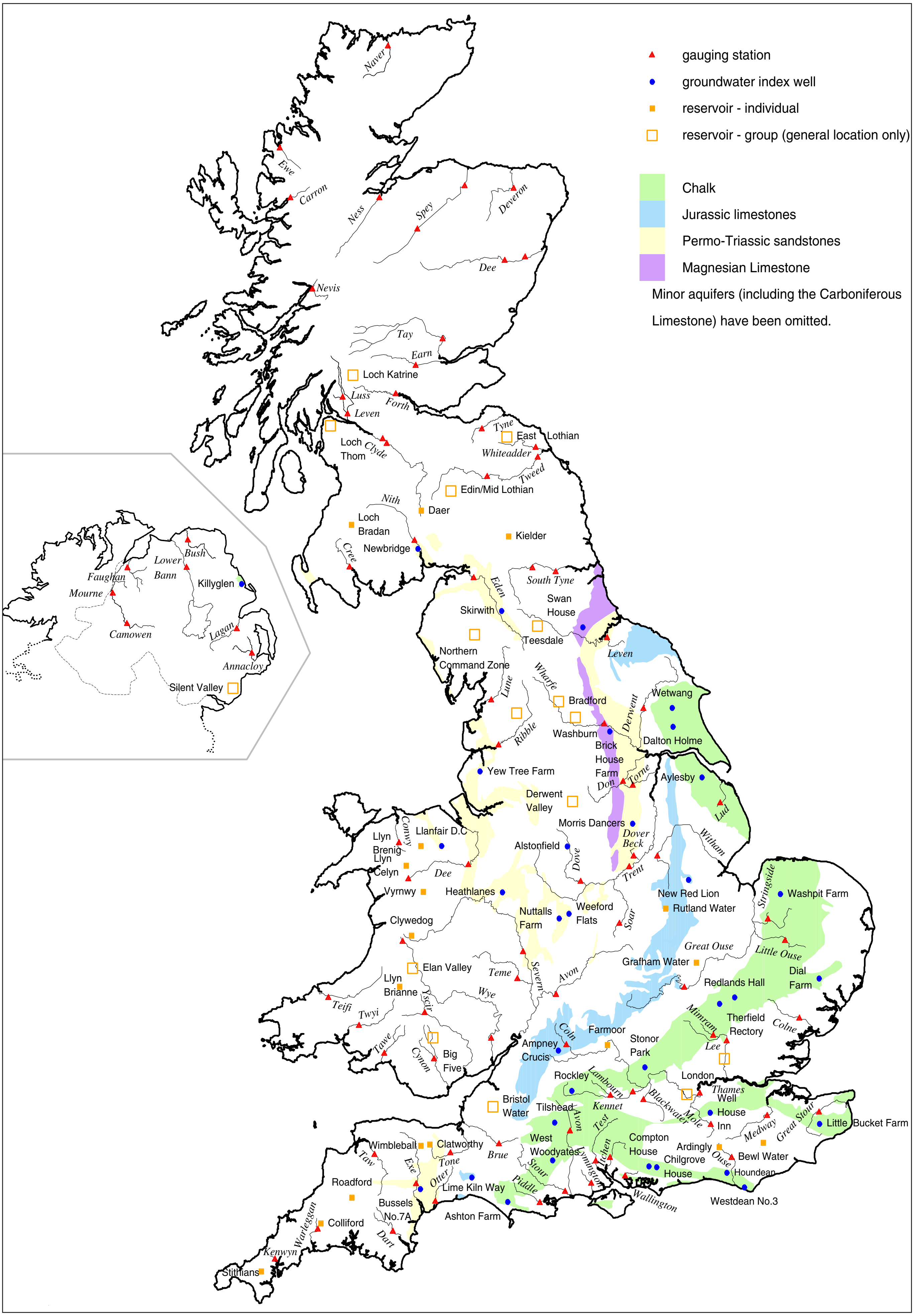


Figure 12 *Variation in overall reservoir stocks for England & Wales (black trace is the monthly stocks and the grey trace is the average; the blue and pink envelopes show the period max. and min. stocks)*
Data sources: Water Service Companies and the Environment Agency

Reference

1. Hough, M. and Jones, R. J. A. (1997). The Meteorological Office Rainfall and Evaporation Calculation System: MORECS Version 2.0 an overview. Hydrol. Earth. Sys. Sci. 1, 227-239

Location Map



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