Hydrological Summary

for the United Kingdom

December 2023

General

Following a cold start, mild and unsettled weather dominated December, with four named storms leading to widespread high flows and associated flood warnings. Rainfall during December was above average for the UK, leading to above normal river flows, many exceptionally so in England, eastern Scotland, and Northern Ireland. Reservoir stocks increased in most impoundments and remained above average at the national scale, although at Celyn & Brenig and Daer stocks were 13% and 12% lower than average respectively. Groundwater levels continued to rise across the major aquifers and were mainly above normal to exceptionally high for the time of year. The water resources position is favourable, and the current UK Hydrological Outlook indicates above normal flows are most likely over the coming months. Flood risk is elevated due to saturated ground and high groundwater levels meaning any further rainfall is likely to prompt a rapid response in flows.

Rainfall

The cold conditions at the end of November continued into the start of December with some very hard frosts and snow. An Amber Weather Warning for snow was issued and a major incident declared in Cumbria due to a number of road closures including the M6. A snow depth of 11cm was recorded at Copley (County Durham) and Middleton (Derbyshire) on the 3rd. A succession of Atlantic low-pressure systems brought the first named storms ('Elin' and 'Fergus') on 9th to 10th with wet, windy, and disruptive weather. Accumulated totals between the 7th and 11th were 30-50mm widely across the UK and over 100mm across upland areas in Wales, north-west England, south-west England and eastern Scotland and transport disruption was reported in many areas including Yorkshire and South London. The unsettled weather continued through the rest of the month, with further rainfall (118mm was recorded at Kinlochewe (Ross & Cromarty) on the 17th), and storm 'Pia' brought additional disruptive wet and windy conditions on the 21st to northern Britain. On the 27th storm 'Gerrit' brought more rainfall to already wet catchments and widespread impacts across the UK. There was major travel disruption over the Christmas period due to flooding, fallen trees, landslips causing road and rail closures and stranded travellers at London Kings Cross. On the 28th, properties lost power (e.g. 36,000 in Ceredigion due to a lightning strike) and a 'mini tornado' in Stalybridge (Greater Manchester) damaged around 100 homes. December rainfall was above average for the UK (148%), with all areas apart from central Scotland seeing above average rainfall. A number of regions recorded in excess of 180% of average, including Severn-Trent, Yorkshire, North East Scotland (with the latter recording its wettest December in a series from 1890). For the July to December period, rainfall was above average, and it was the wettest July-December for the UK as a whole (in a series since 1890).

River Flows

Recessions at the majority of catchments continued in the first few days of the month, but quickly reversed following the onset of more unsettled conditions. The Dover Beck recorded its second highest December peak flow on the 4th, as did the Annacloy on the 7th (in series from 1972 and 1980 respectively). Heavy rain from storm 'Elin' and 'Fergus' between 9th and 10th led to a response and the Yorkshire Don, Yorkshire Derwent, Dove, Derbyshire Derwent, and the Piddle all recorded top five December peak flows following these events (all in series of at least 50 years). River flows in responsive areas receded between storms, however peaked once again following storm 'Gerrit' on the 27th (e.g. the Tees and Ouse recorded their sixth highest December flows in series of at least 55 years). December mean flows were above average across the UK, with the exception of western Scotland where flows were normal. Many catchments in eastern Scotland, across England and in Northern Ireland recorded over twice their average December flows. Some catchments in these areas recorded the highest average December monthly river flow on record including the Deveron, Ythan, Mersey, Derbyshire Derwent, and Stringside – all in records in excess of 40 years. Over the six-month period of July-December monthly river flows in some catchments in Northern Ireland (Mourne and Annacloy), England (Ribble and Stringside) were also the highest on record – all in series in excess of 40 years. For 2023, mean flows in south Wales and south-west England (e.g. Twyi, Dart, Brue, Stour) were the highest annual mean flows on record – in series in excess of 50 years. The October-December outflows for Great Britain were the second highest in records from 1961, whilst the annual outflow (January-December) for Northern Ireland was the highest in a record from 1980.

Soil Moisture and Groundwater

Soil moisture deficits were overcome across the UK following the above average rainfall and soil moisture was above field capacity for most COSMOS-UK sites. Groundwater levels continued to rise across the Chalk and were notably or exceptionally high at the majority of sites. Exceptionally high levels were observed in the Chalk of Yorkshire and Lincolnshire. Levels peaked mid-month in the Wessex Chalk and South Downs; the end December values in these areas are relative low points in fluctuating hydrographs with an overall rising trend. For example, at West Woodyates Manor the end of December levels were in the normal range, but mid-month they were over 5m higher. Further recharge to the Jurassic limestones led to a record high level (in a 60-year series) at New Red Lion. Levels rose in the Magnesian Limestone and became exceptionally high at Aycliffe and remained so at Brick House Farm. Groundwater levels rose at all sites in the Carboniferous Limestone with notably high levels at Greenfield Garage and Alstonfield, and above normal levels at Pant y Lladron. In the Permo-Triassic Sandstones levels continued to rise, remaining exceptionally high at Weir Farm, and becoming so at Skirwith. Exceptionally high levels continued to be observed at Lime Kiln Way in the Upper Greensand. The Devonian sandstones received further recharge and the level became above normal for the time of year at Feddan Junction. The groundwater level rose at Royalty Observatory, in the Fell Sandstone, and became exceptionally high.

National Hydrological Monitoring Programme | UK Centre for Ecology & Hydrology | BGS British Geological Survey

Rainfall . . . Rainfall . . .

Met Office

Rainfall accumulations and return period estimates

Percentages are from the 1991-2020 average.

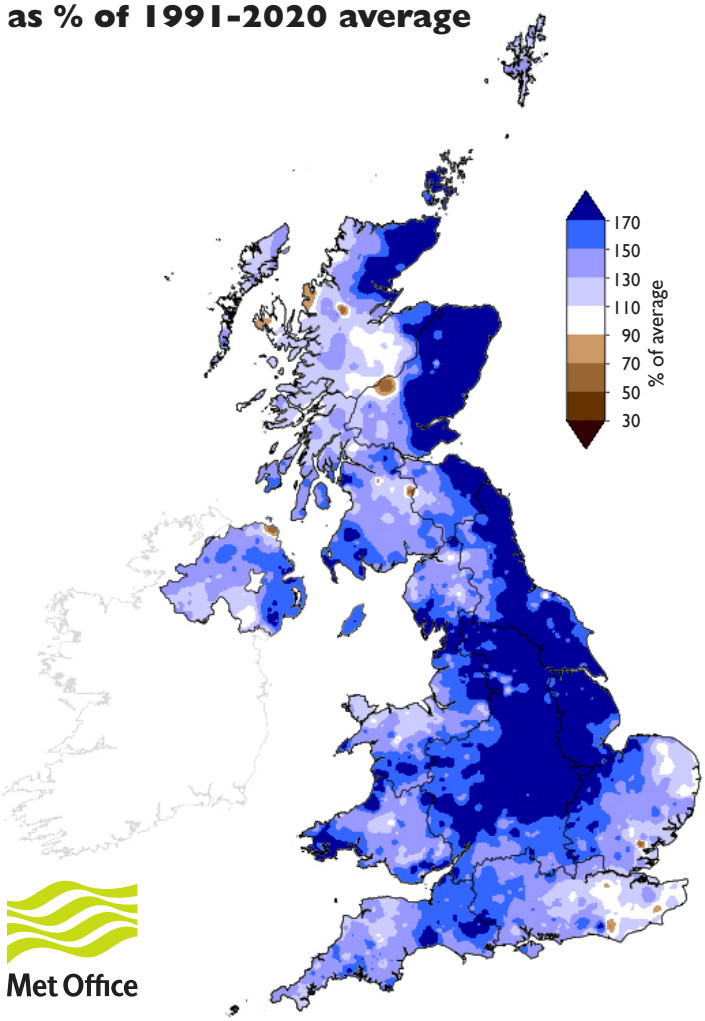
Region	Rainfall	Dec 2023	Nov23 – Dec23	RP	Oct23 – Dec23	RP	Jul23 – Dec23	RP	Jan23 – Dec23	RP
United Kingdom	mm	**189**	308		479		828		1290	
	%	**148**	123	10-15	128	25-40	129	>100	111	25-40
England	mm	**145**	256		403		677		1046	
	%	**158**	139	10-20	147	50-80	140	>100	120	60-90
Scotland	mm	**246**	368		567		993		1574	
	%	**141**	109	2-5	112	5-10	116	15-25	100	5-10
Wales	mm	**258**	433		641		1093		1680	
	%	**147**	128	8-12	129	10-20	134	50-80	115	15-25
Northern Ireland	mm	**170**	262		453		910		1399	
	%	**140**	107	2-5	127	20-30	144	>>100	121	>100
England & Wales	mm	**160**	280		436		734		1132	
	%	**155**	136	10-20	143	40-60	139	>100	119	50-80
North West	mm	**231**	390		541		1020		1538	
	%	**158**	140	20-30	131	15-25	140	>100	120	50-80
Northumbria	mm	**153**	258		429		726		1038	
	%	**166**	137	20-30	156	>>100	144	>>100	114	20-30
Severn-Trent	mm	**147**	228		383		625		964	
	%	**180**	142	10-20	159	70-100	142	80-120	120	25-40
Yorkshire	mm	**162**	267		415		721		1051	
	%	**182**	149	20-30	158	>100	151	>100	121	30-50
Anglian	mm	**92**	162		290		484		746	
	%	**158**	135	5-10	157	60-90	137	30-50	118	10-20
Thames	mm	**106**	202		325		544		894	
	%	**143**	132	5-10	141	15-25	135	25-40	122	15-25
Southern	mm	**119**	263		441		648		1026	
	%	**125**	137	5-10	154	20-35	139	30-50	125	20-35
Wessex	mm	**159**	292		450		734		1176	
	%	**157**	142	10-20	147	20-35	145	>100	129	80-120
South West	mm	**212**	407		556		914		1479	
	%	**139**	136	10-20	128	10-15	131	25-40	117	25-40
Welsh	mm	**245**	413		616		1049		1615	
	%	**147**	128	5-10	129	10-20	133	50-80	115	15-25
Highland	mm	**276**	402		616		1086		1763	
	%	**131**	100	2-5	103	2-5	110	5-10	95	2-5
North East	mm	**190**	293		529		822		1214	
	%	**186**	136	10-20	157	>100	139	>>100	114	20-35
Tay	mm	**233**	343		628		1034		1521	
	%	**157**	115	5-10	140	40-60	137	>100	109	10-20
Forth	mm	**196**	291		486		838		1285	
	%	**148**	114	5-10	126	15-25	124	40-60	103	5-10
Tweed	mm	**177**	271		428		762		1135	
	%	**152**	119	5-10	125	20-30	127	60-90	104	5-10
Solway	mm	**265**	396		490		968		1579	
	%	**150**	114	5-10	95	2-5	110	5-10	100	2-5
Clyde	mm	**286**	438		623		1125		1836	
	%	**133**	105	2-5	101	2-5	108	5-10	97	2-5

% = percentage of 1991-2020 average *RP = Return period*

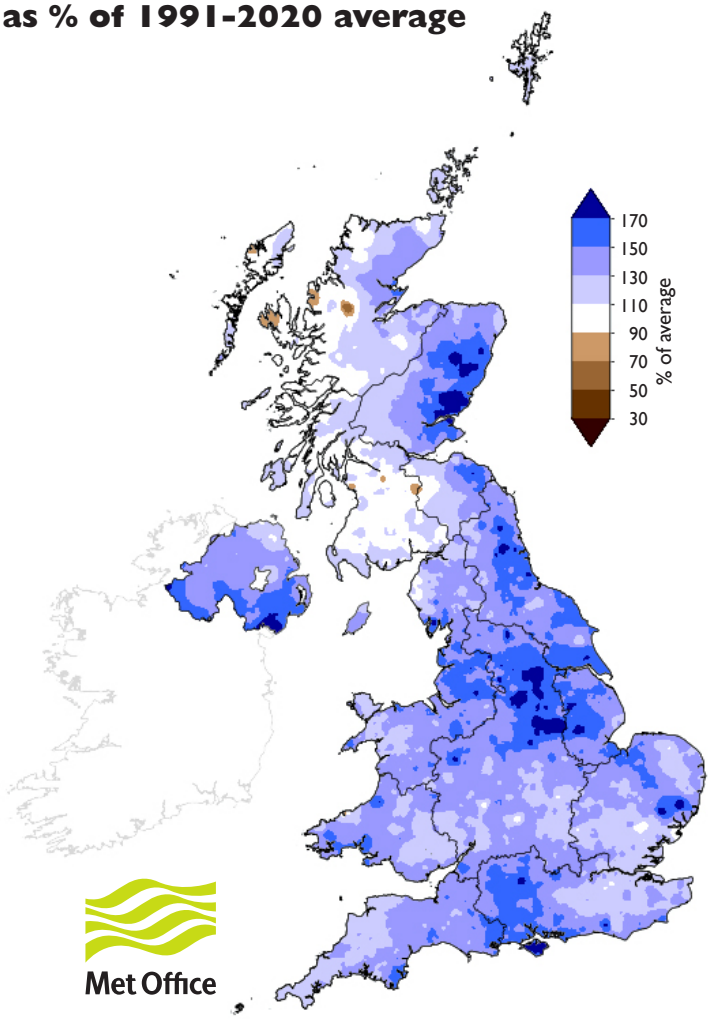
Important note: Figures in the above table may be quoted provided their source is acknowledged. Where appropriate, specific mention must be made of the uncertainties associated with the return period estimates. The RP estimates are based on data provided by the Met Office and reflect climatic variability since 1836; they also assume a stable climate. The quoted RPs relate to the specific timespans only; for the same timespans, but beginning in any month the RPs would be substantially shorter. The timespans featured do not purport to represent the critical periods for any particular water resource management zone. For hydrological or water resources assessments of drought severity, river flows and/or groundwater levels normally provide a better guide than return periods based on regional rainfall totals. Note that precipitation totals in winter months may be underestimated due to snowfall undercatch. All monthly rainfall totals since January 2023 are provisional. Source: Data from HadUK-Grid dataset at 1km resolution v1.2.0.0.

Rainfall . . . Rainfall . . .

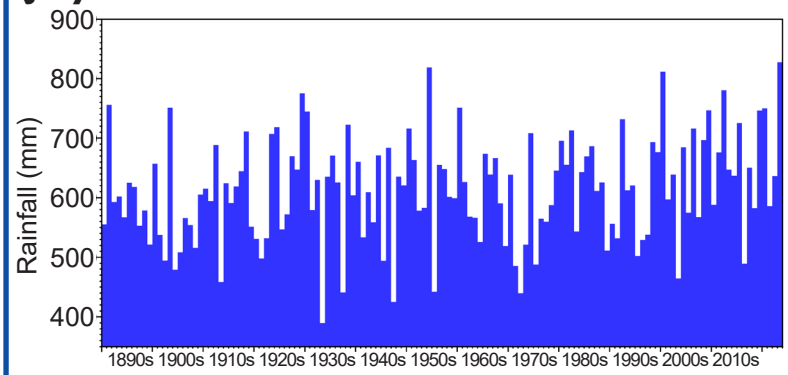
December 2023 rainfall as % of 1991-2020 average



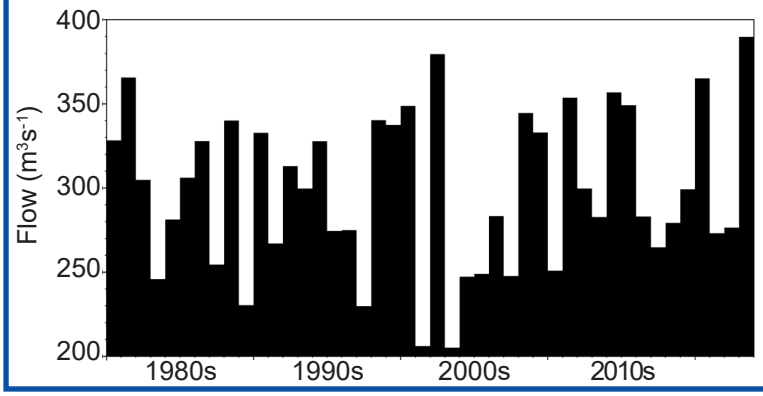
July 2023 - December 2023 rainfall as % of 1991-2020 average



July - December rainfall for the UK



January - December outflows for Northern Ireland



UK Hydrological Outlook

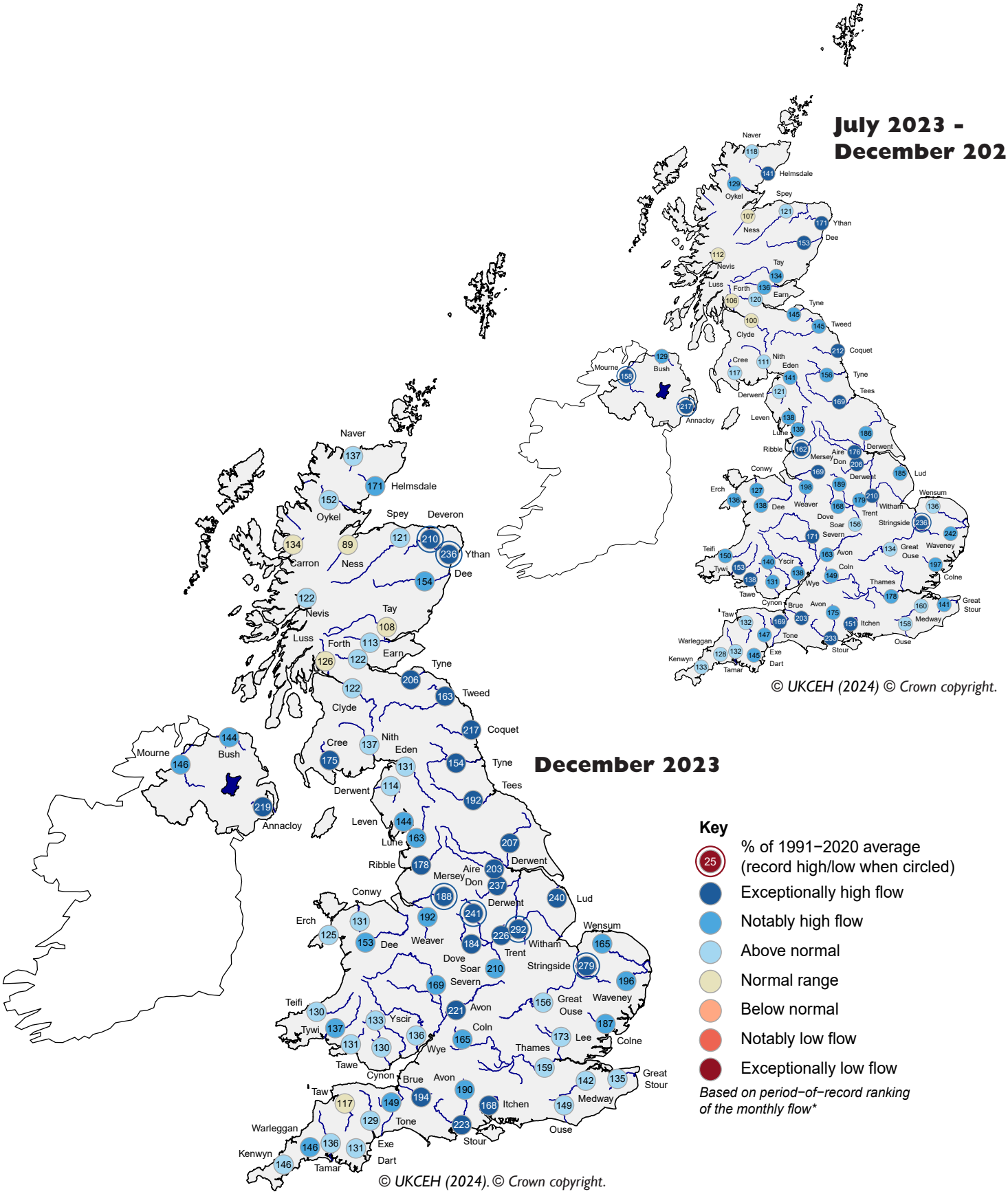
The Hydrological Outlook provides an insight into future hydrological conditions across the UK. Specifically it describes likely trajectories for river flows and groundwater levels on a monthly basis, with particular focus on the next three months.

The complete version of the Hydrological Outlook UK can be found at: www.hydoutuk.net/latest-outlook/

Period: **from January 2024**
Issued: **10.01.2024**
using data to the end of December 2023

The outlook for January is for above normal river flows in eastern Britain, and normal to above normal river flows in western Britain. The three-month outlook is for normal to above normal river flows for the whole of the UK. Groundwater levels are likely to be notably high to exceptionally high for January, and normal to notably high in January-March over the next three months.

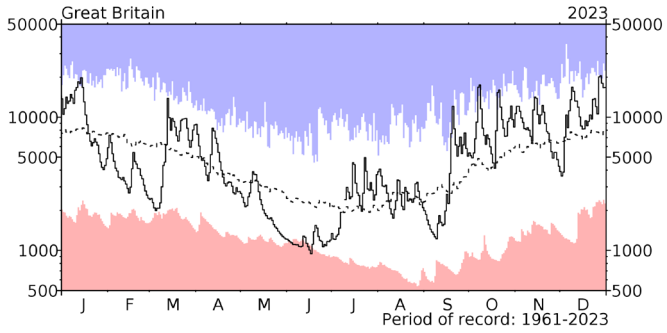
River flow . . . River flow . . .

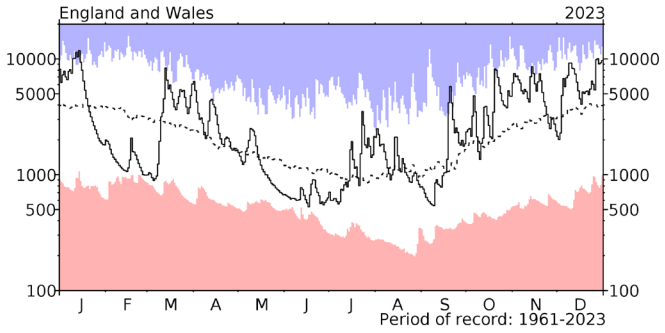


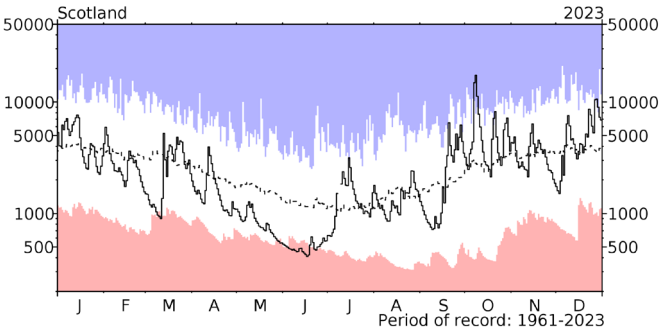
River flows

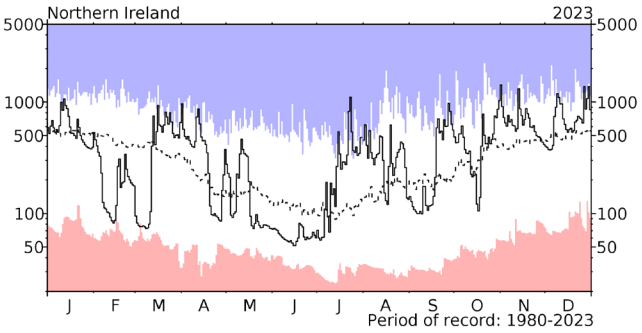
*Comparisons based on percentage flows alone can be misleading. A given percentage flow can represent extreme drought conditions in permeable catchments where flow patterns are relatively stable but be well within the normal range in impermeable catchments where the natural variation in flows is much greater. The categories of the spots are based on the full period-of-record data whereas the percentages are based on the 1991-2020 averaging period for consistency between rainfall and river flows. Percentages may be omitted where flows are under review.

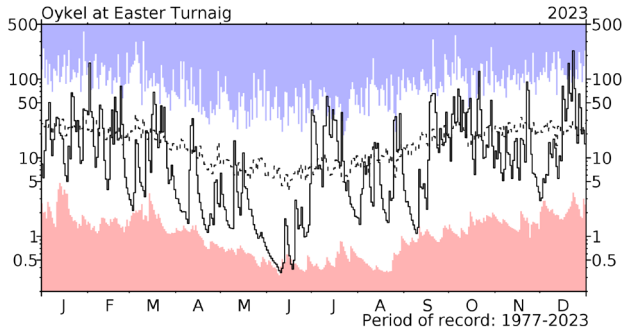
River flow . . . River flow . . .

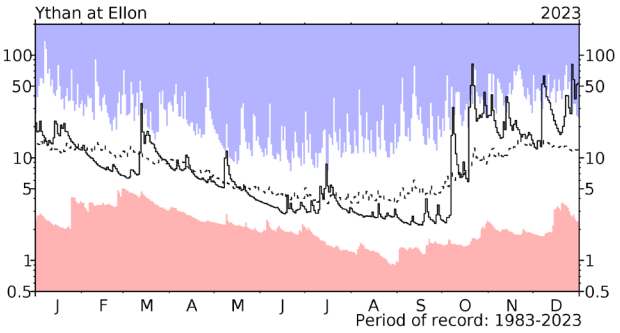


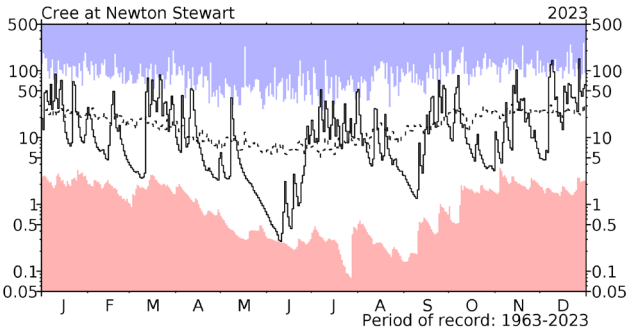


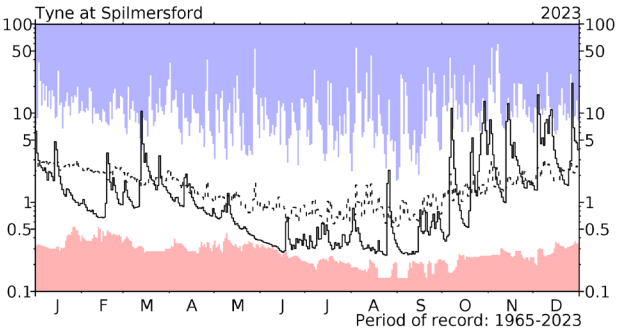


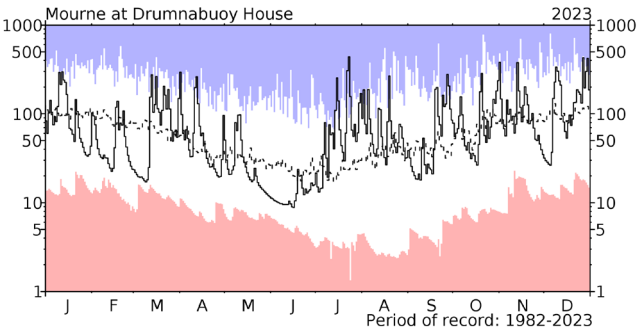


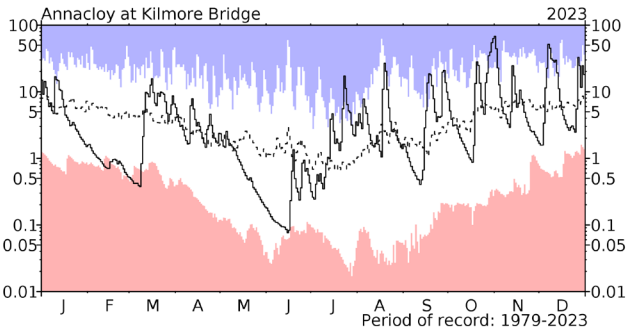








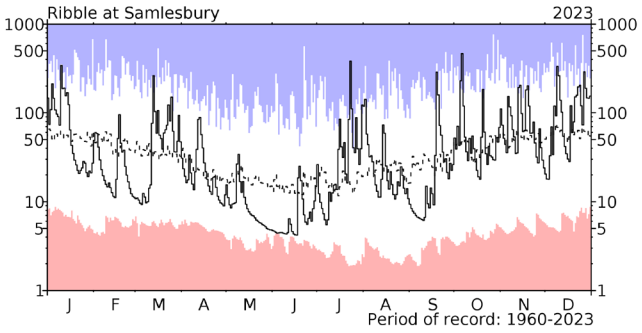


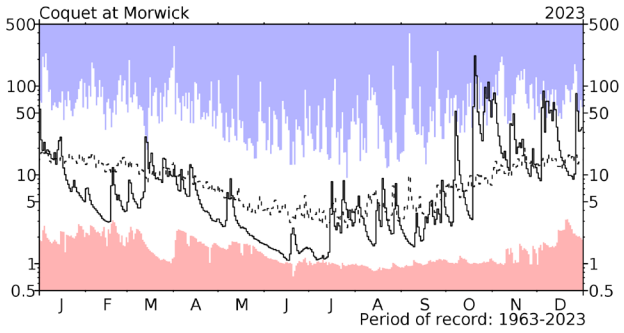


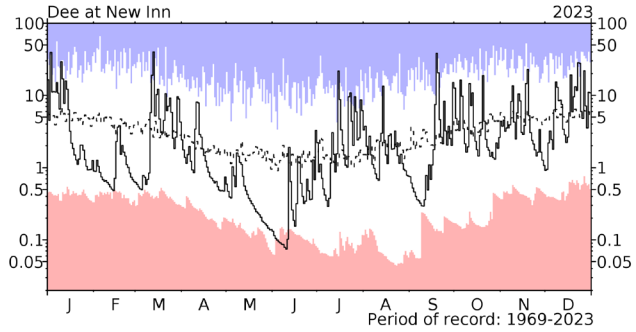
River flow hydrographs

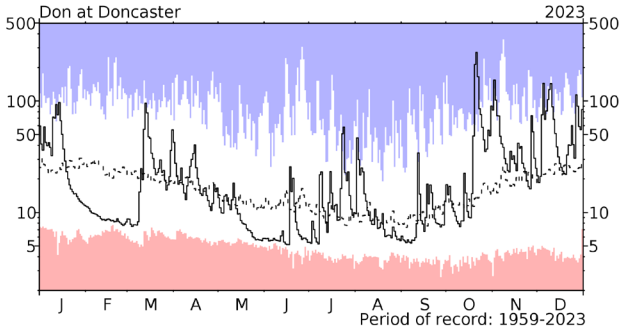
*The river flow hydrographs show the daily mean flows (measured in m^3s^{-1}) together with the maximum and minimum daily flows prior to January 2023 (shown by the shaded areas). Daily flows falling outside the maximum/minimum range are indicated where the bold trace enters the shaded areas. The dashed line represents the period-of-record average daily flow.

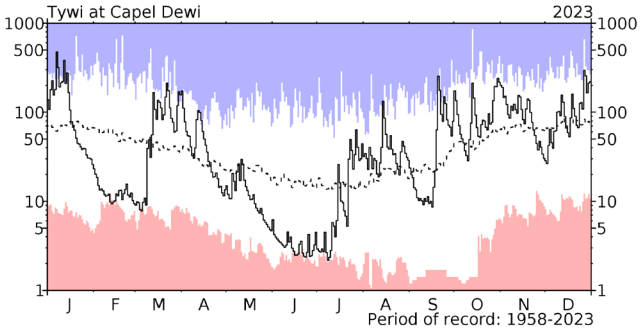
River flow . . . River flow . . .

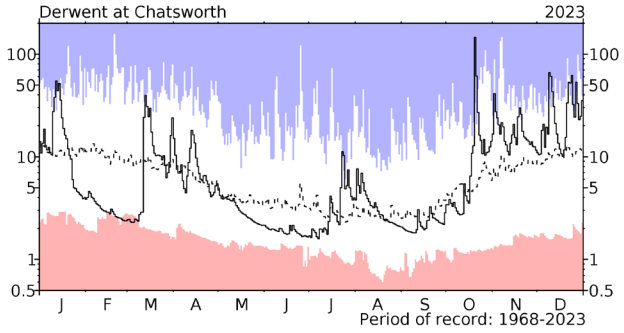


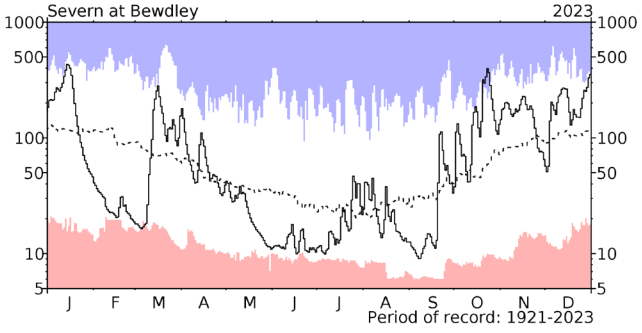


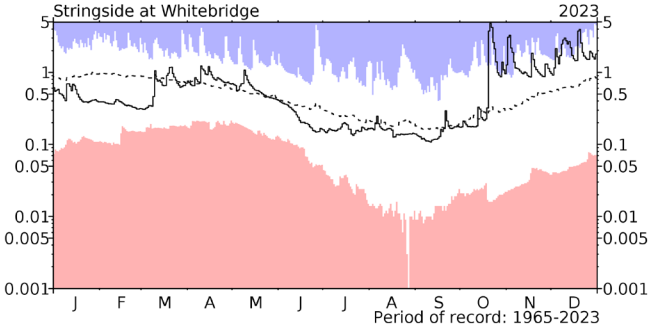


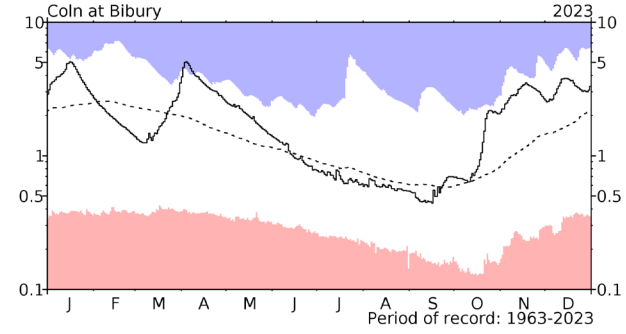


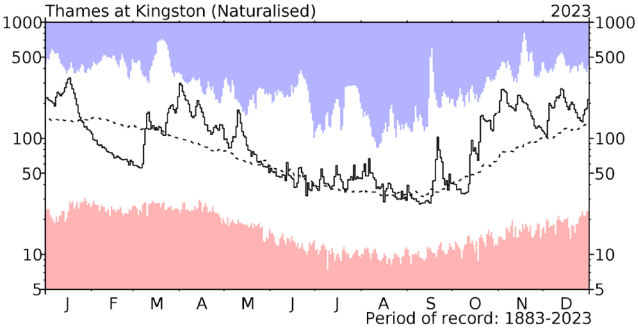


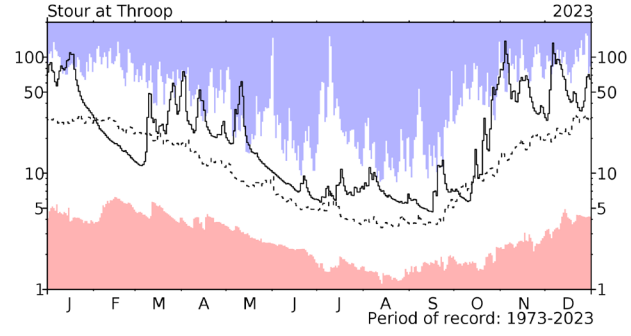


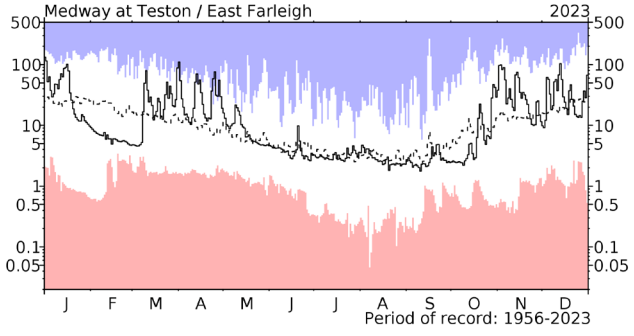




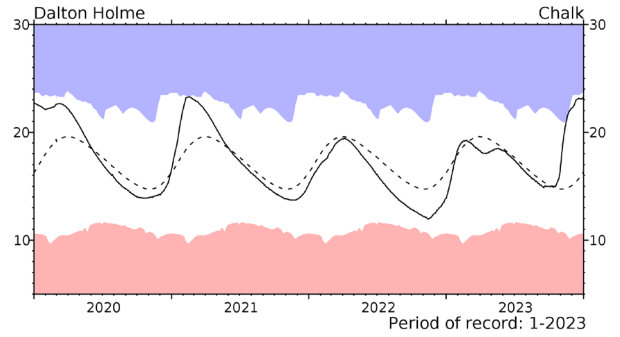


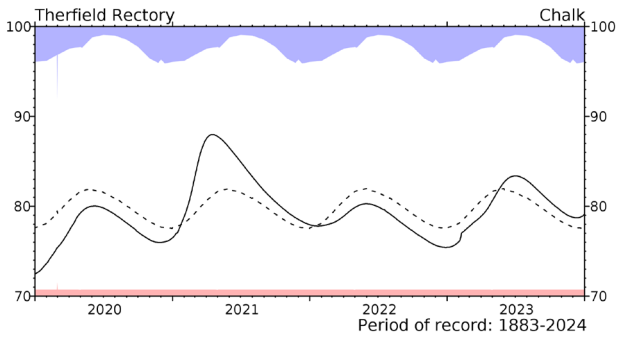


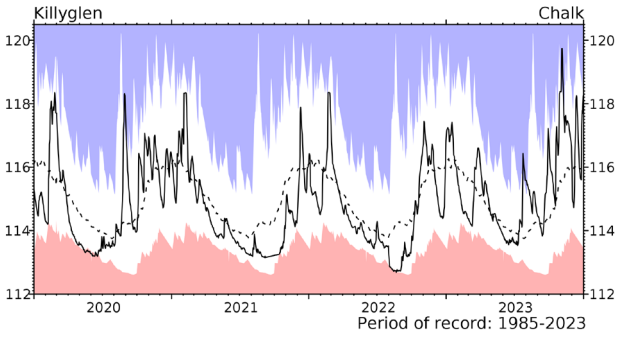


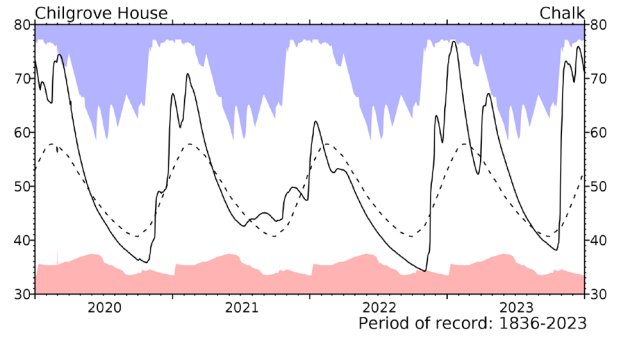


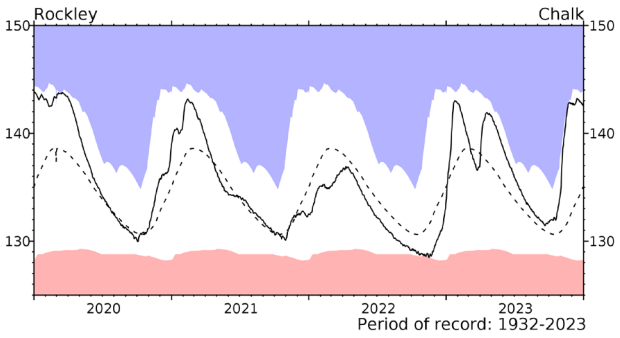
Groundwater…Groundwater

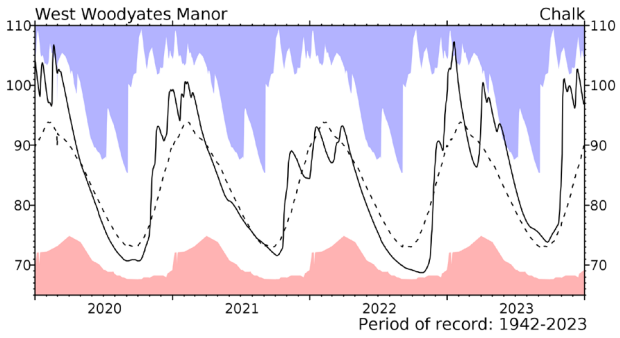


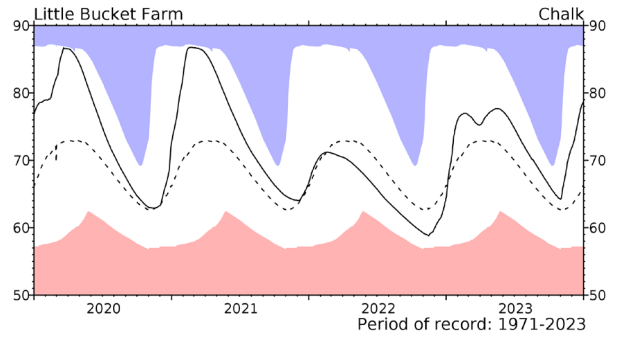


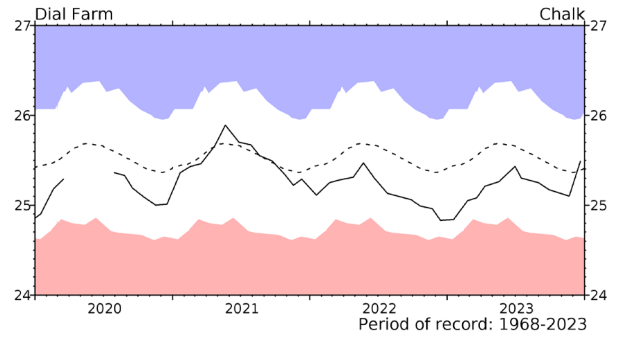


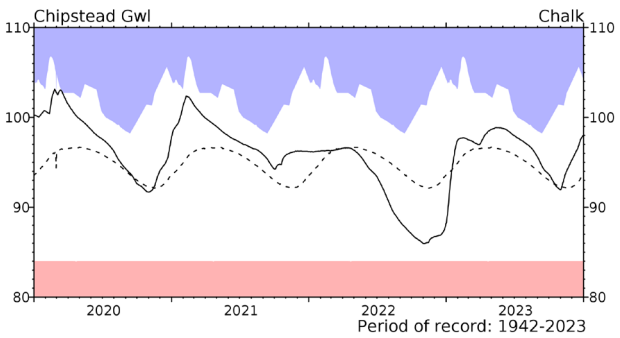


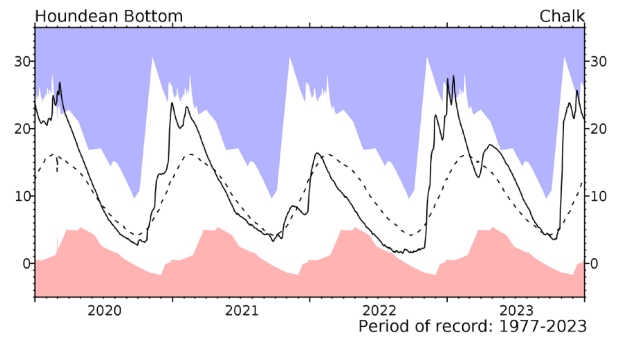






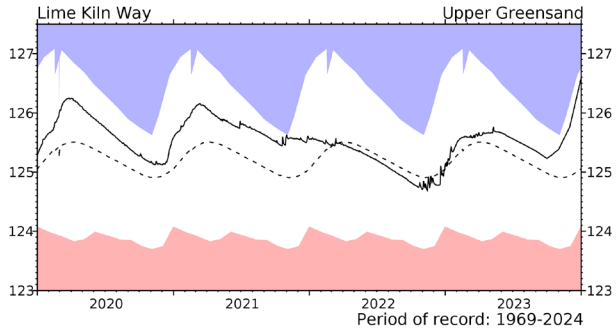


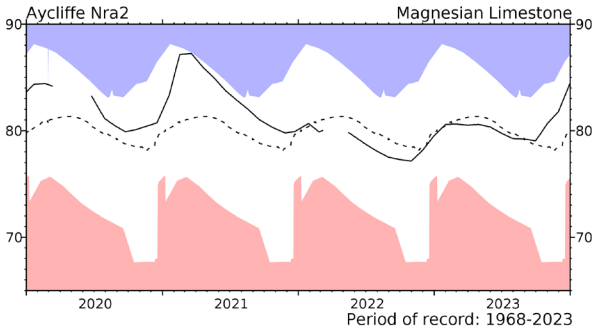


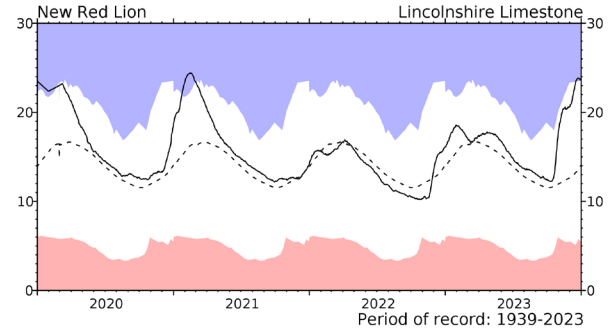


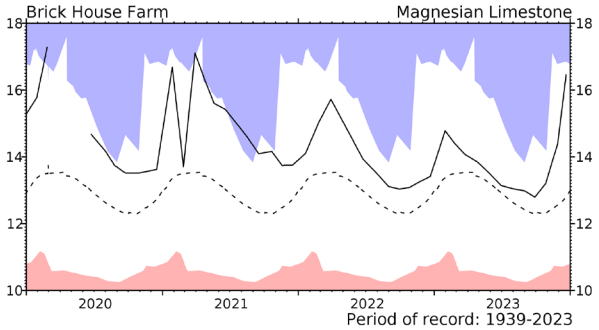
Groundwater levels (measured in metres above ordnance datum) normally rise and fall with the seasons, reaching a peak in the spring following replenishment through the winter (when evaporation losses are low and soil moist). They decline through the summer and early autumn. This seasonal variation is much reduced when the aquifer is confined below overlying impermeable strata. The monthly mean and the highest and lowest levels recorded for each month are calculated with data from the start of the record to the end of 2019. Note that most groundwater levels are not measured continuously and, for some index wells, the greater frequency of contemporary measurements may, in itself, contribute to an increased range of variation.

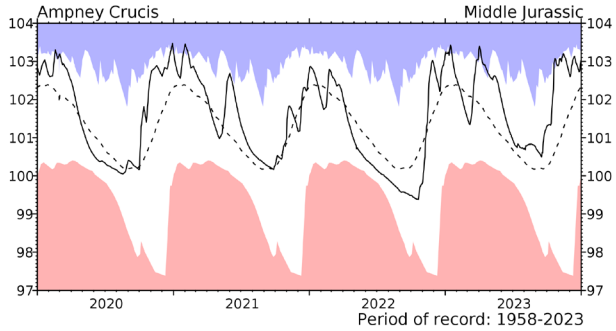
Groundwater…Groundwater

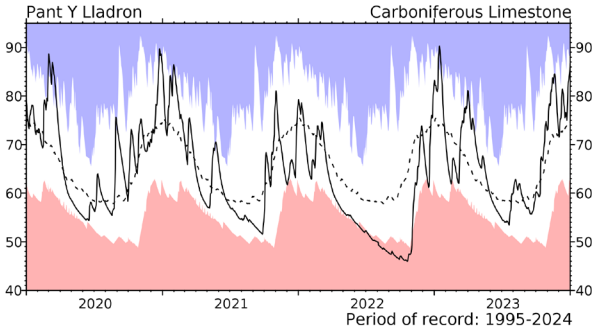


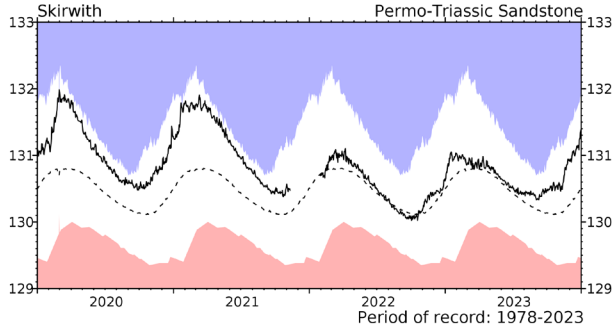


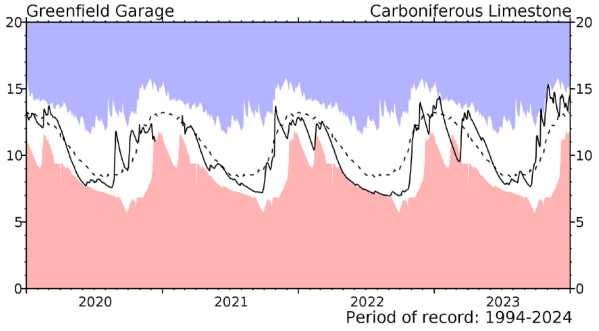


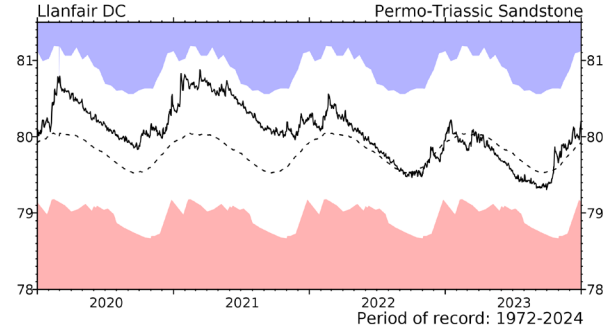


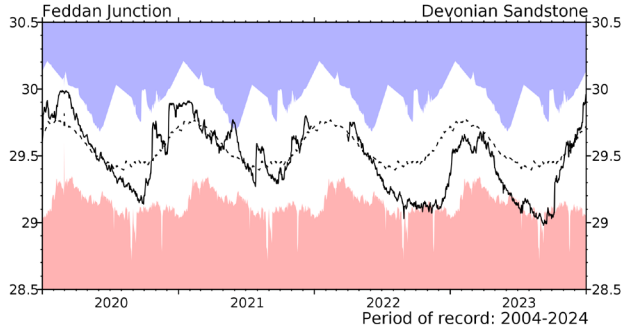


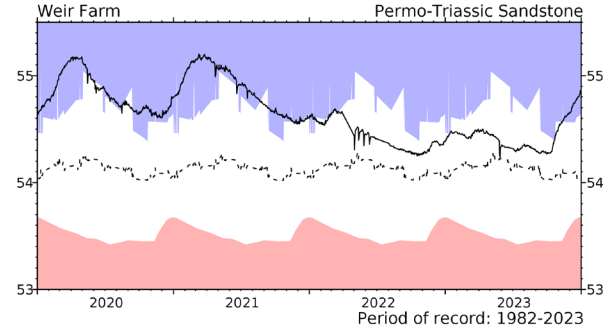


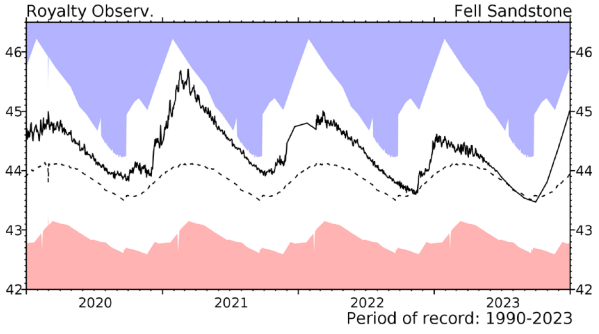


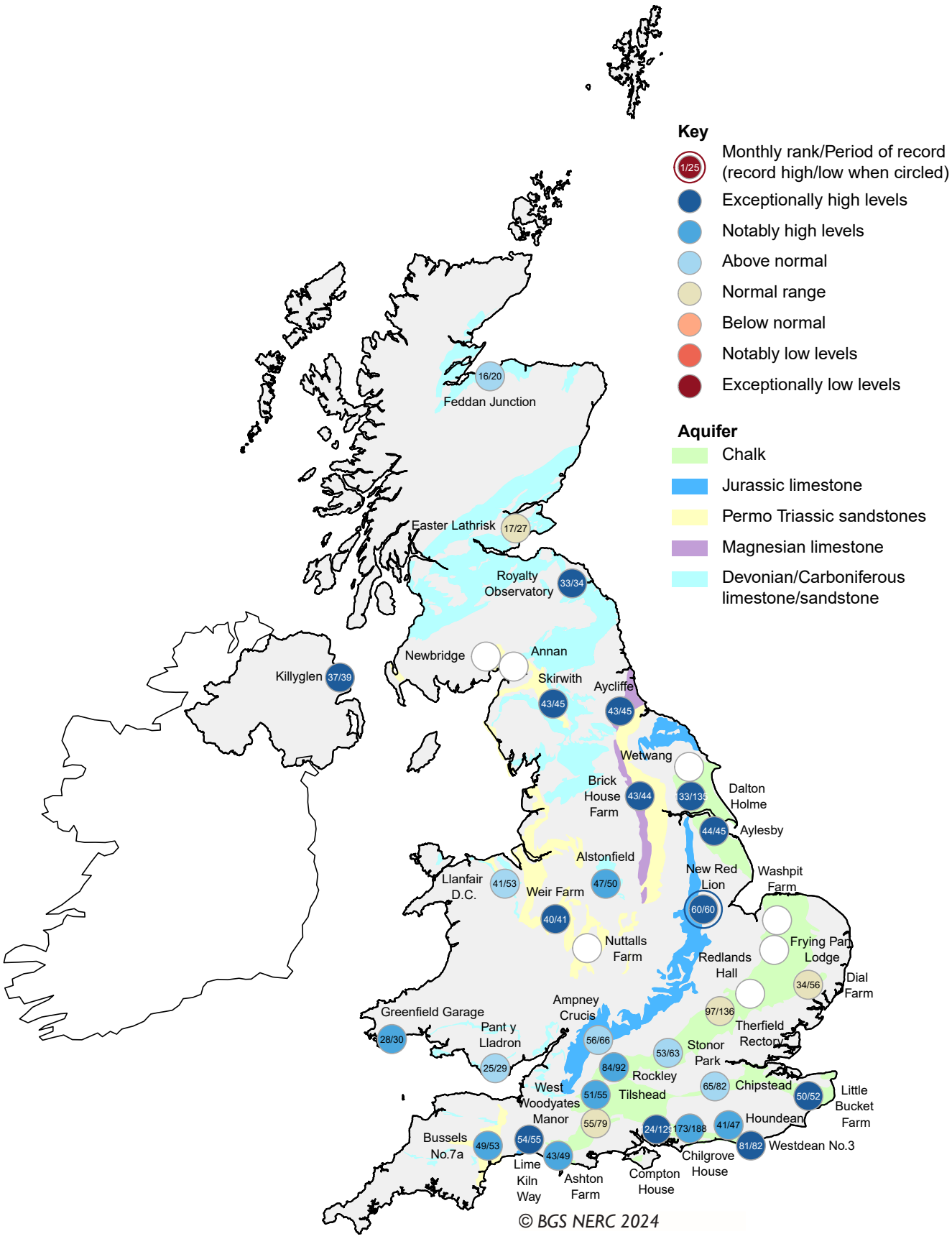










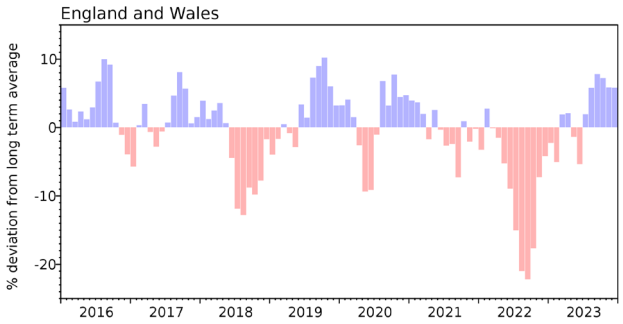


Groundwater levels - December 2023

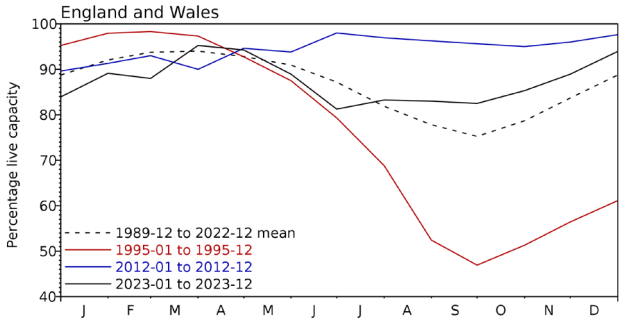
The calculation of ranking has been modified from that used in summaries published prior to October 2012. It is now based on a comparison between the most recent level and levels for the same date during previous years of record. Where appropriate, levels for earlier years may have been interpolated. The rankings are designed as a qualitative indicator, and ranks at extreme levels, and when levels are changing rapidly, need to be interpreted with caution.

Reservoirs . . . Reservoirs . . .

Guide to the variation in overall reservoir stocks for England and Wales



Comparison between overall reservoir stocks for England and Wales in recent years



Percentage live capacity of selected reservoirs at end of month

Area	Reservoir		Capacity (Ml)	2023 Oct	2023 Nov	2023 Dec	Dec Anom.	Min Dec	Year* of min	2022 Dec	Diff 23-22
North West	N Command Zone	•	124929	80	89	100	13	51	1995	82	17
	Vyrnwy		55146	100	100	100	8	35	1995	88	12
Northumbrian	Teesdale	•	87936	100	99	100	10	41	1995	89	11
	Kielder		(199175)	85	90	99	8	70	1989	92	6
Severn-Trent	Clywedog		49936	85	86	100	15	54	1995	86	14
	Derwent Valley	•	46692	93	96	100	9	10	1995	85	15
Yorkshire	Washburn	•	23373	93	91	89	2	23	1995	94	-5
	Bradford Supply	•	40942	99	100	100	10	22	1995	75	25
Anglian	Grafham		(55490)	85	82	82	-1	57	1997	67	15
	Rutland		(116580)	85	90	92	9	60	1990	87	5
Thames	London	•	202828	91	87	89	2	60	1990	82	7
	Farmoor	•	13822	91	97	85	-5	71	1990	97	-12
Southern	Bewl+										
	Ardingly		4685	44	80	100	15	30	2011	100	0
Wessex	Clatworthy		5662	81	100	100	8	54	2003	100	0
	Bristol	•	(38666)	78	97	100	20	40	1990	86	14
South West	Colliford		28540	52	67	73	-4	35	2022	35	38
	Roadford		34500	55	62	82	4	20	1989	51	30
	Wimbleball		21320	83	100	100	17	46	1995	69	31
	Stithians		4967	57	89	100	21	33	2001	61	39
Welsh	Celyn & Brenig	•	131155	67	72	80	-13	54	1995	76	4
	Brianne		62140	100	100	100	2	76	1995	100	0
	Big Five	•	69762	78	86	98	8	67	1995	88	10
	Elan Valley	•	99106	96	99	100	3	56	1995	95	5
Scotland(E)	Edinburgh/Mid-Lothian	•	97223	95	98	98	7	60	1998	99	-1
	East Lothian	•	9317	100	100	100	3	48	1989	100	0
Scotland(W)	Loch Katrine	•	110326	88	95	99	7	75	2007	100	-1
	Daer		22494	85	85	86	-12	83	1995	94	-8
	Loch Thom		10721	91	99	100	3	80	2007	97	3
Northern	Total++	•	56800	99	99	100	10	61	2001	95	5
Ireland	Silent Valley	•	20634	100	99	100	13	39	2001	100	0

( ) figures in parentheses relate to gross storage

• denotes reservoir groups

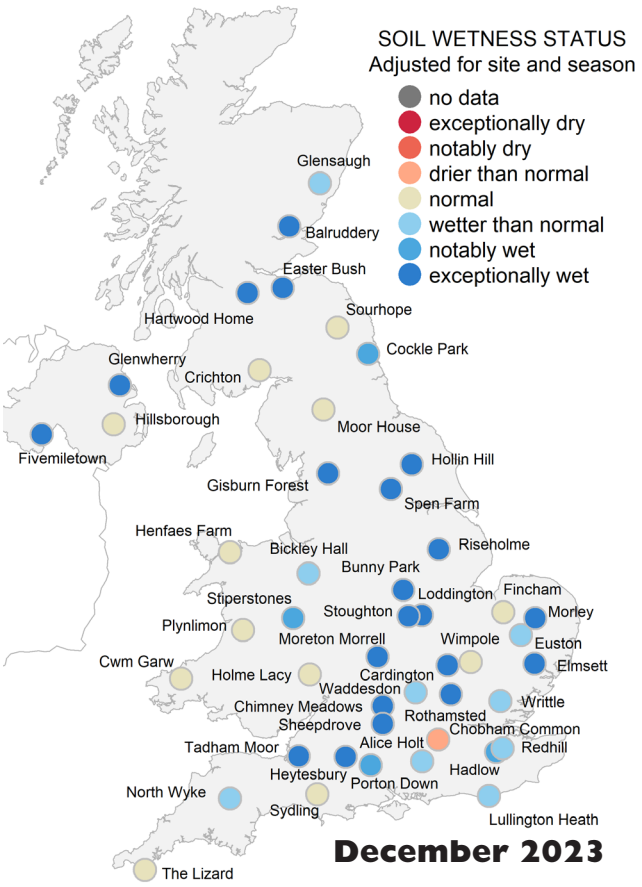
*last occurrence

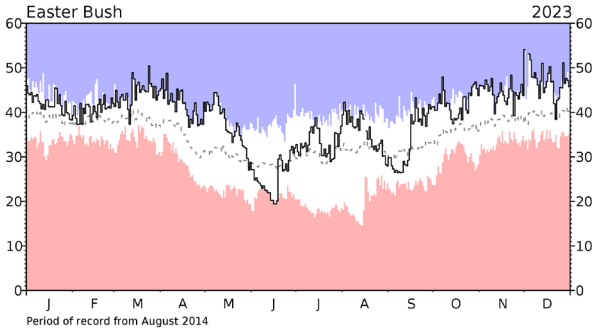
+ no data are available for Bewl

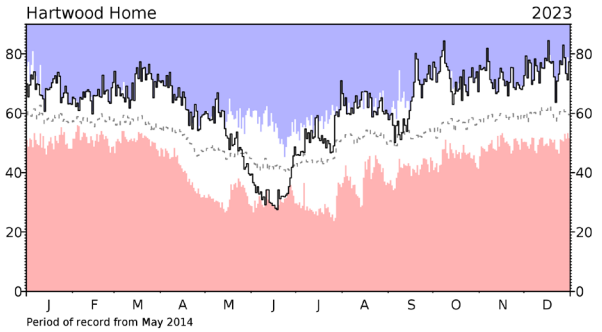
++ excludes Lough Neagh

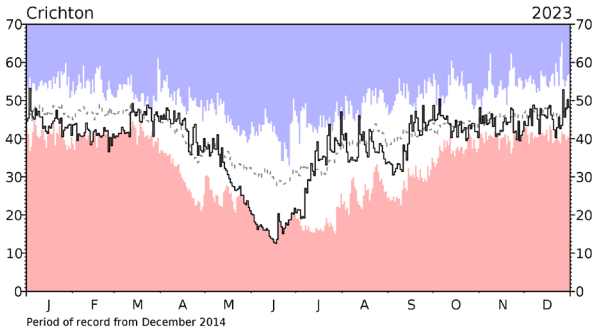
Details of the individual reservoirs in each of the groupings listed above are available on request. The percentages given in the Average and Minimum storage columns relate to the 1988-2012 period except for West of Scotland and Northern Ireland where data commence in the mid-1990s. In some gravity-fed reservoirs (e.g. Clywedog) stocks are kept below capacity during the winter to provide scope for flood attenuation purposes. Monthly figures may be artificially low due to routine maintenance or turbidity effects in feeder rivers.

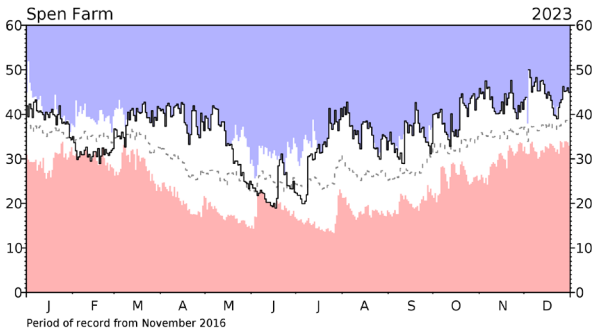
Soil Moisture . . . Soil Moisture

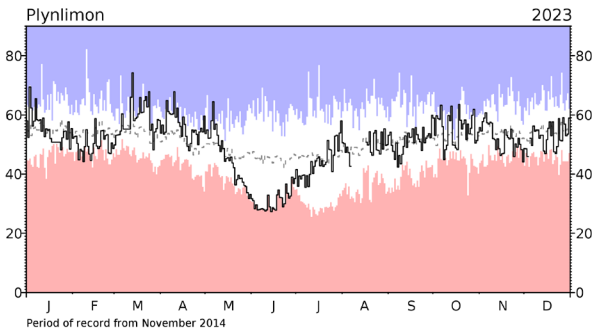












At the end of the month, soil moisture was above field capacity for most COSMOS-UK sites. Easter Bush, Hartwood Home, and Spen Farm remained very wet, whereas other sites, such as Crichton and Plynlimon, were within the normal range for this time of year. Several sites had standing water on the surface, and this will be interpreted as 'soil moisture' by the integrated large area Cosmic-ray neutron sensing technique, hence soil wetness reported can be well above saturation values for those sites.

Overall, soil moisture is above field capacity for much of the COSMOS-UK network, given that December was such a wet month.

Soil moisture data

These data are from UKCEH's COSMOS-UK network. The time series graphs show volumetric water content as a percentage in black together with the maximum and minimum daily values for the period-of-record of the sites. The dashed line represents the period-of-record mean VWC. For more information visit cosmos.ceh.ac.uk.

NHMP

The National Hydrological Monitoring Programme (NHMP) was started in 1988 and is undertaken jointly by the UK Centre for Ecology & Hydrology (UKCEH) and the British Geological Survey (BGS). The NHMP aims to provide an authoritative voice on hydrological conditions throughout the UK, to place them in a historical context and, over time, identify and interpret any emerging hydrological trends. Hydrological analysis and interpretation within the Programme is based on the data holdings of the National River Flow Archive (NRFA; maintained by UKCEH) and National Groundwater Level Archive (NGLA; maintained by BGS), including rainfall, river flows, borehole levels, and reservoir stocks.

The Hydrological Summary is supported by the Natural Environment Research Council award number NE/R016429/1 as part of the UK-SCAPE programme delivering National Capability.

Data Sources

The NHMP depends on the active cooperation of many data suppliers. This cooperation is gratefully acknowledged. A location map of all sites used in the Hydrological Summary can be found on the NHMP website. River flow and groundwater level data are provided by the Environment Agency (EA), Natural Resources Wales - Cyfoeth Naturiol Cymru (NRW), the Scottish Environment Protection Agency (SEPA) and, for Northern Ireland, the Department for Infrastructure - Rivers and the Northern Ireland Environment Agency. In all cases the data are subject to revision following validation (high flow and low flow data in particular may be subject to significant revision).

Details of reservoir stocks are provided by the Water Service Companies, the EA, Scottish Water and Northern Ireland Water.

The Hydrological Summary and other NHMP outputs may also refer to and/or map soil moisture data for the UK. These data are provided by the Meteorological Office Rainfall and Evaporation Calculation System (MORECS). MORECS provides estimates of monthly soil moisture deficit in the form of averages over 40 x 40 km grid squares over Great Britain and Northern Ireland. The monthly time series of data extends back to 1961.

Rainfall data are provided by the Met Office. To allow better spatial differentiation the rainfall data for Britain are presented for the regional divisions of the precursor organisations of the EA, NRW and SEPA. The areal rainfall figures have been produced by the Met Office National Climate Information Centre (NCIC), and are based on the HadUK-Grid 1km resolution gridded data from rain gauges. The majority of the full rain gauge network across the UK is operated by the EA, NRW, SEPA and Northern Ireland Water; supplementary rain gauges are operated by the Met Office. The Met Office NCIC monthly rainfall series extend back to 1836 and form the official source of UK areal rainfall statistics which have been adopted by the NHMP. The gridding technique used is described in Hollis, 2019 available at https://doi.org/10.1002/gdj3.78

Long-term averages are based on the period 1991-2020 and are derived from the monthly areal series.

The regional figures for the current month in the hydrological summaries are based on a limited rain gauge network so these (and the associated return periods) should be regarded as a guide only.

The monthly rainfall figures are provided by the Met Office NCIC and are Crown Copyright and may not be passed on to, or published by, any unauthorised person or organisation.

For further details on rainfall or MORECS data, please contact the Met Office:

Tel: 0370 900 0100
Email: enquiries@metoffice.gov.uk

Enquiries

Enquiries should be directed to the NHMP:

Tel: 01491 692599
Email: nhmp@ceh.ac.uk

A full catalogue of past Hydrological Summaries can be accessed and downloaded at:

http://nrfa.ceh.ac.uk/monthly-hydrological-summary-uk

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