

SUMMARY

The outlook for September favours below normal river flows and groundwater levels across much of the country. For September–November, below normal river flows are likely in southern Britain, and normal to below normal flows in northern Britain. Groundwater levels are likely to be below normal in the far south, and normal to below normal elsewhere.

Rainfall:

Rainfall in August was significantly below average for the UK as a whole, and it was an exceptionally dry month for most of England and Wales.

The rainfall outlook (issued by the Met Office on 29.08.2022) for September suggests near-average rainfall is more likely than wet or dry, and the September–November Outlook slightly favours a wetter rather than drier autumn, although notes southern and eastern regions have an increased risk of dry weather continuing.

River flows

River flows in August were below normal across most of the country, with normal range flows constrained to parts of northwest Britain. Across much of England and Wales, flows were notably or exceptionally low, the lowest on record in some cases.

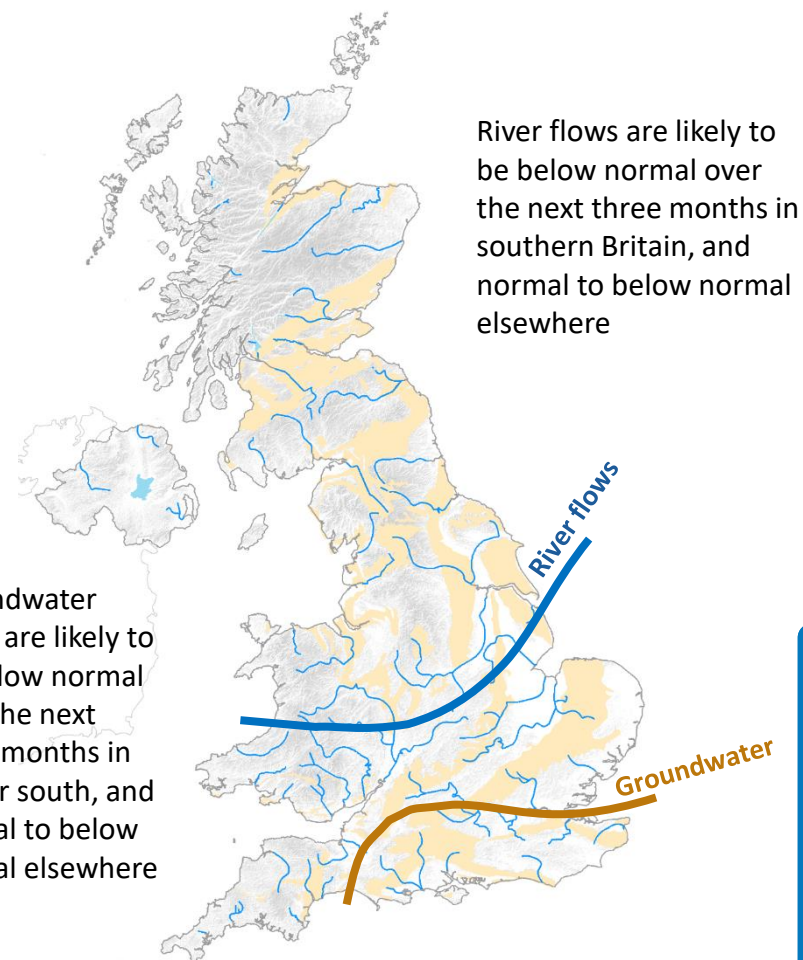
River flows in September are likely to continue to be below normal across the country, with a likelihood of exceptionally low flows in parts of southern Britain – although a wetter start to September could be influential. The three month outlook indicates below normal flows in southern Britain and normal- to below-normal flows further north.

Groundwater

Groundwater levels in August were normal to below normal across all aquifers, with notably and occasionally exceptionally low levels in the far south.

Groundwater levels in September are likely to be normal to below normal across northern aquifer areas, and below normal further south (with exceptionally low levels persisting in some boreholes). The three month outlook suggests a similar picture, but with levels tending towards normal, away from the far south, although there is much uncertainty looking ahead into the recharge season.

The Hydrological Outlook UK provides an outlook for the water situation for the UK over the next three months and beyond. For guidance on how to interpret the outlook, a wider range of information, and a full description of underpinning methods, please visit the website: www.hydoutuk.net



Shaded areas show principal aquifers

About the Hydrological Outlook:

This document presents an outlook for the UK water situation for the next 1 – 3 months and beyond, using observational datasets, meteorological forecasts and a suite of hydrological modelling tools. The outlook is produced in a collaboration between the UK Centre for Ecology and Hydrology (UKCEH), British Geological Survey (BGS), the Met Office, the Environment Agency (EA), Natural Resources Wales (NRW), the Scottish Environment Protection Agency (SEPA), and for Northern Ireland, the Department for Infrastructure – Rivers (DfIR).

Data and Models:

The Hydrological Outlook depends on the active cooperation of many data suppliers. This cooperation is gratefully acknowledged. Historic river flow and groundwater data are sourced from the UK National River Flow Archive and the National Groundwater Level Archive. Contemporary data are provided by the EA, SEPA, NRW and DfIR. These data are used to initialise hydrological models, and to provide outlook information based on statistical analysis of historical analogues.

Climate forecasts are produced by the Met Office. Hydrological modelling is undertaken by UKCEH using the Grid-to-Grid, PDM and CLASSIC hydrological models and by the EA using CATCHMOD. Hydrogeological modelling uses the R-groundwater model run by BGS and CATCHMOD run by the EA. Supporting documentation is available from the Outlooks website:

<https://www.hydoutuk.net/about/methods>

Presentation:

The language used in the summary presented overleaf generally places flows and groundwater levels into just three classes, i.e. below normal, normal, and above normal. However, the underpinning methods use as many as seven classes as defined in the graphic to the right, i.e. the summary uses a simpler classification than some of the methods. On those occasions when it is appropriate to provide greater discrimination at the extremes the terminology and definitions of the seven class scheme will be adopted.

Percentile range of historic values for relevant month

Exceptionally high flow	> 95
Notably high flow	87-95
Above normal	72-87
Normal range	28-72
Below normal	13-28
Notably low flow	5-13
Exceptionally low flow	< 5

Disclaimer and liability:

The Hydrological Outlook partnership aims to ensure that all Content provided is accurate and consistent with its current scientific understanding. However, the science which underlies hydrological and hydrogeological forecasts and climate projections is constantly evolving. Therefore any element of the Content which involves a forecast or a prediction should not be relied upon as though it were a statement of fact. To the fullest extent permitted by applicable law, the Hydrological Outlook Partnership excludes all warranties or representations (express or implied) in respect of the Content.

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From April 2018 the Hydrological Outlook is supported by the Natural Environment Research Council funded [UK-SCAPE](#) and [Hydro-JULES](#) Programmes.

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Further information:

For more detailed information about the Hydrological Outlook, and the derivation of the maps, plots and interpretation provided in this outlook, please visit the Hydrological Outlook UK website.

The website features a host of other background information, including a wider range of sources of information which are used in the preparation of this Outlook.

Contact:

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t: 01491 692371 e: enquiries@hydoutuk.net

Reference for the Hydrological Outlook:

Hydrological Outlook UK, 2022, September, UK Centre for Ecology and Hydrology, Oxfordshire UK, Online, <https://www.hydoutuk.net/latest-outlook/>

Other Sources of Information:

The Hydrological Outlook should be used alongside other sources of up-to-date information on the current water resources status and flood risk.

Environment Agency Water Situation Reports: provides summary of water resources status on a monthly and weekly basis for England:

<https://www.gov.uk/government/collections/water-situation-reports-for-england>

Flood warnings are continually updated, and should be consulted for an up-to-date and localised assessment of flood risk:

Environment Agency: <https://flood-warning-information.service.gov.uk/map>

Natural Resources Wales: <https://flood-warning.naturalresources.wales/>

Scottish Environment Protection Agency: <https://www.sepa.org.uk/flooding.aspx>

Hydrological Summary for the UK: provides summary of current water resources status for the UK:

<https://nrfa.ceh.ac.uk/monthly-hydrological-summary-uk>

UK Met Office forecasts for the UK: <https://www.metoffice.gov.uk/#?tab=regionalForecast>

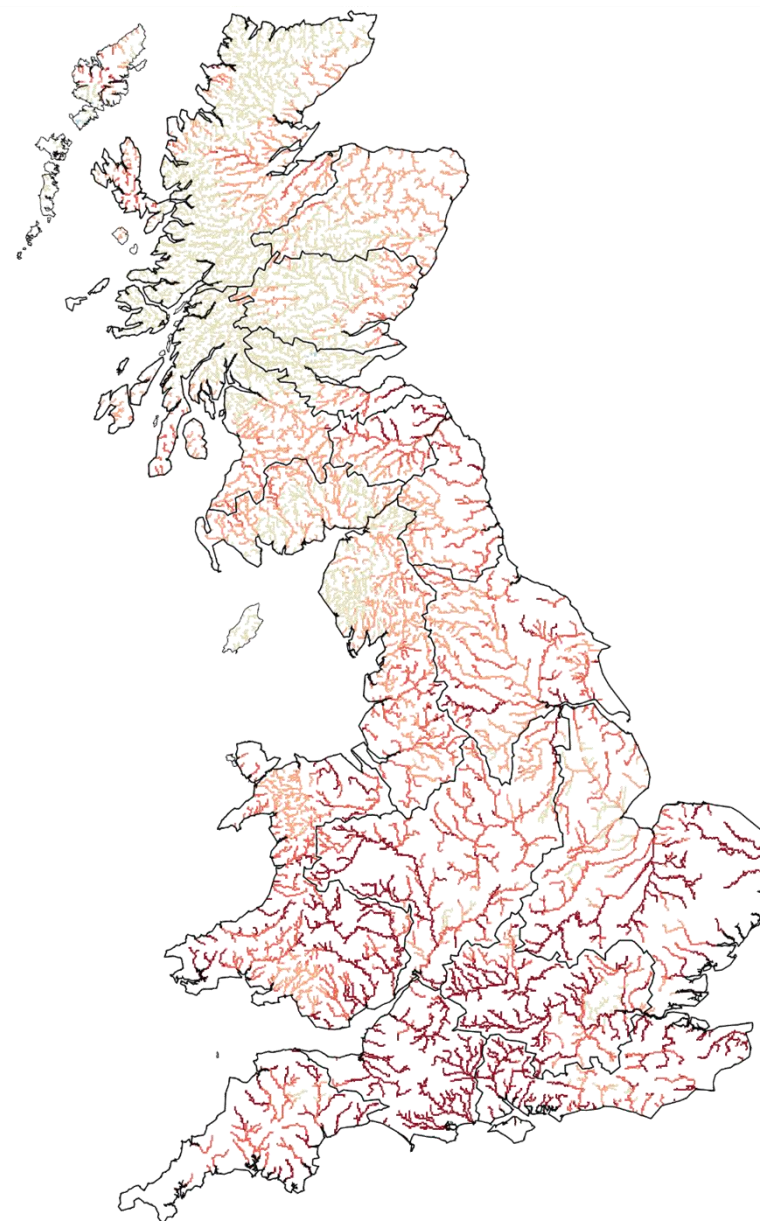
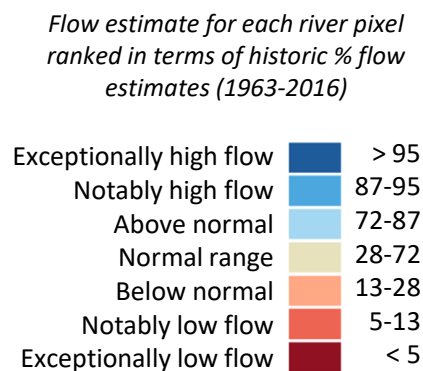
UK Water Resources Portal: monitor the UK hydrological situation in near real-time including rainfall, river flow, groundwater and soil moisture from COSMOS-UK:

<https://eip.ceh.ac.uk/hydrology/water-resources/>

This map shows the simulated monthly mean flow across Great Britain for last month, ranked in terms of 54 years of historical flow estimates (1963 – 2016).

These flows are produced by the 1km resolution Grid-to-Grid (G2G) hydrological model, which is run up to the end of each calendar month using observed rainfall and MORECS potential evaporation as input.

Note that the G2G model provides estimates of natural flows.



Current Daily Simulated Subsurface Water Storage Conditions

Based on subsurface water storage estimated for 31st August 2022

Issue date: 02.09.2022

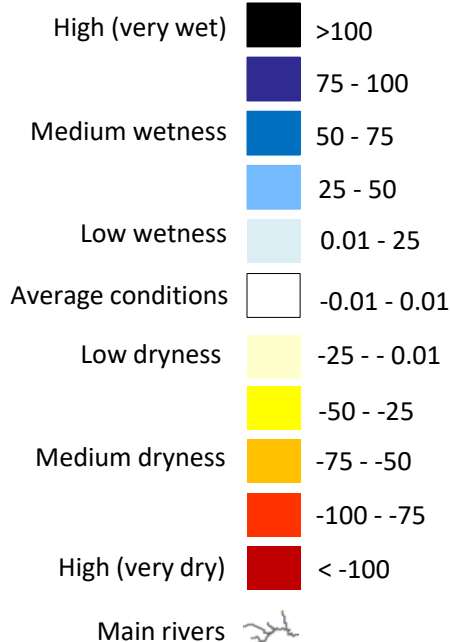
These maps are based on Grid-to-Grid (G2G) hydrological model simulated subsurface water storage, expressed as an anomaly from the historical monthly mean. To highlight areas that are particularly wet or dry, the storage anomaly is presented here using a colour scale highlighting water storage relative to historical extremes. The maps below show the “relative wetness” which combines maps previously shown separately as the “relative wetness” and “relative dryness”.

These maps do not provide a forecast and are not maps of soil moisture. Instead they indicate areas which are particularly wet or dry. Rainfall in areas with high positive relative wetness could result in flooding in the coming days/weeks. Areas of negative relative wetness provide an indication of locations which are particularly dry, and little or no rain in these areas could potentially lead to (or prolong) a drought.

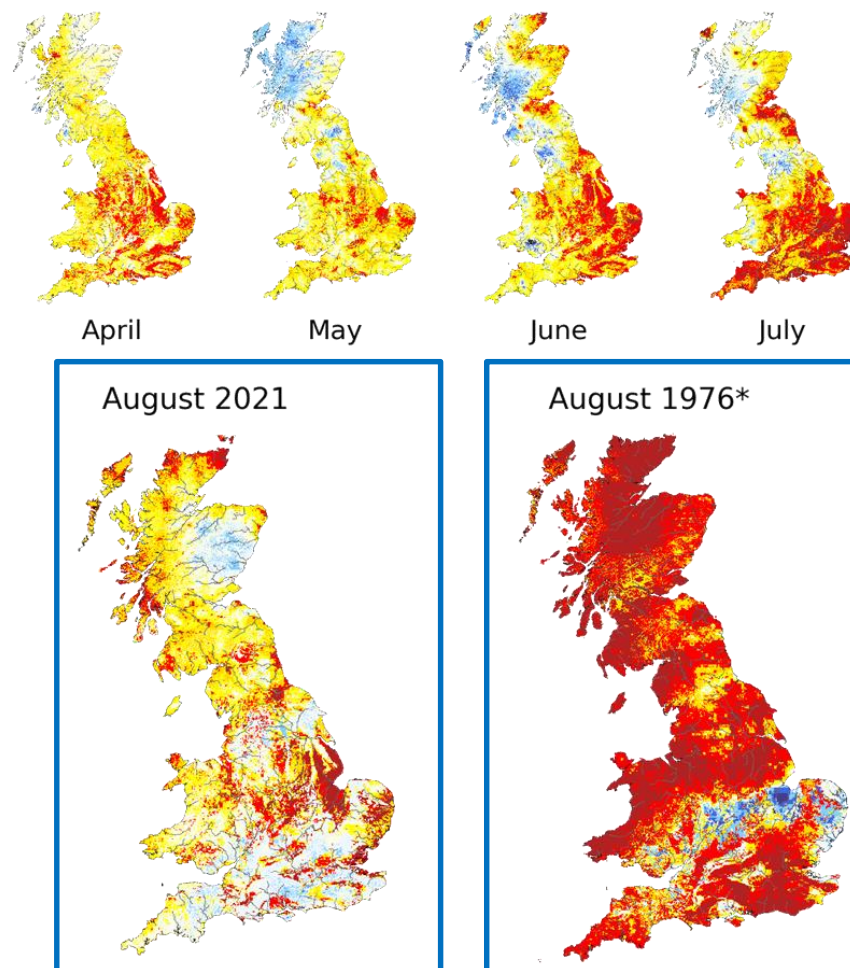
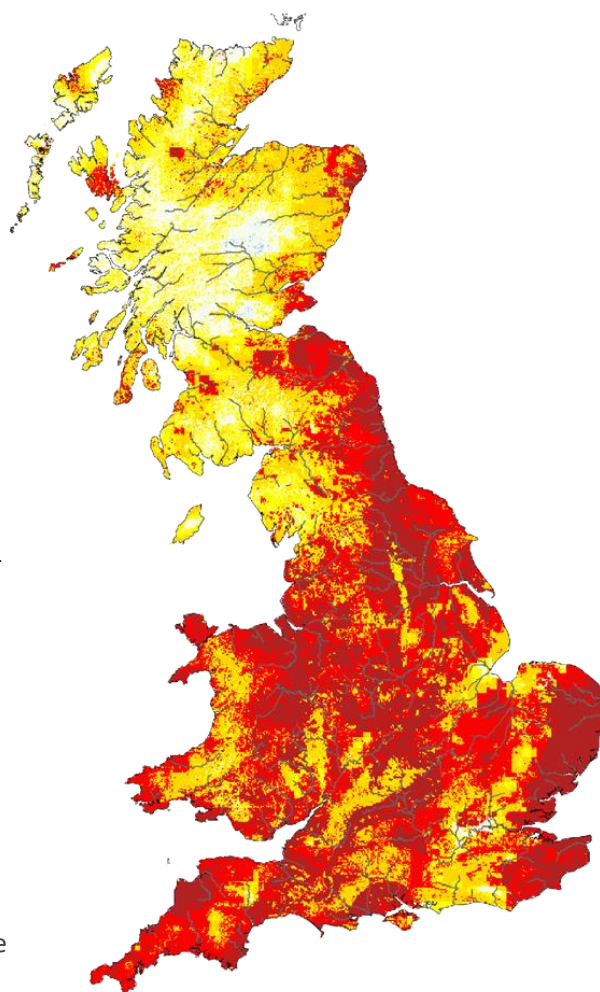
SUMMARY: At the end of August subsurface water levels were lower (drier) than normal across most of Great Britain, especially across England and Wales where widespread areas were very dry.

Relative wetness

Water storage anomaly as a % of maximum (positive wetness) or minimum (negative wetness) storage anomaly (zero indicates average value)



Labels refer to estimated storage on *final day* of named month



*Example month displaying extreme negative wetness

Return Period of Rainfall Required to Overcome Dry Conditions

Period: September 2022 – February 2023

Issue date: 02.09.2022








These maps show the **return period** of the rainfall required to overcome dry conditions simulated using the Grid-to-Grid (G2G) hydrological model. The maps are coloured according to the return period of accumulated rainfall required to overcome the estimated current subsurface water storage deficit over the next few months.

These maps do not provide a drought forecast. Instead they indicate the return period of rainfall required to overcome the dry conditions for the following 6 months based on current conditions.

SUMMARY: During September to October, regions in southern and eastern England would require rainfall with a return period of between 10 and 100 years to overcome the dry conditions. In Wales and parts of eastern Scotland rainfall of a 5 to 10 year return period would be required for conditions to return to normal.

Rainfall of a 5 to 10 year return period would be required for conditions to return to normal in parts of southern England by the end of February.



Rainfall amount / Probability		Return period (years)	
Low (this rain is likely to occur)	> 20%		< 5
	< 20%		5 - 10
	< 10%		10 - 25
	< 4%		25 - 50
High (less likely)	< 2%		50 - 100
	< 1%		100 - 200
Extreme (unlikely but still possible)	< 0.5%		> 200

SCOTLAND

HR Highlands Region
NER North East Region
TR Tay Region
FR Forth Region
CR Clyde Region
TWR Tweed Region
SR Solway Region

ENGLAND

N Northumbria
NW North West
Y Yorkshire
ST Severn Trent
A Anglian
T Thames
S Southern
W Wessex
SW South West

WALES

WEL Welsh



NORTHERN IRELAND

This method cannot currently be used in Northern Ireland

Estimate of Additional Rainfall Required to Overcome Dry Conditions

Based on subsurface water storage estimated for 31st August 2022

Issue date: 02.09.2022

These maps show the Grid-to-Grid (G2G) hydrological model simulated subsurface water storage, expressed as an anomaly from the historical monthly mean (1981-2010), presented on a 1km grid and as regional means.

Subsurface storage deficits, i.e. where the subsurface water storage anomaly is less than zero, are highlighted by the red/pink colours.

The **subsurface storage deficit (mm)** can be interpreted as an estimate of additional rainfall that would be required in future months to overcome dry conditions (i.e. rainfall in addition to what is expected on average). Regional mean values of additional rainfall required are provided in the table below.

Regional estimate of additional rainfall required (mm)

SCOTLAND

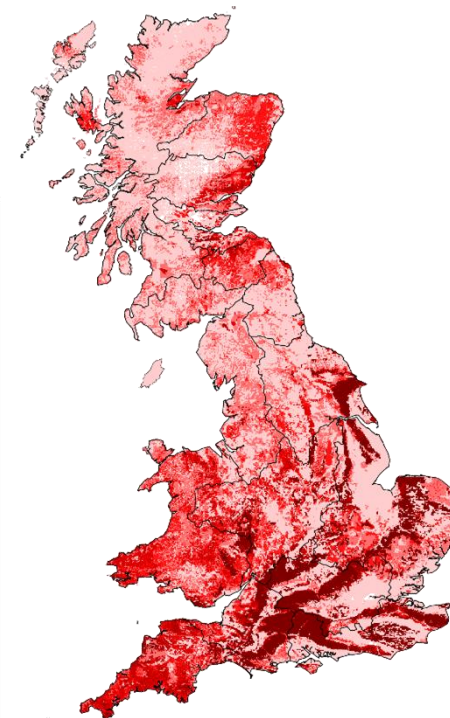
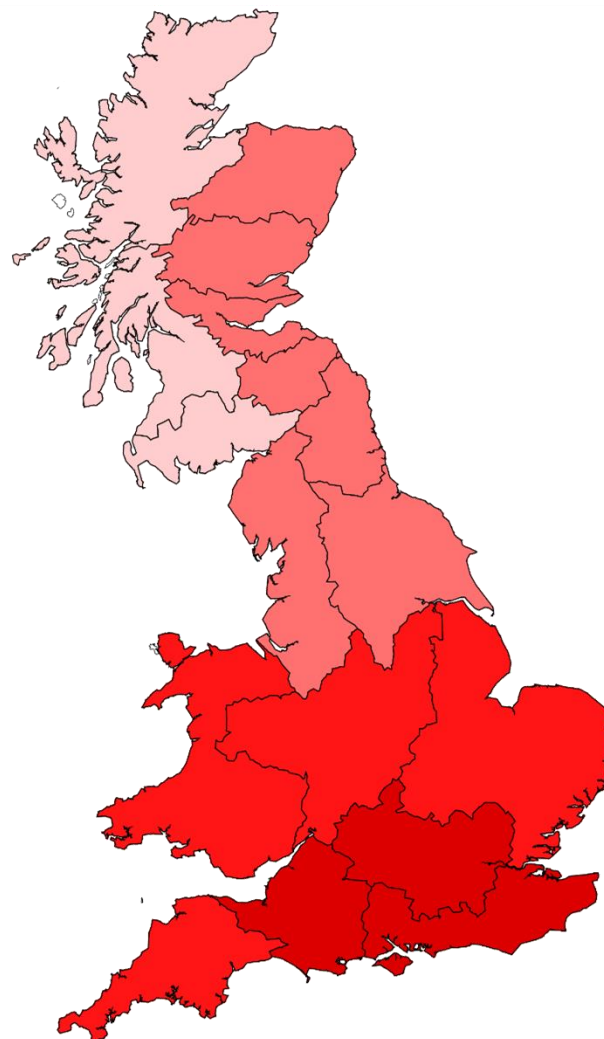
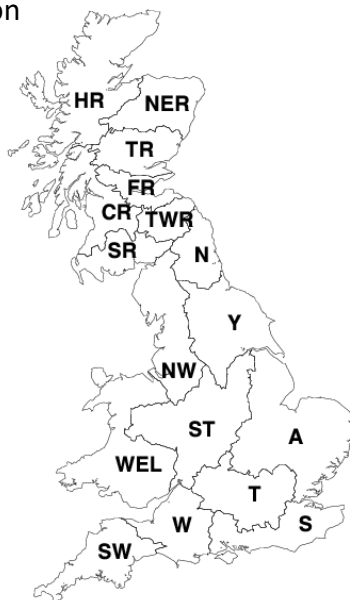
20	HR	Highlands Region
35	NER	North East Region
30	TR	Tay Region
31	FR	Forth Region
21	CR	Clyde Region
49	TWR	Tweed Region
22	SR	Solway Region

ENGLAND

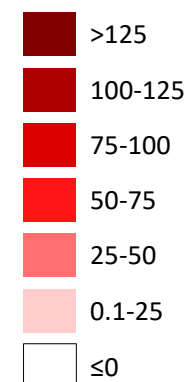
25	N	Northumbria
28	NW	North West
40	Y	Yorkshire
52	ST	Severn Trent
57	A	Anglian
81	T	Thames
95	W	Wessex
82	S	Southern
75	SW	South West

WALES

56	WEL	Welsh
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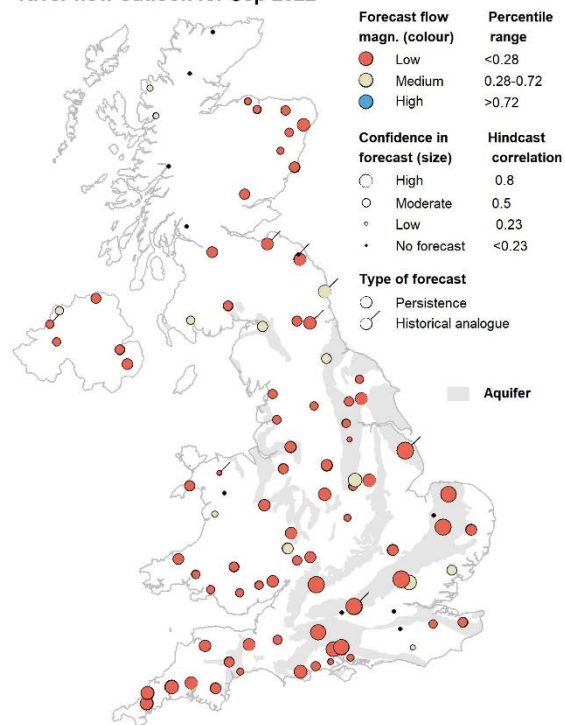


Water storage deficit
(anomaly, mm)



SUMMARY: The outlook for September and for September to November is for below normal flows across most of the UK. Please note there are few forecasts available in north-west Britain.

River flow outlook for Sep 2022



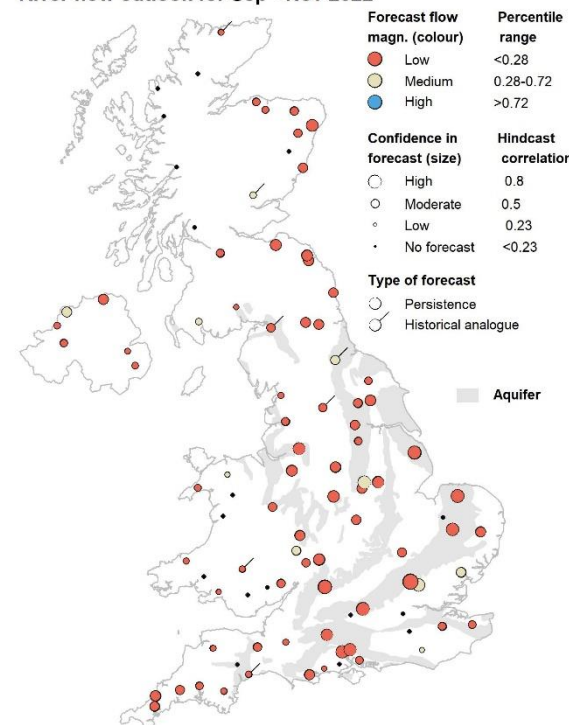
1-month flow outlook

Outlooks from hydrological analogues are based on a comparison of river flow during recent months with flows during the same months in previous years at a set of approximately 90 sites from across the UK. These sites are depicted on the two maps. Years with observed flows that most closely resemble current conditions are identified as the best analogues and the outlook is based on extrapolating from current conditions based on these analogues.

It is, however, often the case that a simpler forecast based on the persistence of river flow provides a better forecast than provided by analogy. This is particularly true for slowly responding catchments associated with aquifer outcrops.

Both methods are considered at each site and the forecast from the method with the higher confidence is presented. A simple classification of flows is used (high, medium and low) as indicated by the colours of the dots, with the confidence

River flow outlook for Sep - Nov 2022



3-month flow outlook

of the forecast being represented by the size of the dot. A tag on the dot indicates which method has been used in each instance.

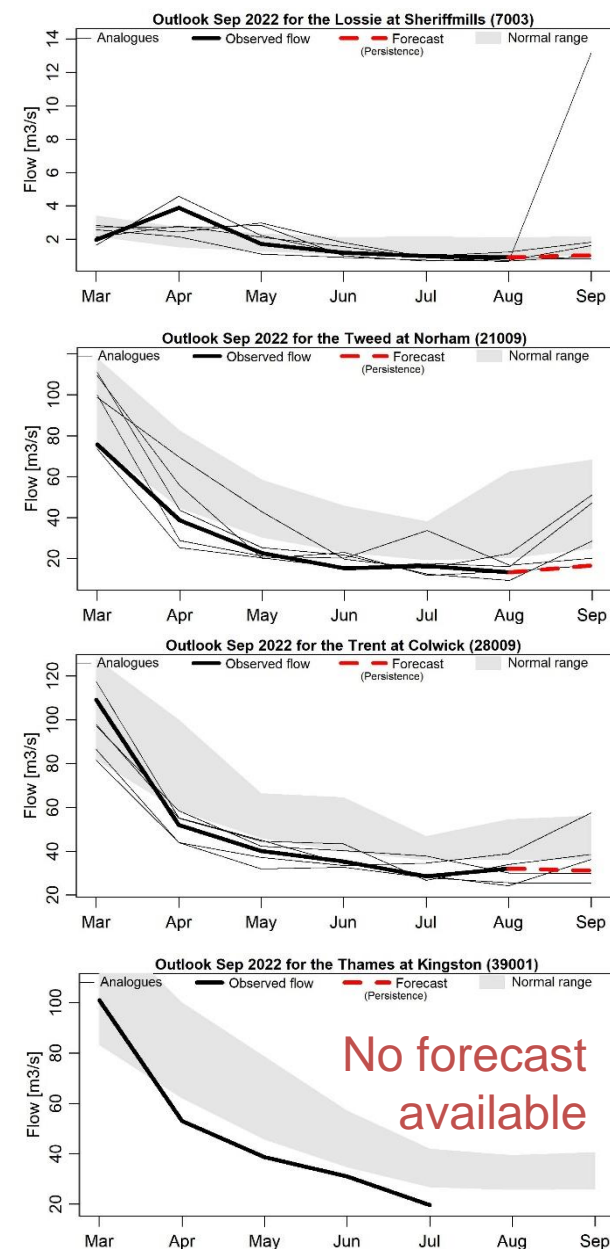
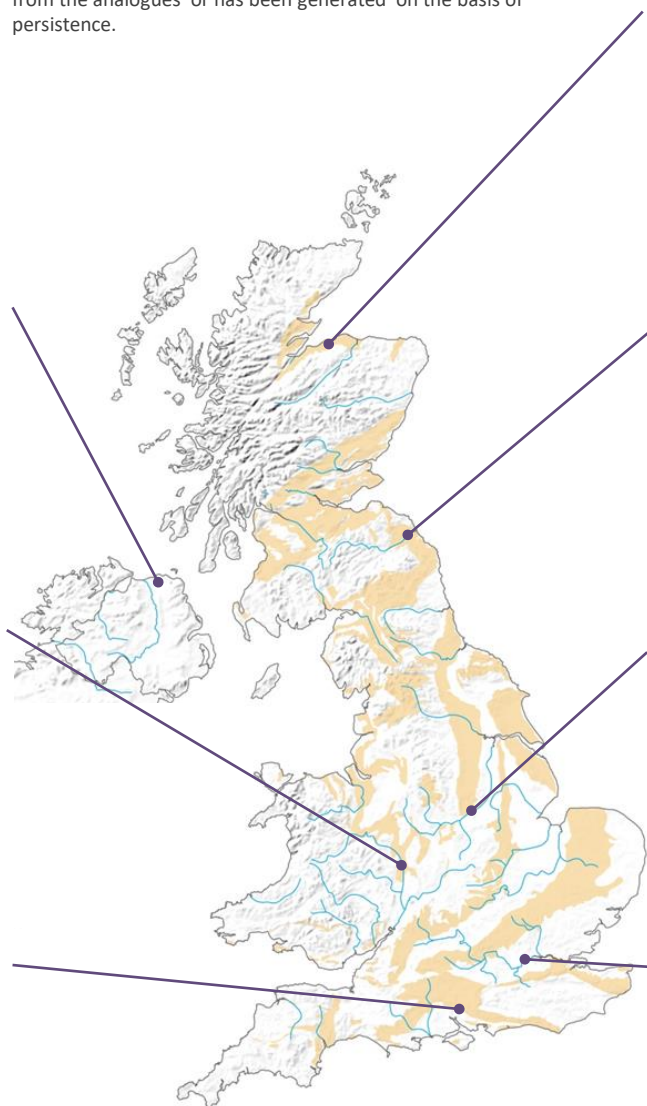
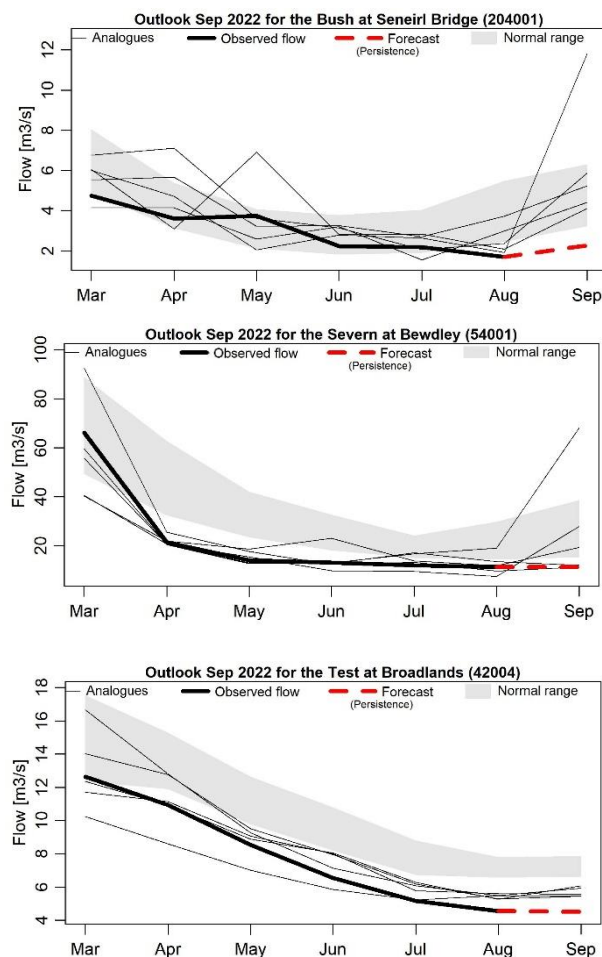
Period: September 2022

Issued on 06.09.2022 using data to the end of August 2022

These figures provide insight into the hydrological analogue methodology for a set of sites from across the UK.

In each of the time series graphs the bold black line represents the observed flow during the past six months. The grey band indicates the normal flow range (the normal band includes 44%

of observed flows in each month). The selected analogues are shown as thin lines and the trajectories that flows took in the following month are also shown. The forecast is shown as the dashed red line, and in each plot it states whether this has come from the analogues or has been generated on the basis of persistence.



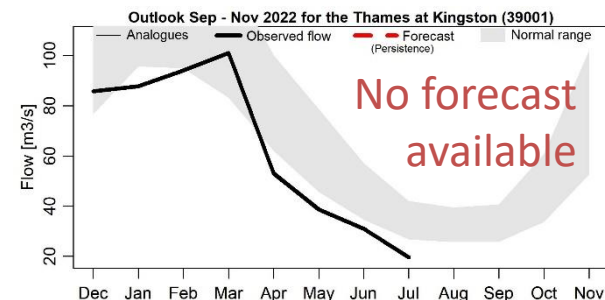
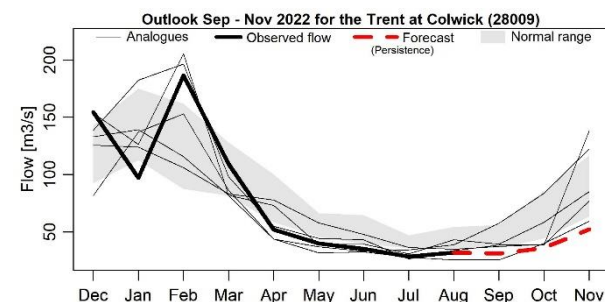
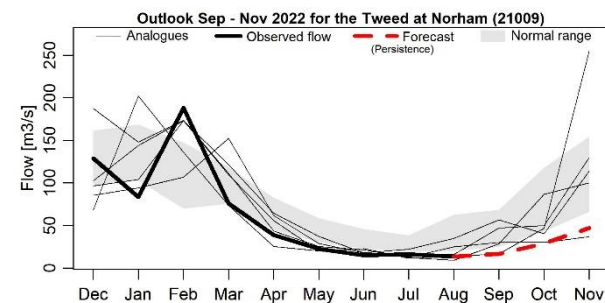
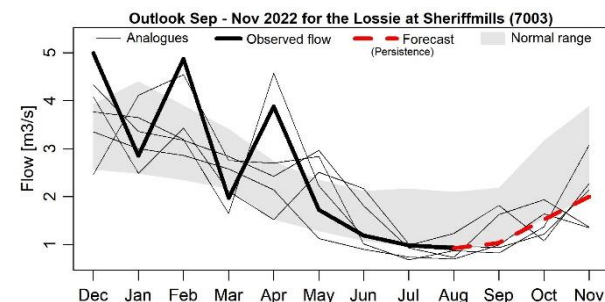
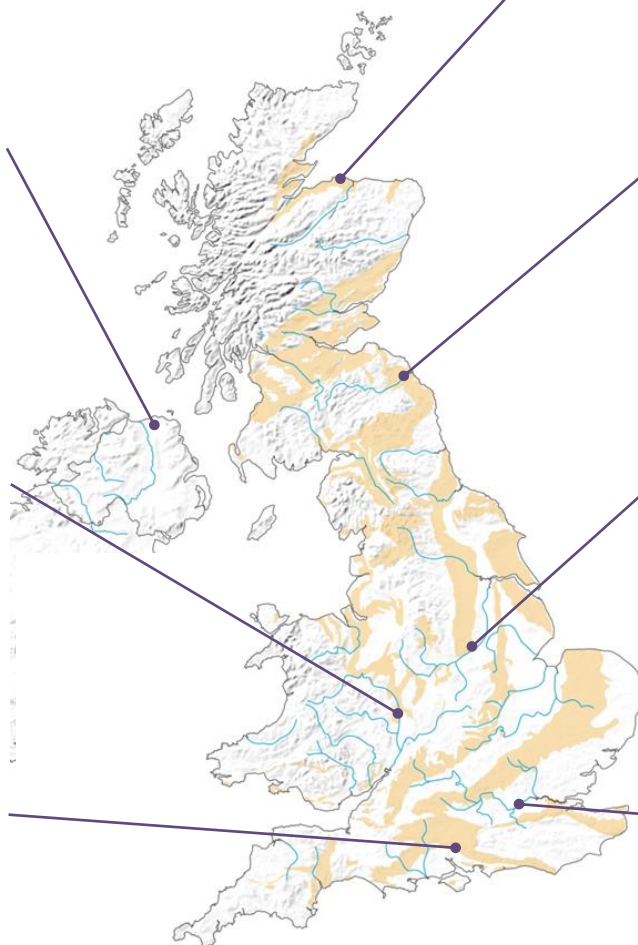
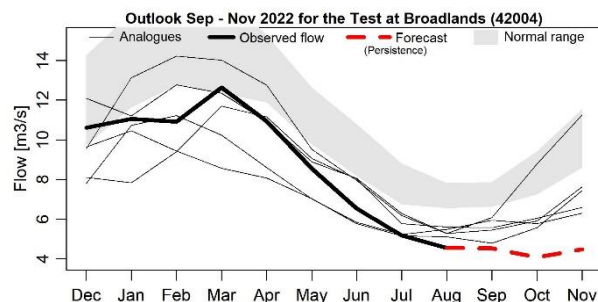
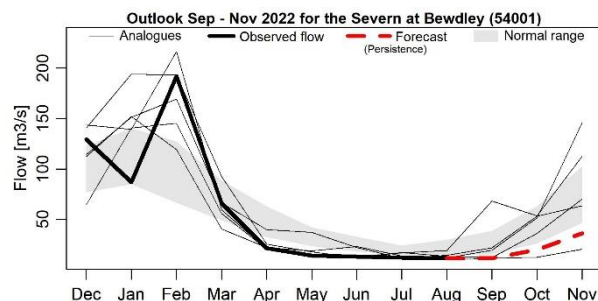
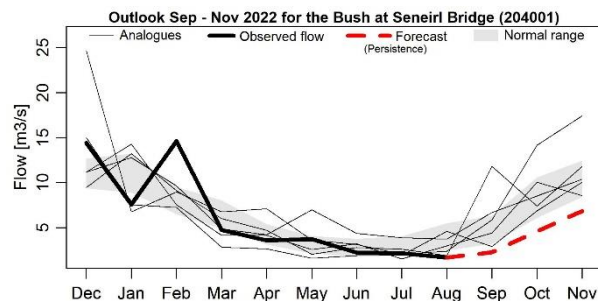
Period: September 2022 – November 2022

Issued on 06.09.2022 using data to the end of August 2022

These figures provide insight into the hydrological analogue methodology for a set of sites from across the UK.

In each of the time series graphs the bold black line represents the observed flow during the past nine months. The grey band indicates the normal flow range (the normal band includes 44%

of observed flows in each month). The selected analogues are shown as thin lines and the trajectories that flows took in the following three months are also shown. The forecast is shown as the dashed red line, and in each plot it states whether this has come from the analogues or has been generated on the basis of persistence.

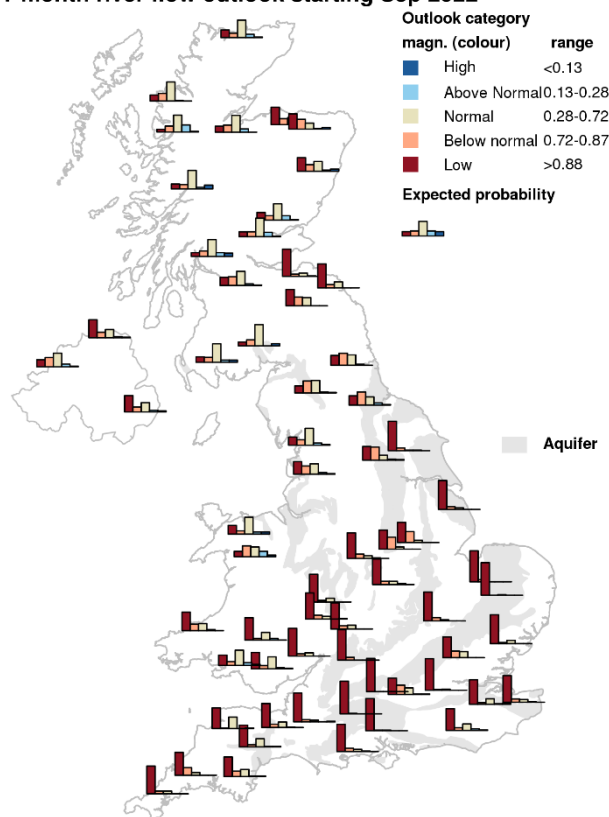


Period: September 2022 – February 2023

Issued on 05.09.2022 using data to the end of August 2022

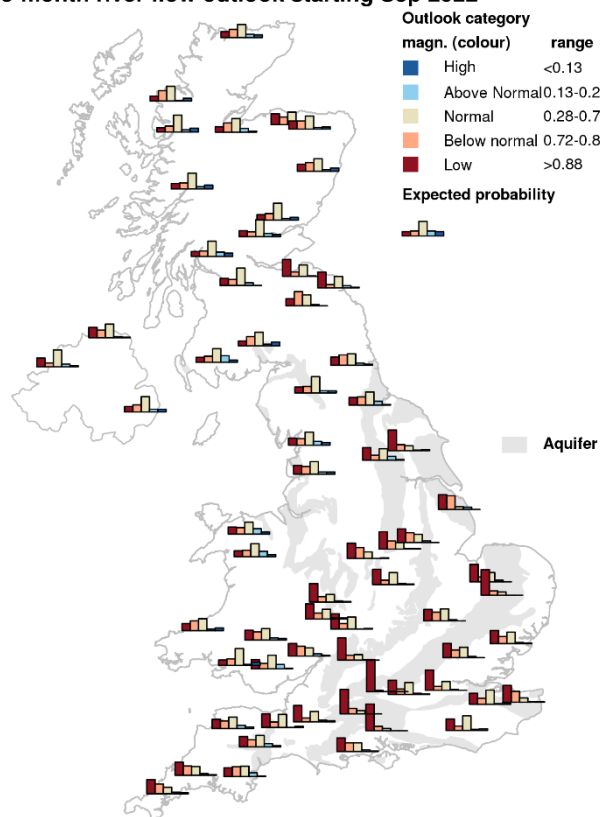
The outlook for September indicates that flows are most likely to be low for south eastern England, below normal to low for south western and central England, southern Wales and eastern Scotland, and normal for the rest of the UK. The September-October-November outlook indicates that flows are likely to be below normal to low for south eastern England, normal to below normal for south western and central England, and normal for the rest of the UK.

1-month river flow outlook starting Sep 2022



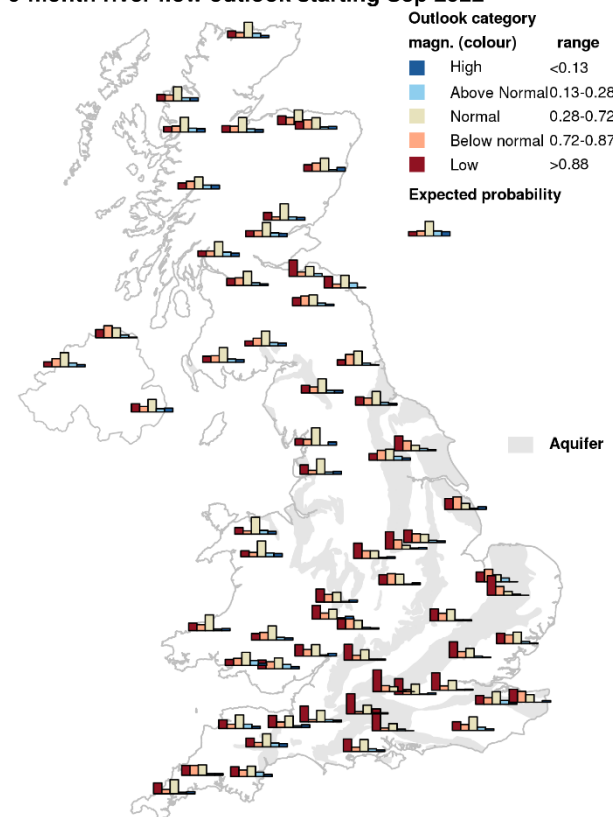
This outlook is based on monthly ensembles of historical sequences of observed climate (rainfall and potential evapotranspiration) that form input to a hydrological model. The outputs are probabilistic simulations of the average river flow over the forecast period (1 to 12 months ahead), at each location. The simulations are generated by the GR4J conceptual rainfall-runoff model from IRSTEA (France) calibrated on observed or naturalised flows.

3-month river flow outlook starting Sep 2022



The bar plot maps show the outlook distribution for 1, 3 and 6-month period for 64 catchments across England and Wales. Each bar plot represents the probabilistic distribution of the simulated river flow compared to the historical river flow, for the same n-month period. The probabilities fall within five categories, classified as: low, below normal, normal, above normal and high.

6-month river flow outlook starting Sep 2022



This outlook is based entirely on historical sequences and therefore does not contain any knowledge of the state of the atmosphere and ocean. It is hence possible that some of the historical sequences used might be inconsistent with current large-scale atmospheric conditions and would therefore be unlikely to occur in the next few months.



This outlook is based on monthly ensembles of historical sequences of observed climate (rainfall and potential evapotranspiration) that form input to a hydrological model. The outputs are probabilistic simulations of the average river flow over the forecast period (1 to 12 months ahead), at each location. The simulations are generated by the GR4J conceptual rainfall-runoff model from IRSTEA (France) calibrated on observed or naturalised flows.

The stack diagrams show the variation over time of the outlook distribution for a number of individual catchments. Each graph represents variation over time of the number of simulated river flows, in each month ensemble, that fall within each of seven categories: exceptionally low, notably low, below normal, normal, above normal, notably high and exceptionally high. The categories represent cumulative flow conditions, e.g. For 3-month, the simulated total 3-month flow compared to the historical 3-month flow distribution. The monthly variations can be compared to the long-term average distribution of river flows (shown as columns

on the right of each timeline graph).

This outlook is based entirely on historical sequences and therefore does not contain any knowledge of the state of the atmosphere and ocean. It is hence possible that some of the historical sequences used might be inconsistent with current large-scale atmospheric conditions and would therefore be unlikely to occur in the next few months.

SUMMARY: During September, river flows in southern England, western England and Wales are likely to be *below normal* or lower, with a high chance of *exceptionally low* flows in the southwest. Elsewhere, river flows are likely to be in the *Normal range* or below.

Over the next 3 months river flows in southeast England and the Tweed Region are likely to be *Below normal* or lower. Elsewhere, river flows are likely to be in the *Normal range* or below.

These forecasts are produced by using five members of the Met Office rainfall forecast ensemble as input to a water balance hydrological model to provide the five estimates of river flows shown on the left for one month and three months ahead.

Regional forecast monthly-mean river flows are derived from the average of 1km river flow estimates within each region and ranked in terms of 54 years of historical flow estimates (1963 – 2016).

The five maps illustrate the wide range of possible flows and while there is a 50% chance of flows between the 1st and 3rd quartiles, actual flows may be more extreme than the flows derived using the highest or lowest rainfall forecasts.

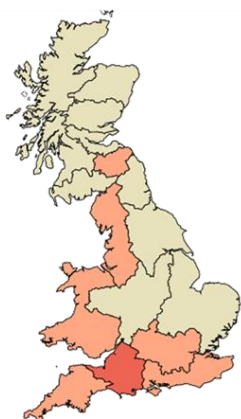
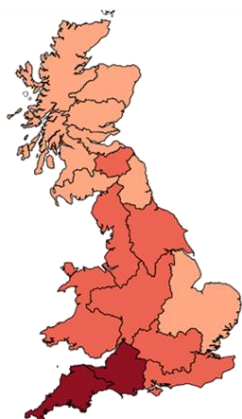
Lowest rainfall forecast

1st quartile

Median

3rd quartile

Highest rainfall forecast



Key

Exceptionally high flow
Notably high flow
Above normal
Normal range
Below normal
Notably low flow
Exceptionally low flow

Percentile range of historic values for relevant month

> 95
87-95
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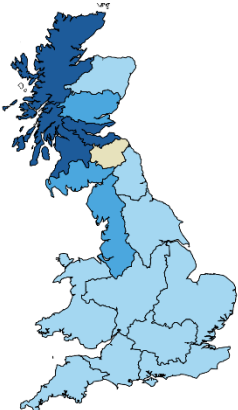
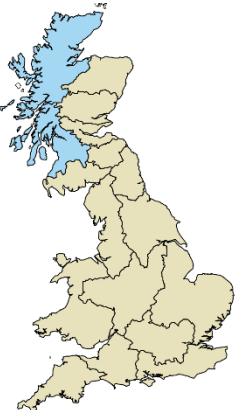
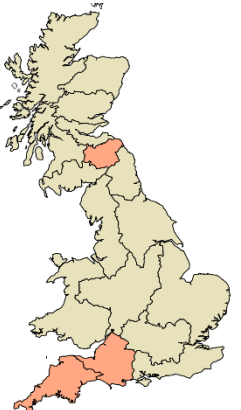
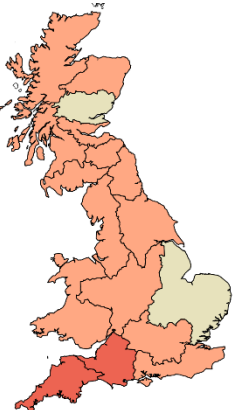
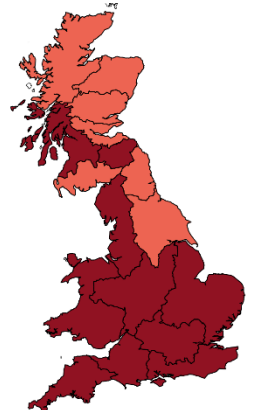
Lowest rainfall forecast

1st quartile

Median

3rd quartile

Highest rainfall forecast



SCOTLAND

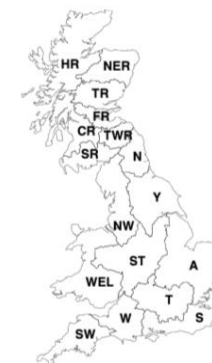
HR Highlands Region
NER North East Region
TR Tay Region
FR Forth Region
CR Clyde Region
TWR Tweed Region
SR Solway Region

ENGLAND

N Northumbria
NW North West
Y Yorkshire
ST Severn Trent
A Anglian
T Thames
S Southern
W Wessex
SW South West

WALES

WEL Welsh



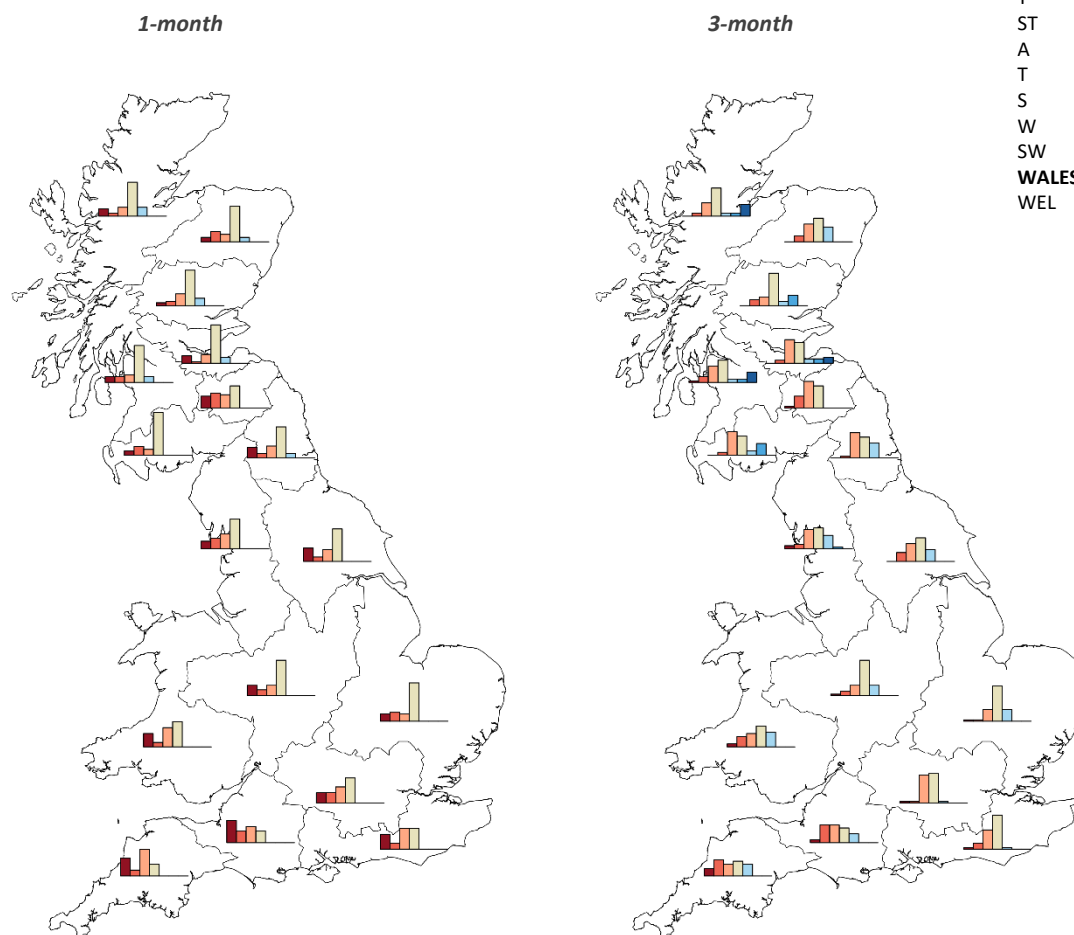
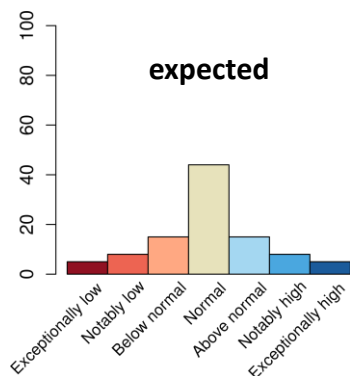
NORTHERN IRELAND
This method cannot currently be used in Northern Ireland

The regional maps illustrating the regional river flows for five members of the Met Office ensemble of rainfall forecasts give some indication of the range of possible river flows in the coming months. As noted previously, the actual flows could be more extreme than the flows generated by either the lowest or highest members of the rainfall ensemble.

The bar charts (below) give further insight into the range of river flow forecasts by considering all members of the forecast rainfall ensemble. The regional bar charts show the percentage of ensemble forecasts falling in each of the flow categories as generated by the monthly-resolution water-balance model. As before results are averaged by region then ranked in terms of 54 years of historical regional flow estimates (1963 – 2016).

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TWR Tweed Region
SR Solway Region

ENGLAND

N Northumbria
NW North West
Y Yorkshire
ST Severn Trent
A Anglian
T Thames
S Southern
W Wessex
SW South West

WALES

WEL Welsh



NORTHERN IRELAND

This method cannot currently be used in Northern Ireland

Percentile range of historic values for relevant month

Exceptionally high flow	> 95
Notably high flow	87-95
Above normal	72-87
Normal range	28-72
Below normal	13-28
Notably low flow	5-13
Exceptionally low flow	< 5

The maps illustrating the regional river flows for five members of the Met Office ensemble of rainfall forecasts give some indication of the range of possible river flows in the coming months. As noted previously, the actual flows could be more extreme than the flows generated by either the lowest or highest members of the rainfall ensemble.

The tables below give further insight into the range of river flow forecasts by considering all members of the forecast rainfall ensemble. The numbers in the tables are the percentage of ensemble forecasts falling in each of the flow categories as generated by the monthly-resolution water-balance model. As before results are averaged by region then ranked in terms of 54 years of historical regional flow estimates (1963 – 2016).

SUMMARY: During September, river flows in southern England, western England and Wales are likely to be *below normal* or lower, with a high chance of *exceptionally low* flows in the southwest. Elsewhere, river flows are likely to be in the *Normal range* or below.

Over the next 3 months river flows in southeast England and the Tweed Region are likely to be *Below normal* or lower. Elsewhere, river flows are likely to be in the *Normal range* or below.

SCOTLAND

HR Highlands Region
NER North East Region
TR Tay Region
FR Forth Region
CR Clyde Region
TWR Tweed Region
SR Solway Region

ENGLAND

N Northumbria
NW North West
Y Yorkshire
ST Severn Trent
A Anglian
T Thames
S Southern
W Wessex
SW South West

WALES

WEL Welsh



NORTHERN IRELAND
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1-month ahead	A	NW	N	ST	SW	S	T	Welsh	W	Y	CR	FR	HR	NER	SR	TR	TWR
Exceptionally high flow	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Notably high flow	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Above normal	0	0	7	0	0	0	0	0	0	0	10	10	14	7	0	12	0
Normal range	62	48	50	57	19	33	40	40	19	52	60	62	55	57	69	57	36
Below normal	12	24	19	17	43	33	26	31	26	19	12	14	14	12	10	19	21
Notably low flow	14	17	7	10	10	10	17	7	19	7	10	2	5	17	14	7	24
Exceptionally low flow	12	12	17	17	29	24	17	21	36	21	10	12	12	7	7	5	19

3-months ahead	A	NW	N	ST	SW	S	T	Welsh	W	Y	CR	FR	HR	NER	SR	TR	TWR
Exceptionally high flow	0	0	0	0	0	0	0	0	0	0	17	10	19	0	0	0	0
Notably high flow	0	2	0	0	0	0	0	0	0	0	5	7	5	0	19	17	0
Above normal	19	21	24	17	19	2	2	24	14	19	5	7	5	24	7	7	0
Normal range	57	33	33	57	24	55	48	33	24	38	36	33	45	38	31	52	36
Below normal	19	31	40	17	19	31	45	21	29	29	26	38	21	29	38	14	43
Notably low flow	2	7	2	7	26	10	2	17	29	14	10	5	5	10	5	10	19
Exceptionally low flow	2	5	0	2	12	2	2	5	5	0	2	0	0	0	0	0	2

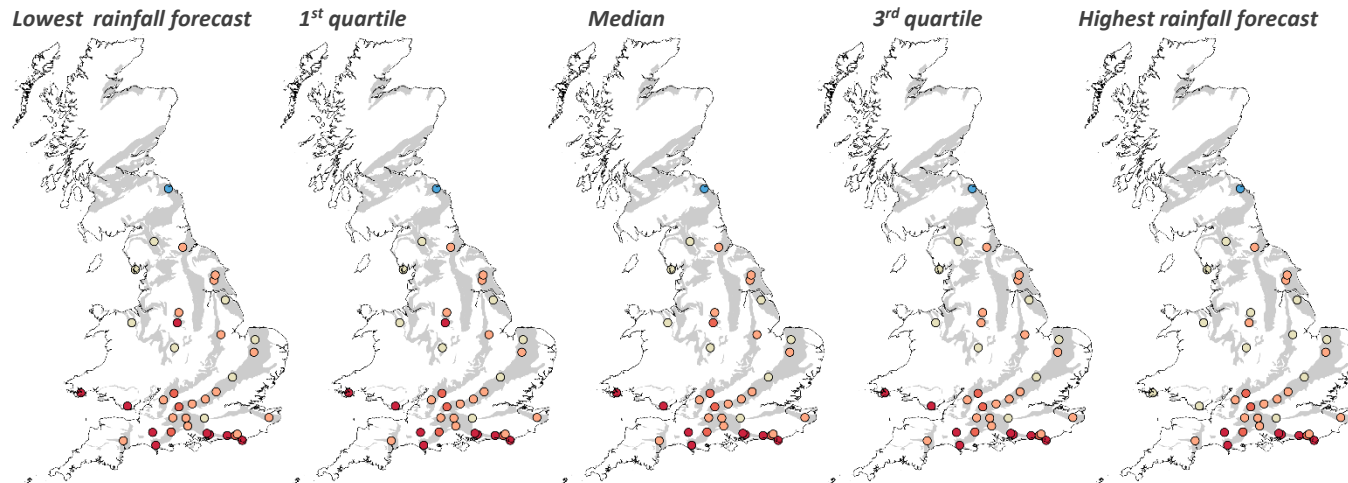
Period: September 2022 – November 2022

Issued on 06.09.2022 using data to the end of August

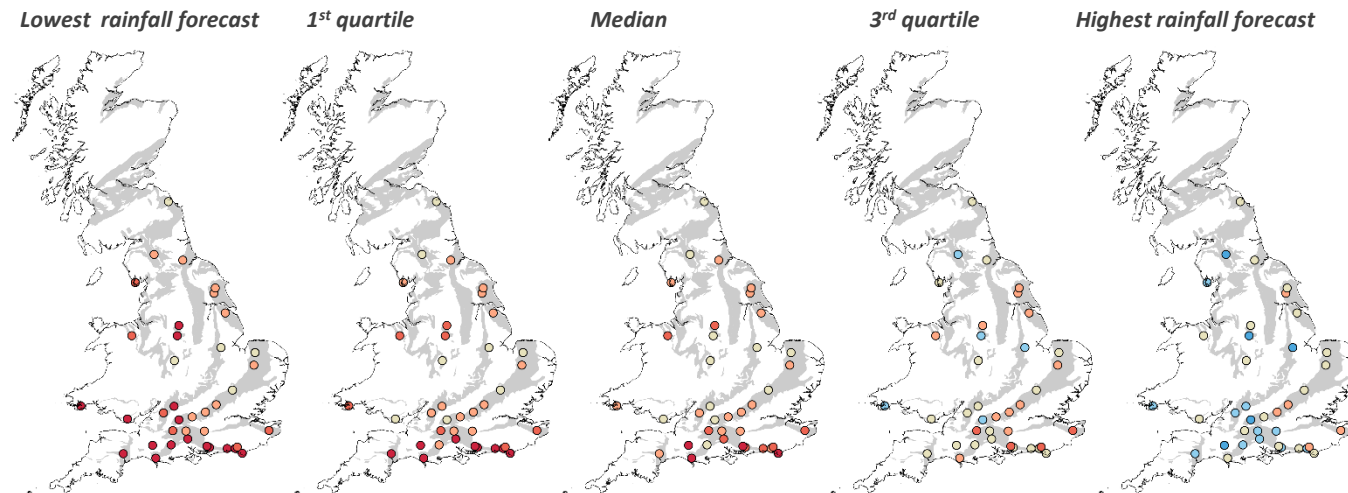
The 1-month forecast is for below normal to exceptionally low groundwater levels across southern and eastern England and southern Wales, with below normal to normal levels in northern and north-western England. Levels are predicted to be notably high at Royal Observatory. The situation is expected to remain broadly similar over 3 months, with notably low or exceptionally low levels persisting in many aquifers with median rainfall., although with the onset of recharge in the autumn, levels are more sensitive to variations in amounts and timing of rainfall. Note there are a reduced number of modelled sites due to IT issues in Scotland.

These forecasts are produced by running five members of the Met Office ensemble climate forecast through groundwater models of observation borehole hydrographs at 42 sites across the country. The sites are distributed across the principal aquifers.

Based on the distribution of observed historical groundwater levels in a given month, seven categories have been derived for each site: very low, low, below normal, normal, above normal, high, and very high. The forecast groundwater level is assigned to one of these seven categories depending on where it falls within the distribution of the historically observed values.

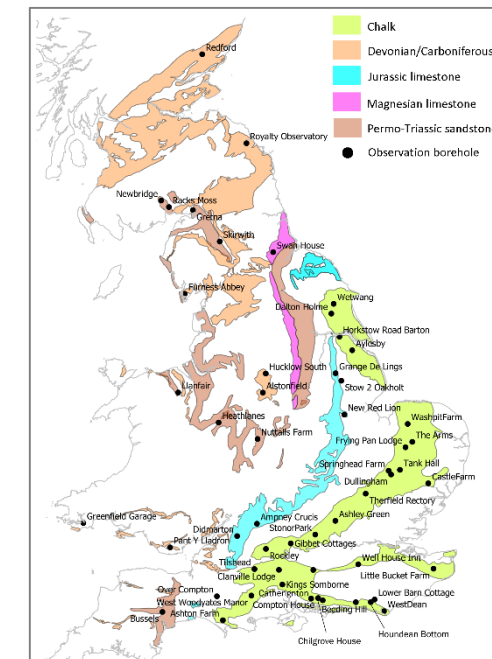


1-month outlook



3-month outlook

Key	Percentile range of historic observed values for relevant month
Exceptionally high levels	> 95
Notably high levels	87-95
Above normal	72-87
Normal	28-72
Below normal	12-28
Notably low levels	5-13
Exceptionally low levels	< 5

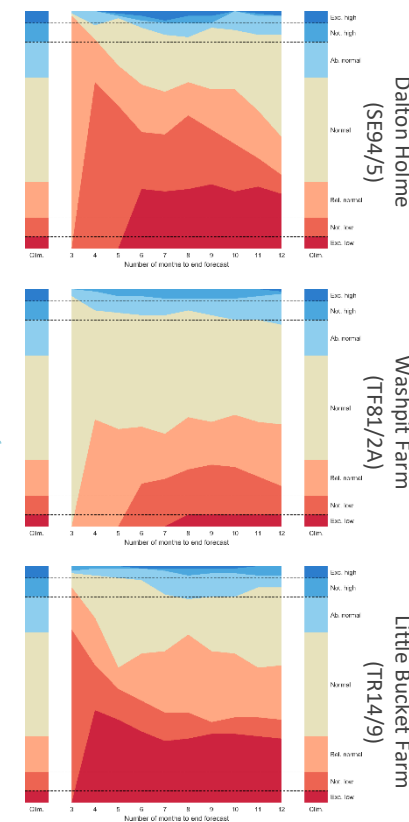
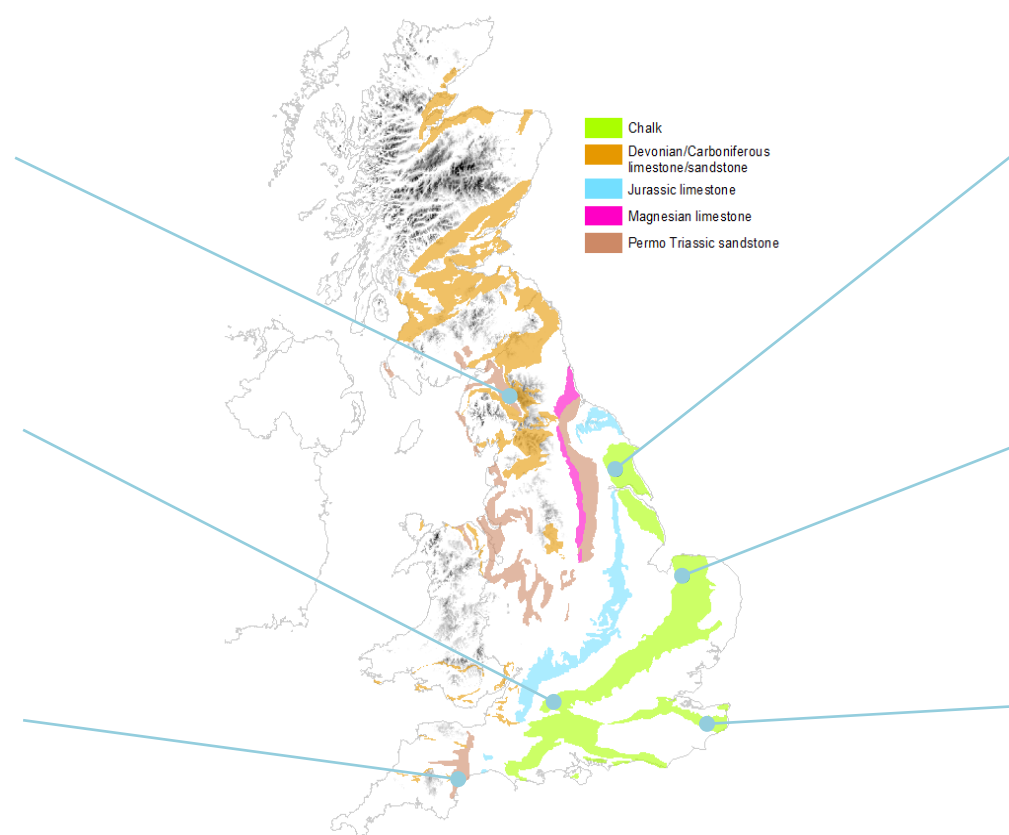
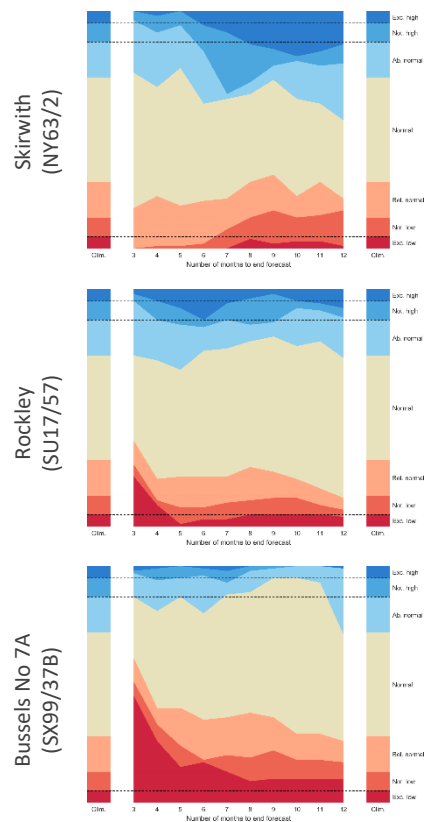


Outlook based on modelled groundwater from historical climate

Period: September 2022 – August 2023

Issued on 06.09.2022 using data to the end of August

At Dalton Holme and Little Bucket Farm groundwater levels are predicted to be above normal for the next 12 months. At the other four sites levels are predicted to trend towards normal levels over the next 6 months although levels at Bussels may remain above normal even out to 12 months.



This outlook is based on monthly ensembles of historical sequences of observed climate (rainfall and potential evapotranspiration) that form input to hydrological models. The outputs are probabilistic simulations of the average groundwater level over the forecast horizon (3 to 12 months ahead), at each location.

The graphs show variation over time of the number of simulated groundwater levels in each monthly ensemble,

that fall within each the seven categories: exceptionally low, notably low, below normal, normal, above normal, notably high and exceptionally high. The monthly variations can be compared to the long-term average distribution of levels, which are shown as columns on the left and right of each graph.

This outlook is based entirely on historical sequences and therefore does not contain any knowledge of the state of

the atmosphere and ocean. It is hence possible that some of the historical sequences used might be inconsistent with current large-scale atmospheric conditions and would therefore be unlikely to occur in the next few months.