An overview of the 2010-12 drought and its dramatic termination

The 2010-12 drought in summary

Across most of the UK, 2010-12 has been remarkable in climatic terms – characterised by exceptional departures from typical seasonal rainfall patterns. Drought conditions developed through the first half of 2010 impacting most severely on Northern Ireland, western Scotland and, especially, northern England. 2011 was the 2nd warmest year on record[1] for the UK and witnessed an extreme exaggeration in the normal north-west to south-east runoff gradient across the country. With most rain-bearing weather systems following northerly tracks, the drought became focused on south-west England and, later, the English Lowlands where concentrations of population, intensive agriculture and commercial activity generate the highest water demand.

The drought intensified through the winter of 2011/12 and parts of England recorded their lowest 18-month rainfall (for periods ending in March) in at least 100 years (see Figure 1); the rainfall deficiencies were disproportionately concentrated in the October-March periods. Correspondingly, winter replenishment to most reservoirs has been meagre and was followed, in 2012, by the largest March decline in overall reservoir stocks for England & Wales since 1993. Early April stocks were the lowest on record for a number of major reservoirs and many farm reservoirs had also failed to refill through the winter.

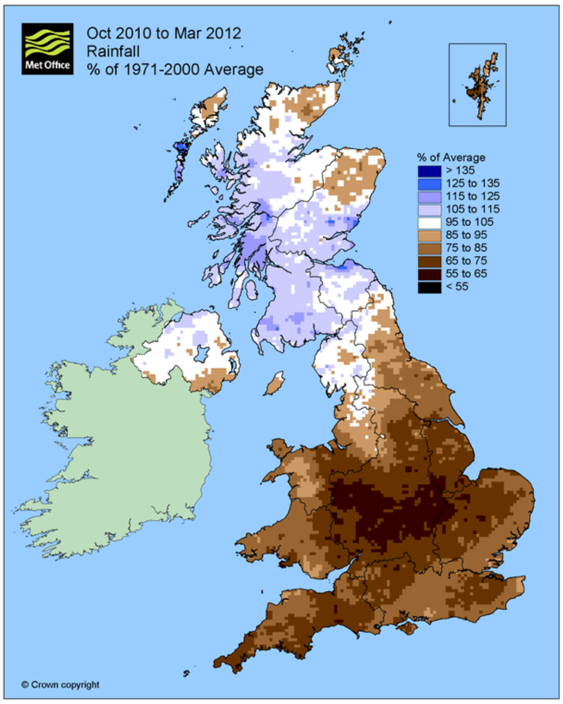


Figure 1 *October 2010 to March 2012 rainfall as a % of the 1971-2000 average*

At a national scale, runoff for March was the lowest in a series from 1961 (see Figure 2) and, in many rivers, flows during the final week fell below those recorded at the same time during the extreme drought of 1976. As more spring sources continued to fail, the associated contraction in the stream network was as severe, for the time of year, as any experienced in at least the last 50 years. This, together with the associated loss (albeit temporary) of aquatic habitat, the desiccation of wetlands, low oxygen levels, limited effluent dilution and the appearance of algal blooms underlined the environmental and ecological stress that was a defining characteristic of the 2010-12 drought.

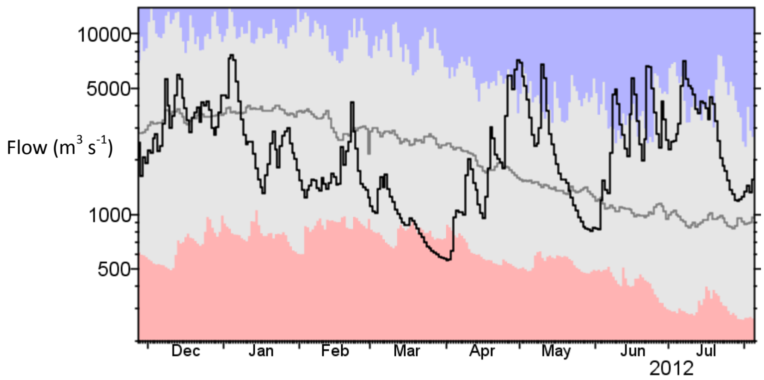


Figure 2 *Estimated daily outflows (m^3 s^{-1}) from England & Wales 2011/12 (the blue and pink envelopes indicate pre-2012 daily maxima and minima; the grey trace is the long term daily average)*

Generally, the drought was most intense in those parts of England where groundwater is a major source of water supply. The failure of wells and springs increased through 2011 and, following England's 2nd lowest rainfall for successive winter half-years, groundwater levels in many Chalk and limestone outcrop areas were approaching, or below, seasonal minima in early April 2012. For the Chalk, the country's most important aquifer, estimated overall storage, for the time of year, was lower than in 1976 and, in a series from 1951, only 1992 has registered marginally lower aquifer storage.

1 Unless otherwise stated all climatological comparisons are based on data provided by the National Climate Information Centre (Met Office); the rainfall and temperature series extend back to 1910.

The drought was of a very severe magnitude through the early spring of 2012 and hosepipe bans affecting 20 million consumers were introduced in the first week of April. With soils at their driest on record for the time of year[2] (Figure 3), the drought continued to impact severely on agriculture and the environment. Crucially, with evaporation rates set to climb through the late spring and summer, no early recovery in runoff and aquifer recharge rates could be expected. Correspondingly, the water resources outlook was fragile across large parts of central, eastern and southern England.

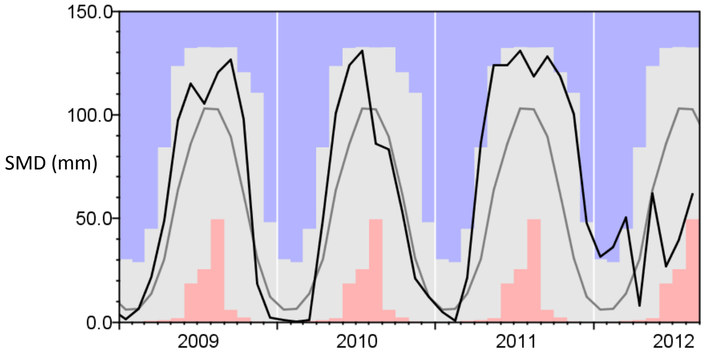


Figure 3 *Variations in monthly soil moisture deficits (mm) for the English Lowlands (the blue and pink envelopes indicate pre-2012 monthly maxima and minima; the grey trace is the long-term monthly average). Data source: MORECS*[2]

A remarkable hydrological transformation

Early April 2012 witnessed a decisive change in synoptic patterns and, with the Jet Stream adopting a persistent southerly track, a sequence of very active Atlantic frontal systems crossed the UK. April rainfall totals were the highest on record across most of the country and for England & Wales it was the wettest April for at least 230 years[3]. The extreme rainfall initiated a dramatic hydrological transformation which, at a critical time for water resources, rapidly reversed the normal seasonal decline in runoff and recharge rates. As a consequence, the focus of hydrological concern switched rapidly from drought stress to flood risk.

Cyclonic synoptic patterns continued to dominate through the late spring and early summer, and rainfall over the April-July period for England and Wales (Figure 4) was the highest in the long England & Wales series which extends back to 1766. The agricultural drought may be considered to have terminated as soils wetted-up through April in most areas. However, the subsequent persistence of near-saturated soil conditions resulted in limited access to farmland, damaged crops and restricted harvesting opportunities through the late summer. It also made most rivers very responsive to the summer deluges and, very unusually, allowed sustained recharge to most major aquifers.

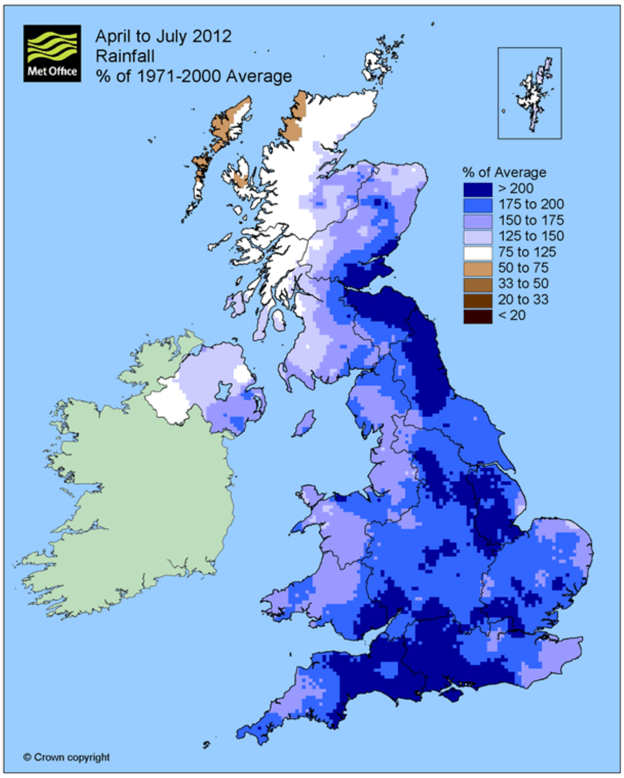


Figure 4 *April-July 2012 rainfall as a % of the 1971-2000 average*

Differing catchment and aquifer characteristics substantially influenced the rate and magnitude of the runoff and recharge responses to the exceptional rainfall. In April, runoff rates increased smartly in impermeable catchments and, by the final week, flood alerts were widespread – affecting rivers from Cornwall to north-east Scotland. For England & Wales as a whole, late-April outflows eclipsed the previous maximum in a series from 1961. After a respite in May, exceptional runoff rates continued well into the summer The Environment Agency reported that over 4000 properties in England & Wales had suffered fluvial or flash flooding by the end of August. The

2 Based on the MORECS time series from 1961 (Hough, M. and Jones, R. J. A. (1997) The Meteorological Office Rainfall and Evaporation Calculation System: MORECS Version 2.0 an overview. *Hydrology and Earth System Sciences*, 1(2), 227-239.)

3 Alexander, L.V. and Jones, P.D. (2001) Updated precipitation series for the U.K. and discussion of recent extremes. *Atmospheric Science Letters*, doi:10.1006/asle.2001.0025.

seasonally remarkable runoff rates helped replenish parched wetlands and extend the drainage network into the previously dry headwater reaches of many rivers, but they also presented further problems for wildlife (e.g. the inundation of nesting areas in the Ouse Washes).

By contrast, the impact on water resources was clearly beneficial. Contrary to the normal seasonal pattern, reservoir stocks increased, albeit erratically, through the late spring and summer and, for early September, overall stocks for England & Wales were the highest on record. More remarkably, average stocks through the summer of 2012 exceeded the December-February average for all but the wettest of winters. In the drought-afflicted regions the water resources recoveries were remarkable. At Rutland, a major reservoir in East Anglia, stocks registered their greatest two-month increase in a series from 1988 (Figure 5) and generally all index reservoirs with the exception of Bewl (East Sussex) were within 10% of capacity at the end of August.

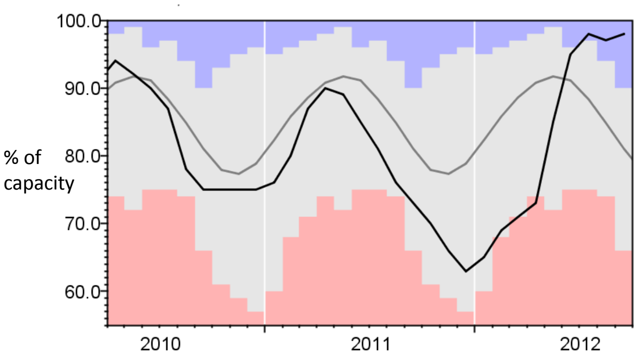
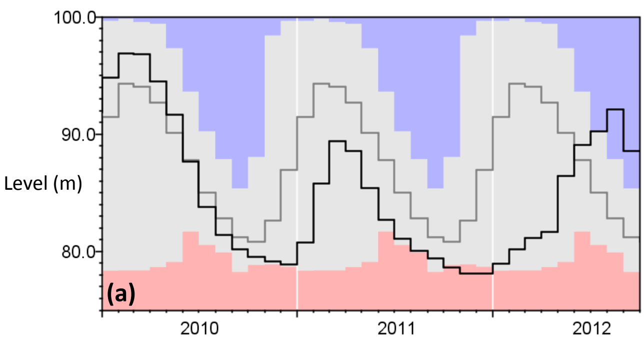


Figure 5 *Variations in monthly stocks (% of capacity) for Rutland Water (the blue and pink envelopes indicate pre-2012 monthly maxima and minima; the grey trace is the long-term monthly average)*

Facilitated by the remarkably wet soil conditions, aquifer recharge – normally very meagre in late spring and summer – was both substantial and sustained in 2012. However, differences in local rainfall patterns, the depth to the depressed water-tables and the storage characteristics of individual aquifer units made for marked differences in the time of onset and the rate of groundwater level recoveries. Rapid recoveries characterised most limestone outcrops and much of the southern and western Chalk, leaving July groundwater levels above, or close to, previous summer maxima (see Figure 6a); in a few areas (e.g. Dorset) local instances of groundwater flooding were reported. However, levels remained depressed in parts of the slow-responding Chalk (e.g. in the Chilterns) and, particularly, in the Permo-Triassic sandstones of the Midlands where high storage capacities result in very sluggish groundwater level recoveries; at Heathlanes (Figure 6b), even in September levels continued to track close to the lowest on record and the full impact of the spring/summer recharge may not be evident until early 2013.



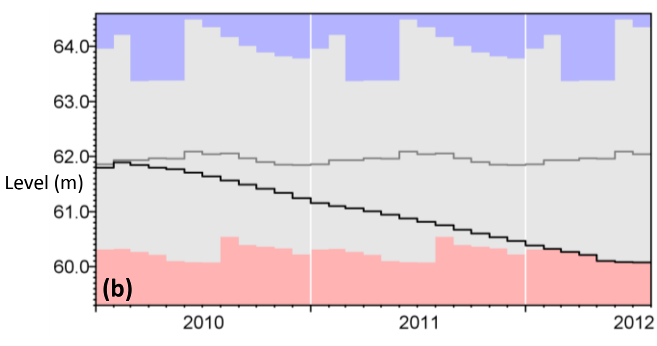


Figure 6 *Monthly mean groundwater levels (m) for: (a) Tilshead (Wiltshire) in the Chalk; and (b) Heathlanes (Midlands) in the Permo-Triassic sandstone (the blue and pink envelopes indicate pre-2012 monthly maxima and minima; the grey trace is the long-term monthly average)*

How rare was the transformation?

There is no close modern parallel to the hydrometeorological conditions experienced over the first half of 2012. Rapid drought terminations are not particularly rare – examples in the 20th century include 1992[4], 1989, 1976, 1959, 1929 and 1922. Unlike 2012, however, none of the runoff recoveries occurred during the late spring and early summer when, in many of the areas recently afflicted by drought, evaporation rates normally exceed rainfall, and seasonal declines in river flows and groundwater recharge continue with only short-lived interruptions.

[4] In 1992, there was a substantial lag between the sustained rainfall through the late spring and early summer and the associated recovery in runoff and recharge rates.

In 2012, the April-June rainfall for England was nearly three times that for the preceding three months; Figure 7 illustrates the rarity of such a disparity. Using the extended historical series for England & Wales, the degree of contrast in 2012 has not been approached since 1830 and has been exceeded only in 1779 when extraordinary climatic conditions characterised the late winter and early spring; the January-March rainfall in 1779 was easily the lowest in the 246-year national rainfall series.

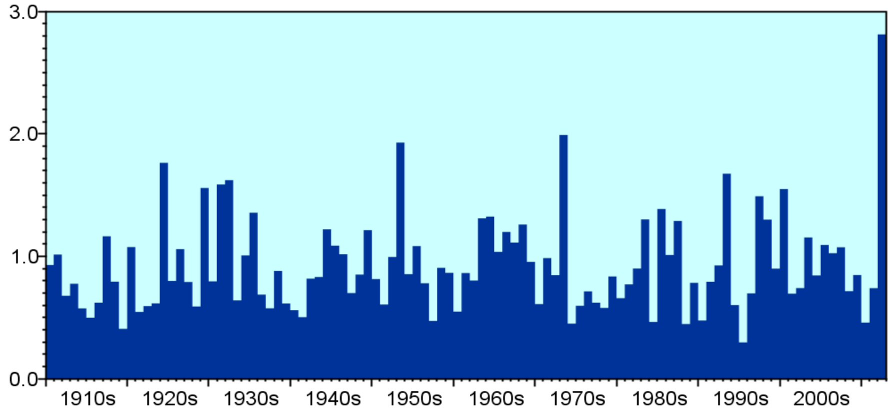


Figure 7 *Ratio of April-June to January-March rainfall for England.*

Data sources: NCIC, Met Office

In runoff terms, the singularity of runoff patterns over the first half of 2012 was even more evident. In a series from 1961, the May-July runoff for England & Wales has never exceeded 65% of that for the preceding January-March; in 2012, it exceeded 150%. A longer historical perspective is provided by the 138-year flow record for the River Thames. In 2012, flows were very depressed entering April but increased dramatically to exceed previous daily maxima for late April. Flows over the May-July period have exceeded (modestly) those for the preceding January-March in only two years and on average the runoff is around 40%; the corresponding figure for 2012 is over 220% (see Figure 8). Some parallels may be drawn with 1903 when, following a three-year drought, May-July runoff for the Thames actually exceeded that in 2012 but the terminal phase of the drought was well underway by the late winter of 1902/03.

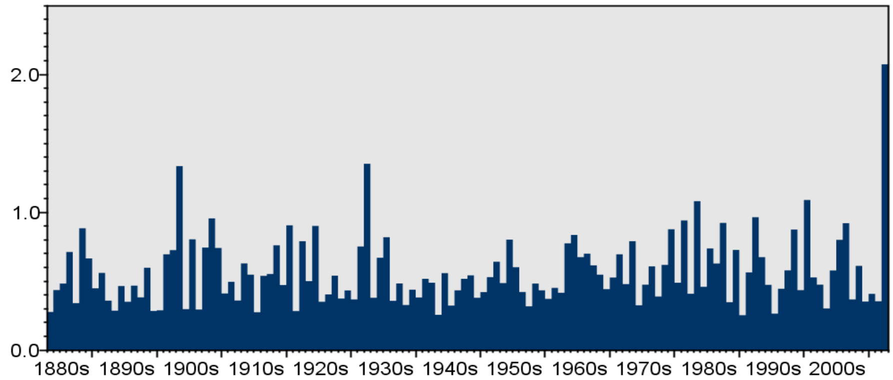


Figure 8 *Ratio of mean Thames naturalised flows for May-July to those of January-March.*

Data source: Environment Agency

Acknowledgement

This note provides an overview of the 2010-12 drought and the remarkably wet spell that terminated it. More detailed coverage of the development and rapid decay of the drought can be found at:

http://www.ceh.ac.uk/data/nrfa/index.html
http://www.metoffice.gov.uk/climate/uk/

This report has been compiled with the active cooperation of the principal measuring authorities in the UK: the Environment Agency, 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. The provision of the basic data, which provides the foundation both of this report and the wider activities of the National Hydrological Monitoring Programme, is gratefully acknowledged.

Note: A fuller report on the drought and its terminal phase is currently being compiled. The report will be published in the National Hydrological Monitoring Programme series in early 2013.

Please visit: http://www.ceh.ac.uk/data/nrfa/nhmp/nhmp.html