UK Hydrological Bulletin: November 2015 – January 2016

A remarkably persistent and exceptionally mild cyclonic episode beginning in early November and lasting more than 12 weeks brought severe, extensive and protracted flooding which impacted most severely on, northern Britain, north Wales and Northern Ireland. Many existing temperature, rainfall and river flow records were eclipsed during this period. Initial analyses suggest that there are very few close parallels in the historical record to a hydrometeorological episode which, together with the sustained flooding in southern Britain through the winter of 2013/14, raises important questions about the resilience of existing flood-management strategies in a warming world.

(Note: A proportion of the data featured in this report is necessarily provisional.)

The early autumn of 2015 was mild and relatively dry across much of the country and estimated outflows from Britain in October were the second lowest for 43 years. In many areas runoff rates and groundwater levels remained moderately depressed into early November but, thereafter, a very mild and moist sub-tropical airflow brought a sustained sequence of very active low pressure systems across much of the country. Their impact was dramatic. In Snowdonia, the Capel Curig raingauge recorded 285 mm over the 6 days ending on the 11th and catchment rainfall totals for November were exceptional in broad zone from mid-Wales to the Highlands of Scotland; many exceeding twice the long term average. For the North West region of England it was the second wettest November in the 106-year National Climate Information Centre rainfall series. This exceptionally wet phase triggered a corresponding hydrological response (see Fig 1). Runoff rates increased steeply through the second week and, by mid-month, flood alerts were widespread and increasingly persistent. A number of rivers with flows records of 50-years or more – including the Ribble, Lune and Wharfe – registered new November maximum peak flows. In Cumbria, the flooding necessitated the evacuation of properties in Kendal and Egremont and in much of north Wales, northern England and the central lowlands of Scotland, floodplain inundations were substantial with consequential disruption to local and regional transport links. River flows remained more modest across much of southern England and northern Scotland but, by month end, catchments across much of the UK remained very vulnerable to further rainfall.

December saw a continuation and strengthening of the late-autumn synoptic patterns. The persistent sub-tropical airflow, coincided with above average sea surface temperatures, in the South West Approaches, a very positive North Atlantic Oscillation and a notably strong El Niño (together with the influence of other teleconnections). In addition, and perhaps most notably, the Jet Stream guided a succession of very vigorous low pressure systems along similar tracks across the UK, provided the backcloth to a month that was truly remarkable

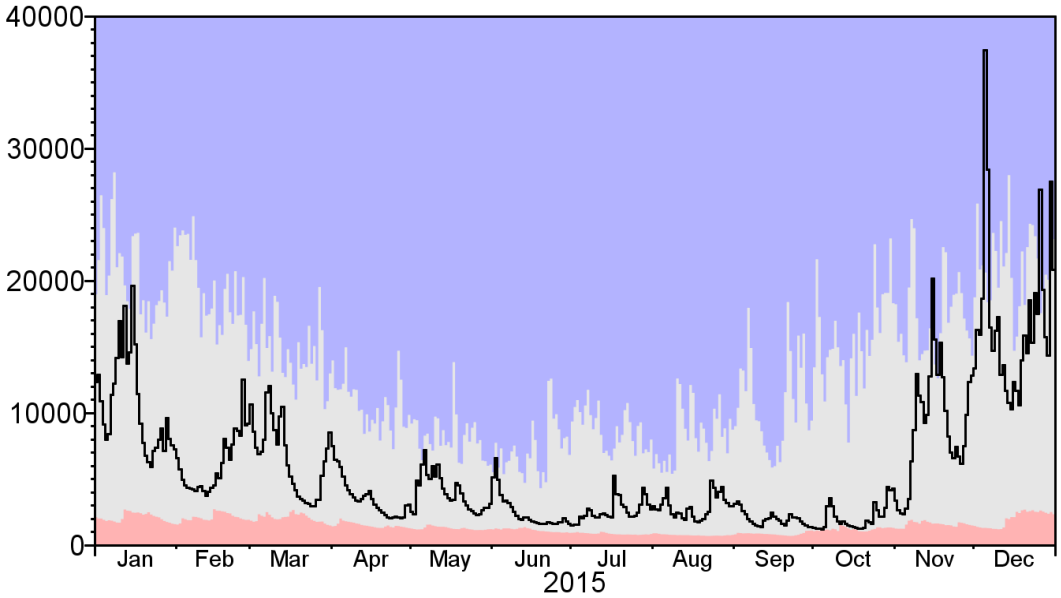


Fig 1 *Daily outflows from the UK (m3s-1). The blue and pink envelopes show the daily max and min flows for the pre-2015 record*

in climatic and hydrological terms. December's singularity is heavily underlined by the mildness of its weather. Provisionally, the average Central England Temperature was 1.6 C warmer than for any other December in a series from 1659; an extreme outlier. Virtually no frost was reported in England and many spring flowers were in bloom; the unseasonably mild conditions also impacted markedly on the behaviour of wildlife – migratory birds in particular.

Rainfall totals, across a broad range of timespans, were also very exceptional in December. Early in the month, rainfall associated with the passage of storm Desmond resulted in a new 24-hour rainfall record for the UK (341.4mm at Honister in the Lake District) and a new 48-hr record at nearby Thirlmere. (see page? for discussion of issues surrounding record falls). Monthly accumulations were also outstanding. In Snowdonia, the Crib Goch raingauge registered 1,396 mm in December – equivalent to around twice the annual average for the Thames basin. And despite below average rainfall in some areas (e.g. parts of East Anglia), the December rainfall total for the UK exceeded the previous maximum for any month in the NCIC series. The previous maxima were also eclipsed for Wales and Scotland by a wide margin in the case of the latter. Additionally, the combined November and December rainfall total was the highest for any two-month sequence in the UK series With many catchments close to saturation throughout December runoff rates were also outstanding. Preliminary analyses indicate that in a zone from south west Wales to north east Scotland, previous maximum flows were exceeded or closely approached in a substantial proportion of index rivers during December– see Table 1. On the 5th, the Lune at Caton (Lancs) and Tyne at Bywell (Northumbria) both recorded daily flows in excess of the previous maximum for England and Wales held on the National River Flow Archive – a repository of over fifteen million daily flows. The credibility of a proportion of these new maxima is considerably enhanced by gaugings well in excess of 1000 m3s-1 on, for example the Tay and Tyne, (see Fig. 2); much to the credit of the hydrometric personnel involved. In Northern Island, the Mourne, having recorded its second highest flow in mid-November exceeded it on December 5th. More remarkably, the estimated outflows from Britain on December 5th exceeded the previous daily maximum, in a series from 1961, by a margin of around 30% (see Fig. 1). Less direct, but still compelling, evidence of the magnitude of the floods were the number of bridges (around 50) destroyed or rendered dangerous during the events, these included Tadcaster bridge built around 1700.
In Cumbria, where extreme flows were common, the flooding followed two other very damaging flood episodes in 2005 and 2009. Carlisle was among the communities worst affected and, throughout the county, a number of existing flood defences – a few upgraded in recent years – were overtopped. A brief respite in mid-month merely heralded a further exceptionally wet period. In the 11 days from the 16th, the Capel Curig raingauge recorded 492 mm and by Boxing Day more than 200 Flood Warnings and 300 Flood Alerts were in operation across England & Wales; warnings were also very widespread in Scotland. In some areas, the associated flooding was exacerbated by a combination of sedimentation (following the earlier floods), landslides and debris accumulations which, locally, reduced channel conveyance. With many roads awash and bridges unsafe local and regional transport which was significantly restricted. The passage of storm Frank then brought further flooding in, for example, Manchester, Leeds (around 1000 homes flooded) and York. In north Wales, low-lying parts of Conwy were inundated and road transport badly disrupted. Similar problems afflicted much of Scotland where outstanding flows were recorded late in December: Initial analyses indicate that the Aberdeenshire Dee exceeded its previous maximum level in a continuous series from 1929.

Fig 2 *Gauging (ADCP) on the river Tyne, December 2015*

Photo credit: Ian Downs (Environment Agency)

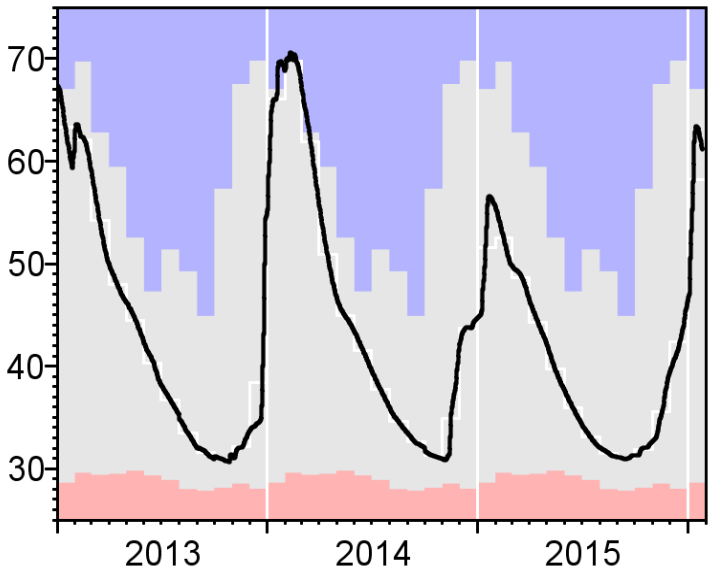
Despite below average December flows in most index catchment across the English lowlands, the estimated December outflow from Britain was easily the highest for any month in a series from 1961 and, in the most flood-affected regions, the previous monthly maxima were exceeded by wide margins. Preliminary examinations strongly suggest that a substantial majority of index gauging stations in a zone from south west Wales to the Moray Firth recorded new maximum runoff totals for any month (see Table 1). Groundwater levels, having been

Table 1 *Peak flows (m3s-1) in December 2015 for selected UK gauging station. Note: all 2015 entries may be subject to future revision*

River	Catchment Area (km^2)	Peak Flow Record Start	Dec 2015 Peak Flow (cumecs)	Date (Dec 2015)	Rank in Dec	Pre-2015 max Dec Peak Flow (cumecs)	Year (Dec)	Rank in any month	Pre-2015 max Peak Flow (cumecs)	Date
Spey at Boat of Garten	1267.8	1951	319.0	6th	2	373.6	1966	4	373.6	Dec-1966
Dee at Woodend **	1370.0	1929	1532.0	30th	1	606.0	1932	1	1133.0	Jan-1937
Tay at Ballathie	4587.1	1952	1683.0	30th	2	1706.0	2006	4	2268.0	Jan-1993
Earn at Kinkel Bridge	590.5	1951	313.1	4th	1	308.6	2006	2	357.7	Jan-1993
Forth at Craigforth	1036.0	1983	558.5	5th	3	882.7	2006	8	882.7	Dec-2006
Clyde at Daldowie	1903.1	1963	610.4	6th	4	1107.0	1994	7	1107.0	Dec-1994
Tweed at Norham	4390.0	1960	1361.0	5th	1	976.9	1994	3	1518.0	Jan-1982
Nith at Friars Carse	799.0	1957	752.2	30th	2	778.7	1962	5	1274.0	Jan-1962
Cree at Newton Stewart	368.0	1963	430.4	30th	1	322.3	1991	1	396.4	Oct-2000
Mourne at Drumnabuoy	1843.8	1982	925.5	5th	1	773.1	1991	2	1059.0	Oct-1987
Eden at Sheepmount	2286.5	1967	1680.0	6th	1	881.7	1985	1	1520.0	Jan-2005
Tyne at Bywell	2175.6	1956	1730.0	5th	1	1317.0	1964	1	1360.0	Jan-2005
Tees at Broken Scar	818.4	1956	614.0	5th	1	571.0	2011	5	646.0	Jun-2000
Lune at Caton	983.0	1968	~1700	5th	1	757.1	1985	1	1181.8	Jan-1995
Nidd at Hunsingore	484.3	1935	297.0	26th	1	252.0	1965	1	256.0	Oct-2000
Wharfe at Flint Mill Weir	758.9	1955	582.0	26th	1	298.1	1983	1	414.9	Oct-2000
Ribble at Salmesbury *	1145.0	1964	1130.0	26th	1	891.3	1964	1	891.3	Dec-1964
Aire at Armley	691.5	1961	297.0	26th	1	180.1	1978	1	252.8	Oct-2000
Calder at Mytholmroyd	171.7	2000	260.0	26th	1	82.4	2002	1	217.0	Jun-2000
Irwell at Adelphi Weir*	559.4	-	-	-	1	-	-	1	-	-
Conwy at Cwm Lanerch	344.5	1964	550.0	26th	2	566.0	2006	2	566.0	Dec-2006
Dee at New Inn	53.9	1969	98.0	12th	1	80.8	2006	2	98.1	Nov-2009
Teifi at Glenteifi	893.6	1959	281.0	19th	3	328.0	1992	6	448.8	Oct-1987

seasonally depressed in October, rose rapidly in many, but not all, index wells and boreholes through December. Notable rises were evident in some responsive southern outcrops (e.g. Ampney Crucis in the Cotswolds) but, more notably, record monthly levels were recorded for index boreholes in Northern Ireland (Killyglen, in the Chalk) and, in Dumfries and Galloway (Newbridge in the Permo-Triassic sandstones); In Yorkshire, levels also rose smartly in the final week at Wetwang (Chalk).

Synoptic patterns in January exhibited greater variety than in December; there were several cold and drier interludes but, for most of the UK, it was another wet and windy month. With soils saturated entering 2016 and river levels remaining high in many areas, most catchments remained vulnerable to even moderate additional rainfall. Intense downpours on the 2nd triggered flash flooding in the South East and in the following days flows approached bankfull in many lowland rivers including the Thames. In Wales many rivers remained in high spate and modest flooding occurred in Llanelli on the 3rd. With snow accumulations adding to flood risk, exceptional flows persisted in much of Scotland and around the 7th floodplain inundations were common. Significant flooding was reported for Inverurie and Kintore on the Don and exceptional levels were recorded on the Dee with significant flooding in, and around, Aberdeen. In southern England, with groundwater levels continuing to rise, a new dimension to the flood risk was confirmed as groundwater flood alerts were issued early in the second week (e.g. in Dorset and Hampshire). In the event, levels then declined in some of the threatened aquifer units (see Fig 3). Nonetheless, with heavy recharge later in the month, groundwater flooding is likely to remain a continuing threat into the spring. In Northern Ireland, the record November and December (combined) rainfall total was reflected in a continuing rise in the level of Lough Neagh resulting in the inundation of low-lying farmland and some severe agricultural impacts (e.g. to lettuce production). Colder and much drier conditions during the third week provided a welcome respite but the 26-28 saw Atlantic influences dominate one more. Capel Curig recorded 67.8mm in 24 hrs (25/26) and further frontal rainfall on the following day saw extensive flood alerts once more.



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Discussion

This winter, as in 2013/14, has been characterised by severe, extensive and, in many areas, prolonged flooding. Much further analytical work requires to be undertaken but there can be few, if any, close parallels to a flood episode where existing peak flows and monthly runoff totals have been eclipsed across such a substantial proportion of the country. The impact of the flooding was exacerbated by storm damage (e.g. to utility infrastructure and the transport network); the Association of British Insurers estimate the insurance costs of storm Desmond alone at £520 million. In relation to fluvial impacts, initial estimates suggest that around 16,000 homes were flooded in England alone with a substantial proportion in Cumbria. Although causing misery to those directly affected this could be considered a relatively modest total given the duration and intensity of the rainfall – more than half this number were inundated in Hull alone during the 2007 flood. The duration of notably high flows – and the repeated inundations in some catchments caused particular problems for the civil authorities and military assistance was required on some occasions to assist stricken communities and help restore transport links. Whilst, as yet, few compelling trends in runoff patterns have been identified in the UK, the cluster of flood events over the last decade has strengthened the emerging evidence of an increase in frequency of high flows.

Better understanding of the synoptic driving mechanisms are needed to determine, with more confidence, that the flow patterns recently experienced will become a more common feature in a warming world. The sheer volume and intensity of the recent rainfall was the primary cause of the exceptional peak flows in November and December but, in circumstances where a modest reduction in peak flows would have had obvious benefits, the influence of catchment land use and land drainage practices will, once again, need to be the focus of research effort. Continuing attention will also need to be directed to maximising the homogeneity of hydrometerological time series – to provide an objective framework within which to develop future engineering design procedures and flood management strategies.

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Terry Marsh
Centre for Ecology & Hydrology
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