

Supplementary Material

A comparison of the 31 January–1 February 1953 and 5–6 December 2013 coastal flood events around the UK

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1 Appendix 1: Other significant UK Flood Events Since 1953

This paper described two storm surge and flood events, 31 January-1 February 1953 and 5-6 December 2013 and with the former having being the most severe in terms of loss of life. There have been events in the UK since 1953, other than 5-6 December 2013, which were hazardous to coastal communities and/or impacted a comparable number of properties (to the 2013 event). A few years previous to the Big Flood of 1953, a notable North Sea surge occurred on 8 January 1949 ([Corkan, 1950](#)); and it was after the 1953 event that the Waverly Report advised that flood defences should be improved to reflect land use in the protected areas. Furthermore, the surge warning service (which existed at the time to protect London, and was rather basic) was substantially upgraded, to a much more far-reaching [flood forecasting and warning](#) system (e.g. [Horsburgh et al, 2008](#); [Lumbroso and Vinet, 2011](#)). These measures can save lives and protect property, although an increasingly fortified coast is sometimes associated with risk paradoxes such as the depletion of natural defences, and an increased floodplain population – in the UK various sources suggest approximately 2.5 million properties are (to varying degrees) exposed to coastal flooding (c.f. [Wadey et al, 2013b](#)). Since 1953, several storm events have generated extreme conditions that have exceeded the protective capacity of flood defence systems and/or exposed issues with any one or combination of other factors on that occasion (e.g. defences, planning, management, forecasting and warning).

There were three particularly notable west coast events from 1977 to 1990. Firstly, the overtopping of defences at Fleetwood (Fylde peninsula) on the 11 November 1977, which flooded 1800 homes, many to depths of more than 1 m ([Posner, 2004](#)) and also affected over 5000 properties across Lancashire and Cumbria. On 13 December 1981 a storm surge in the Bristol Channel, overtopped and damaged 11km of coastal defences, causing flooding in Avon and Somerset. Floodwaters reached the M5 motorway, inundated 1000 properties and 50 km² land and drowned 2500 livestock (sheep, cattle and pigs). On 26 – 27 February 1990 at Towyn (a town in Kimmel Bay, north-east Wales) high tide, surge and waves breached 467 m of Network Rail owned sea wall, inundating 10 km² of land and 2800 properties ([Bates et al., 2005](#)). Although there was no direct loss of life from the floods, the Towyn event was associated with at least 50 premature deaths in the 6 months after the flood (Welsh Consumer Council, 1992). The 13 December 1981 event was also considered dangerous – [“miraculously there was no loss of human life”](#) (EA, 2011).

Large North Sea surge events since 1953 have included 3 January 1976, 11-12 January 1978, 1-2 February 1983, 21 January 1993 ([Pratt, 1995](#)) and 9 November 2007. Also on 16-17 February 1962 over [315 people were killed in the Elbe Floods, which badly impacted Hamburg](#) – but this surge did not affect the UK. The 1978 event caused larger HWs than 1953 at Whitby, Immingham, Dover and Newhaven, and propagated into the English Channel; London only escaped flooding by 0.5 m. [Steers et al. \(1979\)](#) reported that the 11 January 1978 HW was 0.2 m-0.3 m larger than the HWs of 1953

between Wick (Scotland) and King's Lynn (Norfolk), and at a similar level to 1953 at Harwich (Essex). In particular, the 1978 event exceeded 1953 HWs north of the Wash in Lincolnshire (Steers et al, 1979). A 70-year old woman was reported to have drowned in her flooded home in Wisbech, Cambridgeshire ([YV, 1978](#)). The 1-2 February 1983 event marked the first closure of the Thames Barrier, and impacted the northwest, south and the North Sea coasts. [Flather \(1984\)](#) commented this was nowhere near as intense as the event of 1953 in terms of wind and waves, and the 1983 HWs were exceeded by more 0.5 m in places by the December 2013 event. A notable and tragic event in Scotland (which also affected [sea levels in the North Sea](#)) was the storm of 10-11 January 2005, when [five people were killed](#) when two cars were swept from a causeway in South Uist in the Outer Hebrides, Scotland. The most intense effects of this storm surge were in northern Scotland, where this storm generated more extreme winds than the 2013 Xaver Storm – at Tobermory there was a 1.5 m skew surge (almost 3 times larger than the 2013 surge at this site).

The south coast of England is generally subject to smaller surges than the east and west coasts, although has [historically experienced large coastal flood events](#), and [swell waves](#) from south-westerly storms often play an important role in the worst coastal floods – including floods during 13 February 1979 and 3 November 2005. A notable event in recent decades in the central English Channel was the December 1989 storms (Wells et al, 2001; [Ruocco et al, 2011](#)) – impacts included coastal flooding in the city of Portsmouth. The 10 March 2008 was a notable storm surge and flood event which impacted coastal communities from Cornwall to Sussex.

During the [exceptional storm season](#) of October 2013 to March 2014; as well as the Xaver storm, the south and west UK coast and Ireland were also impacted by a series of storms and floods between late ([Matthews et al, 2014](#); [Wadey et al, 2014](#); [Sibley et al, 2015](#)); particularly those of 3 January 2014 and 14 February 2014. The SurgeWatch database (<http://www.surgewatch.org/>) provides details of many of the UK's coastal flood incidents that correspond with tide gauge records (and extreme sea levels) since 1915, and also includes accounts of pre-20th century events.

2 Appendix 2. Additional summary of the 1953 and 2013 event impacts and incidences in the UK by region.

Region	Location	1953		2013	
		Reports	Sources	Reports	Sources
Wales	Rhyl	No flooding reports available.		400 people evacuated, and 150 properties flooded. A further 160 indirectly affected (e.g. loss of access, water surrounding property) as coastal flood defences failed.	BBC (2013a); News North Wales (2014).
	Barkby Beach & Gronant Dunes	No flooding reports available.		Lateral dune erosion losses of up to 8 m.	CNC/NRW (2014a, b); Parker (2014); Davies (2013).
	Kinmel Bay, Conwy	No flooding reports available.		6 properties flooded and a rest centre set up. The Conwy Valley rail line between Llandudno and Blaenau Ffestiniog closed (ballast washed away at Tal-y-cafn).	
	Llandulas	No flooding reports available.		3 properties flooded.	
	Red Wharf Bay, Anglesey	No flooding reports available.		1 property flooded.	
	Mostyn, Flintshire; Dee estuary	No flooding reports available.		North Wales mainline: damage to sea wall; debris carried by floodwater on the line.	
Northwest England	Wirral peninsula (between the Dee and Merseyside) - mainly the towns of New Brighton and West Kirby	No flooding reports available.		Cars and businesses partly submerged by sea water; sea walls and promenades overtopped across Liverpool Bay. In the Sefton region, sea wall and visitor car park at Crosby damaged and the boardwalk at Formby was partly washed away.	BBC (2013b); Wirral (2014); NWRM (2014).
	Lancashire	No flooding reports available. It was reported that the first to die from this event were the crew of a working trawler (the 'Michael Griffiths') from Fleetwood, which sank without trace off the Outer Hebrides. All 13 crew were lost.	http://www.fleetwood-fishing-industry.co.uk/2008/09/michael-griffith/	14 properties flooded in Blackpool (as well as large areas of the promenade and seafront), Fleetwood and Lytham.	NWRM (2014).
	Cumbria	No flooding reports available.		Whitehaven harbour: £300,000 worth of damage. The A595 and A5087 (at junction with road to Leece, Goadbarrow) obstructed. Cars "almost submerged" at Glasson Dock and Vickerstown on Walney "completely cut off".	WMG (2013); The Bay (2013).

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Scotland	West coast	<p>No flooding reports available.</p> <p>The worst single incident of the 1953 storm took place 5 miles [8 km] of the coast off Kirkcolm, when the ferry <i>MV Princess Victoria</i> capsized in the North Channel killing 133 of the 177 people on board.</p>	<p>https://blog.findmypast.co.uk/the-great-north-sea-flood-of-1953-and-the-local-heroes-who-leapt-into-1406268374.html</p>	<p>Oban (–Argyll and Bute) – Esplanade and George Street were badly affected; properties flooded.</p>	<p><i>Oban Times</i> (2013).</p>
	East coast	<p>The most northerly known of the UK flood locations for this event were in the Orkney islands – these included the towns of Westray, Finstown, Stromness, Flotta, and Kirkwall.</p> <p>Further south, at Portgordon (village in Moray, near Buckie) houses were flooded to a depth of up to 1 m. Also reported flooded were: Drainie, Crovie, Seatown, Edinburgh, and Musselburgh.</p>	<p>Hickey (2001); http://dnn.ess.ex.gov.uk/Portals/36/Documents/2013-Julian-Inqils-1953-Floods.pdf</p>	<p>Eymouth (Scottish Borders) – up to 50 properties and businesses affected – locals claimed this was the worst flood in 105 years.</p> <p>Roads flooded in Moray, 10 people trapped in a bus near Buckie. In Inverness and Aberdeen rivers (Ness and Dee) burst their banks, closing roads. Sea levels along the coast and in watercourses around Grangemouth were high.</p> <p>Leith (Edinburgh): 19 flood warnings, and reports of minor flooding.</p> <p>Orkney: severe wave overtopping.</p>	<p><i>Berwickshire News</i> (2013); <i>Curran</i> (2014); <i>STV News</i> (2013).</p>
England	Berwick, Tyne and Wear	<p>Flooding to properties in Berwick Pier Road.</p> <p>Tyne catchment: floods up to 1 m deep “caused by high tides and gales up to 82 mph” [132 km per hour] in Golden Fleece, Regent Street, Waterloo Road, Havelock Street and Bondicar Terrace in Blyth.</p>	<p>NCC (2010).</p>	<p>> 8 residential properties flooded across 4 settlements in Northumberland. Flooding and coastal erosion impacted roads, paths, and fields. Parts of Berwick were flooded when high tide came in before 17:00 and the River Tweed burst its banks</p> <p>North Blyth, near Cambois, roads were closed as the area was cut off: 150 homes flooded.</p> <p>Newcastle: the River Tyne burst its banks flooding the Quayside area of the city and requiring Newcastle Crown Court to be evacuated and on the south side of the river, 100s of properties were flooded around Gateshead.</p> <p>Sunderland: at the National Glass Centre in at adjacent university, buildings were evacuated amid fears the River Wear was to burst its banks which it did at the Fish Quay in Sunderland’s East End. A stretch of promenade destroyed at Hendon.</p> <p>In Middlesbrough a flooded sub-station led to a rush hour power cut in the town centre, and 100s of people in Port Clarence had to leave their homes after the River Tees burst its banks.</p>	<p>NCC (2015); <i>Berwick Advertiser</i> (2013); <i>ITV</i> (2013a); <i>Chronicle Live</i> (2013); <i>EA</i> (2014d); <i>BBC</i> (2013c); <i>Sunderland Echo</i> (2013).</p>
	Yorkshire	<p>Whitby: severe overtopping and surface water on the sea front.</p> <p>Scarborough’s sea defences “stood up to the onslaught” but suffered extensive damage.</p>	<p>WYC (2013); <i>SSD</i> (2013); http://www.whitbyweather.com/Stom53/Storm1953.html</p>	<p>Easington (Holderness): on the open coast the sea broke over the dunes and the flood water made exits to the Humber near Skeffling.</p> <p>Whitby: 200 properties flooded.</p> <p>Scarborough: promenade flooded damage to about a third of sea defences around the Sands development area of North Bay.</p>	<p>(<i>BBC</i>, 2013e).</p>

<p>East Riding of Yorkshire; Humber; North Lincolnshire</p>	<p>Remarkably, the storm surge did not breach the Spurn Head peninsula, though caused some damage.</p> <p>There is not evidence for flooding in Hull; although the flood map by Steers (1953) shows areas of flooding either side of the River Humber – it was noted that “Some damage occurred in Northumberland, Durham, and on the coasts of northeast Yorkshire”.</p> <p>42 people were killed in Lincolnshire; and the coast was heavily flooded from Cleethorpes to Barton.</p> <p>Ships were turned over in Immingham Docks and people evacuated from Goxhill (10 km north of Immingham in the Humber Estuary). Over 900 troops took command of the operation, including evacuating people.</p> <p>At the town of Mablethorpe, a complete evacuation of all residents was ordered (although 16 died here and the adjacent Sutton-on-Sea); whilst in Skegness 200 people were left homeless and the famous Holiday Camp was completely submerged. In Ingoldmells, 18 people were killed.</p>	<p><i>Steers (1953); May (1980); Skegness Today (2003); Collins (2013).</i></p>	<p>Spurn Head: Buildings and freshwater habitat on the spit were damaged, Hebridean Sheep drowned and the road was swept away.</p> <p>Hull: 400 properties flooded. Costs for reactive works (road closures, sweeping, gully cleaning, debris disposal, equipment hire etc.) were £95,000, and permanent repair works (damaged roads and footways) £425,000. Road closures: A63 in Hull closed overnight, A1077 Scunthorpe-Immingham, A178 Seaton Carew road.</p> <p>Immingham Port: 43 substations damaged, over 20 vehicles written off, with other items totalling £12 million direct losses, an estimate thought to be much higher when factoring in disrupted business – recent reports suggest damages exceeded £40 million.</p> <p>Trent: Keadby and Burringham: 500 properties evacuated, 80 homes flooded (at approx. time 20:00).</p> <p>No properties were damaged by flooding in Mablethorpe (the Lincolnshire coastline underwent a £6 million upgrade following the 1994 Mablethorpe to Skegness). However more than 20 m of dune was eroded, and two properties were flooded at Skegness.</p> <p>Boston was the worst hit town in UK, with 800 residential properties flooded, and £8 million damage Defence failures included a 40 m-wide hole in a flood bank at 'Slippery Gowt' which was temporarily repaired with 2,000 tonnes of stone. Flooding was dangerous, with water "literally pouring down the streets", whilst the recently renovated St. Botolph's church was flooded.</p>	<p><i>Hull Daily Mail (2013); HCC (2014); ERYC, (2014); Scunthorpe Telegraph (2013); EA/GOV UK (2014a); EA (2014a); Skegness Standard, (2014); BBC (2014c).</i></p>
<p>Wisbech (Cambridgeshire)</p>	<p>32 flooded properties, 11 pumps deployed in the clean-up</p>	<p><i>Baker (2006).</i></p>	<p>Less severe flooding than 1953, but flooding did cause traffic “chaos” due to water backfilling tidal drains, flood water spilling over the quayside and defences, getting “dangerously close to homes and businesses”.</p>	<p><i>Fenland Citizen (2013).</i></p>
<p>Norfolk</p>	<p>Hunstanton: 31 people died, 16 of them American service personnel and their families, including 6 from one household, as they lodged in wooden homes; part of 66 fatalities across Snettisham, Heacham and Hunstanton.</p> <p>A 22 year old Sculthorpe-based US airman, Reis Leming, saved 27 people from their wooden prefabricated homes in Hunstanton (despite being unable to swim). He collapsed from exhaustion, and was hailed for his heroic efforts, and become the first non-Briton to win the George Medal for bravery in peacetime.</p> <p>King's Lynn: cars picked up by the force of the floodwater and the streetlights of London Road “exploded” as the water rose, plunging the town into darkness. Dead animals floated down the streets.</p>	<p><i>EDP24 (2013); Lynn Museum (n.d); Steers (1953).</i></p>	<p>Wells-next-the-Sea: the quay was flooded, inundating a pub and several houses.</p> <p>Despite that the 2013 HW exceeded 1953 HW at King's Lynn the flooding was less – although defences were reportedly “severely tested” and sea water covered the quays.</p> <p>Hemsby: 3 cliff-top homes collapsed into the sea, 4 more were badly damaged, and a lifeboat station was also washed into the sea.</p> <p>Seawalls protecting at least 3 conservation sites were breached, and at Winterton 170 seal pups were washed away. In Cromer, 6 people were rescued from the pier, whilst railings on the promenade were broken and twisted and debris was littered across the sea front – over 30 beach huts were destroyed.</p> <p>Great Yarmouth: the army was brought in to protect the telecommunications</p>	<p><i>BBC (2003); BBC (2013g); EA (2014c).</i></p>

	<p>Wells-next-the-Sea: a motor torpedo boat was lifted out of the water onto the quay.</p> <p>Walcott: main street and many buildings damaged.</p>		<p>infrastructure. Several properties were flooded.</p> <p>Blakeney: approx. 6 boats were deposited on the quayside over the 3 ft [1 m] high railings, along with tonnes of seaweed and mud from the Blakeney Haven inlet which separates the village from the North Sea.</p> <p>Walcott: dozens of properties were flooded, several people rescued, and 2 caravans were washed onto the flooded road.</p>	
Suffolk	<p>Felixstowe: 41 deaths after collapse of flood walls on the Orwell Estuary. Homes were washed away at Langer, and occupants struggled to climb to safety on their roofs.</p> <p>Ipswich: 1 km² urban area flooded; 700 residential and more than 580 commercial and industrial properties.</p> <p>Thorpeness: the sea crashed over the shingle bank gouging a channel 50 ft [15.2 m] wide in the sand dunes.</p> <p>Lowestoft: 400 properties flooded.</p> <p>Other impacts included flooding of Ness Point gas works, which cut off the railway line from Lowestoft to Norwich.</p> <p>Southwold: 5 people killed and the town was “a virtual island for two days and nights”</p>	<p><i>NRA Anglian (n.d.); GNUK (2013); Baxter (2005).</i></p>	<p>Ipswich and Felixstowe escaped substantial damage. In Ipswich the River Orwell overtopped near the Waterfront and blew manhole covers near the DanceEast building. The Strand at Wherstead flooded and a man and his teenage daughter were rescued from the roof of their car.</p> <p>15 breaches across the coast and estuaries, up to 30m wide. For example the beach between Dunwich and Walberwick was breached, flooding Dingle Marshes.</p> <p>Lowestoft: 233 properties flooded (143 commercial and 90 residential). In the Waveney District, both bridges were closed, effectively cutting the town in half.</p> <p>Southwold: pubs hit by flooding, Christmas dinners cancelled. The impacts were not as severe as during 1953.</p> <p>Blythburgh: sea defences failed, which caused the closure of the A12 road (link between Lowestoft and Ipswich).</p> <p>The Crown Pub flooded in the village of Snape (between Aldeburgh and Orford), 40 turkeys drowned.</p> <p>Rail services between Lowestoft and Norwich, and Lowestoft and Ipswich disrupted as a consequence of flooding at Lowestoft Central and damage to the signalling network. The Lowestoft to Ipswich line was closed for eleven days.</p> <p>Waldringfield: suffered flooding to properties and gardens along the Quay.</p> <p>A12 Ipswich to Lowestoft road closed due to flooding.</p>	<p><i>The Southwold Museum (n.d.); SDC (2014); SFCN (2014).</i></p>
Essex	<p>Canvey Island: 120 killed. The sea first broke into Canvey through the South Benfleet Creek in the Sunken Marsh area on the northeast of the island, where 53 of the 58 flood victims died. Tragic accounts of that night, such as: “One couple pushed their baby in its cot through a window into the water and it was found floating, like Moses. That child lived, but the parents didn’t – they drowned and were found in each other’s arms.” [Bronwen Sadler].</p> <p>Jaywick was cut off from the rest of Essex and 37 people were killed. The islands of the River Crouch became “one vast expanse of water”. In Harwich</p>	<p><i>Baxter (2005); Grieve (1959); Jonkman & Kelman (2005); Kent News (2013); Essex Life (2013); Essex Record Office (2013).</i></p>	<p>38 properties were flooded (33 commercial, 5 residential). Forecasts initially suggested that more than 5,000 homes could be affected. Multiple evacuations across the county, and coastal erosion was a problem – e.g. Seawick (near Clacton) the remainder of the already-damaged coastal path was completely washed away.</p> <p>No reported flooding on Canvey, minor flooding on Southend seafront near the Three Shells cafe and at some beach huts in Thorpe Bay.</p>	<p><i>Echo (2013); Heart (2013) Johnson (2014).</i></p>

	<p>8 people were killed- the flood here was described as a "2 m high wall of rolling water". The 8 people drowned when trapped in their basements in Main Street. Harwich Junior School were flooded to a depth of 1.5 m. An additional hazard was when high explosives floated away from the army base on Bramble Island (near Harwich), and public were advised to be on the lookout for them.</p>			
Thames	<p>Flooding from Tilbury to London's docklands: oil refineries, factories, cement works, gasworks and electricity generating stations brought to a standstill.</p> <p>London East End: 100 yards [91 m] of sea wall collapsed, causing more than 1,130 houses to be flooded killing one person at Tidal Basin and causing 640,000 m³ of Thames water to flow into the streets of West Ham</p>	<i>Taylor (2011).</i>	<p>Water levels came close to tops of quays/defences, and flood warnings were given, but no reported flooding.</p>	
Kent	<p>Large swathes of the coastline from Erith to Whitstable were flooded. Some sources suggest no loss of life in the county, although it is believed that a sluice-keeper from Belvedere was killed, and whose body was never properly identified. The surge propagated up the River Medway, which "became awash with the bloated corpses of drowned cattle and sheep".</p> <p>Floods put the county's main railway line out of action ("leaving it hanging between two and five feet in the air"), and >5,000 acres [20 km²] land was flooded, and thousands of livestock were drowned.</p> <p>Isle of Thanet: sea water broke through a wall at the northern end of the channel, which quickly spread to Sarre near Canterbury, about 4 miles [6.4 km] from the sea, with the water 12 to 15 feet [3.7m to 4.6m] deep.</p> <p>The Isle of Thanet was "virtually cut off again" as it had been before the 17th century when it was separated from the Kent mainland by the Wanstum Channel. The storm also destroyed the lighthouse on the end of Margate's stone pier.</p>	<i>BBC (2013f); BBC (2013g); Kent News (2013).</i>	<p>Two women and two babies were rescued after being hit by a large wave whilst walking in Louisa Bay, Broadstairs at 13:30 5 December (well before the peak of the surge hit the region around midnight).</p> <p>1,000 homes in Sandwich, Seasalter, Faversham and Medway were evacuated.</p> <p>The EA's temporary flood barriers reportedly protected 219 properties in Sandwich, although "about 40 homes in Faversham, Sandwich and Strood were submerged when water broke through defences in the early hours of Friday, leaving hundreds of people evacuated". Minor floods were also reported in Sittingbourne, Whitstable, Dover, Rochester and Margate. Beach huts were overturned at Broadstairs, and fire crews rescuing a man from a stranded lorry at Dover's docks.</p>	<i>Kent Online, (2013a); Kent Online (2013b).</i>
Sussex, Hampshire, Isle of Wight	No flooding reports available.		<p>At Rye there was a breach which flooded the low lying areas of the nature reserve; the Sailing Club, Bosun's Bite, Rye Harbour Marine and Lime Kiln Cottage were all flooded. Roads were flooded in Littlehampton, Newhaven and Shoreham, disrupting the morning commute (e.g. the A595) and the Newhaven swing bridge was damaged. At</p> <p>Floodwaters left railway lines out of action, and all trains were suspended from Brighton to Seaford, Shoreham airport was under water after the River Ader burst its banks, including a significant breach. A number of homes on the A259 in Shoreham were also flooded.</p>	<i>Yates (2013); BBC (2013d); ITV, (2013b); IWCP (2013); Daily Echo (2013); Taylor (2013).</i>

		<p>Sea flooding was reported at Cowes, Yarmouth and St Helens on the Isle of Wight – sandbags were issued at 03:00 when the surge caused the River Medina to rise “dangerously high”. Locations affected also included Bursledon and Hamble (both on the tidal River Itchen, Hampshire), “the Abbey” in Beaulieu (adjacent to the Beaulieu River, New Forest) and roads were closed on Hayling Island and in Emsworth.</p> <p>Taylor (2013) described how in Southampton, properties on low-lying areas of the River Itchen barely escaped flooding. The EA issued a flood alert; and it was fortunate that the highest part of the surge corresponded to the (normally lower) second high water. Residents noticed in Priory Road that on the Friday morning (6th December) that a “<i>high tide mark of leaves and twigs</i>” had been left outside their back door.</p>
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Please note that fatalities quoted can vary according to source. Refer to [Kelman \(2009\)](#) as a source which includes a detailed breakdown.

