The Natural Hazards Partnership

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Inland Flooding

This note is one of a series of short guides covering a range of natural hazards. These guides aim to provide non-experts with a brief introduction to each hazard and to highlight key aspects that may need to be taken into account in decision-making during an emergency involving this hazard. They are not intended to be fully comprehensive, detailed analyses or to indicate what will happen on any particular occasion. Instead they will signpost issues that are likely to be important and provide links to sources of more detailed information. Each note will be updated on an annual basis in line with the review of the National Risk Assessment.

What is Inland Flooding?

Most inland flooding results when ground conditions inhibit water drainage after intense and/or persistent rainfall. The flooding can take several forms, over a wide range of space (or area) and time scales, and degrees of impact.

How Does Inland Flooding Affect the UK?

There are several different physical processes which contribute to inland flooding in the UK:

Surface Water (pluvial) flooding occurs when intense rainfall overwhelms local drainage capacity. It can occur anywhere, and can be particularly disruptive in urban areas. It is most commonly associated with summer thunderstorms, where the effects can be very localised. But more extensive surface water flooding can occur at any time of year during extended wet periods in which the ground is saturated. While heavy rain is the dominant factor, surface water flood risk can be exacerbated by ground conditions that promote rapid run-off or prevent drainage: very wet ground, very dry and/or compacted ground, frozen ground or an abundance of concrete or other impermeable surfaces, blocked channels or uncleared trash screens. Another contributory factor is fallen leaves and tree debris during autumn, which can rapidly block drains and streams.

River (fluvial) flooding occurs when a river cannot adequately convey downstream the water flowing from surrounding land or other rivers. The excess water then spills onto a flood plain or other adjacent land. The speed at which a river's level and flow increases in response to rainfall depends largely on the size and shape of its catchment; small rivers can respond rapidly, on a timescale of a few hours or less, while peak levels and flows for major rivers such as the Thames or the Severn may only be reached several days after the rain has fallen. River or tidal flooding in estuaries can be more likely when tidal water levels are high, preventing river water from draining quickly into the sea.

Groundwater flooding is the emergence of ground water at the earth's surface. Groundwater is usually stored below the surface, often within layers of permeable rock (aquifers) such as chalk. This type of flooding is often not directly related to a single rainfall episode, and occurs over much longer timescales as groundwater levels slowly rise during and after an extended spell of wet weather. Due to the

dependence on geological factors, certain areas are much more prone to groundwater flooding than others.

Snowmelt following a very cold winter period with lying snow can occasionally cause significant flooding due to rapid or prolonged thaw, particularly in areas where widespread and prolonged snow-cover is unusual. Snowmelt usually occurs in association with heavy rain, with both components contributing to the flooding.

Note that all of the above types of flooding can often occur in combination in major events, particularly when the ground is already saturated. A prolonged period of wet weather (such as the summers of 2007 and 2012, and the autumn and early winter of 2012) may lead to a similarly prolonged period of very elevated flood risk. This may contain numerous individual river, surface water and groundwater flood events, as each successive period of rain tends to make ground conditions even more sensitive to further rain.

What are the Impacts of Inland Flooding?

At its worst, inland flooding can cause disruption on a scale and level of severity greater than other weather-related hazards (with the exception of coastal flooding). But there is a broad range of impact, from localised, minor and temporary impacts to national-scale disruption with significant and lasting effects.

Summer thunderstorms in the UK frequently result in isolated and minor surface water impacts, such as temporary flooding of roads and small numbers of properties. More rarely the storms can become organised into bands or become slow-moving causing much more significant impacts. The severe, although localised, flooding in Lynmouth (1952) and Boscastle (2004) both resulted from over 100 mm of rain falling in just a few hours across rapidly-responding and steep, populated river catchments.

Persistent rain, usually associated with large-scale slow-moving frontal systems can cause both river and surface water flooding at multiple locations over a wide area.

In the worst cases, a number of events, as described above, may occur within a period of several weeks (or even months) of ever heightening flood risk. This phenomenon occurred in both the summer of 2007 and the early-summer of 2012, where weather patterns were conducive to slow-moving low pressure systems in the vicinity of the UK.

Flooding most commonly affects people and communities at risk, properties and the transport network– notably road and rail. It can also disrupt utilities and other critical infrastructure, and services such as hospitals, schools and our emergency response capability. Impacts can be of short duration, but can often linger well after the flood water has receded for example, homes may be uninhabitable for many months.

Agricultural disruption, particularly in the case of river flooding, can be significant and prolonged, with flood plains and other low-lying land often used for farming. The effects of flooding on health are extensive and significant and can be direct or indirect. Direct health effects are those immediately associated with flood water and the debris contained within it, including drowning, injuries, stress, disease and

respiratory, skin and eye infections. It is dangerous to drive or walk through flood water. Most deaths associated with flooding are from drowning; other causes include physical trauma, heart attacks, electrocution, carbon monoxide poisoning (from using fuel-powered appliances indoors to dry out spaces without good ventilation) and fire. Injuries can occur when flood water displaces or conceals objects, or when people attempt to remove themselves, their families or their belongings from approaching flood water. Other direct health effects include the risk of infections from contact with contaminated flood water (by chemicals, sewage and residual mud), vector-borne disease (as certain diseases are associated with flooding), and rodent-borne disease (such as leptospirosis, as flood water may drive rodents into closer contact with humans).

In the longer term, indirect health effects are those which occur as a consequence of the flood and include damage to infrastructure (including healthcare facilities), disrupted food, water and power supplies, population displacement, impacts on mental health and disruption to people's livelihood and income.. Further longer term effects include mental anguish, fear of recurrence and on occasions post traumatic stress disorder.

Population vulnerability to the health effects of flooding is due to a complex interaction of a variety of factors: severity and rapidity of the flooding, health status and necessity of regular medical treatment, access and availability of warning, rapidity of response measures and being located in high-risk areas and high-risk built environments.

Timeline for Inland Flooding?

Broadly speaking, the larger the geographical scale, the greater our ability to identify the potential for flooding at longer lead times. However, small scale detail is critical and can be difficult to resolve, even at short lead times. Our UK capability for flood warning varies greatly by each situation depending on meteorological and hydrological factors.

Surface water flooding can be particularly difficult to predict accurately, being often dependent on the coincidence of small-scale intense rainfall features with equally small-scale geographical features and ground conditions. This degree of precision lies close to the limits of modern rainfall forecasting techniques, and it is common to be unable to identify a location likely to be affected in sufficient time to make location specific warnings effective.

Hydrological forecasting enables flooding of large rivers to usually be predicted with some accuracy providing lead times of several days. Predicting flooding in smaller rapid-response' catchments suffers from many of the same limitations associated with surface water flood forecasting.

Groundwater flooding is the end result of a slow rise in groundwater levels over several weeks following a wet period. These rises can be monitored, and flooding

can usually be predicted more than several days in advance. It is important to be aware that groundwater levels will continue to rise even after a wet period.

Flooding from snowmelt usually results from a transition to much milder weather at the end of a prolonged very cold period with extensive lying snow. Such transitions are usually forecast accurately a number of days in advance. However, the thawing of snow and the interaction of the resulting water with the ground and rivers is less well understood and modelled in the UK. As a result, there can be considerable uncertainty on the extent and impact of flooding from snowmelt.

Example Historical Events

Thames Valley, Spring 1947 – over 100,000 properties affected, also severe impacts along River Severn from Shrewsbury downsteam to Gloucester – river and surface water flooding due to snowmelt

Lynmouth, 15-16 August 1952 - 35 deaths, over 100 properties severely damaged – rapid response river flooding.

Strathclyde, 10-12 December 1994 - 3 deaths, 700 properties flooded, 80 roads closed, severe rail disruption - river flooding.

Chichester, January 2004 - severe local transport disruption – groundwater flooding.

Boscastle, 16 August 2004 – extensive damage - rapid response river flooding.

Gloucestershire, 22 July 2007 - Tewkesbury cut off, over 400,000 people without drinking water, 50,000 without electricity – river flooding.

Hull, 15 and 25 June 2007 - over 8,000 properties and 1,300 business affected, 6,300 people forced to live in temporary accommodation, over 90 schools temporarily closed – surface water flooding.

Cumbria, 18-19 November 2009 - A596 Northside road bridge collapsed, over 5000 businesses affected – river flooding.

Northern/Central England and Southern Scotland, 28 June 2012 - one death, widespread transport disruption, hundreds of properties flooded – surface water flooding.

Where is most at risk?

The Environment Agency in England, Natural Resources Wales and SEPA (in Scotland) have all published flood risk assessments highlighting local authority areas which are statistically most susceptible to flooding. Links to these documents are given below. Additional information and the warnings available are also highlighted.

When mapped in this manner on a national scale, inland flood risk by area initially appears counter intuitive as it is not concentrated in either the wettest areas or where population density is highest. This reflects the complex interaction of meteorological, hydrological, geological and human factors which determine the potential for flooding.

How can we reduce the impacts of flooding?

Impacts can be reduced by avoiding placing people, properties and infrastructure in areas prone to flooding.

Once a location has been identified as being at high risk of flooding, flood management schemes and/or flood plans may be created to reduce the risk and lessen the impacts. This approach is applicable to all type of flooding, despite the differing levels of likelihood and predictability of the various sources of flooding, and various responsibilities for flood management. The National Flood Emergency Framework brings together information, guidance and key policies and is relevant for all involved in flood emergency planning.

Emergency responders should make use of the flood forecasting and warning services provided by the Environment Agency, Natural Resources Wales and SEPA, in conjunction with the Met Office, to plan for and respond to flooding in their areas. Flood Guidance Statements for emergency responders (indicating national and county/local authority scale flood risk for the next 5 days) are produced at least daily by the Flood Forecasting Centre (FFC) for England and Wales, and by the Scottish Flood Forecasting Service (SFFS) for Scotland. These forecasts are summarised in the daily NHP Strategic Assessment, and their content is also reflected in the Met Office's National Severe Weather Warning Service. In addition river levels are now available on the internet, and a three day Public Flood Risk Forecast is available for England and Wales.

At shorter lead times, Flood Alerts, Flood Warnings and Severe Flood Warnings for specific locations are produced by the Environment Agency, Natural Resources Wales and SEPA (links below).

References and Further Information

Environment Agency and SEPA flood risk assessments:

http://www.environment-agency.gov.uk/research/library/publications/108660.aspx

http://www.environment-agency.gov.uk/research/library/publications/108958.aspx

http://www.sepa.org.uk/flooding/idoc.ashx?docid=cbbf7c88-b41e-4ba0-bbaf-c51d676ca36a&version=-1

Real-time Flood Alerts and Warnings:

http://www.environment-agency.gov.uk/homeandleisure/floods/31618.aspx

http://floodline.sepa.org.uk/floodupdates/

http://naturalresourceswales.gov.uk/alerts/flood-warnings/?lang=en

Health Effects of Flooding:

Coulthard T, Frostick L, Hardcastle H, Jones K, Rogers D, Scott M, Bankoff G. (2007) The June 2007 floods in Hull: Final Report by the Independent Review Body. Hull City Council. Available at: http://www2.hull.ac.uk/science/pdf/geogfloodsinhull3.pdf

Public Health England (2013). Flooding: Advice for the Public

http://www.hpa.org.uk/Topics/EmergencyResponse/ExtremeWeatherEventsAndNaturalDisasters/EffectsOfFlooding/

Menne and Murray (eds) (2013,) Floods: Health effects and prevention in the WHO European Region, World Health Organization, Regional Office for Europe and Health Protection Agency, Copenhagen. http://www.euro.who.int/en/health-topics/environment-and-health/Climate-change/publications/2013/floods-in-the-who-european-region-health-effects-and-their-prevention