

Environment Group

Research Programme

Research Findings No.19

Climate Change: Flood Occurrences Review

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This study examines the recent history of flooding in Scotland and predicts likely changes in flooding given what is presently known about climate change. It identifies those areas of Scotland most vulnerable to flooding and estimates current and future financial damage in these areas. Public awareness and concern about flooding is reviewed and recommendations made to improve flood hazard management and public awareness of the problem.

Main Findings

- Since the mid 1980s Scotland has seen an increase in the number of floods and high flows on many large rivers. Similar “flood rich” periods have occurred in the past, but these floods and high flows could occur increasingly in the warmer and wetter Scotland predicted by climate scientists.
- The sea level at Aberdeen has risen by nearly 70mm since 1900 and parts of the Scottish coast has seen an increase in flood risk. This worsens when storm-generated surges add several metres to high tides around vulnerable coasts.
- Climate scenarios prepared by the UK Hadley Centre, when converted into river flows, suggest inland floods in the 2080s increasing by up to 10% (Low and Medium low scenarios) or by up to 20% (Medium high and High scenarios). In especially sensitive rivers basins what is now a one in 50-year flood could become a one in 20-year flood.
- By 2050 sea levels are predicted to rise by an additional 80-300mm which, when combined with future storm surges, could make most of Scotland’s coasts below the 5 metre contour more vulnerable to flood risk.
- At present 93,000 properties are estimated to be at risk from coastal flooding and 77,000 from inland flooding. Current estimates of annual average damage from inland floods are around £20 million. This could rise by 27% (2020), by 86% (2050) and by 115% (2080) due to climate change.

The Study in Context

Current predictions of climate change suggest that over the present century Scotland will become warmer and wetter, sea level will rise and the number of storms around the coast will increase. As a result, the threat of flooding both inland and around the coast will increase damaging Scotland's economy and society. Transport links, housing, the public water supply and commercial properties are especially vulnerable to such an increase in flooding. Although land owners are primarily responsible for flood protection, local and central government also have a role in reducing the adverse impact of floods.

Frequency and Severity of Flooding in Scotland

Inspection of the longest river flow records reveals considerable variation in the size and frequency of floods year on year making it difficult to identify trends. Across most of Scotland, however, the number of floods peaked during the 1980s and 90s especially in the west due to more storms coming in off the Atlantic. In the north an earlier peak was reached in the 1950s. Since 1989 most of Scotland's largest rivers have reported their highest recorded flows. During these 'flood rich' periods it is clear that floods of a given size were more common, although it is less clear whether the size of the largest floods increased. Whether, over the last 15 years this increase in flooding has been due to climate change is still being debated, but it is consistent with 'flood rich' periods in the past and increased flooding in the future given current estimates of climate change.

Flooding along the coast depends on sea-level, storm surges and whether or not the storms coincide with high tides. Changes in sea-level and storm frequency and severity can thus have a significant impact on coastal flooding. It is now generally accepted that global sea levels have risen by 1-2 mm per year during the last century with Aberdeen reporting a rise of nearly 70mm during this period. More generally, changes in sea level around Scotland's coast varies depending on continued uplift of the land following the melting of the last ice sheet 10,000 years ago and changes in the amount of water stored in the world's

oceans. International authorities reckon that half the rise in global sea levels in the twentieth century was due to thermal expansion of the oceans, a view locally questioned by one authority for the seas around Scotland. Sea level rise represents one part of the coastal flood threat, but more important is the role of storm surges especially when they coincide with high tides. At present it is unclear whether or not coastal storms are becoming more frequent, but the flood levels reached by current 50 year and 100 year storms can be estimated to determine the current flood risk.

Future Severity and Magnitude of Flooding

Flood risks due to both river and coastal flooding are expected to increase during the 21st Century. For river flooding, changes have been estimated using climate change scenarios developed by the Met Office's Hadley Centre. These scenarios cover a range of emissions effects scenarios. Under the Low and Medium low scenarios, increases in the size of floods by the 2080s are likely to be less than 10% for most of Scotland. However, under the Medium high and High scenarios, the same floods may be 20% larger. In especially sensitive river basins what is now a one in 50-year flood on average could, by the 2080s, become as frequent as a one in 20-year flood. However, these changes can only be indicative: it is difficult to separate out the effects of natural climatic variability from those due to human activity, and natural variations are sure to continue affecting our climate in the future.

In coastal areas, future changes in flood risk are estimated from rising sea levels and the size of storm surges. Sea level rises ranging from more than 300 mm to 80mm have been predicted around Scotland's coasts by 2050. Flooding of coastal land and property normally takes place when storm surges occur, although the largest surge effects can be expected to occur only infrequently. Nevertheless, the effects of combining sea level rise with estimated storm surge effects lead to most of the Scottish coastline up to 4 - 5 m becoming vulnerable to low-risk coastal flooding by the 2050s, unless adequately protected by defences. Again, uncertainty in the scientific community reflects the difficulty of making precise estimates of future coastal flood risk.

Economic Impacts

Without taking into account the protection offered by flood defences, more than 93,000 properties are presently at risk of coastal flooding, while a further 77,000 are at risk of river flooding. Properties located in the following coastal areas (the Carse of Gowrie, the lower Forth estuary, the lower Clyde estuary), inland areas (the lower Tay, Earn and Isla, the lower Kelvin) and urban areas (Paisley, Cathcart, Kirkintilloch and Kilmarnock) are especially vulnerable. Some 6.7% of Scotland's prime agricultural land is also vulnerable. In the coastal zone, these assessments are based on areas lying below the 5 m contour, while inland, flood risk areas have been estimated using assessments based on maps produced by the Scottish Environment Protection Agency (SEPA).

The increases in flood risk imply increases in future damage, unless the flood hazard is appropriately managed. Against a background of average annual flood damages in Scotland in the region of £20 million today, it is estimated that losses may increase by 27% (in 2020) by 68% (in 2050) and by 115% (in 2080) due to climate change. These figures are first-order approximations and take no account of present or future levels of protection offered by flood defences.

Public Awareness and Concern about Flooding

Whilst the impacts of floods can be lessened by actions taken by individual land owners and local and central government, raising public awareness has a major part to play. SEPA operates 43 flood warning schemes across Scotland: the police and local authorities providing emergency action teams when a flood alert is on. SEPA also comment on planning actions submitted to local authorities. Floods across the whole of the UK in recent years have raised the profile of flooding as an issue and the social and health-care costs as well as economic losses. This heightened awareness has meant that organisations involved in flood management have been exposed to greater public scrutiny. But the public at large also has

a role in lessening the impacts of floods. One way of achieving this is via the recently created Flood Appraisal Groups working with local planners and other government bodies. Further public involvement could involve voluntary Community Flood Groups to improve local understanding of flood risk and flood warden schemes on how to respond in an emergency.

Research Implications and Possible Priorities

The following recommendations are suggested both to improve our scientific understanding of floods and find better ways of identifying and managing flood risks:

Scientific understanding of floods

- develop rainfall-runoff models which enable the best predictions of future climate change to be converted into more accurate estimates of future inland flood risk
- review the role of the warming of the oceans and uplift and subsidence of the Scottish coastline as contributors to sea level rise. Combine the best estimates of future sea levels with any changes in the frequency and size of storm surges to improve predictions of future coastal flood risk

Identifying flood risks

- produce more accurate topographic maps of inland and coastal areas already identified at risk using new remote sensing tools (LiDAR and SAR)
- develop more detailed flood risk maps identifying the limits of a once in 200 year flood incorporating the effects of climate change up to 2050 or beyond
- undertake ground-based surveys of existing flood defences to produce an up-to-date assessment of the protection they currently provide
- assess the impact of future climate change on the protection provided by current flood defences
- retain SEPA's existing record of the extent of recent floods and expanded this as further floods occur

Managing flood risks

- undertake surveys on current public awareness and concern about floods. These to include questions on how flood risk is currently viewed, the likely costs of a flood, awareness of any flood warning schemes and opportunities to be involved in a community response.

About the Study

This study was undertaken by Prof Alan Werritty, Dr Andrew Black and Dr Rob Duck of University of Dundee and Bill Finlinson, Neil Thurston, Dr Simon Shackley and Prof David Crichton of Entec UK Ltd between February 2000 and August 2001. The study consisted of a literature review, new runoff modelling based on climate change scenarios, flood trend analysis, GIS analysis of the Centre for Ecology and Hydrology flood risk data for Scotland, and expert consultation and interpretation.

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