Chapter 10
Flood Forecasting and Early Warning: An Example from the UK Environment Agency

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Abstract The frequency and severity of floods have increased in England in recent years and is expected to increase in the future due to climate change and land-use change. It is neither technically feasible nor economically affordable to prevent extreme events, such as floods. The UK government has invested more resources to build engineering defences and developed a hydro-meteorological forecasting system by bringing the latest scientific and engineering knowledge to protect the public and property from floods. The Environment Agency (EA) in England has advanced flood warning dissemination systems as a part of their flood risk reduction and adaptation strategy. In addition, more focus has been given to inform people and to influence their decision and behaviours in times of extreme events. Together with the advancement of their early warning system for hazard detection and forecasting, the EA is also making efforts to provide effective and appropriate information to trigger and influence the behaviours and actions of the communities at various levels so that they can be prepared to respond to extreme events and disaster situations. More importantly, the government has embedded disaster risk reduction in its development planning. For example local planning authorities must now consult with the EA on the planning application for any proposed development, especially if the proposed development is at risk from flooding. This chapter briefly describes the process of issuing flood warnings in England.

Keywords Early warning • Forecasting • Climate change • Flood • Extreme event

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10.1 Introduction

Flooding is, in many ways, a natural occurrence. However, there are areas of the world more likely to be at risk of flooding than others (Fig. 10.1). More recently, with population growth, residential and commercial areas now have increased vulnerability to flooding (Zong and Tooley 2003). Recent flood events in China, India, Canada, the USA, India, Germany, Austria, Australia and the UK have shown flooding is by no means restricted to one ‘type’ of country or another and often takes no preference with which individuals it affects (NASA Earth Observatory 2013). Increasing global average temperature will result in more evaporation from almost 75 % sea surface and land surface water bodies and the atmosphere carrying more water. The atmospheric rivers (ARs), also described as narrow bands (around 300 km wide and 1,000 s of km in length) of intense moisture flux in the lower troposphere, are associated with episodes of heavy and prolonged rainfall. Lavers et al. (2013) noted a well-established link between ARs and peak river flow for the present day. The increased water vapour transport in projected ARs implies a greater risk of higher rainfall and therefore larger winter floods in the UK, with increased AR frequency leading to more flood episodes. The loss from UK flooding in summer/winter 2012 is estimated to be about $ 1.6 billion in damages. The study suggests increasing flood risk as a result of the projected change in ARs due to warming from anthropogenic radiative forcing (Lavers et al. 2013). In the light of changing climate and extreme events, the EA has adopted flood forecasting and early warning approaches as one of the key measures for disaster reduction and adaptation strategies to improve livelihood security.

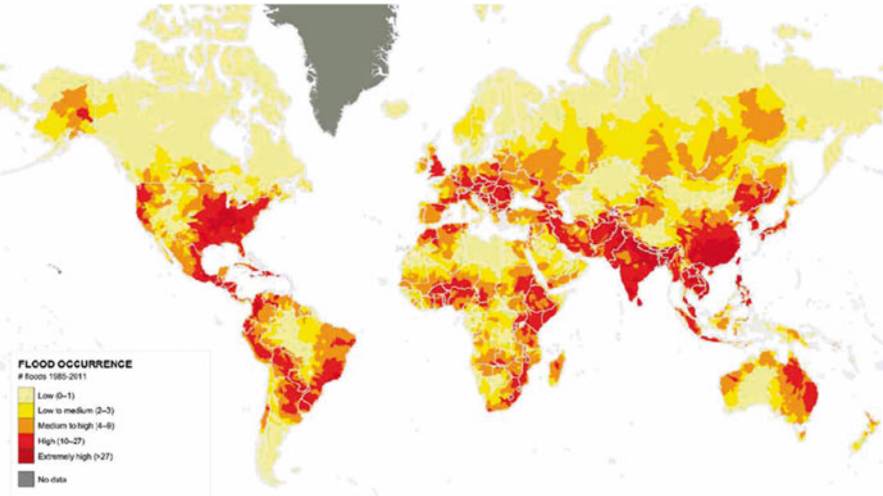

Fig. 10.1 Map of flood occurrence 1985–2011, used as a proxy for areas at flood risk (World Resources Institute 2013)

Flooding is one of the largest current risks identified in the UK Government's National Risk Register. The assessment of the Adaptation Sub-Committee noted that without action, four times as many properties will be at risk of flooding in England (Committee on Climate Change 2012). Flooding is therefore a major concern related to climate change in the UK. This chapter tries to provide a case study approach – giving an example of how England's Environment Agency makes flood forecasts and issues early warnings. The EEA system is highlighted because it is particularly effective in its timeliness, reliability, cost-effectiveness and accuracy, rather not just limited to EWS but imbedded in its national development planning and broader public awareness (EA 2009a, 2013c). Their system tries to provide an end-to-end approach including general procedure and organisation to post-event data collection, reporting and archiving (EA 2002). In addition, the EA is also engaged in influencing the national development process to consider flood risk at all levels of planning process and to avoid inappropriate development in flood risk areas by supporting national planning policies, such as, Planning Policy Statement 25 (PPS25) (DCLG 2009).

10.2 The Environment Agency

The Environment Agency (EA) is an executive non-departmental public body which plays a central role in implementing the UK government's environmental strategy.[1] Created in April 1996, the Environment Agency aims to protect and improve the environment and 'create a better place' for people and wildlife in England (EA 2011a). In September 1996, the Environment Agency was designated as the lead authority for issuing accurate, reliable and timely flood warnings to the public in England and Wales, and to reduce the risks to people and properties from floods and the impacts when flooding occurs (Whitfield 2005). Because the Environment Agency's work is largely funded by public taxation, cost-effectiveness is very important. The Environment Agency does implement and maintain physical engineering schemes but also relatively cheaper options. A flood warning service is an equally important aspect of the Environment Agency's work. In England about one in six residential and commercial properties is at risk from river, coastal or surface water flooding (EA 2009b).

10.3 Identifying Flood Risk Areas

The first step to reduce the impact of flooding is to understand what areas are at risk of flooding, from which sources and at what magnitude.

[1] Note: following devolution of power in Scotland and Wales, the Environment Agency is now primarily focussed on work in England.

10.3.1 Flood Map

In England, the Environment Agency has produced a 'flood map' to try and answer these questions. Using varying methods depending on their geographical availability ranging from 'simple' GIS analysis up to 'complicated' 2D models, the Environment Agency has mapped the risk of flooding for a 1 in 100 (or greater chance), 1 in 200 (for coastal flooding) and 1 in 1,000 (or greater chance) of flooding from river or sea. These maps are available for everyone to view on the Environment Agency's website (EA 2013d). They include no defenses. In other words, they present a 'worst-case' scenario to plan and build better adaptive capacity and coping mechanisms.

The Environment Agency has also produced;

- A flood map that includes the presence of defences. The National Flood Risk Assessment (NAFRA) provides the likelihood of flooding at a national scale with cells of 100 m by 100 m (EA 2013b). The results are presented into three categories as used by insurance industry. For example:
  - Low – the chance of flooding each is 0.5 % (1 in 200) or less.
  - Moderate – the chance of flooding in any year is 1.3 % (1 in 75) or less but greater than 0.5 % (1 in 200).
  - Significant – the chance of flooding in any year is greater than 1.3 % (1 in 75) (EA 2013b).
- A flood map for the risk of surface water (flooding from heavy rain and exceedance of drainage capacity. Banded in two categories (deep/less deep) for two scenarios (1 in 30 chance, 1 in 200 chance) (EA 2013e).
- A flood map for the risk of reservoir flooding (for large reservoirs holding over 25,000 cubic metres of water) (EA 2013d).

All of these are, or soon will be, available for free from the Environment Agency's website.

10.4 Mitigating Flooding

Once risk areas are identified, actions can be taken to reduce the risk. Mitigating flooding is not an easy, small or straightforward task. There are many different approaches favoured in different locations around the world, ranging from the minimum approaches, such as, a simple GIS-based mapping for flood risk and introducing ecosystem-based preventive measures (Defra 2007) to engineering defences which protect all but the most extreme events (Deltares 2010).

This range can also be observed within countries. In England, for example, the Environment Agency uses at least four methods to reduce flood risk:

1. Influencing the planning process to avoid inappropriate development in flood risk areas, for example, Flood Risk Assessments (EA 2013f).

Planning Policy Statement 25: Development and Flood Risk Practice Guide (PPS25)[2] sets out the UK Government's national planning policies on development and flood risk, with the aim that flood risk should be considered at all levels of the planning process, encouraging positive planning to deliver appropriate sustainable development in the right place. The aim is to avoid inappropriate development in flood risk areas and to locate development away from flood risk whenever possible (DCLG 2009).

2. Engineering solutions to reduce the risk of flooding. With a fixed budget, the most cost-effective schemes nationally will be preferred (those that protect the most properties, for the cheapest amount per property). An example of this is the new flood defence in Keswick (EA 2013g).
3. Maintenance programmes. Ensuring rivers are clear from obstruction and have maximum capacity. Routine maintenance activities take place annually, such as, channel maintenance, and instruction to undertake your own watercourse maintenance (EA 2013h).
4. Warning and informing. Raising awareness of flood risk and encouraging individuals and groups to plan and prepare. The Environment Agency aims to have 66 % of high risk areas covered by its free flood warning service by 2015 (EA 2013j).

10.4.1 Flood Forecasting and Warning Process

The main objective of the flood forecasting and warning process (FFWP) is to provide additional lead time to allow actions to be taken to moderate against flooding's impacts. The baseline review on existing good practice found that the FFWP within the Environment Agency involves a series of six steps, including a commonly adopted conceptual model of flood forecasting and warning (Haggett 1998). The EA FFWP also includes a sequential process involving information management along with general procedure and organisation, post-event data collection, archiving and reporting (Fig. 10.2) (EA 2002).

10.4.2 Planning and Preparedness

Before any operational action can be taken in the flood warning and forecasting process, a lot of work needs to be carried out. Detailed understanding needs to be gained of when flooding occurs, and instructions and triggers set for when warnings will be issued (Sene 2008).

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[2] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/7772/pps25guideupdate.pdf

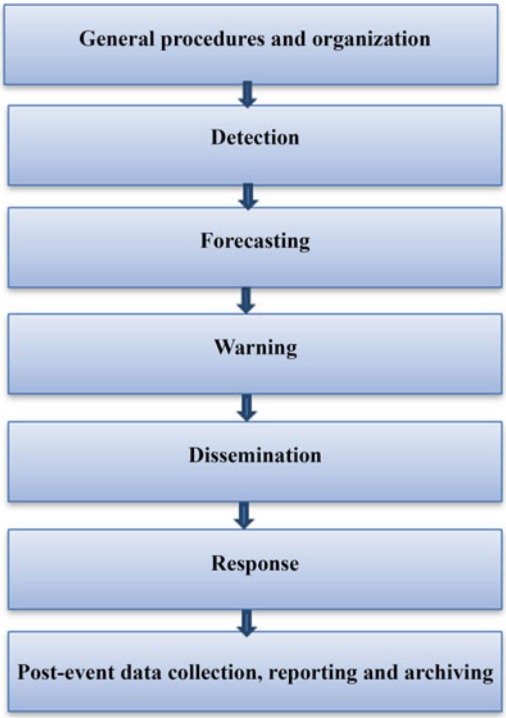

Fig. 10.2 Conceptual model of flood forecasting, warning and response processes (Environment Agency 2002) (Contains Environment Agency information © Environment Agency and database right)

10.4.3 Detection

The Environment Agency is an evidenced-based organisation. Data collected in many parameters is cross-referenced against records of flooding. This information allows staff an understanding of when flooding may be possible. To deliver its flood warning service, the Environment Agency has an extensive network of monitoring stations, measuring many hydrological and meteorological variables including river level and flow, rainfall and tide (Figs. 10.3, 10.4, and 10.5). As many of these sites are connected via telephone line to the telemetry network, measurements are able to be viewed remotely in 'real time'. Since 2010, the Environment Agency provides this data from 2,000 of its sites, for free, in near real time, for example river levels for Arun and Western Streams[3] (EA 2013i). Monitoring stations are calibrated and validated to ensure high-quality information is used for all its applications. Generally, in the Environment Agency, flood warnings are still primarily issued on the detection of rising water levels. Therefore, data quality is highly important.

[3] http://www.environment-agency.gov.uk/homeandleisure/floods/riverlevels/136474.aspx

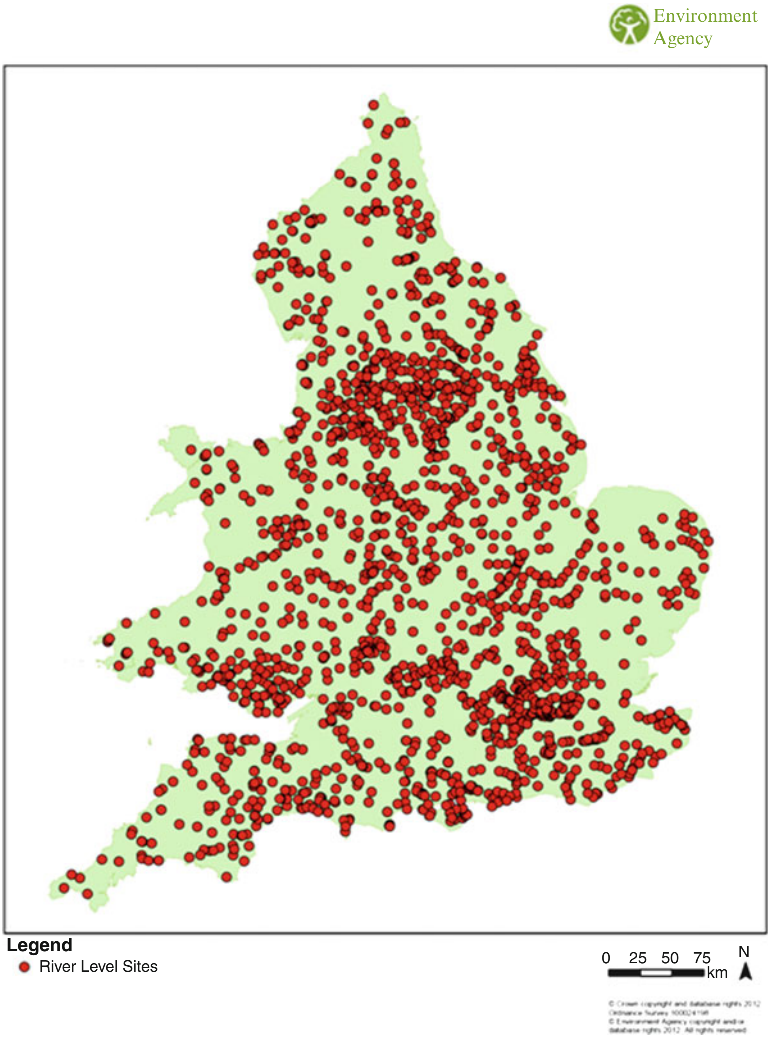

Fig. 10.3 River level sites in England and Wales (EA 2013a) (Contains Environment Agency information © Environment Agency and database right)

10.5 Moving Towards Forecasting

10.5.1 Weather Forecasting

The UK Met Office is the UK's national weather service and also a world leader in providing weather and climate services, with a history tracing back to 1854 (Met Office 2013a). The Met Office measures thousands of meteorological conditions

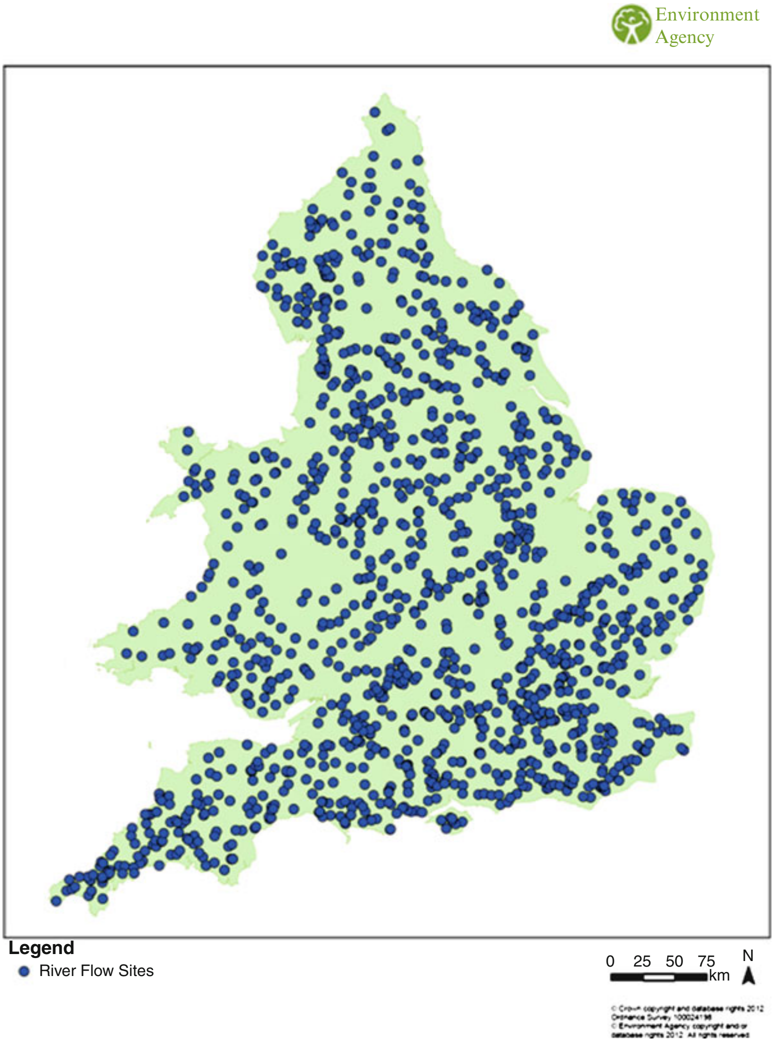

Fig. 10.4 River flow sites in England and Wales (EA 2013a) (Contains Environment Agency information © Environment Agency and database right)

each day and feeds that data into a high-performance supercomputer running an advanced atmospheric model. The outputs are delivered to a large range of customers including the government, businesses, the general public and the armed forces (Met Office 2013b) as a range of tailored forecasts and briefings.

The Environment Agency is a customer of the Met Office's probabilistic and deterministic forecasts for spot and areal locations. The Met Office's observations and predictions of the weather feed into the flood warning and flood forecasting

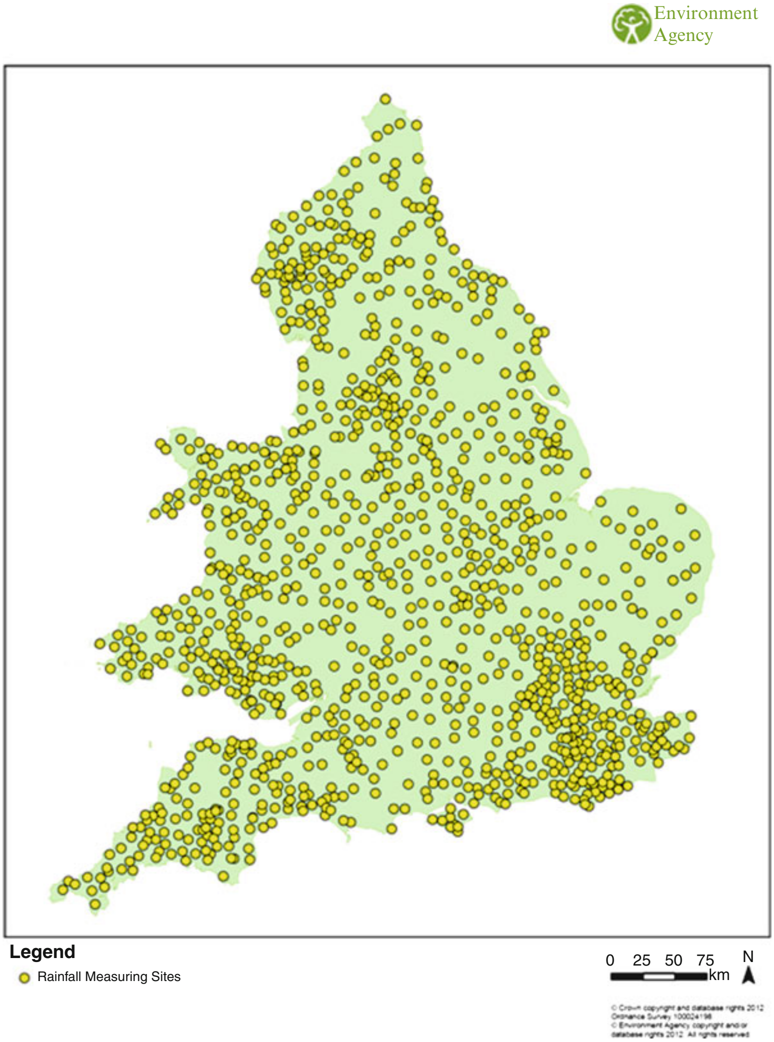

Fig. 10.5 Rainfall measuring sites in England and Wales (EA 2013a) (Contains Environment Agency information © Environment Agency and database right)

process, giving advance notice of potentially hazardous weather conditions verified, or otherwise, by the observations.

Rainfall observations and predictions are shared with the Environment Agency through their Hyrad programme (CEH 2013). Ten radar sites across England and Wales ‘measure’ rainfall intensities and feed into the modelled rainfall forecast, providing coverage and information across the whole country (Fig. 10.6).

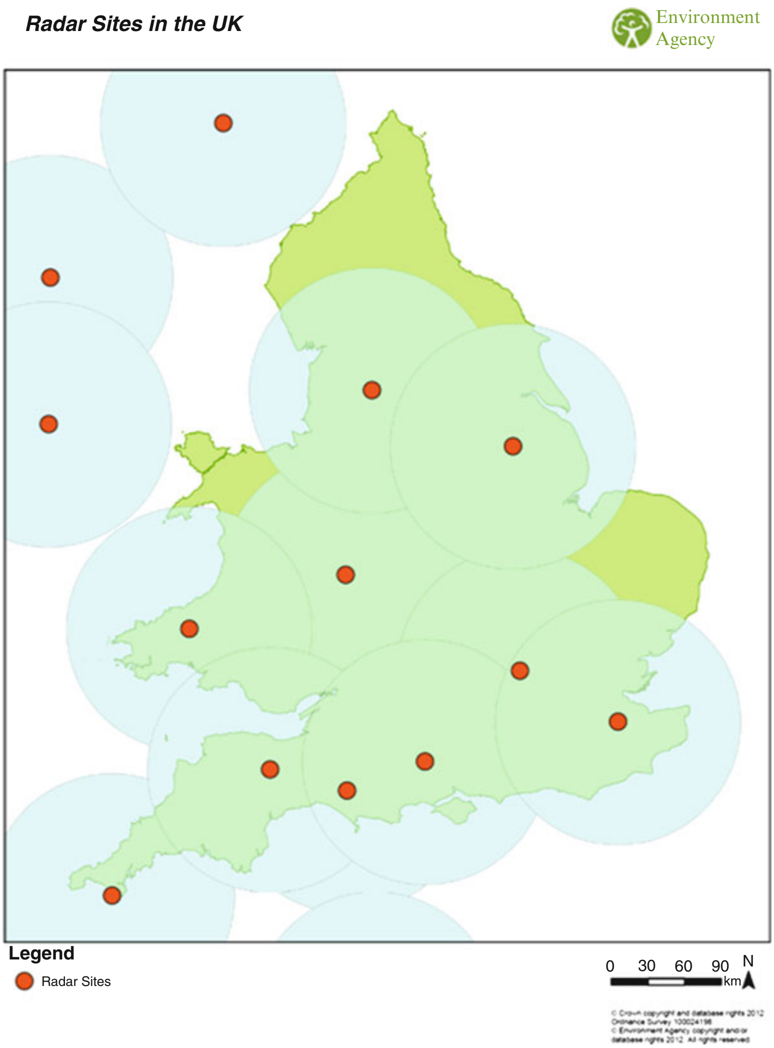

Fig. 10.6 Radar sites in England and Wales showing indicative coverage (EA 2013a) (Contains Environment Agency information © Environment Agency and database right)

10.5.2 Flood Forecasting Centre

As an addition to the Met Office, the Flood Forecasting Centre has also been created. Following the devastating summer floods of 2007 in parts of England, which cost the economy £3.2 bn (BBC NEWS 2010), the Pitt review[4] called for urgent and

[4] http://webarchive.nationalarchives.gov.uk/20100807034701/http:/archive.cabinetoffice.gov.uk/pittreview/thepittreview/final_report.html

fundamental changes in the way the country is adapting to the increased risk of flooding. It urged the UK government to show leadership and set out the process and timescale for improving resilience in the UK (The Pitt Review 2010). Following the recommendations, the Environment Agency and the Met Office have combined their efforts and have established the Flood Forecasting Centre (FFC)[5] to pool the best possible intelligence and provide the best inputs to be used in the remainder of the flood forecasting service. The Flood Forecasting Centre combines the meteorological forecast with assessing consequences and impacts to produce overview guidance and products to the responding communities across England and Wales.

10.5.3 Flood Forecasting

Predicting when flooding will occur at a local level still remains the remit of the EA.

The Environment Agency has set itself a target to provide flood warnings at least 2 h before flooding (EA 2011a). Traditionally, warning systems have relied upon measured levels acting as a trigger. If set appropriately, these triggers can give some lead time. With the development and use of forecasting models, the intention is to extend the lead time and give more time to act on a warning.

Flood forecasting methods in various forms have been available since before the Environment Agency took the responsibility for delivering flood warnings in 1996, but have gained sophistication and accuracy with time. These forecasting methods range from relatively simple techniques such as correlation of peak levels/flows between different sites, to linked rainfall-runoff models with hydrological channel routing models (Table 10.1) (EA 2013a; Whitfield 2005).

10.5.4 National Flood Forecasting System (NFFS)

To use these forecasting techniques (Table 10.1) operationally, the Environment Agency commissioned the development of the National Flood Forecasting System (NFFS). The NFFS uses a forecasting solution called Delft Flood Early Warning System (Delft-FEWS) developed by Deltares[6] (Deltares 2008), with help from Tessella Scientific Software Solution (UK).[7]

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[5] http://www.environment-agency.gov.uk/static/documents/Leisure/FFC_introduction.pdf

[6] http://www.deltares.nl/en

[7] http://www.tessella.com/

Table 10.1 Methods used for forecasting flooding

(i) Levels, records and trends techniques		
(a)	Historic flood records	A comprehensive recording of historical flooding on a catchment basis, with detailed information on river-monitoring sites. Provides an indication of how a site may react to different weather conditions, based on its previous behaviour. This is used as backup to more technical methods, or where no other methods are available
(b)	Alarm levels	Based on known information, alarm levels will be set up on river-monitoring sites, at appropriate levels, to alert of high and rising river levels
(c)	Linear trend	It is used to record the rise in level at a river level gauge over the previous 1 or 2 h and calculates the same rate of rise into the future
(ii) Modelling and correlation techniques		
(a)	Rainfall to river level correlation	A relationship between amount of rainfall, which can be used to predict the peak river level. Used for river gauges which are furthest upstream without the availability of any other information
(b)	Upstream and downstream river level correlation	Correlation method used as a forecasting technique by monitoring the river level at an upstream river gauge to predict a level at another gauge downstream. Based on a relationship between two sites that is easily repeated
(c)	Rainfall-runoff modelling	Different versions exist. For example, Probability Distributed Model (PDM) and Physically Realisable Transfer Function (PRTF) Model. Real-time rainfall and river data is fed into the models to predict timing and magnitude of maximum river levels or flows. The model can use rainfall forecast taken from radar prediction. The model depends on good quality data to calibrate accurately and good quality rainfall forecast to produce extra lead time with accurate results
(d)	Routing modelling	Routing models route the flow from upstream to downstream river-monitoring stations, taking account of inflow from other tributary systems
(e)	Hydrodynamic modelling	Different versions exist. For example, ISIS and Mike 11 model software. Originally developed for flood mapping purpose but now adapted for use as a real-time forecasting tool. These model river systems on detailed topographic survey data rely on detailed topographic survey data to replicate the ‘real-world’ river systems in a computer, to forecast levels and flows at required locations

10.5.5 Delft-FEWS

Delft-FEWS is a configurable shell with an open interface data handling platform. It provides tried-and-tested code to drive a wide range of existing forecasting models with real-time data from hydrological and meteorological observations and permits data assimilation, and the dissemination of prediction results through appropriate products to the warning process (Werner et al. 2013) (Fig. 10.7).

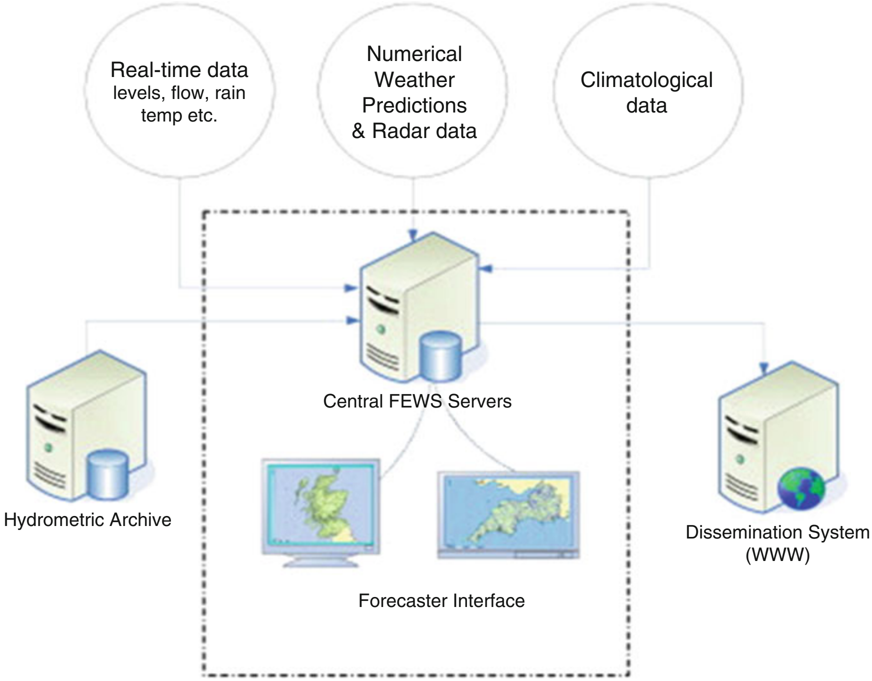

Fig. 10.7 Schematic structure of the Environment Agency's National Flood Forecasting System, with Delft-FEWS links to other primary systems within the operational environment (Werner et al. 2013)

Delft-FEWS contains no in-built forecasting models. Instead, it provides an avenue to integrate different types of forecasting models from a wide range of sources. It is supported by the General Adapter, which communicates to different forecasting models built in different programming languages via an open eXtensible Markup Language (XML)-based interface. This setup allows, 'plugging-in' of practically any forecasting model, linking to the central database of hydrological and meteorological time series, and then executing models to produce forecasts (Fig. 10.8). The Delft-FEWS system also provides a sophisticated interface for visualising and interacting with observed data and forecast outputs. The flexibility, adaptability, wider customisable system and effectiveness of the Delft-FEWS system have led to its growing use in over 40 operational forecasting systems worldwide (Werner et al 2013).

10.5.6 Delft FEWS in NFFS

Due to the flexibility of Delft FEWS to integrate different types of forecasting models, staff at the Environment Agency can setup and configure the NFFS so it meets their needs to run the correct models and workflows, and produce displays as required.

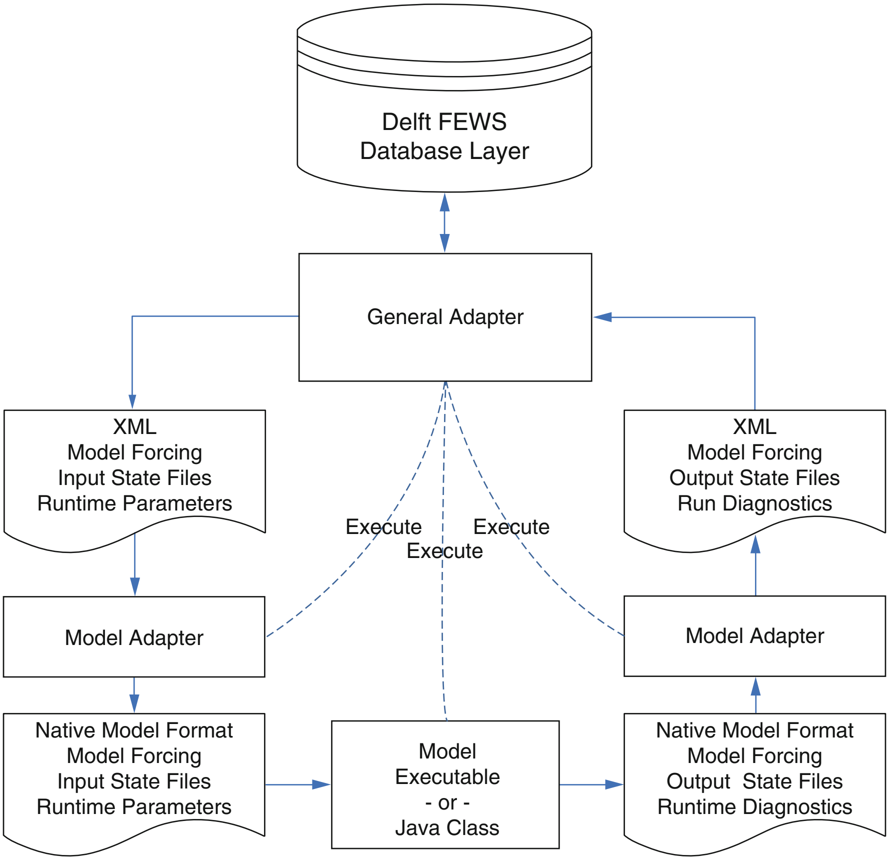

Fig. 10.8 Concept behind linking Delft-FEWS with external models and the flow of data through XML and native model formats using *solid lines*. *Dashed lines* indicate executable commands (Werner et al. 2013)

This is undertaken first on a ‘standalone’ system. This is then uploaded to the ‘operational’ system. The NFFS operational system is set up as a client-server application. Forecasters use a client application from their office PC to visualise data, schedule forecast runs and generate “what if” scenarios. All the ‘effort’ is computed on the server side. To build resilience, the server architecture has been designed with parallel duty servers located at the Environment Agency’s two data centres.

Real-time hydrological and meteorological measurements, weather forecasts and climate predictions are fed into the server. Computational processes occur, and the results are returned and visualised to the client at their PC. The philosophy behind this system is to provide a shell through which an operational forecasting application can be developed specific to the requirements of an operational forecasting centre (Werner et al. 2013).

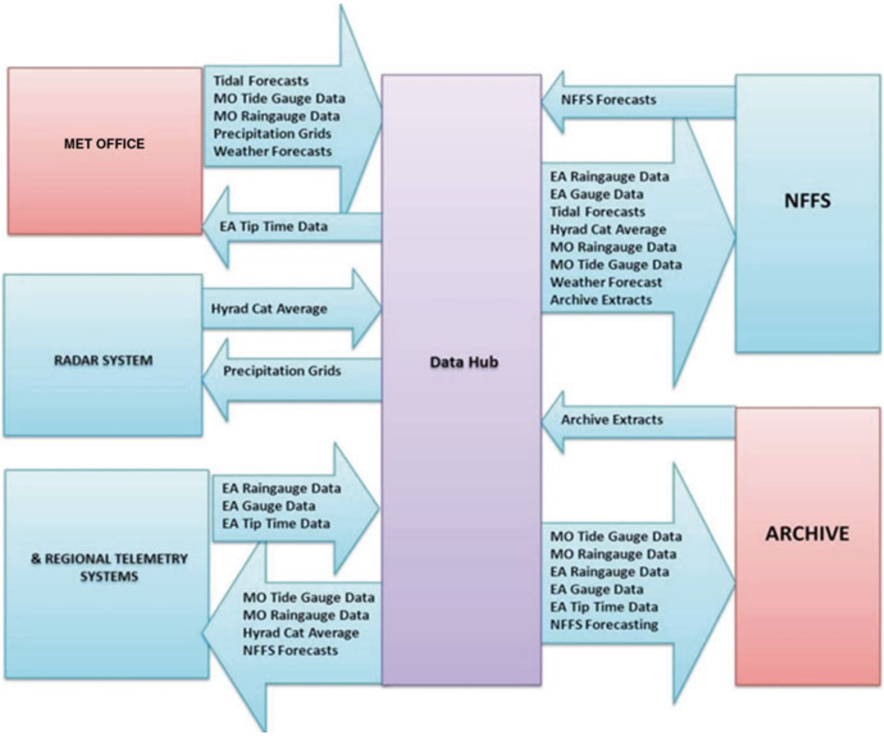

Fig. 10.9 An overview of data flow between EA systems (Whitfield 2005) (Contains Environment Agency information © Environment Agency and database right)

10.5.7 Operational Use of NFFS

10.5.7.1 Automatic Data Manipulation

The NFFS provides both the fluvial and coastal flood forecasting capability for England and Wales (Deltares 2008). The process of these predictions starts with data.

Observed and forecast, point and areal data from Environment Agency sources and beyond are all imported within minutes of being measured, real time into NFFS for processing. All these data are held centrally in the national system, but there is significant flow of data between systems and sources. Data flow between EA systems gives an overview of overall design of their flood forecasting system, including NFFS as a national platform which much of the system managed centrally (Fig. 10.9).

10.5.7.2 Selection of Input Observed Data

- Environment Agency regional telemetry systems feed in measured rainfall, river level, river flow and gate positions amongst other data sources.
- The Met Office provides 'observed' intensity and accumulations of rainfall, 'measured' from their radar network.
- The National Tidal and Sea Level Facility send measurements of sea level at key ports.

10.5.7.3 Selection of Input Forecast Data

- The Met Office use their expertise and systems to provide grids of forecast rainfall, tide level, surge level, wind speed and direction and wave height and direction four times a day, for the forthcoming 48 h.
- Longer term forecast data sets are also used, including astronomical tide levels and evaporation profiles.

Imported data is automatically processed within NFFS, to appropriate spatial and temporal scales, accuracies and formats. All the data are then fed into the various modelling platforms on a regular, scheduled, basis to produce outputs at specified locations. Where the input data is a forecast, the computed outputs also look into the future. Some outputs then also use mathematical formulae to 'error correct', and improve the results. Combining the outputs with understanding of at what level flooding will occur produces, in effect, a flood forecast.

River flood forecasts use rainfall forecasts as inputs, with models generating forecast river flows and levels. Tidal flood forecasts use meteorological forecast inputs to adjust the tide levels from the 'normal' level predicted by the interaction and movement of the sun and the moon.

Users can interact with and assess the data put into and being generated by NFFS (Fig. 10.10). They can run the required models more frequently than scheduled and can also create customisable 'what if' scenarios to know the magnitude and characteristics of the anticipated flood. 'What if' runs allow users to modify inputs to represent a range of scenarios. The resulting predictions allow users to understand the bounds of the forecasts and how sensitive forecasts are to changeable inputs.

Forecasts that are approved, either automatically or manually, are shared with the wider flood response teams within the Environment Agency, via a set of customisable HTML reports displaying snapshots of the forecast information, packaged and exported by the NFFS (Fig. 10.11). Based on the results, flood warnings may be issued.

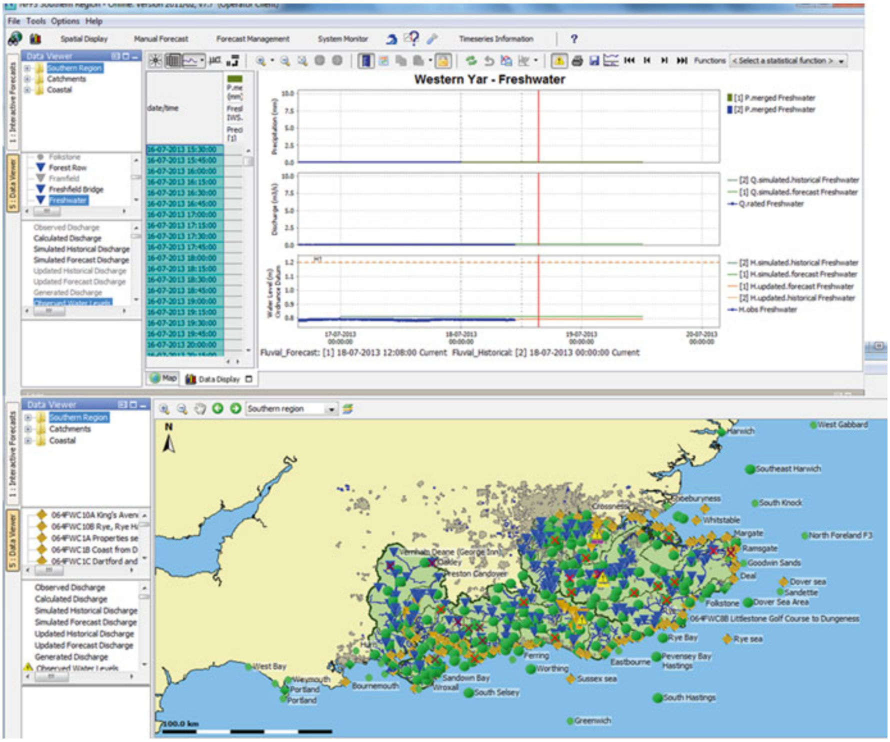

Fig. 10.10 NFFS operator client, time series display and spatial display for Environment Agency South East Region (EA 2013a) (Contains Environment Agency information © Environment Agency and database right)

10.6 Flood Warnings

10.6.1 Floodline Warnings Direct

Once it has been decided flooding is possible, and a flood warning should be disseminated, the next challenge is to quickly communicate this message to the potentially affected people. The Environment Agency commissioned Fujitsu to create Floodline Warnings Direct (FWD), which was delivered in 2006, to undertake this task.

The application developed by Fujitsu is based on a service-oriented architecture (SOA) that uses ‘standard’ platforms, like XML, SOAP, and J2EE, to enable the seamless exchange of data between applications. FWD also employs a combination of highly innovative technologies, such as spatial databases, Text to Speech conversion and Outbound Communication/Telephony Control software, which are accessible through an easy to use web browser front end (Fujitsu 2008).

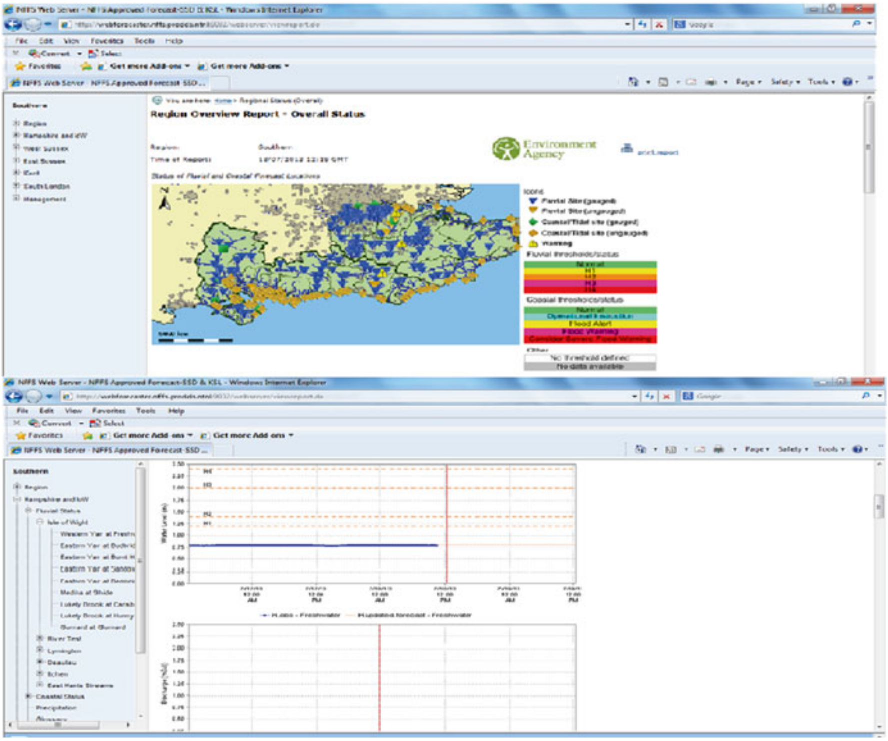

Fig. 10.11 NFFS webservice: exported HTML reports exported by NFFS (EA 2013a) (Contains Environment Agency information © Environment Agency and database right)

Staff at the Environment Agency adds real-time information, detail and context into the front end of their web-based FWD, supplementing the standardised, pre-populated text and layouts. Differing customer groups such as ‘home’, ‘business’, ‘media’ and ‘professional partners’ have tailored messages which are packaged into templates and their text converted into speech. Once approved, staff instructs the system to issue the chosen messages.

Residents and businesses at risk of flooding, friends and relatives of those at risk, as well as emergency responders and media broadcasters, are encouraged to register to receive the free flood warnings. Customer addresses’ and contact details are entered and stored in FWD’s database. Those registered receive warnings appropriate to their location and can choose to receive messages by a variety of methods: pager, SMStext, fax or email. However, the main distribution method of the Environment Agency’s flood warnings is by telephone. To make the warning system timely and effective, FWD has over a thousand phone lines; 430,000 people had signed up for EA’s Floodline Warning Direct service (EA 2009a).

As well as being alerted when flood warnings are issued, customers can call a phone line – called Floodline – at any time to pick up the latest message about flooding in their area. Each location has an associated 'quickdial' number that can be entered to retrieve the information or users can follow a menu structure to pick up the information they require. Messages are again written by Environment Agency staff and entered into FWD. FWD then automatically converts text to speech and distributes to the location on Floodline. Floodline also has a call centre staffed with trained advisors. Staff levels can be increased during times of flood and any locally specific or difficult questions can be passed through to Environment Agency staff in the relevant location.

Following the 2007 floods in Britain and the Pitt Review, the Environment Agency was encouraged to increase the number of flood warning recipients (The National Archives 2010). As a result, in 2010, the EA's flood warning service became an 'opt-out' rather than an 'opt-in' service. Each week, FWD spatially queries all the phone numbers of properties 'at risk' of flooding. Any phone numbers that are not registered to receive flood warnings are added to FWD's database.

With the proliferation of connectivity to the Internet, and portable connectivity, as well as online media and social networks, there have been a few recent enhancements to the flood warning service in England. Individuals can now register for and manage their Floodline Warnings Direct account online from the Environment Agency's website.[8] In the past, registrations were managed over the phone but now 'customers' can add or change their contact information, address details and recipient type themselves.

The Environment Agency also provides information, advice and tools on its website. Individuals and community groups at risk of flooding are encouraged to be aware and prepare for flooding. Personal and community flood plan templates are available, as are suggestions for contents of flood kits.[9] A flood widget featuring an RSS feed of warnings in force is available to download to display on users' websites.[10] The EA also provides "Three Day Flood Risk Forecast"– an open web-based product showing counties risk of flooding over the next 3 days.[11]

And since 2010 the Environment Agency has also provided free near real-time river level data from 2000 of its river level sites,[12] allowing those at risk to have more detail and awareness of the approaching flood risk in their surroundings.

The Environment Agency now provides a version of its flood warning service specifically for category 1 and 2 responder organisations.[13] The 'Targeted Flood Warning Service for Civil Contingency Act Responders' allows organisations with lots of assets to track the many different flood warning areas, how they relate to each individual asset and when each one is specifically at risk of flooding.[14]

[8] https://fwd.environment-agency.gov.uk/app/olr/home

[9] http://www.environment-agency.gov.uk/homeandleisure/floods/38329.aspx

[10] http://www.environment-agency.gov.uk/homeandleisure/floods/137543.aspx

[11] http://www.environment-agency.gov.uk/homeandleisure/floods/3days/125305.aspx

[12] http://www.environment-agency.gov.uk/homeandleisure/floods/riverlevels/default.aspx

[13] http://www.dft.gov.uk/mca/mcga07-home/emergencyresponse/resilience/list-of-responders.htm

[14] http://www.environment-agency.gov.uk/business/topics/116877.aspx

The Environment Agency also sells some of its information to licensed developers. 'Value Added Resellers' have developed Environment Agency data into a 'Flood Alert' app[15] and a live interactive flood warning map[16] which started off, and still is a Facebook app.[17] These apps do not require registration to the flood warning service. They display all warnings 'in force' and also use location information acquired from the user's device to display the most proximate flood warning area's status.

10.7 Preparedness and Exercising

To ensure all systems, infrastructure, plans and procedures work effectively when required, and to identify areas in need of improvement, all aspects of flood preparedness are "exercised" regularly. The largest national flood exercise in the UK occurred in March 2011 – Exercise Watermark. More than 20,000 participants in over 200 different venues took part, including communities and businesses, local authorities, responder organisations, the UK government and about 2,000 staff from the Environment Agency. Test flood warnings were issued, demountable flood barriers erected, stranded 'victims' rescued and ministers activated the Cabinet Office Briefing Rooms. All worked together to manage the widespread flooding scenario. Exercise Watermark highlights how many individuals and groups are involved in mitigating flood risk in England and how much coordination is needed between actors. Local Resilience Forums bring many organisations together to effectively plan a multi-agency response for emergencies (EA 2011b; Cabinet Office (2013 (V2)). The Environment Agency is by no means the only flood responder. For an early warning system to be effective, all actors need to be prepared. Preparedness among the public varies however, despite all efforts. Some have active, caring, community groups and have created community flood plans. But others are indifferent or unaware of the flood risk in their location. Perhaps it could be fair to say that one of the most significant factors limiting the effectiveness of the flood forecasting system and flood warning service in England is the understanding and awareness of those receiving the messages. People need to understand the flood warning in order to respond and to reduce the impact of flood to their properties and to minimize human casualties.

10.8 Conclusion

Flood warnings are by no means the only method used by the Environment Agency to manage flood risk in England. Examples include flood and coastal erosion risk management,[18] coastal defence and research into resilience and knowledge

[15] http://www.halcrow.com/floodalert

[16] http://www.shoothill.com/FloodMap/

[17] https://www.facebook.com/FloodAlerts

[18] http://www.environment-agency.gov.uk/homeandleisure/floods/38337.aspx

generation (Research & Development Programme – a joint initiative by Department of Environment, Flood and Rural Affairs (Defra) and EA) (Defra 2004).

However, our focus in this chapter has been the formal flood warnings which the Environment Agency have been disseminating in England for a significant amount of time. In recent times, developments in science and technology have allowed improvements to their warning and forecasting system. As ever, there are further advances that could be made. Forecasts are by no means accurate yet. There is always a desire to improve. The Environment Agency currently assesses the forecast accuracy using statistical measures to identify bias, systematic errors and areas for improvement. The results would suggest that modelling technology, allowing prediction into the future should still be considered in development, with the quality and calibration of the models requiring further improvement. Similarly, flood warnings are by no means, at all times completely accurate, or applicable to all, or given with sufficient notice.

Further research and development is underway to try to better understand uncertainty in forecasts and to integrate climate information amongst other advances. However on the whole, the flood warning service in England should already be considered an excellent response mechanism to reduce the impact of flooding in England. This was shown during Exercise Watermark, a large-scale test of all aspects of England's preparedness for flooding which was deemed largely a success (EA 2011b).

Understanding of localised flooding mechanisms has been gathered, compiled and shared by staff over the years. In fact, staff at the Environment Agency are a key factor in the whole process. Their training, knowledge and dedication are critical at all stages of forecasting and warning processes, involved in all aspects from interpreting models and tailoring warnings.

However a large amount of money has also been invested, particularly to improve systems. Historical and real-time flood information now feeds into systems developed by leading companies in their own fields, allowing models to be run, data be displayed and manipulated and messages distributed effectively. By having separate systems for specific parts of the warning and forecasting service, each section can improve simultaneously and separately, allowing faster and better improvements.

The result of all factors is that excellent flood warning and flood forecasting systems and processes have been developed. These are resilient and adaptable but, most importantly, effective. The systems allow large volumes of messages to be disseminated in a timely manner, with sufficient lead time, directly influencing the behaviour and actions of communities at risk of flooding.

More importantly perhaps, this 'model' of a flood warning and forecasting process is essentially replicable and could be transposed to another location. If scaled appropriately and given sufficient investment, this early warning system structure and operations could be effective in other locations as well as England.

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