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DESIGNING FLOOD FORECASTING, WARNING AND RESPONSE SYSTEMS FROM A SOCIETAL PERSPECTIVE

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The drive to improve flood warnings

There is pressure to improve the performance of flood forecasting, warning and response systems (FFWRS) in Europe and elsewhere. The scientific community and politicians suspect that climate change generated by anthropogenic emissions of greenhouses gases is producing increased flood activity on the coast and inland. Global competition and the process of economic competition between European municipalities is leading to more development on floodplains. About 5-10 per cent of Western Europe's population is estimated to live or work on floodplains and even more are exposed to flood risk because of recreational and transportational facilities which are flood prone (Handmer 2001). Not suprisingly the public and political acceptability of flooding and its consequences appears to be reducing as living standards rise. Many Europeans have more property to protect than previously and as the population becomes more graduate and articulate.

A growing number of Europeans is becoming used to instant personal access to data and information, whether it be by mobile telephone, digital television, radio or the internet. The population is increasingly expecting rapid access to information including weather and related data, including warnings of extreme weather events. At the same time, the information and communication technology revolution is increasing the prospect of providing rapid personalised access to weather and flood information and warnings. The technologies for collecting (e.g. remote sensing technologies), recording and transmitting (e.g. telemetric systems), displaying (e.g. geographic information systems), processing and analysing data by computer have become very much more powerful.

Fast and cheap electronic communication, and access to rapidly expanding data over the Web, have unfortunately created a new class of haves and have nots (the so-called 'digital divide'). The divide between those with and without access to flood risk and

flood warning data is already evident and is threatening to enlarge. There is a growing commitment in the European Union and elsewhere to reduce such divides - social exclusion has become an important issue. In the case of flooding and flood warnings this commitment provides a basis for considering how the circumstances of vulnerable groups - (e.g. low-income, ethnic minority, disabled, elderly, deaf members of society) who are disproportionately at risk to floods – can be improved. In the case of flood warning the issue becomes one of reaching out to potentially excluded sectors of the community, who may otherwise be neglected and suffer disproportionate flood impacts.

Despite the widespread employment of structural flood protection measures (e.g. levees, river regulation) and flood-sensitive land management initiatives, many localities now require effective FFWRS. Even those enjoying a reasonably high standard of structural flood protection (as for example in The Netherlands and in the Thames estuary and London, UK) require effective FFWRS. This is because flood defences are operated on receipt of a flood forecast or because we need to cater for residual, potentially catastrophic flood risk (i.e. the risk of flood embankment overtopping or breaching).

FFWRS often operate effectively. However, there have been several (and possibly many) recent cases of flooding where an improved FFWRS might have helped save lives and reduce property and infrastructure loss. For example, in the Gard Department of South-East France on September 8/9 2002, 24 people lost their lives and flood damage is reported at about 1 million Euros. This is by no means the first flood event of this nature to occur in this part of France where improved FFWRS might have helped. In England and Wales in April 1998, large parts of the Midlands experienced a flood with an estimated 100 year return period on some rivers. The FFWRS under-performed and the majority of those flooded did not receive a flood warning. Five lives were lost, there were many narrow escapes and the property damage is estimated at 540 million Euros. The consequent public and political criticism of the Environment Agency was sufficient to force the Agency to undertake an independent inquiry into its flood forecasting and warning systems. In turn this led to a development programme for flood warnings between 1998 and the present day. These are just two examples where FFWRS have under-performed or failed, but there are many other cases, and there are many ways in which Europe's FFWRS are under-developed (Parker and Fordham 1996).

A number of European countries are now actively seeking to establish or improve FFWRS. In the United Kingdom, strategies designed to improve FFWRS in England and Wales have helped spark initiatives in both Northern Ireland and Scotland. In France there are government-led initiatives to understand the reasons for recent flood catastrophes (e.g. in Gard in 2002) and to learn how to develop more robust flood management systems, including improved flood warning systems. Similar initiatives have been undertaken in Portugal, Spain, Italy and the Netherlands. Parallel initiatives have been taken in Australia and in the USA the Inland Flood Forecasting and Warning System Act of 2002 (Public Law 107-253) is designed to improve inland flood forecasting and warning systems.

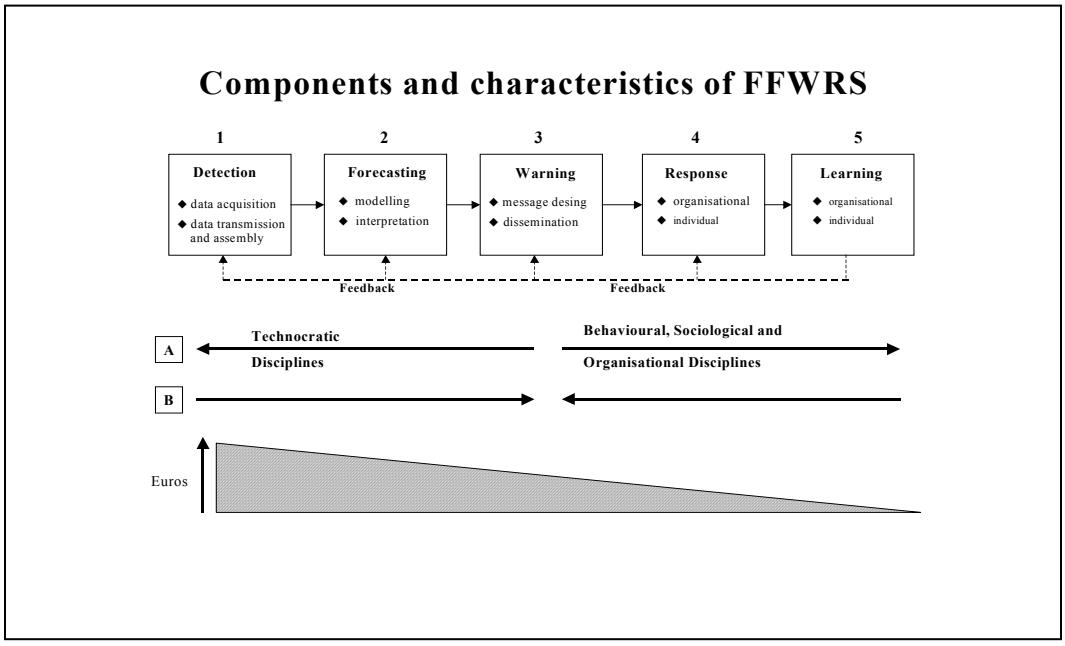
This paper discusses recent developments in, and experience with, designing FFWRS to take account of the societal context in which they should be embedded. This paper is limited to inland flood warnings. Most of the recent developments and experience are from England and Wales where there is a new impetus to improve FFWRS. However,

the content of the paper is also based upon previous extensive research flood warning systems in a number of European Union countries (Parker and Fordham 1996) and is informed by research and experience on flood and cyclone warnings from the USA, Australia and a number of other countries including the Republic of Mauritius (Parker 1999).

Conceptual perspectives

Designing FFWRS is demanding and requires dedication. Figure 1 portrays FFWRS as a five-stage process for reducing the impacts of floods which begins with detection of the environmental conditions leading to flooding. An important feature of FFWRS is that they span the technocratic disciplines of meteorology, hydrology and hydraulic engineering and the human behavioural, sociological and organisational disciplines. Sometimes (as in A in Figure 1) these disciplines are not successfully brought together and integrated as they need to be (as in B in Figure 1), and this is one of the fundamental causes of ineffective or partially effective FFWRS. FFWRS need to be designed by multi-disciplinary teams and the design process requires cross-agency integration and understanding. Experience indicates that effective FFWRS are rarely designed and implemented without a thorough learning process (5 in Figure 1) in which the system is progressively refined on the basis of monitoring of performance and lessons learned from operational events.

Figure 1



There has been a tendency in most world regions to focus attention and investment upon stages 1 and 2 of the process i.e. detection and forecasting, and there is no doubt about the need to continue to investment in research and development in these stages. There is much to be done to improve detection and measurement of floods and the meteorological conditions leading to floods. Advanced computational power made available through the information technology revolution has improved forecasting capabilities but there is

worrying evidence of a decline of research into flood prediction in recent years (Cordery and Pilgrim 2000). Not surprisingly, historically meteorological service organisations have perceived their expertise, and perhaps their organisational responsibilities, to lie mainly with the first two stages. In contrast, and until recently, comparatively little attention has been paid to stages 3, 4 and 5, and comparatively little investment has been put into these stages (Figure 1). The consequence has been that where a capability to detect and forecast floods has developed, sometimes an equivalent capability has not developed to formulate appropriate warning messages, to disseminate them in timely manner and to respond to them appropriately. The result is that some of the key benefits of investing in flood detection and forecasting are lost, and loss of life and flood damage is perhaps higher than need be. This paper focuses upon stages 3, 4 and 5.

The lack of a clear legal responsibility to disseminate flood warnings sometimes hinders the effective development of FFWRS as an integrated five-stage process. For example, prior to 1996 the legal responsibility for disseminating flood warnings in England and Wales was unclear. Between the 1950s and 1996, and because of their superior communication capability, the police accepted the role of communicating flood warnings to the public, but had no legal duty to do so. As police budgets came under pressure during the 1990s the police became progressively less willing to communicate flood warnings. Because of this, and because of evidence of flood warnings not reaching targeted populations, the Government directed the Environment Agency to disseminate flood warnings. Giving clear direction of this sort has been an important stimulus in England and Wales to improving FFWRS and investing in the development of stages 3, 4 and 5.

A useful perspective is to consider designing FFWRS from the social end of the process (i.e. from stages 3, 4 and 5) rather than from the technocratic end (i.e. stages 1 and 2). Several questions are posed by such a perspective including (1) what are the social, economic and political benefits of a well-organised, timely, accurate and reliable FFWRS (Table 1); and (2) who are FFWRS designed for and what are the requirements of these customers ?

Table 1

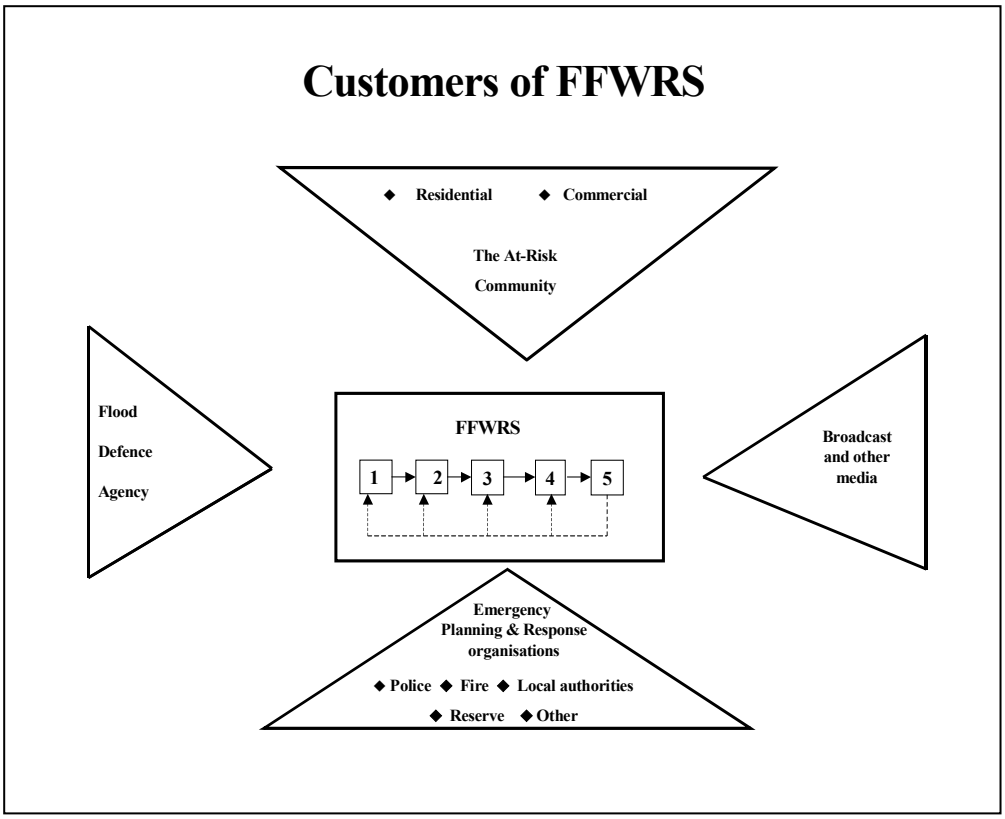
The principal benefits of effective FFWRS

- Minimisation of loss to property and infrastructure
- Minimisation of agricultural damage and industrial disruption
- Avoidance of human injuries, stress, associated ill-health and deaths
- The reduction of secondary and tertiary economic impacts of floods
- Enhanced community, and sometimes regional, security
- An aid towards water resource management, commercial waterway navigation and to the availability of cooling water for industry
- Avoidance of adverse political fall-out owing to the damaging effects of floods

Figure 2 portrays FFWRS from a customer viewpoint in which there are four main customer groups:

- those who occupy, live and work in floodplains e.g. residents; commercial managers (the 'At-Risk' community);
- the emergency planning and response agencies, including for example the police, fire and rescue services;
- the broadcast and other media who inform the public of events and who have a role in both disseminating flood warnings and providing information about flooding (and which either reinforce or question public confidence on flood warning agencies); and
- the flood defence agency or agencies (although these agencies may be the flood forecasting and warning agencies they are also fairly complex organisations with their own divisions and procedures for operating flood defences on receipt of flood warnings).

Figure 2



An effective FFWRS must be capable of serving the needs of each of these customer groups, and must therefore seek to continually integrate them throughout the process of design, operation and learning. In other words there is a very important requirement for strong stakeholder involvement and customer inter-facing. Australian flood warning practitioners and researchers term this integrated FFWRS a 'Total Flood Warning System' (Emergency Management Australia 1999). The hallmarks of a total flood warning system approach are (a) that it must be customer-centred and (b) each agency involved in the warning system must accept ownership of it and work cooperatively with other agencies for system improvement.

Diversity is usually a marked characteristic of the customer groups. Often residential communities will not be at all homogeneous. Their members are likely to vary according to age, presence or absence of infirmity or disability, gender, ethnicity, language, socio-economic status and access to help (Table 2). These differences lead to further differences in access to, and ability to use, information and communication technologies. Members of residential communities will also vary according to the personal communication networks which they possess, their flood risk experience and awareness and their knowledge of appropriate responses to flood warnings.

Table 2

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Diversity in the At-Risk Community

- 80% of properties are residential; 20% commercial
- 32% of residents are aged 55 yrs +
- 18% of the residents are from various ethnic minorities with various first languages
- 22% of households contain at least one member with a long-standing disability or infirmity
- 35% of residents claim to have a hearing impairment or are deaf
- 55% of the residents are female

The emergency planning and responding agencies are likely to be fairly numerous. They are unlikely to possess the same organisational structures and internal sub-cultures, and at any point in time several of them are likely to be undergoing organisational change from one structure or internal culture to another. The range of commercial and municipal organisations with premises and infrastructure present in floodplains is a further complexity to add to this picture.

How communities organise themselves to address floods when there is no formal (i.e. official) flood protection or flood warning service available to them is instructive in designing formal FFWRS. Social scientists in England and Wales, Australia and India have observed the existence of informal community level flood and cyclone warning systems (Parker and Handmer 1998). In England and Wales the leading regional flood warning officer in the national flood defence agency (the Environment Agency) has made a special study of such systems in the London region. The findings are that communities are sometimes able to develop their own FFWRS capabilities and have developed warning dissemination systems which use the community's social network. Sometimes these informal FFWRS fail to perform adequately, but on other occasions they appear to meet many of the requirements of those who need flood warnings. There are a number of

lesson to be learned from these informal FFWRS which can be usefully employed in designing formal FFWRS (Table 3). The main lesson is that those implementing formal FFWRS should seek to integrate any existing elements of informal FFWRS into them rather than supplanting them, because this will normally lead to important improvements.

Table 3

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Advantages of informal warning systems

- Amplifies formal warnings extending warning penetration in the community
- Increases the quality and specificity of information received, reinforcing formal warnings
- Gives greater local credibility to warnings, and may address emotional or affective needs
- Translates warning messages into the vernacular
- Delivers warning as a dialogue reducing the need for confirmation

Taking a social perspective to improve FFWRS

The new impetus which has developed for enhanced FFWRS in England and Wales is firmly based upon (1) improving flood detection and flood forecasting and (2) a social perspective. The latter was previously largely missing. The Environment Agency is the national and regional flood defence agency for England and Wales. This Agency has the responsibility for designing and implementing effective FFWRS. England and Wales has up to 2 million properties located in flood prone areas including along coastlines. The majority of these properties are homes. The estimates of the exposure of properties to flooding have been progressively revised upwards as higher quality floodplain maps have become available, and as growth of development on floodplains has taken place. Over half of those properties at risk from flooding are defended by structural flood protection works, although many of these works rely upon FFWRS for them to become operational flood defences. This includes the UK's largest flood defence system, the Thames tidal flood barrier and associated defences and barriers which protect London and the Thames estuary areas. By global standards Britain's rivers are relatively short and so flood warning lead times vary from at the most about 72 hours, down to very short lead times of 30 minutes or less in some circumstances. Flash floods are common in metropolitan areas where convectional activity can produce intense rainfall which rapidly overloads

urban drainage capacities. Flash floods are also common in upland Britain and some of the country's worst flood disasters have been in these upland catchments.

Serious flooding occurred in the midlands of England and Wales in April 1998. Only 31 per cent of those flooded received a flood warning of any sort prior to the flood. Since then the UK has experienced flooding of unusual frequency, geographical extent and duration. As often occurs over time, a period of infrequent flood activity (during the earlier part of the 1990s) has been followed (in the latter part of the 1990s and the early part of the twenty-first century) by flood activity which is unusually intense and frequent. The aftermath of the April 1998 floods led to a major programme of development and investment in FFWRS in England and Wales. This programme has now run for four years or so and has a strong social component. At the core of the investment programme is an understanding of the factors, including social ones, which are likely to determine the effectiveness of FFWRS.

In the Environment Agency's investment model, effectiveness is measured as actual flood damage avoided (FDA). The methodology on which the investment model is based seeks to maximise the economic benefits of flood warnings which are measured by FDA:

FDA = (AAD x DR x C) x (R x PRA x PHR x PHE)
(flood damage component) (warning response component)

The above equation has two components and expressions are defined and explained in Table 4. In England and Wales methods for estimating the potential flood damages to different types of properties (e.g. residences, retail, industrial etc.) are well developed (Parker et. al. 1987, FHRC 2001). These methods allow the anticipated annual average flood damages (AAD) to be estimated on a property-by-property basis in any floodplain given knowledge of property types, property heights and flood frequency-magnitude-level relationships. Research into damage-reducing effects of flood warnings has generated data which allows the amount of flood damage which can be avoided (DR) to be estimated for different classes of property according to the flood warning lead time given (Parker 1991).

The FFWRS improvement strategy is principally aimed at the residential sector and rests upon improving C, and the elements of the warning response component i.e. R, PRA, PHR and PHE. Improving coverage involves extending rainfall and runoff instrumentation and telemetry and developing the reliability of flood forecasting models. Improving reliability (R) involves improving flood forecasting processes including modelling and enhancing the flood warning dissemination system. PRA can also be improved by introducing flood warning dissemination systems with improved penetration and reach, and to some extent PHR can also be addressed through such improvements. Improvements in PHE are being pursued through raising public awareness of flooding and flood warning processes and by improving the public's knowledge of appropriate responses to flood warnings. The performance targets for 2009/10 for each factor are given in Table 4.

Table 4

Methodology for deriving economic benefits of flood warnings: definition and explanation of expressions

Expression	Definition	Explanation
FDA	Actual flood damage avoided	The economic value of the losses avoided through the provision of a flood warning service
AAD	Annual average flood damages	The anticipated annual average damages to property at the existing levels of protection (if any)
C	Coverage of the flood warning service	The percentage of the properties defined at risk which receive a full, targeted flood warning service. Target 40%
DR	Damage reduction factor	The potential flood damage which could be avoided from the amount of warning received by at risk properties where flooding occurs. Target 40%
R	Reliability of the flood warning service	The proportion of at risk properties which are warned with sufficient lead-time to take action. Target 80%
PRA	Proportion of residents available to respond to a warning	The proportion of properties in which at least one adult is awake/at home/at work and can also receive a flood warning. Target 80%
PHR	Proportion of residents able to respond to a warning	Proportion of at risk residential properties where the occupants are able to respond (this recognises the numbers who are elderly, disabled, ill, pregnant or otherwise unable to respond to reduce flood damage). Target 85%
PHE	Proportion of residents who respond effectively	The proportion of residents who are willing to respond effectively and who take appropriate action to minimise flood damage and personal risk. Target 85%
Target date = 2009/10		

Flood warning codes and messages

Most hazard warning systems utilise a graduated scale of warnings in which warning messages have been designed out of flood time. Experience suggests that such warning scales provide an appropriate means of categorising risk and communicating it consistently over time and space to those who need to know about the risk. The advantage of these warning scales or codes is that they save time when a flood occurs (this is particularly important in flash flooding) and the public can become used to their meaning over time. Such warning scales or codes convey pre-formulated, templated message wordings and meanings.

Since September 2000 England and Wales has employed a new graduated 4 stage flood warning code system (Table 5) designed by the Environment Agency to categorise the severity and urgency of unfolding events so that this can be communicated to the public and to other customers. National and regional television weather forecasts are now almost fully integrated with flood warning codes, and with the details of the Environment Agency's Floodline telephone number (a dial-up information and advice service). A similar approach is used by national and local radio stations. Research revealed that the previous 'colour-coded' (yellow, amber, red) flood warning codes, used in England and Wales for many years, were widely misunderstood and were interpreted rather like Britain's road traffic signals, which is inappropriate. A similar 4 stage flood warning code system is used for flash floods in Denver, Colorado and the tropical cyclone warning system for the Republic of Mauritius also adopts four warning classes together with a fifth all-clear message. All three warning codes incorporate a final 'All-clear' message.

Table 5

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Flood Warning Codes for England and Wales post-September 2000

Flood Watch	Flood Warning	Severe Flood Warning	All Clear
"Flooding is **possible.** Be aware! Be prepared! Watch out!	"Flooding of homes, businesses and main roads is **expected.** Act now!	"**Severe flooding** is **expected.** Imminent danger to life and property. Act now!""	"There are **no Flood watches or warnings** currently in force in the area"

Experience with these new warning codes reveals a number of issues. One of these is that the Flood Watch is being applied to very wide areas and for relatively lengthy periods in some circumstances, apparently reducing the extent to which it is taken notice of by the public. The Meteorological Service in Mauritius found a similar problem with Class 1 cyclone warnings since 50 or more could be issued during a cyclone season. The public can become de-sensitised by over-exposure to these lower level warning states when the intent is to sensitise them to possible threat (Parker and Budgen 1998). At the other end of the spectrum the Severe Flood Warning code has been used too frequently. In England and Wales the manner in which the flood codes are used is therefore under review.

Another issue is that, once a pre-formulated warning message has been communicated, there is often a need for additional warning messages to be formulated and communicated at the local level and by those involved with at-risk communities. It is sometimes by these additional reinforcing warning communications that appropriate responses are

elicited. To persuade people to react to warnings, warning messages need to arouse emotion and feeling. The choice of words becomes important in this regard and words commonly used in warnings have been found have different arousal strength (Wolgater and Silver 1995). Warning messages should also suggest or indicate appropriate responses as well as giving information about when the flood will occur, how long it will last, where the floodwater will come from, and the depth and velocity of the floodwaters. Warnings frequently fail to completely penetrate the target community and so messages should suggest that recipients should alert their neighbours.

Warning communication

One of the principal issues in making FFWRS more effective involves the efficient communication and dissemination of warnings. Among the main problems of disseminating warnings effectively are the following: (1) the availability of an up-to-date and sufficiently accurate and reliable floodplain maps and related listings of flood-prone properties and customers (without such information those providing flood warnings cannot know who their customers are), (2) providing a sufficiently rapid and timely warning, (3) disseminating warnings through channels of communication to which customers have access, (4) providing an all-hours service, (5) providing several channels of communication for warnings for each customer to maximise the possibility that warnings will be received, (6) providing a service which allows customers to confirm that a warning received is genuine and real, and (7) providing a flood information service in support of warnings so that customers can regularly update themselves on the progress of the flood event.

Overcoming these problems has led to a stream of innovation in flood warning service provision in England and Wales as well as elsewhere, and the progressive employment of a variety of information and communication technology advances. Table 6 shows the technologies available for communicating flood warnings categorised into well-tried methods, relatively new methods and methods that might be classed as near-future in terms of their application to flood warnings (although some of these are now being brought into use).

During the late 1990s and early 2000s the Environment Agency adopted a strategy of seeking to provide every flood warning recipient with access to two flood warning dissemination methods – one direct and one indirect method (Table 7). Given relatively short warning lead times, and because of the large numbers of floodplain users who need to be warned, the Agency rapidly developed Automatic Voice Messaging (AVM) systems. These systems have the capacity to dial large numbers of telephones at the same time and to warn by voice mail. Worldwide an increasing number of flood warning systems employ AVM including in the United States. In Australia the towns of Euroa and Benalla in Victoria use these systems. In Pacific Haven in the Hervey Bay City Council area of Queensland, Australia, where flash flooding is a serious problem from the Burrum River, these systems are also in use. However, in this flash flood case the AVM telephone alerts are automatically triggered when local rain and river gauges reach nominated levels (Emergency Management Australia 1999).

Table 6

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Technologies for communicating flood warnings

Well Tried	New	Near Future
• Standard analogue telephone	• Press- button digital telephone	• Electronic mail
• Radio telephone/VHF	• Mobile telephone	• Internet and website with real-time warnings
• Radio		
• Facsimile	• Pagers	• WAP telephones
• Flood siren	• Automatic Voice Messaging	• Activation of local radio/electronic signal alerts
• Door to door	• Flashing signs	
• Loudspeaker	• Teletext	• Integrated AVM/Floodline service
• Written letters	• Recorded messages	
• Leaflets	• Floodline	
• Flood Wardens	• Television/radio	• Home computer links
• Automatic water level alert linked to telephone	• Electronic file transfer via AVM	• Real time data on web
		• MMWDS

Table 7

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Recent flood warning dissemination strategy for England and Wales

Direct alerting methods	Indirect (broadcast) warning
• Automated voice messaging (AVM)	• Floodline
• Sirens	• Flood wardens
• Door-to-door	• Media (TV, local radio, teletext)
• Other (e.g. personal telephone call)	• Via intermediaries (local authorities, emergency services)
	• Internet

AVM was introduced in Britain in 1996 and approximately 5 per cent of those at risk from flooding (i.e. around 65,000 people) are now connected to AVM for flood warning. Properties are only connected at the owner's consent and it has been found that some property owners refuse the option. Although the capacity of the system has been improved, capacity still constrains use in some densely populated urban areas. In September 1999 and November 2000, the AVM system delivered flood warnings to 85,715 locations with a 75-85 per cent success rate. The most important advantages of AVM are (1) it permits direct communication of warnings between warning sender and recipient (this is a hallmark of excellent warning systems) and (2) it reduces the time taken to disseminate warnings. The main disadvantages are (1) the need for prior owner consent to connect, (2) the time-consuming nature of the task of collating and maintaining the telephone number database, and (3) the 'disembodied' voice warning which also does not permit dialogue. Research indicates that personal verbal warning messages delivered face-to-face are likely to be most effective (Drabek 1986).

Telephone lines may also be lost in severe storms and customers using their sole telephone line for internet connection can block incoming warnings.

Public dial-and-listen telephone services are now widely used in weather and flood warning systems. For example, in Mauritius the public may dial TELMET which provides tropical cyclone warnings in English, French and Creole. Floodline was introduced in 1999 and has grown rapidly into a well-developed dial-and-listen brand in England and Wales. This telephone service, which can be accessed on 00 44 845 988 1188, is updated during flood events. The service was introduced amongst heavy publicity at the beginning of the 1999-2000 flood season. 781,000 calls were received between 1/10/2000 and 31/12/2000 and the peak daily rate was 58,000 on 7/11/2000. Fortunately for the growth in public awareness of the service, this flood season was a very active one and the telephone number gained widespread and lengthy public exposure which has contributed to its success. Floodline allows a caller to link to an advice centre to allow dialogue which includes summaries of flood warnings in force 24 hours per day. Floodline is also a hotline for access to flood managers and allows people to confirm warnings and to learn about appropriate warning response actions. With growing use of mobile telephone technology Floodline provides a rapid, flexible and very useful service. The system can become overloaded on occasions and the Environment Agency has had to increase capacity of the system on a number of occasions to avoid this. Those who call Floodline are now logged and termed 'the engaged community' providing the Environment Agency with a known customer base for flood information dissemination and flood warnings.

The use of national television and local radio to carry flood warnings has developed rapidly. Enhancement usually focuses upon the degree to which there is a high degree of integration between the broadcast news and weather services and the flood warning service. Until comparatively recently in England and Wales integration was partial, but now as a result of inter-agency agreements (Meteorological Office-British Broadcast Corporation-Environment Agency) these services and their presentation is much more integrated. Televised weather forecasts now carry flood warnings using agreed warning code icons and displaying the Floodline telephone number.

Domestic web access and use of electronic mail has grown rapidly. The Environment Agency launched its website some time ago (www.environment-agency.gov.uk) and this now provides generalised flood maps for all of England and Wales, together with advice on how to respond to flood warnings. Live flood warnings are now also available through the internet. Like Floodline, domestic web technology currently depends partly upon the integrity of telephone lines which may be damaged during storm conditions accompanying floods.

The next step in the evolution of the warning and warning response elements of FFWRS in England and Wales and elsewhere is the Multi-Media Warning Dissemination System (MMWDS). The Environment Agency in England and Wales is constructing an MMWDS which will take over from AVM in due course, and will be a means of integrating and linking customers to a range of existing and new warning innovations such as internet sites, digital TV and radio delivery, teletext delivery, SMX texting, facsimile, pagers and Floodline. Importantly the MMWDS will be designed so that customers can opt-in to the system and can choose which warning services they need.

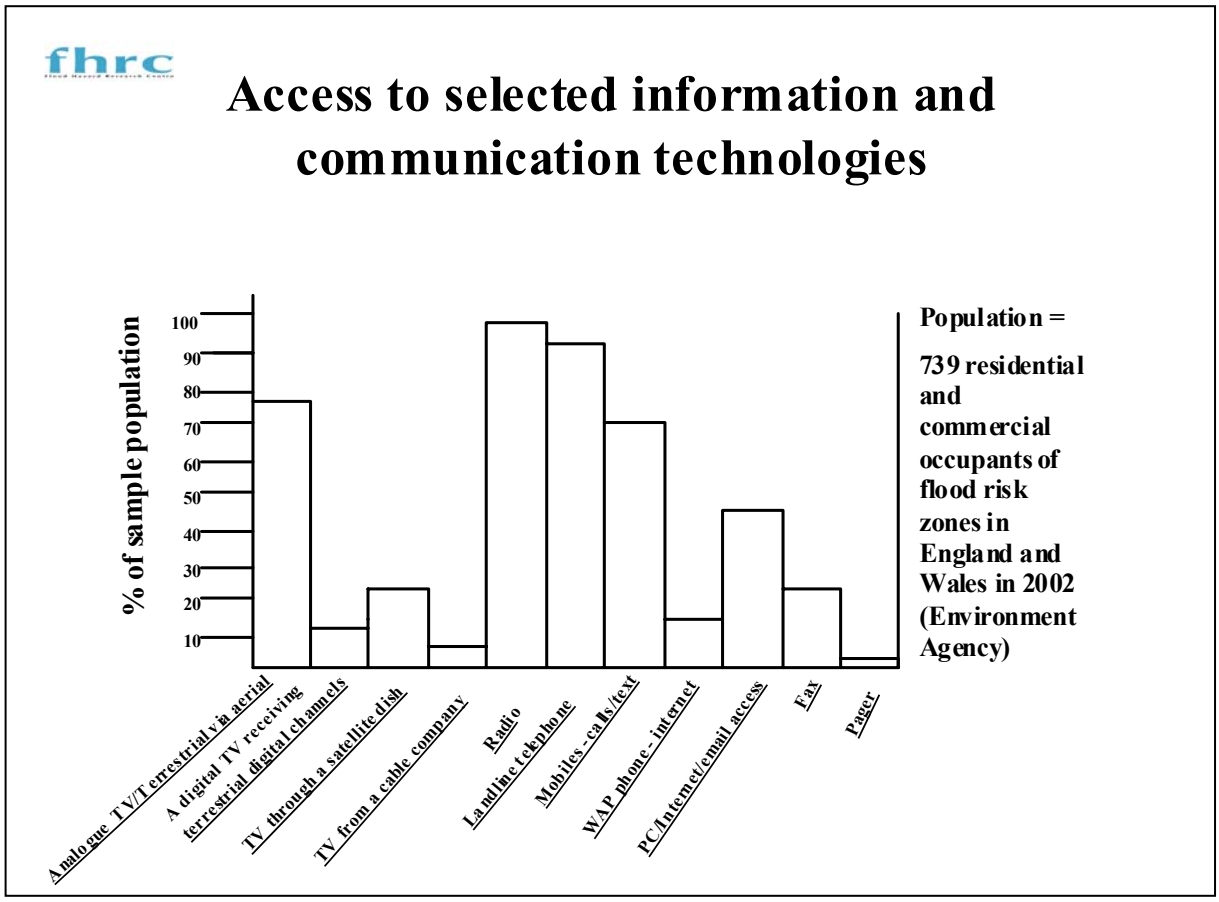
The aim is to get up to three-quarters of flood-prone customers to opt-in to the system in time.

Warning response

FFWRS and flood risk management form the basis of risk management by the individual citizen and relevant authorities. They should be designed to facilitate appropriate and effective action to minimise risk to life, property and infrastructure. Improving the response to flood warnings once received is a very important issue in improving FFWRS.

In the April 1998 floods in England and Wales a disappointing 19 per cent of those flooded reported that they took action to minimise damage. Apart from failure to receive a flood warning, the most common reason for people not taking action was that they were unaware of the range of appropriate actions which they could employ to reduce loss. Contributory factors are likely to be illness and infirmity. Also in a working community, people may not be at their home when a flood warning is issued sometimes making it difficult for them to respond in a timely manner or at all. A further reason for people not receiving a flood warning is that they may not have access to the warning means either through their lack of access to the technology used (Table 8) or because their circumstances excludes them. For example, most flood warning methods used in England and Wales rely upon the warning being heard, and for the deaf and hard-of-hearing this is problematic.

Table 8



A strategy has been designed by the Environment Agency in England and Wales to address this issue and to increase the number of flood warning recipients who respond appropriately to flood warnings. The strategy aims to increase the PRA percentage (Table 4) by using AVM which can be linked to work or mobile, as well as home, telephone numbers. But most importantly the strategy aims to increase the PHE percentage (Table 4) by making floodplain users much more aware and knowledgeable about the preparations that they can take for flooding and the appropriate damage-reducing actions that they can adopt on receipt of a flood warning. The key strategies in use are shown in Table 9.

Table 9

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Strategies to improve warning response

- Floodline linked to an advice centre - also allows warning confirmation
- Flood risk maps published on internet
- Flood leaflets
- Annual media flood awareness campaign
- Local flood forums and fairs
- National Flood Forum
- Best practice guidelines for flood wardens
- Other communications with the flood risk community

A distinct problem in England and Wales has been the relatively frequent re-organisation and renaming of the nation's flood defence agency. This has meant a low level of public awareness about which agency is responsible for flood warnings, and which agency is able to provide them with flood risk information and advice on response to warnings. To counteract this and to improve flood warning response, the Environment Agency has engaged in major public awareness raising and information campaigns at the beginning of the flood season and also at other times during the year. Since 1999 an annual Flood Awareness Campaign has been launched in September and national and local newspapers and the public have been provided with press- and public-friendly campaign materials. The approach to publicity and awareness raising has been multi-faceted and has included issuing new Flood Guides, a flood information film, school educational initiatives and so on. The Agency also produces 'Flood Directories' for most of its catchments which contain local information in leaflet form which is designed to raise local people's awareness of flooding and the flood warning system and codes, Floodline and how to respond appropriately to floods.

Getting at-risk communities engaged in preparing for flooding and in helping themselves in flood situations can sometimes be problematic because of apathy between flood events. However, as a result of increased flood activity in the past 4 years in England and Wales, local community members have begun to establish local flood committees or local flood forums to articulate their demands and to seek flood solutions. The Environment Agency's approach to these local groups has been to encourage them and to work with alongside them because they can help greatly in improving response to flood warnings and in combating floods. The Bewdley Residents' Flood Committee (Bewdley is on the River Severn in Worcestershire in west-central England) was formed in this way in November 2000 in the aftermath of the first flood of that autumn. Since its inception this committee sees itself as having helped its residents combat future floods, deal with bureaucracy and share best practices. The committee helped set up a Flood Defence Fair in June 2001 which was the first in the UK that gathered together companies with flood defence products to sell. The development of this local flood committee has now led to the setting up of the National Flood Forum which is a non-profit making organisation dedicated to reducing the suffering of people from flooding by conducting research on remedies and disseminating good practice in the UK. The Forum is seeking to facilitate a nationwide network of at-risk communities.

The development of MMWDS will be a major step forward in assisting both flood warning dissemination and warning response because it will provide a more complete warning and information service for customers (table 10). Through its choice approach it should be able to reach more categories of customers – including low income and other 'excluded' groups such as the hard-of-hearing - and provide more completely for their needs.

Table 10

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Migration to a future flood warning communication strategy

- **Multi-media flood warning dissemination systems (probably integrated with warnings for other hazards)**
- **Customers to be given choice of access to a wide range of flood warning dissemination and flood risk information media**
- **Choice responds to customer diversity - it enables the characteristics and needs of warning recipients to be matched by the recipient to the warning technologies of their choice**

Performance monitoring results

The performance of the flood warning dissemination and warning response elements of the FFWRS in England and Wales appears to have improved in the past four years (1). This may be due to the effort which the Environment Agency has put into improving these aspects of performance, or it may be due to the effect of increased flood activity over these years. Increased flood activity tends to force awareness levels upwards as the at-risk and national populations become more aware of floods through personal experience and news coverage. It appears likely that both the Agency's strategy and the effect of increased flood activity have caused improved performance, although the influence of each factor is unlikely to be the same.

The Environment Agency has monitored the performance of its FFWRS and improvement strategy by undertaking regular sample surveys over the past four years. A number of performance measures are used including the proportion of at-risk respondents who are aware of at least one flood warning method which operates in their area. Between 1998 and 2001 this measure has increased from 68 per cent to 83 per cent. The proportion of properties flooded which received a flood warning prior to flooding is measured from post-event surveys. This measure has increased slightly from 62 per cent in 1998 to 66 per cent in 2001. The proportion of respondents who were flooded and were warned by the Agency and who also received at least 2 hours prior notice of flooding has risen from 79 per cent in 1998 to 91 per cent in 2001. The proportion of respondents who were flooded above their property floor levels and who also took action to mitigate damage and perceived risk increased only slightly from 36 per cent in 1999 to 91 per cent in 2001 (in excess of the 2009/10 target). National awareness of the Environment Agency's flood mitigation and flood warning role has improved over the period and national awareness of Floodline has also increased.

The social performance of flood warning technologies

Research and practice is now moving on to address the social barriers to FFWRS programmes. This becomes more important to address as warning response improves because the target percentages for PHR and PHE have not yet been achieved. The social performance of flood warning methodologies is being investigated by the Flood Hazard Research Centre for the Environment Agency. Because of financial, educational and other factors, some flood warning recipients – who might be regarded as belonging to 'excluded groups' in society – have limited access to some information and communication technologies. There may also be psychological and social barriers to adoption of some of these technologies.

Conclusions

Although it is not the only requirement for effective FFWRS, thorough attention to the social aspects of FFWRS is required to make systems work effectively. It may therefore be necessary in some cases to rethink the approach being taken towards developing FFWRS with this in mind. It is nearly always necessary to build multi-disciplinary teams of professionals to construct FFWRS.

Information – especially high-quality information – is one of the keys to a successful future of living with floods. Floods are often rapid-onset phenomena and a further key to success is rapid access to warnings and related data.

Human beings will not respond to flood warnings unless their commonplace denial of threat is overcome by sufficiently persuasive evidence of threat. Warnings must be capable of overcoming denial and tipping the balance in the mind in favour of taking actions to reduce threat. Humans will often not succeed in responding effectively to warnings unless they are informed and educated about appropriate responses.

There is no doubt that information and communication technology has opened up new avenues for access to flood warnings and related flood risk information, and there is no doubt that new technology can help communicate warnings more rapidly than previously. This is particularly important where flash floods are concerned and warning lead times are heavily constrained. Gaining even a small quantity of time to receive and respond appropriately to a flood warning can save lives and can lead to significant property loss reduction.

Maintaining the at-risk population's attention to flood preparations, and maintaining their awareness of flood risks, continues to be an up-hill struggle in many places – especially where flooding is infrequent but can be catastrophic and where there are high levels of residential mobility which contributes to leakage of awareness and knowledge over time.

The evolving philosophy is to provide the diverse range of floodplain users with an array of warning and communication methods and channels from which they may choose according to their own needs, preferences and circumstances. In England and Wales flood warning philosophy has therefore evolved over time through a number of distinct stages as follows:

1. No flood warning system or local self-help, informal flood warning systems, flood loss is variable but often high

2. Provision of a single formal means of warning for all, but little recognition of the value to be added by connecting with informal warning systems and local community communication networks. Flood loss may be reduced to some extent but losses suffered by those who remain unwarned or lacking knowledge of how to respond to a warning once received.

3. Provision of several or a range of warning methods employing various ICTs but with methods remaining quite prescribed in particular locations, but with recognition of the value of connecting with local informal systems where they exist and efforts to utilise local community communication networks and local flood wardens. Flood loss may be reduced to some extent but losses suffered by those who remain unwarned or lacking knowledge of how to respond to a warning once received.

4. Provision of a multi-media array of flood warning technologies for all, from which floodplain users can choose according to their personal needs, preferences and circumstances, with recognition of the value of connecting to local informal

systems where they exist and making use of local community communication networks, local flood wardens and local self-help flood activists. The 'at-risk' community is well-informed about the flood risk, flood warnings and how best to respond to them. Flood loss is reduced including amongst formerly vulnerable groups.

Notes

(1) Survey and performance data are contained in a series of internally published reports prepared by the British Market Research Bureau for the Environment Agency

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