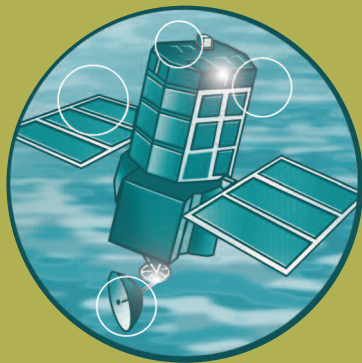


Flood Risks to People

Phase 2

FD2321/TR2

Guidance Document



**Defra / Environment Agency
Flood and Coastal Defence R&D Programme**

R&D OUTPUTS: FLOOD RISKS TO PEOPLE

Phase 2

FD2321/TR2 Guidance Document

March 2006

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Statement of use

This is one of three final technical reports for Flood Risks to People Phase 2 project. It describes the development of the final methodology including the methodology for mapping risks to people.

Dissemination Status

Internal: Released internally

External: Released to public domain.

Keywords

Flood risk mapping; flood estimation, flood risks to people, flood risk modelling

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Published by the Department for Environment, Food and Rural Affairs. Printed in the UK (March 2006) on recycled material containing 80% post-consumer waste and 20% chlorine-free virgin pulp.

PB NO. 11545

Acknowledgements

The authors are grateful for David Murphy (Environment Agency's Flood Risk Policy Manager - Strategy, Planning & Risk) for his chairmanship of Project Board and for his commitment and ownership towards this project. This project benefited from the Project Board and a large group of consultees, who participated in several consultation activities. We acknowledge their valuable contributions to the project that went beyond our expectations and, therefore, really made a difference to the success of the project. Special thanks are extended to John Goudie (Defra) and Ian Meadowcroft (EA). Thanks also to an extensive team of technical staff at HR Wallingford, Middlesex University's Flood Hazard Research Centre and Risk & Policy Analysts Ltd for whom supported this project.

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EXECUTIVE SUMMARY

Flooding from rivers, estuaries and the sea poses a risk to people as well as causing significant economic impacts. In the 20th century floods accounted for 12% of all deaths from natural disasters, claiming about 93000 lives across the world (OECD International Disasters Database). In 1953 the North Sea floods caused approximately 2500 deaths across the UK, Netherlands, Belgium and Germany and concentrations of fatalities have been associated with flash floods such as Lynmouth in Cornwall (1952, over 30 deaths) and Vaison-la-Romaine in France (1992, 38 deaths). In the UK, there were a small number of fatalities associated with the Easter 1998 and Autumn 2000 floods. In August 2004, a major airborne rescue operation was required to rescue victims of the Boscastle flood and in January 2005, the media reported 3 fatalities in flooding in Carlisle.

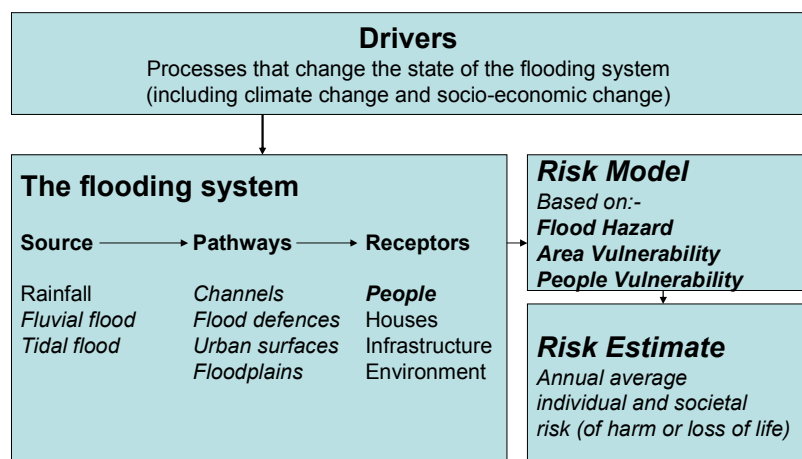
A key Government objective for the Environment Agency is *“to reduce the risks to people and to the developed and natural environment from flooding.”*

Environment Agency indicator: *“No loss of life attributable to flooding in areas receiving a full flood warning service.”*

Environment Agency Corporate Strategy, 2002-07.

Flood forecasting and warning, emergency planning, land use planning and the operation of flood defence systems have all contributed to reducing risks in the UK. However, flood risks cannot be completely eliminated and to support Government targets for flood risk management there is a requirement for methods to estimate the risks to people, as well as risks of economic and environmental damage. As shown in Figure ES1 the project is focused on people and provides measures of annual average risk that can be used alongside annual average economic damage and other social and environmental criteria to improve flood risk management.

Figure ES1. The Risks to People project in the context of the source-pathway-receptor model of flood risk.



The overall objective of the Risks to People project was to develop a methodology for assessing and mapping the risk of death or serious harm to people caused by flooding. The project considered death or serious harm to people that occurs as a direct result of a flood either during or up to one week after the event.

The research has a wide range of potential applications from raising awareness of the dangers of flood water, targeting flood warning, emergency planning, development control and flood mapping. The approaches developed can make use of information from other projects, such as the National Flood Risks Assessment (NaFRA) and be incorporated into the overall Risk Assessment for Strategic Planning (RASP) framework as well supporting Catchment Flood Management Plans and more local initiatives to understand manage flood risks.

This report is the second of two technical reports. Technical Report 1 (FD2321/TR1) describes the Risks to People Methodology that is based on a multi-criteria assessment of factors that affect Flood Hazard, the chance of people in the floodplain being exposed to the hazard (Area Vulnerability) and ability of those affected to respond effectively to flooding (People Vulnerability).

This report (FD2321/TR2) is a guidance document that explains how the overall method or its component parts can be applied in flood risk management for the following applications:

- Management of flood defences and appraisal of new flood defence schemes
- Flood hazard and risk mapping
- Flood warning and emergency planning
- Flood awareness campaigns
- Flood Defence regulation and development control
- Spatial planning
- Flood plans for reservoirs
- Information for ongoing and new research projects.

Finally, the outputs of consultation, workshops and background research are included in the Project Record (FD2321/PR).

A comment on the concepts of 'tolerable' and 'acceptable' risks

In the UK there have been various Government reports that have developed the concepts of 'tolerable' and 'acceptable' risks, most notably the Health and Safety Executive reports 'Tolerability of Risk' (HSE, 1992) and 'Reducing risks, protecting people' (HSE, 1999). These advance upper limits of tolerability for annual individual risk for workers in 'risky' occupations and for the general public. If the annual risk of fatality or serious harm is less than the 'tolerable' risk it is deemed 'acceptable.'

Suggested thresholds for 'tolerable' and 'acceptable' risk have been used in several case study examples in this report and were discussed in Phase 1 of the research project (HR Wallingford, 2003). While these concepts are valuable, current Government policy for flood risk management does not consider a specific threshold for tolerable risk so the values used in this report should be regarded as illustrative only.

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1. INTRODUCTION

Flooding from rivers, estuaries and the sea poses a risk to people as well as causing significant economic impacts. In the 20th century floods accounted for 12% of all deaths from natural disasters, claiming about 93000 lives across the world (OECD International Disasters Database). In 1953 the North Sea floods caused approximately 2500 deaths across the UK, Netherlands, Belgium and Germany and concentrations of fatalities have been associated with flash floods such as Lynmouth in Cornwall (1952, over 30 deaths) and Vaison-la-Romaine in France (1992, 38 deaths). In the UK, there have been lower numbers of fatalities in recent flood events, with 5 deaths associated with the 1998 floods in Central England and 4 deaths reported by the media during the Autumn 2000 floods (Kelman, 2003). In August 2004, a major airborne rescue operation was required to rescue victims of the Boscastle flood and in 2005, the media reported 3 fatalities in flooding in Carlisle.

A key Government objective for the Environment Agency is *“to reduce the risks to people and to the developed and natural environment from flooding.”*

Environment Agency indicator: *“No loss of life attributable to flooding in areas receiving a full flood warning service.”*

Environment Agency Corporate Strategy, 2002-07.

Flood forecasting and warning, emergency planning, land use planning and the operation of flood defence systems have all contributed to reducing risks in the UK. However, flood risks cannot be completely eliminated and to support Government targets for flood risk management there is a requirement for methods to estimate the risks to people, as well as risks of economic and environmental damage.

The Risks to People research project investigated the factors that cause injuries or fatalities during, or immediately after a flood event. A method for estimating risks to people was developed and is described in detail in Technical Report 1 (HR Wallingford, 2005b). This report provides guidance material that relates the concepts and method developed in the project to different aspects of Government policy, process and scientific research. It is aimed at a wide range of stakeholders, which have been identified in the Inception Report, Section 2.2 (HR Wallingford *et al*, 2004a).

1.1 Risks to People

The Risks to People method considers the physical characteristics of flooding and flood vulnerability, to determine the overall flood risks to people. Figure 1-1 provides an overview of (a) the approach and (b) project outputs.

(a) Concepts

FD2321 Flood Risks to People Project

Methods to estimate:

- 'Flood Hazard'** - *The flood conditions that cause people to be swept away*
- Risk of death or serious injury to people due to floods** - *Individual risk (chance per year)*
- *Societal risk (number of people per year)*

The process for calculating Flood Risks to People is shown below



Figure 1.1 Overview of the Flood Risks to People project

(b) Project outputs

FD2317 Flood Risks to People Phase 1

R&D Technical Report (July 2003)

FD2321\PR Project Record

Inception Report

Interim Report 1

Interim Report 2

Consultation Notes

FD2321/TR1 Technical Report 1

Risks to People
Methodology

FD2321/TR2

Guidance Document
(Including information for
ongoing research)

Key

Internal project reports

Published documents

Journals & conference
papers

1.2 Risks to People concepts

The method is based on three concepts:- ‘Flood Hazard’, ‘Area Vulnerability’ and ‘People Vulnerability’. These are combined for each zone of the floodplain in order to estimate the annual average individual or societal risk of serious harm or fatalities due to flooding. Some key concepts and definitions are listed below.

- **Flood risk.** Flood risk is defined as probability multiplied by consequences. For flood risks to people, probability is associated with the return period of flood events. This may be a combined probability when the flood event is due to a combination of high water levels and the failure of a flood defence system. The consequences are serious harm or fatality during or within the week following a flood event.
- **Flood Hazard** describes the flood conditions in which people are likely to be swept over or drown in a flood, and is a combination of flood depth, velocity and the presence of debris. The results are classified in hazard classes (TR1, Section 7).
- **A Flood Hazard map** shows the location of different classes of flood hazard on a map of areas prone to flooding.
- **Area Vulnerability** describes the characteristics of an area of the floodplain that affect the chance of being exposed to the flood hazard. People are more vulnerable in areas of low rise, single-storey buildings, campsites and open floodplain areas than in areas of two-storey or high-rise buildings that can provide “safe refuge” above the maximum flood level.

- **People Vulnerability** describes the characteristics of the people affected by flooding and their ability to respond to ensure their own safety and that of their dependants during a flood.
- A **Flood Vulnerability map** provides information based on the concepts of Area and People Vulnerability. This map is a by-product of the Risks to People method that may be useful for other applications. It is produced by mapping the area, typically within the Environment Agency's Extreme Flood Outline (0.1% flood) according to area and population characteristics. Vulnerability can be classified into Low, Medium and High classes.
- **Flood Risks to People** combines information on Flood Hazard and Flood Vulnerability and considers a number of flood events to provide estimates of annual average individual or societal risk. A **Flood Risks to People map** shows the individual or societal risk of serious harm as an annual average risk based on the consideration of at least 5 event probabilities. The maps can be classified into classes with references to the concept of **Acceptable Risk**.
- **Average annual individual risk** is the annual probability of an individual being harmed or killed due to flooding. It is calculated as the number of injuries/deaths per year divided by the population for each zone. The calculation is described in TR1, Section 6.
- **Average annual societal risk** is the estimated annual number people being harmed or killed due to flooding. For mapping purposes it is calculated as the number of injuries/deaths divided by the area. The calculation is described in TR1, Section 6.
- **Acceptable risk.** The risks to people method produces average annual risk estimates. In order to use the results to inform decision making, policy makers must define a level of acceptable risk, or alternative criteria, to evaluate risks to people. This guidance uses illustrative examples of risk criteria but these do not constitute recommendations or guidance. (Note that this issue was outside the scope of the project).

1.3 Risks to People variables

During the development of the method the research project reviewed a large number of flood hazard and vulnerability variables and criteria (HR Wallingford, 2005a). The final set of criteria required for each element of the method are:-

Flood Hazard

- Depth of flood water (m)
- Velocity of flood water (m/s)
- Debris factor (score)

Area Vulnerability

- Flood warning: including % of at risk properties covered by the flood warning system; % of warnings meeting the two-hour target; and % of people taking effective action (score).
- Speed of onset of a flood (score).
- Nature of area: multi-storey apartments; typical residential/commercial/industrial properties; bungalows, mobile homes, campsites, schools etc (score)

People Vulnerability

- % residents aged 75 years or over
- % residents suffering from long term illness

A full description of the method is provided in Section 6 and 7 of Technical Report 1.

1.4 Using this guidance document

The guidance is based on outputs of the Risks to People research project. It is in draft form and elements of the guidance may be developed further or changed significantly as required by the needs of stakeholders.

The Guidance is divided according to the needs of a range of stakeholders who were consulted as the research developed. The types of guidance identified for each stakeholder group are summarised in Section 2. The Guidance is provided in the following Guidance Notes which are matched to the needs of different stakeholder groups:-

1. General guidance on Flood Risks to People, for use in planning discussions.
(Stakeholders: Environment Agency development control and Local Authority spatial planners)
2. Flood awareness
(Stakeholders: Environment Agency and Local Authority staff involved in public awareness campaigns)
3. Project appraisal (including management of flood defences)
(Stakeholders: Defra and Environment Agency flood management)
4. National and regional mapping
(Stakeholders: Environment Agency flood mapping programme)
5. Flood warning and emergency planning
(Stakeholders: Environment Agency flood warning and Local Authority emergency planners)
6. Flood Defence regulation and development control
(Stakeholders: Environment Agency development control)
7. Spatial planning
(Stakeholders: Regional and Local Authority spatial planners)
8. Flood plans for reservoirs
(Stakeholders: Environment Agency reservoir regulation and reservoir owners)
9. Information for ongoing and new research projects
(Stakeholders: Researchers and those responsible for ongoing and future research programmes)

Thus each group of stakeholders should consult the relevant Guidance Note for their needs. Each Guidance Note is intended to be self-contained and there should be no need to cross-reference to other Guidance Notes. However some are clearly linked, for example, those dealing with spatial planning and development control.

2. STAKEHOLDER REQUIREMENTS

Consultations were carried out with stakeholders during the project, and the results are summarised in Table 2.1. The key stakeholder organisations are as follows:

EA: Environment Agency
 Defra
 LA: Local Authorities
 RA: Regional Authorities/County Councils

Table 2.1 Summary of stakeholder requirements

Function	Stakeholder Requirements	Potential use of Risks to People outputs
Project appraisal (Defra, EA)	A method for estimating flood risks to people for Multi-Criteria Analysis (MCA). The MCA approach should link with the Risks to People outputs.	The method developed for estimating risks to people is based on scoring and combining attributes. The ‘risks to people’ methodology should feed into an overall MCA methodology for project appraisal. By incorporating the monetary value of an injury (or death), risk estimates could be converted to ‘damage’ values for use in cost-benefit analysis to assist in project appraisal.
Flood mapping (EA strategic planning)	Methods that can be used to calculate the following for national mapping purposes: <ul style="list-style-type: none"> • Flood hazard • Vulnerability • Flood risks to people 	An important output from the project is a method that can be incorporated into the EA’s flood mapping strategy. The general approach to mapping risks to people can be adapted for different applications and different spatial scales.
Flood warning (EA flood warning)	<p>a) Methods that can be used to calculate flood hazard and vulnerability for local application.</p> <p>b) Guidance on identifying areas of high flood risks to people is needed for Agency flood warning plans.</p> <p>c) Guidance arising from the project on what to do and what not to do during a flood.</p>	<p>a) The methodology is designed for ‘high level’ mapping. As such, it is intended that risks can be determined from consideration of ‘area’ characteristics (for example, by postcode or national census “Output Areas’ ~ ca. 120 houses). The methodology could be adapted for local use with local data to target warnings.</p> <p>b) It is intended that the ‘high level’ mapping resulting from the application of the methodology presented in this report will identify areas of high flood risks to people. Therefore the method could be used to target catchments with high risks to people for improved flood warning.</p> <p>c) During the course of the project, a number of relevant items have been identified (for example, ‘safe’ flood depths for vehicles).</p>

Function	Stakeholder Requirements	Potential use of Risks to People outputs
Emergency planning and response (EA, LA and RA emergency planners)	<p>a) Methods that can be used to calculate flood hazard and vulnerability for local application.</p> <p>b) Guidance on identifying areas of high flood risks to people is needed for Local Authority emergency plans. Guidance should be based on local data where possible.</p>	<p>a) As long as detailed information on velocity and depth are available, maps could be produced highlighting the most “at risk” people, areas of danger for people and vehicles and safe access and exit routes.</p> <p>b) As above. People vulnerability can be mapped down to areas of ca. 120 houses. This information could be supplemented by local authority social services information.</p>
Flood awareness (EA and LA)	Guidance arising from the project on what to do and what not to do during a flood.	The research has shown that people exhibit particular types of behaviour during a flood. It is important to be aware of these behaviours in order to reduce the risk of injuries or fatalities.
Flood defence regulation and development control (EA development control)	<p>a) Method for calculating flood hazard information for development control and planning.</p> <p>b) Method for assessing flood risks behind defences, which could be used by the Agency to develop guidance. <i>Note: Guidance on this topic has been developed under project FD2320.</i></p> <p>c) Guidance on flood risks to people to help the Agency develop tools and other information that can be used to influence planners.</p> <p>d) Guidance on the acceptability of risk is desirable</p>	<p>a) Since the level of flood risk to people can be determined at a regional level, these outputs would be suitable for consideration in developing strategic plans. If good quality data on velocity and depth are available from site flood risk assessments, the method may be adapted to assess local risks. It would be hoped that such factors would be considered in the site-specific flood risk assessment prepared in accordance with PPG25</p> <p>b) The Risks to People method was developed for sites with and without defences. Information on 5 flood events (extents, depths, and velocities) is required to apply the full methodology. The choice of events should include scenarios where defences are overtopped or breached.</p> <p>c) The full Risks to People method or component parts, such as flood hazard, can be incorporated into other guidance, e.g. FD2320 on Development and Flood Risk.</p> <p>d) In order to apply the method for planning purposes clear policy guidelines are required on the acceptability of risk. Specific guidance on acceptability is not included in this guidance document but example thresholds of acceptability are provided in the Risks to People methodology report (FD2321/TR2).</p>

Function	Stakeholder Requirements	Potential use of Risks to People outputs
	e) A method that identifies the influence of mitigation measures (flood warning, development control) so that the benefits of these measures can be identified.	e) The methodology can be used to demonstrate the risks 'before' and 'after' particular improvements. As such, it is possible to demonstrate the 'benefits' (in terms of reduced risk) associated with mitigation measures.
Spatial planning (LA and RA spatial planning)	Flood hazard information for development control and planning.	The full risks to people method or component parts of the method could be used for regional and local spatial planning.
Flood Plans for reservoirs (EA regulation)	Methods for calculating flood hazard, vulnerability and flood risks to people for inclusion in the specification for reservoir Flood Plans.	It should be possible for those involved in developing reservoir 'flood plans' to adopt/ adapt the methodology presented in this report. The methodology can also be used to improve existing guidance on reservoir safety.
Information for ongoing R&D	Outputs that can inform other ongoing and planned R&D.	

The components of the Flood Risks to People method for which guidance is required to fulfil the needs set out in Table 2.1 are summarised in Table 2.2.

Table 2.2 Summary of guidance required

Abbreviations:

FH Flood Hazard
 AV Area Vulnerability
 FRP Flood Risks to People

Scales: N National
 R Regional
 L Local

Function	Guidance					
	FH	AV	FRP	High risk areas	Scale	Other guidance
Project appraisal			✓		R L	
Flood mapping	✓ Map	✓ Map	✓ Map		N R	
Flood warning	✓ Map	✓ Map	✓ Map	✓ Map	L	Flood behaviour
Emergency planning	✓ Map	✓ Map	✓ Map	✓ Map	L	
Flood awareness						Flood behaviour
Regulation & development control	✓ Map	Could be estimated for developments			L	General guidance on FRP. Flood risk behind defences already available (FD2320)
Spatial planning	✓ Map				L	
Flood plans	✓ Map	✓ Map	✓ Map		L	
Information for other R&D						General guidance

From Table 2.2 it can be seen that the guidance is required at a range of scales. The fundamental differences between applying the method at different scales are level of detail and availability of different data sets.

3. GUIDANCE NOTES

3.1 Introduction

The Guidance Notes from the Flood Risks to People project are listed in Table 3.1.

Table 3.1 Guidance Notes

Abbreviations:

FH Flood Hazard
 AV Area Vulnerability
 FRP Flood Risks to People

Scales: N National
 R Regional
 L Local

Note no.	Title	Content	Scale	Comment
1	General guidance on Flood Risks to People	Summary of main issues		Needed for development control, but could have wider application
2	Flood awareness	Guidance on behaviour during a flood		
3	Project appraisal	FRP method	R, L	
4	Flood mapping	FH method	N, R	Mapping needed. AV and FRP mapping included but not needed by EA at present
5	Flood warning and Emergency planning	FH, AV and FRP methods. High risk locations.	L	Mapping needed. Flood warning also requires Guidance Note 2.
6	Flood defence regulation & development control	FH method. Includes AV and FRP for new development.	L	Mapping needed. Also requires Guidance Note 1.
7	Spatial planning	FH method	L	Mapping needed.
8	Reservoir flood plans	FH, AV and FRP methods.	L	Mapping needed. Applicable to dam-break situations
9	Information for ongoing and future R&D	Summary of R&D		

Flood Risks to People

GUIDANCE NOTE 1 General guidance on Flood Risks to People

The purpose of this guidance note is to identify some of the main issues that affect flood risks to people, and summarise the calculation method.

People are at risk of suffering death or serious injury when flooding occurs. People are unable to stand in deep or fast flowing floodwater. Once they are unable to stand, there is a high risk of death or serious injury.

Adults are unable to stand in still floodwater with a depth of about 1.5m or greater, although this is obviously affected by the height of the person. The depth of flowing floodwater where people are unable to stand is much less. For example, some people will be at risk when the water depth is only 0.5m if the velocity is 1m/s (about 2 mph). If the velocity increases to 2m/s (about 4mph), some people will be unable to stand in a depth of water of only 0.3m. Most people will be unable to stand when the velocity is 2m/s and the depth is 0.6m.

The chances of people being unable to stand in floodwater is increased if the ground is uneven or there are holes in the ground beneath the water surface, for example service access covers that have been displaced.

There is therefore a high risk that people will be unable to stand in floodwater, and be exposed to a risk of death or serious harm.

The chance of people being exposed to floodwater depends on where they are, for example outdoors on foot, outdoors in a vehicle, or in a building. If they are in a multi-storey building when the flood occurs, there can avoid being exposed to floodwater by staying above the flood level. If they are in the open or in a single-storey building, for example a bungalow, supermarket or single-story school, they will be exposed to floodwater. They will be at even greater risk if they are in a tent or caravan, as these are likely to be damaged or washed away in a flood, or below ground, for example in a basement.

People are more exposed to a flood in some types of buildings than others. Buildings in flood risk areas where people are exposed to floodwater should be provided with a safe escape route.

The degree to which people are exposed to floodwater also depends on whether flood warnings are received and acted upon. Whilst many areas are covered by flood warning schemes, there are many people who do not receive warnings. There are many reasons for this, for example people passing through the area in cars are unlikely to receive a warning aimed at the local population.

Whilst flood warning can reduce the risk of people being exposed to a flood, many people will either not receive the warning or not respond in an appropriate way.

The speed with which a flood occurs has a major impact on whether or not people will be exposed to floodwater and therefore the risk of death or serious injury. Where the flood onset is gradual and the rate of rise is slow, people have time to take action and, if

necessary, leave the flood risk area. Where flooding occurs very rapidly, people have very little time to respond. Examples of rapid flooding that result in high risks to people are when a flood defence overtops or fails, and when a ‘flash flood’ occurs in an urban area following very heavy rainfall.

People are particularly vulnerable to death or serious injury where the speed of onset of a flood is very rapid, for example when a defence overtops or fails.

The ability of people to respond to a flood depends on their physical condition. Those who are old and those who are disabled or have a long-term illness find it more difficult to deal with a flood situation, and are therefore more prone to death or serious injury.

Vulnerable people (the old, disabled and sick) are less able to cope with floods than others and are therefore at greater risk.

The method for calculating Flood Risks to People combines all the above factors together with the number of people in a particular area to estimate the number of people at risk of death or serious injury because of flooding. The method is summarised in Figure 1.1.



Figure 1.1 Method for calculating Flood Risks to People

The **Flood Hazard** depends on flow depth and velocity

The **Area Vulnerability** depends on the nature of the area (including types of buildings), availability of flood warnings and speed of onset of a flood

The **People Vulnerability** depends on the age and physical condition of the people exposed to a flood.

Flood Risks to People

GUIDANCE NOTE 2 Flood awareness

Purpose

This Guidance Note provides guidance on what to do and what not to do during floods, arising from the Risks to People project. The guidance is not comprehensive and should be used to supplement awareness raising information already provided by the Environment Agency and others.

Whilst some of the guidance might appear simplistic and obvious, it is clear that in the stressful situation of floods people do not always take the most sensible course of action. Awareness campaigns should stress the important factors to minimise risks to people, however obvious they might be.

Introduction

People can be very resilient during floods and the number of deaths and serious injuries in floods is often less than might be expected. For example, in the 2004 flood at Boscastle, no one died even though many vehicles were swept away and some buildings were destroyed. However deaths and serious injuries do occur in floods, particularly in the following circumstances:

- Where people are overwhelmed by a flood with little or no warning, for example the 1953 coastal floods in the UK.
- Where the ferocity of a flood causes the destruction of buildings, for example at Lynmouth in 1952.
- A wide range of circumstances in the more ‘typical’ floods that occur in the UK, where the speed of onset or ferocity of the flood is not as high as the examples given above. Causes of death include being swept over while wading in floodwater, being swept away in vehicles, etc.

People may put themselves at risk, or increase the risk to themselves, through their own behaviour. This can be a major cause of loss of life and serious injury during a flood event. However people can only behave ‘rationally’ according to the information that they have, and this information may be incomplete or incorrect. Motorists, for example, should be better informed as to what actions should, and should not, be taken in flood conditions.

Walking in floodwater

People are often unaware of the power of floodwater and may be swept away.

Adults are unable to stand in still floodwater with a depth of about 1.5m or greater, although this is obviously affected by the height of the person. The depth of flowing floodwater where people are unable to stand is much less. For example, some people will be at risk when the water depth is only 0.5m if the velocity is 1m/s (about 2 mph). If the velocity increases to 2m/s (about 4mph), some people will be unable to stand in a depth of water of only 0.3m. Most people will be unable to stand when the velocity is 2m/s and the depth is 0.6m.

Guidance on the depths and velocities of floodwater that cause risks to people is shown on Figure 2.1.

$d * (v+0.5) + DF$	Depth									
Velocity	0.25	0.50	0.75	1.00	1.25	1.50	1.75	2.00	2.25	2.50
0.00	0.13	0.25	0.38	0.50	0.63	0.75	0.88	1.00	1.13	1.25
0.50	0.25	0.50	0.75	1.00	1.25	1.50	1.75	2.00	2.25	2.50
1.00	0.38	0.75	1.13	1.50	1.88	2.25	2.63	3.00	3.38	3.75
1.50	0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00
2.00	0.63	1.25	1.88	2.50	3.13	3.75	4.38	5.00	5.63	6.25
2.50	0.75	1.50	2.25	3.00	3.75	4.50	5.25	6.00	6.75	7.50
3.00	0.88	1.75	2.63	3.50	4.38	5.25	6.13	7.00	7.88	8.75
3.50	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00
4.00	1.13	2.25	3.38	4.50	5.63	6.75	7.88	9.00	10.13	11.25
4.50	1.25	2.50	3.75	5.00	6.25	7.50	8.75	10.00	11.25	12.50
5.00	1.38	2.75	4.13	5.50	6.88	8.25	9.63	11.00	12.38	13.75

Categories of flood hazard:

	From	To	
Class 1	0.75	1.50	Danger for some
Class 2	1.50	2.50	Danger for most
Class 3	2.50	20.00	Danger for all

Note: The table gives values of flood hazard ($= d \cdot (v+0.5) + DF$)

Figure 2.1 Combinations of flood depth and velocity that cause danger to people

In addition, the safety of wading is affected by factors such as evenness of the ground surface or presence of depressions, potholes, excavations, ditches, or major stormwater drains. Service covers are often removed by floodwater from drains. It is particularly difficult to see underwater obstructions even in very shallow water at night or if the water is silty.

Guidance

- The public should be aware of the dangers of walking in floodwater.
- People should avoid walking in floods wherever possible.
- People should not attempt to ford rivers or drainage channels during a flood.
- The public should be aware that ‘Floods are dangerous’

Waves

Waves can be very dangerous during storm events on the coasts. People can be unaware of the power of waves resulting from the volume and velocity of water that is swept over coastal structures including promenades and breakwaters. The rush of water back into the sea can also cause people to be washed into the sea and almost every year there are one or more deaths caused by people being washed into the sea by wave action.

Guidance

- The public should be aware of the dangers of waves during storms on the coast.
- People should avoid walking in areas where there is (or could be) wave action during a storm.

Driving vehicles in floodwaters

Many deaths in floods occur because people attempt to drive through or away from floodwater and get swept away or trapped in their cars. Their cars either then get swept away as a result of positive buoyancy or stuck in the floodwater.

Most cars and vans are unstable in 0.5 metres of still water. This depth reduces as the velocity of the water increases. Even large vehicles such as fire engines become unstable in 0.9 metres of still water, and this value also reduces as the velocity of the water increases.

The danger of driving through floodwaters is not widely publicised in the UK. The Highway Code does not give advice on driving in flood conditions, and there is no easily accessible information on the Environment Agency website. The motorist who drives into a flood-stricken area is therefore often unaware of the risks.

Guidance

- It can be dangerous to be in a car in floodwater.
- The public should be aware of the dangers of driving in floodwater.
- People should avoid driving in floodwater.
- People should not drive on roads that have been closed because of floods

Bridges

Bridges can fail in a flood either because scour undermines the bridge supports or abutments, or because the openings are blocked by flood borne debris, the bridge then failing catastrophically under the build up of water. The flood wave, together with the debris carried with it, then poses a threat to the lives of people downstream.

In addition to threatening the stability of a bridge, the build up of debris can block bridges, culverts and other flood flow routes, thereby increasing flood levels and causing flooding in areas that may not have flooded before.

Bridges can also be bypassed during a flood, and one or both accesses can be blocked by floodwater.

Guidance

- The public should be aware that bridges over flooded rivers can be dangerous.
- People can be trapped on a bridge if rising floodwater cuts off the accesses.
- The public should be aware of the dangers of driving on bridges over flooded rivers.

Buildings

Buildings are a potential place of refuge in a flood and are frequently used as such by the people in a flood risk area. The partial or complete failure of the buildings in which they are sheltering to provide a safe refuge is consequently a significant factor in the number of deaths resulting from flooding.

Buildings can collapse because of water pressure, scour of foundations, or a combination of these. In addition, the debris carried by a flood in the form of trees and boulders can cause damage. Buildings close to a watercourse frequently experience undermining as the flood erodes the channel and undercuts the buildings' foundations.

Some damage can occur to buildings if the depth differential between the outside and inside water levels exceeds 0.5 metres. Severe damage can occur if the differential reaches one metre, or a differential of 0.5 metres occurs in combination with high flow velocity (greater than about 3m/s). More severe conditions can lead to irreparable damage (for example, a differential depth of one metre and a flow velocity of 6m/s, or a differential depth of two metres and a flow velocity of 3m/s).

Where buildings are “floodproofed”, and there is a higher level of water outside than inside, the maximum differential pressure that brickwork walls can resist is of the order of one metre.

As the depth of floodwater increases, caravans and buildings of light construction will begin to float. In these circumstances the buildings can be severely damaged when they settle unevenly in receding floodwaters. If the flood velocity is significant, buildings can be destroyed and caravans can be swept away.

In campsites, people in tents are effectively unprotected from floods. Occupants of campsites are normally tourists who are unfamiliar with local conditions, and may be completely unaware of the flood risk.

Deaths can also occur where people are trapped in single story buildings, ground floor apartments, basements, cellars or underground structures, such as car parks, which can pose a particular threat to life in urban areas. The growing tendency to multi-levelled cities where shopping centres and cinemas are below ground level is increasing this risk. Metro systems present a particularly high risk, especially from flash floods but also from burst water mains and surcharged sewers

Guidance

- The public should be aware that buildings in vulnerable positions (adjacent to steep rivers, or close to flood defences) are at risk of being damaged or destroyed during a flood.
- The public should be aware that ‘floodproofed’ buildings could collapse if the differential in water levels between outside and inside becomes too large (of the order of one metre for a brick house).
- Caravans and tents should not be permitted in high hazard areas.
- People living in single storey buildings or basements in flood risk areas should be aware of the flood risk.

Asset protection and/or recovery

People can unintentionally put themselves at risk by trying to protect or retrieve personal property. People are particularly at risk when trying to retrieve property in vulnerable locations such as underground car parks and cellars.

Guidance:

- People should not delay evacuation in order to try to save personal assets.
- People should not enter a flooded property in order to retrieve personal assets.
- People should not try to retrieve property in vulnerable locations.

Interest and excitement of major floods

This behaviour can be classified as either active involvement with floodwaters, or passive spectator activity. The first behaviour type may include attempting to swim, surf or sail on floodwaters. This behaviour is generally to be expected from children and male adolescents.

The second behaviour type, passive spectator activity, applies to a broad cross-section of people. It is clear that ‘disaster tourists’ put themselves in danger unnecessarily; perhaps more important is the fact that disaster tourism may hamper emergency response activities, thereby endangering innocent third parties.

Guidance

- People, especially children, young adults and parents, should be made aware of the risks of treating floodwaters as a recreational resource.
- People should be made aware of the risks they create, to themselves and others, when they treat a disaster as if it were a tourist attraction.

Rescuing people or pets

Members of the public, unlike the emergency services, are unlikely to have the training or the resources necessary to rescue a person or a pet without endangering themselves. The impulse of a parent to rescue their children from danger is understandable and many people have strong emotional attachments to their pets.

Coastguard rescue teams are aware of this phenomenon. They always respond to calls about dogs in distress in case the owners, or bystanders, put themselves at risk by trying to rescue the dogs themselves.

Guidance

- People should be made aware of the dangers of floods so that they are better able to judge the risks when other people are in difficulties or pets are in danger.

Evacuation

Access is generally divided into two categories: pedestrian and vehicular. The provision of road access trafficable in all conditions will obviously assist in reducing the flood hazard and enhance the effectiveness of the emergency response.

Evacuation is normally organised by the emergency services. Evacuation can be affected by:

- Loss of trafficability on evacuation routes because of rising floodwaters
- Bottlenecks on evacuation routes (i.e. roads cannot cope with the increased volume of traffic and the number of people that have to be evacuated)
- Unavailability of suitable evacuation equipment such as boats, lorries and helicopters.

In some urban situations, access to flood-prone residents can be lost relatively early in the flood, for example where:

- Evacuation routes lead downhill onto and across the floodplain. Access to the evacuation route and trafficability can be lost early in the flood because of rising floodwaters
- Cul de sac residential developments built on rising land that only have downhill road access. Vehicular access is likely to be lost early in the flood although it may be possible to evacuate residents by walking to high land behind the development.
- Roadways may become overland flow paths for severe stormwater flooding. This will reduce their trafficability and could affect evacuation.

A potentially hazardous situation develops when rising floodwater isolates an area of land, leaving an island in a sea of floodwater. The degree of hazard depends on the depth, velocity and rate of rise of floodwaters between the island and possible places of refuge. Vehicle access may be cut rapidly. Rescue by boat, helicopter or large vehicle may be necessary, so putting the rescuers' lives at risk.

Guidance

- Avoid evacuation wherever possible.
- Where evacuation may be necessary, it should be carefully planned and practised. All those involved in the evacuation (including the public) should participate.

Use of boats

Boat handling in floods is dangerous. Boats can be swept away in floodwater or may be trapped under bridges. Boats can be damaged by underwater hazards. Moving people using boats is hazardous.

Guidance

- The public should be aware that the use of boats in floods is dangerous.
- Boats should be handled by personnel trained in emergency rescue.

Vulnerable groups

Some people are more vulnerable than others. Particularly vulnerable groups include:

- The elderly
- The disabled and long-term sick
- Financially deprived
- Single parents and their children
- The very young, for example infant school children
- Ethnic minorities, particularly those who have poor English language skills
- Newcomers to an area, who may be unaware of local issues
- Campers and other tourists, who may be unaware of local risks
- The homeless
- Work related (eg emergency services)

Guidance

- Be aware of vulnerable people and their specific needs in flood events.
- The public and politicians should be aware of the risks to emergency service personnel during floods. These should be minimised.

Other factors

There are many factors that can contribute to deaths during floods, and a few examples are given below:

- People trapped in buildings or on the roofs of buildings may die from exposure.
- People may suffer from heart attacks or other sudden illness caused by the stress of a flood.
- Falling trees and other flying debris (for example, roof tiles) can occur in the storms that cause the floods.
- Electricity can be a hazard during a flood.
- Fire, caused by electrical short-circuits for example.
- Mudslides.

The emergency services also have greater difficulty attending to fires, accidents, etc. during floods.

Guidance

- The public should be aware of other risks that can occur during floods.

Flood Risks to People

GUIDANCE NOTE 3 Guidance for project appraisal

Purpose

Project appraisal (including management of existing flood defences and new flood management schemes) requires a way of estimating the change in flood risks to people caused by proposed changes to the flood defence/flood management system. The results could be used in a Multi-Criteria Analysis appraisal process.

This Guidance Note provides a method for estimating the change in number of people per year who are likely to die or be seriously injured by a flood,

Scales

The methods in this Guidance Note apply to the following scales:

- Regional (CFMP, SMP, Strategy Study)
- Local (scheme appraisal)

Procedure

The general procedure is as follows:

- Calculate the risks to people for present day conditions
- Calculate the risks to people with the proposed flood management policies and measures in place.
- Calculate the change in risks to people

Risks to people are calculated using the method set out below. The outputs are expressed as the total number of people per year who are likely to die or be seriously injured by flooding.

Description of method

The basic method for calculating flood risks to people is described below. Further detail and more background information is given *Flood Risks to People Phase 2, The Risks to People Methodology, Report FD2321/TR1*. It is expected that users of this Guidance Note will refer to this report.

Overview

The number of deaths/injuries is calculated using the following equation:

$$N(I) = N \times X \times Y.$$

Where:

- N(I) is the number of deaths/injuries
- N is the population within the floodplain
- X is the proportion of the population exposed to a risk of suffering death/injury (for a given flood). The value of X is based on the Flood Hazard and the Area Vulnerability.
- Y is the proportion of those at risk who will suffer death/injury. The value of Y based on People Vulnerability.

The risk of suffering N(I) deaths/injuries will simply be the likelihood of the given flood. In order to calculate the annual average number of deaths/injuries, at least five events should be used. Guidance on selection of events is given below.

Thus the method requires the calculation of:

- Flood Hazard
- Area Vulnerability
- People Vulnerability

The calculation methods for these parameters are described below.

Selection of events

The greatest impact on life is likely to be for more extreme events and therefore the choice of events must include or, in a special cases, exceed the 0.1% annual probability or 1 in 1000 year flood. The area considered for typical risks to people assessment will be defined by the Environment Agency’s 0.1% annual probability flood outline. The choice of events should cover a similar range to those outlined below:

- (a) For an undefended area with regular flooding choose the 20, 50, 100, 250, 1000 year events;
- (b) For a defended area (to, say, 1 in 75-year standard) choose 100, 200, 300, 500, 1000 year events;
- (c) For a highly defended area (to, say, 1 in 1000) choose 1000, 1500, 2000, 5000 and 10000 year events.

The scenarios may include combined probability events of water level and defence failure by using methods developed under the Risk Assessment for Strategic Planning (RASP) framework.

Flood Hazard

The Flood Hazard rating is calculated using the following equation:

$$HR = d \times (v + 0.5) + DF$$

- where,
- HR = (flood) hazard rating;
 - d = depth of flooding (m);
 - v = velocity of floodwaters (m/sec); and
 - DF = debris factor calculated using Table 3.1

Table 3.1 Guidance on debris factors for different flood depths, velocities and dominant land uses

Depths	Pasture/Arable	Woodland	Urban
0 to 0.25 m	0	0	0
0.25 to 0.75 m	0	0.5	1
d>0.75 m and/or v>2	0.5	1	1

Ref: FD2321/TR1 Table 3.1

Area Vulnerability

The Area Vulnerability is calculated using Table 3.2.

Table 3.2 Area Vulnerability

Parameter	1 - Low risk area	2 - Medium risk area	3 - High risk area
Speed of onset	Onset of flooding is very gradual (many hours)	Onset of flooding is gradual (an hour or so)	Rapid flooding
Nature of area	Multi-storey apartments	Typical residential area (2-storey homes); commercial and industrial properties	Bungalows, mobile homes, busy roads, parks, single storey schools, campsites, etc.
Flood warning	Score for flood warning = $3 - (P1 \times (P2 + P3))$ where P1 = % of Warning Coverage Target Met P2 = % of Warning Time Target Met P3 = % of Effective Action Target Met		
Area Vulnerability (AV) = sum of scores for 'speed of onset', 'nature of area' and 'flood warning'			

Ref: FD2321/TR1 Table 4.4

Recent values for P1, P2 and P3 are given in Table 3.3. These can be updated using more recent data when available.

Table 3.3 Calculation of Flood Warning Score

Agency Region	% of Warning Coverage Target Met (80%) = P1	% of Warning Time Target Met (100%) = P2	% of Effective Action Target Met (75%) = P3	FW Score = $3 - (P1 \times (P2 + P3))$
Anglian	0.69	0.75	0.48	2.15
Midlands				
- East	0.16	0.54	0.48	2.83
- West	0.34	0.54	0.48	2.66
North East				
- Yorkshire & Humber	0.94	0.88	0.48	1.73
- North East	0.66	0.88	0.48	2.10
North West	0.81	0.00	0.48	2.61
Southern	0.76	0.65	0.48	2.14
South West	0.76	0.61	0.48	2.17
Thames	0.76	0.65	0.48	2.14
England	0.76	0.63	0.48	2.15
Wales	0.56	0.63	0.73	2.23

Ref: FD2321/TR1 Table 4.3

People Vulnerability

The People Vulnerability score (Y expressed as a percentage) is simply:

$$Y = \% \text{residents suffering from long-term illness} + \% \text{residents aged 75 or over.}$$

Method for calculating flood risks to people

The calculation procedure is described below using example numbers from a theoretical flood risk area.

1. Calculate Flood Hazard Rating (HR)

The flood hazard is calculated using the formula given above for zones of different hazard in the floodplain. It is therefore necessary to divide the floodplain into zones of different hazard. In the example below, the floodplain has been divided into strips of different hazard based on the distance from the river/coast.

Distance from river/coast (m)	N(Z)	Typical depth, d (m)	Typical velocity, v (m/sec)	Debris factor (DF)	Hazard rating = $d(v+0.5) + DF$
0-50	25	3	2	1 – possible	8.5
50-100	50	2	1.8	1 – possible	5.6
100-250	300	1	1.3	1 – possible	2.8
250-500	1000	0.5	1.2	1 – possible	1.85
500-1000	2500	0	0	0 - unlikely	0

Ref: FD2321/TR1 Table 6.1

2. Calculate Area Vulnerability

Calculate the Area Vulnerability using Tables 3.2 and 3.3.

Distance from river/coast (m)	Flood warning	Speed of onset	Nature of area	Sum = area vulnerability
0-50	2.15	3	2	7.15
50-100	2.15	2	1	5.15
100-250	2.15	2	3	7.15
250-500	2.15	1	2	5.15
500-1000	2.15	1	2	5.15

Ref: FD2321/TR1 Table 6.2

3. Calculate those exposed to the flood (X)

This Area Vulnerability score is simply multiplied by the Hazard Rating derived above to generate the value for X (the % of people exposed to risk). Should the score exceed 100, this is simply taken as 100. Whilst this is not a true percentage, it provides a practical approach to the assessment of flood risk. X is multiplied by the number of people in each zone to determine the number of people exposed to the flood.

Distance from river/coast (m)	N(Z)	Hazard rating (HR)	Area vulnerability (AV)	X = HR x AV	N(ZE)
0-50	25	8.5	7.15	61%	15
50-100	50	5.6	5.15	29%	14
100-250	300	2.8	7.15	20%	60
250-500	1000	1.85	5.15	10%	95
500-1000	2500	0	5.15	0%	0

Note: N(Z) is the population in each hazard zone

N(ZE) is the number of people exposed to the risk in each hazard zone

Ref: FD2321/TR1 Table 6.3

4. Calculate People Vulnerability (Y)

Distance from river/coast (m)	N(Z)	Factor 1 (% very old)	Factor 2 (% Disabled or infirm)	Y
0-50	25	15%	10%	25%
50-100	50	10%	14%	24%
100-250	300	12%	10%	22%
250-500	1000	10%	15%	25%
500-1000	2500	15%	20%	35%

Ref: FD2321/TR1 Table 6.4

5. Calculate the numbers of injuries and deaths

The number of injuries is assumed to be proportional to the People Vulnerability Y. The number of people exposed to the risk (N(ZE)) is multiplied by 2Y to obtain the number of injuries. The fatality rate (ie the proportion of injured people who die) is assumed to be proportional to the Hazard Rating. The number of injuries is multiplied by 2HR (as a percentage) to obtain the number of deaths.

Distance from river /coast (m)	N(ZE)	Y = 1 + 2 (as %)	No. of injuries = 2 * Y * N(ZE)	Fatality rate = 2 x HR	No. of deaths
0-50	15	25%	8	17%	1
50-100	14	24%	7	11%	1
100-250	60	22%	26	6%	1
250-500	95	25%	48	4%	2
500-1000	0	35%	0	0%	0
All	185		89		5

Ref: FD2321/TR1 Table 6.5

6. Apply to a range of events and estimate annual average risks

The same calculation must be repeated for other flood events. A summary of injuries and deaths for all 5 events is shown below.

The number of injuries and fatalities for 5 flood events

Numbers injured

Distance from river /coast (m)	1000yr	250yr	100yr	50yr	20yr
0-50	12	10	8	6	2
50-100	11	9	7	5	2
100-250	53	38	26	17	0
250-500	103	75	48	0	0
500-1000	243	158	0	0	0
All	421	289	89	28	4

Number of fatalities

Distance from river /coast (m)	1000yr	250yr	100yr	50yr	20yr
0-50	3	2	1	1	0
50-100	2	1	1	0	0
100-250	6	3	1	1	0
250-500	8	4	2	0	0
500-1000	13	6	0	0	0
All	32	17	5	2	0

Ref: FD2321/TR1 Table 6.6

By plotting the numbers of injuries/deaths against flood frequency and calculating the area under the curve, it is possible to estimate the annual average flood risks to people.

Data requirements

1. Regional applications

Variable	Type	Data sources
Floodplain extent	Variable	<ul style="list-style-type: none"> EA Flood Map NAFRA Flood Map
Flood depth	Variable	<ul style="list-style-type: none"> Flood extents and topographic data (eg NextMap DTM, LiDAR, DTM). The Modelling and Decision Support Framework (MDSF) can derive flood depths from these data. Hydraulic modelling (see Note below). NAFRA Flood Map
Flood velocity	Variable	<ul style="list-style-type: none"> Expert judgement for broad-brush assessment (see Note below) Hydraulic modelling (see Note below)
Flood depth and velocity	Variable	<ul style="list-style-type: none"> Flood Hazard could be calculated using existing Flood Zones modelling data for available events (1%/0.5% and 0.1% annual probability). Changes could be estimated from inspection of options (in order to avoid modelling for depth and velocity at regional scale). This will only provide

		<p>approximate data for the Annual Average Risks to People calculation, but possibly good enough for comparisons of options.</p> <ul style="list-style-type: none"> Hydraulic modelling (see Note below)
Nature of area	Score	<ul style="list-style-type: none"> OS Maps National Property Database (NPD) and other address-point products to develop information on property types. Local knowledge to identify main vulnerable areas (eg areas of bungalows, etc).
Flood warning	Score	<ul style="list-style-type: none"> EA performance indicators
Speed of onset	Score	<ul style="list-style-type: none"> EA flood warning information Catchment characteristics Location and nature of defences
Population	Variable	<ul style="list-style-type: none"> National Census data by Output Area
Residents suffering from long-term illness	%	<ul style="list-style-type: none"> National Census data by Output Area
Residents aged 75 or over	%	<ul style="list-style-type: none"> National Census data by Output Area

2. Local applications

Variable	Type	Data sources
Floodplain extent	Variable	<ul style="list-style-type: none"> EA Flood Map Hydraulic modelling (see Note below)
Flood depth	Variable	<ul style="list-style-type: none"> Hydraulic modelling (see Note below).
Flood velocity	Variable	<ul style="list-style-type: none"> Hydraulic modelling (see Note below)
Flood depth and velocity	Variable	<ul style="list-style-type: none"> Hydraulic modelling (see Note below)
Nature of area	Score	<ul style="list-style-type: none"> OS Maps National Property Database (NPD) and other address-point products to develop information on property types. Site inspections.
Flood warning	Score	<ul style="list-style-type: none"> EA performance indicators
Speed of onset	Score	<ul style="list-style-type: none"> Hydrological calculation using catchment characteristics Location and nature of defences

Population	Variable	<ul style="list-style-type: none"> National Census data by Output Area Use of local information including ‘non-resident’ population (eg people in workplaces, in transit, on campsites, etc) and places where people congregate (eg shopping areas, etc)
Residents suffering from long-term illness	%	<ul style="list-style-type: none"> Local data from local authorities or health services. Contact local authorities in the first instance
Residents aged 75 or over	%	<ul style="list-style-type: none"> Local data from local authorities or health services. Contact local authorities in the first instance

Note: calculation of flood depths and velocities

Estimating flood depths and velocities by hydraulic modelling can be onerous, particularly at regional scale. A summary of possible approaches is given below (in order of least complex to most complex)

- Existing flood maps and topographic data. Existing maps can be used to estimate flood depth but do not provide any information on velocities. For some simple applications of the method it may be appropriate to estimate peak velocities based on normal depth calculations or even expert judgement. Any assumptions made should be conservative (assuming high velocities).
- Conveyance calculation. The new Conveyance Estimation System (CES) can be used to estimate velocities across a floodplain for river valleys without defences (see <http://www.river-conveyance.net>).
- One-dimensional hydraulic models with defined flood storage areas and active floodplain channels, for example ISIS Flow or MIKE11 software, can be used to estimate average velocities. Maximum velocities can be significantly higher in some parts of the floodplain, for example where water spills over a defence, in narrow streets and any other “pinch points” in the floodplain.
- Flow routing using a “raster” GIS system, for example the JFLOW model used for the fluvial component of the Flood Zones project.
- Two-dimensional hydraulic modelling using a fixed grid, for example the TUFLOW hydraulic model that has been used for modelling floodplains on the tidal Thames or HYDRO F that was used for the tidal component of the Extreme Flood Outline project (see below).
- Two-dimensional hydraulic modelling using a triangular mesh, for example the Telemac 2D model. This can provide good velocity estimates but model run times are significantly longer than grid based models.

Hydraulic modelling requires the following data:

- Flow (for rivers) or sea level (coasts)
- Ground levels. Digital Terrain Models (such as LiDAR or the NextMap DTM) are often used for floodplains. Filtered data (with removal of buildings, vegetation, etc) are normally used for broadscale assessments but this does not identify the high

hazard associated with flow in constricted areas such as streets. Ideally buildings should be included in models for local application.

- Flood defences, including location and level.

Uncertainty

Uncertainty in the results is high, particularly in the number of people who will be exposed to a flood and the wide range of site specific factors that affect whether people are injured or killed. The results do however provide a guide to flood risks to people, and can be used to compare the impacts of different options.

Flood Risks to People

GUIDANCE NOTE 4 Flood Mapping

Purpose

This Guidance Note outlines methods for mapping the following:

- Flood Hazard, the hydraulic conditions affecting the safety of people in floods.
- Area Vulnerability, the vulnerability of different parts of the floodplain to exposure to floods.
- Flood risks to people.

These three types of mapping have been considered separately, as the Environment Agency is unlikely to implement all three at the same time.

Events to be used for mapping depend on the requirement. It is expected that Flood Hazard will be calculated for the same events as those used for the national Flood Map (1%/0.5% and 0.1% annual probabilities). Area Vulnerability is a floodplain parameter and is independent of event. If flood risks to people are to be presented as annual average data, several events will be needed (usually five). These should include very extreme events as these cause the greatest risks to people.

Scales

The methods in this Guidance Note apply to the following scales:

- National, to contribute to the Environment Agency's national flood mapping programme
- Regional, to enable mapping of flood risks to people for Catchment Flood Management Plans (CFMPs) and Shoreline Management Plans (SMPs) should this be required.

Overview of method for calculating Flood Risks to People

The number of deaths/injuries is calculated using the following equation:

$$N(I) = N \times X \times Y.$$

Where:

- N(I) is the number of deaths/injuries
- N is the population within the floodplain
- X is the proportion of the population exposed to a risk of suffering death/injury (for a given flood). The value of X is based on the Flood Hazard and the Area Vulnerability.
- Y is the proportion of those at risk who will suffer death/injury. The value of Y based on People Vulnerability.

The risk of suffering N(I) deaths/injuries will simply be the likelihood of the given flood.

Further detail and more background information is given ***Flood Risks to People Phase 2, The Risks to People Methodology, Report FD2321/TR1***. It is expected that users of this Guidance Note will refer to this report.

Uncertainty

Uncertainty in the results is high, particularly in the number of people who will be exposed to a flood and the wide range of site specific factors that affect whether people are injured or killed.

FLOOD HAZARD MAPPING

Method of calculating Flood Hazard

The Flood Hazard is calculated using the following equation:

$$HR = d \times (v + 0.5) + DF$$

where,

HR = (flood) hazard rating;

d = depth of flooding (m);

v = velocity of floodwaters (m/sec); and

DF = debris factor calculated using Table 4.1

Critical values of Flood Hazard are shown in Table 4.2. These are used to categorise the hazard in terms of danger to people.

Table 4.1 Guidance on debris factors for different flood depths, velocities and dominant land uses

Depths	Pasture/Arable	Woodland	Urban
0 to 0.25 m	0	0	0
0.25 to 0.75 m	0	0.5	1
d>0.75 m and/or v>2	0.5	1	1

Ref: FD2321/TR1 Table 3.1

Table 4.2 Hazard to People as a Function of Velocity and Depth

$d \times (v + 0.5)$	Degree of Flood Hazard	Description
<0.75	Low	Caution <i>“Flood zone with shallow flowing water or deep standing water”</i>
0.75 - 1.25	Moderate	Dangerous for some (i.e. children) <i>“Danger: Flood zone with deep or fast flowing water”</i>
1.25 - 2.5	Significant	Dangerous for most people <i>“Danger: flood zone with deep fast flowing water”</i>
>2.5	Extreme	Dangerous for all <i>“Extreme danger: flood zone with deep fast flowing water”</i>

Ref: FD2321/TR1 Table 3.2

Mapping Procedure

The general procedure for flood hazard mapping is to calculate the key parameters needed for the Flood Hazard equation, and map the result. The Flood Hazard is applied to a single event.

Two approaches are considered in this Guidance Note.

1. Hydraulic modelling for the required events to determine flood depth and velocity. Combine the results and add a debris score to calculate flood hazard. This is the method used to produce Figure 4.3. **See section on hydraulic modelling below.**
2. Derive flood hazard maps using existing data, as follows:
 - Use existing ‘Flood Zones’ depth and velocity data for available events (1%/0.5% and 0.1% annual probability). These do not include flood defences.
 - Supplement these data by information on flood hazard in defended areas and areas prone to wave attack. **See sections on defended areas and wave attack below.**
 - Use depth data from NAFRA flood maps and use expert judgement to estimate velocities on the floodplain. The advantage of this approach is that it takes into account the probability of defence failure.

Estimates of depth and velocity using the ‘Flood Zones’ method are subject to large uncertainties. However it is the only national method currently available that generates depth and velocity. The method does not take account of defences and therefore it is necessary to estimate flood hazard behind defences independently, as indicated above.

Methods for hydraulic modelling to estimate flood depths and velocities

A summary of possible approaches for estimating flood depths and velocities for national and regional mapping is given below.

- Conveyance calculation. Recent national floodplain mapping projects have employed a conveyance calculation approach based on the new Conveyance Estimation System (CES). Flows are obtained from the national CEH Flow Grid and ground levels from the national NextMap DTM. Flood levels and extents are calculated using a ‘normal depth’ calculation. This can be used to estimate velocities across a floodplain for river valleys without defences (see <http://www.river-conveyance.net>).
- One-dimensional hydraulic models with defined flood storage areas and active floodplain channels, for example ISIS Flow or MIKE11 software, can be used to estimate average velocities. Maximum velocities can be significantly higher in some parts of the floodplain, for example where water spills over a defence, in narrow streets and any other “pinch points” in the floodplain.
- Flow routing using a “raster” GIS system, for example the JFLOW model used for the fluvial component of the Flood Zones project. This calculates depths and velocities on a fixed grid, based on the DTM grid.
- Two-dimensional hydraulic modelling using a fixed grid, for example the TUFLOW hydraulic model that has been used for modelling floodplains on the tidal Thames or HYDRO F that was used for the tidal component of the Flood Zones project (which does not include flood defences).

- Two-dimensional hydraulic modelling using a triangular mesh, for example the Telemac 2D model. This can provide good velocity estimates but model run times are significantly longer than grid based models.

Hydraulic modelling requires the following data:

- Flow (for rivers) or sea level (coasts)
- Ground levels. Digital Terrain Models (such as LiDAR or the NextMap DTM) are often used for floodplains. Filtered data (with removal of buildings, vegetation, etc) are normally used for broadscale assessments but this does not identify the high hazard associated with flow in constricted areas such as streets.
- Flood defences, including location and level.

Flood hazard in defended areas

Flooding behind defences can occur from overtopping or breaching. Table 4.3 shows the flood hazard with distance from a flood defence for different water levels above the defence crest, assuming a flat and clear floodplain..

Table 4.3 Danger to people from overtopping relative to distance from defence

Distance from defence (m)	Head above crest level (m)			
	0.5	1	2	3
100	Yellow	Red	Red	Red
250	Yellow	Red	Red	Red
500	Yellow	Yellow	Red	Red
1000	Yellow	Yellow	Red	Red
1500	Yellow	Yellow	Yellow	Red
2000	Yellow	Yellow	Yellow	Yellow
2500	Yellow	Yellow	Yellow	Yellow
3000	Yellow	Yellow	Yellow	Yellow
3500	Yellow	Yellow	Yellow	Yellow
4000	Yellow	Yellow	Yellow	Yellow
4500	Yellow	Yellow	Yellow	Yellow
5000	Yellow	Yellow	Yellow	Yellow

Key:  Danger for some
 Danger for most
 Danger for all

Figure 4.1 shows that way in which the flood depth and hazard varies when a breach occurs in a flood defence. Table 4.4 shows the flood hazard with distance from a flood defence for breaches with different water levels above floodplain level, assuming a flat and clear floodplain..

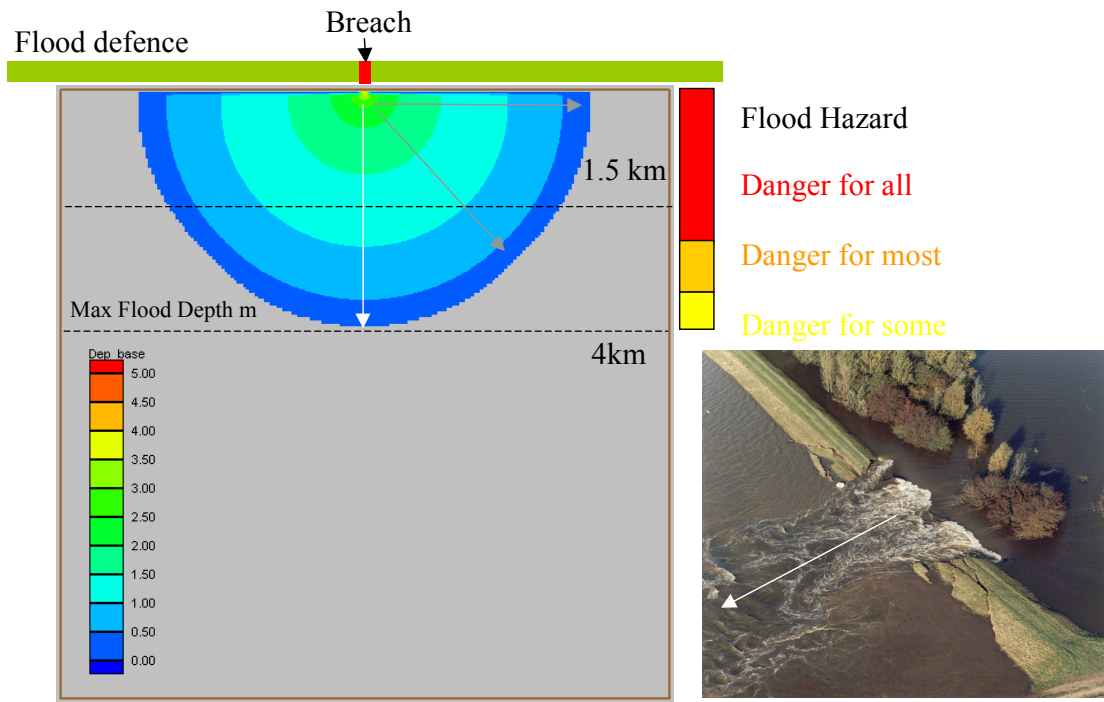


Figure 4.1 Flood hazard at a breach in a flood defence

Table 4.4 Danger to people from breaching relative to distance from defence

Distance from breach (m)	Head above floodplain (m)						
	0.5	1	2	3	4	5	6
100	Yellow	Orange	Red	Red	Red	Red	Red
250		Yellow	Red	Red	Red	Red	Red
500		Yellow	Yellow	Red	Red	Red	Red
1000			Yellow	Orange	Red	Red	Red
1500			Yellow	Yellow	Orange	Red	Red
2000				Yellow	Yellow	Orange	Red
2500					Yellow	Yellow	Orange
3000						Yellow	Yellow
3500							Yellow
4000							
4500							
5000							

Key:
 Danger for some
 Danger for most
 Danger for all

Tables 4.3 and 4.4 can be used to assess the hazard behind defences based on the water level of the selected design event compared with either the defence crest level (for overtopping) or floodplain level (for breaching). The results can be overlaid on a map of flood hazard obtained from models which do not include flood defences.

An example of a flood hazard map for a defended area based on data from Tables 4.3 and 4.4 is shown on Figure 4.2.

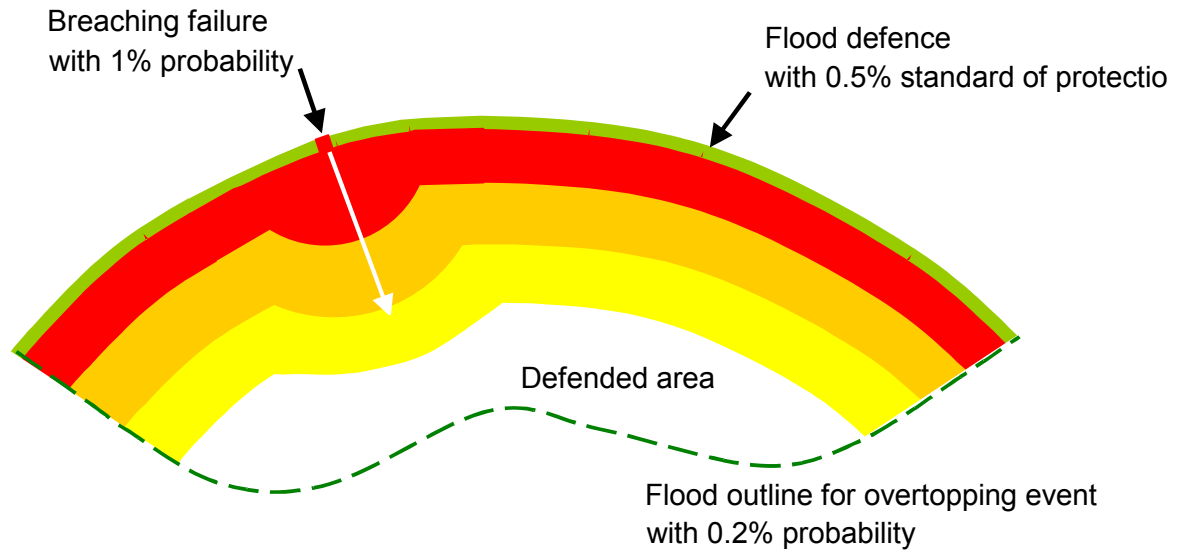


Figure 4.2 Example flood hazard map with one overtopping scenario and one breach scenario

Flood hazard caused by waves on the coast

The risks of violent waves overtopping sea walls leads to significant flood hazard. Every year there are one of more deaths caused by people being washed into the sea by wave action. Risks are greatest where there are vertical sea walls fronting pedestrian promenades, roads or railways. In order to predict the risks posed by violent waves, data are required on the defences, sea levels and wave heights.

For national and regional mapping it is proposed that exposed sea walls are shown on flood hazard maps as areas of high hazard.

Data requirements for flood hazard mapping

1. National applications

Variable	Type	Data sources
Floodplain extent	Variable	<ul style="list-style-type: none"> EA Flood Map NAFRA map
Flood defence location and level	Variable	<ul style="list-style-type: none"> EA Flood Map for location NFCDD for level/Standard of Protection, supplemented by other EA data if required.
Flood depth	Variable	<ul style="list-style-type: none"> Outputs from Flood Zones mapping. Flood extents and topographic data (eg NextMap DTM, LiDAR, DTM). The Modelling and Decision Support Framework (MDSF) can derive flood depths from these data. Hydraulic modelling. NAFRA map

Flood velocity	Variable	<ul style="list-style-type: none"> • Outputs from Flood Zones mapping • Hydraulic modelling
Flood depth and velocity	Variable	<ul style="list-style-type: none"> • Outputs from Flood Zones mapping • Hydraulic modelling

2. Regional applications

Variable	Type	Data sources
Floodplain extent	Variable	<ul style="list-style-type: none"> • EA Flood Map • Hydraulic modelling • NAFRA map
Flood defence location and level	Variable	<ul style="list-style-type: none"> • EA Flood Map for location • NFCDD for level/Standard of Protection, supplemented by more detailed local data if required.
Wave hazard zones	Variable	<ul style="list-style-type: none"> • Local information on exposed sea walls
Flood depth	Variable	<ul style="list-style-type: none"> • Flood extents and topographic data (eg NextMap DTM, LiDAR, DTM). The Modelling and Decision Support Framework (MDSF) can derive flood depths from these data. • Hydraulic modelling. • NAFRA map.
Flood velocity	Variable	<ul style="list-style-type: none"> • Hydraulic modelling
Flood depth and velocity	Variable	<ul style="list-style-type: none"> • Hydraulic modelling

Example of a flood hazard map

An example of a flood hazard map developed using a 2D hydraulic model is shown in Figure 4.3.

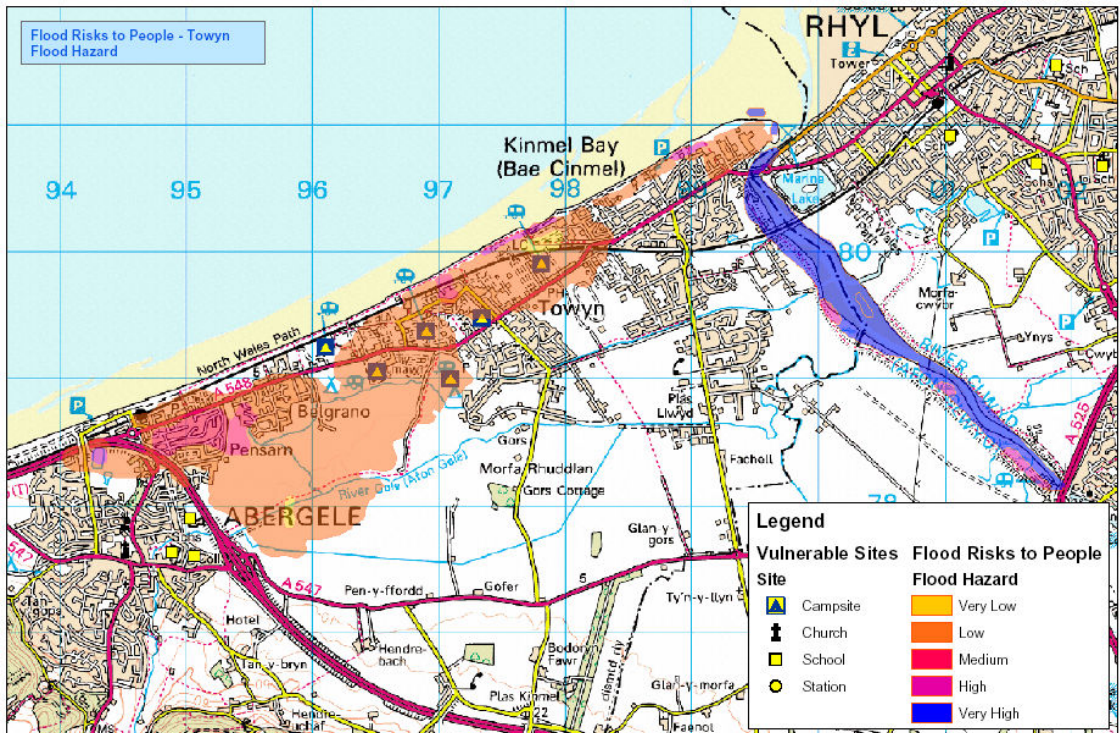


Figure 4.3 Flood hazard map

AREA VULNERABILITY MAPPING

Method for calculating Area Vulnerability

The Area Vulnerability is calculated using Tables 4.5 and 4.6.

Table 4.5 Area Vulnerability

Parameter	1 - Low risk area	2 - Medium risk area	3 - High risk area
Speed of onset	Onset of flooding is very gradual (many hours)	Onset of flooding is gradual (an hour or so)	Rapid flooding
Nature of area	Multi-storey apartments	Typical residential area (2-storey homes); commercial and industrial properties	Bungalows, mobile homes, busy roads, parks, single storey schools, campsites, etc.
Flood warning	Score for flood warning = $3 - (P1 \times (P2 + P3))$ where P1 = % of Warning Coverage Target Met P2 = % of Warning Time Target Met P3 = % of Effective Action Target Met		
Area Vulnerability (AV) = sum of scores for 'speed of onset', 'nature of area' and 'flood warning'			

Ref: FD2321/TR1 Table 4.4

Recent values for P1, P2 and P3 are given in Table 4.6. These can be updated using more recent data when available.

Table 4.6 Calculation of Flood Warning Score

Agency Region	% of Warning Coverage Target Met (80%) = P1	% of Warning Time Target Met (100%) = P2	% of Effective Action Target Met (75%) = P3	FW Score = $3 - (P1 \times (P2 + P3))$
Anglian	0.69	0.75	0.48	2.15
Midlands				
- East	0.16	0.54	0.48	2.83
- West	0.34	0.54	0.48	2.66
North East				
- Yorkshire & Humber	0.94	0.88	0.48	1.73
- North East	0.66	0.88	0.48	2.10
North West	0.81	0.00	0.48	2.61
Southern	0.76	0.65	0.48	2.14
South West	0.76	0.61	0.48	2.17
Thames	0.76	0.65	0.48	2.14
England	0.76	0.63	0.48	2.15
Wales	0.56	0.63	0.73	2.23

Ref: FD2321/TR1 Table 4.3

Mapping Procedure

The general procedure for mapping of Area Vulnerability is to calculate the Area Vulnerability using Table 4.5 and plot on maps.

The scale at which this is done will depend on the application but, in view of the approximate nature of much of the data, the areas with different values should not be too refined. For example, at the Regional scale it is suggested that different Area Vulnerability scores should be applied to the main zones of different housing type in a settlement (see example in Figure 4.4).

Data requirements

1. National applications

Variable	Type	Data sources
Floodplain extent	Variable	<ul style="list-style-type: none">EA Flood MapNAFRA map
Nature of area	Score	<ul style="list-style-type: none">OS MapsNational Property Database (NPD) and other address-point products to develop information on property types.
Flood warning	Score	<ul style="list-style-type: none">EA performance indicators
Speed of onset	Score	<ul style="list-style-type: none">EA flood warning informationNational classification of catchments based on catchment area, land use and slopeLocation and nature of defences

2. Regional applications

Variable	Type	Data sources
Floodplain extent	Variable	<ul style="list-style-type: none">EA Flood MapNAFRA map
Nature of area	Score	<ul style="list-style-type: none">OS MapsNational Property Database (NPD) and other address-point products to develop information on property types.Local knowledge to identify main vulnerable areas (eg areas of bungalows, etc).
Flood warning	Score	<ul style="list-style-type: none">EA performance indicators
Speed of onset	Score	<ul style="list-style-type: none">EA flood warning informationCatchment characteristicsLocation and nature of defences

Example of an Area Vulnerability map

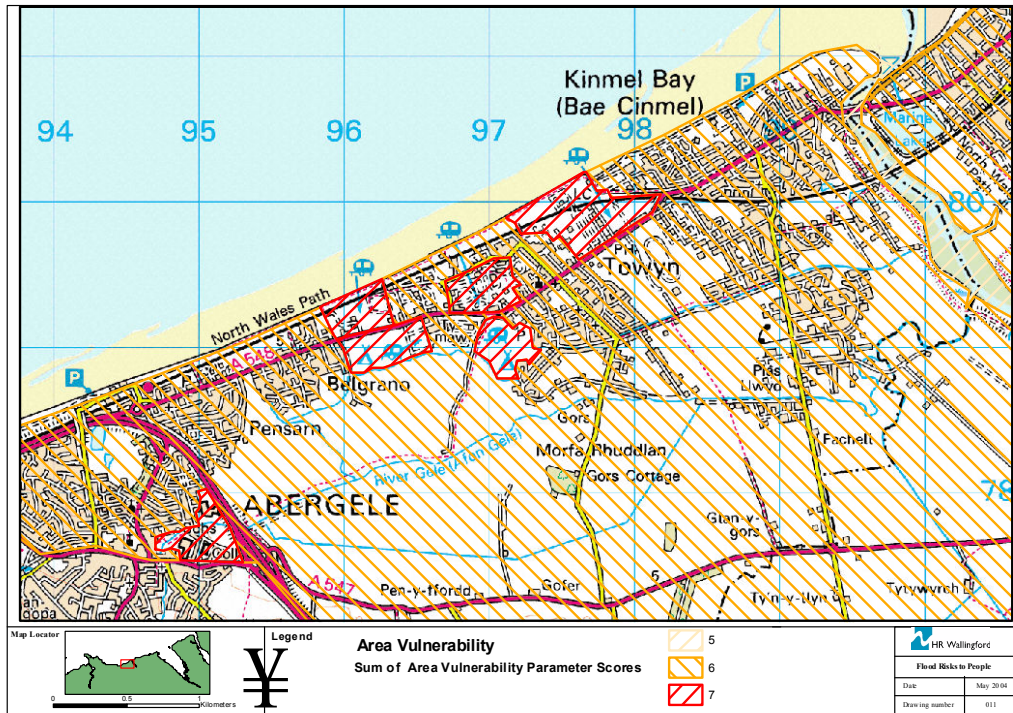


Figure 4.4 Area Vulnerability map

MAPPING OF FLOOD RISKS TO PEOPLE

Method for calculating Flood Risks to People

The method is outlined in the introduction to the flood mapping section, and requires the calculation of:

- Flood Hazard (see under Flood Hazard mapping)
- Area Vulnerability (see under Area Vulnerability mapping)
- People Vulnerability
- Population (from national census data)

The People Vulnerability score (Y expressed as a percentage) is simply:

$$Y = \% \text{residents suffering from long-term illness} + \% \text{residents aged 75 or over.}$$

The steps for calculating Flood Risks to People are given below with reference to an example.

1. This Area Vulnerability score is multiplied by the Hazard Rating to generate the value for X (the % of people exposed to risk). Should the score exceed 100, this is simply taken as 100. X is multiplied by the number of people in each zone to determine the number of people exposed to the flood. See example numbers in the table below.

Distance from river/coast (m)	N(Z)	Hazard rating (HR)	Area vulnerability (AV)	X = HR x AV	N(ZE)
0-50	25	8.5	7.15	61%	15
50-100	50	5.6	5.15	29%	14
100-250	300	2.8	7.15	20%	60
250-500	1000	1.85	5.15	10%	95
500-1000	2500	0	5.15	0%	0

Note: N(Z) is the population in each hazard zone

N(ZE) is the number of people exposed to the risk in each hazard zone

Ref: FD2321/TR1 Table 6.3

2. The People Vulnerability (Y) score is calculated, see example numbers in the table below.

Distance from river/coast (m)	N(Z)	Factor 1 (% very old)	Factor 2 (% Disabled or infirm)	Y
0-50	25	15%	10%	25%
50-100	50	10%	14%	24%
100-250	300	12%	10%	22%
250-500	1000	10%	15%	25%
500-1000	2500	15%	20%	35%

Ref: FD2321/TR1 Table 6.4

3. The number of people exposed to the risk (N(ZE)) is multiplied by 2Y to obtain the number of injuries. The fatality rate (ie the proportion of injured people who die) is assumed to be proportional to the Hazard Rating. The number of injuries is multiplied by 2HR (as a percentage) to obtain the number of deaths. See example numbers in the table below.

Distance from river /coast (m)	N(ZE)	Y = 1 + 2 (as %)	No. of injuries = 2 * Y * N(ZE)	Fatality rate = 2 x HR	No. of deaths
0-50	15	25%	8	17%	1
50-100	14	24%	7	11%	1
100-250	60	22%	26	6%	1
250-500	95	25%	48	4%	2
500-1000	0	35%	0	0%	0
All	185		89		5

Ref: FD2321/TR1 Table 6.5

Mapping Procedure

The mapping procedure involves combining layers of data on Flood Hazard, Area Vulnerability, People Vulnerability and population using the formulae given above.

In order to plot the average annual numbers of injuries/deaths against flood frequency it is necessary to apply the method to several events. Of the variables in the method, only the Hazard Rating will be different for each event. This affects X and therefore N(ZE), and the fatality rate.

Data requirements

National and Regional applications

Variable	Type	Data sources
Population	Variable	<ul style="list-style-type: none"> National Census data by Output Area
Residents suffering from long-term illness	%	<ul style="list-style-type: none"> National Census data by Output Area
Residents aged 75 or over	%	<ul style="list-style-type: none"> National Census data by Output Area

Example of a Flood Risks to People map

An example of a Flood Risks to People map is shown in Figure 4.5. The figure shows annual number of injuries per hectare. Results could also be expressed in terms of

annual number of deaths per hectare or annual number of deaths/injuries in any defined polygon.

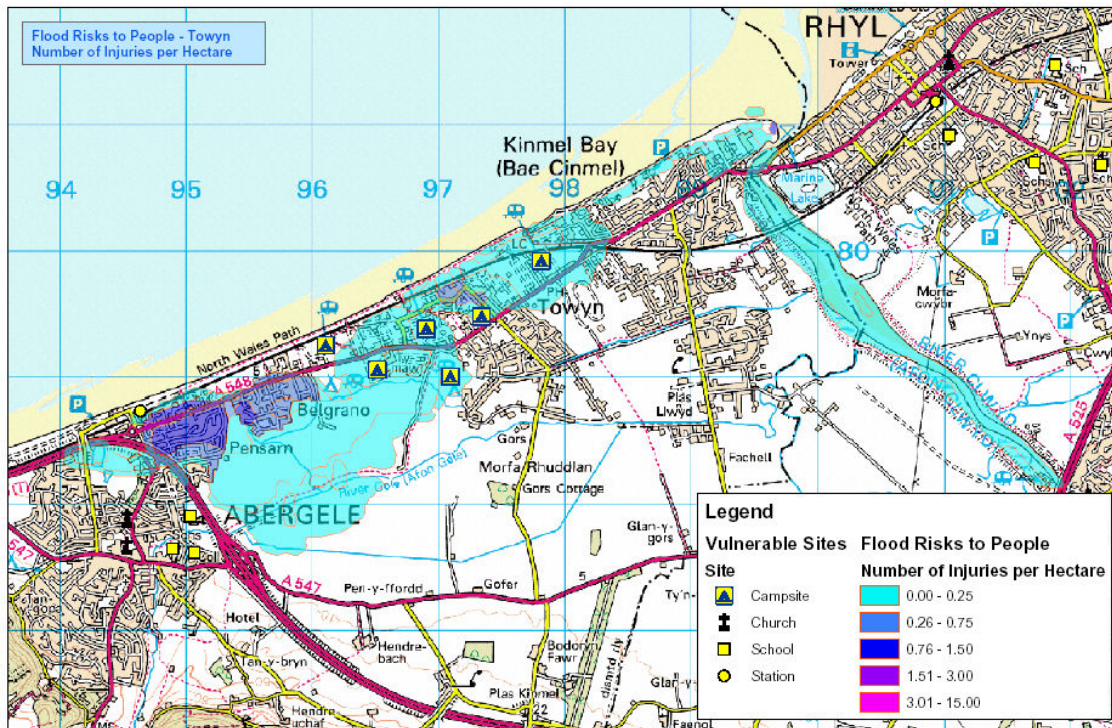


Figure 4.5 Flood Risks to People map

Flood Risks to People

GUIDANCE NOTE 5 Flood warning and emergency planning

Purpose

A flood warning service requires information on people who are most likely to be affected by floods and therefore have the greatest need for warnings.

Emergency planning requires identification of the areas where the risks to people are greatest, safe evacuation routes during floods, and the location of vulnerable people who would need the help of the emergency services.

This Guidance Note provides methods for:

- Calculating and mapping Flood Hazard, for identifying unsafe areas, evacuation routes, etc.
- Calculating and mapping Area Vulnerability, to know where vulnerable areas are.
- Calculating People Vulnerability, to identify where assistance may be needed.
- Estimating and mapping flood risks to people.
- Identifying high-risk areas to prioritise flood warning and emergency response.

Uses of this information for flood warning and emergency planning are summarised in the table below.

Map	Shows	Flood warning benefit	Emergency response benefit
Hazard	Unsafe areas for exposed people in flood.	Prioritise warnings.	Plan safe access and evacuation
Area Vulnerability	Development most vulnerable to floods.	Provide appropriate warnings (eg short lead-time where onset is rapid). Provide appropriate warning messages.	Target areas where assistance may be required.
Risks to people	Where people are most likely to die.	Prioritise warnings. Ensure warning dissemination is adequate.	Target areas where Risks to People are greatest. Identify vulnerable people. Prioritise response.

The EA's flood warning function also requires guidance on behaviour during floods. This is provided by Guidance Note 2. Emergency planning should link with Civil Contingencies Guidance under the Civil Contingencies Act and the development of local risk registers.

Scales

The methods in this Guidance Note apply to the following scales:

- Local

Description of method

The basic method for calculating Flood Risks to People is described below. Further detail and more background information is given *Flood Risks to People Phase 2, The Risks to People Methodology, Report FD2321/TR1*. It is expected that users of this Guidance Note will refer to this report.

This Guidance Note provides methods for the calculation and mapping of:

- Flood Hazard
- Area Vulnerability
- Flood risks to people

Flood Hazard is calculated for individual events. Area Vulnerability is a floodplain parameter and is independent of event. In order to calculate the annual average number of deaths/injuries, at least five events should be used (see guidance on selection of events).

Selection of events

Events selected for flood warning and emergency planning should be selected according to key flood thresholds. These may include the 1%/0,5% and 0.1% annual probability floods, to correspond to the existing national floodmaps. It may only be necessary to use a small number of events (perhaps two or three) to adequately describe the flood hazard and flood risks to people. Suggested events are given below:

- (a) For an undefended fluvial floodplain area with regular flooding choose the 20, 100 and 1000 year events;
- (b) For a defended area (to, say, 1 in 75-year standard) choose the 100 and 1000 year events.
- (c) For a highly defended area (to, say, 1 in 1000) choose 1000, 5000 and 10000 year events.

The scenarios may include combined probability events of water level and defence failure by using methods developed under the Risk Assessment for Strategic Planning (RASP) framework.

Flood Hazard

The Flood Hazard rating is calculated using the following equation:

$$HR = d \times (v + 0.5) + DF$$

where,

HR = (flood) hazard rating;

d = depth of flooding (m);

v = velocity of floodwaters (m/sec); and

DF = debris factor calculated using Table 5.1

Critical values of Flood Hazard are shown in Table 5.2. These are used to categorise the hazard on maps in terms of danger to people.

Table 5.1 Guidance on debris factors for different flood depths, velocities and dominant land uses

Depths	Pasture/Arable	Woodland	Urban
0 to 0.25 m	0	0	0
0.25 to 0.75 m	0	0.5	1
d>0.75 m and/or v>2	0.5	1	1

Ref: FD2321/TR1 Table 3.1

Table 5.2 Hazard to People as a Function of Velocity and Depth

$d \times (v + 0.5)$	Degree of Flood Hazard	Description
<0.75	Low	Caution <i>“Flood zone with shallow flowing water or deep standing water”</i>
0.75 - 1.25	Moderate	Dangerous for some (i.e. children) <i>“Danger: Flood zone with deep or fast flowing water”</i>
1.25 - 2.5	Significant	Dangerous for most people <i>“Danger: flood zone with deep fast flowing water”</i>
>2.5	Extreme	Dangerous for all <i>“Extreme danger: flood zone with deep fast flowing water”</i>

Ref: FD2321/TR1 Table 3.2

Mapping of flood hazard

The general procedure for flood hazard mapping is to calculate the key parameters needed for the Flood Hazard equation, and map the result. This is normally done using hydraulic modelling for each of the required events to determine flood depth and velocity. The depth and velocity results are combined and a debris score added to calculate flood hazard.

Possible approaches for estimating flood depths and velocities for local mapping are given below.

- One-dimensional hydraulic models with defined flood storage areas and active floodplain channels, for example ISIS Flow or MIKE11 software, can be used to

estimate depths and average velocities. Maximum velocities can be significantly higher in some parts of the floodplain, for example where water spills over a defence, in narrow streets and any other “pinch points” in the floodplain. An advantage of this approach is that it is the standard method used for hydraulic modelling for flood management schemes.

- Two-dimensional hydraulic modelling of floodplains using a fixed grid, for example the TUFLOW hydraulic model that has been used for modelling floodplains on the tidal Thames or HYDRO F that was used for the tidal component of the Flood Zones project.
- Two-dimensional hydraulic modelling using a triangular mesh, for example the Telemac 2D model. This can provide good velocity estimates but model run times are significantly longer than grid based models.

Hydraulic modelling requires the following data:

- Flow (for rivers) or sea level (coasts)
- Ground levels. Digital Terrain Models (such as LiDAR or the NextMap DTM) are often used for floodplains. Filtered data (with removal of buildings, vegetation, etc) are normally used for broadscale assessments but this does not identify the high hazard associated with flow in constricted areas such as streets. Ideally buildings should be included in models for local application.
- Flood defences, including location and level.

Area Vulnerability

The Area Vulnerability is calculated using Table 5.3.

Table 5.3 Area Vulnerability

Parameter	1 - Low risk area	2 - Medium risk area	3 - High risk area
Speed of onset	Onset of flooding is very gradual (many hours)	Onset of flooding is gradual (an hour or so)	Rapid flooding
Nature of area	Multi-storey apartments	Typical residential area (2-storey homes); commercial and industrial properties	Bungalows, mobile homes, busy roads, parks, single storey schools, campsites, etc.
Flood warning	Score for flood warning = $3 - (P1 \times (P2 + P3))$ where P1 = % of Warning Coverage Target Met P2 = % of Warning Time Target Met P3 = % of Effective Action Target Met		
Area Vulnerability (AV) = sum of scores for ‘speed of onset’, ‘nature of area’ and ‘flood warning’			

Ref: FD2321/TR1 Table 4.4

Recent values for P1, P2 and P3 are given in Table 5.4. These can be updated using more recent data when available.

Table 5.4 Calculation of Flood Warning Score

Agency Region	% of Warning Coverage Target Met (80%) = P1	% of Warning Time Target Met (100%) = P2	% of Effective Action Target Met (75%) = P3	FW Score = 3 - (P1 x (P2 + P3))
Anglian	0.69	0.75	0.48	2.15
Midlands				
- East	0.16	0.54	0.48	2.83
- West	0.34	0.54	0.48	2.66
North East				
- Yorkshire & Humber	0.94	0.88	0.48	1.73
- North East	0.66	0.88	0.48	2.10
North West	0.81	0.00	0.48	2.61
Southern	0.76	0.65	0.48	2.14
South West	0.76	0.61	0.48	2.17
Thames	0.76	0.65	0.48	2.14
England	0.76	0.63	0.48	2.15
Wales	0.56	0.63	0.73	2.23

Ref: FD2321/TR1 Table 4.3

Mapping of Area Vulnerability

The general procedure for mapping of Area Vulnerability is to calculate the Area Vulnerability using Table 5.3 and plot on maps. It is suggested that the Area Vulnerability is calculated for different zones of the floodplain based on the types of properties (for example, bungalows, two-storey houses, etc).

Method for calculating Flood Risks to People

The number of deaths/injuries is calculated using the following equation:

$$N(I) = N \times X \times Y.$$

Where:

- N(I) is the number of deaths/injuries
- N is the population within the floodplain
- X is the proportion of the population exposed to a risk of suffering death/injury (for a given flood). The value of X is based on the Flood Hazard and the Area Vulnerability.
- Y is the proportion of those at risk who will suffer death/injury. The value of Y based on People Vulnerability.

The risk of suffering N(I) deaths/injuries will simply be the likelihood of the given flood. The method requires the calculation of:

- Flood Hazard (see under 'Flood Hazard' above)
- Area Vulnerability (see under 'Area Vulnerability' above)
- People Vulnerability
- Population of area (see 'Data requirements' table)

The People Vulnerability score (Y expressed as a percentage) is simply:

$$Y = \% \text{residents suffering from long-term illness} + \% \text{residents aged 75 or over.}$$

The steps for calculating Flood Risks to People are given below with reference to an example.

1. This Area Vulnerability score is multiplied by the Hazard Rating to generate the value for X (the % of people exposed to risk). Should the score exceed 100, this is simply taken as 100. X is multiplied by the number of people in each zone to determine the number of people exposed to the flood. See example numbers in the table below.

Distance from river/coast (m)	N(Z)	Hazard rating (HR)	Area vulnerability (AV)	X = HR x AV	N(ZE)
0-50	25	8.5	7.15	61%	15
50-100	50	5.6	5.15	29%	14
100-250	300	2.8	7.15	20%	60
250-500	1000	1.85	5.15	10%	95
500-1000	2500	0	5.15	0%	0

Note: N(Z) is the population in each hazard zone

N(ZE) is the number of people exposed to the risk in each hazard zone

Ref: FD2321/TR1 Table 6.3

2. The People Vulnerability (Y) score is calculated, see example numbers in the table below.

Distance from river/coast (m)	N(Z)	Factor 1 (% very old)	Factor 2 (% Disabled or infirm)	Y
0-50	25	15%	10%	25%
50-100	50	10%	14%	24%
100-250	300	12%	10%	22%
250-500	1000	10%	15%	25%
500-1000	2500	15%	20%	35%

Ref: FD2321/TR1 Table 6.4

3. The number of people exposed to the risk (N(ZE)) is multiplied by 2Y to obtain the number of injuries. The fatality rate (ie the proportion of injured people who die) is assumed to be proportional to the Hazard Rating. The number of injuries is multiplied by 2HR (as a percentage) to obtain the number of deaths. See example numbers in the table below.

Distance from river /coast (m)	N(ZE)	Y = 1 + 2 (as %)	No. of injuries = 2 * Y * N(ZE)	Fatality rate = 2 x HR	No. of deaths
0-50	15	25%	8	17%	1
50-100	14	24%	7	11%	1
100-250	60	22%	26	6%	1
250-500	95	25%	48	4%	2
500-1000	0	35%	0	0%	0
All	185		89		5

Ref: FD2321/TR1 Table 6.5

Mapping Procedure

The mapping procedure involves combining layers of data on Flood Hazard, Area Vulnerability, People Vulnerability and population using the formulae given above.

In order to estimate the annual average number of injuries/deaths, it is necessary to combine the results from several different flood frequencies (usually five). Of the variables in the method, only the Hazard Rating will be different for each event. This affects X and therefore N(ZE), and the fatality rate.

Data requirements

Variable	Type	Data sources
Floodplain extent	Variable	<ul style="list-style-type: none"> EA Flood Map Hydraulic modelling
Flood depth	Variable	<ul style="list-style-type: none"> Hydraulic modelling.
Flood velocity	Variable	<ul style="list-style-type: none"> Hydraulic modelling
Flood depth and velocity	Variable	<ul style="list-style-type: none"> Hydraulic modelling
Nature of area	Score	<ul style="list-style-type: none"> OS Maps National Property Database (NPD) and other address-point products to develop information on property types. Site inspections.
Flood warning	Score	<ul style="list-style-type: none"> EA performance indicators
Speed of onset	Score	<ul style="list-style-type: none"> Hydrological calculation using catchment characteristics Location and nature of defences
Population	Variable	<ul style="list-style-type: none"> National Census data by Output Area Use of local information including 'non-resident' population (eg people in workplaces, in transit, on campsites, etc) and places where people congregate (eg shopping areas, etc)

Residents suffering from long-term illness	%	<ul style="list-style-type: none"> Local data from Local Authorities or health services. Contact local authorities in the first instance
Residents aged 75 or over	%	<ul style="list-style-type: none"> Local data from Local Authorities or health services. Contact local authorities in the first instance

Examples of information for Flood Warning and Emergency Response

Sample results from the analysis are given in Figures 5.1, 5.2 and 5.3 for Flood Hazard, Area Vulnerability and Flood Risks to People respectively.

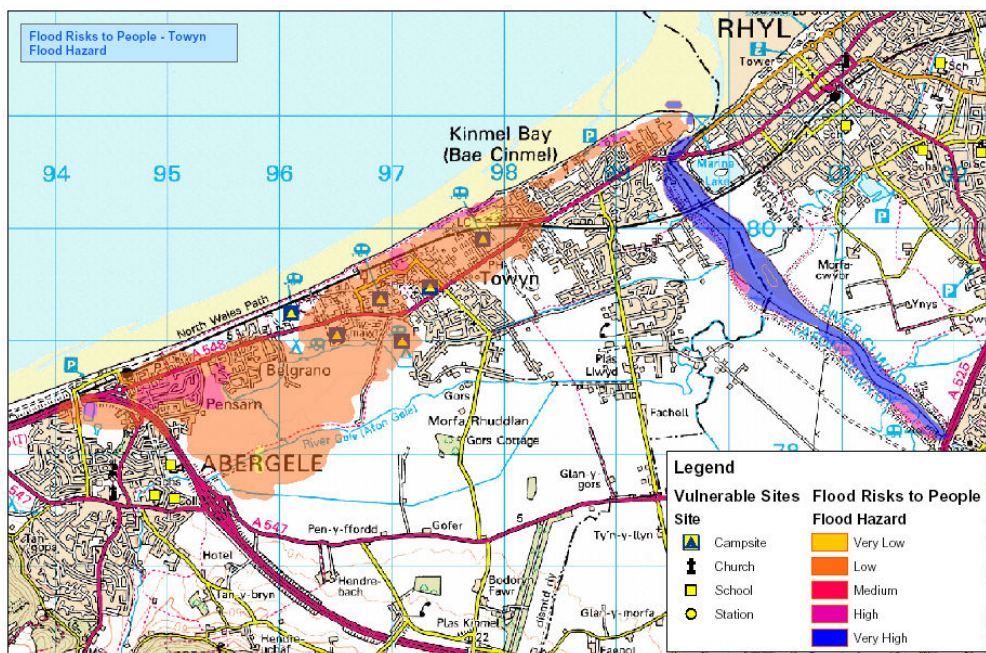


Figure 5.1 Flood hazard map

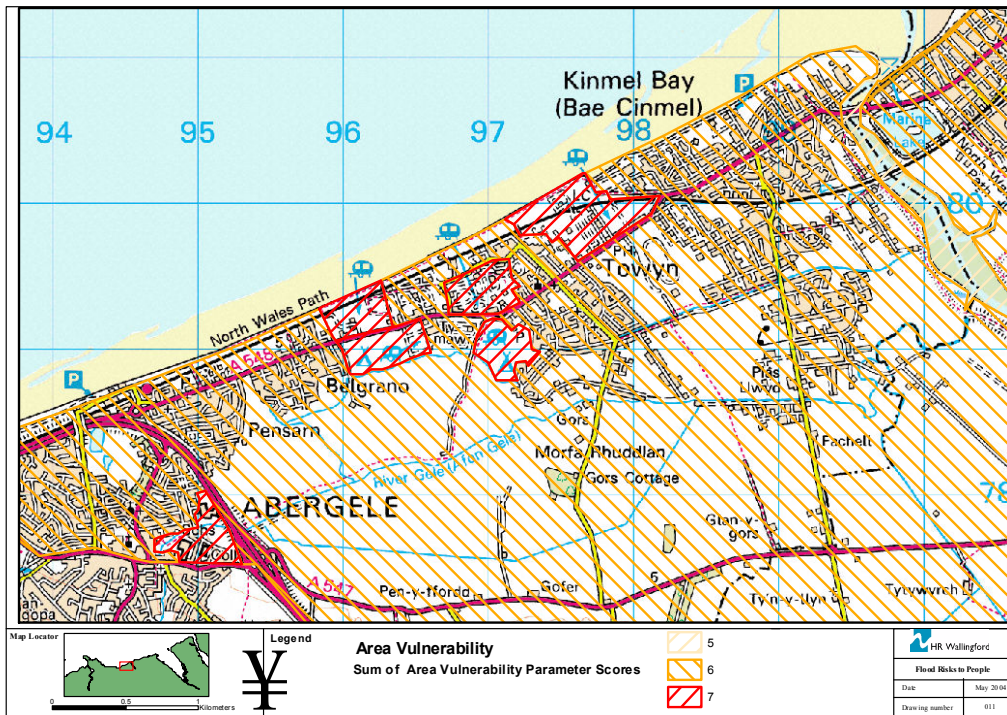


Figure 5.2 Area Vulnerability map

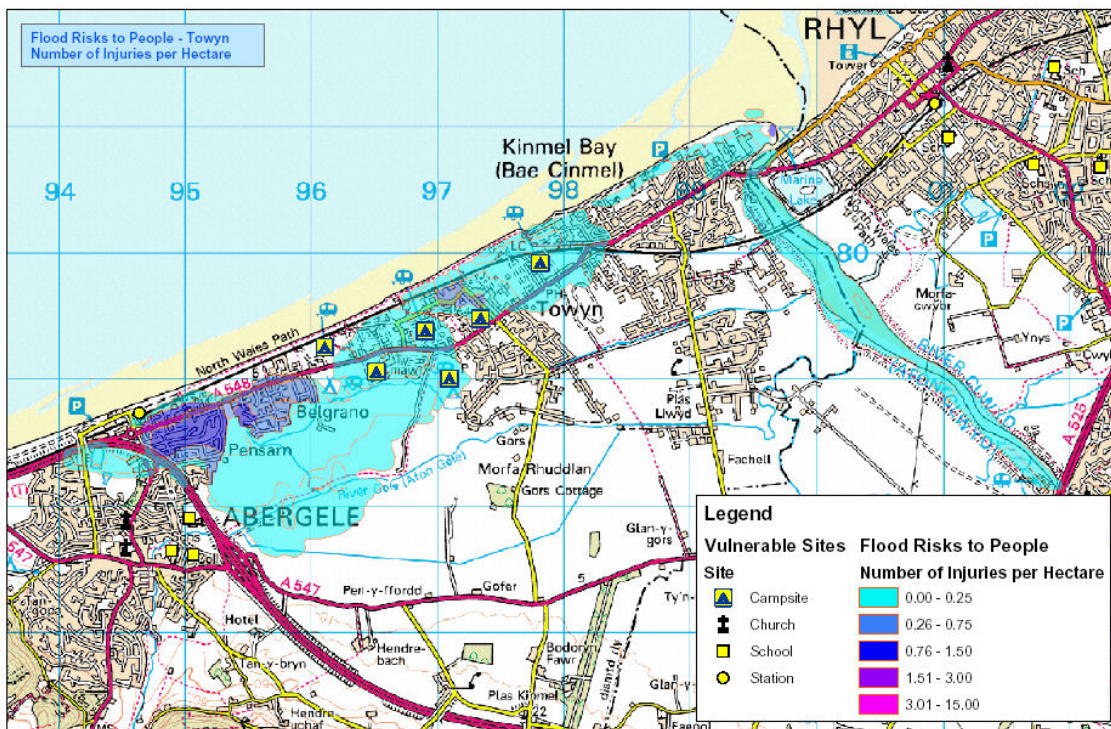


Figure 5.3 Flood Risks to People map

Uncertainty

Uncertainty in the results is high, particularly in the number of people who will be exposed to a flood and the wide range of site specific factors that affect whether people are injured or killed.

Flood Risks to People

GUIDANCE NOTE 6 Flood defence regulation and development control

Purpose

Flood defence regulation and development control apply to new developments. This Guidance Note provides methods for:

- Calculating and mapping Flood Hazard in and adjacent to new development sites, for identifying unsafe areas, evacuation routes, etc. This will also guide the type and layout of buildings and infrastructure in order to minimise the risks to people in the development.
- Estimating Area Vulnerability in proposed developments, to indicate the vulnerability of development sites to flooding. The Area Vulnerability can be influenced by the design of the development and mitigation measures (for example flood warning). The Area Vulnerability can be calculated for different scenarios to assist in planning of the development.
- Estimating flood risks to people for proposed developments. The People Vulnerability can be calculated for different scenarios to provide guidance on whether potentially vulnerable occupants can be accepted in a development. This will affect the development design.

The results can be used to assess the risk in development sites, advise on mitigation measures for developments, identify access routes, and advise on flood warning requirements.

Other information required for regulation and development control are covered as follows:

- Guidance on a method for assessing flood hazard behind defences has been provided in project FD2320 using the Flood Risks to People method.
- General guidance on flood risks to people is provided in Guidance Note 1.
- Guidance on acceptability of risk is outside the scope of the project. See comment in Table 2.1.
- The assessment of mitigation measures on risk is not provided directly but can be deduced using the Flood Risks to People method. See comment in Table 2.1.

Scales

The methods in this Guidance Note apply to the following scales:

- Local

Description of method

The basic method is described below. Further detail and more background information is given ***Flood Risks to People Phase 2, The Risks to People Methodology, Report FD2321/TR1***. It is expected that users of this Guidance Note will refer to this report.

This Guidance Note provides methods for:

- Calculating and mapping Flood Hazard

- Estimating Area Vulnerability for new developments
- Estimating flood risks to people for new developments

Flood Hazard is calculated for individual events. Area Vulnerability is a floodplain parameter and is independent of event. In order to calculate the annual average number of deaths/injuries, at least five events should be used.

Selection of events

Events selected for development planning are normally the 1%/0,5% and 0.1% annual probability floods, which correspond to the existing floodplain planning zones. Additional events can be used if required, particularly if an annual average estimate of injuries/deaths is required.

The scenarios may include combined probability events of water level and defence failure by using methods developed under the Risk Assessment for Strategic Planning (RASP) framework.

Flood Hazard

The Flood Hazard rating is calculated using the following equation:

$$HR = d \times (v + 0.5) + DF$$

where,

HR = (flood) hazard rating;

d = depth of flooding (m);

v = velocity of floodwaters (m/sec); and

DF = debris factor calculated using Table 6.1

Critical values of Flood Hazard are shown in Table 6.2. These are used to categorise the hazard in terms of danger to people.

Table 6.1 Guidance on debris factors for different flood depths, velocities and dominant land uses

Depths	Pasture/Arable	Woodland	Urban
0 to 0.25 m	0	0	0
0.25 to 0.75 m	0	0.5	1
d>0.75 m and/or v>2	0.5	1	1

Ref: FD2321/TR1 Table 3.1

Table 6.2 Hazard to People as a Function of Velocity and Depth

d x (v + 0.5)	Degree of Flood Hazard	Description
<0.75	Low	Caution <i>“Flood zone with shallow flowing water or deep standing water”</i>
0.75 - 1.25	Moderate	Dangerous for some (i.e. children) <i>“Danger: Flood zone with deep or fast flowing water”</i>
1.25 - 2.5	Significant	Dangerous for most people <i>“Danger: flood zone with deep fast flowing water”</i>
>2.5	Extreme	Dangerous for all <i>“Extreme danger: flood zone with deep fast flowing water”</i>

Ref: FD2321/TR1 Table 3.2

Mapping of flood hazard

The general procedure for flood hazard mapping is to calculate the key parameters needed for the Flood Hazard equation, and map the result. This is normally done using hydraulic modelling for the required events to determine flood depth and velocity. The results are combined and a debris score added to calculate flood hazard.

Possible approaches for estimating flood depths and velocities for local mapping are given below.

- One-dimensional hydraulic models with defined flood storage areas and active floodplain channels, for example ISIS Flow or MIKE11 software, can be used to estimate depths and average velocities. Maximum velocities can be significantly higher in some parts of the floodplain, for example where water spills over a defence, in narrow streets and any other “pinch points” in the floodplain. An advantage of this approach is that it is the standard method used for hydraulic modelling for flood management schemes.
- Two-dimensional hydraulic modelling of floodplains using a fixed grid, for example the TUFLOW hydraulic model that has been used for modelling floodplains on the tidal Thames or HYDRO F that was used for the tidal component of the Flood Zones project.
- Two-dimensional hydraulic modelling using a triangular mesh, for example the Telemac 2D model. This can provide good velocity estimates but model run times are significantly longer than grid based models.

Hydraulic modelling requires the following data:

- Flow (for rivers) or sea level (coasts)
- Ground levels. Digital Terrain Models (such as LiDAR or the NextMap DTM) are often used for floodplains. Unfiltered data (with removal of buildings, vegetation, etc) should normally be used for new development sites although buildings in new developments could be added to identify the hazard caused by water flowing between buildings, etc.

- Flood defences, including location and level.

Area Vulnerability

The Area Vulnerability is calculated using Table 6.3.

Table 6.3 Area Vulnerability

Parameter	1 - Low risk area	2 - Medium risk area	3 - High risk area
Speed of onset	Onset of flooding is very gradual (many hours)	Onset of flooding is gradual (an hour or so)	Rapid flooding
Nature of area	Multi-storey apartments	Typical residential area (2-storey homes); commercial and industrial properties	Bungalows, mobile homes, busy roads, parks, single storey schools, campsites, etc.
Flood warning	Score for flood warning = $3 - (P1 \times (P2 + P3))$ where P1 = % of Warning Coverage Target Met P2 = % of Warning Time Target Met P3 = % of Effective Action Target Met		
Area Vulnerability (AV) = sum of scores for 'speed of onset', 'nature of area' and 'flood warning'			

Ref: FD2321/TR1 Table 4.4

Recent values for P1, P2 and P3 are given in Table 6.4. These can be updated using more recent data when available.

Table 6.4 Calculation of Flood Warning Score

Agency Region	% of Warning Coverage Target Met (80%) = P1	% of Warning Time Target Met (100%) = P2	% of Effective Action Target Met (75%) = P3	FW Score = $3 - (P1 \times (P2 + P3))$
Anglian	0.69	0.75	0.48	2.15
Midlands				
- East	0.16	0.54	0.48	2.83
- West	0.34	0.54	0.48	2.66
North East				
- Yorkshire & Humber	0.94	0.88	0.48	1.73
- North East	0.66	0.88	0.48	2.10
North West	0.81	0.00	0.48	2.61
Southern	0.76	0.65	0.48	2.14
South West	0.76	0.61	0.48	2.17
Thames	0.76	0.65	0.48	2.14
England	0.76	0.63	0.48	2.15
Wales	0.56	0.63	0.73	2.23

Ref: FD2321/TR1 Table 4.3

For new developments the speed of onset of a flood should be calculated as follows:

- For rivers this can be done using a hydrological approach based on catchment characteristics, or from information on the speed of flooding provided by the Environment Agency.
- For coastal areas without defences the speed of onset can be rapid but flood warnings are likely to be provided.
- For areas behind defences, the speed of onset is always considered to be rapid because of the unpredictability of flood defence failure.

The nature of the area is dictated by the type of development. The flood warning score should initially be based on current local flood warning arrangements.

Flood Risks to People

The number of deaths/injuries is calculated using the following equation:

$$N(I) = N \times X \times Y.$$

Where:

- N(I) is the number of deaths/injuries
- N is the population within the floodplain
- X is the proportion of the population exposed to a risk of suffering death/injury (for a given flood). The value of X is based on the Flood Hazard and the Area Vulnerability.
- Y is the proportion of those at risk who will suffer death/injury. The value of Y is based on People Vulnerability.

The risk of suffering N(I) deaths/injuries will simply be the likelihood of the given flood. The method requires the calculation of:

- Flood Hazard (see under 'Flood Hazard')
- Area Vulnerability (see under 'Area Vulnerability')
- People Vulnerability
- Population

The People Vulnerability score (Y expressed as a percentage) is simply:

$$Y = \% \text{residents suffering from long-term illness} + \% \text{residents aged 75 or over.}$$

The steps for calculating Flood Risks to People are given below.

1. The number of people in the development is estimated (N(Z)).
2. The percentage of people likely to be exposed to the flood risk (X) is estimated based on the Area Vulnerability score multiplied by the Hazard Rating (ie $X\% = HR \times AV$).
3. X is multiplied by the number of people in the development (N(Z)) to determine the number of people exposed to the flood (N(ZE)).
4. An estimate is made of the percentage of very old and percentage of disabled people who are likely to be in the development, to obtain the People Vulnerability

(Y) score. This is used in the risks to people methodology to estimate the number of injuries.

5. The number of people exposed to the risk is multiplied by 2Y to obtain the number of injuries.
6. In practice the value of Y is likely to be very low for new developments. It is therefore suggested that a different approach is used, with a standard percentage of those exposed to the flood being injured. A figure of 50% is suggested.
7. The fatality rate (ie the proportion of injured people who die) is assumed to be proportional to the Hazard Rating. The number of injuries is multiplied by 2HR (as a percentage) to obtain the number of deaths.
8. In order to estimate the annual average number of deaths/injuries, it is necessary to repeat the above calculations for a number of different flood frequencies (usually five) and combine the results.

The method may be applied using average figures for the whole development, or dividing the development into zones of different hazard and summing the results.

Data requirements

Variable	Type	Data sources
Floodplain extent	Variable	<ul style="list-style-type: none"> • EA Flood Map • Hydraulic modelling
Flood depth	Variable	<ul style="list-style-type: none"> • Hydraulic modelling.
Flood velocity	Variable	<ul style="list-style-type: none"> • Hydraulic modelling
Flood depth and velocity	Variable	<ul style="list-style-type: none"> • Hydraulic modelling
Nature of area	Score	<ul style="list-style-type: none"> • Development plan
Flood warning	Score	<ul style="list-style-type: none"> • EA performance indicators for current performance in the area, assuming that flood warning will be provided.
Speed of onset	Score	<ul style="list-style-type: none"> • Hydrological calculation using catchment characteristics • Location and nature of defences
Population	Variable	<ul style="list-style-type: none"> • Development plan
Residents suffering from long-term illness	%	<ul style="list-style-type: none"> • Development plan
Residents aged 75 or over	%	<ul style="list-style-type: none"> • Development plan

Use of the results

The Flood Hazard map can be used in the design of the development to minimise the risk of people being located in the areas of high hazard. For example, areas of high flood hazard could be used as landscaped amenity areas, as people are unlikely to be in these areas during a flood.

The Area Vulnerability results can be used to:

- Decide whether the nature of the area would have to change (ie whether the proposed buildings are suitable or not).
- Investigate ways reducing the speed of onset of a flood, if this is a critical issue. Options include moving the development to another location.
- Review flood warning arrangements to improve the flood warning score. For example, in a flood risks to people context any warning (even a few minutes) is better than no warning. Currently the Environment Agency does not provide warnings where the warning time is less than two hours.

The People Vulnerability score in the calculation of flood risks to people can be used to decide whether the types of occupants should be restricted.

Other development guidance that could arise from this analysis includes the following.

- Development should provide safe refuges above flood level.
- Where the onset of flooding is rapid, living spaces with floor levels below flood level should be avoided.
- Safe access should be provided, particularly where the flood duration is long.
- Avoid dangerous developments in flood risk areas:
 - Underground car parks
 - Basements
 - Ground floor flats
- Developments for vulnerable people should not be permitted in flood risk areas, for example:
 - Old peoples' homes
 - Sheltered housing
 - Housing for disabled
- Places where people congregate should not be permitted in flood risk areas
 - Schools
 - Hospitals
 - Supermarkets and shopping areas

Uncertainty

Uncertainty in the results is high, particularly in the number of people who will be exposed to a flood and the wide range of site specific factors that affect whether people are injured or killed. The results do however provide a guide to flood risks to people, and can be used to compare the impacts of different development options.

Flood Risks to People

GUIDANCE NOTE 7 Spatial planning

Purpose

Spatial planning is concerned with future development. Information on flooding is required at potential development sites. This Guidance Note provides methods for:

- Calculating and mapping Flood Hazard at potential development sites, for identifying unsafe areas, evacuation routes, etc. This will also guide the type and layout of buildings and infrastructure in order to minimise the risks to people in the development.
- Estimating of the speed of onset of flooding, to indicate the vulnerability of development sites to flooding.

The results can be used to assess the flood hazard in potential development sites in order to guide the suitability of sites for development, the layout of developments, the likely requirement for mitigation measures, safe access routes and the need for flood warning requirements.

Other information required for spatial planning are covered as follows:

- Guidance on acceptability of risk is outside the scope of the project. See comment in Table 2.1.

This Note does not cover the calculation of Area Vulnerability or Risks to People as relevant information is unlikely to be available when spatial planning is carried out. Guidance on calculating these aspects of the flood risks to people method for new developments is given in Guidance Note 6.

Scales

The methods in this Guidance Note apply to the following scales:

- Local

Description of method

The basic method is described below. Further detail and more background information is given *Flood Risks to People Phase 2, The Risks to People Methodology, Report FD2321/TR1*. It is expected that users of this Guidance Note will refer to this report.

Selection of events

Events selected for assessing flood hazard in development planning are normally the 1%/0,5% and 0.1% annual probability floods, which correspond to the existing floodplain planning zones. Additional events can be used if required.

Flood Hazard

The Flood Hazard rating is calculated using the following equation:

$$HR = d \times (v + 0.5) + DF$$

where, HR = (flood) hazard rating;
d = depth of flooding (m);
v = velocity of floodwaters (m/sec); and
DF = debris factor calculated using Table 7.1

Critical values of Flood Hazard are shown in Table 7.2. These are used to categorise the hazard in terms of danger to people.

Table 7.1 Guidance on debris factors for different flood depths, velocities and dominant land uses

Depths	Pasture/Arable	Woodland	Urban
0 to 0.25 m	0	0	0
0.25 to 0.75 m	0	0.5	1
d>0.75 m and/or v>2	0.5	1	1

Ref: FD2321/TR1 Table 3.1

Table 7.2 Hazard to People as a Function of Velocity and Depth

$d \times (v + 0.5)$	Degree of Flood Hazard	Description
<0.75	Low	Caution <i>“Flood zone with shallow flowing water or deep standing water”</i>
0.75 - 1.25	Moderate	Dangerous for some (i.e. children) <i>“Danger: Flood zone with deep or fast flowing water”</i>
1.25 - 2.5	Significant	Dangerous for most people <i>“Danger: flood zone with deep fast flowing water”</i>
>2.5	Extreme	Dangerous for all <i>“Extreme danger: flood zone with deep fast flowing water”</i>

Ref: FD2321/TR1 Table 3.2

Mapping of flood hazard

The general procedure for flood hazard mapping is to calculate the key parameters needed for the Flood Hazard equation, and map the result. This is normally done using hydraulic modelling for the required events to determine flood depth and velocity. The results are combined and a debris score added to calculate flood hazard.

Possible approaches for estimating flood depths and velocities for local mapping are given below.

- One-dimensional hydraulic models with defined flood storage areas and active floodplain channels, for example ISIS Flow or MIKE11 software, can be used to estimate depths and average velocities. Maximum velocities can be significantly

higher in some parts of the floodplain, for example where water spills over a defence, in narrow streets and any other “pinch points” in the floodplain. An advantage of this approach is that it is the standard method used for hydraulic modelling for flood management schemes.

- Two-dimensional hydraulic modelling of floodplains using a fixed grid, for example the TUFLOW hydraulic model that has been used for modelling floodplains on the tidal Thames or HYDRO F that was used for the tidal component of the Flood Zones project.
- Two-dimensional hydraulic modelling using a triangular mesh, e.g. the Telemac 2D model. This can provide good velocity estimates but model run times are significantly longer than grid based models.

Hydraulic modelling requires the following data:

- Flow (for rivers) or sea level (coasts)
- Ground levels. Digital Terrain Models (such as LiDAR or the NextMap DTM) are often used for floodplains. Filtered data (with removal of buildings, vegetation, etc) should normally be used for spatial planning but this does not identify the high hazard associated with flow in constricted areas such as streets. Existing buildings should be included in models where they significantly affect hazard at potential development sites.
- Flood defences, including location and level.

Speed of onset of flooding

For new developments the speed of onset of a flood should be calculated as follows:

- For rivers this can be done using a hydrological approach based on catchment characteristics, or from information on the speed of flooding provided by the Environment Agency.
- For coastal areas without defences the speed of onset can be rapid but flood warnings are likely to be provided.
- For areas behind defences, the speed of onset is always considered to be rapid because of the unpredictability of flood defence failure.

Data requirements

Variable	Type	Data sources
Floodplain extent	Variable	<ul style="list-style-type: none"> • EA Flood Map • Hydraulic modelling
Flood depth	Variable	<ul style="list-style-type: none"> • Hydraulic modelling.
Flood velocity	Variable	<ul style="list-style-type: none"> • Hydraulic modelling
Flood depth and velocity	Variable	<ul style="list-style-type: none"> • Hydraulic modelling
Speed of onset	Score	<ul style="list-style-type: none"> • Hydrological calculation using catchment characteristics Location and nature of defences

Use of the results

The Flood Hazard map can be used to identify the potential development sites where the greatest hazards exist. This information can be used to influence:

- The selection and prioritisation of development sites
- The types of developments on each site
- The planning policies needed to manage the risks.

In general, people should not be located in areas of high hazard and such areas should not be accepted for development. They could be allocated to such uses as landscaped amenity areas, as people are unlikely to be in these areas during a flood.

An example of a flood hazard map developed using a 2D hydraulic model is shown in Figure 7.1.

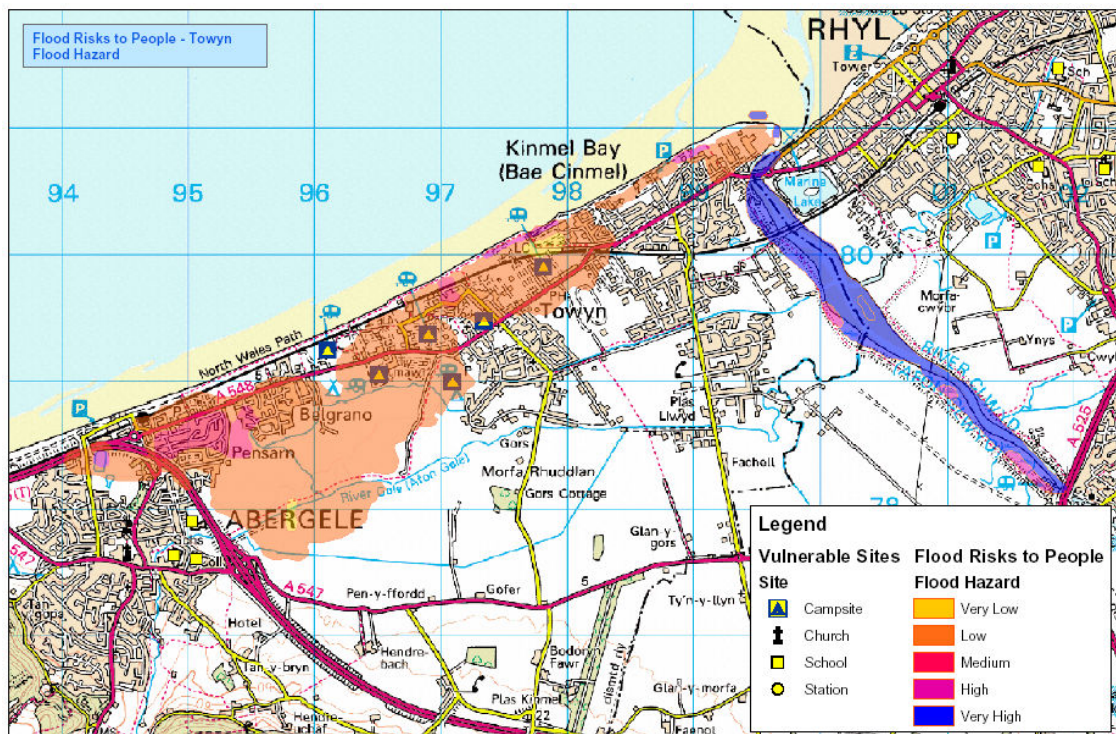


Figure 7.1 Flood hazard map

The speed of onset of flooding will provide guidance on the type of flood warning and emergency response arrangements needed for different sites. Where flood warning times are short:

- There should be safe refuges above flood level for everyone in the development site.
- People in the development should be aware of the risk
- Living spaces with floor levels below flood level should be avoided.

Other development guidance that could arise from an understanding of the flood hazard at potential development sites includes the following.

- Avoid dangerous developments:
 - Underground car parks
 - Basements
 - Ground floor flats
- Developments for vulnerable people should not be permitted in flood risk areas, for example:
 - Old peoples' homes
 - Sheltered housing
 - Housing for disabled
- Places where people congregate should not be permitted in flood risk areas
 - Schools
 - Hospitals
 - Supermarkets and shopping areas

Uncertainty

Uncertainty in the results is high, particularly in the number of people who will be exposed to a flood and the wide range of site specific factors that affect whether people are injured or killed. The results do however provide a guide to flood risks and can be used to compare different development sites.

Flood Risks to People

GUIDANCE NOTE 8 Reservoir flood plans

Purpose

Reservoir flood plans are likely to require estimates of flood risks to people arising from dam overtopping or failure. This Guidance Note provides methods for:

- Calculating and mapping Flood Hazard, for identifying unsafe areas, evacuation routes, etc.
- Calculating and mapping Area Vulnerability, to identify which parts of the floodplain are most vulnerable to floods.
- Estimating flood and mapping flood risks to people (the number of people per year likely to be killed or seriously injured during floods).
- The results can then be used to identify the high risk locations.

The results of the analysis will provide:

- Locations where high flood hazard would occur in the event of a dambreak or overtopping of a dam.
- The most vulnerable areas to flooding. A dambreak can cause very high flood depths and velocities where even multi-story buildings could be inundated or damaged during a flood. The Area Vulnerability calculation should take account of this special case.
- The number and location of people at risk during floods caused by dam overtopping or failure.

The above information can be used for contingency planning and, where the risks are considered to be unacceptable, planning of mitigation measures. These could range from measures to control development and change land uses, to physical actions such as lowering the reservoir water level.

Scales

The methods in this Guidance Note apply to the following scales:

- Local

Description of method

The basic method for calculating Flood Risks to People is described below. Further detail and more background information is given ***Flood Risks to People Phase 2, The Risks to People Methodology, Report FD2321/TR1***. It is expected that users of this Guidance Note will refer to this report.

This Guidance Note provides methods for the calculation of:

- Flood Hazard
- Area Vulnerability
- Flood Risks to People

Flood Hazard is calculated for individual events. Area Vulnerability is a floodplain parameter and is independent of event. Guidance on the selection of events is given below.

Selection of events

Events selected for reservoir flood plans will be very extreme events in which either the dam is overtopped or the dam fails. In order to calculate the annual average number of people at risk of injury/death in a flood, several events should be used (typically five).

Whilst the probability of the flood might be low (perhaps in the range of 0.1% to 0.01% annual probability of occurrence), the consequences can be high and therefore the risks to people can be high. This information will enable reservoir owners and regulators to take steps to reduce the risk.

Flood Hazard

The Flood Hazard rating is calculated using the following equation:

$$HR = d \times (v + 0.5) + DF$$

- where,
- HR = (flood) hazard rating;
 - d = depth of flooding (m);
 - v = velocity of floodwaters (m/sec); and
 - DF = debris factor calculated using Table 8.1

Critical values of Flood Hazard are shown in Table 8.2.

Table 8.1 Guidance on debris factors for different flood depths, velocities and dominant land uses

Depths	Pasture/Arable	Woodland	Urban
0 to 0.25 m	0	0	0
0.25 to 0.75 m	0	0.5	1
d>0.75 m and/or v>2	0.5	1	1

Ref: FD2321/TR1 Table 3.1

Table 8.2 Hazard to People as a Function of Velocity and Depth

d x (v + 0.5)	Degree of Flood Hazard	Description
<0.75	Low	Caution <i>“Flood zone with shallow flowing water or deep standing water”</i>
0.75 - 1.25	Moderate	Dangerous for some (i.e. children) <i>“Danger: Flood zone with deep or fast flowing water”</i>
1.25 - 2.5	Significant	Dangerous for most people <i>“Danger: flood zone with deep fast flowing water”</i>
>2.5	Extreme	Dangerous for all <i>“Extreme danger: flood zone with deep fast flowing water”</i>

Ref: FD2321/TR1 Table 3.2

Mapping of flood hazard

The general procedure for flood hazard mapping is to calculate the key parameters needed for the Flood Hazard equation, and map the result. This is normally done using hydraulic modelling for each of the required events to determine flood depth and velocity. The depths and velocities are combined and a debris score added to calculate flood hazard.

Possible approaches for estimating flood depths and velocities for local mapping are given below. All these methods require a dambreak model or reservoir routing model to generate the flood hydrograph from the dam.

- One-dimensional hydraulic models with defined flood storage areas and active floodplain channels, for example ISIS Flow or MIKE11 software, can be used to estimate depths and average velocities. Maximum velocities can be significantly higher in some parts of the floodplain, for example where water spills over a defence, in narrow streets and any other “pinch points” in the floodplain. An advantage of this approach is that it is the standard method used for hydraulic modelling for flood management schemes.
- Two-dimensional hydraulic modelling of floodplains using a fixed grid, for example the TUFLOW hydraulic model that has been used for modelling floodplains on the tidal Thames or HYDRO F that was used for the tidal component of the Flood Zones project.
- Two-dimensional hydraulic modelling using a triangular mesh, for example the Telemac 2D model. This can provide good velocity estimates but model run times are significantly longer than grid based models.

Hydraulic modelling requires the following data:

- Flow, obtained from a dambreak model or reservoir routing model
- Ground levels. Digital Terrain Models (such as LiDAR or the NextMap DTM) are often used for floodplains. Filtered data (with removal of buildings, vegetation, etc) are normally used but this does not identify the high hazard associated with flow in

constricted areas such as streets. Ideally buildings should be included in models for local application.

- Flood defences, including location and level.

Area Vulnerability

The Area Vulnerability is calculated using Table 8.3.

Table 8.3 Area Vulnerability

Parameter	1 - Low risk area	2 - Medium risk area	3 - High risk area
Speed of onset	Onset of flooding is very gradual (many hours)	Onset of flooding is gradual (an hour or so)	Rapid flooding
Nature of area	Multi-storey apartments	Typical residential area (2-storey homes); commercial and industrial properties	Bungalows, mobile homes, busy roads, parks, single storey schools, campsites, etc.
Flood warning	Score for flood warning = $3 - (P1 \times (P2 + P3))$ where P1 = % of Warning Coverage Target Met P2 = % of Warning Time Target Met P3 = % of Effective Action Target Met		
Area Vulnerability (AV) = sum of scores for 'speed of onset', 'nature of area' and 'flood warning'			

Ref: FD2321/TR1 Table 4.4

In the context of floods from dams, the speed of onset is generally rapid although it does decrease downstream. Flood warning is unlikely to be available and therefore the Flood Warning score will normally be 3. In cases where the dam collapses slowly and warning is provided, the Flood Warning score will reduce.

Mapping of Area Vulnerability

The general procedure for mapping of Area Vulnerability is to calculate the Area Vulnerability using Table 8.3 and plot on maps. It is suggested that the Area Vulnerability is calculated for different zones of the floodplain based on the types of properties (for example, bungalows, two-storey houses, etc).

Method for calculating Flood Risks to People

The number of deaths/injuries is calculated using the following equation:

$$N(I) = N \times X \times Y.$$

Where:

- N(I) is the number of deaths/injuries
- N is the population within the floodplain
- X is the proportion of the population exposed to a risk of suffering death/injury (for a given flood). The value of X is based on the Flood Hazard and the Area Vulnerability.
- Y is the proportion of those at risk who will suffer death/injury. The value of Y based on People Vulnerability.

The risk of suffering N(I) deaths/injuries will simply be the likelihood of the given flood. The method requires the calculation of:

- Flood Hazard (see under ‘Flood Hazard’ above)
- Area Vulnerability (see under ‘Area Vulnerability’ above)
- People Vulnerability
- Population (see data requirements)

The People Vulnerability score (Y expressed as a percentage) is simply:

$$Y = \% \text{residents suffering from long-term illness} + \% \text{residents aged 75 or over.}$$

The steps for calculating Flood Risks to People are given below with reference to an example.

1. This Area Vulnerability score is multiplied by the Hazard Rating to generate the value for X (the % of people exposed to risk). Should the score exceed 100, this is simply taken as 100. X is multiplied by the number of people in each zone to determine the number of people exposed to the flood. See example numbers in the table below.

Distance from river (m)	N(Z)	Hazard rating (HR)	Area vulnerability (AV)	X = HR x AV	N(ZE)
0-50	25	8.5	7.15	61%	15
50-100	50	5.6	5.15	29%	14
100-250	300	2.8	7.15	20%	60
250-500	1000	1.85	5.15	10%	95
500-1000	2500	0	5.15	0%	0

Note: N(Z) is the population in each hazard zone
 N(ZE) is the number of people exposed to the risk in each hazard zone
 Ref: FD2321/TR1 Table 6.3

2. The People Vulnerability (Y) score is calculated, see example numbers in the table below.

Distance from river (m)	N(Z)	Factor 1 (% very old)	Factor 2 (% Disabled or infirm)	Y
0-50	25	15%	10%	25%
50-100	50	10%	14%	24%
100-250	300	12%	10%	22%
250-500	1000	10%	15%	25%
500-1000	2500	15%	20%	35%

Ref: FD2321/TR1 Table 6.4

3. The number of people exposed to the risk (N(ZE)) is multiplied by 2Y to obtain the number of injuries. The fatality rate (ie the proportion of injured people who die) is assumed to be proportional to the Hazard Rating. The number of

injuries is multiplied by 2HR (as a percentage) to obtain the number of deaths. See example numbers in the table below.

Distance from river (m)	N(ZE)	Y = 1 + 2 (as %)	No. of injuries = 2 * Y * N(ZE)	Fatality rate = 2 x HR	No. of deaths
0-50	15	25%	8	17%	1
50-100	14	24%	7	11%	1
100-250	60	22%	26	6%	1
250-500	95	25%	48	4%	2
500-1000	0	35%	0	0%	0
All	185		89		5

Ref: FD2321/TR1 Table 6.5

Mapping Procedure

The mapping procedure involves combining layers of data on Flood Hazard, Area Vulnerability, People Vulnerability and population using the formulae given above.

In order to estimate the annual average number of injuries/deaths, it is necessary to combine the results from several different flood frequencies (usually five). Of the variables in the method, only the Hazard Rating will be different for each event. This affects X and therefore N(ZE), and the fatality rate.

Data requirements

Variable	Type	Data sources
Floodplain extent	Variable	<ul style="list-style-type: none"> Hydraulic modelling
Flood depth	Variable	<ul style="list-style-type: none"> Hydraulic modelling.
Flood velocity	Variable	<ul style="list-style-type: none"> Hydraulic modelling
Flood depth and velocity	Variable	<ul style="list-style-type: none"> Hydraulic modelling
Nature of area	Score	<ul style="list-style-type: none"> OS Maps National Property Database (NPD) and other address-point products to develop information on property types. Site inspections.
Flood warning	Score	<ul style="list-style-type: none"> Usually none
Speed of onset	Score	<ul style="list-style-type: none"> Usually rapid, but derived from hydraulic modelling
Population	Variable	<ul style="list-style-type: none"> National Census data by Output Area Use of local information including 'non-resident' population (eg people in workplaces, in transit, on campsites, etc) and places where people congregate (eg shopping areas, etc)

Residents suffering from long-term illness	%	<ul style="list-style-type: none"> Local data from Local Authorities or health services. Contact local authorities in the first instance
Residents aged 75 or over	%	<ul style="list-style-type: none"> Local data from Local Authorities or health services. Contact local authorities in the first instance

Uncertainty

Uncertainty in the results is generally high, particularly in the number of people who will be exposed to a flood and the wide range of site specific factors that affect whether people are injured or killed.

Flood Risks to People

GUIDANCE NOTE 9 Information for ongoing and future R&D

Purpose

This Guidance Note provides a summary of information about the Flood Risks to People project to inform other ongoing and planned research.

The Guidance Note is intended for dissemination to researchers and those planning research projects.

Flood Risks to People research

The Flood Risks to People project provides a method for estimating flood risks to people in terms of the number of deaths/serious injuries caused by floods which occur during or immediately after a flood. The following research has been carried out in order to develop the method:

Flood Hazard Rating

A Flood Hazard Rating has been developed to determine the combinations and flood depth, flood velocity and debris that cause danger to people. The flood depth and velocity components are based on a review of previous research in this area. No new research was carried out. No previous research was identified on the impacts of debris on flood risks to people, and a simple approach is included in the Flood Hazard Rating.

Some additional information on flood hazard behind flood defences has been developed based on modelling of simple cases. The project outputs also include information on flood hazard for vehicles and buildings, and flood hazard due to waves on the coast.

Area Vulnerability

The Flood Risks to People method includes the calculation of ‘Area Vulnerability’, which provides a measure of the vulnerability of different parts of the floodplain to flooding. The Area Vulnerability is calculated empirically as a score based on the following three factors:

- Nature of area, based on type of buildings, etc.
- Speed of onset of flooding.
- Flood warning, derived using Agency data on Flood Warning targets. These targets cover the warning coverage, proportion of warning time targets met, and proportion of effective action targets met.

Pollution and flood risks to people

Research was undertaken into the impact of pollution on flood risks to people. Whilst potential sources of risk were identified, for example hazardous facilities in floodplains and transport of hazardous materials, the risk is low and no allowance for this risk is included in the Flood Risks to People method. There will however be a residual risk of an incident resulting in death or serious injury.

People vulnerability

The results of research from a range of sources has been used to identify the social factors that increase the risk of death or serious injury. It was concluded that age and

long-term sickness/disability are the main factors, and these are combined in a 'People Vulnerability' score for use in the Flood Risks to People method.

Behaviour of people during floods

Research was carried out into the behaviour of people leading to death or serious injury during floods. Whilst many aspects of inappropriate behaviour were identified, for example returning to flooded properties to collect belongings, the incidents leading to death/serious injury are very random. The results are used to provide guidance on appropriate behaviour during floods, but have not been directly incorporated in the Flood Risks to People calculation method.

Flood Risks to People calculation method

The final calculation method has been calibrated using a number of incidents where lives have been lost during floods. In view of the random nature of factors that contribute to risks to people, it was decided that a sophisticated and detailed method could not be justified. Instead, a simple and robust approach has been developed, intended for immediate use by practitioners.

The implementation of the method will lead to a better understanding of flood risks to people which, in turn, should lead to future improvements to the method.

Flood Risks to People documents

Documents produced by the project are listed below.

FD2317 Flood Risks to People Phase 1

R&D Technical Report (July 2003)

FD2321\PR Project Record,
March 2005

Inception Report

Interim Report 1

Interim Report 2

Consultation Notes

FD2321/TR1 Technical
Report 1, March 2005

Risks to People
Methodology

FD2321/TR2

Guidance Document
March 2005

Key

Internal project reports

Published documents

Journals & conference
papers

The published documents are available from Defra and the Environment Agency via normal dissemination routes for the joint Flood and Coastal Defence R&D programme.

Relevant ongoing and planned projects

With regard to information for ongoing projects, the concepts of flood hazard and flood vulnerability are the subject of a number of ongoing research projects including research underway in the Flood Risks Management Research Consortium (FRMC) (<http://www.floodrisk.org.uk/>) and FLOODsite project (<http://www.floodsite.net/>).

Information on flood risks to people is likely to be required for future flood risk assessment and appraisal methods at regional and local scale including:

- Multi-criteria analysis for strategy and project appraisal
- Flood Hazard Mapping: Scoping Study
- Methods for Catchment Flood Management Plans (CFMPs) and Shoreline Management Plans (SMPs)
- Method to be incorporated in the Modelling and Decision Support Framework (MDSF) and the upgrade MDSF2.
- Risk Assessment for Strategic Planning (RASP).
- Performance and Asset Management System (PAMS).
- Risk management for UK reservoirs (CIRIA C542).

Areas for future research

The research has identified a number of areas where further research would lead to improved assessments of flood risks to people, and improved tools and techniques for mapping and using the results.

Flood hazard

- Testing and validation of JFLOW and HYDROF output for flood hazard and risks to people mapping. These two models, developed by JBA and Atkins respectively, were used to develop the national ‘Flood Zones’.
- Testing and validation of Conveyance Estimation System (CES) for flood hazard and risks to people mapping.
- Further research on breach failure and probability, exploring the links with PAMS and RASP, and implementing risks to people within the RASP framework.
- Violent waves. Injuries and fatalities associated with violent wave overtopping have not been considered in detail as part of this project. Further work is recommended to improve the estimating and mapping of flood hazard caused by wave overtopping at coastal sites.

Area Vulnerability

- Building failure. International research on building failure has focused on timber-framed buildings that are less resilient than typical construction styles in England and Wales. Evidence of building collapse due to flood in the UK should be collated and reviewed.
- Vehicles. The calculations completed for typical vehicles were informative but further work would help to highlight the vulnerability and flood risks associated with the UK road network.

People Vulnerability

- Behaviour. The typology of behaviour developed in the project could be useful for understanding the factors that contribute to effective action during a flood.

Overall risks to people method

- Integration of the risks to people method into the MDSF
- Integration of annual average individual and societal flood risks to people into RASP
- International comparisons on flood risk to people predictions
- More calibration of the overall method, for example the method should be tested for Carlisle and Boscastle.
- Pilot studies for applying the method.
- Information management: How will the EA manage risks to people data and information?
- Risk communication. How should the maps be presented? What are the business risks?

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