Defra Flood and Coastal Defence Appraisal Guidance

Social Appraisal

Supplementary Note to Operating Authorities

Assessing and Valuing the Risk to Life from Flooding for Use in Appraisal of Risk Management Measures

May 2008

1 INTRODUCTION AND BACKGROUND

1.1 Purpose of this supplementary note.

This guidance is supplementary to the Flood and Coastal Defence Project Appraisal Guidance. It provides a new method for the valuation of the risk to life associated with flood risks. Its main purpose is to enable the risk of fatalities to be assessed as part of a more comprehensive flood risk appraisal where the social benefits associated with any reduction in this risk are also taken into account when considering options for risk management.

The proposed method provides an approach that allows the relative risk to life to be included in the comparison of options and thus inform the decision making process, making the best use of available information. There is no assumption of certainty of loss of life for any specific flood event.

1.2 Background

Flooding from rivers, estuaries and the sea poses a risk to people as well as causing significant economic impacts. In 1953 the North Sea floods caused approximately 2500 fatalities across the UK and northern Europe, and concentrations of fatalities have been associated with flash floods such as Lynmouth in Cornwall (1952, over 30 fatalities) and Vaison-la-Romaine in France (1992, 38 fatalities). In the UK there were a 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 three fatalities during flooding in Carlisle and surrounding areas. Some 13 fatalities have been linked to the flooding during June/July 2007, which was predominantly local flooding of urban areas rather than flooding from rivers or the sea.

Over the last 50 years a wide range of flood risk management measures have reduced the risk of fatality from flooding in the UK. The selection of measures has been informed largely by assessing the flood risk of areas where people live and work and the infrastructure on which they depend. Significant improvements to flood warning capability has been a major contributor to the reduction of risk to life. Flood risks cannot be completely eliminated, but by identifying hot spots where peoples lives are at greatest risk and prioritising effort, Government aims for flood risk management can be supported. It was recognised that there was no clear method for estimating the direct risk of fatalities from floods and that including this aspect would improve flood risk assessments and subsequent management responses. Defra commissioned research to investigate the problem.

1.3 Research on which this method is based.

The "Risks to People – Phase 2" (R2P) (FD2321) research project completed in March 2006 developed and demonstrated a method for estimating and mapping serious injury or fatalities from flooding which may occur during, or in the immediate aftermath, of a flood event. This Phase built on Phase 1 (FD2317) and links with other existing Defra and Environment Agency R&D projects. The Risks to People (R2P) method is nested within a 'Source – Pathway – Receptor' (S-P-R) model, predominately dealing with a key component of the receptors (e.g. people) and is the method recommended for use by Operating Authorities in this note.

1.4 Social context

The focus of the research was on the assessment of possible risk to people, in terms of both fatalities and injuries and is useful in both a social and economic context. In the social context, the simple figure of the possible numbers of fatalities could serve as a useful measure for considering risk management approaches. Alternatively, we could go one step further and assign monetary values to the loss of life as indicated in the H M Treasury 'Green Book'. The research did not attempt to set an economic value on the loss of life as other sectors of Government had covered this ground and had arrived at values that have been adopted for their purposes. The value approved for flood risk management appraisals can be found at http://www.defra.gov.uk/environ/fcd/pubs/pagn/default.htm.

1.5 Expected impact on project selection

It is anticipated that the inclusion of these additional benefits will have only a small impact on projects in urban areas where the economic benefits are high, although the final option choice may change. Marginal projects may be lifted into economic viability, particularly in steep flashy catchments, and the prospects of funding may be improved.

2 OVERVIEW OF THE RECOMMENDED METHODOLOGY

2.1 Overview

The Risks to People 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 possible annual average individual or societal risk of fatality due to flooding which can be given an economic value using a reference valuation.

Flood Hazard describes the flood conditions in which people are likely to be swept over in a flood with the possibility of drowning, and is a combination of flood depth, velocity and the presence of debris.

Area Vulnerability describes the characteristics of an area of the floodplain that affect the chance of being exposed to the flood hazard.

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.

Flood Risks to People combines information on Flood Hazard and Flood Vulnerability and considers a number of flood events to provide estimates of **average annual individual or societal risk**.

Average annual individual risk is the assessed annual probability of an individual losing their life due to flooding. It is calculated as the possible number of fatalities per year divided by the population for each zone.

Average annual societal risk is the estimated annual number of lives that could be lost due to flooding. Where this parameter is to be mapped it is calculated as the number of fatalities divided by the area.

Reference Valuation is that value assigned to the economic value for the loss of life agreed by Government. For flood and coastal erosion risk management purposes, this value will be found at http://www.defra.gov.uk/environ/fcd/pubs/pagn/default.htm.

2.2 Risks to People variables

The variables used in the methodology 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**

2.3 Summary of Risks to People method

The methodology is described in detail in **Annex 1**.

It can be summarised as the following steps:

1. Assess Flood Hazard Rating

2. Assess Area Vulnerability
3. Assess People Vulnerability
4. Decide on the range of events to be used
5. Estimate the possible number of fatalities for each event
6. Estimate the average annual risks from the possible number of fatalities for the range of events
7. Assess the economic value of the possible number of fatalities using the reference valuation

3 APPLICATION OF THE METHODOLOGY

3.1 Primary use

It is intended that this Supplementary Note be primarily used alongside the Flood and Coastal Defence Project Appraisal Guidance (FCD PAG). The methodology described in this guidance will provide a quantitative assessment of the risk of fatalities from flooding in any particular area. This forms the necessary basis for assessing likely changes to risk of loss of life consequent upon a change of flood risk management (FRM) investment.

Such quantitative assessments can be used to assess the social benefits through monetary value of the estimated possible fatalities suffered or avoided through flood management interventions in the cost-benefit appraisal (CBA) of FRM investments by application of the **Reference Valuation**. In this way, a value can be placed upon this particular benefit parameter.

If a multi-criteria analysis (MCA) approach is used the valuation can be included as a Health and Safety (H&S) social benefit for comparing different risk management approaches.

As an alternative approach the number of lives that could be lost could be used as a non monetarised H&S benefit in MCA and perhaps provides a more focused social viewpoint. To avoid double counting, the monetarised valuation and the possible number of lives lost should not be used together in the same assessment.

3.2 Wider considerations

It is likely that the most common application of the methodology will be in assessing the difference in residual risks from different solutions. For example, the benefits in reduced frequency of flooding with a higher flood embankment will need to be put into context against the higher risk of fatalities if the higher embankment fails.

Consideration of risk of loss of life could tip the balance in favour of a channel widening or by-pass solution which retained lower water levels during flood than an embanked channel.

It could also provide a logical basis for decisions such as the threshold for closing access to flooded roads against the economic and social disruption caused by frequent closure.

Reference pages:

A. Extract from H M Treasury 'Green Book'

The Value of a Prevented Fatality or Prevented Injury

26 A benefit of some proposals is the prevention of fatalities or injuries. The appropriate starting point for valuing these benefits is to measure the individual's WTP for a reduction in risk of death (or their willingness to accept a new hazard and the ensuing increased risk).

27 The willingness of an individual to pay for small changes in their own or their household's risk of loss of life or injury can be used to infer the value of a prevented fatality (VPF). The changes in the probabilities of premature death or of serious injury used in such WTP studies are generally very small.[13]

28 In the UK, the main measure of VPF incorporates the 'extra' value placed on relatives and friends, and any further value placed by society on avoiding the premature death of individuals. Accordingly, the addition of an individual's WTP for the safety of others to his 'own' WTP for 'own' safety may lead to double counting.[14]

29 A lower bound on the value of a prevented fatality may be determined by revealed preference and stated preference studies. This lower bound is useful for determining a threshold of value for money for safety expenditure and also for comparing proposals concerning increased safety.

30 Revealed preference studies can derive individual WTP for risk reduction from, for example, the size of wage differentials for more or less risky occupations; or price versus safety trade-offs in choosing transport modes; or WTP for safety devices such as smoke alarms or car air bags. However, in practice, these estimates of the revealed value of a prevented fatality are not precise. Stated preference approaches have also been used to provide estimates of VPF using questionnaires.[15]

31 In the UK, the Department for Transport (DfT) values the reduction of the risk of death in the context of road transport at about £1.145m per fatal casualty prevented (in 2000 prices).[16] In addition to the WTP measures, these estimates include gross lost output, medical and ambulance costs. Values are uprated in line with assumed changes in GDP per head.

32 DfT also attributes monetary values to the prevention of non-fatal casualties, based on a WTP approach. Serious and slight casualties are valued separately and the values are uprated in line with changes in GDP per head. Values currently in use for preventing a serious and slight road injury are £128,650 and £9,920 respectively (at 2000 prices).[17] Costs of police, insurance and property damage are added to these casualty values to obtain values for the prevention of road accidents. The HSE tariff of monetary values for pain, grief and suffering begins at £150 for the most minor non-reportable injury.[18]

33 There is evidence that individuals are not indifferent to the cause and circumstances of injury or fatality. For example, in their estimate of benefits from asbestos proposals, HSE currently doubles the VPF figure to allow for individual aversion to dying from cancer, and the additional associated personal and medical costs.[19]

ANNEX 1

Methodology for assessing the likely number of fatalities caused by flooding

Purpose
This Guidance Note provides a method for estimating the change in number of people per year who are likely to die as a result of flooding.

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 risk of fatality for present day conditions;
- Calculate the risk of fatality with the proposed flood management policies and measures in place;
- Calculate the change in risk of fatality.

Risk of fatality is calculated using the method set out below. The outputs are expressed as the total number of people per year who possibly could lose their lives by flooding.

Description of method
The basic method for calculating flood risk of fatality from flooding is described below. Further detail and more background information is given in ***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.

<u>Overview</u>
The number of fatalities is calculated using the following equation:

$$N(F) = f(N(Z), HR, AV, PV).$$

Where:

N(F) is the possible number of fatalities
N(Z) is the population within the zone at risk of flooding
HR is the Flood Hazard
AV is the Area Vulnerability
PV is the People Vulnerability

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

The risks to people will tend to vary depending upon the distance from the source of flooding due to factors such as different flood water depths, velocities and speed of onset. Thus the method is based on applying the calculations to a number of hazard zones, usually taken as the distance from the river/coast, in order to build up an overall picture of the associated level of risk for a given flood event.

Selection of events

Section 4.3 of the Project Appraisal Guidance should be used to assist the identification of a suitable selection of flood events for the project appraisal. However, the greatest risk of fatality is likely to be from more extreme events and the appraiser should give added consideration to this when making the final selection.

Identification of Flood Hazard Zones

A convenient basis for flood hazard zones is the distance from the source of flooding. Hazard should be broadly equal across individual zones. In some situations it may be appropriate to create further zones perhaps to separate a dense residential area from an industrial area or where water levels or velocities vary unacceptably across a zone. Should it be necessary, further guidance can be gained from Case Studies in the Report FD2321/TR1.

Supporting Calculations

The method requires, the calculation of:

- Flood Hazard;
- Area Vulnerability;
- People Vulnerability.

The calculation methods for these parameters are described below.

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 A.1

Table A.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 A.2.

Table A.2 Area Vulnerability

Parameter	Low risk area Score =1	Medium risk area Score =2	High risk area Score=3
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	Indicative score for England use 2.15 Indicative score for Wales use 2.23		
Area Vulnerability (AV) = sum of scores for 'speed of onset', 'nature of area' and 'flood warning'			

Ref: FD2321/TR1 Table 4.4 and Table 4.3

Note The Flood Warning Scores quoted above are indicative values. Their use is appropriate for most loss of life calculations. However, if significant factors influence flood warning and response in the project area then a specific Flood Warning Score can be calculated using the method in Report FD2321/TR1.

People Vulnerability

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

PV = %residents suffering from long-term illness + %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.

Step 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. Refer to Table A1 for the Debris Factor.

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

Ref: FD2321/TR1 Table 6.1

Step 2. Calculate Area Vulnerability (AV)
Calculate the Area Vulnerability using Table A.2.

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

Step 3. Calculate those exposed to the flood
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 (as %); 0≤X≤100%	**N(ZE) = X x N(Z)**
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: FD2521/TR1 Table 6.3

Step 4. Calculate People Vulnerability (PV)

Distance from river/coast (m)	Factor 1 (% very old i.e. >75 years)	Factor 2 (% Disabled or infirm)	**PV**
0-50	15%	10%	**25%**
50-100	10%	14%	**24%**
100-250	12%	10%	**22%**
250-500	10%	15%	**25%**
500-1000	15%	20%	**35%**

Ref: FD2321/TR1 Table 6.4

Step 5. Calculate the numbers of possible fatalities

The number of possible fatalities is assumed to be proportional to the People Vulnerability and the Hazard Rating. The number of people exposed to the risk (N(ZE)) is multiplied by 2Y x 2HR (as a percentage) to obtain the number of fatalities.

Distance from river/coast (m)	N(ZE)	PV (as %) from Step 4	HR from Step 1	2PV x 2HR (as %)	**No. of fatalities (rounded)**
0-50	15	25%	8.5	8.5%	**1**
50-100	14	24%	5.6	5.4%	**1**
100-250	60	22%	2.8	2.5%	**1**
250-500	95	25%	1.85	1.9%	**2**
500-1000	0	35%	0	0%	**0**
All	185				**5**

Ref: FD2321/TR1 Table 6.5

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

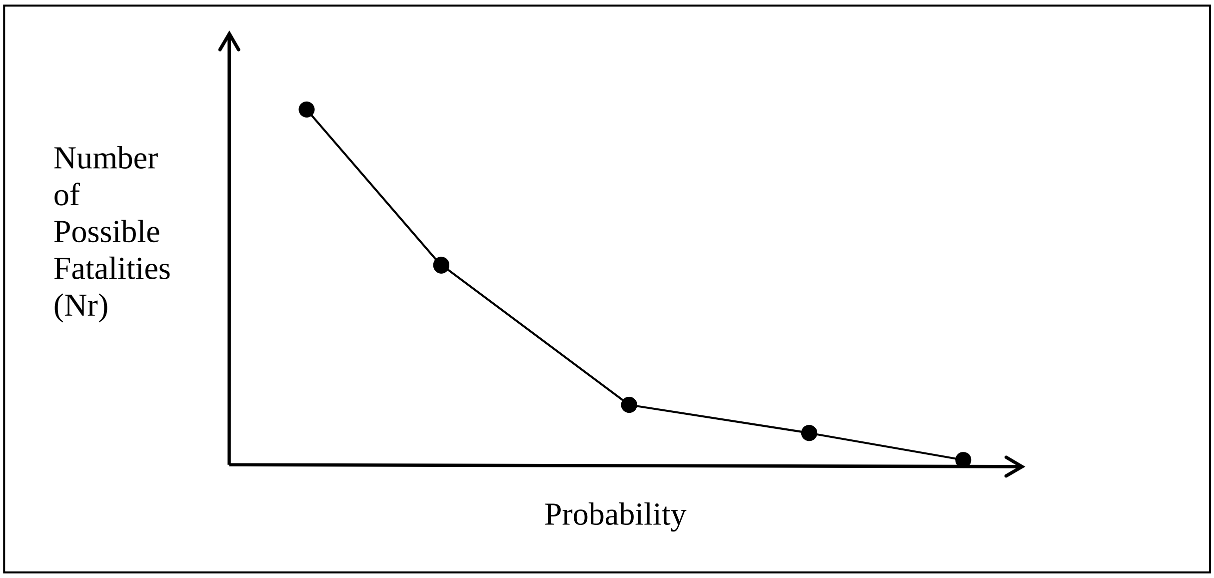
The same calculation must repeated for other flood events, A summary of possible fatalities for all 5 events is shown below.

The number of possible fatalities for 5 flood events

Number of possible 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

The numbers of possible fatalities can be plotted against flood probability and by considering the area under the curve the annual average number of possible fatalities, or those avoided, can be determined for different flood risk management scenarios to support the appraisal process.



Step 7 Monetary Value for Possible Loss of Life

While the number of fatalities itself, suffered or avoided, can be an important consideration to carry forward in the appraisal process it may also be appropriate to determine monetary values. This can be done by applying the **Reference Valuation** as follows:

$$\text{Est. Monetary Value (£)} = \left[\begin{array}{c}\text{Estimated annual average} \\ \text{Number of possible fatalities} \\ \text{(suffered or avoided)}\end{array}\right] \times \text{Reference Valuation}$$

The Reference Valuation is £1,144,890 as at June 2000. This value is kept under review by Defra and the Environment Agency and periodically updated. If you are not viewing this Supplementary Note direct on the Defra or EA website then please refer back for the latest Reference Valuation (http://www.defra.gov.uk/environ/fcd/pubs/pagn/default.htm).

Data requirements

1. Regional applications

Variable	Type	Data sources
Floodplain extent	Variable	• EA Flood Map • NAFRA Flood Map
Flood depth	Variable	• Flood extents and topographic data (e.g. 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	• Expert judgement for broad-brush assessment (see Note below) • Hydraulic modelling (see Note below)
Flood depth and velocity	Variable	• 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 approximate data for the Annual Average Risks to People calculation, but possibly good enough for comparisons of options. • Hydraulic modelling (see Note below)
Nature of area	Score	• OS Maps • National Property Database (NPD) and other address-point products to develop information on property types. • Local knowledge to identify main vulnerable areas (e.g. areas of bungalows, etc).
Flood warning	Score	• EA performance indicators
Speed of onset	Score	• EA flood warning information • Catchment characteristics • Location and nature of defences
Population	Variable	• National Census data by Output Area
Residents suffering from long-term illness	%	• National Census data by Output Area
Residents aged 75 or over	%	• National Census data by Output Area

2. Local applications

Variable	Type	Data sources
Floodplain extent	Variable	• EA Flood Map • Hydraulic modelling (see Note below)
Flood depth	Variable	• Hydraulic modelling (see Note below).
Flood velocity	Variable	• Hydraulic modelling (see Note below)
Flood depth and velocity	Variable	• Hydraulic modelling (see Note below)

Nature of area	Score	• OS Maps • National Property Database (NPD) and other address-point products to develop information on property types • Site inspections.
Flood warning	Score	• EA performance indicators
Speed of onset	Score	• Hydrological calculation using catchment characteristics • Location and nature of defences
Population	Variable	• National Census data by Output Area • Use of local information including 'non-resident' population (e.g. people in workplaces, in transit, on campsites, etc) and places where people congregate (e.g. shopping areas, etc)
Residents suffering from long-term illness	%	• Local data from local authorities or health services. Contact local authorities in the first instance.
Residents aged 75 or over	Residents aged 75 or over	• 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 MIKE 11 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 floodplain 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 building: 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.