“Managing Flood Risk: Past, Present and Future”

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The management of flood risk has changed over the last century as greater knowledge has been added on the subject of hydrology and river engineering. However, it has become clear that the management of flood risk for the future will have to take into account the predicted changes to climate by identifying the degree of change on storm frequency and intensity and the changes to tides and surges. It is also clear that managing flood risk in the future will have to have regard to the impact of past, present and future land use changes.

The use of modern science and technology will be considered and include information technology, mathematical modelling and remote sensing, integrated with existing methods to develop an effective framework for flood risk management. The paper will draw on some of the work done by the DEFRA-sponsored Institution of Civil Engineers Presidential Commission on a Technical Review of Flooding in England and Wales, whose Commissioners consist of:

- Professor George Fleming, University of Strathclyde (Chairman)
- Mr Lindsay Frost, Lewes District Council
- Dr Stephen Huntington, H R Wallingford
- Professor Donald Knight, University of Birmingham
- Mr Frank Law
- Mr Charlie Rickard, Mott MacDonald

Some of the issues dealt with in the paper will include a historical review of how flood risk is assessed; the changing scope of urban flood management; the introduction of river basin management; and will also review some of the flood defence tools and warning systems currently utilised, and will comment on the impact of climate change.

Keywords: floods: risk, management, frequency, design

Introduction – Defining Flood Risk

A flood is a *“great flow of water, causing overflow and inundation”* (*Chambers, 2000*[(2)]). The factors causing a flood to occur are extremes in meteorology and hydrology, coupled with changes to river hydraulics caused by land use and alterations to river geomorphology.

The flood risk or the exposure to flood hazard must be clearly understood and communicated to all concerned. To ensure this, it is important that appropriate and consistent terminology is used.

The source-pathway-receptor model is a useful method of establishing risk relationships. In relation to flooding, it can easily be seen that management of the risk is heavily biased to the receptor end of the scale (Figure 1). The source cannot be controlled (precipitation), and while the pathway (land, watercourses) can have scope for management, ultimately the receptor (people, property) can have the greatest control exerted.

One of the key aims of flood risk assessment is to understand and be aware of the complexities of the situation as best as possible, then to simplify the situation down to an acceptable level to allow practical measures to be put in place. When the risk of a particular event is expressed, the perception of risk can vary, both in scope and scale. It is important to define at the outset what is the context of the risk, and how it relates to hazard.

We must be aware that risk is dynamic both in time and space, and the risk assessment must reflect this. A static system cannot be assumed and continual review is essential every 5-10 years or subsequent to any major changes in the catchment.

Risk-based approaches will tend to provide more information than is available from deterministic analysis. They will often lead to the possibility of a wide range of potential solutions with differing costs and benefits. This information must be provided in as concise and clear a format as possible. This is especially true where uncertainties are concerned, where they should be identified as being inherent or epistemic, and appropriate confidence levels assigned.

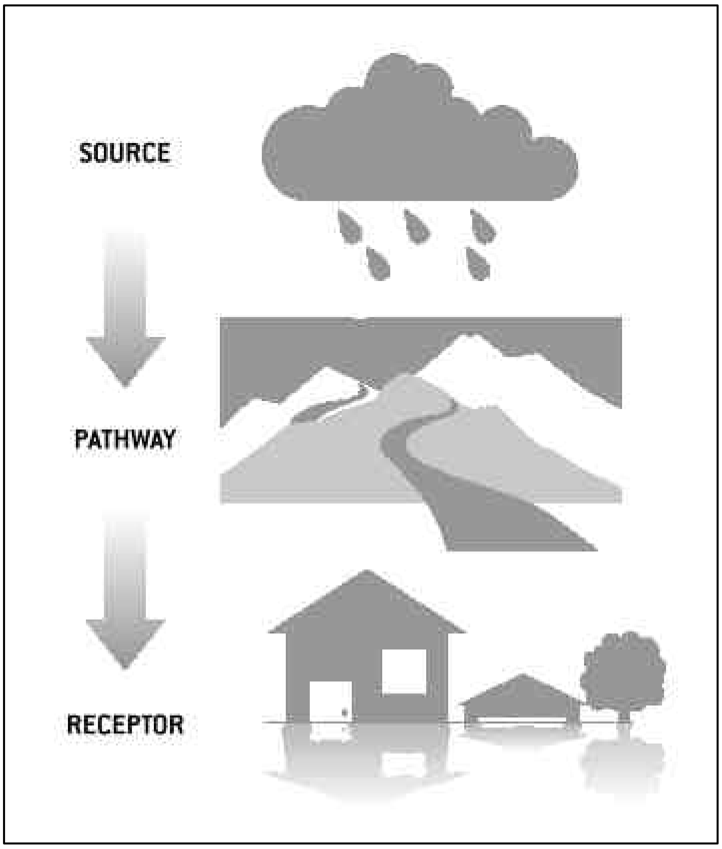


Figure 1 Source-pathway-receptor model

Expressing the risk

The most difficult concept to convey is that of the risk of flood events occurring. We have expressed the extreme nature of the event by calling its probability "The Return Period". However, by trying to make the understanding of probability more straightforward, we have introduced an idea of periodicity which has begun to mislead the non-expert. For example, the design exceedance of the majority of fluvial flood defences has been set at a probability of 1% in any year. This event has been translated into having a return period of 100 years. After any large event deemed to have a return period of 100 years or more, many will regard it, perhaps complacently, as most unlikely such an event will reoccur in their lifetime. However, that same probability applies for any year, including that following a large event.

Taking this probability over a reasonably long time period of a lifetime of 70 years, it can be shown that what is today referred to as a 1 in 100 year flood has a 50% chance of occurrence within the 70 year lifetime period, but more significantly, has a 15% chance of occurring twice in that lifetime.

By conveying this aspect of probability without the attendant periodicity, it becomes obvious that the broader issues of continuous communication to maintain awareness are essential.
The understanding of odds is widespread, arising in many sports involving gambling.

Therefore, in communicating flood risk to the general public, instead of referring to the "100-year flood", we could say that there was "a 100 to 1 chance against the flood in question being equalled or exceeded in any year" (100-1 chance against the flood) or alternatively 1:100 chance of a flood actually occurring or the 1:100 chance flood. We should go on to explain that, other things being equal, the odds would remain the same each year, regardless of any recent severe occurrences.

To communicate the risk to professionals, the alternative terminology of "1% annual probability of flooding" can also be used, however the use of the concept of return period should be discouraged in all future communication.

Historical Development of Flood Risk Assessment

Historically, communities are built on a flood plain because environmentally, flood plain sites were often the most fertile and workable agricultural land, and the urban communities usually grew up on sites of river crossings or where the river provided transport facilities for trading. River systems also afforded protection in terms of defence during times of unrest, and the social and economic conditions of the flood plain were seriously consolidated during the industrial revolution from the 18th Century onwards where flood plains provided flat land for industrial development and housing.

River systems still remain today an economic asset for towns and new developments along the riverbanks as they continue to re-use the previous urbanised land, as shown in Figure 2[(1)].

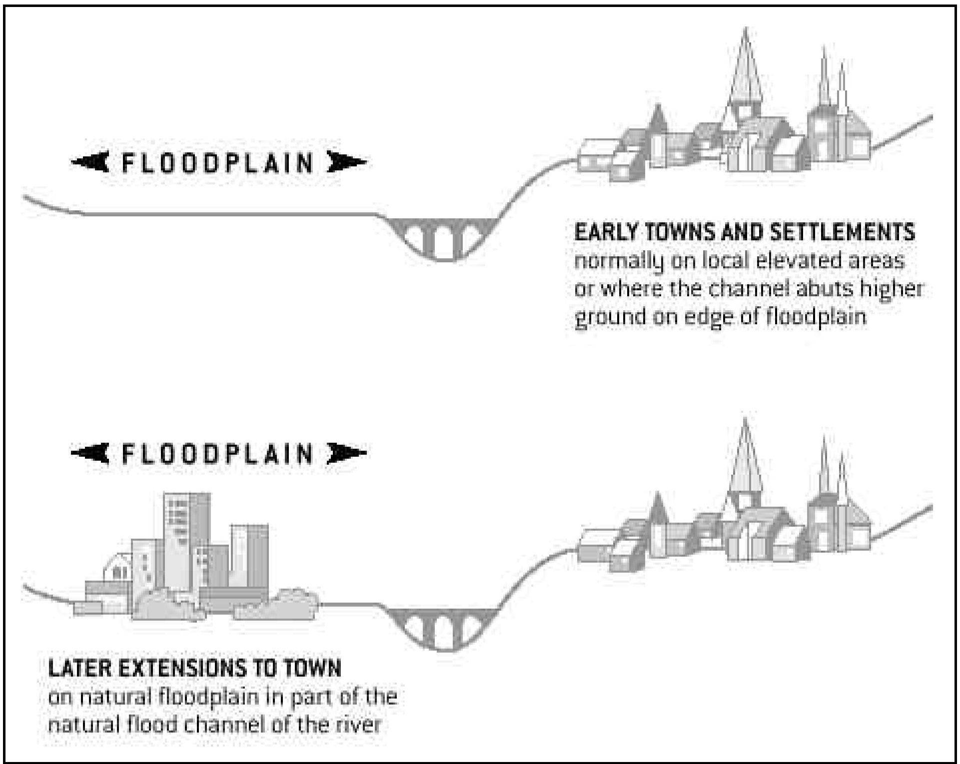


Figure 2 Development in Flood Plains[1]

<u>Historical Flood Estimation</u>

Historical flood assessment has relied on a limited amount of past data to predict extreme flood events that might occur during the design life of current developments, e.g. a bridge built today in the anticipation that its design life may be 100 years. The flood risk that the bridge must cope with is therefore the risk of a flood magnitude occurring within the design life of the bridge, and this has lead to the concept of the return period flow. Figure 3[1] shows the historical data available to the hydrologist in attempting to predict flood magnitude and its associated risk.

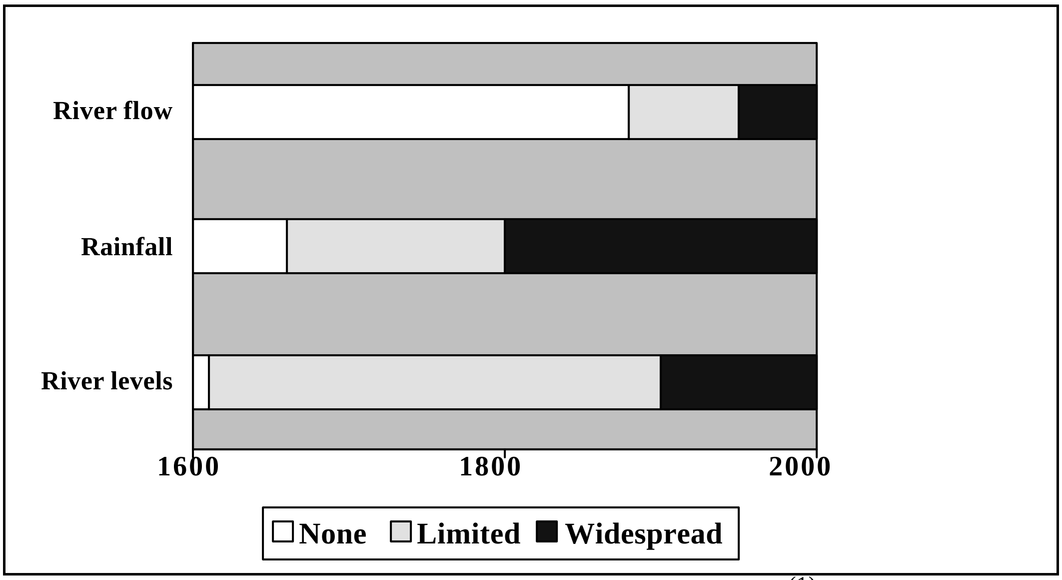


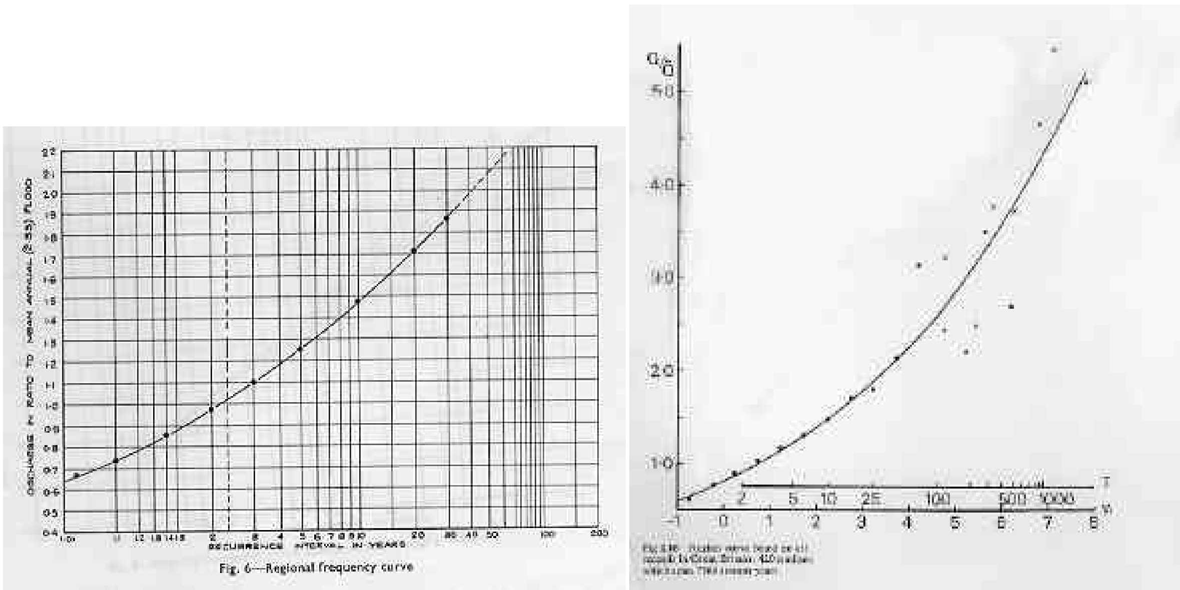
Figure 3 Historical Data Collection[1]

The Institution of Civil Engineers (ICE) has played a leading role in identifying best practice in flood estimation and has produced a number of reports including "The Floods in Relation to Reservoir Practice" in 1933[3].

By 1965 the field of flood "protection" engineering was expanding and the ICE held a symposium on river flood hydrology to assess existing methods. It was felt that frequency analysis methods were only being used when the budget of the project was large enough to justify the work involved and that for smaller projects a variety of methods were being used to produce discharge estimates. A need for a reliable and universal method, applicable to both large and small schemes, was required. In America the U.S. Geological Survey had been developing the regional flood frequency method, combining the flow records of a group of stations in a hydrologically homogeneous area to obtain a longer record and thus reduce the sampling error. This method was widely accepted in the USA and offered significant improvements to flood risk analysis in the UK. These regional frequency curves were produced for England and Wales (Cole, 1965)[4] and Scotland (Biswas & Fleming, 1966)[5].

During the 1960s several major flooding events occurred throughout the UK, in particular the 1968 floods in the Bristol region and south east England caused wide spread chaos and distress, and this together with recommendations from ICE gave the government the impetus to commission the Flood Studies Report (FSR) in 1975 (NERC, 1975)[6], a formal review of flood estimation techniques in use in the UK.

The regional flood frequency curves of Biswas and Fleming in 1966 and the FSR recommendations of 1975 (both shown in Figure 4) are comparable when analysed together, as shown in Figure 5. In other words, the regional flood frequency method although extending the curves up to the 1:1,000 event, have not greatly changed the magnitude of the 1:100 event.



Regional Flood Frequency Curve: Scotland (Biswas & Fleming, 1966)   Regional Flood Frequency Curve: Great Britain (NERC, 1975)

Figure 4 Regional Flood Frequency Curves

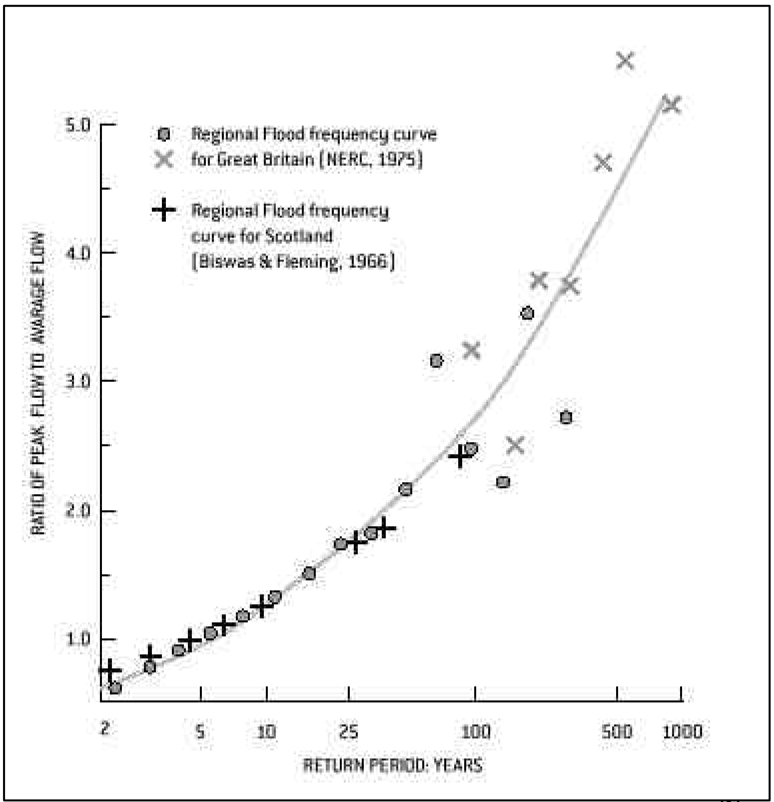


Figure 5 Analysis of Flood Frequency Curves[1]

Both the Flood Studies Report and the Floods and Reservoir Safety reports aimed to provide an accurate assessment of flood risk in order to maximise public protection, and together they formed the cornerstones of flood risk assessment in the UK until the publication and launch of the Flood Estimation Handbook (FEH)[7] in May 2000. Figure 6[1] shows a schematic representation of the different methods used in flood estimation over the last 200 years and a projection of expected developments in the next 50 years.

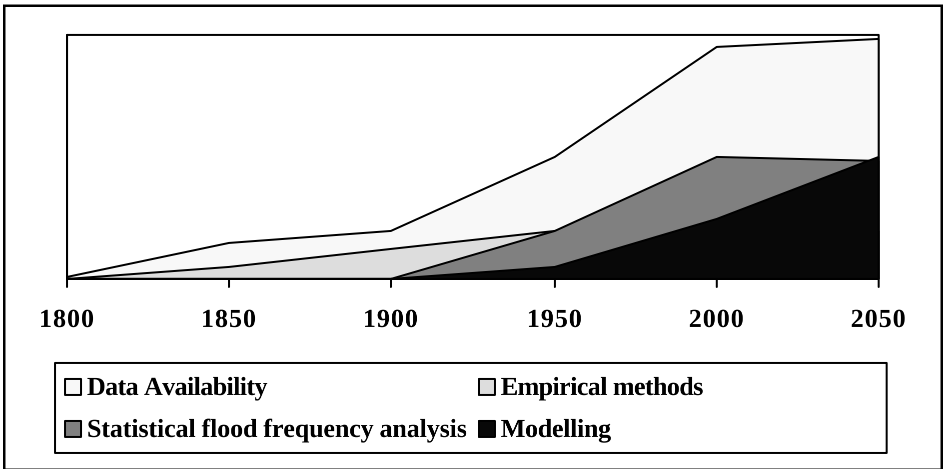


Figure 6 Flood Estimation Techniques[1]

The Flood Estimation Handbook uses data up to 1990 and has improved our ability of calculating flood frequency based on more accurate representation of catchment areas, and is now a better based system operating from a geographical information system. However, the wealth of useful data recorded since 1990 is not utilised in the derivation of the latest curves and therefore the floods experienced in 1993 in the Tay and the recent floods in England and Wales are not incorporated in the flood estimation practice, and they need to be.

From as early as 1958 mathematical modelling of hydrological processes developed as a useful tool in flood estimation. Indeed, the first hydrological simulation carried out in the UK was for the River Clyde based in Scotland (Fleming, 1970)[8]. However computer modelling has not been widely accepted in the UK for operational flood forecasting or for extending the database on which to calculate flood risk. The main focus has been of the statistical methods of FSR and FEH. There is a real need to utilise hydrological models in a much more effective way in the future for calculating flood magnitude and risk.

Flood Estimation – The Current Problem

The current problem of flood risk assessment needs to address a number of issues (Figure 7)[1]. These issues need to take into account not just the hydrological calculations of flood frequency but the interpretation of that flow magnitude in terms of depth, velocity and storage within the river channel system. This requires us to understand the impact of land use change on the flood magnitude. One of the major effects of land use change is constraining our flood plain. Most importantly, the social impact of flooding must be the central issue in flood risk management.

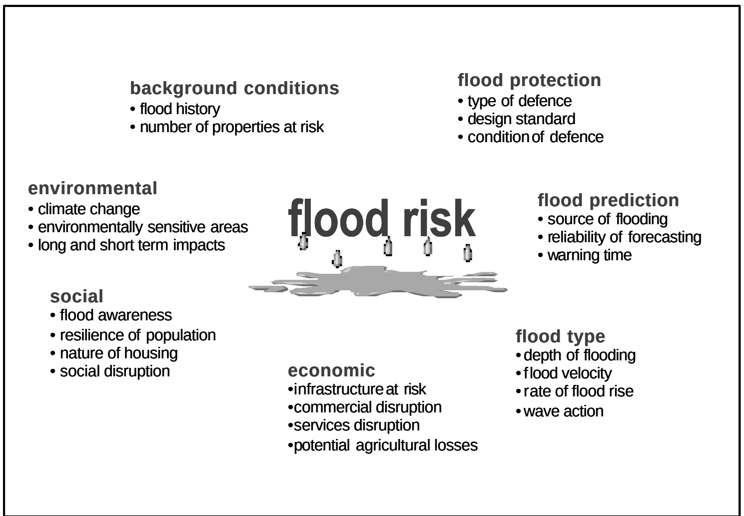


Figure 7 Factors Affecting Flood Risk[1]

If we consider for example a one in 1:100 chance flood occurring in a catchment as shown in Figure 8[1], the impact of this flood on a flood plain in a particular stretch of the river channel results in the hydrograph flow attenuating and lagging. If we constrain the flood plain by building a flood bank, the attenuation is significantly reduced and the flood delay is also reduced.

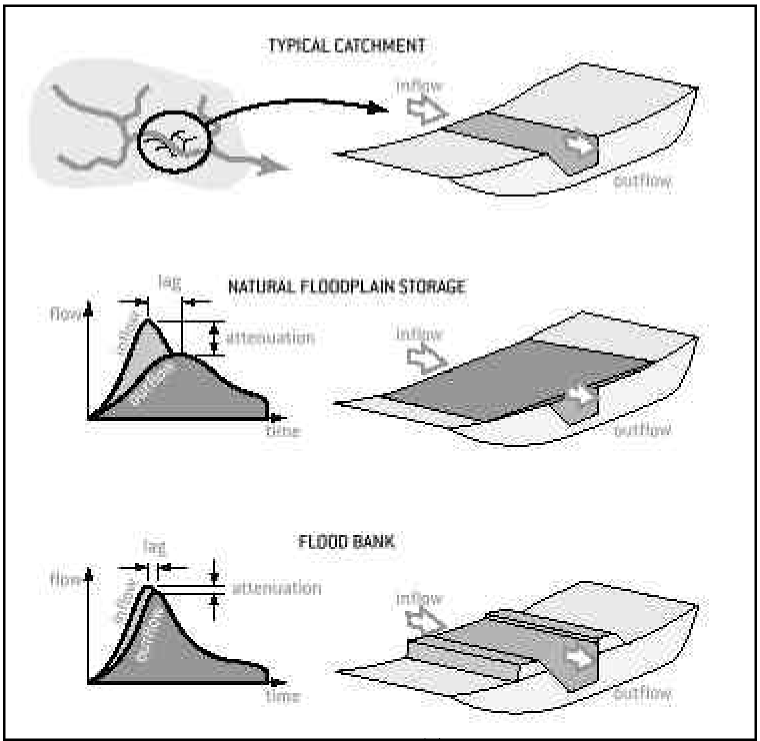


Fig 8 Effect of Constraining Flood Plain[1] (Adapted from Fleming (1975)[9])

The effect on flow of restricting the flood plain is to exaggerate the peak flood for a downstream community, as shown in Figure 9[1].

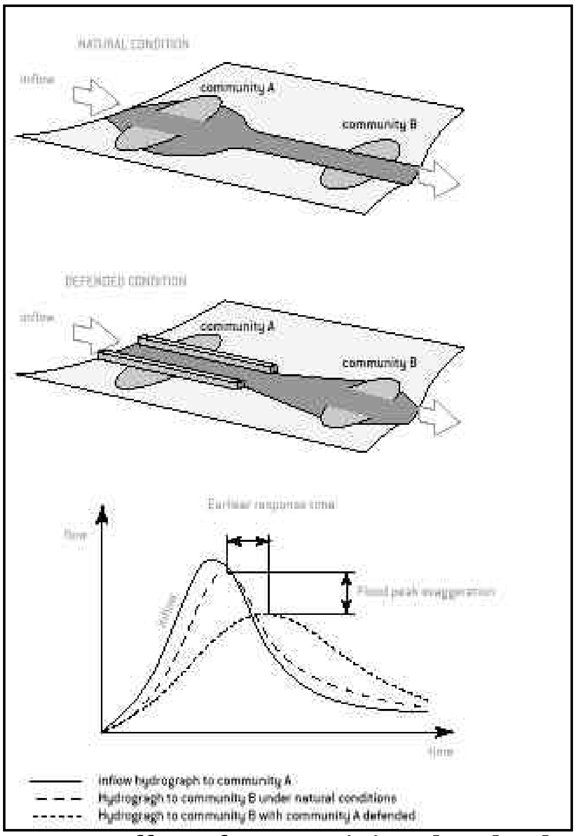


Figure 9 Effect of Constraining the Flood Plain[1]

The use of flood banks has been an historical form of defence which has worked very well for the communities being defended. Figure 10 shows the concept of flood bank protection.

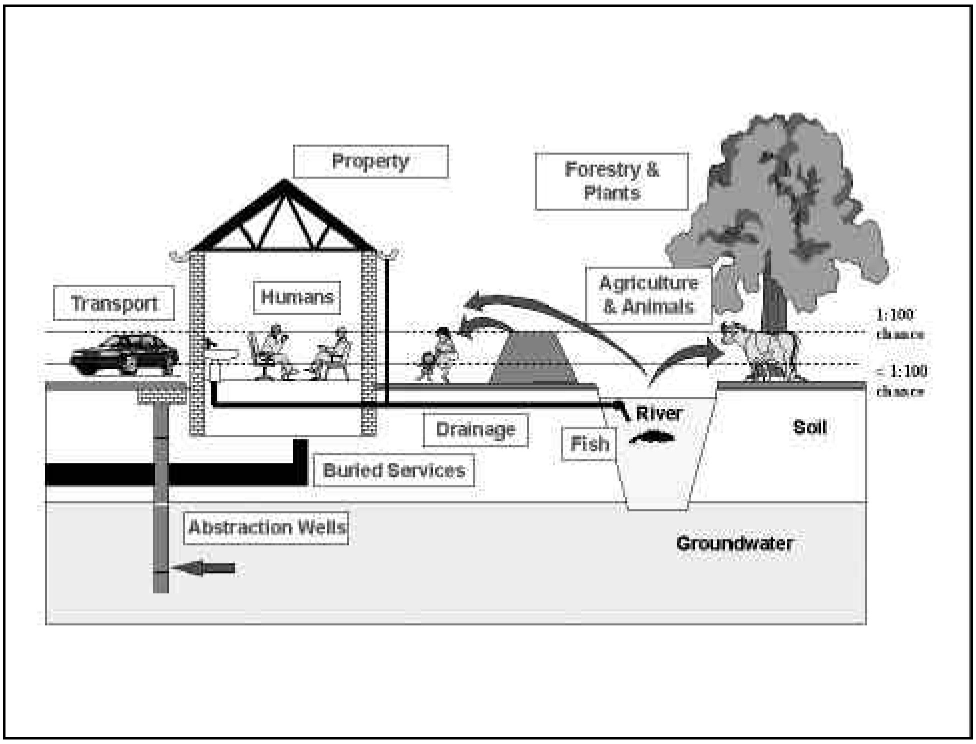


Figure 10 The Concept of Flood Bank Protection

However future constraints of the flood plain must carry with it a means of reducing the downstream exaggeration by building flood mitigation schemes as part of the approved development of the flood plain, e.g. the Leigh Barrier, as shown in Figure 11[1], which provides flood storage to protect downstream communities during times of flooding.

Figure 11 Leigh Barrier in Operation[1]

Where a community has developed close to the mouth of the river as in the case of Gainsborough and Perth, then the use of flood banks that mitigate the effect is a very important tool in flood risk management (Figure 12). In the case of Gainsborough, the flood bank is protecting the community while the historical flood banks on the opposite side of the river have been removed to allow flood plain storage on the rural land on the opposite bank.

Figure 12 Flood Defences at Gainsborough[1]

Future Flooding Issues

Future flooding issues must focus on the social dimension of flood impact and be able to take into account the effects of climate change and our current methods of flood assessment. This in turn must utilise all the techniques available to us, including computer modelling of flood events to develop community awareness in order that the community learns to live with rivers and the natural process of flooding.

Calculations show for example that the projected effects of climate change on run-off for the Clyde catchment are to double the risk of flood over the next 50 year period (Fleming and Guenin, 2001[10]). Table 1[10] shows a calculation done for the River Clyde where the historical rainfall was increased by 10% based on current climate change predictions. Such allowances for flood risk are not currently incorporated in our design practice. Climate change predictions together with the knowledge of land use change sensitivity must be introduced into future flood risk calculations.

Flood chance in any year (return period)	5	10	20	30	50	70	100	200	500
Year 2000 runoff (m^3/s)	678	798	931	1005	1114	1191	**1254**	**1411**	1680
Predicted 2050s runoff (m^3/s) Design event rainfall +10%	750	884	1033	1116	**1239**	1324	**1396**	1572	1875
Increase in runoff (%)	9.6	9.7	9.9	9.9	10.0	10.1	10.1	10.2	10.4

Table 1 Projected Effects on Run-Off for Clyde Catchment[10]

Flood risk management must be founded on an understanding of the dynamic interaction between flood magnitude, climate change and land use changes and real-time management control of flood flows.

In January 2001 the Government invited the President of the Institution of Civil Engineers to establish a Commission to consider what approaches to the management of fluvial flood risks were appropriate to the 21st Century. The Commission's report was published on the 8th of November 2001. All information gathered by the Commission is available on the Flood Commission web page at *http://www.ice.org.uk/presidential.html* and all written evidence together with the minutes of Commission meetings have been lodged in the Library of the Institution of Civil Engineers at One Great George St, Westminster, London, SW1P 3AA.

Conclusions

A number of myths and perceptions have developed around flooding, one of which is that by preventing building on flood plains we can manage flood risk in future. Historically we have in the UK already built on most of the flood plains available to the major rivers and while some re-establishment of flood plan capacity is possible in future development, we will need to continue to manage the built environment already occupying the flood plain. The redevelopment of future brownfield sites which occupy the flood plain should focus on developments which are less susceptible to flood risk, e.g. playing fields and car parks, and where development on the flood plain progresses in future, the planning process must ensure that flood plain developments are flood-resistant but also that the development builds in mitigation for downstream river users. The existing flood warning systems operating in England and Wales and more recently in Scotland are a welcome addition to communicating flood risk to the public. However such warning systems need to be backed up with flood forecasting and management systems founded on sound river basin modelling and remote sensing technologies which can be visualised through the use of advanced Geographic Information Systems. The technology and techniques exist for improved flood risk management – all that is lacking is the will to do it and the resources to enable.

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