A FRAMEWORK FOR INTEGRATED FLOOD RISK MANAGEMENT

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ABSTRACT
Little of the European coast line or land area has escaped human influence, with increasing pressures over generations of settlement, agriculture, industry and commerce. The pressures include water and flood management activities which control the extent and frequency of floods and the drainage of water from the land. Internationally, policies and practice in flood risk management are evolving in response to many drivers including climatic forcing (changes in precipitation, sea level rise etc), increasing potential for damage, decreasing acceptance of and resilience to flooding, competing demands on public expenditure and ageing of flood defence infrastructure. An important development of policy is the European Directive on the assessment and management of flood risks, which entered into force across the EU in November 2007. Full integration of flood risk management with other aspects of water management and spatial planning leads to the concept of integrated flood risk management. The basic characteristics of IFRM are to seek to:

- Reduce the occurrence of flooding – acting on the probability of floods and their, speed, depth and duration
- Reduce the harmful consequences should a flood occur – acting to reduce the potential exposure to flooding or reducing the vulnerability and aiding individuals and organisations to act wisely during a flood.
- Promote sustainable development to let future generations meet their flood risk management needs.

The European Commission funded the Integrated Project FLOODsite (2004-2009) to examine integrated flood risk analysis and management methodologies and to provide support for the European Directive. This paper provides a discussion of what constitutes "integrated flood risk management", in the light of the experience of FLOODsite. There are many references in this paper to individual FLOODsite Tasks (of which there were 35). The project website www.floodsite.net has details of the tasks and over 100 reports on their outcomes.

THE SCALE OF FLOODING AND ITS CONSEQUENCES

Flooding is the most widespread of all natural hazards, often arising from adverse meteorological conditions such as intense or prolonged rainfall in river catchments, storm surges at the coast and in estuaries and storm-generated waves at the coast. Flooding may be triggered by a cascade of other natural hazards – for example, earthquakes may cause tsunamis or cause landslides to retain new lakes which later rupture resulting in a dam-break wave downstream. The source of flooding can also be the failure of water management infrastructure such as dams and raised flood defence embankments. Floods have adverse impacts on humans and their activities causing injuries, fatalities, damage and disruption and for many years the societal response has been directed at flood defence to reduce these consequences.

Many authors and studies provide descriptions of the extent and impacts of past flooding see for example the European compilations of Knight and Samuels (2007), the European Environment Agency (2004) environmental issue report number 35 and the NEDIES report (Colombo & Vetere-Arellano, 2002). Lumbroso *et al.* (2008) provide a catalogue of floods in Mozambique and Knight *et al* (2006) describe impacts of river floods in Japan, China. Jonkman and Vrijling (2008) give examples of the loss of life from coastal flooding worldwide from cyclones and surges. They show that these may cause up to 300,000 fatalities from a single event, which is comparable with the death toll from the Great Indian Ocean Tsunami on 26 December 2004 (Lay *et al*., 2005). Munich-Re compiles annual summaries of natural catastrophes (categorised as: geophysical, meteorological, hydrological and climatological). Since these hazards are effectively random in their occurrence and distribution, the picture in any year will differ. In the classes of hazards, the hydrological hazards include flooding. The NatCatService of Munich-Re (2010) indicates that in 2008:

- out of 750 recorded significant events (the 10-year average is 700) hydrological hazards accounted for 39%
- in terms of the 163,000 fatalities in these events, hydrological hazards accounted for 3%
- in terms of the gross economic loss of $200 Billion, hydrological hazards accounted for 9%
- in terms of the insured loss of $45 Billion, hydrological hazards accounted for 6%

In Europe, nations have institutional and physical infrastructure to combat floods and their effects, and in many cases these have a long history. For example, in the middle Loire valley some major flood embankments are over 200 years old and the courses of the Rivers Rhine and Danube were substantially straightened before 1900 providing improved navigation and flood control. By the 14th century ring dikes had been constructed in the Netherlands creating polders where land and settlements were protected from flooding (Klaassen, 1998). In Hungary, there is documentary evidence of flood defence works as early as the 13th Century and in the UK flood defence legislation can be traced back to 1531. Up to the middle of the 20th century the emphasis was on the prevention of flooding by physical *flood defence* measures.

However, with increasing social and economic development bringing pressure on land use within flood plains of rivers and the coastal zone, the potential for flood damage is increasing. Kundzewicz and Samuels (1997) describe the objective of *flood management* as minimising the flood losses within a river basin over time subject to constraints; they describe a portfolio of different actions before the flood, during the flood or after the event. This is also recognised in the Best Practices document prepared on behalf of the EU Water Directors (2004) which also highlights the need for an "integrated approach" which considers flooding processes at the catchment scale in an integrated and comprehensive plan, implying international and transboundary co-operation. These principles underlie the subsequent development of the European Directive on the assessment and management of flood risks (EC, 2007) – otherwise known as the "Floods Directive". The purpose of the Floods Directive is "*to establish a framework for the assessment and management of flood risks, aiming at the reduction of the adverse consequences for human health, the environment, cultural heritage and economic activity associated with floods in the Community*." As well as embodying the principles of the Best Practices, the Floods Directive requires consideration of the effects of climate change on flood risks (see for example IPCC, 2007), public consultation on the preparation of plans and close coordination with activities under the European Water Framework Directive and other relevant Directives. Thus *flood risk management* has come to the fore to take account of the performance in uncertain future conditions of a legacy of historic infrastructure and increasing social and environmental pressures to maintain the economic and societal uses of fluvial and coastal floodplains.

FLOOD RISK

What is flood risk?

Before advancing the arguments for integrated flood risk management it is important to understand the meaning of "flood risk". These concepts were explored at the outset of FLOODsite (Gouldby *et al.,* 2009). Risk is generally understood as a combination of probability and consequence i.e.:

Risk = f (probability and consequence)

Probability is the measure of our strength of belief that an event will occur. We consider probability over a specific timeframe (1 tide, 1 month, 1 year, 1 lifetime etc). It reflects, therefore, the chance of a source and pathway leading to a flood event, and the associated chance of a receptor being exposed and suffering adverse consequences.

- Sources – are the causes or origins of flood hazards (for example, heavy rainfall, strong winds, surge etc). In the context of a risk based approach it is important to consider a full range of possible events and not predetermined "design" events – an approach that is inconsistent with a risk-based philosophy.
- Pathways – are the routes that flood water takes from its source to reach the Receptors. Pathways must exist for a hazard to be realised. It is essential to identify, characterise and assess the relative importance of the pathways for flooding of each specific area.
- Receptors – are the entities that may be harmed (a person, property, habitat etc.).
- Consequences – are impacts such as economic, social or environmental damage/improvement that may result from a flood. They may be expressed quantitatively (e.g. monetary value), or by category (e.g. High, Medium, Low) or descriptively.

The assessment of the consequences of flooding depends upon two key components – exposure and vulnerability.

- Exposure – is the quantification of the receptors that may be influenced by a flood; for example, number of people and their demographics, number and type of properties etc. The chance of a receptor being exposed to a flood at a given location reflects both the chance of the flood event and the behaviour of the receptor.
- Vulnerability – is a characteristic of a system that describes its potential to be harmed. Vulnerability comprises:
  - → Susceptibility – is the propensity of a particular receptor to response. This describes the nature of the response caused in objective terms (for example, material destruction – a carpet maybe destroyed – to loss of a particular flora or fauna, human death or injury etc)
  - → Value – which externalises a society's normative value system by attributing value to the response; objective response becomes 'harm'.

Some receptors, such as residential properties, can be considered "static", whereas receptors such as people and cars may be "dynamic", and may or may not be present at the time of a flood. This may reflect actions taken to evacuate or simply due to the time of day the flood occurs (rush hour, night time etc). Dynamic behaviour can change the chance of a receptor being present and hence the exposure to a flood. Often receptors can initiate secondary sources of risk. For example, pollutants may be released from a flooded sewerage works (leading to public health issues), water supply maybe disrupted, roadways blocked etc. More elaborate methods are emerging that can deal with these interactions, which, however, are not considered here (Tapsell, 2008).

Both exposure and vulnerability can have a seasonal element, for example, for damages associated with agriculture or tourism. The valuation of flood damages has been examined in FLOODsite Task 9, which has provided guidance on the assessment of flood damages across Europe (Messner et al, 2007).

Moving from flood defence to flood risk management

The change in practice from flood defence firstly to flood management and then to flood risk management has been documented elsewhere, for example by Samuels *et al.* (2006) and Klijn *et al.* (2008). Flood Risk Management is now embedded in many policy documents across Europe and further afield. The definition of Flood Risk Management adopted in FLOODsite is a process of "holistic and continuous societal analysis, evaluation and reduction of flood risk" (Schanze, 2006). The intended outcome above of "reduction of flood risk" is consistent with the aim of the framework established by the Floods Directive and the implementation of its flood risk management plans. Flood risk management involves many actors each with their own perspectives, objectives and priorities; hence the process of flood risk management depends upon the governance structures in place.

The interpretation of the simple relationship of "risk" as a combination of probability and consequence is more complex and powerful than first appears. A detailed consideration of the elements that make up "risk" enables a more subtle and useful understanding of the drivers of risk to be developed. In particular, although current approaches seek to support "risk-based" and "sustainable" decision making they are often limited in their consideration of the sources, pathways and consequences of flooding and often fail to integrate within broader spatial planning and social policies. "Risks" are also typically evaluated in deterministic terms with limited effort being devoted to understanding uncertainty, a position counter to the needs of robust decision making.

The stated desire for integration belies dissatisfaction in the current paradigm and the lack of integration or commonality of approach within current flood risk management practice. To make a significant step towards improving our approach to the analysis, evaluation and reduction of risk, which actively supports the broader goal of sustainable development (by providing effective and efficient multi-functional solutions), will not be easy.

A COMPREHENSIVE VIEW OF RISK, ITS ANALYSIS AND ITS MANAGEMENT

By the end of FLOODsite several aspects of understanding risk emerged. These included

- Risk can only be fully analysed by taking a systems approach
- Risk analysis methods used should depend upon the scale of the decisions to be made
- Risk cannot be fully determined and the uncertainty should be explored;
- Risk is also a normative concept with many societal dimensions

Systems based analysis of risk

A full understanding of risk requires a systems-based approach, with the complexity of the system description tuned to the scale of analysis and the context and type of decision. The systems approach considers all (or the "important") sources of flooding, the pathways that flooding may take, exposure of people and property to the flooding, and, the consequences, when analysing the risk at a specific location or over a given spatial extent. For example, flooding may arise from an embankment being over topped in a flood whose severity exceeds the design or through the structural failure of the defence for some less severe loading. Infrastructure failure can be triggered by other causes, for example loss of power to a pumping station. The systems approach relies on the identification of the range of possibilities for the cause of flooding and an assessment of the likelihood of those conditions arising. The RASP methodology used extensively in UK practice (Gouldby *et al,* 2008) is one example of a systems approach and this was the basis of the Thames pilot studies in FLOODsite. Other aspects of flood risk management, e.g. flood warning, rely on other technical and institutional systems for their effectiveness. A systems approach is the prerequisite for analysing the individual and synergetic effectiveness of flood risk management measures to enable the development of a robust and comprehensive flood risk management strategy, which meets the desired performance

Scale of decision and assessment

Flood risk management decisions are made at a variety of scales – from whole basin scale planning as is espoused by the European Floods Directive to local decisions applicable to specific assets or communities. The decisions at the different scales may be directed by nested national, regional and local spatial planning policy or set within some other legal or regulatory context. The use of different methods for different decision scales was illustrated through several of the FLOODsite pilot studies (Schanze *et al*., 2010).

Embracing uncertainty

Until about the 1990's a deterministic approach was usually taken to the design of flood defences. A defence level or capacity was set from an analysis of the hydrometeorological loading and often some factors of safety allowed through additional freeboard. The defence was assumed to be effective or fail according to whether the loading was less than or greater than the design level. A degree of uncertainty was recognised in the statistical assessment of the hydrometeorological extremes from data, but the performance of the defence was assumed to be "as designed". Allowing for the probability of failure of one or more elements of defence infrastructure at less than the design loading or continued performance above the design loading alters the assessment of flood risk. Likewise a failure at one location will not just influence flooding in its immediate neighbourhood but will have a broader sphere of influence. The effect of these factors can be included in a stochastic approach to risk assessment. Similarly, there is uncertainty about the future loading and performance of flood defences and of the socio-economic conditions that determine the damage potential in the face of climatic, environmental, demographic and economic change. Decision making thus must embrace severe fundamental uncertainty in the conditions under which structural and non-structural flood risk management measures and instruments will have to operate over their life-time. This implies a need for appraisal methods to evolve with increasing information becoming available and for the stakeholders in the decision process to take up and implement these changes.

Societal dimensions of flood risk and its management

Floods only cause harm (itself a human valuation) and, therefore pose risk, where flooding conflicts with human activity on, or some valuation of, the land affected; hence FLOODsite contained an important component of social science research. The management of flood risk requires policies for the use of land, decisions and choices on the mobilisation of resources, negotiation between stakeholders, dissemination of information, influencing behaviour etc. The technical aspects of the design, construction and maintenance of flood defences are embedded in this broader context. Within FLOODsite, the societal dimensions of risk were explored through several tasks covering

- socio-economic damages resulting from floods at coastal and in riverine and estuarine areas;
- so-called intangibles (loss of life, ecological impact)
- a method for assessing multiple risk categories;
- risk perception, community behaviour, and social resilience
- design of flood risk management strategies
- methods for appraisal of strategic alternatives
- engagement of stakeholders in flood risk management appraisals

This research illustrated the complexity of flood risk management as a process that involves many actors, with differing perceptions and objectives. Moreover, technocratic top-down approaches tend to dominate in flood risk management and the research on public perception of risk showed residents judged that “technicians” are the most influential actors in decision processes. Most of those surveyed did not feel involved in the decision processes and tended to delegate responsibility to agencies in charge of flood prevention and mitigation. Thus, precautionary measures and flood defence are primarily regarded as the domain of public institutions rather than as a co-responsibility of the individuals affected.

INTEGRATED FLOOD RISK MANAGEMENT

The way ahead

We argue that the focus of practice should be on Integrated Flood Risk Management or IFRM. To make progress towards IFRM refinement of the approach to all aspects of the processes will be required, including:

- Risk analysis - including hazard definition; whole system model integration; software integration; the identification and handling of uncertainty.
- Risk evaluation - including normative perspectives; multi-criteria assessment; acceptability and tolerability; disciplinary integration; the use of future change scenarios.
- Risk management - the development of strategic alternatives; the assessment of their sustainability through consideration of robustness and flexibility to support planning; implementation of measures plus their monitoring and resourcing.

There are several examples of where IFRM is starting to influence practice. These include the integration of international policy (e.g. recognizing the importance of flood risk and flood risk management plans through the Floods Directive), the increasingly integrated national policy guidance (e.g. Making Space for Water in the UK) and the use of hierarchical planning processes – from national scale (e.g. Foresight future flooding in the UK) through to some of the FLOODsite pilots at regional scale (e.g. the Schelde, Netherlands and the Thames, UK) and onto local management planning (e.g. German Bight) to bridge the gap between policy and action. The challenges of achieving IFRM in practice cannot be underestimated. It will depend upon improved and more efficient tools and techniques (providing improved functionality to explore risk and a richer, more useful and useable evidence on risk). It will also crucially depend upon the common desire across all stakeholders (policy makers, regulators and practitioners) to change working practices and integrate the knowledge and understanding now available.

The scope of integration

Integrated Flood Risk Management is a critical extension to the notion of Flood Risk Management. In this context we assert that “integration” incorporates three key factors:

1. **Integration of interventions in space:** this is achieved through analysing and adopting a portfolio of interventions across the sources, pathways and receptors of floods
2. **Integration of actions in time:** this is achieved as a continuous process of assessing and adapting the portfolio of interventions through time including the renewal, upgrading or abandonment of infrastructure and through planning maintenance of all elements of defence systems over their life-cycle.
3. **Integration across sectors and actors:** this is achieved through embedding flood risk management into a broad view of the socio-economic and environmental systems that can determine the objectives of, or be influenced by, flood risk management activities.

This notion of integration implies that skills and understanding are needed to achieve the multi-dimensional objectives, bringing with it the need for cross-disciplinary communication and interaction with many technologists, professionals and the representatives of the stakeholders.

Characteristics of Integrated Flood Risk Management

From the above, it is clear the IFRM is distinct from the primarily reactive approaches that have often characterised traditional flood defence and the often sectorial context of current flood risk management approaches. Thus we propose, from the scope of integration described above, that the characteristics of the IFRM are to:

1. Reduce the likelihood of flooding – acting to reduce the frequency, speed, depth or duration of flooding (this could be through local or remote measures).
2. Reduce the harmful consequences of any flood that may occur by reducing the potential exposure to flooding (through the removal of property from the floodplain for example) or by reducing the vulnerability (through flood proofing critical assets, aiding individuals and organisations to act wisely during the flood to alleviate harm and promote faster recovery).
3. Support sustainable economic growth by providing space for prudent economic development to maintain robust local and national economies.
4. Support good ecological functioning through ensuring that any modifications of the natural processes of coasts, rivers and surface drainage systems enhance ecological potential and avoid adverse impacts.
5. Promote sustainable development by embedding the policy and practice of flood risk management within broader sustainability objectives by enhancing the robustness and ensuring the adaptability of flood risk management policies and strategies.

In simple terms, the first characteristic above maps onto the historic approach of flood defence with flood risk management being the result of also fulfilling the second characteristic. Fully integrated flood risk management however, couples flood risk management into its broader social, economic, ecological and political context, as a component of achieving a route for sustainable development which will enable future generations to have choice in meeting their flood risk management needs. It is clear that with these characteristics, IFRM is closely allied to Integrated Water Resource Management (IWRM). IWRM is understood by Gouldby *et al.* (2009), as a process which promotes the co-ordinated management and development of water, land and related resources, in order to maximise the resultant economic and social welfare in an equitable manner without compromising the integrity of ecosystems.

EXAMPLES FROM FLOODSITE

The FLOODsite research provides some examples of tools and techniques that will support IFRM in practice. These can be accessed from the FLOODsite website www.floodsite.net. They comprise a variety of tools and guidance, such as:

- Methods to assess the morphological response of coasts and rivers from Task 5
- Tools to assess the reliability of flood defence infrastructure from Task 7
- Guidelines on economic assessment of flood damage from Task 9
- A multi-criteria analysis methodology for evaluating flood risk from Task 10
- Guidance on the social impacts of floods on communities from Task 11
- A series of case studies and recommendations on strategies for pre-flood risk management from Task 13
- A method for appraisal of strategic alternatives for flood risk management to promote sustainability from Task 14
- Frameworks for decision support for long-term planning (Task 18) and flood event management (Task 19)
- Frameworks for uncertainty assessment (Task 20) consisting of a conceptual framework; a software framework for flood risk calculation and computational decision support (Reframe); a method for modelling errors in forecasting situations (UNEEC) and new methods for robust decision-making under severe uncertainty.
- The FLOODsite guidelines on flood risk assessment and flood risk management from Task 29.

The applicability of many of these tools and techniques was tried in regional pilots all over Europe at different spatial scales from small flash-flood catchments (Task 23) to the entire Elbe-basin. The Elbe Pilot (Task 21) itself operated at scales from detailed land-use studies of water retention in a tributary's upper basin of less than 1000 km^2 through to basin-scale scenario analyses for the 150,000 km^2 international basin in collaboration with the VERIS-ELBE project. The Thames and Schelde pilots (Tasks 24 and 25) both worked at a sub-basin scale on issues concerned with long term planning and sustainability, whereas the German Bight (Task 27) examined flood risk management in detail for an area of 60 km^2 only.

CONCLUSIONS

The societal response to flooding has evolved in recent years from provision of defences to policies and practice for flood risk management. This change in approach is still to achieve full public acceptance; Steinführer *et al* (2008) document that many people still delegate responsibility for safety to public authorities, rather than accepting their own rôle in risk management. Nevertheless further evolution of policy and practice is needed to achieve Integrated Flood Risk Management which will support sustainable development by providing a balance between risks, the whole cost and impact of mitigation, economic development and the functioning of vital ecosystems. Clearly this is a demanding aim which will require communication, understanding and cooperation between many technical and professional groups as well as with the broader public. FLOODsite has provided examples that show how currently available methods and tools can support IFRM within the context of flood risk management planning as required by the EC Floods Directive. The challenge for policy-makers and practitioners in flood risk management is now to exploit the knowledge and understanding from research (such as FLOODsite) through implementation and uptake into IFRM within their own national context.

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