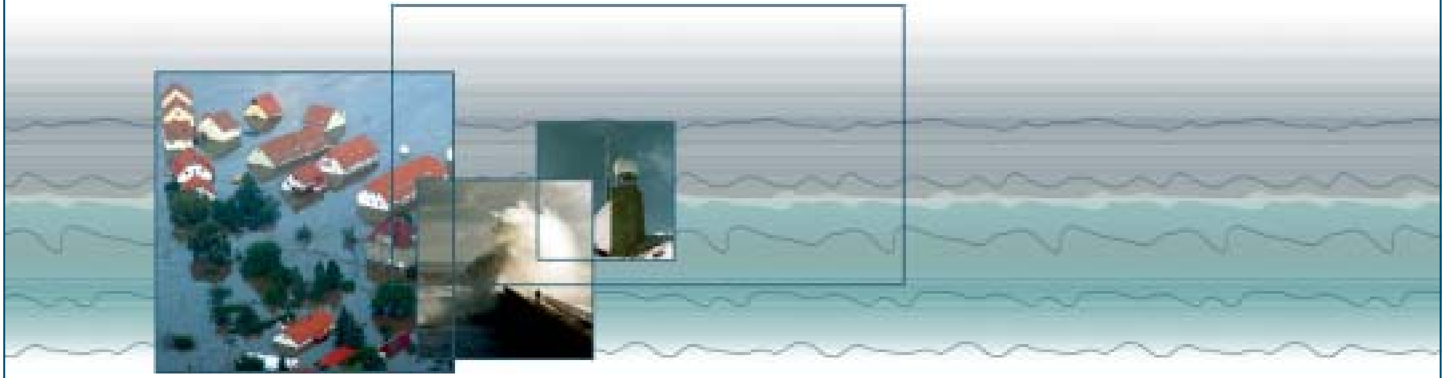
Integrated Flood Risk Analysis
and Management Methodologies



Language of Risk

PROJECT DEFINITIONS

March 2005

Report: T32-04-01

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- References

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SUMMARY

This document provides an overview of the concepts of flood risk management and uncertainty to be used in the **FLOOD*site*** project and includes definitions of various terms.

The discussion provided builds upon a **FLOOD*site*** workshop in July 2004 and subsequent discussions within the project team and experience and references from past international and national studies have been incorporated into the text.

This report now provides the definitions of terms and concepts in the language of risk for use in the context of the Integrated Project **FLOODsite** on flood risk management.

This report represents deliverable number D32.2 and forms part of Theme 6, Task 32.

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1. Introduction

1.1 Terms of reference

The description of Task 32 of the **FLOOD*site*** project states:

> "*The definition of the common terminology will be undertaken at the outset. This is seen as a particularly important component of the project harmonisation, given the different uses of technical terms within the broad risk assessment industry. There is a need to agree precise definitions in English of the project concepts, so that Partners can establish the correct sense in other European languages. This activity will therefore develop a common language of risk (including an uncertainty standard, risk terminology etc.) This will be undertaken as follows:*
> - *identify relevant documents from national, EU and non-European sources*
> - *draft a consolidated terminology*
> - *circulate for comment within the* ***FLOODsite*** *consortium and externally in consultation with DG research*
> - *produce final draft from comments received, for use within* ***FLOODsite"***

The current document has been prepared from the discussion at the First project workshop in Brussels on 5-6 July 2004 as a step in this process of negotiating the common language of risk to be used within the project consortium.

1.2 The Risk of Language

In this discussion of the Language of Risk some remarks on the "Risk of Language" are appropriate.

In an Integrated Project like **FLOOD*site*** the links between scientists involved in flood risk management in the EU should be strengthened in a way that can only be achieved by real and intense co-operation. An outcome of the project should be building a transboundary, multidisciplinary network of research groups and "users" that communicate well. This can only be done by improving the understanding between all those involved.

Cultural differences between regions exist in the way issues and scientists from different regions perceive research questions. There is not necessarily a single "best" flood risk management strategy. The perception of issues varies in space and changes in time with changes in understanding and also the societal, administrative and policy contexts in which flood risk management takes place.

In the reality of Flood Risk Management the public perception of measures is no less important than scientific facts on the effectiveness of these measures. Therefore, for studies on the *feasibility* of measures, and on the best way to implement them, co-operation of physicist and ecologists with economists and social scientists is essential. This should be based on agreement on some basic concepts and terms - scientists from different disciplines still, too often, speak different languages.

Moreover, though all participants in **FLOOD*site*** (from the English, Dutch, German, French, Italian, Spanish, Greek, Czech, Hungarian and Swedish language areas) can communicate very well in English, we should be aware of the fact that in their home country they communicate on Flood Risk Management in their own language. From experience with previous projects (e.g. IRMA-SPONGE) it appeared that certain English terms were interpreted differently by people from different countries, and sometimes even by people from the same country with different scientific backgrounds. In fact, interpretation differences also exist within language areas: in some cases it can be difficult to agree on translation of terms for region-specific concepts (e.g. certain measures) into or from Dutch, German, French or whatever language.

Therefore, apart from the Glossary of terminology in English that is given in this Language of Risk report and that the whole of the **FLOOD*site*** team is planning to use throughout the project, we should be aware of the fact that every language has its own "translation", possibly with different notions of these English terms.

To identify these differences, the IRMA-SPONGE programme produced at the end of the project, a Glossary of terms with German, French and Dutch translations. The original IRMA-SPONGE glossary is reproduced in this report in Appendix 2, as an example only. It shows for instance that the Dutch language has three terms that can be translated by the common English term “Flood”.

Such “many to one” correspondence of words in translation will mask the richness of meaning in an original language, thus both the French words “crue” and “inondation” may be translated in English as “flood” which misses out the different scale of the events implied in the native language.

As further illustration we might quote the word “dike” or “dyke”. The first definition in the Oxford English Dictionary for this word in common English usage is for a watercourse. The second definition is for a bank or embankment. However, within English translation of the use of the word from Dutch practice an embankment is meant, not a watercourse, and this usage is becoming standard in many internationally authored documents. In US practice the word “levee” is used (of course, not levée) for a dike or embankment.

Literal translation by non-experts may also be misleading, such as “lit *mineur*” being the “*minor* bed” of a river, which in English technical usage actually means “*main* channel”.

All these examples emphasise not only the need to define the terms (like “Flood”) unambiguously, but also the need to keep in mind that, some of those we communicate with will have another notion when hearing this word due to the “common” translation in the language they use at home.

Given the broad use of technical terms within the risk assessment industry, establishing a common language of risk in the context in flood risk management is an essential aid to communication between European partners on the **FLOOD*site*** Project. However, without being aware of this “Risk of Language” this report on the Language of Risk will not become our common Flood Risk Management Dictionary it is meant to be.

1.3 The Layout of this Document

This document first provides an overview of the concepts of risk and uncertainty to be used in the **FLOOD*site*** project, then includes standard definitions of various terms and finally, for those interested, a more technical discussion is provided in an appendix. In preparing this document we have identified some words which will need particular care in their use and interpretation, as there is scope for misunderstanding the concept between different professional communities or national practices.

2. Process

This document on the Language of Risk has been prepared primarily for use within the project team to facilitate communication between the project partners. Thus we have attempted to achieve a consensus on the terminology and definitions to be used. Where there are differences in language and definition between different research teams and national practice, it is inevitable that by selecting one definition for each term for use within all project tasks and reports some will need to adjust their normal use of terms.

The timetable for the construction of this document was as follows:

- Prepare a first draft from various source documents
- Discuss the draft at the project workshop in July 2004 in group sessions and plenary
- Seek additional comments to September 2004 from within the team and through EU-MEDIN
- Prepare a second draft
- Discuss within the management team in November 2004
- Seek additional comments including discussion in Theme 1.3
- Discuss a further draft at a working team meeting on 18 January 2005
- Prepare final draft in February 2005

In reviewing the contributions of team members on the various drafts we have considered all the points made even if these are not reflected in the final definitions in Sections 4 and 5 of this report. Section 4 of the report presents alternatives considered for some of the definitions of 14 important terms, to assist team members understand the process adopted for the preparation of this document. Section 5 then presents English language definitions which should be used by all team members in discussion and presentation of results from the project for terms in risk analysis and management. Section 6 contains a list of references, further reading and a list of related EC and other research projects.

It is recognised that the members of the project team will have different backgrounds in the concepts of probability, statistics, uncertainty etc. Thus the first Appendix to this document gives introductory information on some key concepts in these areas. The second appendix provides the IRMA-SPONGE project multi-lingual glossary and the third appendix lists the contributions received from the **FLOODsite** project team members.

It is intended that this document should be “living” that is the information it contains may be reviewed, amended and extended as the project progresses. Comments on this document for consideration in future updates should be sent by e-mail to:

floodsite@hrwallingford.co.uk

3. Concepts

3.1 What is risk?

Today, the term “risk’” has a range of meanings and multiple dimensions relating to safety, economic, environmental and social issues. These different meanings often reflect the needs of particular decision-makers and as a result there is no unique specific definition for risk and any attempt to develop one would inevitably satisfy only a proportion of risk managers. Indeed this very adaptability of the concept of risk is one of its strengths. A difficulty with the terminology of “risk” is that it has been developed across a wide range of disciplines and activities, there is therefore potential for misunderstanding in technical terminology associated with risk assessment, since technical distinctions are made between words which in common usage are normally treated as synonyms. Most important is the distinction that is drawn between the words “*hazard”* and “*risk”*.

To understand the linkage between hazard and risk it is useful to consider the commonly adopted Source-Pathway-Receptor-Consequence (S-P-R-C) model (See Figure 3.1).

This is, essentially, a simple conceptual model for representing systems and processes that lead to a particular consequence. For a risk to arise there must be hazard that consists of a 'source' or initiator event (i.e. high rainfall); a 'receptor' (e.g. flood plain properties); and a pathway between the source and the receptor (i.e. flood routes including defences, overland flow or landslide).

A hazard does not automatically lead to a harmful outcome, but identification of a hazard does mean that there is a possibility of harm occurring, with the actual harm depending upon the exposure to the hazard and the characteristics of the receptor.

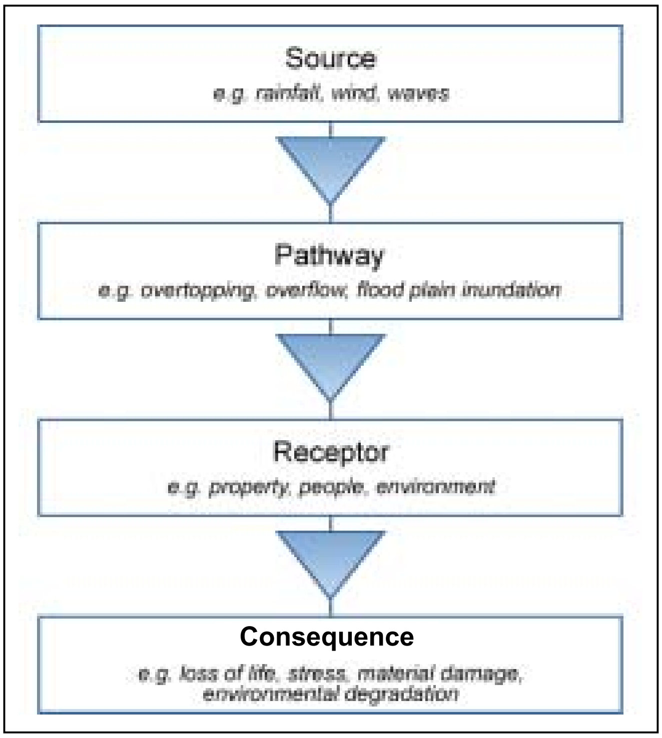

Figure 3.1 Source – Pathway – Receptor-Consequence Conceptual model

Thus, to evaluate the risk, consideration needs to be made of a number of components:

- the nature and probability of the hazard (p)
- the degree of exposure of the *Receptors* (numbers of people and property) to the hazard (e).
- the susceptibility of the *Receptors* to the hazard (s)
- the value of the *Receptors*(v)

Therefore:

Risk = function (p, e, s, v)

In this context vulnerability is a sub-function of risk. The term encompasses the characteristics of a system that describes its potential to be harmed. It can be expressed in terms of all functional relationships between expected damage and system characteristics (susceptibility, value of elements at risk), regarding the whole range of relevant flood hazards. Or, in functional form:

Vulnerability = function (s, v)

In practice, however, exposure and vulnerability are often captured in the assessment of the consequences; thus risk can be viewed in simple terms (with probability understood to be probability of exposure): as

"Risk = (Probability) x (Consequence)"

In terms of flooding, a description of the nature of the hazard will be needed to assess the potential consequences of a flood occurring. The relevant characteristics may include considering the following questions:

- Can the land flood?
- What area is affected?
- What causes the flooding?
- How often does flooding occur?
- How deep is the flooding?
- How rapidly does the flood rise?
- How fast does the water flow?
- How long does the flooding last?
- Can any warning be given?

The degree of flood hazard in an area is often measured by the annual probability of flooding or the return period of the flood which would cause inundation. However, there is a common misconception that once a flood of a given severity, say the 100-year flood (or 1% flood), has occurred then such a flood will not recur for another 100 years. This is false. Floods are random and other factors being unchanged, have the same probability of occurring in any year.

It is important to recognise that flood "risks" are wholly a human or societal concern rather than being an inherent characteristic of the natural system. The mitigation of flood risk can be accomplished through managing any of the hazard, exposure and vulnerability. Broadly speaking, flood hazard may be reduced through engineering or "structural" measures, which alter the frequency (i.e. the probability) of flood levels in an area. The exposure and vulnerability of a community to flood loss can be mitigated by "non-structural" measures, for example, through changing or regulating land use, through flood warning and effective emergency response, and through flood resistant construction techniques.

3.2 What are the units of risk?

In general, risk has units, however, the units of risk depend on how the likelihood and consequence are defined. For example, both the likelihood and consequence may be expressed in a number of equally valid ways. Likelihood can be considered as a general concept that describes how likely a particular event is to occur. Frequency and probability can be used to express likelihood. However, these terms have different meanings and are often confused. It is important to understand the difference between them (further discussion is provided in Appendix 1):

- **Probability** – can be defined as the chance of occurrence of one event compared to the population of all events. Therefore, probability is dimensionless – it is however, often referenced to a specific time frame, for example, as an annual exceedance probability or lifetime exceedance probability.
- **Frequency** - defines the expected number of occurrences of an (particular extreme) event within a specific number of events, often related to a timeframe (in the case of Return Period this is usually expressed in years).
- **Consequence** – represents an impact such as economic, social or environmental damage or improvement, and may be expressed quantitatively (e.g. monetary value), by category (e.g. High, Medium, Low) or descriptively.

Flooding can have many consequences, some of which can be expressed in monetary terms. Consequences can include fatalities, injuries, damage to property or the environment. Consequences of a defence scheme can include environmental harm or benefit, improved public access and many others including reduced risk. The issue of how some of these consequences can be valued continues to be the subject of contemporary research. However, risk-based decision-making would be greatly simplified if common units of consequence could be agreed. It is, therefore, often better to use "surrogate" measures or indicators of consequence for which data are available. For example, 'Number of Properties' may be a reasonable surrogate for the degree of harm / significance of flooding and has the advantage of being easier to evaluate than, for example economic damage or social impact. An important part of the design of a risk assessment method is to decide on how the impacts are to be evaluated. Some descriptions of "consequence" are:

- economic damage (national, community and individual;
- number of people /properties affected;
- harm to individuals (fatalities, injury, stress etc);
- environmental and ecological damage (sometimes expressed in monetary terms)

Clearly these differ in what is described.

3.3 How is the significance of risk perceived?

Intuitively it may be assumed that risks with the same numerical value have equal 'significance' but this is often not the case. On the contrary, numerical values play a marginal role in risk perception, as the term, at least in the traditional approaches to risk perception, refers primarily to everyday processes by which people estimate risks without utilising statistical series and exact computer models. It is therefore a "pre-scientific" process, mostly influenced by believes, attitudes, intuition, expectations, information about and experiences with hazards. For example, the risk perception and, linked to this, the coping capacities of people living in a floodplain with frequent inundation events is probably higher than of those persons who never experienced a flood. However, not only the so-called "layperson", also "experts" perceive risk by referring not exclusively to numerical values.

The institutional setting, power relations, preferences and risk attitudes also have an impact on risk perception and decision behaviour of decision-makers. Thus the primary aim investigating risk perception by means of quantitative and qualitative social science survey techniques is

- to understand and anticipate public responses to hazards,
- to improve the communication of information about the hazard both on the side of laypersons and experts and
- to identify the most relevant criteria to assess risk situations.

On basis of risk perception studies strategies of information and communication can possibly be improved and flood mitigation measures can be better assessed.

3.4 How can the acceptance of risk be studied and measured?

3.4.1 Principles

A central question in risk management refers to the acceptance of risk by the people and the decision-makers. From an engineering point of view a general framework for acceptability criteria has been developed which is based on a three-tier system (Figure 3.2). This involves the definition of the following elements:

(i) an upper-bound on individual or societal risk levels, beyond which risks are deemed unacceptable;
(ii) a lower-bound on individual or societal risk levels, below which risks are deemed not to warrant concern;
(iii) an intermediate region between (i) and (ii) above, where further individual and societal risk reduction are required to achieve a level deemed 'as low as reasonably practicable' (the so-called ALARP principle).

The ALARP method derives from industrial process safety applications and thus is often seen to have an "engineering" rather than "social science" heritage. Although this general framework gives a first impression on how risk acceptance can be approached, it must be stated from a social science point of view that the realms of acceptance and non-acceptance of Figure 3.2 may differ significantly between persons and that a public consensus on risk acceptance may not exist. Furthermore, this framework does not answer the question of how acceptance should be measured. Hence the application of the principle to integrated flood risk management in **FLOODsite** will be the subject of further debate as the project science progresses.

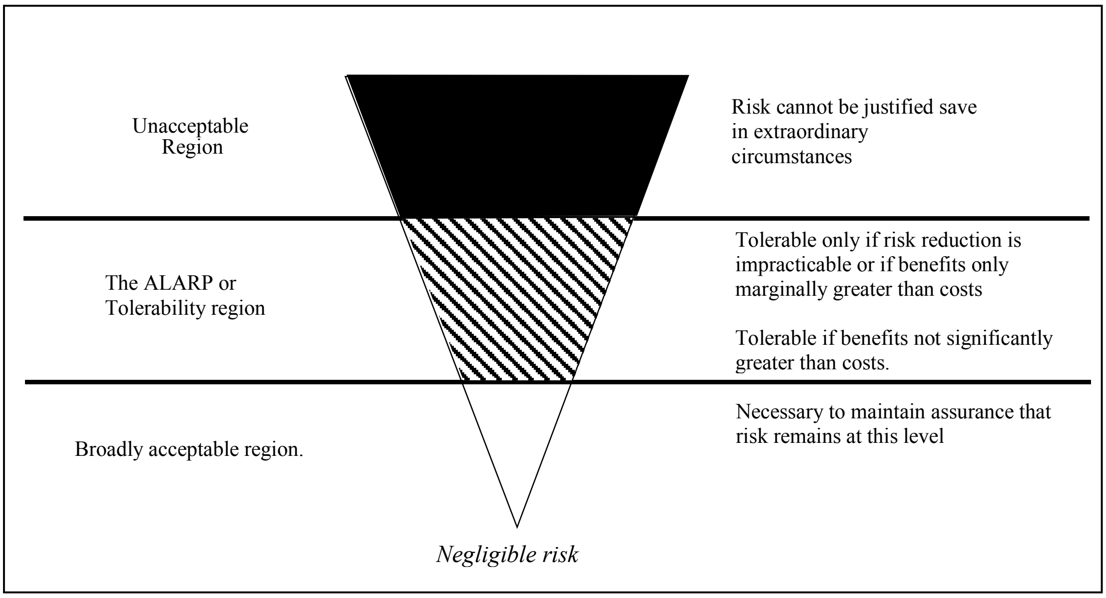

Figure 3.2 Acceptable risk levels and the ALARP principle

Concerning the analysis and assessment of risk situations in the social sciences four major approaches are to be mentioned. They are

(1) analysis of revealed preferences,

(2) analysis of expressed preferences,

(3) cost-benefit analysis and

(4) multi-criteria analysis

3.4.2 Analysis of revealed preferences.

This approach is based on the assumption that society has arrived at a certain optimal balance between risks and benefits attributed to an activity. It is therefore assumed that it is possible to reveal factual patterns of acceptable risk levels by analysing risk behaviour and corresponding economic data. For example, national safety standards of cars, bridges, consumables and the like can be analysed in order to get information about the public acceptance of residual risk levels and the willingness to pay to invest in safety devices aiming at reducing risk. However, this model is based upon a rather rationalistic model of people, neglecting the context and power relations defining people's decisions. It further assumes that risk acceptance is similar in different realms of life and thus risk acceptance levels of one type of risk can be derived from another risk type. However, as several studies showed, risk acceptance levels of different risk areas vary significantly and depend on the type of risk.

3.4.3 Analysis of expressed preferences.

This approach focuses directly on what people express as preferred standard of safety by asking them about acceptable levels of risk regarding a specific risk situation. The advantages of this direct approach seems obvious: data problems and uncertainties, which are usually part of revealed preference analyses can be prevented and risk levels are directly analysed for the risk situation in question. However, this approach can be criticised for its assumption that laypeople can handle appropriately rather complex questions of risky activities. Moreover, demanding a specific safety standard does not mean that people are also willing to pay for higher standards. And even direct questions on their willingness to pay to reduce risk are still hypothetical and do not reproduce real life situations. Choosing a proper design of investigation in order to reduce complexity and uncertainty as well as considering the context of questioning people on their preferences are therefore the most challenging tasks of this direct method.

3.4.4 Cost-benefit analysis

Central for this traditional economic approach is the question whether the expected benefits of a specific risk reducing activity (needed to achieve a safety level) outweigh its expected costs. Cost-benefit analysis requires a holistic analysis of all benefits and costs involved in order to assess a risk reducing activity in comparison to its net benefit. A distinguishing feature of this approach is that is does not aim at identifying commonly accepted risk levels, but may result in recommendations to implement different safety standards for different risk situations, depending on the specific risk and the costs involved to reduce it. The major and often criticised shortcoming of this approach concerns the fact that all benefits and costs are quantified in monetary terms and aggregated to a single number without the possibility to give certain risks a larger weight.

3.4.5 Multi-criteria analysis

This approach is similar to cost-benefit analysis regarding the overall aim to execute a holistic analysis in order to identify and, if possible, to quantify all benefits and costs of risk-reducing activities. However, multi-criteria analysis presents the opportunity to measure the consequences of an activity in terms of different units and to leave the final weighting of criteria to the decision-makers or to a stakeholder meeting. Mathematical algorithms are then used to determine the most favourable risk-reducing activity in the context of different risk perceptions, risk attitudes and preferences of decision-makers and stakeholders. The results are then passed back and discussed within the political process in order to support the finding of the most appropriate risk-reducing activities.

Since cost-benefit analysis and multi-criteria analysis are the most appropriate methods in the context of flood risk management they are used in **FLOOD*site.***

3.5 How is risk managed?

The risk management model used within the **FLOOD*site*** project adopts concepts from the RIBAMOD principles for the comprehensive management of floods (originally defined at the river basin scale but also applicable to estuaries and coasts). The mitigation of flood damage and loss does not only depend upon the actions during floods but is a combination of pre-flood preparedness, operational flood management and post-flood reconstruction and review. In the context of river basin flooding, Kundzewicz and Samuels (1997) describe the RIBAMOD principles of comprehensive flood management to comprise:

Pre-flood activities which include:

- *flood risk management* for all causes of flooding
- *disaster contingency planning* to establish evacuation routes, critical decision thresholds, public service and infrastructure requirements for emergency operations etc.
- *construction of flood defence infrastructure,* both physical defences and implementation of forecasting and warning systems,
- *maintenance of flood defence infrastructure*
- *land-use planning and management* within the whole catchment,
- *discouragement of inappropriate development* within the flood plains, and
- *public communication and education* of flood risk and actions to take in a flood emergency.

Operational flood management which can be considered as a sequence of four activities:

- *detection* of the likelihood of a flood forming (hydro-meteorology),
- *forecasting* of future river flow conditions from the hydro-meteorological observations,
- *warning* issued to the appropriate authorities and the public on the extent, severity and timing of the flood, and
- *response* to the emergency by the public and the authorities.

The post-flood activities may include (depending upon the severity of the event):

- *relief* for the immediate needs of those affected by the disaster,

- *reconstruction* of damaged buildings, infrastructure and flood defences,
- *recovery and regeneration* of the environment and the economic activities in the flooded area, and
- *review* of the flood management activities to improve the process and planning for future events in the area affected and more generally, elsewhere.

Thus the management of flood risks needs to be approached in practice on several fronts, with appropriate institutional arrangements made to deliver the agreed standard of service to the community at risk. These institutional arrangements differ within the EU according to national legislation and public tolerance of flood risks and some of the differences in approach were evident in the papers and discussions, particularly at the First **FLOODsite** Workshop (July 2004). To deliver this comprehensive flood management in practice will require the collaboration of professionals in several disciplines. In many countries these professionals are engaged predominately in the Public Sector, since river basin, estuary and coastal zone regulation and management is usually the responsibility of national or local government departments, agencies and authorities.

3.6 What is uncertainty?

In flood risk management there is often considerable difficulty in determining the probability and consequences of important types of event. Most engineering failures arise from a complex and often unique combination of events and thus statistical information on their probability and consequence may be scarce or unavailable. Under these circumstances the engineer[1] has to resort to models and expert judgement. Models will inevitably be an incomplete representation of the "real" system and so will generate results that are inherently uncertain. Similarly, human expert judgement is subjective and inherently uncertain as it is based on mental models and personal experience, understanding and belief about a situation. Thus in practice every measure of risk has uncertainty associated with it.

3.6.1 Uncertainty in Science and Technology

In the context of science and technology, uncertainty arises principally from lack of knowledge or of ability to measure or to calculate and gives rise to potential differences between assessment of some factor and its "true" value. Understanding this uncertainty within our predictions and decisions is at the heart of understanding risk. Within uncertainty we are able to identify:

- **knowledge uncertainty** arising from our lack of knowledge of the behaviour of the physical world. This is also referred to as: epistemic, functional, internal, or subjective uncertainty or as incompleteness
- **natural variability** arising from the inherent variability of the real world. This is also referred to as: aleatory, external, inherent, objective, random, stochastic, irreducible, fundamental, or "real world" uncertainty
- **decision uncertainty** reflecting complexity in social and organisational values and objectives.

The uncertainties in simulation modelling as used in flood risk management are principally due to natural variability and knowledge uncertainty. There are a number of contributors to these uncertainties that can be considered separately, HR Wallingford (2002). However, this classification is not rigid or unique. For example, uncertainty on weather or climate will be taken as "natural variability" within flood risk management but as "knowledge uncertainty" in the context of climate simulation.

It is important to recognise the differences between accuracy, precision, error and uncertainty. Accuracy precision and error differ from uncertainty as defined above but limitations in accuracy, precision or the possibility for human error will contribute to the overall uncertainty.

- **Accuracy** – can be defined as the closeness to reality. For example, "the crest level of a flood defence is between 3m and 4m above datum", is an accurate statement for a defence crest level of 3.5m above datum.

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[1] By "engineer" we include all professionals involved in making decisions related to the management of flood risk whether or not they are Registered or Chartered Engineers.

- **Precision** – can be regarded as the degree of exactness, regardless of accuracy. For example, “the crest level of a defence is 2.456m above datum”, is a precise statement. If however, the crest level is actually 3.5m above datum, the statement is not accurate.
- **Errors** – are mistaken calculations or measurements with quantifiable and predictable differences, such as errors within datum measurements.

3.6.2 Uncertainty in a Social Science context

The following concepts were identified within the project team working within **FLOODsite** Theme 1.3 - Vulnerability

Issue	Discussion
Ignorance	This includes all the different sorts of gaps in our knowledge which cannot be addressed (or even recognised) within the present status of knowledge and understanding. This ignorance may merely be of what is significant, such as when anomalies in experiments are discounted or neglected, or it may be deeper, as is appreciated retrospectively when revolutionary new advances are made.
Indeterminacy	This is a category of uncertainty which refers to the open-endedness (both social and natural) in the processes of environmental damage caused by human intervention. It applies to processes where the outcome cannot (or only partly) be determined from the input. Indeterminacy introduces the idea that contingent social behaviour also has to be included in the analytical and prescriptive framework. It acknowledges the fact that many knowledge claims are not fully determined by empirical observations but are based on a mixture of observation and interpretation
Institutional uncertainty	This refers to inadequate collaboration and/or trust among institutions (agencies in particular), due to poor communication, lack of understanding, overall bureaucratic culture, conflicting sub-cultures, traditions and missions.
Legal uncertainty	This refers to the possibility of future liability for actions or inactions. The absence of undisputed legal norms strongly affects the relevant actors’ decisions.
Proprietary uncertainty	This indicates contested rights to know, to warn or to secrete. In both risk assessment and management, there are often considerations about the rights of different people to know, to warn or to conceal.
Scientific uncertainty	This emanates from the scientific and technical dimensions of a problem (lack of scientific data, measures, instruments, models, explanations, etc.). It is intrinsic to the processes of risk assessment and forecasting. See Section 3.5.1 above
Situational uncertainty	This is the result of different kinds of uncertainties, scientific as well as other (legal, institutional, proprietary). It describes the predicament of a decision-maker, be it in the phase of risk appraisal or management. Situational uncertainty ultimately refers to inadequacy of available information in relation to necessary decisions.

3.6.3 Uncertainty and decisions

Consideration of uncertainty within the decision process attempts to provide bounds to our lack of sureness and thereby provides the decision-maker with additional information on which to base a decision. Through investigation of the sources of uncertainty, this type of analysis enables the engineer or decision-maker to identify the uncertainties that most influence the final outcome and focus resources efficiently. By understanding the sources and importance of uncertainty within our decisions, we should be able to make better and more informed choices.

3.7 Expressing uncertainties

Uncertainties can be expressed in several ways, both qualitative and quantitative:

- *Deliberate vagueness* – 'There is a high chance of breaching'
- *Ranking without quantifying* – 'Option A is safer than Option B'
- *Stating possible outcomes without stating likelihoods* – 'It is possible the embankment will breach'
- *Probabilities of events or outcomes* – 'There is a 10% chance of breaching'
- *Range of variables and parameters* – 'The design flow rate is 100 cumecs +/- 10%'. These can be expressed as probability distributions
- *Confidence intervals* – 'There is a 95% chance that the design flow rate lies between 90 and 110 cumecs'.
- *Probability distributions*. Can be subjective or 'measured' (See Appendix 1)

3.8 Effect of uncertainty on management decisions

A separate issue on uncertainty is the tolerability of uncertainty in the end use of technical assessments of flood risk. It is possible that for some uses a greater degree of uncertainty is permissible enabling simpler methods to be used, less field data to be gathered or less intensive calibration of the parameters. Hence, there should be an assessment of the sensitivity of the use of information to uncertainties in the results; this will facilitate the identification of the return on investment of effort and resources in reducing uncertainty in estimation or assessment procedures in different contexts.

The effects of uncertainty in the estimation of the capacity of flood defence infrastructure differ with the various processes undertaken by the flood management authority (see for example Samuels *et al* 2002). The sensitivity of decisions to uncertainty in estimation or assessment procedures needs to be established as strategic decisions made early in the project life cycle can have far reaching consequences but it is at this early stage that uncertainties in information and data are greatest.

There is a close relationship between uncertainty and risk in that the greater the uncertainty the greater the probability of the project or maintenance activity of not achieving its objective. This is linked to the confidence on the performance of the scheme or process to meet its intended objectives. Thus, optimisation of performance and the confidence with which performance can be delivered is linked inexorably with understanding and controlling uncertainty.

When faced with uncertainty arising from a risk assessment process there are protocols for decision making that can be adopted. For example, the *Precautionary Principle* is a widely recognised approach. The underlying concepts of which include:

- **Proportionality** of response or cost effectiveness of margins of error to show that the effective degree of restraint is not unduly costly. This can be implemented within benefit cost analysis whereby part of the valuation benefit is the avoidance of risk by playing safe.

- **Preventative** anticipation to take action in advance of scientific uncertainty or acceptable evidence.

- **Consistency of measures**. Adopted measures should be comparable with measures used in similar circumstances.

- **Burden of proof** is focused on those who propose change rather than those effected by the change.

The *Precautionary Principle* does not seek to dictate a decision but enables a decision to be made when faced with significant uncertainties through adoption of a common protocol.

4. Key definitions and discussion

The definitions below have been ordered in a sequence from description of hazard through to risk in general, to flood risks and their management and to sustainability

4.1 Hazard

A potentially damaging physical event, phenomenon or human activity that may cause the loss of life or injury, property damage, social and economic disruption or environmental degradation.

ISDR (2004)

The probability of occurrence of a potentially damaging phenomenon

ITC (2004)

Potential source of harm

ISO/EC (1999)

Situation with the potential to cause harm. A hazard does not necessarily lead to harm.

HR Wallingford (2002)

Recommendation: A physical event, phenomenon or human activity with the potential to result in harm. A hazard does not necessarily lead to harm.

Rationale: It is recognised that hazards can stem from a multitude of sources, it is however clear that a occurrence of a hazard does not always lead to harm.

4.2 Vulnerability

The conditions determined by physical, social, economic, and environmental factors or processes, which increase the susceptibility of a community to the impact of hazards.

ISDR (2004)

The potential for a receptor to be harmed

Green (2004)

The degree of loss resulting from the occurrence of a phenomenon

ITC (2004)

Inherent characteristics of a system that create the potential for harm but are independent of the probability of any particular hazard or extreme event

Sarewitz et al (2003)

*Susceptibility * value*

Klijn (2004)

Refers to the resilience of a particular group, people, property and the environment, and their ability to respond to a hazardous condition. For example, elderly people may be less able to evacuate in the event of a rapid flood than young people.

HR Wallingford (2002)

The amount of potential damage caused to a system by a particular-related event or hazard.

Jones and Boer *(2003)*

The degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate vulnerability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity.

IPCC (2001) Climate change 2001: Impacts, Adaptation and Vulnerability, Summary for Policymakers, WMO.

Recommendation: Characteristic of a system that describes its potential to be harmed. This can be considered as a combination of susceptibility and value.

Rationale: There are a number of conflicting definitions for vulnerability, the overriding theme however, relates to the system characteristics (people, property etc.) that have the potential to be harmed (by a hazard). The "multiplication" of susceptibility by value proposed by Klijn (2004) is too prescriptive, whereas the proposed definition as a "combination" allows flexibility in the descriptions of susceptibility and of value in non-monetary terms.

4.3 Risk

Hazard(exposure)*vulnerability*

Probability(exposure)*consequence*

Klijn (2004)

Combination of the probability of occurrence of harm and the severity of that harm

ISO/EC (1999)

The probability of harmful consequences, or expected losses (deaths, injuries, property, livelihoods, economic activity disrupted or environment damaged) resulting from interactions between natural or human-induced hazards and vulnerable conditions

ISO/EC (2002)

*Impact of hazard * Elements at risk *Vulnerability of elements at risk*

(Blong, 1996, citing UNESCO)

'Risk' is the probability of a loss, and this depends on three elements, hazard, vulnerability and exposure". If any of these three elements in risk increases or decreases, then risk increases or decreases respectively.

(Crichton, 1999)

*Risk = Hazard *Vulnerability ′Value (of the threatened area) ¸ Preparedness*

(De La Cruz-Reyna, 1996)

"Risk (i.e. 'total risk') means the expected number of lives lost, persons injured, damage to property and disruption of economic activity due to a particular natural phenomenon, and consequently the product of specific risk and elements at risk.

*Total risk can be expressed in pseudo-mathematical form as: Risk(total) = Hazard * Elements at Risk *Vulnerability*

(Granger *et al*., 1999)

*Risk = Probability *Consequences*

(Helm, 1996)

"*Risk is a combination of the chance of a particular event, with the impact that the event would cause if it occurred. Risk therefore has two components – the chance (or probability) of an event occurring and the impact (or consequence) associated with that event. The consequence of an event may be either desirable or undesirable…In some, but not all cases, therefore a convenient single measure of the importance of a risk is given by: Risk = Probability × Consequence.*"

(HR Wallingford, 2002)

"*Risk is the actual exposure of something of human value to a hazard and is often regarded as the combination of probability and loss".*

(Smith 1996)

"Risk might be defined simply as the probability of the occurrence of an undesired event [but] be better described as the probability of a hazard contributing to a potential disaster…importantly, it involves consideration of vulnerability to the hazard".

(Stenchion 1997)

Risk is "Expected losses (of lives, persons injured, property damaged, and economic activity disrupted) due to a particular hazard for a given area and reference period. Based on mathematical calculations, risk is the product of hazard and vulnerability".

(UN DHA, 1992)

Risk is a function of probability, exposure and vulnerability. Often, in practice, exposure is incorporated in the assessment of consequences, therefore, for the purposes of this document risk can be considered as having two components — the probability that an event will occur and the impact (or *consequence)* associated with that event.

Recommendation: Probability multiplied by consequence.

Rationale: In general terms, there are two primary sources for a risk definition. These depend on the use of hazard and vulnerability, or probability and consequence. Given the significant differences regarding the definitions of the word "vulnerability" and thus potential confusion, as discussed above, the latter of the two sources, which is itself in widespread use, is preferred.

NB: Some of these definitions of risk and their references, were noted in an article by Ilan Kelman on the Floodrisknet website (http://www.floodrisknet.org.uk/newsletters/2003-1/defining_risk)

4.4 Exposure

Refers to people, assets and activities, threatened or potentially threatened by a hazard

Green et al (2004)

Recommendation: 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.).

Rationale: It is important to note that exposure typically refers to quantities of receptors, hence a more specific definition is preferred.

4.5 Consequence

The direct effect of an event, incident or accident. It is expressed as a health effect (e.g., death, injury, exposure), property loss, environmental effect, evacuation, or quantity spilled.

OHMS (2005)

An impact such as economic, social or environmental damage/improvement that may result from a flood. May be expressed quantitatively (e.g. monetary value), by category (e.g. High, Medium, Low) or descriptively.

HR Wallingford (2002)

Exposure multiplied by vulnerability.

Klijn (2004)

Recommendation: An impact such as economic, social or environmental damage/improvement that may result from a flood. May be expressed quantitatively (e.g. monetary value), by category (e.g. High, Medium, Low) or descriptively.

Rationale: OHMS (2005) is specific for hazardous materials, whilst Klijn (2004) encompasses terms that has the potential to be misinterpreted, in particular the term vulnerability. HR Wallingford (2002) is therefore preferred.

4.6 Flood

Temporary covering of land by water as a result of surface waters (still or flowing) escaping from their normal confines or as a result of heavy precipitation.
(Munich Re - 1997)

Flooding is a natural and recurring event for a river or stream. Statistically, streams will equal or exceed the mean annual flood once every 2.33 years.

This definition is attributed to Leopold et al. in 1964, (http://www.higginslangley.org/definitions.html) but the original source is not given. However, this is just a statement of the frequency of occurrence of the mean of the annual maximum series of floods, using Generalised Extreme Value statistics.

Recommendation: A temporary covering of land by water outside its normal confines.

Rationale: In general, flooding is associated with harm and damage and considered an undesirable occurrence, it is important to note this – hence the notion of the water being normally confined. The first definition, however, is specific for precipitation, whereas **FLOOD*site*** is of broader scope.

4.7 Flood Risk Management

Continuous and holistic societal analysis, assessment and mitigation of flood risk

Schanze et al (2005a,b)

According to context, either action taken to mitigate risk, or the complete process of risk assessment, option appraisal and risk mitigation.

HR Wallingford (2002)

Recommendation: Continuous and holistic societal analysis, assessment and mitigation of flood risk.

Rationale: The general output from the **FLOODsite** Project discussion (Schanze et al, 2005) concluded that Flood management can be considered as a comprehensive activity involving, risk analysis and identification and implementation of risk mitigation measures. It was however, acknowledged that many consider management to be a separate process from the analysis process, focussing primarily on decisions and actions regarding mitigation options. Both these definitions are included in HR Wallingford (2002). This could however, cause potential confusion and the definition is proposed of Schanze (2005 a, b).

4.8 Risk Analysis

A methodology to determine the nature and extent of risk by analysing potential hazards and evaluating existing conditions of vulnerability that could pose a potential threat or harm to people, property, livelihoods and the environment on which they depend.

ISDR (2004)

Recommendation: A methodology to objectively determine risk by analysing and combining probabilities and consequences

Rationale: The definition that has been developed for this project is directly related to the definition of risk that is recommended for use in this project.

4.9 Risk Assessment

The **FLOODsite** project team has introduced the specific meaning of this term and it is acknowledged that “Risk Assessment” has widespread and differing usage in many contexts.

Recommendation: Comprises understanding, evaluating and interpreting the perceptions of risk and societal tolerances of risk to inform decisions and actions in the flood risk management process.

Rationale: Discussion at the FLOODsite Management team meeting (18.01.2005) on the Dresden paper (Schanze *et al*, 2005) identified the term "Risk Assessment" to be used within the context of the perception and tolerance of risks from a societal perspective, based on values, experiences and feelings. In the Dresden paper this concept was described as "Risk Evaluation" but the consensus of the discussion was that "Evaluation" possibly conveyed a to narrow sense of numerical calculation. Risk Assessment as described above comprises part of the overall process of flood risk management and is the crucial step where the analysis of risk is interpreted into the appropriate risk management measures.

4.10 Risk Management Measure

This term has been introduced by the **FLOODsite** project team.

Recommendation: An action that is taken to reduce either the probability of flooding or the consequences of flooding or some combination of the two.

Rationale: Discussion at the **FLOODsite** Management team meeting (18.01.2005) on the Dresden paper (Schanze *et al*, 2005) identified the term 'Risk Management Measure' to be used within the context of flood risk management as opposed to "mitigation" in the Dresden paper. Mitigation in its common usage often has too narrow an interpretation of the actions involved whereas "management" without qualification was considered to have too broad an interpretation.

4.11 Scenario

A plausible description of how the future may develop, based on a coherent and internally consistent set of assumptions about key relationships and driving forces (e.g., rate of technology changes, prices). Scenarios are neither predictions nor forecasts. The results of scenarios (unlike forecasts) depend on the boundary conditions of the scenario.

Green et al (2004)

Recommendation: A plausible description of a situation, based on a coherent and internally consistent set of assumptions. Scenarios are neither predictions nor forecasts. The results of scenarios (unlike forecasts) depend on the boundary conditions of the scenario*.*

Rationale: The definition of Green et al (2004) has an underlying implication of climate change. Within flood system defence reliability analysis, the term 'scenario' is used to define potential combinations of defence failures under specified loading conditions. The definition of Green et al (2005) has therefore been broadened to encompass the defence reliability aspects.

4.12 Strategy

A strategy is defined as combination of long-term goals, aims, specific targets, technical measures, policy instruments, and process patterns (e.g. participation, intense horizontal communication) which are continuously aligned with the societal context. The societal context comprises economic, social, and political conditions, formal and informal institutions, resources and capabilities.

Pettigrew & Whipp (1991), Volberda (1998)

A strategy is defined as combination of measures and instruments as well as the necessary resources for actions to implement the basic long-term goals of a business organisation

Whipp (2001)

A strategy is a consistent set of measures, aiming to influence developments in a specific way

Hooijer et al. 2004

Recommendation: A strategy is a combination of long-term goals, aims, specific targets, technical measures, policy instruments, and process which are continuously aligned with the societal context.

Rationale**:** Changing from the paradigm of flood protection to flood risk management raises challenging questions of formulating and implementing strategic alternatives within society. In particular strategies to reduce vulnerability and to increase preparedness require a comprehensive understanding of flood risk management.

4.13 Sustainable development

The concept of sustainable development originated in the 1987 “Bruntland Report”. It led to Agenda 21 of the Earth Summit at Rio in 1992 and to international conventions on climate change and biodiversity. These conventions constitute a broadly accepted international framework for development, confirmed through the Rio+10 summit in Johannesburg in 2002. Sustainability is explicitly recited in the Treaties of the European Union agreed at Maastrict in 1992 and Amsterdam in 1998. The classic definition of sustainable development (Brundtland et al, 1987)

> “*is development that meets the needs of the present without compromising the ability of future generations to meet their own needs. It contains within it two key concepts: the concept of "needs", in particular the essential needs of the world's poor, to which overriding priority should be given; and the idea of limitations imposed by the state of technology and social organisation on the environment's ability to meet present and future needs.*”

The World Conservation Union *et al* (1991) gave a complementary definition:

> *“Sustainable development means improving the quality of life while living within the carrying capacity of supporting ecosystems.”*

In the 1999 strategy the **UK Government** (DETR, 1999) describes sustainable development as about “ensuring a better quality of life for everyone, now and for generations to come”; and that achieving it means meeting the following four objectives *at the same time*, in the UK and the world as a whole:

- social progress which recognises the needs of everyone;
- effective protection of the environment;
- prudent use of natural resources; and
- maintenance of high and stable levels of economic growth and employment.

No one of these objectives is more important than another. Although there can be tensions between achieving them, in the long-term success in one is dependent on the others.

Recommendation: Sustainable development meets the needs of the present without compromising the ability of future generations to meet their own needs

Rationale: This shortened version of the Brundtland *et al* (1987) definition quoted above is widely used and an internationally accepted definition.

4.14 Sustainable flood risk management

In a contribution to the discussion on this document, the project team on Task 1.3 described “Sustainable flood risk management” as *Flood risk management undertaken in the context of Integrated Water Resource Management.*

Samuels (2000) suggests sustainable flood defence should involve:

- *ensuring quality of life by reducing flood damages but being prepared for floods*
- *mitigating the impact of flood defence activities on ecological systems at a variety of spatial and temporal scales*
- *the wise use of resources in providing, maintaining and operating flood defence infrastructure*
- *maintaining economic activity (agricultural, industrial, commercial, residential) on the flood plain.*

The IRMA-SPONGE Glossary (Appendix 2) gives a definition of a s*ustainable flood risk management strategy as a strategy which aims to*

A) *be effective in the long term, and*
B) *can be combined (‘integrated’) with other functions - usually summarised as economic, social and ecological development.*

The British government policy – under consultation (Defra, 2004) describes in its vision

"*The concept of sustainable development will be firmly rooted in all flood risk management and coastal erosion decisions and operations. Full account will be taken of the social, environmental and economic pillars of sustainable development, and our arrangements will be transparent enough to allow our customers and stakeholders to perceive that this is the case. Account will also continue to be taken of long-term drivers such as climate change. Decisions will reflect the uncertainty surrounding a number of key drivers and will where appropriate take a precautionary approach. Decisions will be based on the best available evidence and science*."

Recommendation:

Sustainable flood risk management involves:

- ***ensuring quality of life by reducing flood damages but being prepared for floods***
- ***mitigating the impact of risk management measures on ecological systems at a variety of spatial and temporal scales***
- ***the wise use of resources in providing, maintaining and operating infrastructure and risk management measures***
- ***maintaining appropriate economic activity (agricultural, industrial, commercial, residential) on the flood plain.***

Rationale: A definition based on Samuels (2000) should be used rather than one deriving from draft policy discussions in a single EU member state. The IRMA-SPONGE definition is for a "strategy" rather than the activity or process. The definition should be broader than just linking to Integrated Water Resource Management. The word "appropriate" has been added to the final part of the definition to reflect the possibility of different criteria being applied in different countries and at different times. The initial use of "Flood defence" has been broadened to "flood risk management"

5. Glossary

Accuracy - closeness to reality.

Adaptive capacity - Is the ability to plan, prepare for, facilitate, and implement adaptation options. Factors that determine a community adaptive capacity include its economic wealth, its technology and infrastructure, the information, knowledge and skills that it possesses, the nature of its institutions, its commitment to equity, and its social capital.

Aims - The objectives of groups/individuals/organisations involved with a project. The aims are taken to include ethical and aesthetic considerations.

Attenuation (flood peak) - lowering a flood peak (and lengthening its base).

Basin (river) ***(see catchment area) -*** the area from which water runs off to a given river.

Catchment area - the area from which water runs off to a river

Bias - The disposition to distort the significance of the various pieces of information that have to be used.

Characterisation - The process of expressing the observed/predicted behaviour of a system and it's components for optimal use in decision making.

Cognition - The conscious or unconscious process of deriving meaning from sensory data. So 'perceived risk' might be more correctly termed "cognated" risk.

Conditional probability - The likelihood of some event given the prior occurrence of some other event.

Confidence interval - A measure of the degree of (un)certainty of an estimate. Usually presented as a percentage. For example, a confidence level of 95% applied to an upper and lower bound of an estimate indicates there is a 95% chance the estimate lies between the specified bounds. Confidence limits can be calculated for some forms of uncertainty (see knowledge uncertainty), or estimated by an expert (see judgement).

Consequence - An impact such as economic, social or environmental damage/improvement that may result from a flood. May be expressed quantitatively (e.g. monetary value), by category (e.g. High, Medium, Low) or descriptively.

Coping capacity — The means by which people or organisations use available resources and abilities to face adverse consequences that could lead to a disaster.

Correlation - Between two random variables, the correlation is a measure of the extent to which a change in one tends to correspond to a change in the other. One measure of linear dependence is the correlation coefficient p. If variables are independent random variables then p = 0. Values of +1 and -1 correspond to full positive and negative dependence respectively. Note: the existence of some correlation need not imply that the link is one of cause and effect.

Critical element – A system element, the failure of which will lead to the failure of the system.

Damage potential — A description of the value of social, economic and ecological impacts (harm) that would be caused in the event of a flood.

Decision uncertainty – The rational inability to choose between alternative options.

Defence system - Two or more defences acting to achieve common goals (e.g. maintaining flood protection to a floodplain area/ community).

Design objective - The objective (put forward by a stakeholder), describing the desired performance of an intervention, once implemented.

Design discharge - See Design standard and Design flood

Design standard - A performance indicator that is specific to the engineering of a particular defence to meet a particular objective under a given loading condition. Note: the design standard will vary with load, for example there may be different performance requirements under different loading conditions.

Dependence - The extent to which one variable depends on another variable. Dependence affects the likelihood of two or more thresholds being exceeded simultaneously. When it is not known whether dependence exists between two variables or parameters, guidance on the importance of any assumption can be provided by assessing the fully dependent and independent cases (see also correlation).

Deterministic process / method - A method or process that adopts precise, single-values for all variables and input values, giving a single value output.

Discharge (stream, river) - as measured by volume per unit of time.

Efficiency - In everyday language, the ratio of outputs to inputs; in economics, optimality.

Element - A component part of a system

Element life - The period of time over which a certain element will provide sufficient strength to the structure with or without maintenance.

Emergency management - The ensemble of the activities covering emergency planning, emergency control and post-event assessment.

Epistemology - A theory of what we can know and why or how we can know it.

Ergonomics - The study of human performance as a function of the difficulty of the task and environmental conditions.

Error - Mistaken calculations or measurements with quantifiable and predictable differences.

Evacuation scheme - plan for the combination of actions needed for evacuation (warning, communication, transport etc.).

Event (in context) – In **FLOODsite**, these are the conditions which may lead to flooding. An event is, for example, the occurrence in *Source* terms of one or more variables such as a particular wave height threshold being exceeded at the same time a specific sea level, or in *Receptor* terms a particular flood depth**.** When defining an event it can be important to define the spatial extent and the associated duration. Appendix 1 expands upon this definition.

Exposure - Quantification of the receptors that may be influenced by a hazard (flood), for example, number of people and their demographics, number and type of properties etc.

Expectation - Expectation, or "expected value" of a variable, refers to the mean value the variable takes. For example, in a 100 year period, a 1 in 100 year event is expected to be equalled or exceeded once. This can be defined mathematically (Appendix 1).

Expected annual frequency - Expected number of occurrences per year (reciprocal of the return period of a given event).

Expected value — see Expectation

Extrapolation - The inference of unknown data from known data, for instance future data from past data, by analysing trends and making assumptions.

Failure - Inability to achieve a defined performance threshold (response given loading). "Catastrophic" failure describes the situation where the consequences are immediate and severe, whereas "prognostic" failure describes the situation where the consequences only grow to a significant level when additional loading has been applied and/or time has elapsed.

Failure mode - Description of one of any number of ways in which a defence or system may fail to meet a particular performance indicator.

Flood: - A temporary covering of land by water outside its normal confines.

Flood control (measure) — A structural intervention to limit flooding and so an example of a risk management measure.

Flood damage - damage to receptors (buildings, infrastructure, goods), production and intangibles (life, cultural and ecological assets) caused by a flood.

Flood forecasting system— A system designed to forecast flood levels before they occur:

Flood hazard map - map with the predicted or documented extent of flooding, with or without an indication of the flood probability.

Flood level - water level during a flood.

Flood management measures ***-Actions that are taken to reduce either the probability of flooding or the consequences of flooding or some combination of the two.***

Flood peak - highest water level recorded in the river during a flood.

Floodplain - part of alluvial plain that would be naturally flooded in the absence of engineered interventions.

Flood prevention - actions to prevent the occurrence of an extreme discharge peak.

Flood protection (measure) - to protect a certain area from inundation (using dikes etc).

Flood risk zoning - delineation of areas with different possibilities and limitations for investments, based on flood hazard maps.

Flood risk management - Continuous and holistic societal analysis, assessment and mitigation of flood risk.

Flood warning system (FWS) — A system designed to warn members of the public of the potential of imminent flooding. Typically linked to a flood forecasting system.

Flooding System (in context) - In the broadest terms, *a system* may be described as the social and physical domain within which risks arise and are managed. An understanding of the way a system behaves and, in particular, the mechanisms by which it may fail, is an essential aspect of understanding risk. This is true for an organisational system like flood warning, as well as for a more physical system, such as a series of flood defences protecting a flood plain.

Fragility - The propensity of a particular defence or system to fail under a given load condition. Typically expressed as a *fragility function curve* relating load to probability of failure. Combined with descriptors of decay/deterioration, fragility functions enable future performance to be described.

Functional design - The design of an intervention with a clear understanding of the performance required of the intervention.

Governance - The processes of decision making and implementation

Harm - Disadvantageous consequences — economic, social or environmental. (See *Consequence).*

Hazard - A physical event, phenomenon or human activity with the *potential* to result in harm. A hazard does not necessarily lead to harm.

Hazard mapping - The process of establishing the spatial extents of hazardous phenomena.

Hierarchy - A process where information cascades from a greater spatial or temporal scale to lesser scale and vice versa.

Human reliability - Probability that a person correctly performs a specified task.

Ignorance – Lack of knowledge

Institutional uncertainty - inadequate collaboration and/or trust among institutions, potentially due to poor communication, lack of understanding, overall bureaucratic culture, conflicting sub-cultures, traditions and missions.

Integrated risk management- An approach to risk management that embraces all sources, pathways and receptors of risk and considers combinations of structural and non-structural solutions.

Integrated Water Resource Management - IWRM is 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 sustainability of vital ecosystems.

Intervention - A planned activity designed to effect an improvement in an existing natural or engineered system (including social, organisation/defence systems).

Inundation - Flooding of land with water. (NB: In certain European languages this can refer to deliberate flooding, to reduce the consequences of flooding on nearby areas, for example. The general definition is preferred here.)

Joint probability - The probability of specific values of one or more variables occurring simultaneously. For example, extreme water levels in estuaries may occur at times of high river flow, times of high sea level or times when both river flow and sea level are above average levels. When assessing the likelihood of occurrence of high estuarine water levels it is therefore necessary to consider the joint probability of high river flows and high sea levels.

Judgement - Decisions taken arising from the critical assessment of the relevant knowledge.

Knowledge - Spectrum of known relevant information.

Knowledge uncertainty - Uncertainty due to lack of knowledge of all the causes and effects in a physical or social system. For example, a numerical model of wave transformation may not include an accurate mathematical description of all the relevant physical processes. Wave breaking aspects may be parameterised to compensate for the lack of knowledge regarding the physics. The model is thus subject to a form of knowledge uncertainty. Various forms of knowledge uncertainty exist, including:

Process model uncertainty – All models are an abstraction of reality and can never be considered true. They are thus subject to process model uncertainty. Measured data versus modelled data comparisons give an insight into the extent of model uncertainty but do not produce a complete picture.

Statistical inference uncertainty - Formal quantification of the uncertainty of estimating the population from a sample. The uncertainty is related to the extent of data and variability of the data that make up the sample.

Statistical model uncertainty - Uncertainty associated with the fitting of a statistical model. The statistical model is usually assumed to be correct. However, if two different models fit a set of data equally well but have different extrapolations/interpolations then this assumption is not valid and there is statistical model uncertainty.

Legal uncertainty - the possibility of future liability for actions or inaction. The absence of undisputed legal norms strongly affects the relevant actors' decisions.

Likelihood - A general concept relating to the chance of an event occurring. Likelihood is generally expressed as a probability or a frequency.

Limit state - The boundary between safety and failure.

Load - Refers to environmental factors such as high river flows, water levels and wave heights, to which the flooding and erosion system is subjected.

Mitigation – *see Flood management measures*

Natural variability - Uncertainties that stem from the assumed inherent randomness and basic unpredictability in the natural world and are characterised by the variability in known or observable populations.

Parameters - The parameters in a model are the "constants", chosen to represent the chosen context and scenario. In general the following types of parameters can be recognised:

Exact parameters - which are universal constants, such as the mathematical constant: Pi (3.14259...).

Fixed parameters - which are well determined by experiment and may be considered exact, such as the acceleration of gravity, g (approximately 9.81 m/s).

A-priori chosen parameters - which are parameters that may be difficult to identify by calibration and so are assigned certain values. However, the values of such parameters are associated with uncertainty that must be estimated on the basis of a-priori experience, for example detailed experimental or field measurements

Calibration parameters - which must be established to represent particular circumstances. They must be determined by calibration of model results for historical data on both input and outcome. The parameters are generally chosen to minimise the difference between model outcomes and measured data on the same outcomes. It is unlikely that the set of parameters required to achieve a "satisfactory" calibration is unique.

Pathway – Route that a hazard takes to reach Receptors. A pathway must exist for a Hazard to be realised.

Performance - The degree to which a process or activity succeeds when evaluated against some stated aim or objective.

Performance indicator - The well-articulated and measurable objectives of a particular project or policy. These may be detailed engineering performance indicators, such as acceptable wave overtopping rates, rock stability, or conveyance capacity or more generic indicators such as public satisfaction.

Post-flood mitigation - Measures and instruments after flood events to remedy flood damages and to avoid further damages.

Precautionary Principle - Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation.

Precision — degree of exactness regardless of accuracy.

Pre-flood mitigation - Measures and instruments in advance to a flood event to provide prevention (reducing flood hazards and flood risks by e.g. planning) and preparedness (enhancing organisational coping capacities).

Preparedness – The ability to ensure effective response to the impact of hazards, including the issuance of timely and effective early warnings and the temporary evacuation of people and property from threatened locations.

Preparedness Strategy - Within the context of flood risk management a preparedness strategy aims at ensuring effective responses to the impact of hazards, including timely and effective early warnings and the evacuation of people and property from threatened locations.

Probability (see also Appendix 1) — A measure of our strength of belief that an event will occur. For events that occur repeatedly the probability of an event is estimated from the relative frequency of occurrence of that event, out of all possible events. In all cases the event in question has to be precisely defined, so, for example, for events that occur through time reference has to be made to the time period, for example, annual exceedance probability. Probability can be expressed as a fraction, % or decimal. For example the probability of obtaining a six with a shake of four dice is 1/6, 16.7% or 0.167.

Probabilistic method - Method in which the variability of input values and the sensitivity of the results are taken into account to give results in the form of a range of probabilities for different outcomes.

Probability density function (distribution) - Function which describes the probability of different values across the whole range of a variable (for example flood damage, extreme loads, particular storm conditions etc).

Probabilistic reliability methods - These methods attempt to define the proximity of a structure to fail through assessment of a response function. They are categorised as Level III, II or I, based on the degree of complexity and the simplifying assumptions made (Level III being the most complex).

Process model uncertainty - See *Knowledge uncertainty.*

Project Appraisal - The comparison of the identified courses of action in terms of their performance against some desired ends.

Progressive failure - Failure where, once a threshold is exceeded, significant (residual) resistance remains enabling the defence to maintain restricted performance. The immediate consequences of failure are not necessarily dramatic but further, progressive, failures may result eventually leading to a complete loss of function.

Proportionate methods - Provide a level of assessment and analysis appropriate to the importance of the decision being made.

Proprietary uncertainty - indicates contested rights to know, to warn or to secrete. In both risk assessment and management, there are often considerations about the rights of different people to know, to warn or to conceal

Random events – Events which have no discernible pattern..

Receptor - Receptor refers to the entity that may be harmed (a person, property, habitat etc.). For example, in the event of heavy rainfall *(the source)* flood water may propagate across the flood plain *(the pathway)* and inundate housing *(the receptor)* that may suffer material damage *(the harm or consequence).* The vulnerability of a receptor can be modified by increasing its resilience to flooding.

Record (in context) - Not distinguished from event (see *Event)*

Recovery time – The time taken for an element or system to return to its prior state after a perturbation or applied stress.

Reliability index - A probabilistic measure of the structural reliability with regard to any limit state.

Residual life - The residual life of a defence is the time to when the defence is no longer able to achieve minimum acceptable values of defined performance indicators (see below) in terms of its serviceability function or structural strength.

Residual risk - The risk that remains after risk management and mitigation measures have been implemented. May include, for example, damage predicted to continue to occur during flood events of greater severity that the 100 to 1 annual probability event.

Resilience - The ability of a system/community/society/defence to react to and recover from the damaging effect of realised hazards.

Resistance – The ability of a system to remain unchanged by external events.

Response (in context) - The reaction of a defence or system to environmental loading or changed policy.

Response function - Equation linking the reaction of a defence or system to the environmental loading conditions (e.g. overtopping formula) or changed policy.

Return period - The expected (mean) time (usually in years) between the exceedence of a particular extreme threshold. Return period is traditionally used to express the frequency of occurrence of an event, although it is often misunderstood as being a probability of occurrence.

Risk - Risk is a function of probability, exposure and vulnerability. Often, in practice, exposure is incorporated in the assessment of consequences, therefore risk can be considered as having two components — the probability that an event will occur and the impact (or *consequence)* associated with that event. See Section 4.3 above.

Risk = Probability multiplied by consequence

Risk analysis - A methodology to objectively determine risk by analysing and combining probabilities and consequences.

Risk assessment - Comprises understanding, evaluating and interpreting the perceptions of risk and societal tolerances of risk to inform decisions and actions in the flood risk management process.

Risk communication (in context) – Any intentional exchange of information on environmental and/or health risks between interested parties.

Risk management - The complete process of risk analysis, risk assessment, options appraisal and implementation of risk management measures

Risk management measure - An action that is taken to reduce either the probability of flooding or the consequences of flooding or some combination of the two

Risk mapping - The process of establishing the spatial extent of risk (combining information on probability and consequences). Risk mapping requires combining maps of hazards and vulnerabilities. The results of these analyses are usually presented in the form of maps that show the magnitude and nature of the risk.

Risk mitigation - See *Risk reduction.*

Risk perception - Risk perception is the view of risk held by a person or group and reflects cultural and personal values, as well as experience.

Risk reduction - The reduction of the likelihood of harm, by either reduction in the probability of a flood occurring or a reduction in the exposure or vulnerability of the receptors.

Risk profile - The change in performance, and significance of the resulting consequences, under a range of loading conditions. In particular the sensitivity to extreme loads and degree of uncertainty about future performance.

Risk register - An auditable record of the project risks, their consequences and significance, and proposed mitigation and management measures.

Risk significance (in context) — The separate consideration of the magnitude of consequences and the frequency of occurrence.

Robustness – Capability to cope with external stress. A decision is robust if the choice between the alternatives is unaffected by a wide range of possible future states of nature.

Robust statistics are those whose validity does not depend on close approximation to a particular distribution function and/or the level of measurement achieved.

Scale - Difference in spatial extent or over time or in magnitude; critical determinant of vulnerability, resilience etc.

Scenario – A plausible description of a situation, based on a coherent and internally consistent set of assumptions. Scenarios are neither predictions nor forecasts. The results of scenarios (unlike forecasts) depend on the boundary conditions of the scenario.

Sensitivity - Refers to either: the resilience of a particular receptor to a given hazard. For example, frequent sea water flooding may have considerably greater impact on a fresh water habitat, than a brackish lagoon; or: the change in a result or conclusion arising from a specific perturbation in input values or assumptions.

Sensitivity Analysis - The identification at the beginning of the appraisal of those parameters which critically affect the choice between the identified alternative courses of action.

Social learning - Processes through which the stakeholders learn from each other and, as a result, how to better manage the system in question.

Social resilience - The capacity of a community or society potentially exposed to hazards to adapt, by resisting or changing in order to reach and maintain an acceptable level of functioning and structure. This is determined by the degree to which the social system is capable of organising itself to increase its capacity for learning from past disasters for better future protection and to improve risk reduction measures.

Spatial planning - Public policy and actions intended to influence the distribution of activities in space and the linkages between them. It will operate at EU, national and local levels and embraces land use planning and regional policy.

Standard of service - The measured performance of a defined performance indicator.

Severity — The degree of harm caused by a given flood event.

Source — The origin of a hazard (for example, heavy rainfall, strong winds, surge etc).

Stakeholders — Parties/persons with a direct interest (stake) in an issue — also Stakeowners.

Stakeholder Engagement - Process through which the stakeholders have power to influence the outcome of the decision. Critically, the extent and nature of the power given to the stakeholders varies between different forms of stakeholder engagement.

Statistic - A measurement of a variable of interest which is subject to random variation.

Strategy (flood risk management-) – A strategy is a combination of long-term goals, aims, specific targets, technical measures, policy instruments, and process which are continuously aligned with the societal context.

Strategic spatial planning - Process for developing plans explicitly containing strategic intentions referring to spatial development. Strategic plans typically exist at different spatial levels (local, regional etc).

Statistical inference uncertainty - *See Knowledge uncertainty*

Statistical model uncertainty - *See Knowledge uncertainty*

Sustainable Development - is development that meets the needs of the present without compromising the ability of future generations to meet their own needs

Sustainable flood risk management - involves:
- ensuring quality of life by reducing flood damages but being prepared for floods
- mitigating the impact of risk management measures on ecological systems at a variety of spatial and temporal scales
- the wise use of resources in providing, maintaining and operating infrastructure and risk management measures
- maintaining appropriate economic activity (agricultural, industrial, commercial, residential) on the flood plain

Sustainable flood risk management strategy — An approach which
- aims to be effective in the long term, and
- can be combined (`integrated') with other international, national and regional activities (transport, environment, conservation etc.)

(*See IRMA-SPONGE Glossary Appendix 2*)

Susceptibility – The propensity of a particular receptor to experience harm.

System - An assembly of elements, and the interconnections between them, constituting a whole and generally characterised by its behaviour. Applied also for social and human systems.

System state - The condition of a system at a point in time.

Tolerability -. Refers to willingness to live with a risk to secure certain benefits and in the confidence that it is being properly controlled. To tolerate a risk means that we do not regard it as negligible, or something we might ignore, but rather as something we need to keep under review, and reduce still further if and as we can. Tolerability does not mean acceptability.

Ultimate limit state - Limiting condition beyond which a structure or element no longer fulfils any measurable function in reducing flooding.

Uncertainty - A general concept that reflects our lack of sureness about someone or something, ranging from just short of complete sureness to an almost complete lack of conviction about an outcome.

Validation - is the process of comparing model output with observations of the 'real world'.

Variability - The change over time of the value or state of some parameter or system or element where this change may be systemic, cyclical or exhibit no apparent pattern.

Variable – A quantity which can be measured, predicted or forecast which is relevant to describing the state of the flooding system e.g. water level, discharge, velocity, wave height, distance, or time. A prediction or forecast of a variable will often rely on a simulation model which incorporates a set of parameters.

Voluntariness - The degree to which an individual understands and knowingly accepts the risk to which they are exposed in return for experiencing a perceived benefit. For an individual may preferentially choose to live in the flood plain to experience its beauty and tranquillity.

Vulnerability – Characteristic of a system that describes its potential to be harmed. This can be considered as a combination of susceptibility and value.

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6.3 Recent relevant EC and national projects

The Table 6.1 below summarises recent relevant projects and resources used in compiling this report

Table 6.1 Projects relating to Flood Risk Analysis and Management

Project	Funder	Period	Web Link	Notes
AMRA	EC		www.amra.unina.it	
COMRISK	EC	2002-2005	www.comrisk.org	
EAUE			www.eaue.de	
EU-MEDIN	EC – FP5	2002-	http://www.eu-medin.org	
ESPON-Hazard-Project	EC	2002 -2004	www.gtk.fi/projects/espon/glossary.htm	
EUROTAS	EC – FP4	1997-2000	www.eurotas.org	
FLOODAWARE	EC – FP4	1996-1998	www.lyon.cemagref.fr/projets/floodaware	
FLOWS	ERDF	2002-2006	www.flows.nu	
IEEP			www.ieep.org.uk	
IRMA-SPONGE	EC InterReg III	1999 -2002	www.irma-sponge.org	
MITCH	EC- FP5	2001-2003	www.mitch-ec.net	
NUSAP			www.nusap.net	
RIBAMOD	EC – FP4	1996-99	www.hrwallingford.co.uk/projects/RIBAMOD	
RINAMED	EC		www.rinamed.net	
Risk and uncertainty theme	UK National – Defra/EA	2000 -	www.defra.gov.uk/environ/fcd/research/RandDProgCon/RandDREUU.htm	

6.4 Links (recommended by JRC-IPSC)

6.4.1 Flood projects:

FLOWS: http://www.flows.nu

FLOWS is a transnational project with participants from Germany, the Netherlands, Norway, Sweden and the United Kingdom. A government agency from each country acts as lead partner in the respective participant countries.

6.4.2 RISK Projects

RINAMED : http://www.rinamed.net/index.html

Information on natural risks in the Western Mediterranean Arc. Its aim is to raise awareness of the citizens regarding natural risks. It is an INTERREG III B project.

AMRA : http://www.amra.unina.it

This is the website of the Regional Centre of Competence: Analysis and Monitoring of Environmental Risks (Italian)

RISK-EOS: http://www.risk-eos.com

It aims to set-up a European operational servicing capacity, taking benefit of Earth Observation capabilities in combination with other data sources and models, to support the organisations and institutions mandated for the management of Natural Hazards, throughout the prevention, anticipation, response and post-response phases. (IST-funded and GMES framework).

Note: RISK-EOS was working on a risk lexicon.

ORCHESTRA: soon to be launched (no URL yet)

Open Architecture and Spatial Data Infrastructure for Risk Management (ORCHESTRA) is a European Commission Information Society Directorate General-funded research integrated project (IP) prepared in 2003, which aims to design and implement an open service oriented architecture t hat will improve the interoperability among actors involved in Multi-Risk Management. It will facilitate the sharing and integrating of data in standard format from a multitude of sources and provide better services to the end users based upon de facto or de jure standards. ORCHESTRA consists of 12 partners with a total budget of 14 Million Euro in 3 years.

PREVIEW: in negotiation phase (no URL yet)

PREVIEW will develop targeted services based on user demand, potential impact and the societal benefit of the new services for an enriched risk management ability, maturity of research and technology results to start from and converge toward new end-users applications, strong will of potential operators to develop and operate these new applications in the near future, added value that can be gained during the 4-year project, programmatic that is required to develop a coordinated action at European level on the addressed topics, preparation of technology transfer or operational implementation of the results of parallel scientific projects. These initiatives will have an impact on increasing the critical mass of the risk community in decision-making and will continue to foster the multi-disciplinary approach and dialogue required in disaster risk reduction.

6.4.3 Glossaries:

http://www.unisdr.org/eng/library/lib-terminology-eng%20home.htm

These are general disaster/risk reduction terms (with a degree of endorsement)

http://www.mc2consulting.com/riskdef.htm

General risk-related terms (no endorsement)

http://www.proventionconsortium.org/objectives.htm

The ProVention Consortium is a global coalition of governments, international organizations, academic institutions, the private sector and civil society organizations dedicated to increasing the safety of vulnerable communities and to reducing the impact of disasters in developing countries.

6.4.4 Risk-related links

http://www.riskworld.com

This site contains interesting news risk-related issues.

http://www.irgc.org

The International Risk Governance Council (IRGC) is an independent foundation that involves a public-private partnership which supports the various sectors such as governments, business and other organizations in developing and developed countries.

The IRGC creates value by offering a unique platform for global debate and as a source of compiled, and if possible unified, scientific knowledge. IRGC also elaborates generic recommen dations and guidelines. As a new kind of transparent network it follows a transsectoral and multidisciplinary approach on global issues of governance, focused both traditional changing and emerging human-induced risks.

Note: They have a pilot project specifically on: Taxonomy of Risks and Risk Governance Approaches

http://www.eu-medin.org

The EU-MEDIN project aims to improve the interaction and synergy between the actors of European research in the field of natural risks and disasters and all organizations, institutions or individuals interested in disaster management research and development issues.

6.4.5 Other documents:

Reducing Disaster Risk: A Challenge for Development

http://www.undp.org/bcpr/disred/rdr.htm

UN Living with risk: A global review of disaster reduction initiatives 2004 version

http://www.unisdr.org/eng/about_isdr/bd-lwr-2004-eng.htm

Review of Indexes relevant for Risk and Vulnerability Indexing

The *Summary Review of Selected Regional and Global Indexes:*

Disaster Risk Reduction and Sustainable Development can be downloaded here:

http://www.unisdr.org/eng/task%20force/tf-working-groups3-eng.htm

Tools and best Practices for Risk and Vulnerability Analysis at the Local and Urban Levels

The *Quantification of risk, vulnerability and impact of disasters* can be downloaded here:

http://www.unisdr.org/eng/task%20force/tf-working-groups3-eng.htm

Pro-vention Publications/docs:

http://www.proventionconsortium.org/publications.htm

Many interesting documents related to vulnerability and risk!!!

Benfield Hazard Research Centre Publications/docs

http://www.benfieldhrc.com/SiteRoot/activities/publications.htm

Appendix 1 – Further technical discussion

What is an Event?

An event is a portion of the "sample space". The statistical term "sample space" means the totality of possible occurrences of the conditions which are of interest (in the context of **FLOODsite**, these are the conditions which may lead to flooding). An event is, for example, the occurrence in *Source* terms of one or more variables such as a particular wave height threshold being exceeded at the same time a specific sea level, or in *Receptor* terms a particular flood depth**.** When defining an event it can be important to define the spatial extent and the associated duration. It is also important to distinguish between *events* and *sample points*. For example, if a coin is tossed 2 times the *event* of obtaining at least one head contains the *sample points* head/tail, tail/head, and head/head.

What is probability?

There are a number of equally valid concepts of probability. In general, these concepts conform to the *axioms of probability*:

Let A and B be events. Let P(A) denote the probability of the event A. The axioms of probability are three conditions on the function P:

- The probability of every event is at least zero. - For every event A, P(A) >= 0.ie it is not possible to have negative probabilities.
- The probability of the entire outcome space is 1. The chance that *something* in the outcome space occurs is 1, because the outcome space contains every possible outcome.
- If two events are disjoint (mutually exclusive), the probability that either of the events happens is the sum of the probabilities that each happens. $P(A \cup B) = P(A) + P(B)$.). ie two mutually exclusive events cannot occur at the same time.

There exist, however, different philosophies in the application of probability. Two commonly distinguished philosophies are *Frequentist* and *Bayesian*.

Frequentist's assign probabilities based on the relative frequencies of specified events when compared to the set containing all possible events. i.e. if an event E happens m times in n trials then:

$$P(E) = \lim_{n \to \infty} it \frac{m}{n}$$

Whilst *Bayesian's* are prepared to assign probabilities to uncertain phenomena based on degrees of subjective or logically justified belief. The differences between these philosophies can be described with reference to abstract examples:

What is the probability that there was life on Mars a Billion years ago?

Based on a subjective judgement or a logically inferred belief a *Bayesian* would be prepared to assign a probability to this uncertain phenomena. A *frequentist*, however, would not consider it suitable to assign a probability since this is not a random event that has a long run frequency of occurrence.

Expressing the probability an frequency of particular individual event

Within the flood and coastal defence community, the environmental data from which probabilities are to be calculated is often continuous in time (i.e. a 50-year record of fluvial flow). Therefore, to calculate the probability of a particular event occurring it may be necessary to discretise the continuous record into a series of events (i.e. to determine the overall possible number of events).

- **Defining an event duration** – For example, time series wave records are often discretised into 3 hour records. Once the duratin is fixed, peak values for each 3 hour interval can be extracted, although care needs to be taken to ensure the separate 3 hour events are independent of one another.
- **Peaks over Threshold (POT) –** A threshold is selected above which peak levels are extracted. Typically the threshold is selected to include between five and ten events per year. Once again is required to ensure that subsequent peak levels are independent of one another.

- **Annual maximum –** This approach involves extracting the maximum value from a series for a given year. The selection of annual maxima is a way of ensuring independence, assuming an event doesn't span the end of one year and the start of the next. For this reason, the definition of the "year" boundaries may differ from the calendar year when the seasonality of the hazard is important. For example, if most floods in a river basin or coastal zone occur between November and March it would be appropriate to define a water year from October to September.

Once an event has been defined, and the outcome space established, it is then possible to calculate probability. In flood and coastal defence, probability is expressed in a number of different ways:

- **Event probability -** This refers to the probability of a particular realisation of a variable/s on any given trial.
- **Annual probability of exceedence -** This refers to the probability of a particular realisation of a variable occurring within any given year.
- **Life time probability of exceedence -** This refers to the probability of a particular realisation of a variable within a lifetime.

Frequency can also be expressed in a number of different ways. Two of the more common ways used in flood and coast defence are described below:

- **Annual exceedance frequency**

  This refers to the number of times per year, or frequency, that a particular threshold level may be expected to occur (i.e. the *expectation* or *average*).

- **Return period**

Traditionally, expected frequency of occurrence has been described using return period. Return period specifies the frequency with which a particular condition is, on average, likely to be equalled or exceeded. It is normally expressed in years and is therefore the reciprocal of the *annual exceedence frequency*. It is **not** a reciprocal of the *annual probability of exceedence* – although this is a reasonable approximation at higher return periods.

Probabilities of combination of events

Where the source of flooding consists of one or more variables (e.g. extreme wave heights and sea levels) or the *Pathway* consists of a series of flood defences protecting a floodplain area, it may be necessary to determine their combined probability. When assessing combined probabilities it is necessary to consider the degree of dependence between the variables. Different approaches can be adopted when considering dependence:

- **Independent** can be considered as the respective probabilities of two events occurring, remaining unaltered by knowledge that one or other of the events has occurred. Two events can be considered as independent if and only if:

$$P(A \cap B) = P(A)P(B)$$

- **Dependence** exists if the variables are not independent

$$P(A \cap B) \neq P(A)P(B)$$

Dependence often exists between wave heights and water levels around the UK. Simplified analyses treat this dependence as either full dependence or independence, it is however, wherever possible, preferable to quantify this dependence. Correlation is a measure of linear dependence typically expressed through a correlation coefficient that varies between –1 and 1 (0 being independent).

Analysing whole system flood risk

Flooding can be dependent on the interaction of *Source* variable/s.with a system of flood defences that comprise the *Pathway*. For example, in estuaries both river discharge and tidal level may be important, for coastal conditions wave height, wave direction, wave period, tide and surge level may all influence the flood hazard. In these circumstances the derivation of the probability of flooding can be complex, resulting in analysis of the *Source* and *Pathway* variables described as probability distributions with associated dependencies. This leads to the simulation of thousands of flood scenarios and associated impacts on the *Receptors*. It can be computationally expensive and impractical to model the numerous scenarios it is thus necessary to refine the analysis to reduce the computational burden. Techniques here include:

- Importance sampling, and
- Response/structure function approximation.

Expressing flood risk

Risk information is typically presented as a probability distribution or frequency distribution of the consequences. Flood risks can be presented as probability distributions of obtaining specified flood levels in a given area or probability distributions of economic damage arising from flooding across an area. These probability distributions can be aggregated to provide summary information such as expected annual damage (EAD). To perform an aggregation of the probabilities and consequences, typically the standard formulae for expectation (mean) value can be used:

$$E(X) = \int_{\mathbf{x} \in \{measure\ of\ all\ floods\}} \mathbf{x} f(\mathbf{x}) \quad d\mathbf{x}$$

Here **x** is a random variable of flood consequences and *f(x)* is a continuous probability density function of flood consequences.

Appendix 2 Glossary from IRMA-SPONGE Project

Glossary of terms related to flood risk management, produced by IRMA-SPONGE

Note that this glossary is reproduced verbatim from the IRMA-SPONGE report and no attempt has been made to refine or amend the definitions

English	*Dutch*	*German*	*Français*
alluvial plain: flat area shaped by river processes and formed by river sediments.	alluviale vlakte	alluviales Flachland	Plaine alluviale
attenuation (flood peak-): lowering a flood peak (and lengthening its base).	hoogwatervervlakking	Hochwasserverflachung	Recul du pic de crue
basin (river-) (*same as catchment area*): the area from which water runs off to a river.	stroomgebied	Einzugsgebiet	Bassin
biodiversity: the variability among living organisms; this includes diversity within species, between species and of ecosystems.	biodiversiteit	Artenvielfalt	Biodiversité
catchment area (river-) (*same as river basin*): the area from which water runs off to a river	stroomgebied	Einzugsgebiet,	Bassin versant
channel (river-): main watercourse.	stroomgeul (hoofd-)	Hauptrinne	Lit
climate change scenario: prediction of expected long-term developments in climate, i.e. in the average temperature, rainfall and wind speed, and in the variation therein.	klimaatveranderings scenario	Klimaveränderungs-szenario	Scénario de changement climatique
compartmentalisation (*Dutch concept*): dividing a dike-protected area into smaller protected areas.	compartimentering	Untergliederung	Compartimentation
cyclic rejuvenation: periodic floodplain lowering (through excavation), setting back morphological and ecological processes to an earlier stage of development.	cyclische verjonging	zyklische Verjüngung	Rajeunissement cyclique
design discharge: flood discharge for which the river system (channels, dikes, structures) was designed.	onwerpafvoer	Entwurfswassermenge	Écoulement prévu
design flood: flood level for which the river system (channels, dikes, structures) was designed.	ontwerphoogwater	Bemessungshochwasser	Crue prévue
detention area (*term used mainly in The Netherlands*): area for controlled storage of floodwater for 'peak shaving', usually in an area surrounded by dikes, with a controlled inlet/outlet for	detentiegebied	Gebiet zur gesteuerten Retention/Wasserspeicherung,	Zone de maîtrise des (eaux de) crues

English	***Dutch***	***German***	***Français***
river water. The difference with ‘retention’ is that detention is more effective in storing water only during peak discharges, without being filled (and losing space for further storage) during early stages of floods, and without releasing water as soon as river levels drop. *Note that the terms detention and retention are sometimes used for the same concept, and that the term 'detention' is not universally accepted.*		(Taschenpolder, Rückhalteraum)	
dike relocation: moving a dike away from the river in order to provide more space for the river water during floods.	dijkverlegging	Deichrückverlegung,	Déplacement de digues
discharge (stream-, river-) (*same as flow*): as measured by volume per unit of time.	rivierafvoer, debiet	Abflussmenge	Débit, écoulement
downstream (-area): situated relatively close to the outlet of a river basin.	benedenstrooms	Stromabwärts	(en) aval
ecological infrastructure: system of linkages between habitat patches.	ecologische infrastructuur	Ökologische Infrastruktur	Infrastructure écologique
ecotope: spatial ecological unit with (more or less-) uniform abiotic site conditions - location of an ecosystem.	ecotoop	Ökotop	Écotope
evacuation scheme: plan for the combination of actions needed for evacuation (warning, communication, transport etc.).	evacuatieplan	Evakuierungsplan	Plan d'évacuation
flood (1): high river discharge.	hoogwaterafvoer	Hochwasserabfluß	Crue
flood (2): high water level.	hoogwater	Hochwasser	Montée des eaux
flood (3): inundation of land.	overstroming	Überschwemmung	Inondation
flood damage: damage to investments (buildings, infrastructure, goods), production and intangibles (without direct monetary value: life, cultural and ecological assets).	overstromingsschade	Hochwasserschaden	Dommages provoqués par les crues / inondations
flood control (-measure): *usually understood as* a set of actions aiming to limit the (potentially) flooded area as much as possible.	hoogwaterbeheersing	technischer Hochwasserschutz	Maîtrise des crues
flood discharge: flow during a flood event.	hoogwater afvoer	Hochwasserabfluß	Écoulement des eaux de crue

English	***Dutch***	***German***	***Français***
flood early warning system (FEWS): suite of systems designed to provide a warning of flood levels well before they occur: A) flood forecasting system, B) warning system	hoogwater waarschuwingssysteem	Hochwasserwarnsystem	Système d'avertissement précoce des crues
flood flow (*same as* flood discharge): flow during a flood event.	hoogwater afvoer	Hochwasserabfluß	Écoulement des eaux de crue
flood forecasting system: suite of models designed to provide an early prediction of flood discharges: A) hydrological models (converting precipitation to discharge); B) hydraulic models (predicting channel discharge and wave propagation).	hoogwater voorspellings systeem	Hochwasservorhersage-system	Système de prévision des crues / inondations
flood hazard map: map with the predicted or documented extent of flooding, with or without an indication of the flood probability.	kaart van overstroombaar gebied	Karte der überschwemmungs-gefährdeten Bereiche.	Carte des zones menacées par les crues / inondations
flood level: water level during a flood.	hoogwaterstand	Hochwasserstand	Niveau des eaux de crue
flood peak: highest water level during a flood.	hoogwaterpiek	Hochwasserspitze	Pic de crue
flood peak shaving: storing only the top of a flood wave, by 'detention' (or 'controlled retention'). Flood water is not allowed in the storage area until water levels are high. The effect it that the flood peak is lowered more than in the case on 'attenuation' in 'retention areas'.	aftopping van hoogwaterpiek	'Abschneiden' der Spitze der Abflusswelle	Écrêtement du pic de crue
floodplain: part of alluvial plain (formed by river sediments) which is still regularly flooded.	uiterwaard, overstromingsvlakte	Flussvorland	Plaine inondable / d'inondation
flood prevention: actions to prevent the genesis of an extreme discharge peak.	voorkoming van hoogwaterafvoer	Hochwasserprävention	Prévention des crues
flood protection (-measure): to protect a certain area from inundation (using dikes etc).	hoogwaterkering, bescherming tegen hoogwater	Hochwasserschutz	Protection contre les inondations
flood risk: function of both probability of flooding, and potential damage due to flooding *(this is* ***not*** *the probability or 'danger' of flooding!)*	overstromingsrisico	Hochwasserrisiko	Risque de crue / d'inondation
flood risk management: totality of actions involved in reducing the flood risk - the aim can be to reduce the probability, the	hoogwater risico beheer	Management des Hochwasserrisikos	Gestion du risque de crue / d'inondation

English	***Dutch***	***German***	***Français***
damage, or both.			
flood risk zoning: delineation of areas with different possibilities and limitations for investments, based on flood hazard maps.	hoogwater risico …?	Risikozonierung	Zonage des risques de crue
flood routing: calculation (or modelling) of the movement (propagation) of a flood wave through the river channel.	hoogwaterberekening	Hochwasserberechnung	Calcul du trajet de la crue
flood wave: high water volume moving downstream through a river channel.	hoogwatergolf	Hochwasserwelle	Vague de crue, onde de crue
flow (stream-, river-): A) *same as* discharge, as measured by volume per unit of time, B)*:* movement of water *(not used in this summary).*	**A) afvoer** **B) stroming**	A) Abfluß(-menge), B) Strömung	Débit, courant
FRM: abbreviation for flood risk management	-	-	-
green river (*Dutch concept*): an additional channel (constructed through presently dike-protected area) which increases the discharge capacity of the river system during high waters.	groene rivier	‘Grüne Flüsse’, Umflußkanal	Rivière verte
habitat: natural environment of an organism. Also: the set of (riverine) ecotopes that a species can utilise during the various stages of its life cycle.	habitat, leefgebied	Habitat	Habitat
hazard (flood-): specific natural event, such as a flood, with the potential to cause damage characterised by a certain probability of occurrence and an intensity.	(overstromings-)gevaar	(Überschwemmungs-) Gefahr	Danger
headwater: source area for a stream, i.e. highest area in a river basin.	brongebied	Quellgebiet	Cours amont
hydrological model: model that simulates the conversion of precipitation into channel flow (there are several fundamentally different types).	hydrologisch model	Hydrologisches Modell	Modèle hydrologique
hydraulic model: model which simulates water movement through a channel.	hydraulisch model	Hydraulisches Modell	Modèle hydraulique
inundation: flooding of land with water.	overstroming	Überschwemmung	Inondation

English	***Dutch***	***German***	***Français***
measure (flood risk management-): measure that can be used as part of FRM.	maatregel	Maßnahme	Mesure
modelling (hydrological-, hydraulic-, habitat-): simulation of natural processes and conditions, using a computer program	modelleren	Modellierung	Modélisation
nature rehabilitation: allowing or enhancing natural processes.	natuurherstel	Renaturierung	Réhabilitation naturelle, renaturement
peak flow / flow peak: highest discharge during a flood.	piekafvoer	Spitzenabfluß	Pic de crue
precipitation: rainfall plus snowfall.	neerslag	Niederschlag	Précipitations
resilience (-flood risk strategy): consistent set of measures aiming to minimise the effects of floods, rather than to control (resist) them.	veerkracht	Dehnfähigkeit	Résilience
retention (flood water-): temporary, uncontrolled, storage of flood waters, in a basin (sometimes a wetland) which is open towards the river. *Note that this term is not universally accepted, e.g. in 'Anglosaxon' areas it can be understood as 'seasonal storage of water', and in Europe it is sometimes used for what is called 'detention' in this summary.*	retentie	Retention	Rétention, retenue
retention area: area in which water is stored.	retentiegebied	Retentionsgebiet	Zone de rétention / retenue
river regulation: adapting (e.g. straightening, widening, deepening) a river (or part of it).	rivierregulatie	Flußregulierung	Régulation fluviale
runoff: the part of precipitation that appears as streamflow.	afstroming	Abfluß	Ruissellement des précipitations
scenario (flood risk-): a sequence of expected *autonomous* events which have an impact on flood risk but can not (at the moment) be influenced directly by flood risk management (though FRM aims to respond to scenarios with strategies). Events shaping scenarios may be: (A) 'natural' (e.g. climate change), (B) caused indirectly by human intervention (e.g. land use change in the catchment), (C) the direct result of social changes (e.g. trends in valuation of flood losses), (D) or result from economic changes (e.g. progressive investments in floodplains).	scenario	Szenario	Scénario

English	***Dutch***	***German***	***Français***
Side channel: secondary channel through the floodplain.	nevengeul	Seitenrinne	Lit secondaire, lit parallèle, bras
spatial planning: decisions and regulations aiming to regulate and optimise the use of space for different functions.	ruimtelijke ordening	Raumplanung,	Aménagement du territoire
stakeholders: parties with a direct interest (stake) in an issue.	belanghebbenden	Interessengruppen	Parties intéressées
strategy (flood risk management-): consistent set of measures, developed to achieve a certain goal - often responding to a scenario.	strategie	Strategie	Stratégie
sustainable flood risk management strategy: strategy which aims to A) be effective in the long term, and B) can be combined ('integrated') with other functions - usually summarised as economic, social and ecological development.	duurzaam	nachhaltig	Durable
uncertainty analysis: determining the accuracy of a (modelling) result. A measure of the accuracy is needed to judge the fitness of a value as a basis for making decisions.	onzekerheidsanalyse	Unsicherheitsanalyse	Analyse des incertitudes
upstream (-area): situated relatively close to highest parts of a river basin.	bovenstrooms	stromaufwärts	(en) amont
winterbed (*Dutch term, sometimes same as major bed or floodplain*): area between the dikes, across a river, consisting of the channel plus the floodplains.	winterbed, hoogwaterbed	Flußbett, Hochwasserbett	Lit majeur

Appendix 3 – Record of contributions from partners

Date	Correspondent	Contributors	Description
29.04.04	Ad van Os	Irma Sponge team	Irma sponge glossary of terms (Appendix 2 of this report)
24.06.04	Jochen Schanze	IOER colleagues	Contribution of IOER to language of risk, including a series of definitions and supporting text.
01.07.04	Frans Klijn	N/a	General comments and suggested amendments, including specific definitions
08.07.04	Frans Klijn	Group 1 (August 04 Workshop)	Comments from Group 1. Updated comments from Frans Klijn. Baan and Klijn (2004) paper on flood risk perception in the Netherlands.
09.07.04	Bruna de Marchi		References, glossary terms and definitions.
23.07.04	Ricardo Brigganti		'Note on the Language of risk', includes various definitions supporting text.
28.07.04	Jim Hall		'Terms of Risk' report from the UK National Radiological Protection Board.
02.08.04	Ana Lisa Arellano		EC communication on the Precautionary Principle. Link to EC information on treaties. Links to related project web sites. News release on EEA report on precautionary principle.
03.08.04	Jochen Schanze		Language of risk PowerPoint presentation. 'Uncertainty' group discussion results on language of risk.
16.09.04	Ad van Os		Link to ICID web site for order of Manual on non-structural approaches to flood management.
15.11.04	Frank Messner	Colin Green, Bruna de Marchi and Frank Messner.	Results from discussion on language of risk document from meeting of social scientists of sub theme 1-3, October 2004.
17.11.04	Frans Klijn		Manuscript comments on V_2_1 of document
18.11.04	Frans Klijn		Baan & Klijn (2004) IAHR paper on risk perception.
23.11.04	Frans Klijn		Email details definitions from papers and ISO/IEC and UN/ISDR guides.
29.11.04	Ad van Os		IRMA-SPONGE Glossary. Contribution to document on risk of language.
10.12.04	Jochen Schanze	Paul Sayers, Frans Klijn, G. Hutter, Frank Messner	Contribution to document on language of risk. The 'Dresden Paper'.
04.01.05	Frans Klijn		Email contains comments on Dresden paper. Attached document of edits to Dresden paper.
14.01.05	Jochen Schanze	Paul Sayers, Frans Klijn, G. Hutter, Frank Messner	Updated "Dresden" Paper
3.02.05	Frank Messner		Contribution and comments on language of risk document – especially in Section 3.5
03.03.05	Jochen Schanze		Definition of flood risk management and other comments