RASP - A hierarchy of risk-based methods and their application

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RASP - A HIERARCHY OF RISK-BASED METHODS AND THEIR APPLICATION

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Abstract

It has long been recognised that flood risk cannot be eliminated completely and that understanding risk is key to improving risk management. In particular, this means deciding on actions such as:

- construction of new defences where they are most efficient in reducing risk;
- maintaining and operating defences and defence systems to minimise risk;
- flood forecasting and warning to minimise the consequences in the event of flooding;
- restricting development in flood and erosion-prone areas to control the impacts.

The need for improved risk assessment methodologies to support better flood risk management has been widely recognised and in 2001 the Environment Agency and Defra commissioned HR Wallingford to lead an R&D project titled RASP – *Risk Assessment for Strategic Planning*. The RASP project was completed in 2004 and for the first time provided a hierarchical risk-based analysis framework to help the Environment Agency and Defra understand flood risk and in particular how flood defences, and investment in flood management, influence flood risk.

This paper builds upon previous presentations at the Defra conference in 2002 and 2003 (Sayers *et al*, 2002, 2003). The development of the RASP methodologies and the hierarchy of decision-specific tools which they are now beginning to support are outlined and the hierarchical nature of the RASP methods are demonstrated.

The paper concludes that a sound risk assessment approach is essential for better flood risk management decision-making and to improve the effectiveness of our flood management systems.
In particular, it shows how a structured hierarchical approach to risk assessment ensures that the level of analysis undertaken is appropriate to the complexity of the decision at hand and its sensitivity to uncertainty – thus maximising the efficiency of the resources applied to the decision making process.

Introduction

General philosophy of a risk-based approach

A key aim of the Agency's Environmental Vision is to reduce flood risk. Through their Corporate Strategy and Strategy for Flood Risk Management the priorities to achieve this aim and deliver the targets set by Government are set out. Fundamental to this strategy, is the adoption of a risk-based approach to flood risk management. This is a proactive approach where resources and efforts are targeted at the locations or communities where greatest benefits can be achieved. These benefits are framed in terms of reducing the probabilities and consequences of flooding, which together constitute the risk.

In support of these stated goals significant advances have been achieved in understanding the concepts that underpin a risk-based approach to flood management (Environment Agency 2002, Sayers *et al*, 2002). The Source-Pathway-Receptor conceptual model is widely used to assess and inform the management of environmental risks across Government. It has now been adopted to describe the flooding system (see Figure 1) and forms central framework for risk assessment and management.

A hierarchical set of decisions

In tandem with adopting the common S-P-R conceptual assessment framework, the Environment Agency has identified a series of integrated planning decisions (Figure 2).

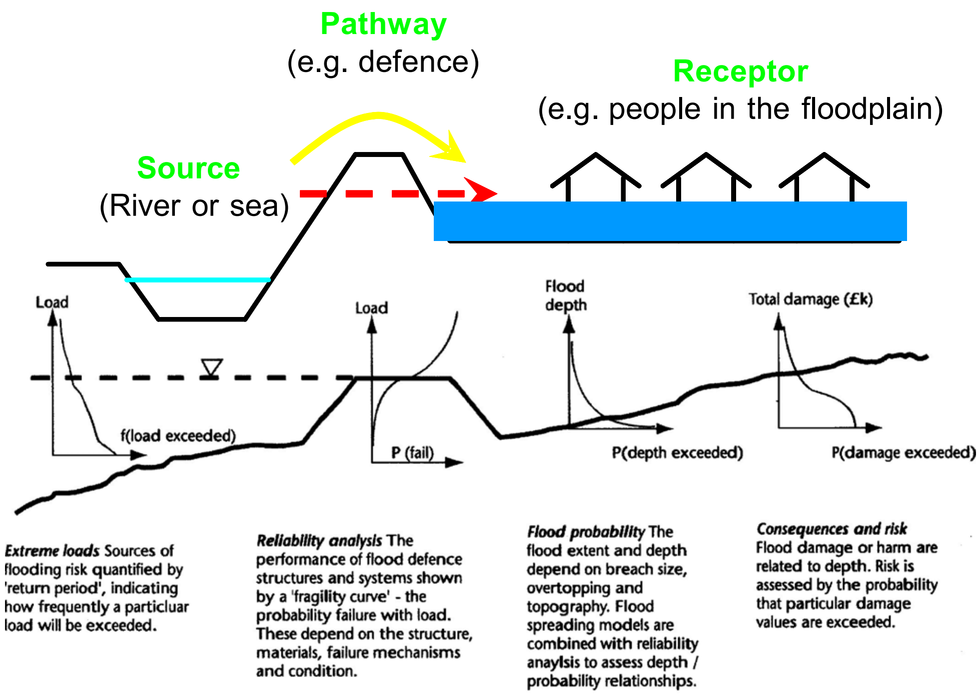


Figure 1 Source / Pathway or Barrier / Receptor assessment framework for the assessment of flood risk (adapted from Sayers *et al*, 2002)

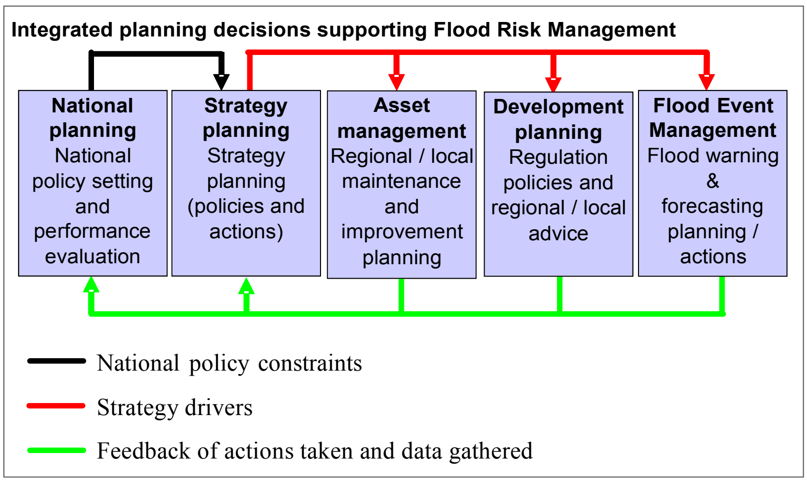


Figure 2 Integrated planning decisions supporting Flood Risk Management (adapted from RASP Summary Report, Environment 2004)

The role of each decision in the context of integrated flood risk management is outlined below:

- ***National policy development*** – At a national level decision makers need to have a national *picture* of risk; including national exposure, the general spatial distribution of risk and how this may change in time. To provide effective policy guidance, decision makers need to explore the effectiveness and efficiency of a wide range of strategic alternatives (regulation, protection, flood warning etc) that includes knowledge of both likely implementation costs, the associated risk reduction achieved and associated uncertainties. These may form the basis for monitoring changing risk on a national basis, and also for target-setting.

- ***Strategy planning*** – Strategy planning seeks to translate policy to practice. As such strategists have similar needs to national policy makers, but demand more certainty to ensure decisions are robust at a regional scale. In particular strategy plans needs to be based on an exploration of the effectiveness and efficiency of a wide range of strategic alternatives (regulation, protection, flood warning etc) and the preferred combination of interventions and actions identified and enshrined within a costed programme of activities. As with national policy making, good strategy planning needs approaches that are robust to future change (climate and socio-economic etc) and reflect the need for sustainability.

- ***Asset management planning*** – Asset managers seek to manage infrastructure based on a whole life philosophy that includes design, maintenance and eventual removal / replacement of an asset. Asset managers take their lead from national policies and the specific policies or measures set out within the higher level strategy plans (where they exist). Where these policies include management or improvement of assets, asset managers seek to ensure that these are implemented in the most efficient and effective manner. An important added benefit of an integrated approach is that data collection and detailed analysis from asset managers can be fed back to the higher levels to inform future decisions.

- ***Development planning*** – Regulation and development control represents the most direct route to managing future flood risk through the removal of receptors or improvements to their resilience to flooding. The response of the Agency to proposed development will need to be guided by higher level policies and strategies. Specific information gathered, including for example, locally detailed topographic surveys and property threshold levels and detailed information on development proposals established through *Strategic Flood Risk Assessment*s or more detailed *Flood Risk Assessment*s fed back to inform future strategies and policies.

- ***Flood event management*** – Reliable forecasting and effective warning is likely to play an increasingly important role in future flood risk management. Strategic plans should provide the flood event manager with a clear articulation of the role of flood forecasting and warning as part of an integrated flood risk management response within a specific area, together with the level of service that is expected. Within this context flood event managers will seek to maximize risk reduction and the efficiency and effectiveness of the flood forecasting and warning process. Detailed information gathered on flood evacuation routes and the likely performance of flood warning, detailed address point information and housing types will then provide improved data and information to inform future strategy and policy updates.

As demonstrated above, ***strategy planning*** (including CFMPs/SMPs/CDSs) is a key element of the overall framework and provides the regional policy and planning lead for the asset management, regulation and flood event management functions. In turn, the strategy plans take their lead from clearly articulated national policies that are based on reliable evidence on exposure to risk, perceived societal preferences and resource constraints. As more detailed analysis is completed (under the asset, development and flood event management planning) an improved understanding of the flooding system (both data and models) is fedback into the higher level planning processes (see Figure3).

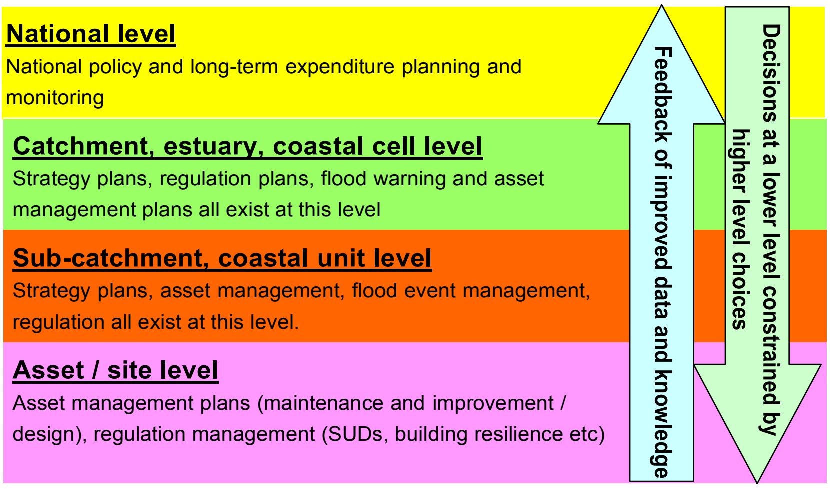


Figure 3 A hierarchy of risk assessment and management planning (adapted from RASP Summary Report, Environment 2004)

A tiered set of supporting analysis tools

To support the decisions outlined above, a hierarchy of risk assessment methodologies have been developed. These range from broad scale to detailed and utilise the RASP methods (HR Wallingford, 2004); including the so-called RASP High Level Method, HLM (more recently extended to the so-called HLM*plus*); the RASP Intermediate Level Method (ILM); and the most the RASP Detailed Level Method (DLM). The relationships between the decisions, the supporting tools and the RASP methods are should in Figure 4 and discussed below.

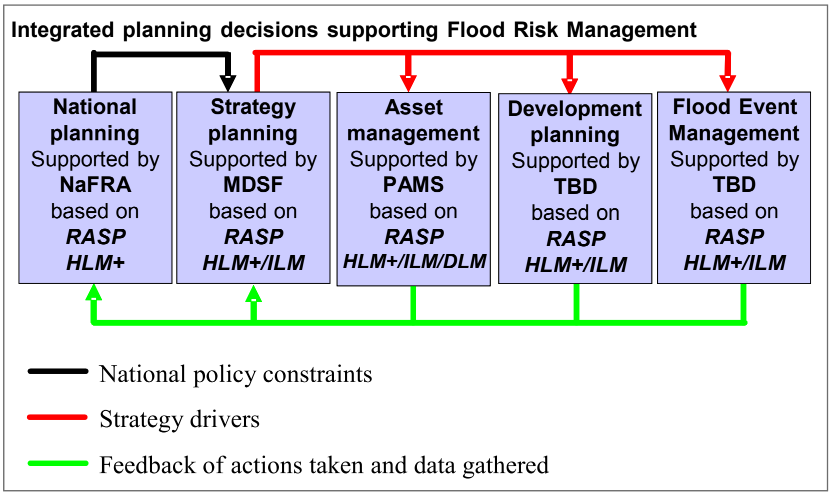


Figure 4 Software tools developed or under development to support the tiered concept of planning (illustrated in Figure 2).

- **NaFRA – National Flood Risk Assessment – A tool for the monitoring of targets and supporting policy setting**
  The National Flood Risk Assessment (NaFRA) studies (HR Wallingford, 2002, Deakin *et al*, 2005) utilise the RASP High Level Methods. The NaFRA tool is a self contained single "model" that estimates load conditions, assesses defence system performance, spreads floodwater on floodplains and calculates the risk metrics of choice. In 2003 the NaFRA tool was further developed to support a National Assessment of Defence Needs and Costs (NADNAC – Halcrow, 2003) through the inclusion of a simplified whole life costing module.

  The NaFRA tool is necessarily constructed to use datasets available at a national scale, and is dependent on the NFCDD. The NaFRA tools have been used, and continue to be used, to provide a country-wide 'snapshot' of flood probability and risk at a common resolution of throughout the fluvial and tidal floodplain in England and Wales. For NaFRA 2004 this resolution was set at a nominal cell size of 100m x 100m.

  At present the NaFRA is constructed to be run by the model's developers, but the aim is to provide the NaFRA tool in a semi-packaged format for running by multiple consultants (2007/8 onwards). The application of NaFRA in 2004 is described in more detail in Deakin *et al* (2005).

- **MDSF - Modelling Decision Support Framework – A tool for supporting the development of strategic plans**
  MDSF is specifically designed to support the development of integrated strategies and hence must be flexible and capable of distinguishing the performance of different options and operating at a range of levels of detail (reflecting the demands of a particular situation) – Environment Agency, 2003. MDSF supports the specific option appraisal process implicit in CFMPs/SMPs and strategies. Therefore MDSF must continue to be capable of exploring the trade-off between engineering solutions, flood warning and social resilience, regulation etc and exploring various future scenarios. It is not possible to prescribe the level of detail that is universally appropriate to CFMPs/SMPs or strategy. MDSF is therefore independent of the level of detail applied – with the defining issue relating to the nature of the decision and its sensitivity to uncertainty.

  Note: The current version of MDSF does not deal particularly well with the risk of failure of flood defence systems and it is planned to improved this and other aspects in future (HR Wallingford, 2005).

- **PAMS – Performance-based Asset Management System for supporting asset management**
  The maintenance and management of flood defence assets has hitherto been a largely *ad hoc* process and it could perhaps be said to be behind strategy planning in its use of IT supported tools. A scoping study has recently been completed outlining the user needs for PAMS and the recommendations from this study are now being taken forward (Environment Agency, 2004). PAMS will utilise the RASP methods is currently being scoped and developed. Its aim is to utilize the notion of asset systems and relate asset management and performance to flood risk in a more transparent and justifiable way.

  The PAMS tool will compromise a suite of tools and guidance (currently under development and due for completion in 2007) that will improve both the way defence information is collected and maintenance and improvement decisions are made. It will also be important that the added-value provided by PAMS through detailed site specific analysis is feeds back to the higher level tools to inform future decisions. The primary vehicle for the transfer of information is likely to be NFCDD, with PAMS providing the underpinning defence data for all other tools and decisions.

Unlike NaFRA or MDSF, PAMS is being constructed with the goal of providing a tool for use directly by Agency staff. As such it is likely that PAMS will include a series of user-friendly tools with close links to NFCDD and other datasets.

- **Regulation (tool yet be de defined)**
  The decision support tools associated with the Agency regulation function have been explored as part of a recent study led by HR Wallingford titled "Flood risk assessment for new developments". This project adopts the source-pathway-receptor and the notion of a hierarchical assessment utilising the RASP methodologies. However, a specific software decision support tool is yet to be developed.

- **Flood event management (tool yet to be defined)**
  A number of scoping studies have been completed that setout an approach to flood warning that utilise the risk information provided by the RASP methods (Environment Agency, 2004). Detailed guidance and tools for both flood warning and flood forecasting that utilise the source-pathway-receptor concepts within a system-based analysis are likely to be developed in the next few years.

  An important feature of this envisaged hierarchy of tools is their ability to share information and data. The concept within RASP is that all data is provided from, and returned to, nationally accessed data bases. This may be an online or offline access, but the principle of common data usage and continual improvement of data quality remains. This interaction is shown schematically in Figure 5.

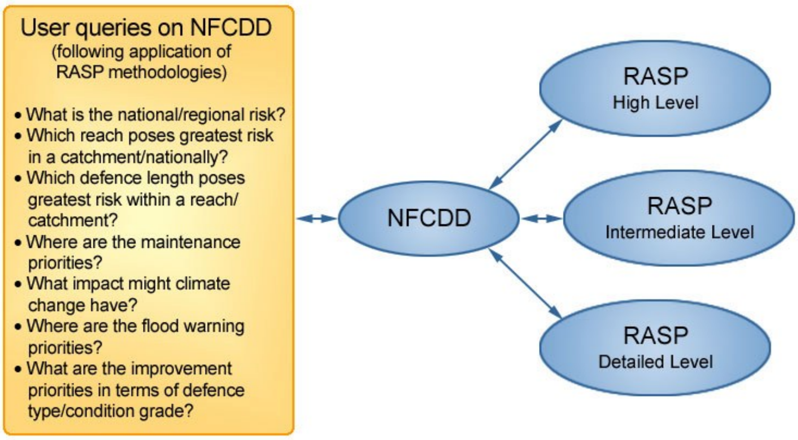


Figure 5 Use and evolution of common datasets
All tiers of RASP utilize common datasets; extracting data from. and returning improved/added data to, NFCDD (RASP Summary Report, Environment Agency, 2004)

The benefits of adopting a hierarchical risk assessment process
Traditionally, engineers have adopted a precautionary approach to of risk and uncertainty. This may mean adopting a 'conservative' view of both the likely strength of system (i.e. under estimating its resilience\resistance to flooding) and the likely loading on the system (i.e. biasing the analysis to over state the wave and surge conditions). Risk assessment methods seek to remove bias from the analysis enabling a more transparent debate as to which management options are preferred and which features of the flood system contribute greatest to the risk and drive the uncertainties in determining that risk. This is not a new approach and one advocated for many years.

In the 17th Century Jacob Bernouilli captured the need to develop unbiased expectations of performance and risk noting *"The value of our expectation always signifies something in the middle between the best we can hope for and the worst we can fear."*

More specifically, a hierarchical risk-based approach has the following benefits:

An embedded notion of appropriateness and recognition of uncertainty - The data and resources used to explore both the probability (source and pathway terms) and consequence (receptor terms) should to sufficient (and perhaps no more) to make a robust decision. This has always been the case. However, risk-based methods provide an ability to vary the level of detail of the analysis to reflect the decision in-hand. This has been, for the first time, formally recognised in the RASP hierarchy of approaches that utilise expert judgement and process-based models to varying degrees and have different data demands. It is not, however, the formal recognition of this hierarchy that is innovative within RASP but rather the progressive nature of analysis from one level of analysis to the next.

A structured assessment of the problem – All of the RASP supported tools demand an articulation of the problem within the context of an S-P-R framework. This provides rigour to the expert judgement and transparency of the management process. The S-P-R framework is not new and has been successfully used in may branches of environmental risk assessment, and will, ultimately, support moves towards a more integrated environmental risk management in the future.

Structured use of judgement and appropriate use of supporting science – As noted above the notion of appropriateness is fundamental to efficient decision making. The use of expert judgement is a fundamental input to the RASP methods at all levels and will always remain a vital component of our decision making processes. However, it is important that expert input adheres to the same principles of transparency and rigor that is demanded of computational models. RASP does not require the application of complex models *per se*, but it does force expert judgement to be quantified and assumptions justified.

Use of available data – There is a commonly held view that the application of risk-based methods demands more data. But we do not share this view. A risk-based method enables *available* data to be utilised and the uncertainty reported to the decision maker – if the decision warrants further targeted data collection to reduce uncertainty this can be clearly justified and commissioned. We also believe that the application of risk assessment methods has served to highlight shortcomings in data which should be rectified.

Costs and benefits of application – There are inevitable 'start-up' costs in developing and using new risk assessment tools. These include the cost of R&D, and developing and applying new tools. There also needs to be training and activities to raise awareness. But the benefits, while difficult to quantify, are numerous and far-reaching. As risk assessment tools are applied to different parts of the business then benefits will be realised in terms of better targetting of flood and coastal risk management measures.. The hierarchy of tools outlined above enable structured data and information sharing thereby avoiding the need for repeated work. And by providing trusted assessments of flood probabilities and consequences we will be in a better position to influence a wide range of stakeholders to take appropriate action - even in areas where floods are a distant memory, or even unheard of.

Overview of the supporting risk analysis framework - RASP

In determining flood risk, all levels of RASP consider the following terms and their interactions:

- *Source terms* – in the context of RASP *Source* refers to loading conditions, for example the in-channel river water levels and coastal surges and wave conditions.

- *Pathway terms* – in the context of RASP *Pathway* refers to the process by which a connection is established between a particular source (e.g. a marine storm) and a receptor (e.g. a property) that may be harmed. For example, the pathway within RASP consists of the flood defences (or high ground) and floodplain that may exist between the in-channel river flows and a house. Therefore two primary issues are considered at all levels:
  - Defence performance under load (expressed as a "fragility" function – see Figure 6)
  - Floodplain inundation

- *Receptor terms* – in the context of RASP, *receptor* refers to any entity that may be harmed by a flood and the material damage that may be suffered where a quantitative relationship between flood depth/velocity and the magnitude of the damage incurred exists.

Within RASP, these terms are characterised within the context of a Flood System. A Flood System is defined as a continuous area of the floodplain with an uninterrupted boundary with the river, coast or high ground.

Although the methodologies applied to each of the source, pathway and receptor terms vary between the levels of detail (and the associated complexity and detail of the data used – see Table 1) the generic steps within the RASP analysis remain the same (as outlined in Figure 8).

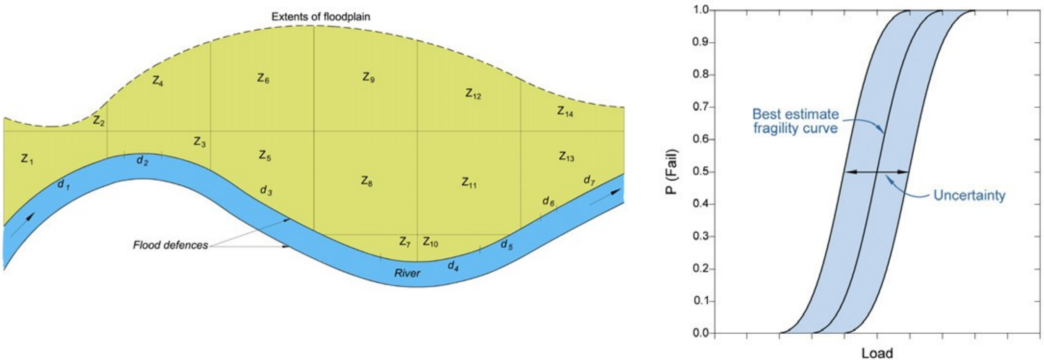


Figure 6 Fundamental building blocks of the RASP framework – Defence systems, defence fragility and impact zones (Environment Agency, 2004)

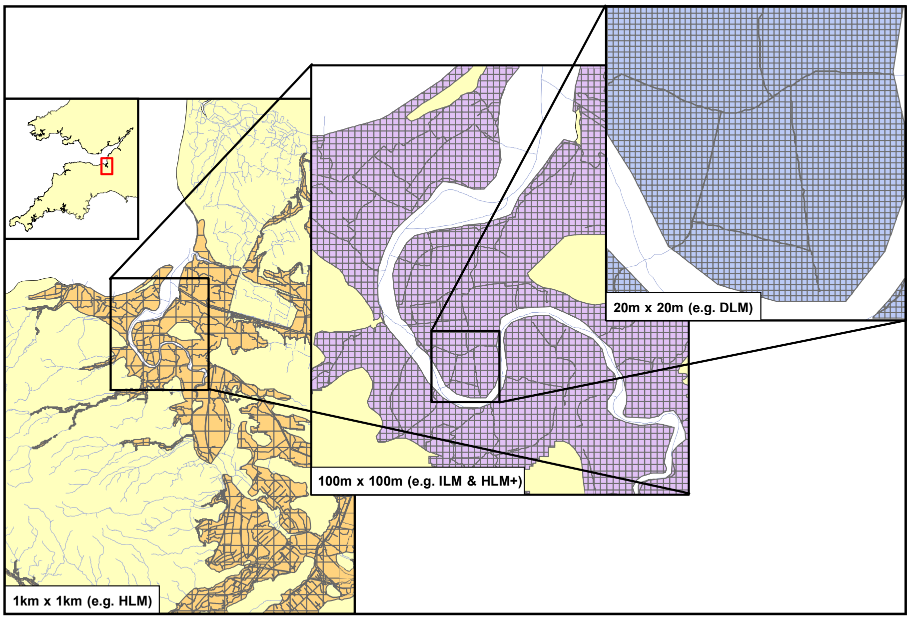


Figure 7 Example of the spatial hierarchy of Impact Zones utilised in the RASP framework (Environment Agency, 2004)

Table 1 Hierarchy of RASP methodologies, decision support and data required (Environment Agency 2004)

Level of assessment	**Decisions to inform**	**Data sources**	**Methodologies**
High	National assessment of economic risk, risk to life or environmental risk Prioritisation of expenditure Regional Planning Flood Warning Planning	Defence type Condition grades Standard of Service Indicative flood plain maps Socio-economic data Land use mapping	Generic probabilities of defence failure based on condition assessment and SOP Assumed dependency between defence sections Empirical methods to determine likely flood extent
High Level Plus	*As above*	*Above plus:* Digital Terrain Maps Quantitative loading Floodplain depths in the absence of defences	*As above*, with improved estimate of flood depth using DTM
Intermediate	*Above plus:* Flood defence strategy planning Regulation of development Maintenance management Planning of flood warning	*Above plus:* Defence crest level and other dimensions where available Joint probability load distributions Flood plain topography Detailed socio-economic data	Probabilities of defence failure from reliability analysis Systems reliability analysis using joint loading conditions Modelling of limited number of inundation scenarios
Detailed	*Above plus:* Scheme appraisal and optimisation	*Above plus:* All parameters required describing defence strength Synthetic time series of loading conditions	Simulation-based reliability analysis of system Simulation modelling of inundation

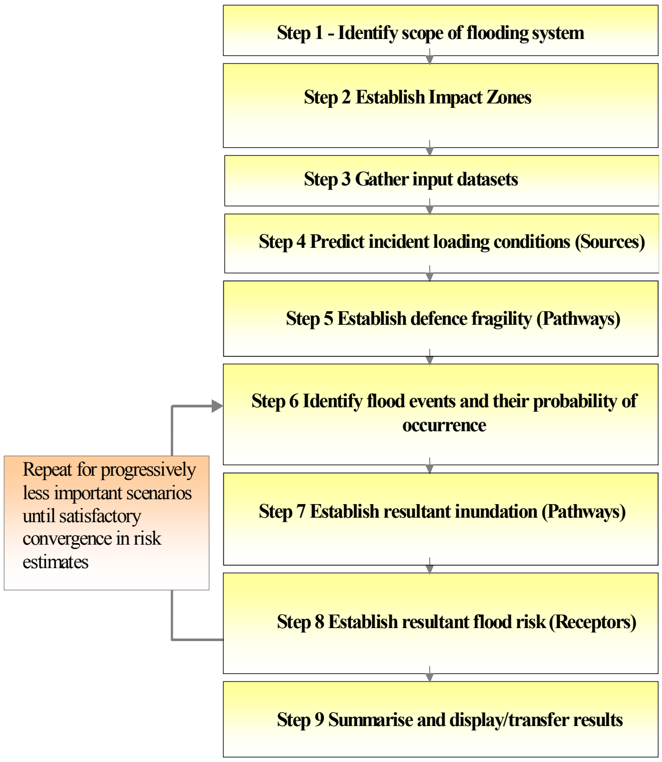


Figure 8 Generic process of analysis common to all tiers of the RASP hierarchy (HR Wallingford, 2004)

An illustration of the RASP hierarchy in action

A key feature of RASP is its use of structured information on defence performance under load expressed in terms of a fragility curve. In general terms, the physical mechanisms that lead to failure continue to be poorly understood. There is therefore significant uncertainty in the any attempt to understand the performance of a defence under load. The approaches initiated in RASP enable this uncertainty to be capture explicitly and provide a powerful tool in directing effort towards gathering an improved understanding. This uncertainty is typically represented through upper and lower bounds on the fragility curve. Through the tiered analysis the uncertainty regarding the likely performance of the defence under load is reduced and more defence specific data and models are used (Figure 9).

Throughout the hierarchy the way in which the defence reliability under load is established varies reflecting the data and resources available. This are briefly outlined below by way of illustration.

A traditional deterministic approach

Defence performance has always been considered within the context of flood management. A deterministic approach, as apposed to the probabilistic approach advocated in RASP, would identify a single step function to represent the defence fragility. In such a model, the defence is considered *perfectly* safe up to a given loading limit, and considered to have *surely* failed once that limit is exceeded. This deterministic approach is compared to the "fragility curve" adopted by RASP in Figure 10.

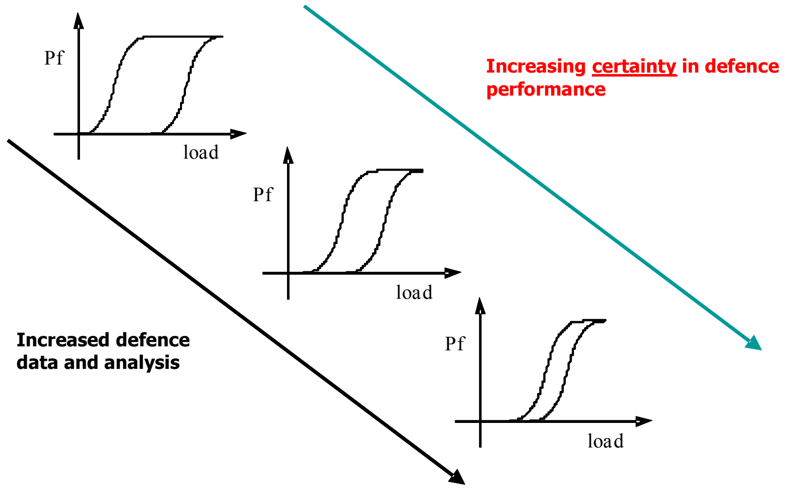


Figure 9 Progressively reducing uncertainty in defence performance through the RASP tiers

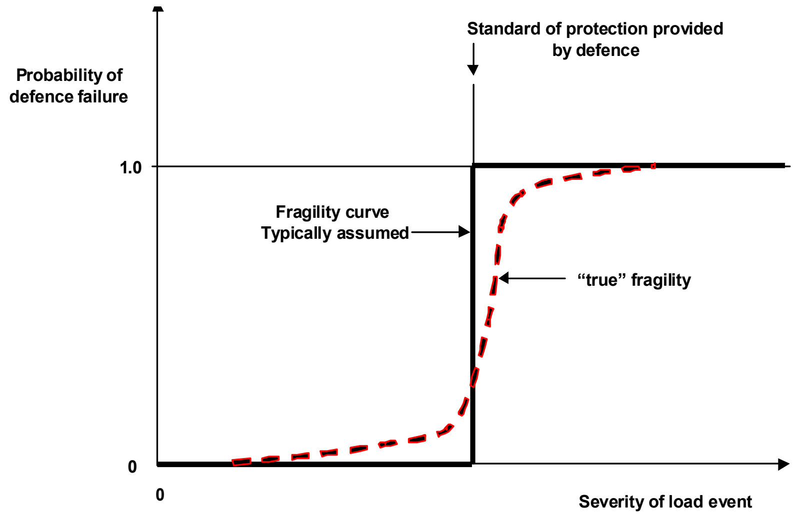


Figure 10 A comparison between deterministic and probabilistic views of defence fragility

A probabilistic approach

Depending upon the demands of the decision, the reliability of the defence can be established using various methods. However, before illustrating these methods it is worth considering the basic principles that lie behind the defence reliability analysis prompted within RASP:

At all levels the RASP methods seek to solve the simple limit state equation:

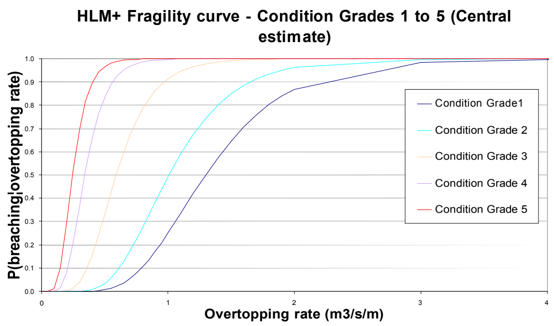
Z= R – S, where

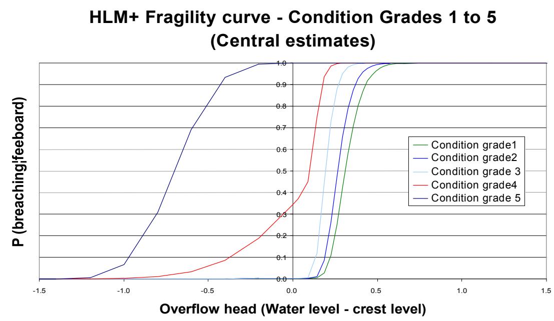
- R represents the gathering together of all terms or parameters which relate to the *strength* of the structure.
- S will represent the gathering together of all terms or parameters which relate to the *loading* applied to the structure.
- Z = the limit state function – If Z >= 0 the defence does not fail, if Z < 0, the defence fails

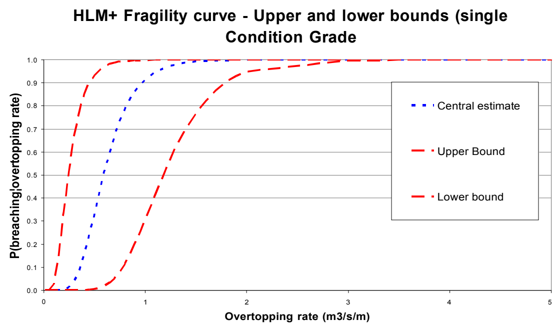
It is the degree to which R and S are resolved that varies between levels as discussed below.

A high level (coarse) defence reliability analysis

Quantitative loading information and basic information on geometry and condition can be used together with expert judgement to establish initial estimates of defence fragility. These methods have been applied to the NaFRA 2004 (Figure 11) and include the use of overtopping rate as the primary indicator failure mode for coastal defences, whereas for fluvial defences two indicator failure modes have been considered representing the two situations of the water level in the river being below or above the crest level of the defence. These simple, but structured fragility curves, have been established as part of an ongoing R&D project:Performance and Reliability of Flood and Coastal Defences (Environment Agency, 2004).







Above left: A family of fragility curves for a single defence type reflecting different condition grades based on an overtopping limit state equation.

Bottom Left: Typical uncertainty bands around the central estimated – based on the overtopping limit state equation for a single condition grade and structure type

***Above right: A family of** fragility curves based on two failure modes – piping and overtopping. Note the change in dominant failure process as the depth of water over the crest increases (positive freeboard) from piping to overtopping. In poorer condition defence failure can be expected through piping significantly before the water level reaches the crest.*

Figure 11 Example fragility curves taken from NaFRA 2004.

Application within the RASP Intermediate Level Methods

The ILM provides an opportunity to collect more data and apply defence-specific process models and expert judgements to identify appropriate failure modes. For an embankment these may include uplifting/piping, instability, overtopping, third party interference and animal burrowing, (Figure 12). Different structure types have a different set of failure mechanisms. For sheet pile walls for example failure modes include corrosion and accidental damage arising from ship collision or removal of tie rods.

At the intermediate level it me appropriate to use information on the joint loading conditions, in cases where combinations of two or more environmental loads such are important in determining risk.. The example shown in Figure 13 uses the results of the JOINSEA analysis of waves and water levels to produce a fragility surface (rather than a fragility curve) for a rock revetment in North Wales.

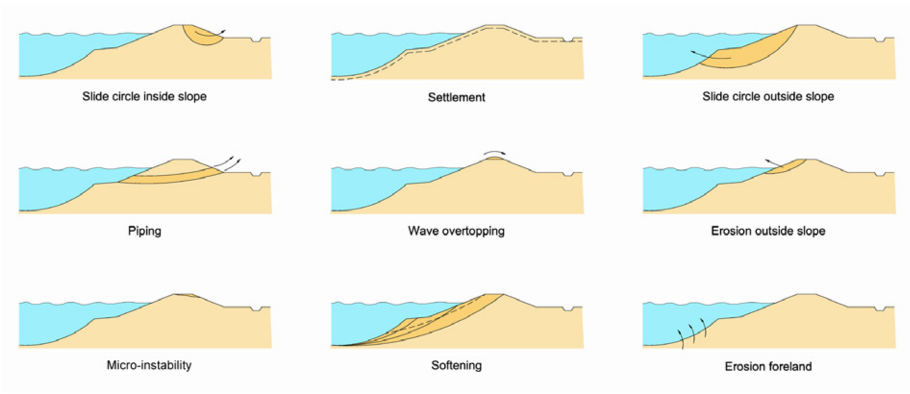


Figure 12 Example failure modes of an embankment (HR Wallingford, 2004) – Multiple failure modes can be analysis at the intermediate level

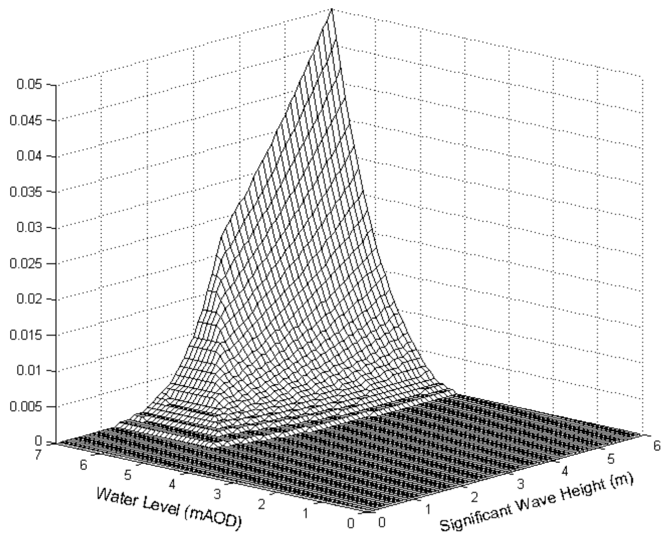


Figure 13 Example of a fragility surface taken from application of the RASP ILM methods at Conwy, North Wales.

Application within the RASP Detailed Level Methods

At a detailed level defence reliability under load may be established based a full reliability analysis taking account of:

- Multiple failure modes – slips, piping, crest erosion, overturning etc
- Utilise many strengthen parameters – geotechnical parameters, crest levels, toe levels, etc
- Include the dependencies between failure modes – both spatial and temporal

However, of course, our knowledge and understanding of how defences perform and fail (and our ability to model individual failure modes) remains limited and restricts the development of a reliability model based solely on physical based process understanding. We remain particularly unclear about deterioration processes and how these may effect the strength parameters in time and how to capture these processes in quantified terms. Therefore, even at the most detailed level expert judgement is needed to establish strengthen parameters and limit state equations related to a range of failure modes. There is however, significant know-how there are proven process models in existence around the world and these have been collated and reviewed as part of an on-going project tilted Performance and Reliability that is due for completion in the Summer of 2005. Using these available models detailed reliability analysis using multiple failure modes and detailed defence data are currently being trialed. An example of the range of failure modes being considered is shown in Figure 14.

While it is likely to be some time before these methods are used routinely, there is no doubt that they have the potential to give more reliable assessments of risk. They also provide added benefits such as improved understanding of critical failure mechanisms or weak links, more targeted intervention strategies, and monitoring and data collection to detect key failure modes.

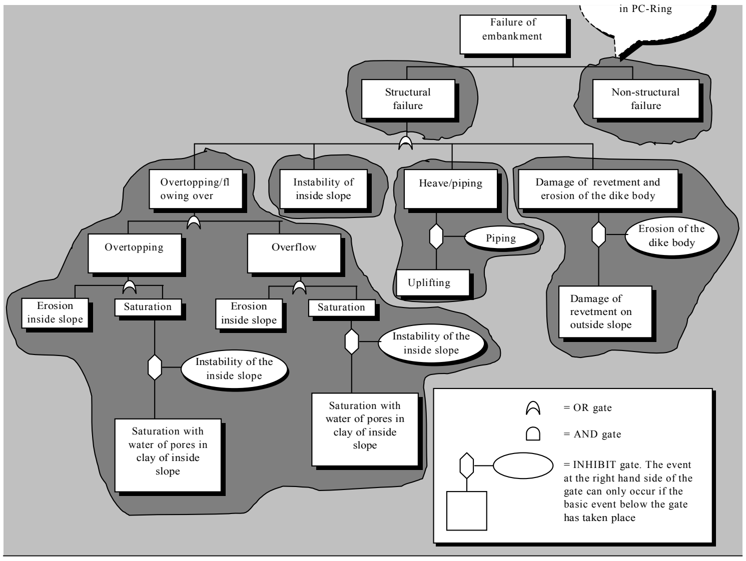


Figure 14 Use of multiple and interacting failure modes to establish defence fragility at the detailed level of RASP

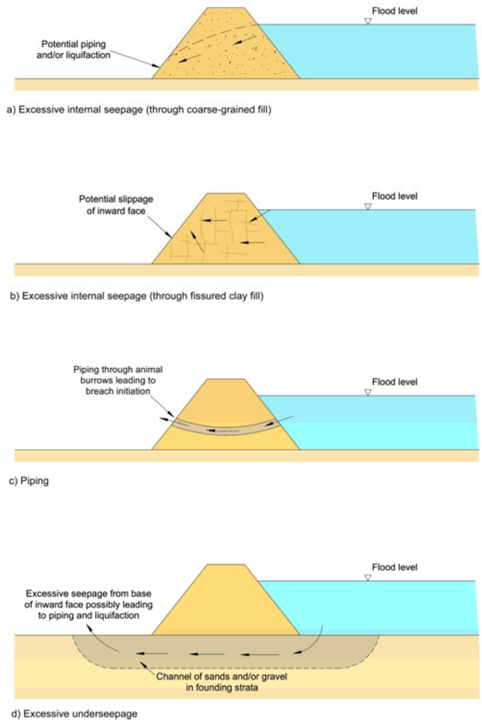


Figure 15 Improved guidance outlining the visual indicators associated with range of failure is currently under development (Environment Agency, 2004)

Supporting condition assessment

The notion of reliability analysis, based on an understanding of failure modes and their interaction is also being used to develop smarter ways of assessing the condition of defences. These new methods are being developed as part of the PAMS project and will directly link the condition inspection process to the likely performance of a defence under load. In particular, a more structured approach to the visual assessment process, where visual indicators of different possible failure modes (Figure 15) are used to guide the inspectors together with simplified process models.

In common with the notion of a tiered approached adopted within the planning and analysis process, the condition assessment approach will also be tiered. The approach currently under development includes a two tiered visual inspection combined with simple measurement before initiating more detailed site survey where the uncertainty in defence condition has a material influence on the preferred management approach and associated cost. This is currently under trial and development at a number of case study sites.

Summary of methods and condition inspection

The RASP project has developed a hierarchy of defence performance analysis and the PAMS project is currently developing the supporting inspection methods These are summarised in Table 2 below.

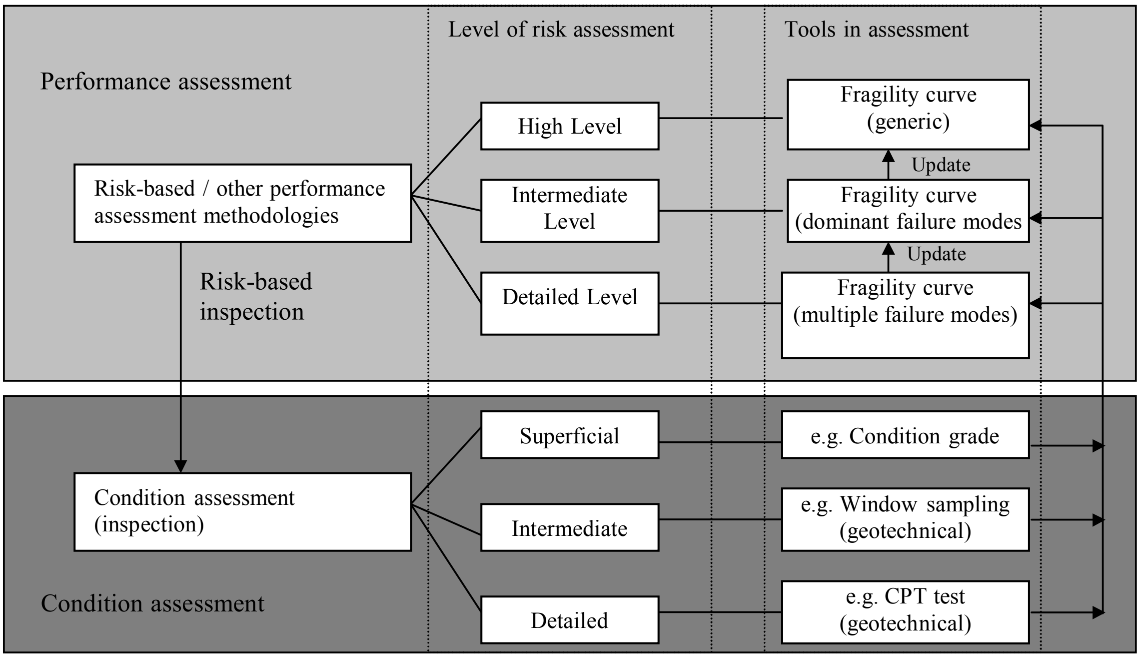


Figure 15 The hierarchy of defence performance assessment and associated condition assessment supported by RASP and being taken forward in PAMS

Conclusions

The need for improved risk assessment methodologies to support better flood risk management was the primary driver in support of the RASP project. The methods that have been developed will help the Environment Agency and Defra to understand more about how flood defences affect flood risk. In particular, they provide a significantly improved ability to predict the spatial distribution of both the probability and consequences of flooding, taking the influence of defences into account. The RASP methods will therefore directly support the Agency and Defra in better management of risk.

Similar results, but progressively more reliable, are obtained from each tier of analysis, with primary outputs including:

- For each defence within the flooding system
  - A description of defence performance under load (overtopping and breach failure)
  - The contribution of each asset to risk and risk reduction
- For each Impact Zone within the flooding system
  - An estimate of the probability of flooding within a given area of the flood plain (*Impact Zone*) taking account of all scenarios of load and defence failure combinations.
  - A range of risk metrics, such as expected economic damage, for each Impact Zone

The hierarchical approach enables the results from different tiers to be readily aggregated to regional and national scales. The RASP methods can be used in developing strategies and policies. They can include scenarios of change, such as flood frequency, investment in flood defences or floodplain occupancy.

Over the coming few years significant effort will be required to translate the RASP methods into specific tools to support flood management decisions in practice and this is already progressing through the NaFRA, MDSF and PAMS programmes. These activities will enable a comprehensive picture of the likelihood of flooding and associated risks to be established, taking account of a wide range of loads and wide range of defence failure scenarios. This will help deliver effective integrated management in practice.

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