Department for Environment Food and Rural Affairs

Environment Agency

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Scoping study for coastal asset management

Project: SC070061/R1

Flood and Coastal Erosion Risk Management Research and Development Programme

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Our work includes tackling flooding and pollution incidents, reducing industry's impacts on the environment, cleaning up rivers, coastal waters and contaminated land, and improving wildlife habitats.

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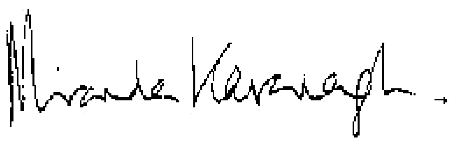

Miranda Kavanagh

Director of Evidence

Executive Summary

Considerable change is taking place in the approach, structure and funding of coastal erosion and flood risk management in the aftermath of the adoption of the Government's strategy, *Making Space for Water*. There is a strong move away from defending against erosion and flooding to the management of risks from erosion and flooding, with increasing application of risk-based approaches to the whole of coastal erosion and flood risk management. Practitioners are now, or soon will be, faced with new and challenging issues related to 'risk' management rather than that of traditional 'defence'. Overall these issues fall under the following headings:

- the need for a thorough understanding of the current and future performance and cost of existing defences;
- management of the process of ceasing to defend some areas from both human and engineering viewpoints;
- a broadening of the approach to sustainability in terms of time (long-term and short-term) and space (regional as well as local).

The Environment Agency's new role of overseeing responsibilities for coastal protection and flood defence has highlighted the need to ensure that adequate methods and tools are available to all coastal practitioners for the analysis and quantification of associated flood and coastal erosion risks and for future asset management. This scoping study sought to:

- identify the requirements of practitioners;
- identify and build on existing best practice;
- recommend a programme of future scientific work to fill gaps in knowledge and thereby contribute to improved procedures and decision support tools.

The report outlines the framework and scope of flood and coastal risk management, and proposes a decision-support framework and its important elements. The final recommendations take account of the results of a consultation that aimed to capture the needs of practitioners.

Some of the improvements and advances would take significantly longer to achieve and implement than others. The proposed programme therefore indicates dependences and suggests quick-to-implement steps for initial tasks, with less urgent and more complex steps foreseen as longer term requirements. Implementation would require a revision of flood and coastal asset management guidance to smooth the introduction of new components. A combination of software, databases, activity procedures, work instructions and training for the responsible authorities would be needed over the longer term. Any new methodologies need to be useful to practitioners and useable by both the Environment Agency and local authorities. A standardised method would help to promote good working relationships between the responsible authorities and allow data sharing to occur more readily.

The report also recommends that the Environment Agency, together with advisors from the flood risk management industry and representatives of Coastal Groups, consider the proposals for future developments with a view to facilitating a staged improvement in underpinning science, tool development and coastal asset management practice.

Glossary

Asset	In flood defence or coast protection, any man-made or natural object (e.g. a raised defence, retaining structure, channel, pumping station, culvert or beach) that performs a flood defence, land drainage or coast protection function.
Asset management	Systematic and co-ordinated activities through which an organisation optimally and sustainably manages its assets and asset systems – including their associated performance, risks and expenditures – over their life-cycles for the purpose of achieving its strategic aims.
Assessment	The process of understanding the state and structural competence of an existing asset or asset system in order to inform the planning of future interventions.
Benefits	In flood defence, land drainage or coast protection appraisal, the value placed on the reduced likelihood of flooding, waterlogging or coastal erosion provided by the asset, asset system or project (see also risk attribution).
Change	In asset management, work that alters the standard of service of an asset (e.g. raising a flood embankment crest above the original design level or asset decommissioning).
Characterisation	The process of expressing the observed or predicted behaviour of a system and its elements in order to inform some aspect of decision-making.
Condition	State of repair or deterioration of an asset. The condition grade is a systematic evaluation of asset condition by visible inspection.
Consequence	Impact such as economic, social or environmental damage of an event such as extreme storm, asset failure or coastal erosion. Can be expressed quantitatively (e.g. monetary value), by category (e.g. high/medium/low) or descriptively.
Crest level	Highest point of an asset at a particular locality that could be overtopped by a rising flood.
Critical element	Element of a system, the failure of which will lead to the failure of the system.
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 that, with probabilistic methods, the design standard can vary with load and there may be different performance requirements under different loading conditions.
Deterministic	Descriptor of method or process that adopts precise, single values for all variables and input values, giving a single value output.
Deterioration	Decline in the material properties of some or all components of an asset caused by external agents (e.g. freeze/thaw) leading to

	a reduction in its structural strength.
Discharge	Flow volume of a river, watercourse, drain or surface flood pathway as measured by volume per unit of time.
Disposal	Activities necessary to dispose of decommissioned assets.
Element	A component part of a system or asset.
Engineering inspection or survey	Detailed appraisal of an asset – including its foundations and internal structure as appropriate – to determine its condition, including any structural faults.
Event	Conditions which may lead to flooding or trigger a coastal landslip.
Failure	Inability to achieve a defined performance threshold. 'Catastrophic failure' describes the situation where the consequences are immediate and severe.
Failure mode	Description of one of any number of ways in which an asset or asset system may fail to meet a particular performance indicator.
Flood defence asset	An asset that by its failure would increase the likelihood of flooding from any main river, watercourse and/or the sea to people, property or infrastructure.
Flood defence system	Two or more flood defence assets acting to achieve a common goal (e.g. maintaining flood protection to a floodplain area/community).
Flooding system	The broad 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 flooding might be propagated and receptors could be harmed, is an essential aspect of understanding risk. This is true for an organisational system such as flood warning as well as for a physical system of assets.
Flow	General term used to describe movement of water in a particular direction (as distinct from specific descriptors such as discharge or velocity).
Fragility	The likelihood of particular defence or system to fail under a given load condition. Typically expressed as a 'fragility curve' relating load to probability of failure. Combined with descriptors of deterioration, fragility relationships enable performance to be described over time.
Frequent maintenance	Planned activities supporting the standard of service of an asset in a cost-effective manner by reducing its rate of deterioration (frequent < five yearly interval).
Function	The purpose that an asset fulfils for those who benefit from or use it, and the environment in which it exists. An asset will have a primary function of flood defence, land drainage or coast protection plus some secondary functions such as ecological, access, health & safety, or amenity.
Frontage	Sub-division of the coastline for asset management purposes.

Harm	Disadvantageous consequence.
Hazard	A situation (physical event, phenomenon or human activity) with the potential to result in harm. A hazard does not necessarily lead to harm – it can be managed.
Hierarchy	Conceptual framework for planning and risk management in which information cascades from a greater spatial or temporal scale to lesser scale, and vice versa.
Infrastructure	Collective term for a group of assets essential to normal life whose primary function is to provide a service to the community.
Intervention	A planned activity designed to effect an improvement in an existing natural or engineered system (particularly with asset management).
Limit state	The boundary between safety and failure for a structure. The limit state function Z = R – S is a function of the structure's strength (R) and loading (S) for a particular failure mode. Failure will not occur if the limit state function is positive.
Maintenance	Work that sustains the desired condition and intended performance of an asset.
Pathway	Route that enables a hazard to propagate from a source to a receptor. A pathway must exist for a hazard to be realised and can be constrained to mitigate risk.
Performance	The degree to which a process or activity succeeds when evaluated against some stated aim or objective.
Planshape	The two dimensional shape of the foreshore or beach in the horizontal plane.
Probability	Measure of the chance that an event will occur. Typically defined as the relative frequency of occurrence of that event out of all possible events and expressed as a percentage with reference to a time period (e.g. 1 per cent annual exceedance probability).
Probabilistic	Descriptor of method or process in which the variability of input values (e.g. asset loading and strength) and the sensitivity of the results are taken into account to give results in the form of a range of probabilities for different outcomes (e.g. failure).
Receptor	The entity (e.g. a person, property, habitat) that may be harmed by an event via a source and pathway. The vulnerability of a receptor can be reduced by increasing its resilience.
Refurbishment	The process of returning an asset to its original 'as designed' performance
Residual life	Service life remaining at a particular moment in time. Residual life can be extended or reduced by altering maintenance practice or by refurbishment.
Residual risk	The risk that remains after risk management and mitigation measures have been implemented. For example, damage predicted to continue to occur during flood events of greater severity than 1 per cent annual exceedance probability.

Resilience	In asset management, the ability of an asset or asset system to resist the damaging effect of extreme loading. Resilience measures can, for example, help to achieve design standards above the Standard of Protection (SoP).
Risk	Risk can be considered as having two components – the probability that an event will occur and the consequence associated with that event to receptors. Risk = f (probability × consequence). Flood risk to a receptor can be indicated graphically by a probability density function (pdf) with probability and consequence as the *x* and *y* axes. The area under the curve is the overall risk.
Risk assessment	The process of identifying hazards and potential consequences, estimating the magnitude and probability of consequences, and assessing the significance of the risk(s). A 'tiered' approach can be used with the effort in assessing each risk proportionate to its importance in relation to other risks and likely consequences.
Risk attribution	The contribution of specified assets or groups of assets to the overall risk to receptors associated with a flooding system or protected by a flood defence system. This helps interventions to be targeted on managing the greatest risks.
Risk management	The systematic process of risk assessment, options appraisal and implementation of any risk management measures to control or mitigate risk.
Source	The origin of a hazard (e.g. storm rainfall, strong winds, surge).
System	Assembly of elements, and the interconnections between them, constituting a whole and generally characterised by its behaviour (e.g. elements in a structure; assets in an asset system).
System Asset Management Plans (SAMPs)	Long-term investment plans for flood defence and coast protection asset systems that identify the investment needed and the benefits they bring.
Toe Level	Depending on the context used, toe level refers either a) to the level at which the foreshore intersects a flood or erosion defence structure (e.g. seawall), or, b) to the height of the toe of the structure itself.
Ultimate limit state	Limiting condition beyond which a structure or element no longer fulfils its intended function(s), e.g. flood defence, amenity, etc.
Uncertainty	Lack of sureness about someone or something ranging from almost complete sureness to almost complete lack of conviction about an outcome. Caused by (a) natural variability (inherent uncertainty) or (b) knowledge (epistemic) uncertainty.
Visual asset inspection	Visual inspection of an asset to evaluate its condition in line with a fixed programme of inspection.
Vulnerability	Characteristic of a particular asset, system or receptor group that describes its potential to be harmed.
Whole life cost	Total cost of managing an asset over its life including cost of construction, use, operation, inspection, maintenance and refurbishment, replacement or disposal.

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1 Introduction

The recent adoption by the Environment Agency of the role of overseeing responsibilities for coastal protection and flood defence has highlighted the need to ensure that adequate methods and tools are available to all coastal practitioners for:

- the analysis and quantification of flood and coastal erosion risks;
- future asset management.

This report provides an evaluation of existing knowledge and tools available to flood and coastal risk management (FCRM) practitioners in support of the management of assets at the coast. Through a combination of consultation and expert review, the gaps in existing knowledge and future development needs have been identified and priorities for action recommended.

The timing of this work is particularly important as two related analytical methodologies – 'PAMS'[1] (for flood defence) and 'RACE'[2] (for coastal erosion) – have recently been developed. The need to link these is recognised and was one of the original drivers for this study.

1.1 Project aim

The aim of the scoping study is to:

- establish a programme of science to underpin the development of procedures and decision-support tools that allow coastal managers to identify and prioritise management interventions;
- review user needs and current best practice including:
  - the requirements of, and current best practice within, the Environment Agency;
  - the requirements of, and current best practice within, local authorities;
  - identification of shared needs and appropriate common systems to ensure take-up of the study outputs;
- identify a coherent framework for future tools that includes consideration of:
  - integration of processes acting at varying scale and temporal scales;
  - cross-shore and longshore coastal process connectivity between assets;
  - load and condition dependent and time-dependent fragility;
  - backshore behaviour;
  - whole life costs;
  - approaches to decision-making, including support for Outcome Measures (see Section 2 and Appendix 12);
- identify a forward programme of science to deliver improved guidance, procedures and, where necessary, supporting tools.

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[1] Performance-based Asset Management System
[2] Risk Assessment for Coastal Erosion

1.2 Project objectives

The project aims have been refined into specific objectives. These include providing:

- a route map for the development of a coherent set of tools/guidance to support the management of FCRM assets;
- an associated programme of supporting science.

Once developed, these tools/guidance will support transparency in the prioritisation of:

- data collection and inspection activities;
- asset maintenance, replacement and removal (cliff, linear, attached and detached structures, beaches, etc.).

This prioritisation will be based on supporting evidence and an improved understanding of:

- **Source** – wave and water levels at the coast and its geology (and future changes), and morphological response;
- **Pathways** – performance of the beach 'system' (i.e. beach levels at the toe of backshore structures or cliffs as a risk influencing mechanism), backshore structures (natural and manmade), cliff face (where it exists) and foreshore;
- **Pathways** – defence failure, cliff erosion (where appropriate) and the propagation of flood waters across the floodplain (where appropriate);
- **Receptors** – those exposed and vulnerable to erosion and flooding;
- **Decision criteria** – costs of actions and decision criteria (benefit/costs, environmental impacts, etc.).

An indicative illustration of the sources, pathways and receptors at the coast is shown in Figure 1.1.

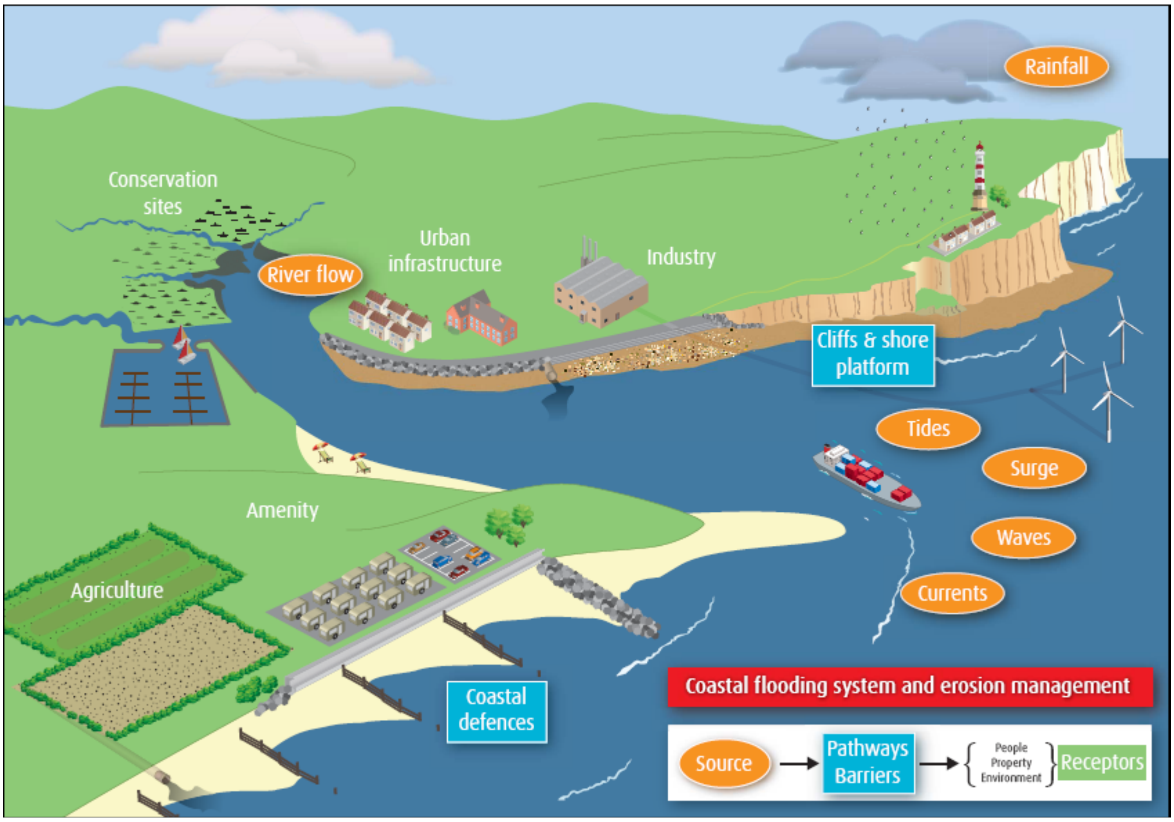

Figure 1.1 Illustrative example of the sources, pathways and receptors for coastal flooding and erosion at the coast.

1.3 Outline of the report

The study approach took for its basis two recently developed methodologies for flood and coastal erosion risk management:

- Risk Assessment for Coastal Erosion mapping methodology (RACE);
- Performance-based Asset Management System (PAMS) approach to strategic flood risk assessment.

RACE has been applied nationally (as the National Coastal Erosion Risk Mapping or 'NCERM' project) to produce coastal erosion risk maps and includes the representation of coastal protection assets. PAMS was a programme of lengthy applied research into the development of tools and methods to support asset management decision-making in fluvial and coastal flood risk assessment.

The basic study approach is illustrated in Figure 1.2. This shows the logic adopted of taking accepted base principles (PAMS and RACE), drawing on related information from appropriate sources, collating it and formulating through reasoned judgement and design into a proposal for a way forward including recommendations for a programme of research work.

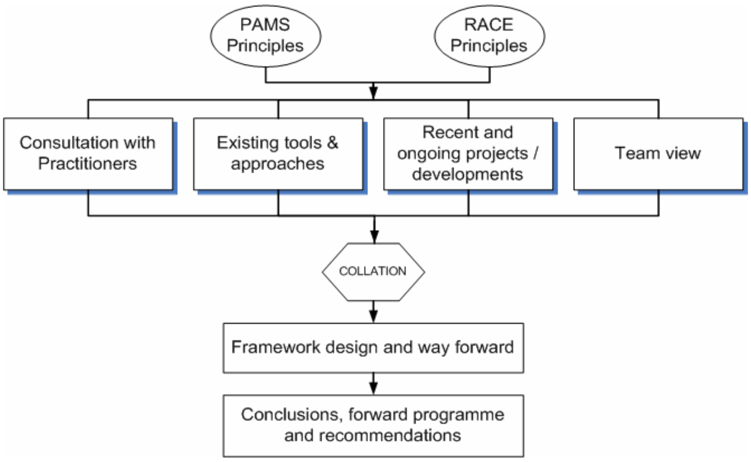

Figure 1.2 Illustration of the study approach.

The rest of the report is structured as follows:

- Section 2 provides a general background to the project and sets the scene within which future work is to take place. It includes an outline of the role that asset management plays in flood and coastal erosion planning and the current planning mechanism(s), and lists users and the relevant responsible authorities.
- Section 3 briefly illustrates the risk principles on which coastal management policy is based including the source–pathway–receptor concept.
- Section 4 summarises the user questions and principles that robust flood and coastal erosion risk management decision-makers require to (a) have answers to and (b) need to understand. These are discussed under the headings of 'asset inspection and recording', 'beach system performance', 'impacts of structures on beach behaviour', 'sustainability and whole life costs', and 'benefits and risk attribution'.
- Section 5 lists existing known data sources for FCRM asset management requirements and the data capture initiatives currently being undertaken at national and regional scales. It also discusses the issues that can constrain the usefulness of data such as availability, quality and scale.
- Section 6 lists various methods and tools that either simply store data or undertake some level of analysis of the data. These may be straight forward databases, bespoke modelling tools or decision-making support systems (DSSs). It also includes a list of recommendations on the subject from the EU-funded FLOODSITE project, which reviewed UK flood risk management DSSs.
- Section 7 reports on information captured from previous consultation work by the Environment Agency's Sustainable Asset Management (SAM) Theme Advisory Group and from a practitioners forum/workshop event designed and conducted specifically to inform this scoping work. The section goes on to outline the knowledge gaps believed to exist in physical processes, the resilience of natural defences, and in asset inspection and condition assessment.
- Section 8 discusses the challenges and opportunities that lie ahead for FCRM science and the Environment Agency in order for it to deliver

effective asset management at the coast. A framework for the development of a coherent set of tools, methods and techniques is proposed and outlined. The elements suggested include ‘decision support’, ‘systems analysis’, ‘inspection and assessment of asset condition’, and ‘common and improved databases’. Finally there is a summary of potential improvements and further research categorised under short-, medium- and long-term timeframes.

The focus of this report is to set out the science and research that will support the development of the new generation of tools and their eventual implementation.

As such, this report is of interest to anyone engaged in the management of flood and coastal erosion risk management assets in England, Scotland, Wales and Northern Ireland such as:

- maritime councils (coast protection operating authorities);
- Environment Agency, Scottish Environment Protection Agency (SEPA) and Northern Ireland Environment Agency;
- drainage authorities;
- private coastal frontage owners.

It will also be of importance to the attendees of:

- the Environment Agency’s Joint Programme Management Team;
- the Environment Agency’s Modelling and Risk Theme Advisory Group (MAR);
- the Environment Agency’s Sustainable Asset Management Theme Advisory Group (SAM);
- Environment Agency staff involved in asset management and operational delivery, the National Environmental Assessment Service (NEAS) and the National Capital Management Programme Service (NCPMS).

1.4 Development programme

Development of the programme for flood and coastal risk management of assets has been organised in three phases:

1. This initial phase is a scoping study to:
    - establish future user needs and requirements;
    - identify existing tools and techniques available;
    - identify the gaps;
    - propose further research and development.
2. A second phase will take forward the highest priorities, develop methodological approaches and test these with pilot studies where necessary. Quick solutions (or ‘measured steps forward’[3]) will also be

[3] ‘Measured steps forward’ are developments that are usually discrete, quick components of work which are relatively easily achieved and have been identified as required and timely products for FCRM practitioners.

developed and integrated into Environment Agency activities where possible, including provision of guidance where required to enable immediate improvements. Detailed system planning will also continue in this phase of work.

3. A final phase will see full development and implementation of the approach which, subject to detailed justification, may include supporting guidance, manuals, work instructions, training and software.

1.5 Links to other projects

This programme of work supports the business objectives of the Flood and Coastal Risk Management Asset Management group and derives from needs identified by the SAM Theme Advisory Group and previous projects such as the 'Operations and Maintenance for Concerted Action', and the PAMS and RACE projects.

The development of this approach will need to be closely linked to a number of recent and ongoing studies and future developments. These are listed in Appendix 1.

Conclusions and recommendations from these recent projects considered particularly pertinent (and available) to this scoping study are given in Appendices 6–11.

Recommendations for further research that were not available at the time of writing but were imminent (e.g. LEACOAST2 project[4]) should be reviewed with a view to incorporation into the future science programme.

[4] http://www.research.plym.ac.uk/cerg/leacoast2/

2 Background

Coastal asset management is one aspect of managing the risk of flooding and erosion for those who live near, work by and visit the coast. The Environment Agency needs to be able to assess the benefits that asset management provides and compare them to other risk management activities. This project will help it to refine this comparison.

The overall objective of this scoping study is to establish a programme of science to provide managers of coast protection assets with improved procedures and decision-support tools for the identification and prioritisation of management interventions. The Environment Agency also needs to introduce the practical benefits of the RACE method into the current PAMS process for flood risk management (FRM). This will enable coast protection assets to be effectively managed within the context of Shoreline Management Plans, coastal erosion risk, and local amenity and environmental requirements.

An important aspect of the work is to:

- make appropriate use of existing FCRM tools and techniques;
- support the implementation of policy and operational changes that will bring a new consistent approach to the strategic planning of coastal defence (i.e. flood defence and coast protection).

In consultation with the Welsh Assembly Government (WAG) and in partnership with the Environment Agency and other operating authorities, Defra promotes a framework for sustainable flood and coastal erosion risk management in England and Wales through national guidance. This consists of:

- a number of high level targets to guide implementation;
- a system of broadly based strategic plans for implementation;
- agreement on risk management policies at catchment or coherent shoreline unit levels.

The Government's new strategy[5] following the 'Making Space for Water' consultation reinforces and develops this approach.

Like risk reduction, any development of asset management methods and tools for sustainable delivery should:

- consider the requirements of these policies;
- support FRCM processes and operations;
- support the achievement of the obligations and objectives.

Three important changes have occurred in recent years which are providing the stimulus for better integration of flood and coastal management:

- In spring 2008, the Environment Agency adopted a strategic overview of coastal protection and flood risk management in England.[6] Consistent with this overview is a desire to ensure that methods are in place to assess the risk to assets (built and environmental) and infrastructure from the threat of both flooding and coastal erosion.

[5] http://www.defra.gov.uk/environment/flooding/policy/strategy/index.htm
[6] http://www.defra.gov.uk/environment/flooding/policy/strategy/coast.htm

- Changes to future planning by local planning authorities (LPAs) and shoreline managers provide the opportunity for better and wider incorporation of coastal risk management policies in town and country planning documents (see Appendix 13).
- The UK Government has introduced a set of Outcome Measures (OMs) for flood and erosion risk management (see Appendix 12).

Outcome Measures were implemented from 1 April 2008 as a performance framework to measure the benefits associated with flood and coastal risk management . Targets have been developed to provide greater clarity on what policies and funding are intended to achieve.

Coastal risk is an increasingly important issue which affects future development and land use at regional level, particularly in relation to major redevelopment and regeneration in low-lying areas. Shoreline Management Plans provide a major source of information for such policy. Bringing together Regional Spatial Strategies (RSSs) and Shoreline Management Plans allows scientific and technological information to inform regional spatial policy. The Regional Spatial Strategy also provides an opportunity for public examination of resulting policy.

To support and underpin asset management decisions that must comply with such remits and policies, the responsible authorities and bodies involved require scientific risk-based methodologies and approaches that are both consistent and robust. Unfortunately, approaches to the management of coastal flood risk and coastal erosion risk have not so far been particularly congruent. This study will begin the process of addressing this issue by:

- understanding user needs;
- determining and integrating appropriate research.

2.1 Role of asset management in the planning hierarchy at the coast

Within a cycle of continuous improvement, a series of levels can be identified at which FCRM planning and decision-making takes place (Figure 2.1). This hierarchy of decision-making is enacted through a series of specific ‘plans’ (Figure 2.2). Any risk assessment and decision support tools must support the decisions made within the context of these plans.

As highlighted in Figure 2.2, strategic planning performs a pivotal role in the system planning process. Understanding of the system, risk assessment, option appraisal and planning decisions made under the heading of strategy planning – including Catchment Flood Management Plans (CFMPs), Shoreline Management Plans (SMPs) and Strategy Plans – set the direction of different management interventions and responses. These include asset management, regulation, development control and incident management for a specific region or coastal cell/sub-cell.

As the more detailed delivery plans are completed (including, for example, system asset management, development control and incident management planning), an improved understanding of the behaviour and the investment needs of the system are fed back into the higher level plans. Asset improvement plans and scheme designs can then be drawn up under this umbrella of delivery planning.

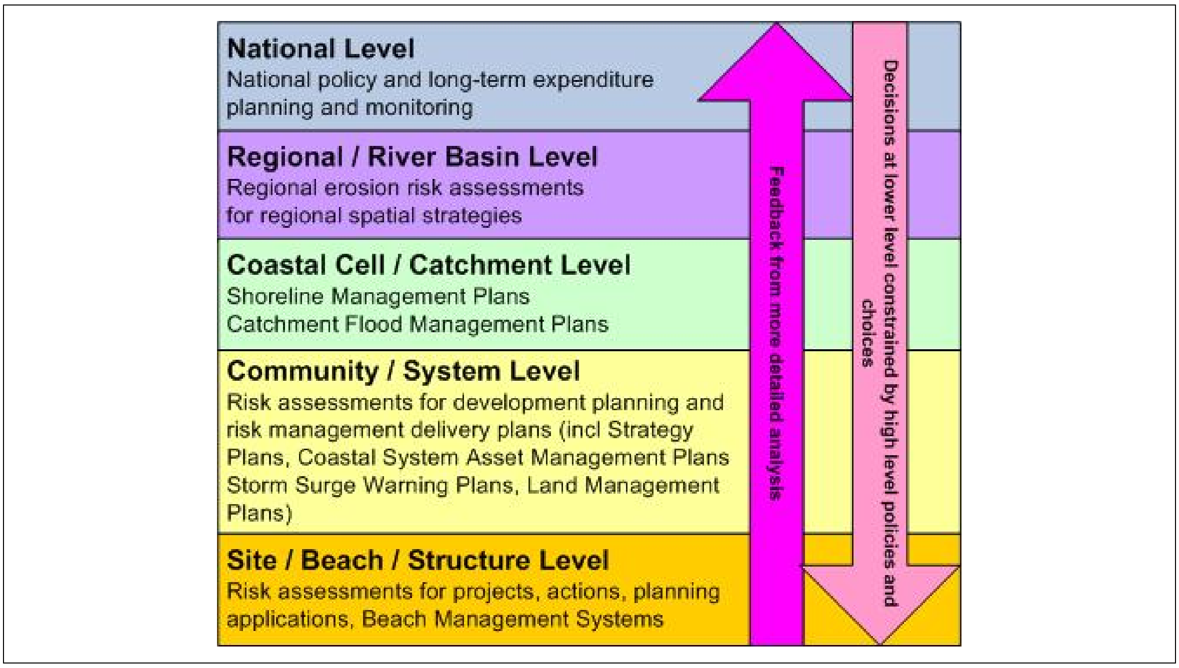

Figure 2.1 Planning levels recognised within the FCRM community.

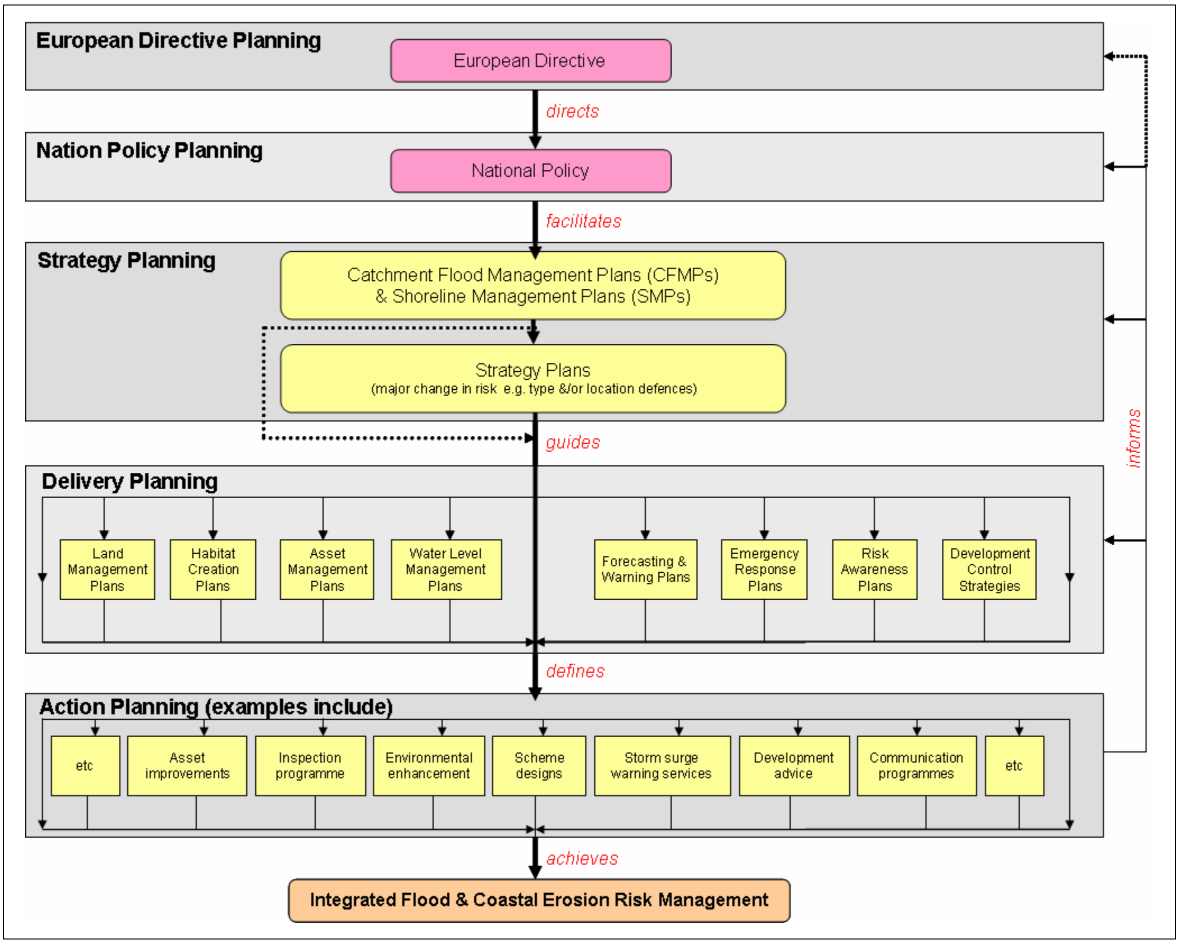

Figure 2.2 Overview of FCRM plans that support the delivery of integrated risk management within the Environment Agency.

Before discussing the needs of those engaged in the preparation of SMPs and Strategy Plans, it is helpful to set the context of the strategic planning framework for coastal defence. Table 2.1 explains the role of Shoreline Management Plans and strategies in selecting policy and management options. Those involved in undertaking these plans, strategies and scheme developments are listed in Table 2.2, together with their primary interests. These people are the anticipated users of, and/or interested parties in, any new performance-based asset management tools for the coast.

Table 2.1 Stages in the strategy development/appraisal process.

Stage	Shoreline Management Plans	Strategy/ implementation studies	Scheme development	Asset management
Aim	To identify policies to manage risks.	To identify appropriate schemes to put the policies into practice.	To identify the type of work to put the preferred scheme into practice.	To manage assets optimally over their life-cycle to ensure performance to required standard.
Delivery	Wide-ranging assessment of risks, opportunities, limits and areas of uncertainty.	Preferred approach, including economic and environmental decisions.	Comparison of different options for putting the preferred scheme into practice.	Comparison of different options for optimal delivery of required performance.
Output	Policies (e.g. hold, retreat, advance) and a broad explanation of how this will be achieved.	Type of scheme (e.g. beach recharge, sea wall, setback embankment)	Design of works (e.g. revetment, wall, recycling).	Optimal performance of asset over its complete lifetime in context of asset system.
Outcome	Improved management for the coast over the long term.	Management measures that will provide the best approach to managing floods and the coast for a specified area.	Reduced risks from floods and coastal erosion to people and assets.	Maintained standards of service from floods and coastal erosion for people and assets.

Table 2.2 Users and interests in coastal strategies and schemes.

Users	Interest
Engineers in local authorities and other bodies such as Network Rail.	Design and implementation of schemes and asset management Costing options
Operational staff in the Environment Agency Coastal Groups	Implementation of schemes and asset management
Engineers within consultancy companies working on behalf of the Environment Agency, local authorities or other operating authorities Coastal Groups	Strategic and management planning Risk assessment Scheme design and asset performance assessment Costing options
Policy advisors	Strategic impact and risk assessment of policy options including consideration of long-term impacts and financial obligations with respect to management decisions Compliance with legislation and litigation
Environmental and other stakeholders with a valid interest in the impacts of policy decisions (e.g. planners, economists) as well as the public at large	Environmental protection of designated areas/species Impacts on private property (loss of land and buildings), archaeology and geology, businesses and amenity for tourism

2.2 The current position

A variety of methodologies and tools are available to assist with analysis and decision-making at the different levels in the hierarchy shown in Figure 2.1. Some of these and the type of data they require are listed in Table 2.3.

Table 2.3 Supporting methods and typically required data for different management levels.

Management level	Current supporting methods/tools (excluding bespoke and commercial tools)	Required data types
National	NaFRA (supported by RASP) RACE	Regional/river basin information National property data, Vulnerability index Depth damage curves Deterioration rates and residual life
Regional/river basin	MDSF (supported by RASP – flooding only) RACE	Coastal cell/catchment information National property data Land use Vulnerability index Depth damage curves Defence reliability, deterioration and residual life Process modelling support
Coastal cell/catchment	PAMS and MDSF2 (supported by RASP – flooding only) RACE	Community/system information, Receptors and people at risk Land use designations, National property data, Vulnerability index Depth damage curves Defence criticality and deterioration rate Process modelling support
Community/system	PAMS RACE	Site/beach/structure information, Receptors/people in the zone of influence Depth damage curves Residual life Process modelling support
Site/beach/structure	PAMS (supported by RASP and associated reliability analysis and inspection) RACE	Joint probability hydraulic loading conditions Topography Defence type, location, geometry and condition data Erosion/accretion rate Sediment transport rate Designated site boundaries Ownership Process modelling support

Notes MDSF2 = Modelling and Decision Support Framework 2
NaFRA = National Flood Risk Appraisal
RACE = Risk Assessment for Coastal Erosion
RASP = Risk Assessment for System Planning

Consistent tools and techniques for risk assessment and asset management decision-making are necessary to undertake the planning and decision-making processes effectively, for example, determining:

- optimal timing of intervention (maintenance or capital) and scheme prioritisation according to risk reduction;
- optimal return on expenditure for multiple benefits (i.e. beyond FCRM benefits).

As discussed earlier, asset managers take their lead from national policies and the specific asset management policies or measures set out within higher level Strategy Plans (where they exist). Where these policies include management or improvement of existing assets, asset managers seek to ensure they are implemented in the most efficient and effective manner.

Defra's *Flood and Coastal Defence Project Appraisal Guidance* (FCDPAG)[7] (MAFF 2001) provides a framework for considering investment decisions taking account of economic, environmental and social benefits as well as legal requirements. It also provides a means of ensuring that the advantages and disadvantages of alternative defence options are fully considered in the light of a wide range of issues such as landscape, conservation and recreation together with more easily measurable benefits such as agricultural outputs and property values. 'Doing nothing', 'maintaining the current line of defence' and 'managed realignment' are among the options that the guidance indicates should be considered before establishing a preferred flood management policy for any particular length of defence.

Asset managers seek to manage infrastructure based on a whole life philosophy that includes the maintenance and eventual removal/replacement of an asset. This necessitates consideration of a long-term appraisal period (>50–100 years) within the Strategy Planning process. Asset managers are then tasked with determining the most efficient and effective programme of interventions within the context of either medium-term (3–5 years) and/or long-term (5–10 years) planning horizons. To do this, decision-makers need to understand:

- the contribution each asset makes to risk;
- the influence a particular intervention has on risk reduction and its associated cost.

Approaches such as Risk Assessment for System Planning (RASP) (Environment Agency 2007) are already being embedded within Environment Agency practice, e.g. through NaFRA (National Flood Risk Appraisal) and MDSF2 (Modelling and Decision Support Framework 2). However, these tools are primarily focussed on systems analysis of catchment flooding at the national and strategic planning levels. Although the underlying risk principles are common, these have limited applicability to coastal erosion or to coastal erosion asset management at the delivery and action planning or 'local' levels. In addition, the data used often require finer resolution to provide more precise outputs for them to be useful.

In the context of a hierarchy of decisions, Asset Management Plans support all other plans by providing bottom–up support. For example, it has always been envisaged that Asset Management staff will provide the base data on the assets, their location, condition, geometry and fragility to other planning processes within the Environment Agency and elsewhere. This is to be done through the data collected as part of the 'day job' and as part of the development of System Asset Management Plans (SAMPs).

MDSF2 is aimed at more complex hydraulic situations where the asset intervention is likely to materially change the hydraulic regime. It is likely to be used by consultants engaged by NCPMS teams to support the development of new schemes and more major asset management strategies.

Under the SAM Theme Advisory Group of the Joint Defra/Environment Agency Flood and Coastal Erosion Risk Management R&D programme, a programme of science is being carried out to develop a performance, systems and risk-based approach to

[7] Consists of five volumes, FCDPAG 1–5 *(currently being updated by the Environment Agency.)*

management of flood defence assets. The principles, procedures, tools and related software are collectively referred to as PAMS.[8]

This methodology is based not only on defence asset condition, but also takes account of the importance of the asset in terms of potential flood risk. Under the PAMS study, HR Wallingford has worked with Royal Haskoning and Halcrow Group to develop the methods and to conduct pilots.[9] The PAMS team is currently finalising the specification of the R&D deliverables under the delivery phase (PAMS Phase 3) with the broader FRM process tools for asset management and investment planning, and related systems such as the National Flood and Coastal Defence Database (NFCDD) and flood risk mapping.

In additional, FCRM staff are working teams and staff from the FRM community to develop suitable supporting IT technologies for the Environment Agency. The vision is for a system which can act as a 'one-stop' shop for all asset management information, bringing together current systems, introducing new ones and replacing systems considered not fit-for-purpose. However, it is not a 'quick fix' solution; the introduction of such a system will be phased over many years through a series of project modules.

In a separate study, the Joint Defra/Environment Agency Flood and Coastal Erosion Risk Management R&D Programme commissioned Halcrow to develop a consistent method for the assessment of coastal erosion risk on a national scale. Under the RACE R&D project (FD2324), Halcrow developed such a method and undertook pilot testing with local authorities (Halcrow 2007). This study has now been extended as part of the Making Space for Water programme to apply the methods developed under RACE throughout England and Wales in a project entitled 'National Coastal Erosion Risk Mapping' (NCERM). Validation tools are currently being rolled out to all local authorities across England and Wales to validate the input data and indicative results. This process has driven the need for improved base datasets. The validated dataset produced during the NCERM project will provide much of that information for re-incorporation into NFCDD.

Although the RACE tools are being used to produce national maps of coastal erosion, they also allow assessment of the effects of coast protection assets on the rate of coastal erosion, and for considering the effect of asset deterioration on asset performance.

There is now a need to link the RACE initiatives with PAMS and other projects to develop a consistent methodology for FCRM within an approved PAMS framework.

While there are a number of similarities between the methods developed by these initiatives, a scoping study is required to:

- plot the course of more integrated future approaches to national and detailed scale analysis;
- verify that methods are sufficiently consistent to enable a transparent and integrated approach to asset management across FCRM assets.

To be effective at a more local scale, methods and tools will need to be developed that can consider the impact of beaches and beach control structures on defence asset performance.

There are other projects that are highly relevant to both PAMS and RACE, including consideration of beach lowering and longshore impacts that should be incorporated into any new techniques to be developed.

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[8] Performance-based Asset Management System for Flood Defences (http://www.pams-project.net/)

[9] http://www.pams-project.net

- Projects commissioned by the Joint Defra/Environment Agency Flood and Coastal Erosion Risk Management R&D Programme:
  - Understanding the Lowering of Beaches in Front of Coastal Defence Structures (FD1927) – improved prediction methods suitable for design and risk assessment for asset management (Sutherland et al. 2007);
  - Characterisation and Prediction of Large-scale, Long-term Change of Coastal Geomorphological Behaviours (SC060074).[10]
- Research by the Flood Risk Management Research Consortium (FRMRC)[11] has included the development of a dynamically linked suite of broad scale numerical hydrodynamic and sediment transport models and analysis methods, which efficiently estimate beach levels immediately in front of sea walls.

It was therefore necessary for this scoping study to consider the approach to future development of tools for coast protection asset management in the light of both RACE and PAMS and other studies, practitioner requirements, and other relevant policy and operational developments (e.g. improved monitoring programmes) currently taking place in coast protection.

The study has identified the needs and requirements of the various potential users of the asset information, allowing the methods developed to enable informed decisions to be made. While not explicitly developing an asset management tool, the study aims to:

- identify and catalogue user needs for decision-support tools;
- develop the underpinning principles that they will need to be founded upon.

2.3 PAMS and RACE – the existing approaches

The PAMS (Performance-based Asset Management System) approach and RACE (Risk Assessment for Coastal Erosion) method were established for different reasons.

- **PAMS** (Section 2.3.1) was devised to:
  - assist asset managers and decision-makers in establishing the relative performance and reliability of (primarily flood) defences and asset systems;
  - attribute flood risk to defences and systems;
  - determine residual risk given different intervention options.

  The aim was to better underpin (with science) the prioritisation of coastal defence schemes and works.
- **RACE** (Section 2.3.2) was established to provide a national method with which to determine the risks of coastal erosion and its uncertainty based on national data modified through local expert input.

Both are system and risk based approaches; although probabilistic, they use probability differently in their respective methods.

[10] http://www.coastalgeomorphology.net/index.html
[11] http://www.floodrisk.org.uk

2.3.1 PAMS – a brief description

PAMS is a tool which enables flood and defence managers to assess the performance of, and management requirements for, existing flood defence assets. These requirements may involve maintenance, adaption/replacement or removal. The long-term planning functionality provides a means of identifying the preferred management intervention to achieve a particular performance outcome or expenditure profile.

The conceptual methodologies that underpin the PAMS DSS are at an advanced stage of development and many of the DSS modules have been finalised; however, the final front end and interfacing between the modules is still under development.

The PAMS DSS includes source, pathway, receptor and consequence modules as well as a management intervention and decision support module. It is based on a probabilistic approach to determining the flood risk and expected annual damage (cost, people, etc.) at a given location in the floodplain as a result of the performance of the system of defences and the floodplain vulnerability. An example output map is shown in Figure 2.3.

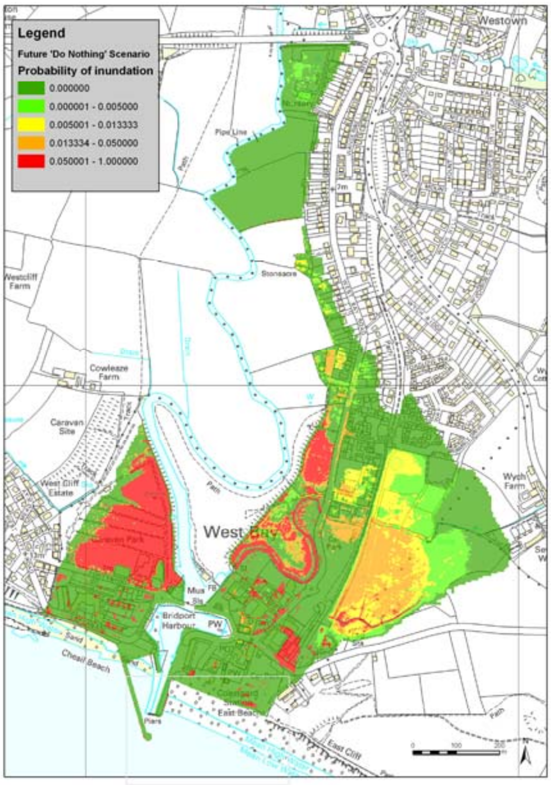

Figure 2.3 Example of mapped output from PAMS showing probability of inundation (Defra/Environment Agency 2009a).

The systems analysis framework is based on Risk Assessment of Flood and Coastal Defence for Strategic Planning (RASP) methods.[12] The PAMS tool specifically focuses on the assets or system of assets, providing information on whether a given asset or asset property increases or decreases the flood risk. Application is unrestricted, i.e. it can be applied to coastal, fluvial and estuary sites.

[12] http://www.rasp-project.net/

Figure 2.4 illustrates the process of the PAMS/RASP analysis engine from data repository to product.

- The source terms include base meteorological data, surge and river levels, and wave heights imported from external models.
- The pathways include the asset description (e.g. crest and toe levels), breach information and the Digital Terrain Model (DTM).
- Information on condition grade, standard of protection and type of defence is also included as the PAMS DSS considers the time-dependent deterioration of due to hydraulic loads (e.g. toe scour) and non-hydraulic loads (e.g. animal burrowing).
- The reliability of assets is also included, e.g. crest erosion and rotational slip.
- The receptor terms include information on exposure (e.g. property locations) and quantified vulnerability (e.g. depth-damage curves).

See http://www.pams-project.net for further information on PAMS.

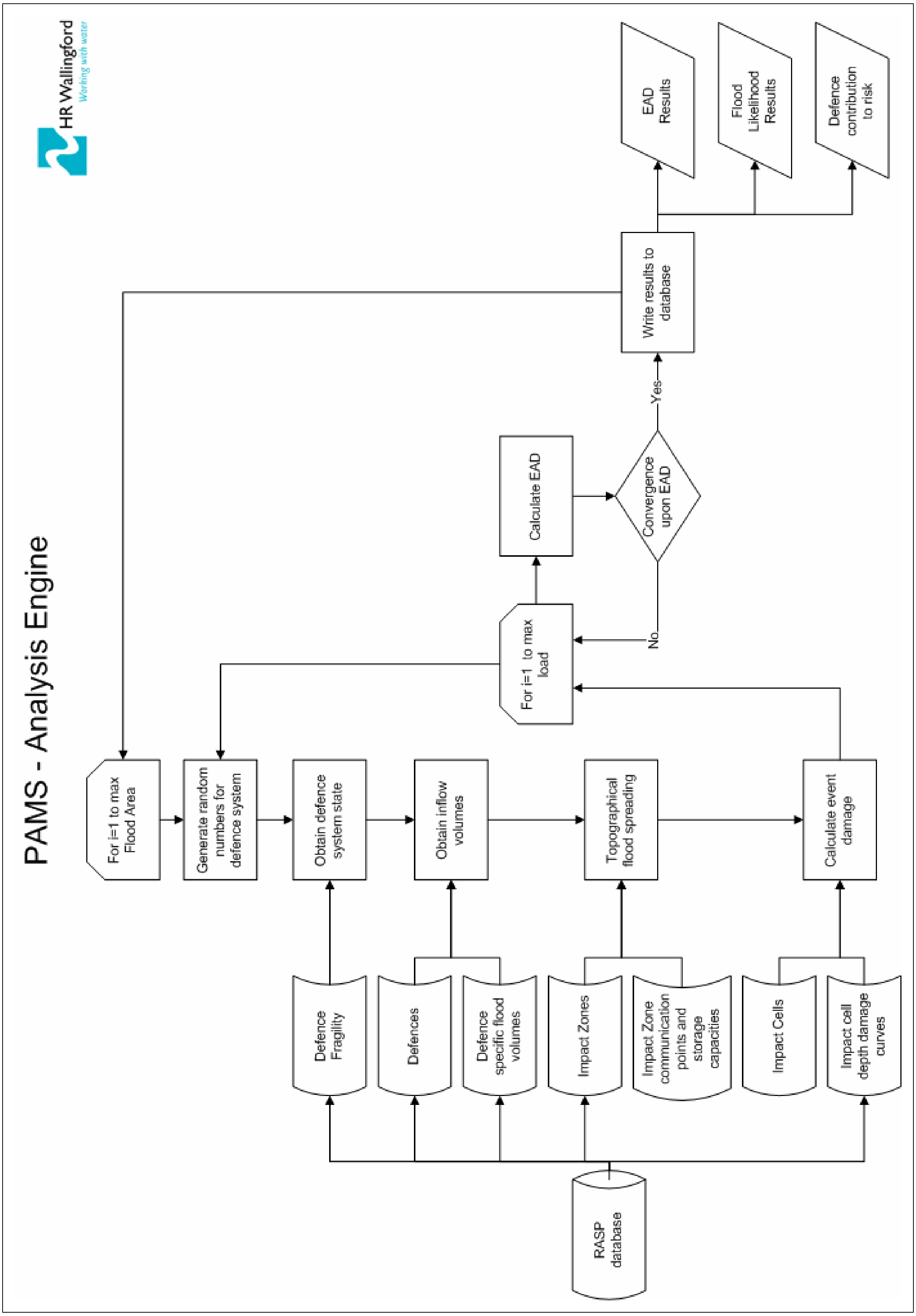

Figure 2.4 A flowchart of the RASP analysis engine used within NaFRA, MDSF2 and PAMS (Gouldby et al. 2008).

2.3.2 RACE – a brief description

The risk of erosion affects a significant number of coastal assets. RACE (Risk Assessment for Coastal Erosion) established a standard method for assessing this risk along the coastline of England and Wales. Figure 2.5 illustrates the factors influencing coastal erosion risk.

The RACE process is summarised in Figure 2.6. The methodology allows the assessment of risks in a consistent manner at local, regional and national levels and does so with a proportionate level of detail and effort.

RACE uses a probabilistic method for assessing coastal erosion risk supported by data from monitoring programmes and risk-based inspections. It is based on a source–pathway–receptor with various sources of the erosive forces and how they transmit to an impact provided by the user before the magnitude of the effect on receptors is assessed.

A range of analysis techniques have been developed, with the choice of which to adopt dependent on the level of detail required and the extent and quality of data available. The source data are determined by a range of techniques of varying complexity appropriate to the level of analysis being undertaken. These techniques include the probabilistic assessment of the hydraulic performance of coastal defences over time and the natural erosion of the coastline. The final risk analysis stage comprises three phases – hazard assessment, data on the location of coastal assets, and the risk assessment itself.

The erosion hazard and asset locations are combined to produce the final probabilistic risk assessment given the estimated position of the coastline over time, within certain confidence bands. The user can intervene to check the results and, if necessary, vary the analysis criteria and produce an improved prediction. The user can also make certain choices such as the format of the final output, e.g. whether the output is required as the probability for a certain point or the probability for a certain year. The final risk assessment stage includes the mapping of the predictions.

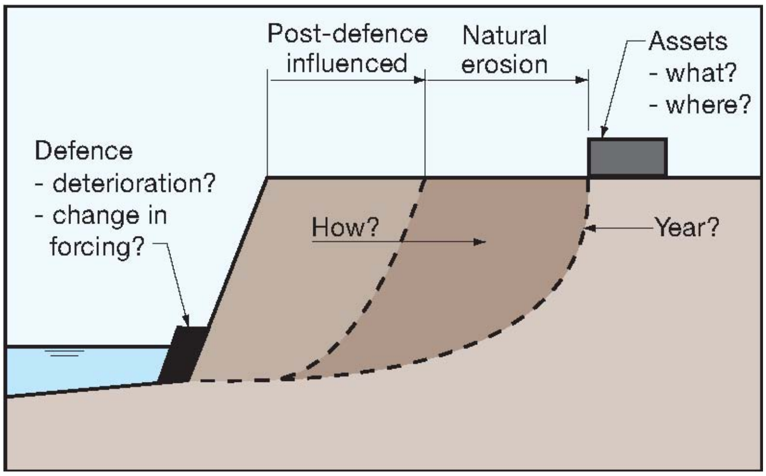

Figure 2.5 Asset risk influences in coastal erosion.

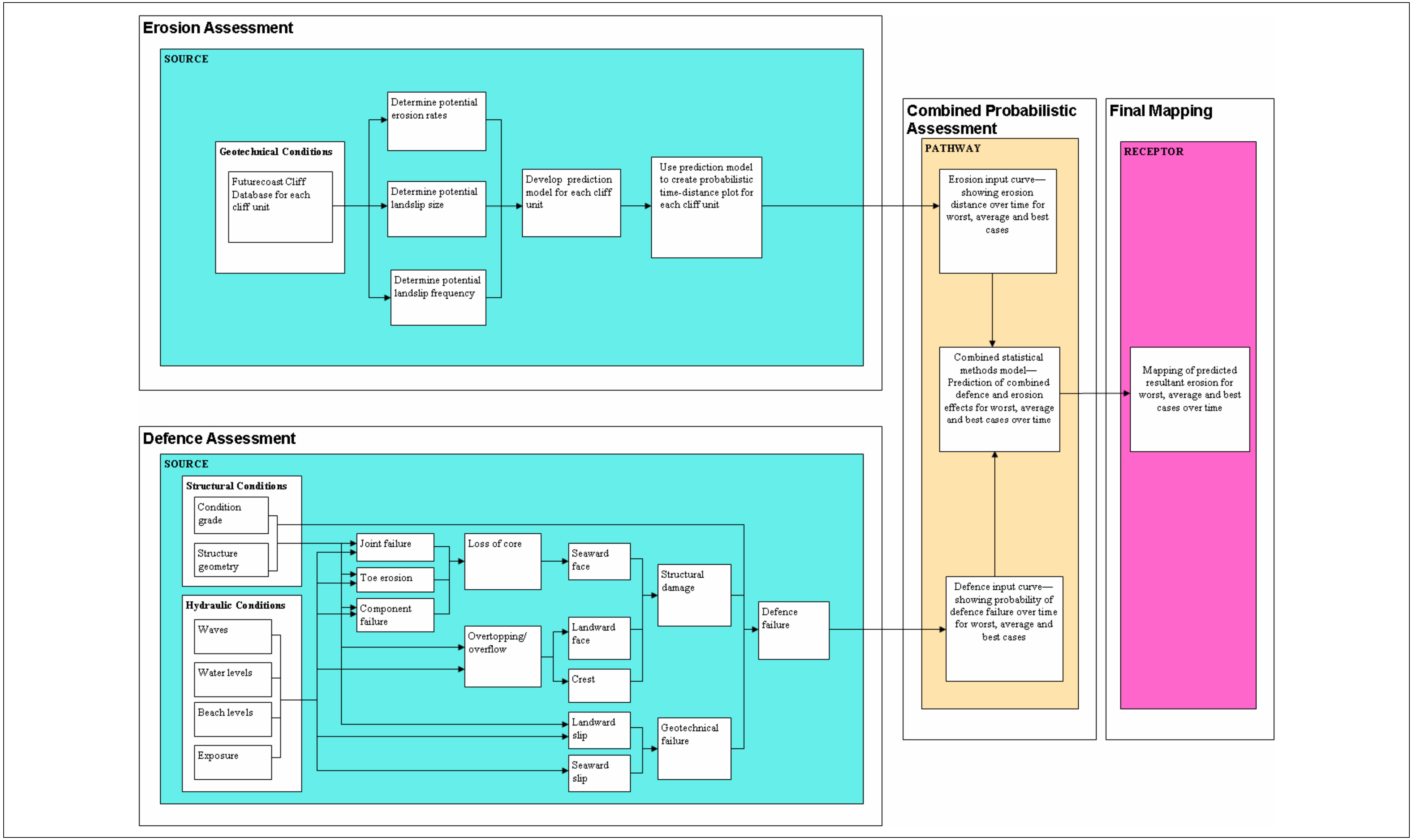

Figure 2.6 Flowchart of method used in the RACE approach and its potential use (shown in pink).

2.3.3 Review of existing approaches

The preceding sections introduce the aims and methods supporting the PAMS and RACE methodologies, but an understanding of how the tools differ requires consideration of their underlying principles. Table 2.4 sets out the main principles and features of each system. Models and methods for determining asset failure vary between the two systems. While PAMS adopts a load dependent fragility curve (based on consideration of a variety of failure modes), RACE uses a residual life based calculation of the annual probability of failure (based on consideration of a variety of failure modes), which in turns acts to modify the onset of recession.

Thus the outputs of the methodologies are significantly different. PAMS provides quantitative results, namely estimated annual or storm specific damages and the risk that can be attributed to assets, whereas RACE predicts recession distances with time.

However, there are a number of significant similarities such that, in some respects, the methods are comparable. Both are based on a system and risk approach using the source–pathway–receptor framework, and use similar input source data. Defences within both systems are defined using the RASP defence hierarchy and assessed through an inspection (typically visual but could be more detailed).

Table 2.4 Comparison of system feature representation in PAMS and RACE methodologies.

Feature	PAMS method	RACE method
Description of main purpose	An asset management tool	A national method for assessing coastal erosion risk
Objective	To assist asset managers and decision-makers in prioritising action.	To provide a consistent national assessment of the risks posed by coastal erosion.
Approach	System and risk based	System and risk based
Driver	Flood risk	Coastal erosion risk
System framework	Source–Pathway–Receptor	Source–Pathway–Receptor
- Source	Extreme distribution of overtopping rates (based on external modelling) of varying complexity, reflecting base meteorological data, surge and water levels, joint probability wave and water levels and wave heights.	Extreme water levels, wave heights, degree of exposure, beach characteristics, base coastal geology, defence geometry and attributes. Potential recession and defence failure probability with best, worst and average cases for both.
- Pathway	Asset parameters including defence type, crest and toe levels, structure geometry, breach information, condition grade, probability of failure and fragility.	Combined statistical methods model to predict combined defence and erosion effects for best, worst and average cases over time.
- Receptor	Commercial and residential property damages (although this list is being expanded in MDSF2).	Mapping of predicted recession of coastline over time for best, worst and average cases.
Applicability	All areas where defences and/or receptors are exposed to flood risk.	All coastal areas not at risk of flooding.

Feature	PAMS method	RACE method
Defence definition	*Individual defences* – fragility curves (with uncertainty) *System of defences* – consideration given to how defences perform as a system – with single and multiple breaches considered	*Individual defences* – residual life (range rather than single estimate)
Defence assessment	Condition Assessment Manual – assessment based on visual inspection.	NFCDD data input
Determination of condition grade	Consideration of failure modes and performance features.	NFCDD data, failure modes and performance for defence type.
Factors causing failure of defences	Defence deterioration, overtopping or breach.	Structural and geotechnical failure
Analysis undertaken	Probabilistic determination of loading conditions, defence fragility, failure probability, flood spreading and damages under different climate change and management scenarios.	Probabilistic determination of defence failure over time and potential erosion along the coastline with subsequent combined probabilistic assessment of these predictions to estimate potential coastline recession over time.
Method for determining failure	Failure modes and fault trees; and reliability analysis – to establish fragility.	Defence failure modes and fault trees; erosion model.
Prediction	Flood risk – within the floodplain and attributed of individual defences within the system. Capable of exploring present day or future conditions.	Erosion lines (50th percentile, 5th percentile and 95th percentile) for distance or time.
Outputs	Estimated annual economic damages, risk attributed defences or systems.	Mapping of recession distances with time.

Consideration of the study objectives identified the following list of features for which it was necessary to review their representation in the PAMS and RACE approaches, based on existing knowledge:

- cross-shore and longshore coastal process connectivity between assets;
- load and condition dependent and time-dependent fragility;
- backshore behaviour;
- incorporation of Outcome Measures or similar;
- whole life costs;
- approaches to decision-making.

Table 2.5 explains how these features are presently represented (or not) in the PAMS and RACE methodologies.

Table 2.5 Identification of features not covered in PAMS and/or RACE methodology.

Feature	PAMS method	RACE method
Cross-shore and longshore coastal process connectivity between assets	Considers defence 'systems' but individual defences are considered independent in strength, i.e. the performance of one does not influence the strength of another, e.g. the loss of a groyne would not influence the beach level and hence performance of an adjacent defence (within a single event).	Considers defence 'systems' – coastal processes affect nature, level and composition of foreshore, which are all input parameters.
Load and condition dependent and time-dependent fragility	Considers load-dependent fragility producing likelihood of failure of defence assets at a (chosen) point in time.	Considers time-dependent recession producing erosion lines for each time period (0–20, 20–50 and 50–100 years).
Backshore behaviour	Uses digital terrain mapping to 'route' floodwater.	Probabilistic assessment to predict combined backshore defence performance and erosion.
Incorporation of Outcome Measures	Considers land and properties at risk in terms of quantity and value, but not non-monetary value (e.g. conservation); also socio-economic factors are not included.	Provides prediction of future recession for use in assessment of all Outcome Measures (excluding contingency planning, which applies to flood risk only).
Whole life costing	Not included.	Not included.
Approaches to decision-making	Prioritisation by risk attributed assets to inform/assist asset management.	To provide information of erosion susceptibility to inform public, government and local authorities (planning).

Consideration of a future programme for scientific development and evolution of the PAMS and RACE tools will need to consider the principles on which they are based and allow for inclusion of their features in any proposed studies. All these factors are important and the ability to include them in any methodologies developed would be of significant benefit to the FCRM community.

The distinction between load-dependent and time-dependent fragility is one of the main differences between PAMS and RACE, and any integration would require development of a method to consider both modes.

In addition, the need for integrated asset management in spatial terms means that ability to model longshore and cross-shore systems would enable coastal managers to ensure that alongshore effects of any changes to assets are minimised.

2.4 Risk principles

Any proposed 'risk-based' approach should of course be founded on the basic risk principles.

Risk is a combination of two factors:

- the probability that an adverse event will occur;
- the consequences of the adverse event.

Risk encompasses impacts on human and natural systems, and arises from exposure and hazard. Hazard is determined by whether a particular situation or event has the potential to cause harmful effects (Pittock 2003). Figure 2.7 illustrates this definition in a simple way.

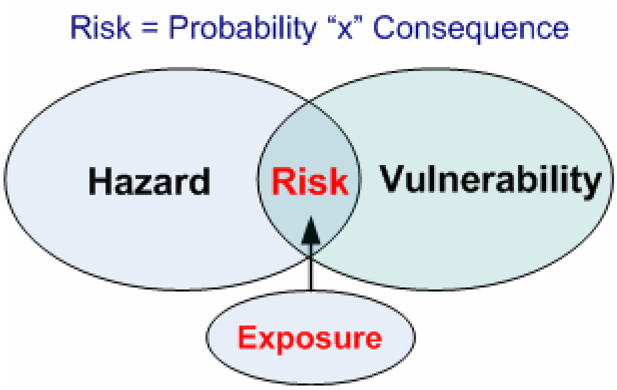

Figure 2.7 A visual representation of the relationship between event probability (the hazard), vulnerability of receptors (or susceptibility to consequences) and Risk (FLOODsite 2009).

Flood and erosion risk systems often exhibit significant spatial (from national level to local level) and temporal (current and future) complexity and consist of different sources, pathways and receptors. System-based thinking enables the complexity to be broken down without losing the behavioural characteristics of the system as a whole.

The 'system state' can be described in a structured source–pathway–receptor (S-P-R) framework. This framework is illustrated in Figures 2.8 and 2.9 for flood and erosion risk respectively. The components of this framework can be defined as follows:[13]

- **Sources** – the meteorological factors that include rainfall, waves, surge and their associated probability of occurrence (singularly or jointly).
- **Pathways and barriers –** the behaviour of catchments, estuaries, coastal zones and cliffs, the nature, extent and condition of assets, topography and land use as well as the hydrological and hydraulic factors that determine the patterns and volume of run-off.
- **Receptors** – the exposure and vulnerability of the people, property and environmental features that may be harmed by a flood or by erosion. A distinct and important difference between effects on flooding receptors and those of erosion receptors is that of permanence of loss due to erosion. Unless relocated beforehand, receptors affected by erosion will be lost permanently as the land erodes. Flooding receptors, although damaged by inundation, are normally recoverable unless repeatedly impacted or damaged beyond repair.

[13] NB PAMS and RACE define sources and pathways differently in their respective approaches (see Table 2.4).

To support robust FCRM decisions, the significance of (system) changes and efficiency and effectiveness of possible management responses on risk must be considered and understood. System-based approaches enable the influence of the factors that change the system state (both positive interventions by the flood or coastal risk manager, and the external influences such as climate change) to be captured in a structured manner.

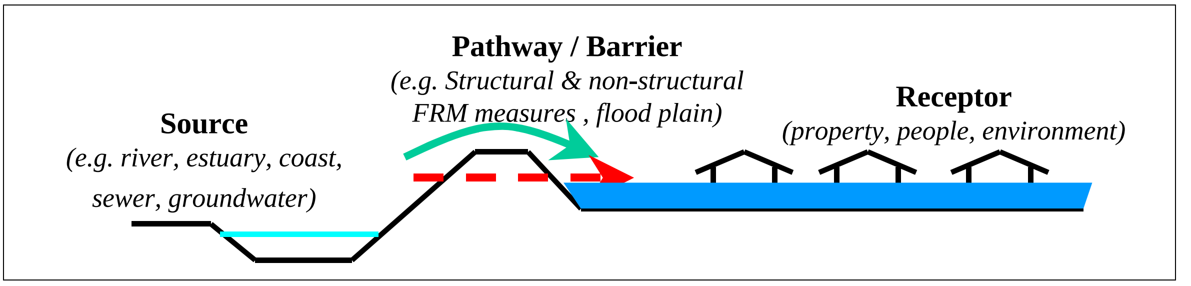

Figure 2.8 Simplified illustration of source–pathway–receptor concept for flooding.

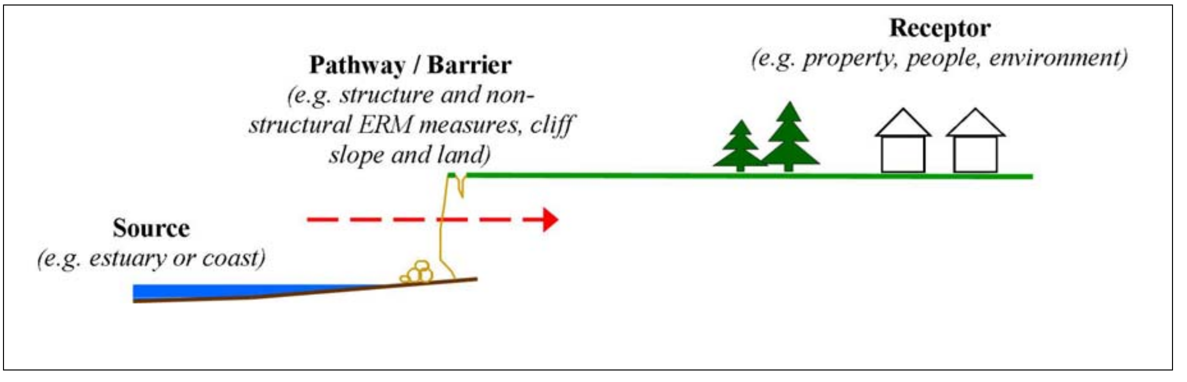

Figure 2.9 Simplified illustration of source–pathway–receptor concept for coastal erosion.

3 User questions and principles

Robust FCRM decision-making requires not only a detailed understanding of risk and the S-P-R system, but also detail on a range of issues often encountered by managers and practitioners. This information and detail is referred to here as ‘user questions and principles’. Before these are examined, it is important to recognise the existing information sources and decision-making ‘mechanisms’ that make up the current approach in FCRM asset management.

The main information sources for strategic planning decision-makers are Shoreline Management Plans and strategy studies (or Strategy Plans). They are distinct according to their objectives, spatial scale and resolution of detail. SMPs are effectively a vehicle for transference of high level policy to a regional/local scale. Strategy studies are more local studies that actually assess and test out potential management options (option appraisal) and undertake cost–benefit analyses of measures.

Strategy Plans develop the policies recommended in SMPs by defining the preferred approach to shoreline management requirements over a 100-year period. For any one SMP policy, there are a range of (intervention and non-intervention) solutions.

By way of an example, suitable shoreline management approaches for ‘Hold the Line’ policies might include sea walls, revetments, groynes, beach recharge, offshore breakwaters, or a combination of these measures. In implementing policies of ‘Hold the Line’, it is also necessary to decide on the Standard of Service[14] to be provided in the light of rising sea levels and climate change. Hence, where there is an existing defence with a ‘Hold the Line’ policy, it is still necessary to decide whether the intention is to:

- sustain the defence such that the level of performance will decrease with time (e.g. as the defence is overtopped more often by higher wave and water levels);
- maintain the present level of performance to address the effects of climate change;
- improve the defence performance.

Strategic studies for flood defence and coastal erosion therefore require much more information than SMPs about particular assets and how they are managed. Strategies are finer scale geographically and focus on coastal sub-cells, defence systems and/or individual defence lengths, usually spanning a few kilometres. The studies supporting Strategy Plans involve the more detailed analysis of coastal processes, asset types, costs, benefits and environmental issues. Strategy studies therefore provide more accurate details for options to be prioritised and assessed against national government criteria. From these strategies individual schemes can be identified and justified.

In the context of assets, the choice of appropriate policy options at SMP and strategy levels involves considering a number of questions and issues, including but not necessarily limited to:

[14] The term ‘level of performance’ is used here to avoid confusion over the difference between the definitions of the terms ‘standard of protection’ and ‘standard of defence’ with respect to flood defence and coastal protection. ‘Performance’ is defined here as the degree to which a process or activity succeeds when evaluated against some stated aim or objective. A ‘performance indicator’ would be a meaningful and measurable objective(s) of a particular asset management policy or project. For example, these may be technical performance indicators (e.g. acceptable wave overtopping rates or erosion rates) or more generic indicators (e.g. public satisfaction).

- **Asset inspection and recording**
  - What issues need to be resolved for improvements to be made in the definition, estimation and recording in data systems of the location and condition of existing defences?
  - What are the different types of construction (e.g. breakwaters, groynes, foreshores and beaches, sea walls, cliffs) and materials (timber, rock, concrete, etc.) of the assets and what condition are they in?
  - In what ways is uncertainty in the resultant data important and how could this be managed?
- **Beach system performance**
  - What improvements are needed in the way in which the performance of beach systems is represented and how this might be reflected in various models and empirical data approaches? Beach systems include man-made structures such as groynes and sea walls as well as natural features such as permeable or barrier beaches, cliffs, marshes and dunes. Thus, the system as a whole should be considered.
  - To what extent are specific beach levels (e.g. at the toe of defences) critical to the understanding of the performance of hard structures? It is also important to understand to what extent the sequencing of storm events influences the way these systems perform and recover after extreme events.
- **Impacts of structures on beach behaviour**
  - What improvements are needed in the understanding of how breakwaters, groynes and sea walls influence beach behaviour?
  - How can the understanding of the impact on beach behaviour of asset deterioration and maintenance be improved for different asset types and forms of construction (e.g. for timber groynes)?
- **Sustainability and whole life costs**
  - In what ways are some structure/asset types more sustainable than others? What kinds of whole life cost solutions might be implemented if more funding were available for maintenance and repair?
  - What novel assets or approaches to asset management might be worth examining?
  - In what ways is improved understanding required of the impact of climatic and morphological changes on long-term coastal defence asset system performance, including recovery after extreme events?
- **Benefit assessment and risk attribution**
  - How might the assessment of benefits in terms of economic risk-reduction of improvements to, and maintenance of, coastal defence systems and individual defence system components (e.g. breakwaters, groynes, foreshores and beaches, sea walls, cliffs) be improved?
  - Methods are becoming available to attribute the economic risk associated with flooding and coastal erosion to individual defences or defence sub-systems. How might this be helpful in the justification of maintenance and improvements?

These questions relate to a number of policy, funding and asset management/optimisation and prioritisation issues about which decision-makers require answers to or information about. A number refer directly to flood defence or coast protection assets themselves, or to their performance in reducing risk from flooding or erosion.

Strategy Plans have a higher spatial resolution and are more detailed in response to these questions than SMPs. As a result, more detailed strategic level analyses may, for example, recommend a review of chosen SMP policy for management units or defence lengths.

It is important for this scoping study to understand why particular questions that refer directly to assets feature in this list and for what purpose the answers are used. Are these the correct questions that should be asked in decision-making for FCRM asset management and are there gaps that should or need to be addressed?

There are a number of methodologies and tools that have been or are being developed that seek to provide answers to the questions that SMPs and Strategic Studies pose and to aid decision-making and prioritisation for funding (see Section 6). The basis for this process is the systems and risk-based approach, Risk Assessment for Strategic Planning (RASP), adopted in the main by the industry (Defra/Environment Agency 2004a).

4 Existing data sources and data initiatives

The collection and use of appropriate data is critical to effective flood and coastal risk management. The Defra/Environment Agency R&D study on improvements to data and knowledge management for effective FCRM (FD2323) produced a guide to good practice that promoted a framework to assist FCRM managers in assessing their data needs and making best use of available knowledge (Robinson et al. 2007).

The study noted the importance of having a full understanding of the types and use of data required before embarking on data collection and manipulation. It promotes the practice of objective-led data and information management, aiming to make significant improvements in awareness and knowledge about FCRM into management (Robinson et al. 2007). As with the current study, the advice is aimed at a wide audience from local authorities managing the assets to consultancies and data providers. The Environment Agency is also developing an asset management support IT system which will feed into further studies regarding data sources and initiatives (see Section 2.2).

While data collection may be undertaken specifically for the purpose of an FCRM activity, a wealth of information is readily available from a variety of data sources, analytical tools and models. This information may be used to aid decision- and policy-making, and to inform the preparation of strategy studies, Shoreline Management Plans (SMPs) and other assessments.

Consideration should also be given to the type of data to be collected, which depends on the scale of asset management to be undertaken. Table 4.1 suggests appropriate types of data for different scales of management. This is not intended to be an exhaustive list, rather an indication of the different scales of management and data required.

Table 4.1 Data requirements for various scales of study.

Data	SMPs/CFMPs	Strategy studies	Asset management
Scale	Sediment cell	Sediment sub-cell/management unit	Frontage/individual asset
Source	Typical wave climate Dominant coastal processes	Joint probability wave and water levels Wave climates	Joint probability wave and water levels Wave climates Time series recent conditions
Pathway	Defence type Residual life band (0–20, 20–50, 50–100 years) Recession/accretion rates	Defence type and condition relating to management unit Residual life of defences Standard of protection Sediment transport rates Beach monitoring data Capital and maintenance costs Crest and beach levels	Asset type and condition grade Design standard Potential failure modes Crest and toe levels Beach slope Deterioration rate and residual life Structure geometry Maintenance history Performance history Reliability and risk attribution
Receptor	Coastal typology National property datasets and average house valuation per area; Receptor types; Critical Infrastructure; Agricultural and other land use, etc.	Social, environmental and economic receptors National property datasets Amenity use Depth/damage curves Potential damages of assets at risk Topography (DTM) Area demographics	Social, environmental and economic receptors Number of properties in the impact zone Potential damages of assets at risk Risk to people Topography (DTM)

In line with the source–pathway–receptor concept described in Section 2.4, Sections 4.1 and 4.2 summarise some of the principal available sources of data and analysis techniques at a range of geographic scales.

Appendix G of the best practice guide produced under project FD2323 provides details of initiatives and systems that store FCRM data and information, grouped according to the resolution of data (national or regional) and type of information gathered (Robinson et al. 2007).

4.1 National data

4.1.1 Source

Water level data

WaveNet[15] is a Defra-commissioned wave monitoring network undertaken by Cefas[16] and the Met Office. Data are gathered from a network of wave buoys and platforms

[15] http://www.cefas.co.uk/data/wavenet.aspx

located offshore from known flood risk areas. The WaveNet initiative integrates data from various sources including the Met Office, Shell and Irish Marine Institute. The aim is to enable improvements to flood and coastal erosion risk management through an increased understanding of risk.

Historic and near real-time wave data may be downloaded from the Cefas website on provision of details of how they will be used. Data are intended for flood managers, local authorities, consultants and other stakeholders involved in flood risk. However, the data consist of a limited network of buoys around the UK, so coverage is sporadic and the deployment period varies at each location.

Bathymetry and hydrodynamics

The British Oceanographic Data Centre (BODC)[17] is a store of publicly available marine data (permitted under a licence agreement) collected using a variety of instruments and samplers. Available data include bathymetry, conductivity–temperature–density (CTD), sea level and tide gauge data for British waters.

As with WaveNet, the data coverage varies; for example, there are 45 tide gauges around the UK, but they were established at different times and many of them had periods where no data were recorded.

River flows and groundwater levels

The National Water Archive[18] is a combination of two data centres:

- National River Flow Archive (Centre for Ecology and Hydrology, CEH);
- National Groundwater Level Archive (British Geologic Survey, BGS).

The archive holds extensive time series data of river flows and groundwater levels, as well as spatial datasets including:

- a digitised river network system of the UK;
- a 100-year flood risk map of England and Wales;
- digitised maps of average rainfall and evaporation rates.

There is good UK coverage of data, though each dataset is provided correct to a specific scale.

Coastal evolution

The Futurecoast study was commissioned by Defra and carried out by a team led by consultants Halcrow over a period of approximately 21 months. The study provides predictions of coastal evolutionary tendencies over the next century to be used to update SMPs and other Strategic Plans with the aim of determining broad-scale future coastal defence policy throughout the open coast shorelines of England and Wales.

The study considered fresh approaches to assessing shoreline evolution within such plans. The analysis of future shoreline evolution potential for each section of coast,

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[16] Centre for Environment, Fisheries & Aquaculture Science
[17] http://www.bodc.ac.uk
[18] See http://www.ceh.ac.uk/data/NWA.htm

which is the main component of the study, provides an improved understanding of the coastal systems and their behavioural characteristics.

The study included a range of supporting studies focussing upon maximising use of existing information and experience. A number of additional datasets were produced covering:

- analysis of coastal processes;
- geomorphological assessment;
- estuary assessment;
- cliff classification (rates of historic change for erosion and landslide and predictions of future change);
- assessment of historical shoreline change;
- prediction of potential shoreline change over next 100 years;
- uncertainty analysis.

4.1.2 Pathway

Defence asset data

The National Flood Coastal Defence Database (NFCDD) was commissioned by the Environment Agency to provide a database for all data on flood and coastal defence assets in England and Wales. However, some (but not all) undefended lengths of coastline are also included. The aim is to enable effective analysis of assets, thereby improving decision-making on Government investment on the maintenance and improvement of defences through prioritisation of high risk areas.

A review as part of the PAMS studies (see Section 2) recommended further development of NFCDD in line with its methodologies. Information such as defence type, condition, design standard and beach conditions may be entered by local authorities for the assets in their regions, along with regular asset inspections. However, there are reports of issues relating to use, access and application of the resource, with the result that some areas have not been populated with data.

4.1.3 Receptor

Property location and value

Databases such as Address Layer – available from the Ordnance Survey (OS)[19] – can be used to describe the assets at risk of flooding or erosion. The original version, which was created from the Royal Mail's postcode information, was found to miss many commercial or industrial properties that may not have postal addresses or letter boxes. Address Layer 2 is now available and contains many more properties, with the inclusion of a number of other datasets. Properties are classified as residential or commercial, with a further 25 categories of commercial buildings where information is

[19] http://www.ordnancesurvey.co.uk/oswebsite/products/index.html

available. However, licences to use the data can be very expensive and permission to use may depend on the proposed use.

The National Property Database (NPD) held by the Environment Agency has been populated using Ordnance Survey data and data from the Valuation Office Agency relating to non-residential properties (Halcrow 2005). This means it contains details of many more properties than the original Address Layer dataset. These data are available for use by the Environment Agency and may also be available for use for contractors working on Environment Agency projects. However, there is currently no process by which other users can access the data.

Basemapping

Digital vector and raster mapping are available from the Ordnance Survey[19] to aid assessment of assets under risk. However, licences to use Ordnance Survey mapping are expensive – potentially prohibitively so for users other than large companies.

Designated conservation sites

Databases of conservation designations are available, both under national and international legislation, and can be used to establish areas that are protected and the character for which they are designated. Designations include:

- Ramsar wetlands (international);
- Special Protection Areas (SPAs) and Special Areas of Conservation (SACs) (European);
- Sites of Special Scientific Interest (SSSIs) (national);
- National Nature Reserves (NNRs) (national).

Sources such as the Joint Nature Conservation Committee (JNCC),[20] Natural England[21] and Countryside Council for Wales (CCW)[22] allow free downloading of this information, including geographical information system (GIS) files.

Designated heritage sites

Databases of protected heritage sites are available including those protected nationally and internationally. Sites are protected via legislation such as the UNESCO Convention concerning the Protection of the World Cultural and Natural Heritage.

Data such as registers of Scheduled Ancient Monuments, World Heritage Sites and Listed Buildings are normally available on request from heritage organisations such as English Heritage,[23] Cadw (in Wales)[24] or Historic Scotland.[25]

Depending on the purpose, these data are normally issued without charge. In England, data may also be freely downloaded from the MAGIC website.[26]

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20 http://www.jncc.gov.uk
21 http://www.naturalengland.org.uk
22 http://www.ccw.gov.uk
23 http://www.english-heritage.org.uk
24 http://www.cadw.wales.gov.uk
25 http://www.historic-scotland.gov.uk

Contaminated land

Information regarding contaminated land is made freely available by local government in accordance with Section 78R (1) of The Environmental Protection Act (1990). However, information included on the register may vary; some councils only list sites recognised as contaminated following the statutory definition and may not include those suspected as being contaminated or which have had a past industrial usage.

Deprivation

In England, the Index of Multiple Deprivation combines a number of indicators representing a range of economic, social and housing issues is available from Communities and Local Government. Factors covered are income, employment, health and disability, education, skills and training, barriers to housing and services, living environment and crime. The scores for each indicator are combined to provide a single score for small areas in England. The index is based on Lower Super Output Areas, areas smaller than wards which therefore allow isolated pockets of deprivation to be identified. More information is available from Communities and Local Government,[27] including the 2007 index which is freely available for download. Similar indices exist for Scotland, Wales and Northern Ireland.

However, these data are somewhat inconsistent in terms of age – the current index for England (2007) contains data that were mostly collected in 2005, although some areas cover a number of years such as 2003–2005. Another factor to consider is that the indicators listed above are combined to provide the final index, according to weighting, and therefore the index is more biased to certain indicators than others.

4.1.4 Recent data initiatives – national

Details of several recent and ongoing initiatives regarding national FCRM data are given below.

Historical Losses to Coastal Erosion (HLCE)

Historical Losses to Coastal Erosion (HLCE) is a two-phase study that aims to 'ground truth' and calibrate the results of the National Coastal Erosion Mapping (NCERM). The first phase aims to provide information on the historical losses to erosion in England and Wales over the past ~100 years. The second phase is a calibration exercise that aims to increase public awareness of the range of understanding that can be captured and lead to increased confidence in the project within the scientific and engineering communities. The exercise will focus on eight sites that will test the full range of erosion mechanisms modelled within NCERM.

This exercise will provide an excellent means of putting the results of the future erosion predictions into context and will raise the public's awareness of what is meant by a zone at risk of future coastal erosion, as well as increasing their confidence in the results.

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[26] http://www.magic.gov.uk
[27] See http://www.communities.gov.uk/communities/neighbourhoodrenewal/deprivation/deprivation07/

Receptors Vulnerable to Coastal Erosion

Receptors Vulnerable to Coastal Erosion (RVCE) project aims to quantify future erosion risk. A three-phase approach has been adopted whereby first the receptors were defined and potential data sources were identified; where possible this drew on work conducted for the National Receptor Database (see below). The second phase will propose methods for quantification and will primarily draw on the findings of NCERM and receptor data sources. The third phase will undertake the quantification.

The National Receptor Database

The National Receptor Database (NRD) project aims to collate/incorporate details of risk receptors for various purposes, including flooding and coastal erosion, for use both within and outside the Environment Agency. The data stored within the database will aim to meet the information requirements of a range of FCRM practitioners.

To date, two reports have been drafted – namely a 'Needs Analysis' and a 'Technical Evaluation'. The former determines what the user requirements are, the necessary content of the database to support these requirements, and the extent to which these requirements can be met by currently available information. The latter recommends options for the operational implementation of the database.

NFCDD Data Improvement Work – Phase 1

A study has been carried out to look at the quality of the data currently stored in the National Flood and Coastal Defence Database (NFCDD) at a national level. The resulting report aims to provide an overall summary of the useable data that have been provided to the NCERM project by local authorities through NFCDD (based on a download of the national database in March 2009) and/or bespoke information sources. The analyses conducted for this report also examine the work necessary to bring NFCDD to the required standard in areas of erodible frontage in order to run the RACE model to its full potential and to feed into the next round of Shoreline Management Plans (SMP3).

4.2 Regional data

4.2.1 Source

Beach monitoring data

A number of regional coastal monitoring programmes are undertaking long-term coastal monitoring and data analysis programmes on a regional basis. These include:

- monitoring by coastal observatories – Channel Coastal Observatory (CCO)[28] and Plymouth Coastal Observatory;
- programmes undertaken by regional Coastal Groups (collectives of local authority and Environment Agency representatives, typically grouped on

[28] http://www.channelcoast.org

the basis of a number of neighbouring SMP areas). An example is the Cell 11 Regional Monitoring Strategy (CERMS).

The development of these programmes is in response to the UK's history of localised ad hoc monitoring whereby monitoring was undertaken with little sense of continuity – either spatially or temporally. Regional coastal monitoring programmes provide frameworks for collating, storing and analysing data. However, as ad hoc programmes, there is little continuity in terms of quantity and frequency of data collected, and therefore the availability and format of data may vary from area to area.

East Anglia Coastal Group Strategic Coastal Monitoring Programme

This programme covers the Humber to Thames coastline, and has been in operation since 1991. Data including beach profiles, beach surveys, bathymetric surveys, sea levels, waves, sediment samples and aerial photographs are collected annually. Data are publicly available, although there may be costs involved.

4.2.2 Pathway

Beach monitoring data

See Section 4.2.1.

The ABMS (Annual Beach Monitoring Survey) also provides beach monitoring data. This regional aerial survey programme measures photogrammetric beach profiles, with data recorded from 1973. It is reported to be the most comprehensive long-term systematic sea defence and coast protection regional monitoring programme in south-east England. Outputs include annual aerial photography, production of annual photogrammetry-derived profiles, annual profile analysis, periodic overviews of the dataset and annual data dissemination. The data are freely available via the Channel Coastal Observatory.[29]

Defence asset data

See Section 4.1.2.

Local authorities may also hold asset databases. Some have extensive datasets on the coastal assets that they are responsible for. At some point in the future these may be incorporated in the Environment Agency's Asset Management support system. As with the NFCDD, consistency, coverage and quality of data may vary from region to region.

4.2.3 Receptor

Council tax evaluations

Local authorities hold information on council tax evaluations and, in some cases, threshold levels that can be used for the derivation of flood risk on a property-by-property or postcode scale. These data may be freely available, although this is dependent on individual councils.

[29] http://www.channelcoast.org

4.3 Data constraints

When collecting and using data, it is important to be aware of issues that may constrain their usefulness and the outputs that could be achieved to enable effective asset management.

The importance of a comprehensive data system was recognised as part of the Catchment Flood Management Plan process (used to deliver flooding and fluvial defence strategies at catchment-scale levels) (Fox and Cooper 2001). Indeed, as part of this process, core data guidelines were produced with the aim of providing a nationally consistent set of available data. There is a need to move towards ‘objective led information management’ such that the management needs drive the information collected and its analysis rather than the other way around (Robinson et al. 2007).

A ‘route map’ was developed as a result of the study to lead to effective and integrated data, information and knowledge management with three steps:

- Follow an objective-led process that is clearly related to flood and coastal risk management.
- Improve efficiencies in whole life data management.
- Embrace a culture change. This culture change is central to the ideas being proposed within this scoping study.

However, there are a number of potential constraints.

- **Availability of data.** Where there are pre-existing data, potential issues concerning ownership and usage permissions need to be considered and resolved promptly. Associated with this is the common historic problem of poor communications between relevant authorities. This often prevents knowledge of available data – and its subsequent use – being shared and may also lead to duplication of datasets (an inefficient use of resources). Ideally, data for managing coasts should be made freely available to all operating authorities (although not necessarily free of charge). In any case, all operating authorities may now be ‘obliged’ by the Floods and Water Bill to freely pass data to one another. However, current corporate policy is pushing the Environment Agency to seek greater control over its data. Although such data are provided free of charge to an operating authority, it is ‘appropriated licensed’ to ensure there is no onward supply of the data.
- **Cost of data.** Even when the data required are easily available, there may be significant cost implications. These may be such that data acquisition is unviable for the intended purpose. This is likely to be a critical factor for many flood and coastal risk management projects, which rely on limited funding.
- **Type of data.** Planning of asset management decision-making is essential such that appropriate types and formats of data can be made available to enable decisions to be made based on best available data. For example, consideration of failure points of structures such as a sea wall requires a comprehensive analysis based on data including failure modes, structure condition, natural defence conditions and assessment of likely future conditions (including joint probability analysis of waves and water levels and latest guidance regarding the impacts of climate change).
- **Quality of data.** Even when it appears that appropriate data are available, it is important to be aware of their limitations. Data may be less suitable than they first appear. For example, cross-shore beach profiles may be

used to extract beach levels at the toe of structures; however, the profiles may not always be measured immediately at the structure toe and thus information may be inaccurate.

- **Scale of monitoring.** Different scales of monitoring are required for different purposes. A Shoreline Management Plan uses much wider datasets than, for example, consideration of failure of a single asset, and thus the data are less detailed. Therefore a suitable scale in terms of area should be chosen.
- **Frequency of data collection.** This factor is important both temporally and spatially. Analysis of beach level trends, for example, requires a long-term dataset to be able to distinguish long-term trends from short-term fluctuations and seasonal variations. Similarly, frequency of data collection along the shore should be considered, with assessment of individual defence lengths requiring more concentrated data than a higher level study.
- **Multiple use of datasets.** The use of multiple datasets and their integration for use in asset management requires prioritisation and consideration of which types of data require a higher level of accuracy or frequency of collection to ensure effective data collection. It might even be that some types of data are not as important, and thus the process could continue without them should budgets/time constraints demand.
- **Consistency of data collected.** The consistency of any data used should be assessed – both in terms of how they are collected, and the subjectiveness of any parameters. This would enable a decision to be made on the usefulness of such data and their likely accuracy.
- **Data uncertainty.** There has historically been a tendency for models and other decision-support systems to be perceived as providing comprehensive assessments. However, in reality this is not the case, and it is essential to fully understand the limitations of any methods used in order to use them effectively and to apply results gained. Any uncertainties regarding data quality, collection or coherence should also be acknowledged and, if possible, eliminated.

Further discussion and recommendations regarding data requirements for the PAMS framework are given in the unpublished project report on this topic, which forms part of the PAMS project record (Defra/Environment Agency 2009b). The findings and recommendations from this report should also be considered in any future developments; the tabulated data requirements for PAMS are provided by way of example in Appendix 3. See also the further discussion on data in Section 7.1.5 of this scoping study report.

5 Existing methods and tools

The data sources described earlier often include some level of data analysis and interpretation. In addition, the scoping study identified a number of UK-based analytical tools, decision-support tools, databases and models. Some of these include protocols for other activities (e.g. scenario or uncertainty analysis) as well as models of processes.

Information about existing methods and tools is summarised below. Further information regarding the aim and functionality of the tools can be found in Appendix 3.

5.1 Risk Assessment for flood and coastal defence systems for Strategic Planning (RASP)

RASP (http://www.rasp-project.net) aims to understand the risk of flooding in terms of systems of defences. It is a tiered methodology enabling decision-making based on appropriate levels of analysis for the assessment of the performance of coastal defences.

- High level methods are based on national datasets and enable the updating of national estimations of flood risk.
- Intermediate methods use estimates of flood water levels and ground elevations to improve estimates of flood risk.
- Detail level methods use information about defences to improve estimates of failure probability as a result of different modes of failure.

These methods enable:

- estimation of flood risk due to failure of single or multiple defences;
- estimation of total flood risk for identified impact zones in the flood plain;
- identification of the proportion of flooding each defence failure is responsible for.

RASP model outputs are compatible with standard GIS systems and can be displayed visually.

5.2 KeySHORE

The KeySHORE package from KeyTERRA-FIRMA Ltd (http://www.roundaboutdesign.com/products/keyshore.shtml) is designed to be used in the development of Shoreline Management Plans and combines Autodesk Map, KeyTERRA-FIRMA and the ShoreBASE coastal database into a GIS system. Monitoring data including beach profiles, land and hydrographic surveys can be entered and stored in the database. The GIS functionality enables manipulation and presentation of these data so that analysis of past and current shoreline behaviour can be used to inform policy decisions. The package has been used to a limited extent in the UK.

5.3 Tyndall Centre Coastal Simulator

The Tyndall Centre's Coastal Simulator (http://www.tyndall.ac.uk/content/tyndall-centre-coastal-simulator) is a system scenario platform that aims to predict the effect of various climate change indicators on the coast. This is done through models of sea level rise, storm surges and wave climates linking to the process-based SCAPE (Soft Cliff and Platform Erosion) model to predict shoreline erosion and associated profile evolution. A further model assesses coastal flood and erosion risk to the shoreline.

The simulator is designed to be a decision-support tool allowing the integration of climate change scenarios and policy response options with information on sediment transport, biodiversity, sea defences and socio-economic activities. Model outputs are linked to a GIS framework.

5.4 Risk Assessment of Coastal Erosion (RACE)

RACE is a probabilistic method for assessing the hazard and risk of coastal erosion developed by Halcrow with funding from Defra under Joint Defra/Environment Agency Flood and Coastal Erosion Risk Management R&D Programme project FD2324 (Halcrow 2007).[30] Data and related information from monitoring programmes are used together with risk-based inspections to enable understanding of coastal erosion risks and their degree of uncertainty.

RACE is a system risk model in that it aims to include all elements of the coastal erosion process, i.e. all mechanisms and processes leading to the recession of the shoreline. This may include cliffs, beaches, lowlands and estuaries. Tools developed can be applied at an operational level to a single section of coast for the management of coastal cliff instability and erosion risk. The effects of coast protection assets on reducing the rate of coastal erosion are assessed, along with the effect of asset deterioration on asset performance.

5.5 Regional bespoke analysis: Overstrand to Walcott strategy approach and methodology

The approach used for the coastal strategy study for the Overstrand to Walcott shoreline (HR Wallingford 2005) included identification of the 'source' conditions which established the loading parameters for the process model for cliff failure and cliff top recession. A one-line beach model (SCAPE) was used to generate further beach toe levels and linked to a probabilistic cliff recession and associated economic appraisal tool. The approach also developed fragility relationship between the level of the beach at the toe of defence structures and probability of failure during a storm event.

5.6 Modelling and Decision Support Framework (MDSF)

MDSF (http://www.mdsf.co.uk) was developed for Defra and the Environment Agency by HR Wallingford, Halcrow, CEH Wallingford and the Flood Hazard Research Centre

[30] To see the full suite of project documents, use the Defra/EA Project Search Tool available on http://www.defra.gov.uk/environment/flooding/research/index.htm

(FHRC). It is intended to be used by Environment Agency staff and consultants when preparing Catchment Flood Management Plans, Shoreline Management Plans and other studies.

MDSF is a flexible tool designed to support a wide variety of data input formats through a set of procedures with a GIS-based user front end. The simple text format enables it to interface with many popular hydraulic modelling packages. The procedures provide guidance including advice catchment modelling and use of future land use and climate scenarios. The software enables storage of base data, management of both geographical and tabular data, and calculation of flood extents and impacts.

The built-in flood mapping tool provides quick and repeatable calculation of flood maps – ideal for catchment and strategy scale studies. Alternatively, externally generated depths can be imported and analysed by the economic and social impact evaluation tools. A common framework for evaluating the economic and social impacts of flood management strategies is currently being developed through the MDSF2 project, which embeds RASP methods.

5.7 Shoreline and Nearshore Data System (SANDS)

SANDS (http://www.halcrow.com/sands/default.asp) is a coastal data capture, monitoring and analysis suite developed by Halcrow for shoreline managers, coastal engineers and environmental scientists. It is available under an unlimited network licence within the Environment Agency and is used by numerous local authorities within England and Wales.

The Environment Agency is also developing a new tool within SANDS for the storage of SMP policies at a regional scale. This database is currently being populated and should be rolled out within the Environment Agency shortly; Figure 5.1 shows an example Shoreline Management Plan from SANDS.

SANDS links to the National Flood and Coastal Defence Database and can be used to visualise and modify defence condition information, including an assessment of the impact on flood risk of different investment decisions. It also enables the analysis of geospatial and temporal data to establish links between forcing and response. Climatic and environmental data can be analysed alongside shoreline monitoring data, enabling trends in forcing conditions to be compared to trends in shoreline response. Weather and shore condition data can be entered, stored, inspected and compared.

Data analysis tools include:

- beach profile analysis;
- volumetric calculations;
- tidal harmonic analysis;
- wave energy analysis;
- sediment transport analysis.

The software can be modified for specific needs.

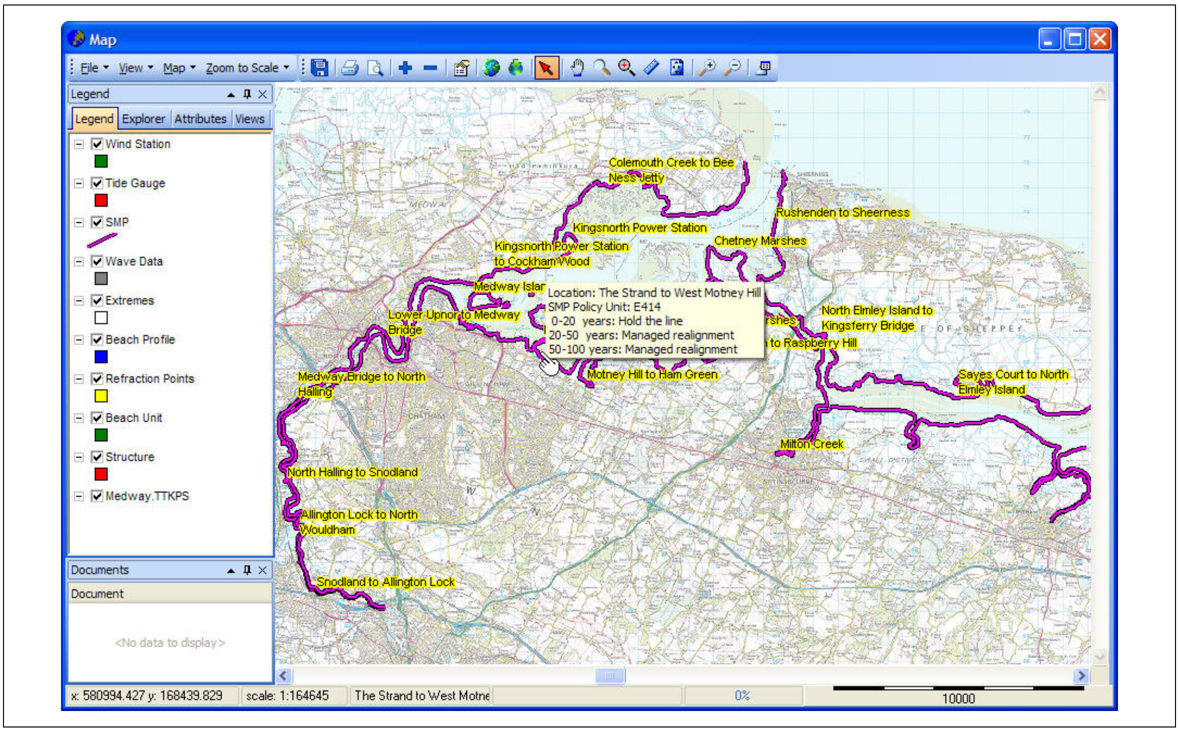

Figure 5.1 Example of a SMP map from SANDS.

5.8 Coastal Defence Asset Management Database (CDAMD)

Bespoke yet simple asset management databases have been in use for a number of years. One such example is the database used by the Public Services Department of the Government of the Island of Jersey as illustrated in Figure 5.2.

The CDAMD simply stores information on:

- defence structures and frontages;
- the environment;
- events such as storms or maintenance activities;
- inspection records;
- drawings and photographs.

The database can be queried to produce reports from the information stored.

Figure 5.2 A bespoke coastal defence asset management database developed for local authority use (HR Wallingford 2002).

5.9 GTI-SEAMaT

GTI-SEAMaT (Geographical Temporal Interface – Shoreline Environment Analysis and Management Tool) is a process-based modelling platform developed by HR Wallingford (Stripling et al. 2007). Hydrodynamic conditions are modelled, including longshore drift, and profile evolution predicted at each transect within the linked one-line models. In addition, large quantities of modelled or measured data can be stored within the GIS framework of the model and the modular nature allows future developments to be included.

The GTI-SEAMaT suite currently consists of the WAVEMaT and BEACHMaT[31] modules.

- The **WAVEMaT** module allows both experienced and relatively inexperienced users to derive nearshore wave climates anywhere within the active model domain. The software also derives extreme wave conditions as part of the automated statistical analysis. Large quantities of data can be generated during normal use and the ArcView interface allows for easy management of these data.
- The **BEACHMaT** module is presently configured such that the long-term longshore transport of beach sediment around the coastline can be calculated using the sub-module PROFMaT. The module also allows a macro-scale assessment of the impacts of shoreline intervention upon shoreline evolution. At present, the type of intervention that can be examined is restricted to structures which present a barrier to the 'normal' longshore drift of beach material.

[31] Wave Management Tool and Beach Management Tool

5.10 EUROTAS

EUROTAS (European River Flood Occurrence and Total Risk Assessment System) is a Decision Support System (DSS) funded by the European Commission (EC) under the second call of the Fourth Framework under the Hydrological Risk component of the Environment and Climate Programme. It provides a framework to enable planners and decision-makers to undertake catchment studies while fulfilling a range of objectives. The framework is based on a GIS-based integrated catchment modelling approach, allowing for the integration of a range of models for assessing the impact of climate change, land use and river engineering measures on flood risk. This structure enables multiple scenarios to be tested and flood risk assessed (McGathey et al. 2006).

5.11 Thames Estuary 2100 project

What might be described as an integrated asset management tool was developed for the Thames Estuary 2100 project (TE2100);[32] often described as a PAMS 'type' tool, this tool carries all the asset information, draws on other databases (such as NPD) and stores other look-up SQL tables for use in running the RASP HLM+ and Rapid Flood Spreading methodologies. This proved to be a very useful and powerful tool for the assessment of future flood risk along the Thames under different management scenarios.

The project also utilised a new methodology for attributing flood risk to particular defence lengths – together with associated estimated annual damages to receptors in the flood affected area. Risk attribution is a key tool for asset management as it enables direct comparison of costs and benefits of different intervention options under different modelled scenarios.

5.12 Long-term change of coastal geomorphological behaviours.

This tool is still under development and aims to characterise and predict large-scale, long-term change of coastal geomorphological behaviours (http://www.coastalgeomorphology.net). Research was commissioned by the Environment Agency with funding from the Joint Defra/Environment Agency Flood and Coastal Erosion Risk Management R&D Programme (project SC060074).

The aim is to develop predictive tools that will assist coastal managers in decision-making by enabling them to better understand the potential impacts of intervention or the cessation of management. The model has been through a 'proof of concept' stage using 'virtual' coasts (Whitehouse et al. 2009) and is ready to be tested and validated with 'real world' data.

[32] See http://www.environment-agency.gov.uk/homeandleisure/floods/104695.aspx

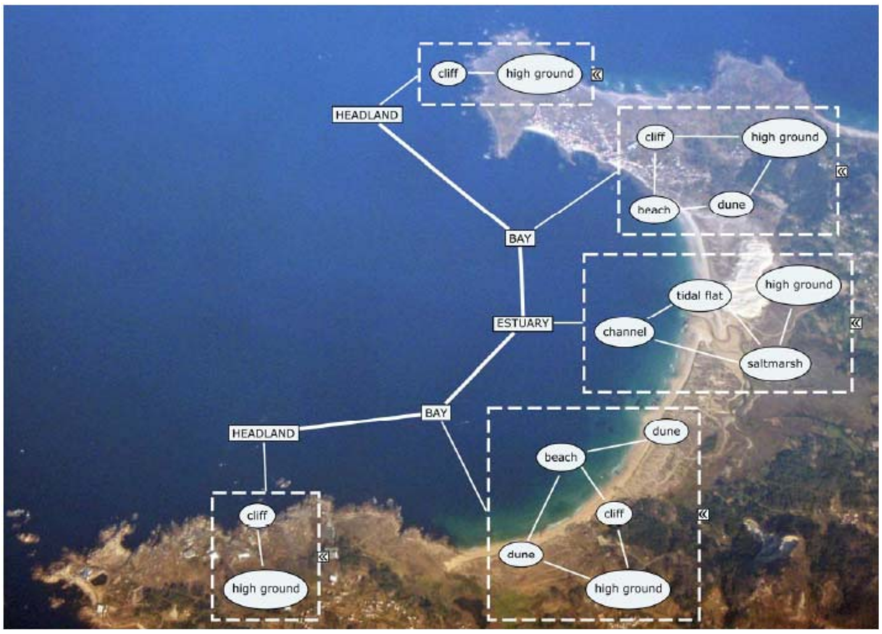

Figure 5.3 Conceptual model for the characterisation and prediction of large-scale, long-term change of coastal geomorphological behaviours (Whitehouse et al. 2009).

5.13 InfoNet™

Other types of water management systems are already used by water service and waste water companies. One example is InfoNet™ (http://www.wallingfordsoftware.com/uk/products/infonet/) (see Figure 5.4). Systems like InfoNet could be linked in the future to that proposed for development by the scoping study, providing modified conditions and real-time measures (e.g. urban pluvial inputs to the system) to flood and coastal risk management tools.

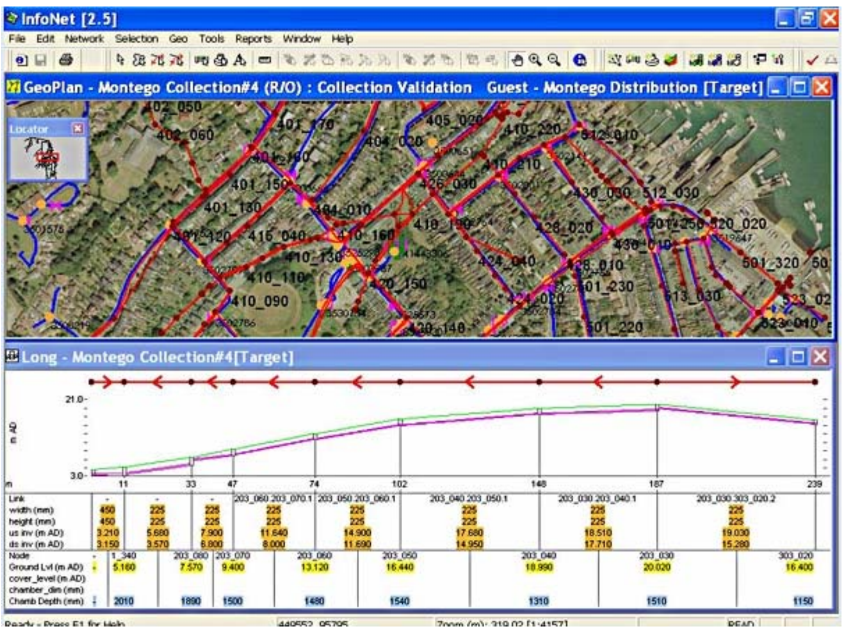

Figure 5.4 InfoNet™ – a commercial water utility asset management database (Wallingford Software Ltd).

5.14 Other non-UK models

Examples of the range of different models used further afield are given below.

5.14.1 Planning Kit

This tool was developed by the Dutch Ministry of Public Works as support for the 'Room for the Rhine Branches' project and provides a method for evaluating a range of river design measures. The effects of these alternatives on flood stages, nature, ecology and costs are considered. However, the model does not include the origin of flood waves or flood impacts (Schanze et al. 2007).

5.14.2 DESIMA

DESIMA (Decision Support for Integrated Coastal Zone Management) was developed by the European Commission Joint Research Centre (JRC) in association with HR Wallingford and others during an EC project in 1998. It provides an information tool for decision-makers to give efficient answers for the development of operational and integrated coastal zone management. Information sources such as in situ data and numerical models have been integrated within a GIS framework to enable such decision-making.

5.14.3 RAMFLOOD

The RAMFLOOD tool was produced as part of the RAMFLOOD (Risk Assessment and Management of Floods) project funded under the EC 5th Framework Programme (http://www.cimne.upc.es/ramflood/) and covering Spain, France and Germany. The tool is a web-based decision support system for risk assessment and management of emergency scenarios due to severe floods. Methods for collecting, processing and managing hydrogeological data were combined with qualitative methods based on numerical modelling and computer simulation modelling; advanced information technologies were then used to provide an integrated method. The aim was to improve the process and outcome of decision making in flood management and risk assessment by providing flood and hazard analysis methods (Schanze et al. 2007).

5.14.4 EBM tools

These tools from the Ecosystem-based Management (EBM) Tools Network in the USA provide a management approach to integrate both natural and socio-economic factors into decision-making (http://www.ebmtools.org). A wide range of tools are available in this network, including coastal zone management tools which integrate coastal process models. The main aims of the tools are to provide models of ecosystems or ecosystem processes; assess the consequences of management decisions through scenario modelling; and facilitate stakeholder involvement in planning processes.

5.15 Summary of requirements

Other reviews of such tools have been undertaken. Table 5.1 summarises the main findings of a review of existing DSS tools under Task 18 (T18-06-11) by the European FLOODSITE project, which highlighted a number of issues for their development (McGathey et al. 2006).

Table 5.1 Conclusions of FLOODsite analysis of UK decision support systems.

No.	Topic	Conclusions
1	Decision support	The DSS should be decision-specific, i.e. not try to support/solve too many things. The evidence provided to the user should be 'rich', e.g. enabling the user to explore the basis of the evidence presented.
2	Flexibility	The DSS should be appropriately flexible (but not designed to be flexible for the sake of it),
3	Open/closed architecture	The system architecture should be appropriately open/closed for the decision at hand and the mode of use. (Open architectures are not always the most beneficial, e.g. in long-term planning it may be appropriate to have embedded hydraulic models).
	Model coupling	A modular approach is recommended where possible. For example, the DSS should provide the user with the option of using default methods/embedded models or entering results from more complex, externally run models or information.
4	Scale	The DSS should be independent of temporal and spatial scale (typically this is easily accommodated with the use of GIS).
5	Use of risk-based methods	The DSS should reflect the policy context within which the decisions will be made. As the policy moves towards risk management, then the DSS should enact risk-based methods that provide rich evidence to the user on both probability and consequence.
6	Use of probabilistic approach to risk	The UK strongly advocates a probabilistic approach to risk and this should be reflected in the DSS. This helps to ensure that the evidence presented to user is appropriately robust and meaningful. A probabilistic method should be appropriately reflected across all aspects of the source, pathway and receptor and not simply applied to only one or two elements of the flood risk system. (Within the NaFRA tool supported by RASP multiple combinations of load, defence failure, inundation and damage are considered.)
7	Presentation of outputs	The representation of output risk metrics should be clear while reflecting the complexity of the underlying analysis. This typically involves the high level aggregation of data into useable evidence. For example, decision-makers value basic information on the spatial distribution of risk and the attribution of that risk to particular assets and driving uncertainties. This helps the targeting of investment.
8	Uncertainty	Uncertainty should be explicitly handled and appropriately disaggregated. It should be expressed in a manner which is accessible. Guidance should be provided on the interpretation and use of this information.
9	Uptake and use	The UK has seen wide uptake and use of two DSS tools in recent years, i.e. MDSF (a strategy planning tool) and NaFRA (national flood risk assessment tool). The main reasons for this are: • User support – this includes general guidance and advice in the form of manual, website, help menu, query hotlines with a 24-hour response time. • Provision of training on request. • Software maintenance – includes release of new versions, upgrades, bug fixing, changes resulting from feedback from user group meetings, etc. • Use of national datasets such as the Digital Terrain Model, the river network, social vulnerability indices, etc. supplied with the software (e.g. MDSF). • Advocated by the appropriate authority/agency (e.g. Environment Agency), i.e. the consultants are required to use these. • Include a variety of calculations, e.g. agricultural damages, coastal erosion metrics, etc. • Automate tedious calculation processes at national (NaFRA) and catchment (MDSF) scale.

The issues highlighted in Table 5.1 should be incorporated, where appropriate, into any consideration of further DSS developments for flood and coastal risk management in the UK.

Of the tools listed above, some provide supporting analytical functionality to coastal asset managers (e.g. modelling processes or simply storing data), while others provide direct support for decision-making. However, there are only two (as far as is known) that can be said to aid decision-making by attributing risk to assets – the TE2100 model and MDSF2.

The PAMS project has identified many other functionalities required for performance-based asset management for flood defence and has helped to develop, improve and deliver many of these in the form of tools, techniques and guidance. These include:

- calculation of joint probability loading conditions (the likelihood of a joint occurrence of wave and water level surge conditions);
- defence reliability and fragility curves (determining the likelihood of failure with loading given structural condition);
- asset condition inspection and assessment (the visual assessment of structural condition of defences);
- setting target condition grades (determining the required condition of defences given the risk to receptors);
- failure modes and fault trees (determining potential modes of failure of defences);
- systems analysis (the analysis of flood defences within systems of flood defence protecting areas at risk of flooding);
- risk attribution and calculation of residual risk (the allocation of flood risk or damages to defence lengths or systems of defences);
- uncertainty analysis (the analysis of the uncertainty associated with the model data used and the results produced);
- conveyance assessment and estimation (the calculation of water conveyance in rivers and watercourses);
- rapid flood spreading (the modelling of flood water extent and depth across the floodplain);
- visual representation and database interface development (in GIS) (the development of computer ability to produce maps and tables of results and to utilise and join databases in a functional way).

Few of these activities are currently undertaken by (flood defence) practitioners on a regular basis. Their introduction and uptake should help to greatly improve the evidence on which (system and defence level) decision-making is based and actions and funding are justified.

For coastal erosion risk, the RACE methodology includes the following functions:

- determination of erosion rate (calculation of the rate of coastal erosion);
- erosion point probability (time dependent) (determination of the likelihood of coastal erosion reaching a certain point by a stated time or period);
- asset deterioration rate (estimation of the rate at which a coastal protection structure or defence deteriorates);

- visual representation and database interface development (in GIS) (the development of computer ability to produce maps and tables of results and to utilise and join databases in a functional way).

Of these activities, practitioners have been calculating erosion rates from historic records for many years although predictions of shoreline position have been calculated probabilistically less often. Until recently, the representation of such erosion estimates in GIS has been mainly the prerogative of industry consultants. The launch of NCERM has made these outputs available to local authority coastal practitioners – albeit for the purpose of national scale mapping and recording purposes.

For outstanding issues regarding the problem of combining the functions of the PAMS and RACE methodologies, see Section 2.3.

6 Knowledge gaps – what are the issues

The previous chapters outline a wealth of information, sources and tools for data analysis and decision support. However, there are significant gaps in FCRM knowledge and therefore methods. This study has identified a number of areas where knowledge and understanding are lacking, but which could lead to improved asset management.

Previous consultation at a workshop held before the start of this project, a practitioner's forum held during the course of the project and experience of the project team identified a number of areas where further research would help improve flood and coastal risk management. The workshop, in particular, aimed to identify the research needs of FCRM practitioners (i.e. the potential users of any tools developed in the future).

The views and opinions expressed by those involved are the product of their perceptions and experiences. They may not therefore always be facts but rather the perspectives of the attending delegates on the various issues discussed. This is because the issues are broad and may have extended beyond the expertise of those involved; where this is the case, delegates could have resorted to their past experience and hearsay on issues from third parties which may have been recent or since remedied.

6.1 Previous consultation

In 2008 the Sustainable Asset Management (SAM) Theme Advisory Group decided to review the coastal aspects of SAM to assess those areas that still require R&D (particularly in view of the Environment Agency's wider strategic role in coast erosion risk management).

A workshop was held on 24 June 2008 to identify issues raised. Attendees considered that:

- there was a lack of sharing and dissemination of good practice within the coastal field;
- this was particularly concerning in view of the number of leading practitioners who are nearing retirement or have left the industry (taking their knowledge and experience with them).

They felt there was a strong need to establish a structure/system that would:

- support the sharing and dissemination of best and 'worst' practice, including aspects relevant to operation (e.g. dealing with blown sand), design and construction;
- incorporate lessons learnt from past schemes and studies – not currently shared widely or consistently;
- avoid 're-inventing the wheel'.

It was concluded that a three-phase approach could be applied as follows:

- **Phase 1**
  - Review existing and other methods for knowledge sharing, taking account of the value of face to face communication.
  - Identify particular key areas that could be considered as initial pilots.
  - Recommend an improved system, including fora and an underpinning digital knowledge management system.
- **Phase 2:** Establish the underpinning knowledge management system, which would be already loaded populated/loaded for the pilot areas identified in Phase 1.
- **Phase 3**: Implement.

Those attending the meeting supported wholeheartedly the idea of improved knowledge management but nonetheless agreed strongly with the value of, and need for, good practice guides (e.g. those recently completed, currently underway, those identified for cliff management and sea walls).

The workshop also discussed data and information. Those attending felt that there was a need for the establishment of good practice and consistency in:

- monitoring of defences, beaches and coastal slopes;
- access requirements;
- asset data – performance, residual life;
- prioritisation of work – maintenance, intervention, etc;
- determining the level of the shore platform;
- aspects of climate change.

The workshop attendees agreed that:

- there was already much work being carried out on these and related topics in the R&D field (notably the PAMS project);
- the issues raised would be noted fully and reported to the relevant teams.

They also felt that there was a strong need for improvements in the general approach to the management of coastal defences. There was also a view that, in this regard (i.e. assessing coastal risk), the asset should be considered as extending from the toe of the beach to the top of the cliff.

Important issues to be covered were stated as:

- improved baseline data on asset condition and type;
- sensitivity of asset condition to external forces (e.g. effect of lowering of beaches in front of coastal structures);
- how the data should be stored?
  - the NFCDD review and development of any future asset management supporting technologies was of great interest.
  - involvement of LPAs in this process was felt to be vital.
- improved focus/balance between asset management and new schemes;

- a better understanding of the performance and risk from natural features such as the collapse of cliffs or the breaching of dunes;
- the need for better tools for operators are necessary as well as high level decision-support systems;
- the need for guidance on asset monitoring;
- the need for improved knowledge on how assets will respond to changing forcing conditions such as sea level rise (SLR) and increased storminess;
- how to build flexibility (possibility for upgrading or removal) into design to allow for future changes.

Following the workshop, six short proposals for R&D projects were prepared for further consideration (Thomas 2008):

- 'schemes with multiple objectives and funders – case studies';
- 'knowledge management across the industry relating to experience and best practice';
- 'removal of defences';
- 'risk and performance in coastal assets';
- 'public education, consultation and good practice case studies';
- 'use of UKCIP08[33]/climate change in asset management'.

It is important that this scoping study takes account of the conclusions of this workshop, and to build and expand on the detail of the 'high level' issues identified – but within the context of 'performance and risk-based asset management' and 'systems analysis'. Two crucial aspects (physical process knowledge and system risk analysis) are therefore considered in the following sections:

6.2 Practitioners forum/workshop

A consultation with FCRM practitioners was held to ascertain user needs and requirements including those representing the Environment Agency, local (maritime) authorities, and industry consultants and researchers. The record of the 'practitioners' workshop' (see Appendix 4) lists those who attended the event. Table 6.1 summarises the issues raised.

Following a review of the points discussed in response to the questions posed, the issues were categorised into five conceptual groups:

- coastal management practice;
- technical understanding and knowledge;
- tools/techniques;
- responsibilities and funding.

The advantage of this categorisation is that:

- it collates similar levels and themes together;

[33] Now known as UK Climate Projections (UKCP09); see UK Climate Impacts Programme (http://www.ukcip.org.uk).

- may help to determine how the issues raised might be addressed in the future.

For example, new management practices might require guidance for dissemination or there may be several issues associated with ‘the practice’ of data handling and storage. If this requires a new tool, then this is also mentioned under the ‘tools and techniques’ section. There are also pertinent issues associated do with ‘responsibilities and funding’.

Under these headings, there are recurring topics that help to further refine the categorisation. The topics fall into issues to do with ‘performance’, ‘monitoring’, ‘data’, ‘planning’, ‘communication’ and ‘modelling’.

Table 6.1 Summaries of issues raised by coastal practitioners.

	Coastal management practice	Technical understanding and knowledge	Tools and techniques	Responsibilities and funding
Performance	Develop performance specifications for all structures and compare these with actual performance (e.g. bank levels).	There is a requirement for: • better understanding of how groynes behave under all conditions (type, deterioration, alignment); • better technical understanding of beach response.	'Replace the National Flood and Coastal Defence Database with something more useful'. The NFCDD has not always been fully utilised by maritime authorities. There is a perception that it does not contain appropriate data fields for coastal asset management. This impression is compounded by the fact that it is often seen as 'an Environment Agency tool' by local authority practitioners who see little benefit in it and are reluctant to spend time duplicating data entry into it in addition to their own databases.	Linking the funding of schemes geographically and over time would provide more security. Sub-optimal solutions are often adopted due to funding uncertainties and rules. Allow flexible design that permits 'works' to encompass change in coastal processes and service requirements (including maintenance).
Monitoring	Monitor particle size distribution of beach material and identify trends. Use fixed point photography during inspections to aid and inform trend analysis of beaches. Make more regular use of global positioning systems (GPS) to monitor beaches and foreshores before and after storm events. Undertake frequent periodic beach monitoring coupled with post storm surveys. Measure long-term beach performance and rate of change and monitor beaches and structures during storm events (not clear what capabilities exist). Utilise best practice.	Investigate causes of asset deterioration in a quantifiable way while recognising uncertainty.	Improve appraisal techniques (for maintenance). Regular series of aerial photographs can be beneficial for monitoring change and can enhance GPS surveys – they offer an insight into beach behaviour that surveys are unable to provide.	No issues reported.

	Coastal management practice	Technical understanding and knowledge	Tools and techniques	Responsibilities and funding
Data	Remove barriers to information sharing, including the form filling required by the Environment Agency which is not easy to do. The computer systems in place for knowledge sharing are not user friendly. A more open, transparent relationship where useful information can be shared would improve matters. Standardisation of data would make collection, storage and access by different organisations and authorities easier.	A review of historic data and information on past events can enhance and extend knowledge about the response of assets. This should form one part of targeted data gathering on physical processes, coastal change and coastal assets. Improve the recording and use of data to in turn improve coastal understanding and to trigger action.	Create a GIS-based asset inventory (linked to datasets). Directional wave data is an area where model representation could be improved. This is a factor that can significantly affect model results, particularly where longshore transport is simulated.	No issues reported.
Planning	Collect comprehensive information (on assets) to create historic datasets (and use them!). Link data with decision-making through the whole life of an asset. Conduct regular reviews. Check regional and national data carefully against local knowledge and common sense. Plan more effectively and be more pro-active in maintenance activities. Treat every beach uniquely (and in context) and develop bespoke solutions. Intervene in a 'little and often' manner.	Develop life-cycle plans for the performance of structures (including cost and maintenance). Develop methods for optimisation of intervention. It is very difficult to optimise interventions because performance appraisal is not linked very well to change during the life span of assets, i.e. get the best return (performance) for the money spent on maintenance/repair, etc. over the lifetime of the asset(s).	Evolve understandable models that link coastal processes and assets, and quantify risk. Models must include estuarine shorelines as well as open coasts and deal with boundaries. Further development of multi-criteria assessment approaches (MCA) would benefit assessment. Undertake a comparison of different models and their effectiveness. Design the planned new Environment Agency Asset Management support system to include some of the requirements of local authorities while also fulfilling the Environment Agency's objectives. Integrate neighbouring authorities and Environment Agency staff so that they can work together and share lessons learnt, etc.	Better co-ordination and funding of spatially connected schemes and improved efficiency in planning would help to secure funding to deliver long-term plans.

	Coastal management practice	Technical understanding and knowledge	Tools and techniques	Responsibilities and funding
Communication	Involve/engage local people and coastal stakeholders as much as possible (including dissemination). Take a broad view, listen to local knowledge, conduct post project appraisal & publish R&D - and failures as well as successes. Liaise frequently with the Environment Agency and with local authorities. High staff turnover and frequent restructuring made it difficult to maintain relationships with the Environment Agency. • A single point of liaison was recommending as a way of dealing with this difficulty, with people developing a working relationship with a single Environment Agency member of staff and turning to them first. • Detailed organisational maps of staff should be available on the Environment Agency website and updated regularly to help find appropriate contacts.	Learn from previous experience and communicate your own problems. Acknowledge the importance of knowledge transfer. The importance of capturing knowledge from local experts is recognised, but it is not clear how this can be done effectively. Modellers are not always able to benefit from local expertise and historic knowledge. Turn data into useful knowledge to ensure that it is used and interpreted correctly. Apply and understand existing tools and methods better. Understanding the appropriateness of models and their use will help to ensure that the correct people are involved in the process and that models are used for the right purposes. Consistency is important nationally, though this should take account of application at appropriate levels of management and consider conditions at particular sites. Practitioners should understand the tools and for what purposes they are appropriate when embarking on or commissioning a new project.	It is often unclear as to whether or not numerical (e.g. planshape) and physical models are sufficiently validated; hence there is a cautionary approach to the use of output from models. Successor planning within the Environment Agency and/or secondment of junior staff to local authorities would enable working relationships to be transferred to the next generation of managers.	Environment Agency and local authority managers often have different aims and objectives; the Environment Agency looks at what is best for the environment and the asset itself, whereas local authorities have other priorities and have to manage for the local community and their needs. This can lead to differences of opinion and thus make relationships difficult. Environment Agency and local Authority staff could aim to provide a more united front to the wider community, with any disputes resolved internally, rather than widening the gap by publicly coming from different perspectives.
Modelling	Use modelling to inform a management decision in combination with other tools (rather than being used alone) and with due regard to known uncertainties and limitations. Validate models based on experience either post-project to inform future works or as a model calibration exercise using historical data. There is a need to disseminate uncertainties and limitations of	Models do not currently capture the full scope of risks. Improvements could be made to representation of the consequences of 'do nothing'. Models need to represent natural processes better and apply this to beach management; they need to represent the whole system and link this to individual structures. A more comprehensive approach to assessment of benefits is required in	Traditionally, models have not been used to best advantage – providing data that is not directly useable to support decisions. New generation models that better support decision-making are more efficient to set up and run, and contain appropriate detail of the important processes. Allow a combination of judgement, validation and honesty with respect	There is some debate on the cost-effectiveness of models. It is acknowledged that large amounts of money have traditionally been spent on modelling. It is questionable as to whether the benefits gained are always worth the amount spent or whether monitoring is of more use.

	Coastal management practice	Technical understanding and knowledge	Tools and techniques	Responsibilities and funding
	specific models and their applications. There tends to be a perception – both by the client and the wider public – that models provide 'the answer'; in reality this is not the case. A model simply gives prediction that is as accurate as the data put in. Models, particularly plan-shape models, should use observations of the natural beach as a starting point rather than solely using modelled reality.	models. Models currently in use are unable to accurately represent mixed beaches – processes are not understood properly (most UK beaches consist of mixed sediment – a significant issue). Interaction with structures is a major feature that is not well represented in models, e.g. different materials are not generally differentiated between. Ensure models include estuarine shorelines as well as open coasts and deal with boundaries. 'Keep it simple' was a request from some practitioners. Models should not used where they would add little or no value.	to uncertainty.	

6.3 Knowledge gaps

There are a number of knowledge gaps in the understanding and modelling capability of the physical processes involved in coastal change and defence structure/ morphology responses and interactions. It is these shortcomings, and those that practitioners think are important to their work, that this study sought to identify. Some of the most important issues are described below.

6.3.1 Physical process knowledge gaps

Performance of sea walls[34] – fragility curves for coastal sea walls

Fragility curves[35] represent a major issue that must be resolved to make progress with implementing performance-based asset management on the coast. Little effort has been devoted to the development of fragility and performance descriptions of sea walls that can be readily used within an asset management context. Various projects (PAMS, RACE, Overstrand to Walcott strategy study and the Tyndall Centre Coastal Simulator) have started to develop useful concepts but these will need to be extended to establish a consistent relationship between loading and the probability of failure, and how this changes over time in order to draw on the best elements of both the PAMS and RACE methodologies.

In developing fragility curves for coastal sea walls, two key issues will need to be considered:

(a) Understanding the failure mechanisms for sea walls in a load dependent way

(b) Understanding how beach system performance affects the toe level at the sea wall.

(a) Understanding the failure mechanisms for sea walls in a load dependent way

In many cases, the critical failure modes for sea walls are related either to toe erosion or wave overtopping causing erosion on the landward side. In turn, wave overtopping is related to the beach toe level and profile fronting the sea wall. Thus, the toe level (and foreshore profile) is a vital parameter to identify while recognising that there may be considerable longshore variability, with global variations arising due to factors such as variation in the longshore transport rate and local variations occurring as a result of more localised factors such as the presence of groynes or wave control structures.

Load-dependent fragility curves for sea walls can be expressed by plotting probability of failure against a parameter such as the difference in height between toe level and crest level. This will drive the undermining failure mode directly. It can also be used for the overtopping mode, since the height of the wall will dictate the overtopping rate which will, in turn, dictate the consequential erosion. The only problem is that it is important to select an overtopping rate of an appropriate return period or some kind of averaged rate.

[34] No distinction is drawn here between sea walls providing flood protection and sea walls providing erosion protection.
[35] For further information on fragility curves, see Buijis et al. (2007).

(b) Understanding how beach system performance affects the toe level at the sea wall

The beach system should be seen as including the beach, any beach control structures (generally groynes) and any wave control structures. Beach modelling of various kinds can be carried out to determine the beach toe levels and their variation (e.g. GTI-SEAMaT or SANDS); it is not necessary to be prescriptive since the most appropriate form of the modelling will depend on the nature of the coastal cell or sub-cell. However, there are significant issues and a potential science gap to close in order to identify the relation between the structural condition of beach and wave control structures such as groynes and their contribution to beach condition. This is discussed in more detail below.

Beach and wave control assets – processes and decision-making for investment

Two main questions arise when thinking about the value that beach and wave control assets offer:

(a) How can we predict how such structures will change beaches?

(b) How do we evaluate the benefits (in the specific context of coastal defence) of those changes in beach morphology?

(a) How can we predict how such structures will change beaches?

A substantial body of research and practical experience in predicting the effects of groynes and breakwaters on beaches has been accumulating since before the earliest days of computer modelling of coastline evolution. A review of such methods can be found, for example, in HR Wallingford (2001). These range from very simple rules-of-thumb through to more complicated empirical methods, a range of different types of computer modelling and even, on occasion, laboratory modelling. However, there have been (and continue to be) considerable advances since the time of the HR Wallingford report; for example, the LEACOAST2 project[36] is investigating the effects of detached breakwaters on a coastline where waves and tidal currents are influential in altering the beach morphology.

Today it would be surprising if such modelling methods were not used in the design of a proposed coastal defence scheme that involved a substantial investment in beach/wave control structures – whether entirely new or, more usually, to replace existing structures.

Such modelling, however, always requires a degree of simplification whether in neglecting some of the processes that are known to occur and/or by only considering a subset of the wide range of tidal and wave conditions that will occur during the lifetime of a scheme. As a result, it is common, for example, to have to make adjustments in a model to the representation of a proposed groyne, e.g. specifying its 'effective' length by applying some factor to its actual length.

Such adjustments to overcome the inaccuracies caused by the simplifications are based on experience of using the model to reproduce the observed performance of existing structures at the same site or of similar structures to those proposed at another location. Where novel types of structure are proposed (e.g. converting traditional timber groynes to rock groynes or permeable structures), the reliability of such adjustments is clearly open to considerable doubt. At present, for example, there is little or no information on whether the comparative performance of timber and rock groynes of the

[36] See http://pcwww.liv.ac.uk/civilCRG/leacoast2/index.htm

same length and crest profile can be judged. This type of problem is greater when very novel structures (e.g. multi-functional reefs) are proposed as contributing to a coastal defence scheme.

It follows that predictive modelling often cannot be satisfactorily calibrated because of a lack of good post-project monitoring. It is rare, for example, to find retrospective reviews of the predictions made about the effects of a scheme after it has been built.

A further problem arises in respect of predicting the wave conditions and, to a lesser extent, the tidal conditions that a scheme involving beach/wave control structures may experience in the future. The simplest approach is to assume that such future conditions will match those experienced in recent years. However, changes in our climate as a consequence of global warming may have a significant effect on beach morphology. The modelling of beach/wave control structures should therefore investigate this possibility by means of sensitivity testing to ensure any decisions made about a proposed scheme are robust should such climate changes occur.

Moving away from the design of major capital works schemes, there is good evidence to show that the performance of beach control structures can be improved by regular maintenance and adjustment, guided by monitoring and reviews of their effects on beaches. However, it is unusual for such modelling to be used to guide the maintenance or adjustment of the structures or of beaches as part of routine operational management of coastal defences.

In this context, existing computer models could be expected to give a reasonably reliable indication of the effects of substantial changes to such structures, e.g. altering their crest heights/lengths or removing or adding a structure. However, it will be more difficult to adjust theoretical basis of these models to reliably represent smaller changes such as gaps appearing between the planks in a timber groyne. This type of small change has been shown by observation to have noticeable and significant effects on beach levels. Representing this loss of efficiency in computer models will need to rely on empirical relationships based on observations and measurements.

Given this, there are potentially three main areas where improvements could be made when setting the direction of future research in the beach system:

1. Defining good practice in beach system modelling
2. Calibration/validation of models, e.g. in relation to the efficiency of beach control structures in various conditions
3. Model improvements.

(b) How do we evaluate the benefits (in the specific context of coastal defence) of those changes in beach morphology?

An important issue that is often neglected in modelling beach/wave control structures is how best to evaluate the predicted changes in the beaches. Few, if any, such schemes (excluding any planned recharge operations) can be relied upon to increase the volume of sediment on beaches and so the changes that do occur involve redistributing the available sediment. The most common outcome is that the widths of beaches are altered, with an associated change in levels. (Perhaps the most significant of beach levels, given the discussion above about defence fragility, are those along the toe of a linear defence such as a sea wall.) These changes in beach width may be very different either side of a structure such as a groyne. There may also be changes in the cross-sectional profile of beaches, particularly close to proposed structures.

Such changes in beach morphology will occur over a range of timescales, i.e. beach levels vary both in the short-term (e.g. in response to changes in wave directions) as well as over longer periods (e.g. as a beach accretes updrift of a long harbour arm).

Some models will allow the prediction of beach changes using realistic sequences of wave and tidal conditions, and output results at short time intervals at any location of interest – though this clearly has the capacity to produce vast quantities of information. Others, which necessarily need to reduce the number of wave/tidal conditions that they use as input, will only seek to provide long-term trends in beach morphology and not give reliable information on shorter term variations.

Outputs from predictive models will subsequently be used to assess the (coastal defence) benefits of the changes in the beach as part of the overall assessment of performance a scheme. This evaluation of a beach as a coastal defence asset is often rather difficult. Both the cross-sectional area and the height of the crest of a beach at any point are often important indicators of its condition. However, there are situations where any further increase in these values would not bring any significant improvement in the performance of a coastal defence, and in very unusual cases, such an increase may be detrimental. It is often important, therefore, to produce information on the predicted minimum beach crest levels, widths or cross-sectional areas. Where it is possible to do so, information on the probability of these parameters falling below some specified value might be useful.

Prescribing how changes in beaches should be evaluated in order to calculate the benefits of beach/wave control structures is important in:

- providing a consistent way of comparing alternative scheme options;
- helping to justify the preferred option that is chosen.

However, the difficulties involved in doing this are considerable at present and this is an area where further thought and research would be valuable.

Cliff geomorphology and beach response

(a) How do different cliff types respond to marine erosion and hydrogeology (i.e. external and internal stresses)?

Current cliff response models are based upon particular types of cliff geomorphology. For example, the CLIFFPLAN and SCAPE models (Meadowcroft et al. 1999, Walkden et al. 2002, Hall et al. 2002) were developed to simulate the recession of an unprotected soft rock cliff (e.g. London Clay) and use a distribution of erosion under breaking waves provided by physical model tests on glacial till (Skafel and Bishop 1994, Skafel 1995). The validity of such models for modelling anything other than soft rock shorelines is undetermined. The model also assumes that cliff 'failure' will occur after 10 'recession events' (i.e. the first 10 tides with active waves). This is an unrealistic assumption on which to derive/model hard rock cliff failure. Recession data should be collected and analytical tools developed to compliment and validate such predictive models.

(b) Wave processes on permeable/barrier beaches – wave processes through permeable strata, particularly barrier beaches remain poorly understood

The following discussion highlights the gaps in understanding that became apparent through the review and consultation carried out in the 'Understanding Barrier Beaches' scoping study (Stripling et al. 2008). These gaps reflect the current poor understanding of barrier beach processes and are all issues that affect efficient flood risk assessment. As a result, effective management strategies are difficult to define.

Uncertainties relating to reliability

The following points were raised in relation to the short-term response of barrier beaches, many of which can be viewed in the light of fragility (i.e. what is the probability of failure under a particular loading).

- What conditions will cause a barrier beach to overtop?
- How much overtopping will occur?
- What conditions will cause a barrier beach crest to be lowered?
- How is a breach likely to form?
- How does the beach material (and its grading) affect the profile change?
- How might permeability change as a result of management?

Uncertainties relating to resilience

The following points were raised in relation to the short-term response of barrier beaches, many of which can be viewed in the light of resilience (i.e. the ability of the barrier to 'self-heal', or otherwise).

- How is a breach likely to form and be sustained?
- Will a breach remain open if no active management is taken?
- If the crest of the beach is breached, will it reform? How quickly will that be?

Uncertainties relating to deterioration

The following points are related to the long-term behaviour of barrier beaches.

- How quickly will a barrier beach migrate?
- What factors affect the rate of barrier beach migration?
- What factors will cause the barrier beach to migrate more quickly?
- How does the underlying geology affect the beach evolution?
- What is the impact of rising/falling land on the migration rate?
- How does longshore sediment supply/rate impact on beach performance?
- How will anticipated sea level rise affect the barrier evolution?
- How will the anticipated increases in the height and/or frequency of extreme wave events affect the barrier evolution?
- How might anticipated changes in mean wave direction affect the barrier evolution?

The full list of conclusions and recommendations from the barrier beaches study is shown in Appendix 6.

(c) How can the morphological evolution of mixed sand–gravel beaches be predicted?

Typical problems faced by those responsible for managing mixed beaches include:

- the inability to determine the sensitivity of the beach profile and cross-sectional area to variations in sediment distributions;
- poor predictive capacity for cross-shore response of mixed sediment beaches to storms and their recovery after storms;
- uncertainty in predicting longshore or offshore losses of recharge sediment over time;
- inability to predict beach response in the vicinity of coastal structures and inability to predict the importance of seepage through barriers – see (b) above.

The Defra/Environment Agency R&D study on the influence of permeability on the performance of shingle and mixed beaches (FD1923) (She et al. 2007) sought to address these and other questions relating to the performance of mixed sand–gravel beaches findings and recommendations related to asset management issues arising from this study should be taken forward. The full list of conclusions and recommendations from this study are shown in Appendix 7.

A review and analysis of collected data from the south coast regional monitoring programme by the Channel Coastal Observatory (A Bradbury, personal communication) highlighted the value and importance of monitoring and validating coastal wave and beach models with field observations and measurements. A range of design variables and system responses were assessed based on an extensive long-term monitoring programme. The context of differences between modelled and measured data was considered relative to a broad range of sites across southern England. The significance of each of the following was considered:

- wave climate characteristics;
- cross-shore beach response;
- planshape beach evolution;
- geotechnical responses of bed geology.

The review found that:

- significant differences in wave climate characteristics were evident between modelled and measured wave conditions;
- cross-shore profile responses are not well described in bimodal wave period conditions, which occur regularly;
- overwashing is under-predicted by the breach prediction model used in bimodal wave conditions;
- simple empirical frameworks do not provide adequate allowance for variability of sediment grading – sand content in particular is not considered;
- significant differences have been observed related to incident wave angle;
- sediment transport rates have been much lower than predicted by numerical models;

- predicted beach settlement rates have found to be generally higher than measured.

6.3.2 Resilience of natural defences

How can the behaviour of natural landforms/defences be represented in analytical models?

Most coastal modelling systems focus on the representation of the behaviour of man made defences or beaches in their analysis. The behaviour (e.g. deterioration, failure, recovery) of natural landforms and defences such as cliffs, dune systems, saltmarsh and cohesive foreshores have not been very well integrated into FCRM mainstream practice and are not particularly well modelled (if at all).

The use of 'real' data as opposed to 'modelled' is preferred, but is limited by the current understanding and deterministic representation of links between physical processes and natural landforms. This represents a substantial and important area for future research given the expected effects of climate change and sea level rise on such systems.

The recommendations from recent studies for future research/study on beaches, sand dunes, cohesive foreshores and saltmarshes are provided in Appendices 6, 7, 8 and 10.

6.3.3 Asset inspection and condition assessment

How can coastal flood defences, erosion protection structures and natural landforms that serve a coastal protection 'service' be visually inspected and effectively assessed?

Experience from the PAMS field trialling of a new inspection methodology revealed that few coastal assets are currently being assessed using the existing approach (Environment Agency T98). Inspectors feel that they lack the knowledge, experience, training and guidance to assess such assets. Figure 6.1 shows an example of a PAMS asset inspection flow chart.

Further developments should look to address the lessons learnt from past experience to increase uptake of methods. The method and guidance (flowcharts) developed for the PAMS approach requires bespoke adaptation for the coastal asset types (sea walls) and further development is required in the method of assessing condition of beaches, dunes, saltmarshes and control structures such as groynes.

The assessment 'condition' or stability of cliffs is another issue that needs to be considered and will depend on the way that the fragility of different cliff types is to be represented (see Sections 6.3.1 and 7.3.2).

Similarly the assessment of the condition (strength or resilience) of saltmarsh is an issue, though guidance on condition assessment for saltmarsh habitats is available (JNCC 2004). Other habitat assessment guides for sand dunes, coastal vegetated shingle, and maritime cliff and slope are also available from the JNCC website (http://www.jncc.gov.uk/page-2204).

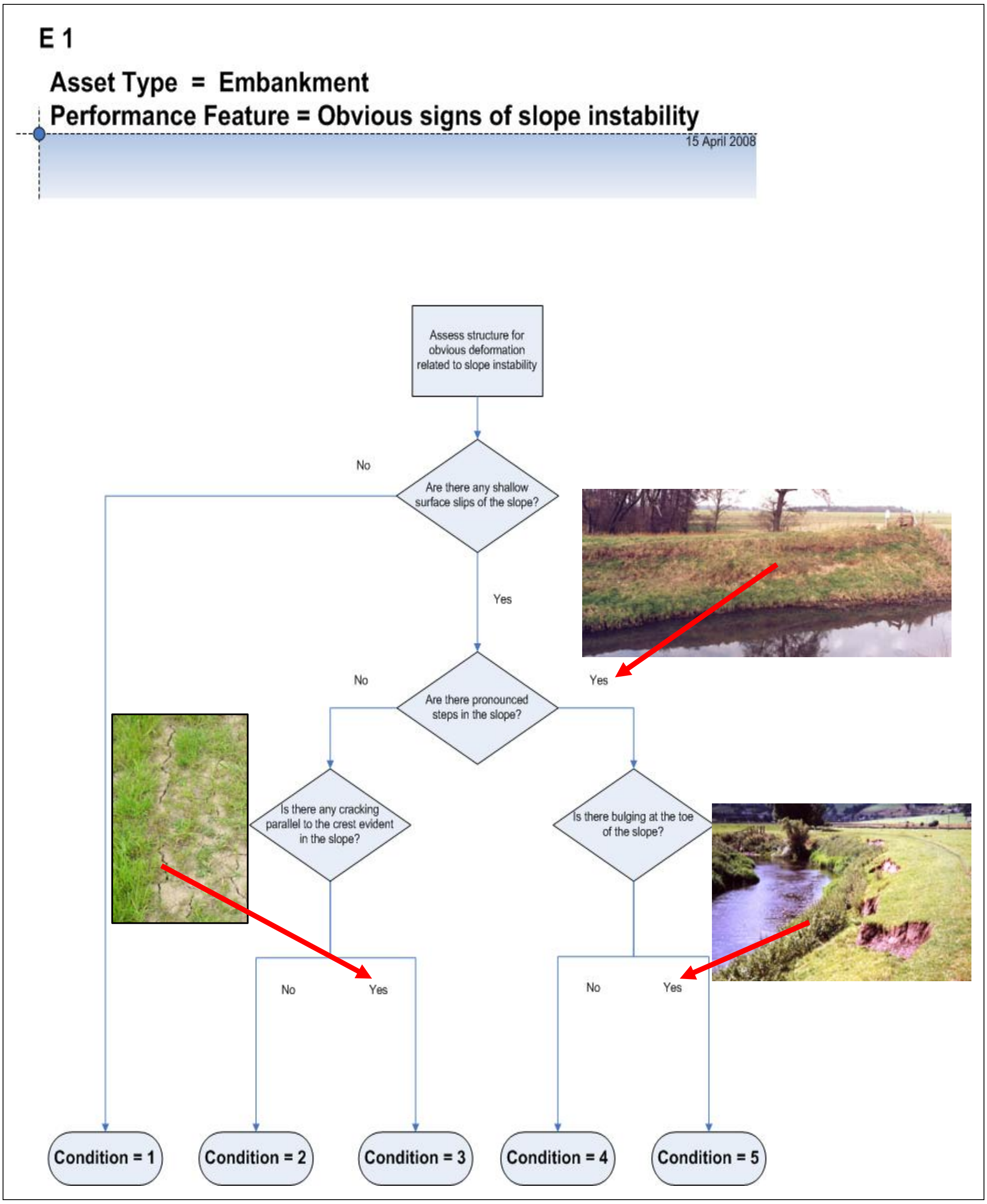

Figure 6.1 Example of a 'PAMS' asset inspection flow chart (Defra/Environment Agency 2009a).

7 Asset management practice – the challenge and opportunities

The Environment Agency's strategy over recent years to adopt a performance and risk-based approach to the management of flood and coastal defence assets – and to encourage other responsible authorities to do the same – has been gathering pace through various projects and initiatives. The science SAM theme advisory group has worked hard to try to integrate ongoing research to provide evidence-based support to management practice and decision-making in the FCRM industry. With its new responsibility for the overview of flood and coastal risk management, the Environment Agency now has the challenge of incorporating coastal assets more explicitly into this process. This includes the need to work closer with maritime local authorities, private owners of coastal frontages and others in the planning and management of coastal assets. The recent advances made through projects such as PAMS and RACE (and others) provide a basis and opportunity on which to build and progress research and increase understanding to further the aims of improving asset management at the coast. This project has sought to identify how this process might move forward by identifying existing gaps in knowledge and capabilities, and to try to understand the industry's existing and future needs.

7.1 The challenge

Part of the problem for coastal asset management is that a bespoke framework has never been devised for, and bought into, by the majority of practitioners. Existing plans and strategies are undertaken to help with planning issues and to meet obligations; however, they do not provide a structure for day-to-day risk management activities.

7.1.1 Overview of the proposed framework

A coherent framework for the development of supporting tools and techniques for the management of flood defence and coastal erosion assets has been previously proposed within the scoping study for PAMS (see Figure 7.1). The high level view remains applicable to coastal assets; the challenge for this project lies within scoping the detail of each of these activities.

The key elements in Figure 7.1 are discussed below:

- decision support;
- systems analysis;
- inspection and assessment of asset condition;
- common databases.

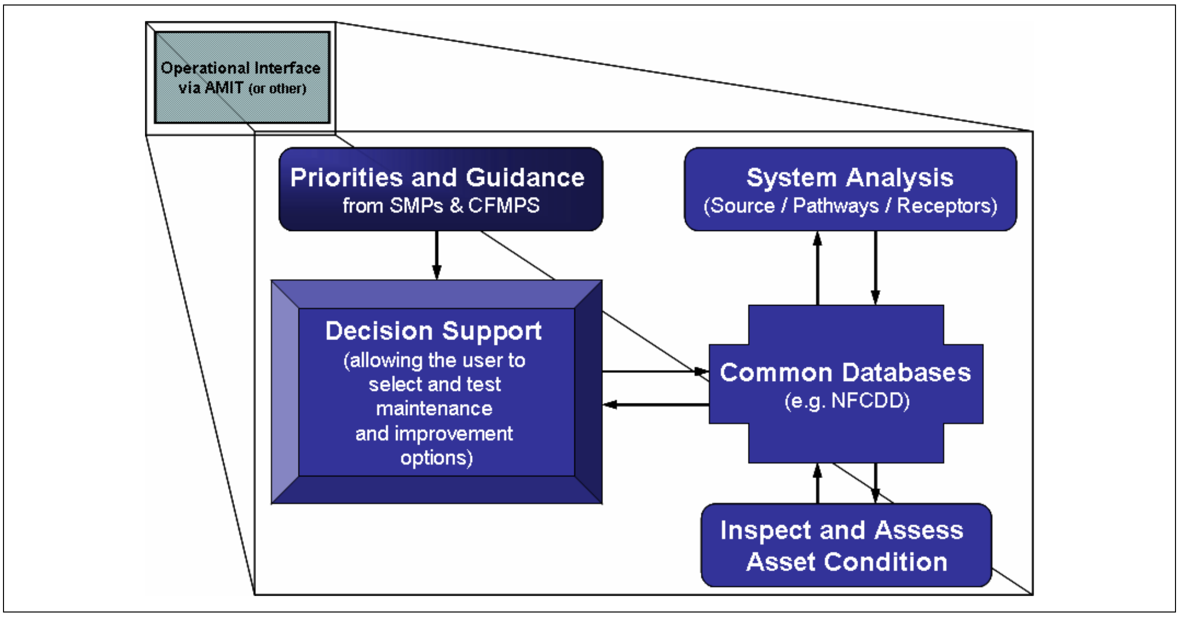

Figure 7.1 Overview of the proposed flood and coastal erosion risk management framework (adapted from Defra/Environment Agency 2004b).

7.1.2 Decision support

The challenge

Supporting coastal asset managers and practitioners in their decision-making requires consistent and available guidance, tools and techniques that are clear and applicable to their needs, which range from inspection frequency to risk attribution and from prioritisation to whole life costing.

Scoping the future approach

A suite of guidance and tools is required to support the decision-making process which itself also requires guidance and process support. The various decision processes that are typically undertaken should be mapped so that any support, tools, etc. currently available can be identified and their suitability assessed.

To promote a common approach to the risk assessment of coastal assets, it is essential to establish an agreed set of **risk metrics** by which performance can be measured. This has not been achieved to date though a lead can be taken from flood risk management metrics. For example such measures may include:

- estimated annual damages (PV[37]) as a distribution if possible;
- estimated annual losses (PV) as a distribution if possible;
- number of properties at risk;
- land loss (hectare total, by type and designation);
- people at risk.

[37] Present (day) Value

As protected entities, these metrics establish the benefits of maintaining defence assets against which the costs of continuing to provide (or not provide) such protection can be compared. This also then allows an assessment of the effectiveness and efficiency of provision by ascertaining a benefit–cost ratio (or rate of return) and/or the amount of risk reduction for the cost of intervention. These are important considerations for asset managers with limited budgets and the responsibility for delivery of equitable and robust solutions.

Beyond the cost–benefit analysis for flood and/or coastal protection, local authorities in particular also need to consider the impacts of interventions, measures and solutions on other activities and parties for which they are responsible (i.e. they have a broader remit than the Environment Agency). For example, they may need to consider impacts on and benefits to tourism, recreation, business, other infrastructure (and services) and conservation. Thus, there are often 'multi' benefits and costs that need to be considered by decision-makers, including those associated with flood and erosion.

Priorities for development

Known issues at present include:

- agreement on risk metrics (including weighting);
- evaluation of the benefits of changes in beach morphology;
- the use of **risk attribution** as a means of assessment of the contribution to risk of an existing asset;
- how to build flexibility (possibility for upgrading or removal) into design to allow for future changes;
- how to optimise (and support optimisation of) interventions;
- representation of 'do nothing' consequences (for erosion particularly);
- accounting for costs and benefits associated with multiple uses of assets (e.g. recreation, conservation, etc.);
- guidance on appropriate use of tools/models.

7.1.3 Systems analysis

The challenge

Flood and erosion risk systems often exhibit significant spatial and temporal complexity with many different sources and pathways (and receptors). System-based thinking enables the complexity to be broken down without losing the behavioural characteristics of the system as a whole.

The main challenge here is to determine the major influences and changes in these systems that change flood and coastal erosion risk (i.e. how does the system function). As with most things, 'the devil is in the detail', requiring in-depth knowledge and understanding of the system processes and the effects on receptors. Some areas and processes are better understood than others. Although the recent project, 'Characterisation and Prediction of Large-scale, Long-term Change of Coastal Geomorphological Behaviours' (SC060074), and others have improved our understanding and capability greatly with respect to coastal morphological change and sediment transport, further research is required to better understand certain aspects (e.g. cross-shore change).

Recent work in the PAMS project has demonstrated the challenge faced by a pilot conducted on a frontage in West Bay in Dorset. Uncertainty associated with the performance of the West Beach was addressed by refining the fragility curve for the defence and re-running the model to ascertain a revised risk attribution. However, no attempt was made to model long-term changes in beach volume as these could not be replicated and demonstrated.

Scoping the future approach

Current research and consultation with practitioners and industry consultants has identified other issues with, and gaps in, understanding of coastal flood and erosion systems. These are listed in Table 7.1.

When it comes to the analysis and modelling of coastal asset related risks, there are two performance parameters that are very important but which have not attracted sufficient focus and study to date. These performance parameters are beach sediment volume and beach depth at the sea wall (or other defence type).

Beach volume is important because this is what coastal mangers need to maintain by means of recycling/renourishment to maintain the integrity of the defence line over time.

Beach depth at the sea wall (or cliff) is important because sufficient sediment is required to prevent undermining of the structure (or landform) and to limit wave overtopping in the case of sea defences (i.e. maintain desired hydraulic performance).

Proper characterisation of beach performance and that of associated beach control structures is required to characterise the fragility of the defence line properly, bearing in mind that in some cases the beach *is* the defence line. This issue requires addressing of both long-term shoreline evolution and local fluctuations in beach levels. Future work will need to tackle:

- the issues of assessment of these parameters;
- the provision of tools to enable managers to investigate options and scenarios given changes in these measures.

Natural beach systems provide significant proportion of our defences in the UK. Unlike fixed structures such as sea walls, natural beaches (barrier beaches and dunes, etc.) respond naturally to the forcing wave and water levels, changing dynamically during the storm and then recovering during calmer periods. This process of recovery is poorly understood and needs to be captured within the systems analysis and the performance models used to underpin asset management.

One of the problems is to understand and predict how the wider sediment transport processes impact on beach volume/area. Another is how this, combined with wave processes, impacts on beach height at the defence. Furthermore, control structures such as groynes are often used to control the movement of beach sediment; understanding and modelling how such management measures perform is a yet further complication.

Thus, risks are realised through the way in which the system behaves. Existing system models are now relatively well-developed for flood risk but they remain more basic in terms of analysis of coastal shoreline systems – as illustrated in Figures 7.2 and 7.3.

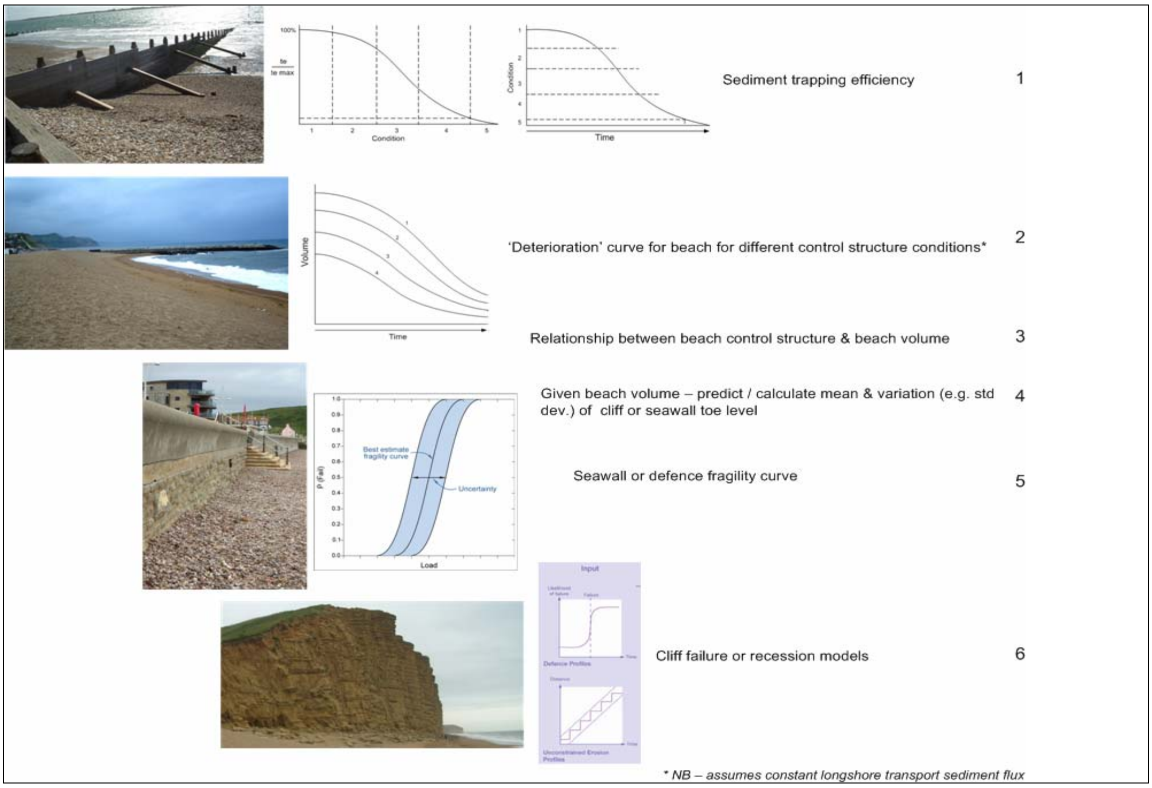

Figure 7.2 Outline of a simplified performance analysis framework for flood and coastal erosion asset management.

Figure 7.2 is a stepwise 'fragility' framework; the difficult aspects are in linking the 'coastal whole system' models efficiently but robustly for processes happening at different temporal (hours, seasons to years) and spatial (single groyne to groyne or beach system) scales. Figure 7.3 is a simplified flow diagram for coastal erosion. There are complex interactions (temporal and spatial) running through the processes at work which need to be captured and described in more detail.

Another issue is risk attribution; the attribution of risk to assets is a key and powerful output from a risk analysis. Embedding systems analysis within software tools (as for flood risk in NCERM, PAMS or MDSF2) enables relatively complex computational calculations to be completed without unnecessary or onerous user inputs. A major challenge will be facilitating a robust system risk analysis (incorporating sequencing issues and probabilistic failure scenarios – groynes, toe defences, cliffs, etc.) in an efficient and transparent manner. Another challenge will be to extend the current RASP type models to enable risk attribution and hence the identification of investment priorities at a regional scale.

Hierarchical planning tools

Hierarchical planning is well established at the coast. However, the use and reuse of data throughout the tools that support these plans is not. For example, data on beach performance, fragility, etc. should be reused in a coherent/consistent manner from a national RACE analysis to local asset management plan. This scoping study has started this rationalisation, but significant further progress is required.

Table 7.1 reflects the uncertainty with which existing datasets, science knowledge and analysis tools can fully represent coastal system behaviour at all such hierarchical levels. One task should be to complete such a gap analysis as thoroughly as possible (see also the discussion in Section 7.1.5 and Appendix 4).

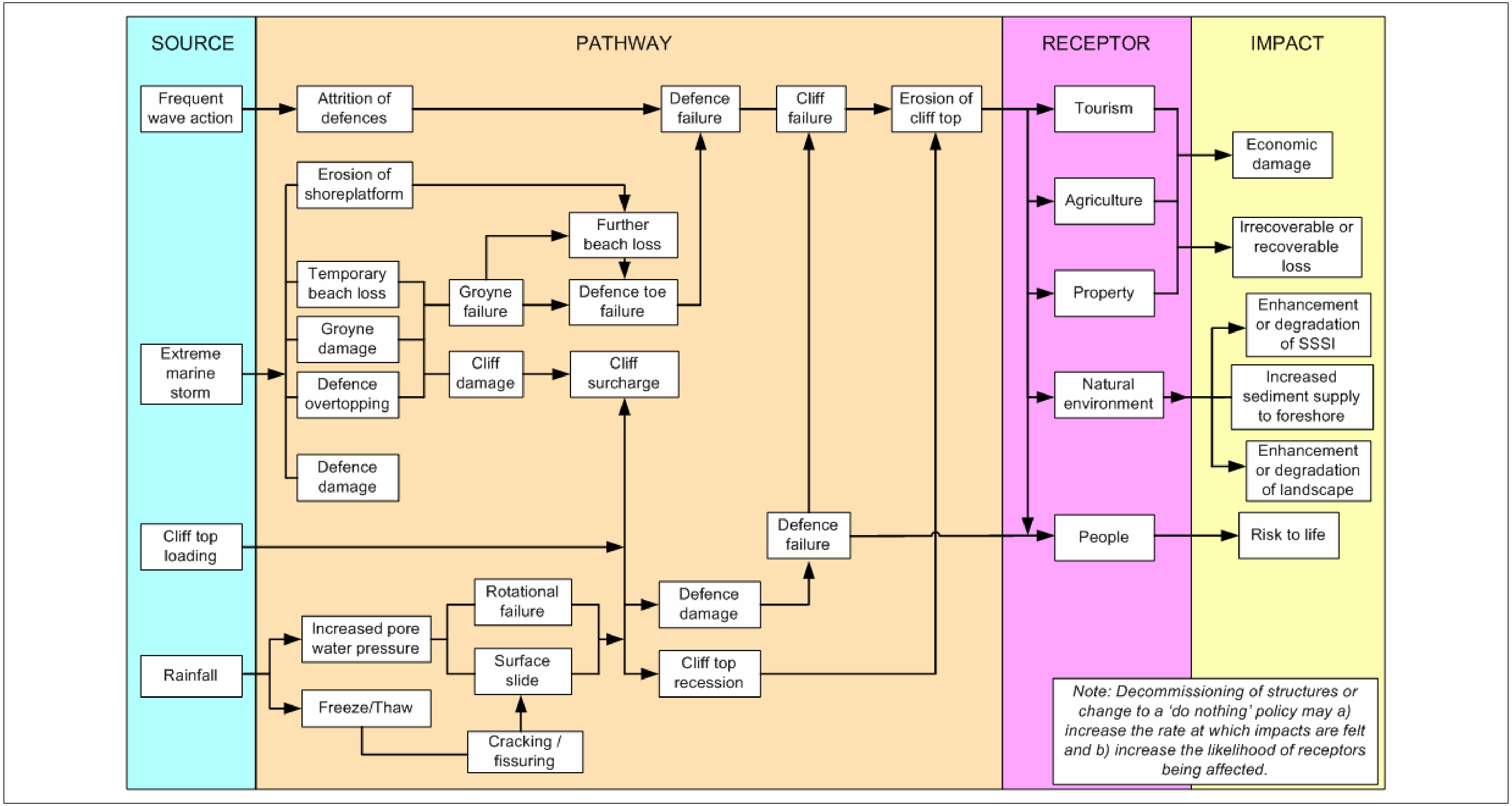

Figure 7.3 A simplified process flow chart (note significant interaction exists that will also need to be captured).

Table 7.1 Coverage and gap analysis of data collection, research and analysis of the coastal S-P-R system for asset management[1].

Description	Tools/data	Data holdings, monitoring, research or developments*	Outstanding*
Source	Joint probability (waves and water levels)	WaveNet, BODC, coastal observatories and strategic coastal monitoring programmes	
		GTI-SEAMaT (?) SANDS (?)	
	Rainfall/groundwater	MET Office (?)	
Pathway	Coastal defences	PAMS, FLOODsite (T4), EUROtop, NFCDD, SANDS	*Longshore connectivity sediment flux effects on performance
	Shore platforms	Lowering of beaches in front of coastal defence structures (FD1927) (?)	
		Characterisation and prediction of large-scale, long-term change of coastal geomorphological behaviours (SC060074) (?)	
	Beaches Dunes Saltmarshes	Lowering of beaches in front of coastal defence structures (FD1927) Characterisation and prediction of large-scale, long-term change of coastal geo-morphological behaviours (SC060074) SANDS GTI-SEAMaT Coastal observatories and ABMS	*Assessment of condition and performance of beaches and control structures *Performance analysis and condition assessment of dune systems and saltmarshes
	Cliffs	RACE, CliffSCAPE	*Cliff failure probability related to rainfall return period events and wave/water level joint probability (JP) return period events.
	Floodplain (topography)	RFSM, MDSF, EUROTAS	
Receptor	People	Risks to People, EUROtop, Social Deprivation Index	(see Section 4)
	Property	NPD, council tax evaluations, Ancient Monuments Record	(see Section 4)
	Environment	Environmental designation datasets [EBM tools (USA)]	(see Section 5)

Notes [1] Those developments that would benefit or be supported well by case studies are marked by an asterisk.

BODC = British Oceanographic Centre; EUROtop = European Overtopping Manual; RFSM = Rapid Flood Spreading Model

Priorities for development

The priorities for development are:

- understanding the importance of sequence on beach behaviour;
- better understanding of the performance and risk from natural features such as the collapse of cliffs, the breaching of dunes and the erosion of saltmarshes;
- reaching consensus on the representation of coastal system behaviour (including estuaries);
- improvement in the technical understanding of beach response;
- improvement in the understanding of how groynes behave under <u>all</u> conditions (type, deterioration, alignment);
- improvements in the understanding of structures such as sea walls in a load dependent way;
- development of fragility curves for coastal asset types where these are not currently available;
- include deterioration and time dependency in the approach.

7.1.4 Inspection and assessment of asset condition

The challenge

Without full understanding of coastal system behaviour, the task of inspection and assessment of coastal flood defence and erosion protection assets – including and especially natural landforms such as sand dunes, beaches and saltmarshes – remains a difficult issue. At present, many practitioners do not regard these as assets in the engineering sense (except perhaps where these are known to be critical and have a history of failure) and, in any case, do not feel they have the training and knowledge to undertake such assessments. This is unsurprising as there is limited guidance on such issues available, and what there is, is not communicated or included in the training of inspectors.

Scoping the future approach

Some steps have been taken to try to address this issue through the revision of the Environment Agency's Condition Inspection Manual with the introduction of performance-based terms where possible. However, the guidance remains tentative and vague and does not address/include coast protection assets specifically. A focused effort on the improvement of understanding and identification of performance features for such assets is required, together with subsequent testing and work-up of guidance and tools.

Further or second level assessment including monitoring is also an issue for some practitioners; many are unsure of the type of assessment and the level of detail of data collection they should be undertaking. This is linked to a lack of guidance on the appropriate methods and technical systems available to them (e.g. LiDAR,[38] laser scanning, intrusive sampling, etc.). The Channel Coastal Observatory's current initiative to provide guidance for regional monitoring programmes is proving popular with local authorities and coastal groups (see http://www.channelcoast.org/reports/ [Accessed 09/12/09]); any future developments by the Environment Agency should take account of this and provide consistency with CCO guidance.

Priorities for development

- Develop best practice guidance for the inspection and assessment of coastal flood defence and erosion protection assets.
- Produce guidance on the development of performance specifications.
- Establish data requirements for erosion protection structures and natural defences.
- Provide clear guidance to Environment Agency coastal staff on the interaction and communication with external partners in regard to the planning of inspections, monitoring and assessment of coastal assets.
- Investigate causes of asset deterioration in a quantifiable way while recognising uncertainty.
- Ensure consistency with CIRIA's *Beach Management Manual*.

7.1.5 Common and improved databases

The challenge

There are particular issues regarding the storage, manipulation and sharing of data. The parameters included and how they are assessed[39] may be different between authorities and different software is used. The Environment Agency's NFCDD system has gone some way to resolving this problem for flood and coastal defence assets, providing a standardised database with defined parameters; however, historically local authorities have not seen the benefit of uploading their data to it. This situation has led to a patchy coverage of coastal data in disparate systems and often in different formats; defence data improvements are currently being considered (see Section 4.1.2).

Improvements in the asset inspections and assessments will naturally result in improvements in the completeness of datasets, but a standardised method and software for storage will enable these advantages to be fully realised. The system would need to be appropriate in terms of:

- the parameters entered;
- the accessibility of the database to all parties;
- the data format for further interpretation or manipulation.

[38] Light distance and ranging
[39] The latter point is discussed in Section 7.1.4.

These discrepancies have made an integrated methodology between interested bodies difficult, preventing a standardised approach. Data sharing is both effective in terms of time and cost, results in better asset management and helps in the development of good working relationships between bodies such as local authorities and the Environment Agency.

If it were to be developed, any approach such as this will require a review of the data types and quality required to support it; such a review was undertaken for the PAMS study (Defra/Environment Agency 2009a). By way of example, the data requirements for PAMS are tabulated in Appendix 5. Any future developments will also need to consider:

- the new Asset Management IT system currently being developed by the Environment Agency;
- existing NCERM arrangements;
- the needs of local authorities.

Scoping the future approach

The Channel Coastal Observatory regional monitoring initiative should be consulted for further guidance on this issue and CCO experience in storing and disseminating large quantities of data utilised. Coastal fora/groups should be consulted on any scoping of the issues which should include data format standardisation, data fields, future planning, etc. There are related and overlapping issues with those discussed in Section 7.1.3 and should be considered jointly in the forward look.

Priorities for development

- Develop standardised methods in association with improved asset inspection and assessment.
- Consult with other operating authorities on data and knowledge sharing, and partner/joint working.
- Develop a protocol for data standardisation, storage and access (including a policy on data sharing)

Full operational implementation of these elements would take time to realise and there are a suite of R&D options that require undertaking to address user needs. However, it would be possible to take some measured steps forward in asset management in the shorter term through a number of key improvements to present practice. These improvements would support both present day analysis and decision-making, as well as improve the development of the framework over a longer time frame.

7.2 Summary of potential improvements and further research

Through desk study review and consultation with practitioners, the project team has identified a number of potential improvements and research initiatives that would need to be addressed to enhance existing capability to develop the approach described above.

These initiatives/improvements are listed in two tables:

- according to their contribution to supporting the proposed framework and underpinning the development of a functional methodology for a performance and risk-based approach to coastal asset management (Table 7.3);
- as supporting tools and guidance to managers/practitioners (Table 7.4). This list could either be developed individually or as part products (where appropriate) of related work listed in Table 7.3.

Not all these improvements can (or should) be attempted congruently as there are many dependencies. Each development proposal is marked with:

- a priority score in terms of the perceived importance to delivery of the framework;
- a rank in terms of perceived importance to the FRM industry as a whole.

The components have also been allocated 'Low', 'Moderate' or 'High' in the range of indicative costs. The categories for the priority scoring and indicative costs are shown in Table 7.2.

Table 7.2 Categories for priority scoring and indicative costs.

Item	Categories
Framework priority score	• High priority (which is in turn ranked from 1 to 10) • Moderate priority • Low priority
FRM industry priority score	• High priority • Moderate priority • Low priority
Indicative cost	• Low (<£50,000) • Moderate (£50,000–100,000) • High (>£100,000)

Dependency relationships are also shown in Tables 7.3 and 7.4 where the commencement of work on one development relies on the completion/delivery of one or more others. Those developments which would benefit or be supported well by case studies are marked with asterisk. The time frames are estimated lengths required for concerted research programmes in the case of science R&D work; for Table 7.4, this refers to estimated durations of the research components.

Table 7.5 shows the research components grouped into logically related projects or initiatives. These have been entitled:

- Developments for decision-making and operational support
- Performance and fragility research and development
- Medium term fundamental research and development on modelling system geomorphology
- Medium to long term fundamental (physical) process research
- Short term – low cost data reviews.

The final (right hand) column of Table 7.5 contains a prioritisation based on the perception of the impact of the R&D/information/tool being available on the uncertainty in the decision being supported. For example, there is great uncertainty associated with the future performance of natural landform (flood) defence systems such as dunes and saltmarshes and currently little way of scientifically assessing them to this end. The consequences of a failure of such systems (given sea level rise) could potentially be catastrophic to low lying undefended receptors in areas behind such frontages. This issue has therefore been given a high priority.

If the resulting five projects listed in Table 7.5 are taken forward, it will be necessary to refine the specific project work items listed into a coherent set of project objectives.

7.3 Conclusions and summary recommendations

The consultation and research undertaken during the course of this study has led to a proposed course of further improvements and progressions, some of which would take significantly longer to achieve and implement than others. However this has been accounted for in the proposed programme with necessary and quick-to-implement steps recommended for initial tasks, with less urgent and more complex steps foreseen as longer term requirements. The operation of this would involve a revision of flood and coastal asset management guidance to smooth the introduction of new components. Over the longer term a combination of software, databases, activity procedures, work instructions and training for the responsible authorities would be needed.

Fully implemented, the information delivered to the user could consist of guidance materials, methodologies, tools and a GIS-based framework (as with the tools described in Section 5), which could display analytical results and produce reports. These data will highlight those assets that contribute most to risk and the components of an asset that contribute most to its performance. This information would then contribute significantly to decisions, for instance, to prioritise, to gather further data, or perhaps to inform the consideration of options for intervention.

The project team are keen to ensure that any methodologies developed are of use to practitioners and useable by both Environment Agency staff and local authorities – helping to address the issue of 'us' and 'them' which can develop between the two groups. A standardised method would help to promote good working relationships and allow data sharing to occur more readily.

It is recommended that the Environment Agency Science Technical Advisory Group, together with advisors from the FRM industry and representatives from Coastal Groups, consider the proposals for future developments in this report with a view to facilitating a staged improvement in underpinning science, tool development and coastal asset management practice.

Table 7.3 Proposed programme(s) of future research and development activities to support coastal performance and risk-based asset management.

Item	Framework component	Dependency	Objectives	Benefits	End users	Priority for framework	Priority for FCRM	Time frame	Indicative cost
	# 1 Decision support (asset management tools) Various guidance and tools are required to support coastal asset managers and practitioners in the decision-making process which require designing and proving.								
1	Agreement of coastal risk management risk metrics and weightings	4	To provide consistency in method of appraisal	Greater consistency in decision-making	Industry wide	High	High	Short	Low
2	Development of a method to evaluate the benefits of changes in beach morphology *	5	To devise method by which beaches can be assessed	Informs/justifies asset maintenance decisions	Consultants Managers Practitioners	Low	Medium	Long	Low
3	Improving knowledge on how defence and protection assets will respond to changing forcing conditions (e.g. sea level rise and increased storminess) and to deterioration (including assessment of beach schemes over the last 10 years)	8, 9, 10	To improve understanding of future physical effects on coastal assets	Will support coastal asset management decisions	Consultants Designers Managers	High	High	Med/Long	Moderate
	# 2 Systems analysis tools and techniques (asset management tools) The understanding of some processes and physical responses at the coast still requires more research to enable new analysis tools and techniques to be developed.								
4	Representation of 'do nothing' consequences (for erosion particularly)		To enable the consequences of 'do-nothing' option to be modelled.	Informs/justifies asset maintenance decisions	Consultants Managers Local authority planners	High	High	Short	Low
5	Research to support attribution of erosion risk (benefits) to individual coastal assets or groups of assets (defences, beaches, groynes, saltmarsh) *	6,	To provide a method by which risk can be	Informs/justifies prioritisation/inter vention	Consultants Managers Analysts	High	High	Short	Moderate

Item	Framework component	Dependency	Objectives	Benefits	End users	Priority for framework	Priority for FCRM	Time frame	Indicative cost
			attributed to coastal assets and systems	decisions	Planners				
6	A better understanding of the performance and risk from natural features such as the collapse of cliffs, the breaching of dunes and the erosion of saltmarsh *	12	To establish the nature of the risks and of performance associated with natural coastal defences	Will allow better representation of the behaviour of such frontages in future models	Consultants Managers Planners	High	High	Medium	Moderate
7	Optimisation of intervention	1, 3, 9	To provide guidance on optimising interventions/schemes	Better return on investment in coastal defence/protection	Managers Analysts Planners	Medium	High	Medium	Moderate
8	Understanding of failure mechanisms for sea walls in a load dependent way *		To establish and understand failure mechanisms of sea walls	Better representation of sea wall failure in ultimate limit state equations and reliability analysis	Consultants Engineers	High	Medium	Short	Moderate (?)
9	Sensitivity of asset condition to external forces (deterioration and failure)	8, 10, 16	To establish typical deterioration rates and life expectancy of coastal assets under variable forcing.	Better representation of deterioration and residual life in scenario modelling	Consultants Engineers	Medium	High	Short/Med	Moderate (?)
10	Failure mechanisms and deterioration for different cliff (soil/rock) types and recession prediction *		To broaden the currently limited types of cliff represented in recession prediction	Better representation of different cliff morphologies in predictive models, and greater	Consultants Engineers Analysts Planners Managers	High	Medium	Medium	High

Item	Framework component	Dependency	Objectives	Benefits	End users	Priority for framework	Priority for FCRM	Time frame	Indicative cost
				confidence in applicability of recession prediction by users					
11	Research to support geomorphological modelling developments to include estuarine shorelines as well as open coasts *		To integrate open coast and estuarine geomorphological models	Creation of coastal models that include open coast/estuary sedimentological interactions	Consultants	Medium	Medium	Short/Med	Moderate
12	Modelling the nature of longshore connectivity of sediment flux effects on performance *	13, 14	To understand longshore sediment flux effects and represent them in coastal models	Will enable the inclusion of the effects of longshore sediment transport in beach performance analysis	Consultants Industry wide	Medium	Medium	Medium	Moderate
13	Beach system modelling and prediction of effects of control structures *	11, 14, 16	To understand and model beach systems and the effects of control structures on morphology	Will enable the inclusion of the effects of sediment control structures in beach performance analysis	Consultants Managers Planners Engineers	High	Medium	Med/Long	Moderate
14	Research to resolve problems with modelling of mixed beaches *	16	To understand behaviour of mixed sediment beaches	To enable the representation of mixed sediment beaches in numerical models	Industry wide	Medium	High	Long	High
15	Understanding of beach system performance and effects on toe level at the sea wall *	11, 12, 13	To link the physical process interface	To link intrinsically beach ‘health’ or	Industry wide	High	Medium	Short/Med	Low

Item	Framework component	Dependency	Objectives	Benefits	End users	Priority for framework	Priority for FCRM	Time frame	Indicative cost
			between beach morphology and critical stability of sea walls	condition and reliability of sea walls					
16	Wave processes on permeable/barrier beaches		To establish the impacts of wave processes on, and responses of permeable barrier beaches	Better understanding of how wave processes affect the morphology and performance of barrier beaches.	Industry wide	Low	Medium	Long	High
	# 3 Inspection & assessment of asset condition Improved guidance on the visual inspection and secondary assessment of coastal defence assets (natural and man-made) is required for practitioners. Appropriate methods need to be designed and tested.								
17	Improving baseline data through inspection and condition assessment of defences (particularly 'natural' defences) that more explicitly recognises the relationship between the condition and the performance of an asset	6, 18	To establish inspection 'performance' criteria by which natural defence assets can be assessed	To enable a consistent approach to the condition assessment of natural defence assets.	Consultants Managers Inspectors	High	Medium	Short	High
18	Improved visual (and second level) condition assessment methodology of beaches, dunes and saltmarsh *	6	To develop improved visual and second level asset inspection methods and guidance for natural defences	To enable a consistent approach to the condition assessment of natural defence assets.	Consultants Managers Inspectors	High	High	Long	Moderate
19	Improved visual (and second level) condition assessment methodology of control structures (including sea walls, groynes and offshore breakwaters and monitoring during extreme events) *	8	To develop improved visual and second level asset inspection methods and guidance for built	To enable a consistent approach to the condition assessment of built defences &	Consultants Managers Engineers Inspectors	High	Medium	Short/Med	Low

Item	Framework component	Dependency	Objectives	Benefits	End users	Priority for framework	Priority for FCRM	Time frame	Indicative cost
			defences and control structures	control structures					
	# 4 Common and improved databases A common protocol for data collection, retention and storage is required for erosion protection assets to ensure consistency on minimum levels and types of data holdings across competent authorities.								
20	Review of data requirements for erosion protection structures.	1, 3, 8, 9, 19	To ensure all data requirements for the framework are captured and listed	Listed data requirements are important for the development of repositories and for guidance to responsible authorities.	Consultants Managers Database designers Coastal Groups	High	Medium	Short	Low
21	Review of data requirements for erosion/flood protection performance of natural defences.	1, 3, 6, 12, 13	To ensure all data requirements for the framework are captured and listed	Listed data requirements are important for the development of repositories and for guidance to responsible authorities.	Consultants Managers Database designers Coastal Groups	High	High	Short	Low

Notes

[1] The components are colour-coded to indicate projects that could logically be placed together under one research title/initiative. However within these there may be a mixture of estimated timeframes and priorities.
[2] Those developments that would benefit from or be supported well by case studies are marked with an asterisk.
[3] Dependency relationships are also shown where the commencement of work on one development is reliant on the completion/delivery of one or more others.
[4] The time frames are estimated lengths required for concerted research programmes in the case of science R&D work.
[5] Priority scores and indicative cost ranges are given in Table 7.2.

Table 7.4 Proposed supporting tools and guidance to support coastal asset managers/practitioners.

	Supporting guidance for managers/practitioners	Dependency (on items in Table 7.3)	Objectives	Benefits	End users	Priority for framework	Priority for FCRM	Time frame	Indicative cost
1	Guidance, including good case examples of cross organisational/boundary co-operation to achieve integrated planning of coastal works, maintenance and data collection, etc. *			Improved guidance	All practitioners	Low	Medium	Short	Moderate
2	Best practice guide on coastal monitoring and data collection, storage and analysis *	1, 3, 6, 12, 13, 20, 21		Improved guidance	Managers Inspectors	High	High	Short	Moderate
3	Best practice/guidance on developing life-cycle asset management plans *	1,3,9,7		Improved guidance	Managers	Low	High	Short	Moderate
4	Best practice guidance (with exemplars) on planning and for coastal community consultation *			Improved guidance	Managers Planners	Low	Medium	Medium	Moderate
5	Review of data capture systems – including GPS systems, laser scanning, fixed point photography – for comparative monitoring/trend analysis *	17, 18, 19		Improved guidance	Managers Inspectors	Medium	High	Medium	Moderate
6	Best practice/guidance on recording of maintenance costs *			Improved guidance	Managers Engineers	Low	Medium	Medium	Low
7	Guidance on appropriate use of tools/models *			Improved guidance	Managers Analysts	High	High	Medium	Moderate
8	Development of a protocol for calibration/validation of models			Improved guidance	Managers Analysts	Medium	High	Medium	Low
9	How to build flexibility (possibility for upgrading or removal) into design to allow for future changes *			Improved guidance	Managers Planners Designers	Low	High	Medium	Moderate
10	Programme of hindcasted numerical modelling of beaches where actual loading and response data are available, using comparison with real data to validate models or identify problems to be solved	14, 16		Improved confidence	Industry wide	Medium	High	Medium /Long	High

Notes
[1] Those developments that would benefit from or be supported well by case studies are marked with an asterisk.
[2] Dependency relationships are also shown where the commencement of work on one development is reliant on the completion/delivery of one or more others.
[3] The time frames are estimated lengths required for concerted research programmes in the case of science R&D work. Here this refers to estimated project durations.
[4] Priority scores and indicative cost ranges are given in Table 7.2.

Table 7.5 Components grouped by proposed project/initiative including ranking.

Item	Framework component	Dependency	Priority for framework	Priority for FCRM	Time frame	Indicative cost	Top ten ranking of priority
	# 1 Decision and operational support (guides and tools)						
1	Agreement of coastal risk management risk metrics and weightings	4	High	High	Short	Low	3
2	Development of a method to evaluate the benefits of changes in beach morphology *	5	Low	Medium	Long	Low	
4	Representation of 'do nothing' consequences (for erosion particularly)		High	High	Short	Low	
5	Research to support attribution of erosion risk (benefits) to individual coastal assets or groups of assets (defences, beaches, groynes, saltmarsh) *	6,	High	High	Short	Moderate	4
6	Better understanding of the performance and risk from natural features such as the collapse of cliffs, the breaching of dunes and the erosion of saltmarsh *	12	High	High	Medium	Moderate	2
7	Optimisation of intervention	1, 3, 9	Medium	High	Medium	Moderate	
17	Improving baseline data through inspection and condition assessment of defences (particularly 'natural' defences) that more explicitly recognises the relationship between the condition and the performance of an asset	6, 18	High	Medium	Short	High	10
18	Improved visual (and second level) condition assessment methodology of beaches, dunes and saltmarsh *	6	High	High	Long	Moderate	5
	# 2 Performance of coastal assets (natural and man-made)						
3	Improving knowledge on how defence and protection assets will respond to changing forcing conditions such as sea level rise and increased storminess, and to deterioration (including assessment of beach schemes over the last 10 years)	8, 9, 10	High	High	Med/Long	Moderate	9
8	Understanding of failure mechanisms for sea walls in a load dependent way *		High	Medium	Short	Moderate (?)	
9	Sensitivity of asset condition to external forces (deterioration and failure)	8, 10, 16	Medium	High	Short/Med	Moderate (?)	
10	Failure mechanisms and deterioration for different cliff (soil/rock) types and recession prediction *		High	Medium	Medium	High	6
19	Improved visual (and second level) condition assessment methodology of control structures (including sea walls, groynes and offshore breakwaters and monitoring during extreme events) *	8	High	Medium	Short/Med	Low	7

Item	Framework component	Dependency	Priority for framework	Priority for FCRM	Time frame	Indicative cost	Top ten ranking of priority
	# 3 Medium term R+D – modelling system geomorphology						
11	Research to support geomorphological modelling developments to include estuarine shorelines as well as open coasts *		Medium	Medium	Short/Med	Moderate	
12	Modelling the nature of longshore connectivity of sediment flux effects on performance *	13, 14	Medium	Medium	Medium	Moderate	
13	Beach system modelling and prediction of effects of control structures *	11, 14, 16	High	Medium	Med/Long	Moderate	1
14	Research to resolve problems with modelling of mixed beaches *	16	Medium	High	Long	High	
	# 4 Medium to long term process research						
15	Understanding of beach system performance and affects on toe level at the sea wall *	11, 12, 13	High	Medium	Short/Med	Low	8
16	Performance of permeable/barrier beaches – during events and recoverability between events		Low	Medium	Long	High	
	# 5 Short term/low cost data reviews						
20	Review of data requirements for erosion protection structures.	1, 3, 8, 9, 19	High	Medium	Short	Low	
21	Review of data requirements for erosion/flood protection performance of natural defences.	1, 3, 6, 12, 13	High	High	Short	Low	

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List of abbreviations

ABMS	Annual Beach Monitoring Survey
ANN	artificial neural network
ASMITA	Aggregated Scale Morphological Interaction between a Tidal inlet and the Adjacent coast [model]
BEACHMaT	Beach Management Tool
BODC	British Oceanographic Data Centre
CCO	Channel Coastal Observatory
CDAMD	Coastal Defence Asset Management Database
CEFAS	Centre for Environment, Fisheries and Aquaculture Science
CEH	Centre for Ecology and Hydrology
CERMS	Cell 11 Regional Monitoring Strategy
CFMP	Catchment Flood Management Plan
CG	Condition Grade [visually assessed index of asset condition]
CIRIA	Construction Industry Research and Information Association
CTD	conductivity–temperature–density [gauge]
Defra	Department for Environment, Food and Rural Affairs
DESIMA	Decision Support for Integrated Coastal Zone Management
DPD	development plan document
DSS	decision support system
DTM	Digital Terrain Model
EBM	Ecosystem-based Management [tool]
EC	European Commission
EPSRC	Engineering and Physical Sciences Research Council
EU	European Union
EUROTAS	European River Flood Occurrence and Total Risk Assessment System
EUROtop	European Overtopping Manual
FCDPAG	Flood and Coastal Defence Project Appraisal Guidance [Defra]
FCRM	flood and coastal risk management
FHRC	Flood Hazard Research Centre [University of Middlesex]
FRM	flood risk management
FRMRC	Flood Risk Management Research Consortium
GIS	geographical information system

GPS	global positioning system
GTI-SEAMaT	Geographical Temporal Interface – Shoreline Environment Analysis and Management Tool
HLCE	Historic Losses to Coastal Erosion
JNCC	Joint Nature Conservation Council
JP	joint probability
LBAP	Local Biodiversity Action Plan
LDD	Local Development Document
LDF	Local Development Framework
LDS	Local Development Scheme
LiDAR	light distance and ranging
LPA	local planning authority
MAR	Modelling and Risk [Environment Agency theme]
MAFF	Ministry of Agriculture, Fisheries and Food
MCA	multi-criteria analysis
MCM	Multi-Coloured Manual [Flood Hazard Research Centre tables]
MDSF	Modelling and Decision Support Framework
MSF	Measured Step Forward
NaFRA	National Flood Risk Appraisal
NCERM	National Coastal Erosion Risk Mapping
NCPMS	National Capital Management Programme Service
NEAS	National Environmental Assessment Service
NFCDD	National Flood and Coastal Defence Database
NPD	National Property Dataset
NNR	National Nature Reserve
NRD	National Receptor Database
OM	Outcome Measure
OS	Ordnance Survey
PAMS	Performance-based Asset Management System
PCPA	Planning and Compulsory Purchase Act 2004
pdf	probability density function
PPG	Planning Policy Guidance
PPS	Planning Policy Statement
PSD	Particle Size Distribution
PV	Present [day] Value

RACE	Risk Assessment for Coastal Erosion
RAMFLOOD	Risk Assessment and Management of Floods
RASP	Risk Assessment for System Planning [HLM+ refers to the high level method of RASP]
RPB	Regional Planning Body
RFSM	Rapid Flood Spreading Model
RSS	Regional Spatial Strategy
RVCE	Receptors Vulnerable to Coastal Erosion
S-P-R	source–pathway–receptor [framework]
SAC	Special Area of Conservation
SAM	Sustainable Asset Management [Environment Agency theme]
SAMP	System Asset Management Plan
SANDS	Shoreline and Nearshore Data System
SAR	synthetic aperture radar
SCAPE	Soft Cliff and Platform Erosion [model]
SDS	Spatial Development Strategy
SEPA	Scottish Environment Protection Agency
SLR	Sea level rise
SMP	Shoreline Management Plan
SoP	Standard of Protection
SPA	Special Protection Area
SPD	Supplementary Planning Document
SPRC	Source–Pathway–Receptor–Consequence [model]
SSSI	Site of Special Scientific Interest
TOID	topographic identifier
UKCIP	United Kingdom Climate Impacts Programme
WAG	Welsh Assembly Government

Appendix 1 Project links

Completed (or near completed) projects

- **NaFRA 2008** supported by RASP High Level Method *plus* (HLM+) – will provide basic flood probability and impact data for England and Wales.
- **Risk, performance and uncertainty in flood and coastal defence – a review** (project FD2302) (Sayers et al. 2003).
- **MDSF2** (development of the Modelling Decision Support Framework) – a tool for use by the Environment Agency and consultants in the development of Catchment Flood Management Plans, Shoreline Management Plans and other studies. This phase is taking on board comments from the recent review of MDSF and will include RASP methodologies.
- **Performance and reliability of flood and coastal defence structures.** This project took a detailed look at the concepts of defence fragility (i.e. the relationship between load and failure) developed in the RASP research project. This provides a sound basis for future improvements in understanding of the reliability of many flood and coastal defence assets.
- **Thames Estuary 2100** supported PhD (supervised by HR Wallingford and Bristol University) to investigate the theoretical aspects of linking time-dependent deterioration processes within the RASP type risk analysis methods.
- **FLOODsite** – a major EC research consortium led by HR Wallingford to investigate a wide spectrum of issues including defence performance.
- **Reducing the risk of embankment failure under extreme conditions** (Defra/Environment Agency, 2003). This report presents an overview of embankment performance issues and guidance on good practice for dealing with many aspects of embankment design, operation and management. The recommendations in the part 2 report to this study (‘Framework for Action’) should also be considered.
- **Performance–based asset management system (PAMS) for flood defence.** This project developed asset management tools and techniques for fluvial (and some coastal) flood management. Suitable and appropriate approaches will be taken forward and developed for coastal assets to complement those developed under the PAMS project.
- **Risk Assessment for Coastal Erosion (RACE)** (FD2324) and **National Coastal Erosion Risk Mapping (NCERM).** These two projects developed and implemented a method for coastal erosion risk mapping for national level appraisal. Suitable and appropriate approaches will be taken forward and developed for coastal assets at the regional/local scale to complement those developed under RACE/NCERM.
- **Flood Risk Management Research Consortium (FRMRC)** Phase 1 and in particular, Research Priority Area 4 ‘Infrastructure’ led by the Engineering and Physical Sciences Research Council (EPSRC).

- Significant advances were made by researchers at Nottingham University through Work Package 4.3 Asset Condition Assessment Methodologies. This work supported an update of operational guidance through a revision of the condition assessment manual and is actively influencing the direction of future R&D on asset inspection.
- The research by HR Wallingford into rapid mega-scale coastal simulations under Work Package 4.2 has shown the practicality of linking coastal morphological models with flood risk assessment (GTI-SEAMaT) – a research strand that is being taken forward in FRMRC Phase 2.
- Work within WP 4.4 on asset reliability also received widespread practitioner and researcher interest. A prototype reliability tool (for flood defence assets) was developed by HR Wallingford in collaboration with international academic partners from The Netherlands and Germany. This work has been further extended through related EPSRC network funding.

- **Influence of permeability on the performance of shingle and mixed beaches** (FD1923). This study addressed issues such as:
  - cliffing;
  - the influence of permeability on the performance of recharged beaches;
  - sediment resources and their management;
  - efficiency of sediment placement techniques;
  - cost-effectiveness of frequent and focussed recycling operations.

  The technical report (She et al. 2007) includes an extensive review of the current state of understanding of mixed beach processes, the method of prediction of the cliffing problem, and preliminary advice on good practices in relation to beach recharge programmes.
- **Understanding barrier beaches** (FD1924) (Stripling et al. 2008). This research project collated and summarised the state-of-the-art understanding of barrier beaches both in terms of relevant processes and management practices. Barrier beaches have been defined, their geomorphological classification reviewed, and current understanding of structural and morphological characteristics has been outlined. The study highlighted the gulf in understanding between those processes occurring on sandy coastlines and those occurring on coarse and mixed sediment coastlines. A suggested framework for further research was presented which is expected to:
  - redress the shortage of tools available to coastal managers who are charged with managing barrier beaches;
  - provide guidance on the use of those tools and management of the beaches.
- **Beach lowering in front of coastal structures** (FD1916) (Sutherland et al. 2003). This reviewed the present state of knowledge on the lowering of non-cohesive sediment beaches in front of coastal defence structures. It concentrated mainly on toe scour – the short-term lowering of beach level close in front of a coastal defence structure.

- **Understanding and predicting beach morphological change processes associated with the erosion of cohesive foreshores** (FD1926) (Royal Haskoning et al. 2007). This scoping report provides a detailed appraisal of previous research in the field of cohesive shore platform weathering and erosion, and examines how these processes may affect the sustainability of the adjoining beaches, the evolution of any backing cliffs, and their influence on sediment budgets. The investigation was not restricted to the foreshore alone, but also covered the subtidal zone.

- **Development and dissemination of information on coastal, fluvial and estuary extremes** (SC060064). This project aimed to enhance and make available information on extreme sea levels (including surge heights), develop a procedure for collation and analyses of the information, populate an extreme event database (coastal and estuarial, in-land flooding and coastal erosion), and develop and disseminate best practice guidance.

- **Sand dune processes and management for flood and coastal defence.** (FD1302) (Pye et al. 2007). This report consists of five parts.

  - Part 1 provides an overview of the project, the main issues addressed, the approaches used and the main conclusions.
  - Part 2 presents a review of sand dune processes and the significance of coastal dunes for coastal flood risk management.
  - Part 3 describes the methods used to obtain data and presents brief descriptions, location maps and database summaries for each dune site.
  - Part 4 reviews available methods to manage and modify coastal dunes.
  - Part 5 discusses the problems and management options at the five example sites (Sefton Coast, Spurn Peninsula, Brancaster Bay, Studland and Kenfig Burrows).

- **Improving data and knowledge management for effective integrated flood and coastal erosion risk management. A guide to good practice.** (FD2323/TR5) (Robinson et al. 2007). Defra commissioned project FD2323 to develop a strategic approach to FCRM data management to ensure it feeds effectively into knowledge about the business and the delivery of FCRM objectives. The project involved the development of a framework for improving data and knowledge management through a move into a more objective-led approach to data management. A number of techniques and tools were developed within the project to support the culture change required to deliver the objective-led approach. The project was carried out within five work packages. Technical Report FD2323/TR5 is the principal output of the project, capturing and presenting its main outcomes in form of guidance to support a more effective management of data and knowledge within FCRM. The guidance aims to support data and knowledge management, through:

  - developing a framework for objective-led data management;
  - establishing links between data and business objectives;
  - enabling data provenance;
  - characterising data consistency, quality and appropriateness;
  - providing a framework for data appraisal;

- focussing on data users and suppliers, and their interactions;
- improving data access and exchange

- **South West Defence Survey (various contracts including Thurlestone to Hinkley Point Coastal Defence Surveys).** Between October 2008 and April 2009, the man-made assets at all major sites throughout the south-west (Durlston Head to Burnham-on-Sea) were surveyed by Halcrow in order to update the information currently stored in NFCDD. Data were collected for roughly 40 fields deemed to be essential to the running of the RACE model and to feed into the next SMPs. The survey covered the area between Durlston Head (south Dorset) and Burnham-upon-Sea (north Somerset). Atkins Ltd has been involved in a similar data collection exercise between Burnham-upon-Sea and Lavernock Point (south Wales). The data have been processed and were submitted to the Environment Agency in early May 2009; at present they have not been uploaded to NFCDD, but have fed directly into the SMP process and are currently being used to update defence data in the RACE model.

Ongoing/starting projects

- **FRMRC 2.** FRMRC 1 research has been taken forward into FRMRC 2. Related titles under Work Package 6 'Infrastructure Management' include:
  - 6.2 Performance Base Inspection of Flood Defence Infrastructure Integrating Visual Inspection and Quantitative Survey Measurements
  - 6.3 Broad Scale Integration of Coastal Flood and Erosion Risk Models
  - 6.4 Breach Size – Rapid Methods of Assessment
  - 6.5 Next Generation Tools to Support Robust and Sustainable Asset Management.
- **Beach Management Manual**. This project led by CIRIA (Construction Industry Research and Information Association) is revising the original Beach Management Manual to incorporate new and improved guidance for beach management practitioners.
- **Characterisation and prediction of large-scale, long-term change of coastal geomorphological behaviours** (SC060074) (Whitehouse et al. 2009). In order to provide generic tools that can be applied throughout the UK, it is necessary to understand and be able to predict the changes that occur within each geomorphological unit and the exchanges between each unit. This study (funded by the Environment Agency MAR theme) focuses on the development of a conceptual model with the ultimate aim of developing practical modelling and analysis tools that will allow scientists and engineers to predict the mid- to long-term morphology of coastlines, enabling the impacts of coastal management options to be examined.
- **The toe of coastal defence structures – a management guide** (SC070056). The Environment Agency (SAM theme) has commissioned a guide for practitioners aimed specifically at the management of the toe of coastal structures incorporating improved methods for predicting beach levels and scour at the beach/structure interface (to include both cohesive and non-cohesive sediments).

- **Assessment and measurement of asset deterioration including whole life costing** (SC060078). The main components of this research project include:
  - the development of conceptual frameworks and quantified or quantifiable models of deterioration processes;
  - an empirically based monitoring programme to collect data on deterioration and whole-life costing of critical elements/materials for key asset types;
  - the development of a method of whole life costing for a range of asset types representative of those held by the Environment Agency and other operating authorities, including generation of realistic cost models and data;
  - recommendations for modifying or adapting NFCDD to make implementation of the above feasible.
- **Larger-scale morphodynamic impacts of segmented shore–parallel breakwaters on coasts and beaches (LEACOAST2).** This EPSRC research project studied sediment transport around detached shore parallel breakwaters in the UK (LEACOAST2 2005). The project was undertaken to improve guidance on the design of nearshore breakwaters, including generic design guidance in macro-tidal environments. The final report is due to be published in 2009. The project aims to provide valuable datasets, useful tools for future management and improvements to current design guidelines for future coastal protection works.
- **Quantifying saltmarsh vegetation and its effect on wave height dissipation.** The quantification of wave attenuation over intertidal surfaces is critical to the development of accurate assessments of their natural sea defence value to be made and incorporated into sea defence schemes. The aim of this research is to:
  - evaluated the use of a digital photographic method for the quantification of marsh vegetation density;
  - investigate the relative roles played by hydrodynamic controls and vegetation density/type in causing the attenuation of incident waves over a macro-tidal saltmarsh.
- **Historical Losses to Coastal Erosion (HLCE).** This two-phase study aims to ‘ground truth’ and calibrate the results of National Coastal Erosion Mapping (NCERM). The first phase aims to provide information on the historical losses to erosion in England and Wales over the past ~100 years. This will involve a significant digest of material that will raise the public’s knowledge of the erosion risk faced in the past. The second phase is a calibration exercise that aims to increase public awareness of the range of understanding that can be captured, and lead to increased confidence in the project within the scientific and engineering communities. The exercise will focus on eight sites that will test the full range of erosion mechanisms modelled within NCERM. The methodology employed will be applied to the historical (approximately 100 years ago) position of the cliff line and be used to estimate the present day at risk zone assuming historical management techniques are employed (where applicable). This exercise will provide an excellent means of putting the results of the future erosion predictions into context and will raise the public’s awareness of what is

meant by a zone at risk of future coastal erosion as well as increasing their confidence in the results.

- **Receptors Vulnerable to Coastal Erosion (RVCE).** This project aims to quantify future erosion risk. A three-phase approach has been adopted whereby first the receptors were defined and potential data sources were identified; where possible, this drew on the work conducted for the NRD. The second phase proposes methods for quantification and will primarily draw on the findings of NCERM and the receptor data sources. The third phase will undertake the quantification.

- **National Receptor Database (NRD).** This project aims to collate/incorporate details of risk receptors for various purposes, including flooding and coastal erosion, for use both within and outside the Environment Agency. The data will aim to meet the information requirements of a range of FCRM practitioners. To date two reports have been drafted, namely a 'Needs Analysis' and a 'Technical Evaluation'. The former determines what the user requirements are, the necessary content of the database to support these requirements, and the extent to which these requirements can be met by currently available information, while the later recommends options for the operational implementation of the database.

- **NFCDD data improvement work – Phase 1.** A study has examined the quality of the data currently stored in NFCDD on a national level. The resulting report aims to provide an overall summary of the useable data which has been provided to the NCERM project by local authorities through NFCDD (based on a download of the national database in March 2009) and/or bespoke information sources. The analyses conducted for this report will also investigate the work needed to bring NFCDD to the required standard in areas of erodible frontage in order to run the RACE model to its full potential and to feed into SMP process.

Appendix 2 DSS review criteria

From *Review of existing UK developed DSS tools*, FLOODsite Task 18, Report T18-06-11 (McGathey et al. 2006)

Category	Sub-category	Review Description
1. Content	1.1 Risk system	This sub-category considers the degree to which the DSS tool characterises the risk system in terms of the SPRC model. Ideally, the tool would include a module for each term, e.g. the Pathway module represents flow in the river, over defences and across the floodplain, or cliff recession, whereas the Receptor module concerns itself with elements which may be harmed by flooding or erosion (e.g. people, houses).
	1.2 Measures and instruments	This involves the degree to which the DSS tool enables the user to represent interventions (i.e. measures and instruments) which may form part of an overall integrated risk management strategy. Measures are direct physical interventions (e.g. dike raising) whereas policy instruments are interventions triggering mechanisms which can lead to reducing flood or erosion risk (e.g. improved publicity and education).
	1.3 Scenarios of external change	This involves the degree to which the DSS tool enables the user to represent future scenarios, where a scenario is defined as 'a plausible description of a situation, based on a coherent and internally consistent set of assumptions'. For example, a scenario based on high market growth may be associated with high climate change, high population growth and urbanisation. Different DSS tools may allow for different degrees of complexities, e.g. the number of parameters which may be varied.
	1.4 Spatial and temporal change	Timescales are relevant as the DSS tool is for long-term planning. The tool needs to assess the flood risk through time, which could include evaluating risk at discrete epochs or use of continuous simulation. Similarly, spatial scales are relevant as the DSS tool should ideally be applied at any scale, typically made possible through use of GIS or MapInfo. The aim is to establish the ability of the tool to model these different scale options and to identify any restrictions.
	1.5 Results	This involves assessing the nature of the DSS outputs, e.g. can the user access the Source loadings, Pathway inundation extents for a given system state, Receptor impacts such as environmental, economic and social vulnerability, Consequences such as spatial risk, etc.
2. Data and methods	2.1 Input data	DSS tools are largely data driven, e.g. water levels, ground models, receptor information, etc. The nature and quality of the data are considered.
	2.2 Methods	What methods are incorporated within the DSS to evaluate the SPRC system model from Source loading through to spatial risk? These may include embedded or linked models, data from external analyses, other. The integration method to evaluate the overall risk is essential.
	2.3 Uncertainty	Understanding uncertainty is essential to the decision making process – and thus each DSS tool is considered in terms of what uncertainty methods and/or information it provides. Here, uncertainty is defined as the difference between assessment of some factor and its 'true' value.
3. Presentation	3.1 Target end-users	This establishes which users are being addressed and their decisions. DSS tools may assist with decisions on a number of levels e.g. strategy vs. local planning or societal vs. professional decisions. Ideally the DSS should operate on all levels and consider the professional context.
	3.2 Visualisation	The decision makers will need to access the results in a useful visual format which is transparent to all, i.e. both experts and non-experts. Note: users have the option of which DSS tool to use so a tool with good visualisation techniques may be favoured.
4. Technology	4.1 Software architecture	The DSS end-to-end process is typically complex, with many routines, methods, models and databases. Thus, the software architecture is critical. This criterion considers modularity, embedded models, interfaces, development environment, coding language and accessibility, etc.
5. Other	5.1 Support	Addresses software support and future development and maintenance, e.g. what level of support was provided? Was it sufficient to ensure the ongoing use? Would the tool have benefited from improved roll-out and support planning? Who has ownership?
	5.1 Application, strengths, weaknesses	Application considers the acceptance of the system and its application in practice. The strengths and weaknesses highlight the key elements from the review as well as any items not explicitly covered.

Notes SPRC = Source–Pathway–Receptor–Consequence

Appendix 3 Supporting literature for analytical tools

RASP

Website: http://www.rasp-project.net/

See also *Risk assessment for flood and coastal defence for strategic planning (RASP)*, R&D Technical Report W5B-030/TR (Defra/Environment Agency 2004a).

The RASP methods enact the basic cross-government framework for environmental risk assessment and risk management as well as addressing the specific needs of flood and erosion risk management. By enacting these frameworks within a generalised hierarchical methodology that combines the *sources* (e.g. the waves and water levels), *pathways* (e.g. the defences) and *receptors* (e.g. the people and property) of risk, RASP provides an important step towards an ability to manage flood risk in a more integrated way.

All tiers of the RASP risk assessment methodologies reflect the data availability and constraints of temporal and spatial scale placed on the analysis.

Each tier of the RASP hierarchy considers the flooding systems where a flooding system is defined by:

- its loading conditions (coastal waves and surge, fluvial flows and water levels);
- its linear natural and man-made flood defences;
- the performance of the linear defences taking account of both overtopping/overflow and breaching of defences that reflects their type and condition;
- the inundation of the floodplain (and propagation of water across the floodplain) following an overtopping or overflow event.

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 (e.g. expected economic damage).

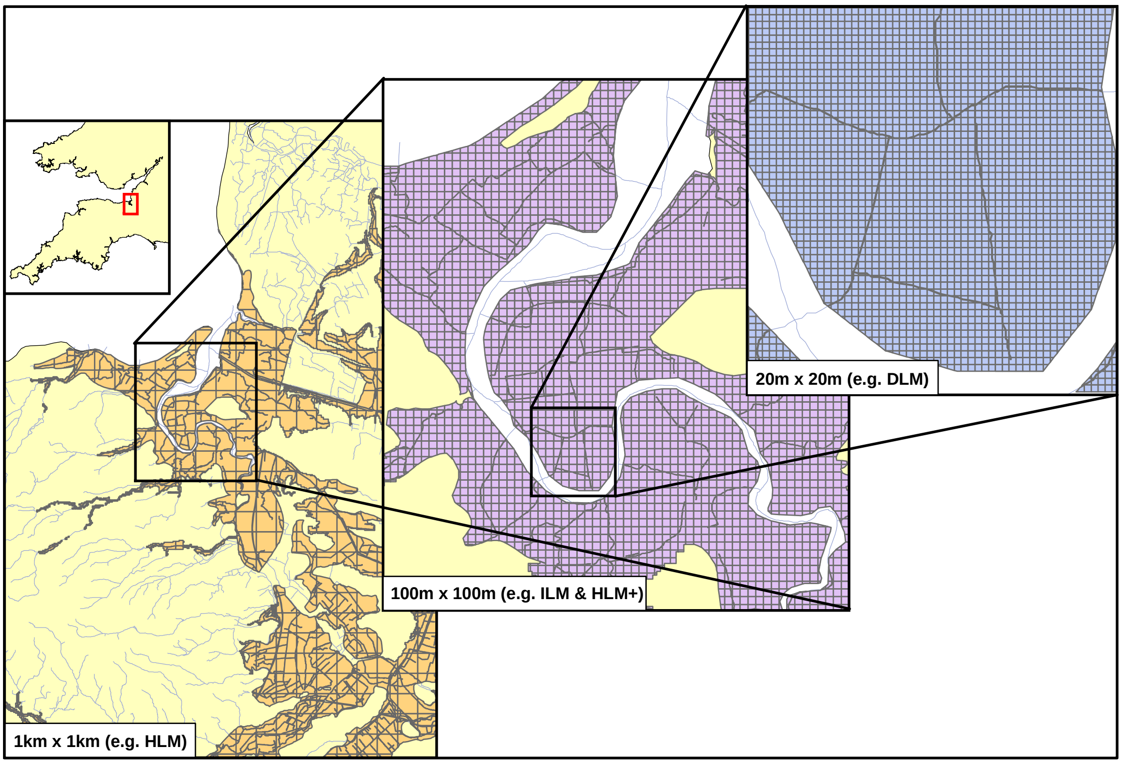
The hierarchical approach enables the results from different tiers to be readily aggregated to regional and national scales.

The RASP methods can be used in developing strategies and policies enabling scenarios of change (e.g. flood frequency, investment in flood defences or floodplain occupancy) to be readily incorporated and analysed.

The utility of the RASP methods has been demonstrated:

- at national scale through National Flood Risk Assessment studies since 2002;
- at a regional scale through various coastal and fluvial case studies.

Over recent years, significant efforts have been made to translate the RASP methods into specific tools to support flood management decisions in practice – mainly 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.



Impact Zones from RASP – increasing resolution with increasing detail of analysis.

KeySHORE

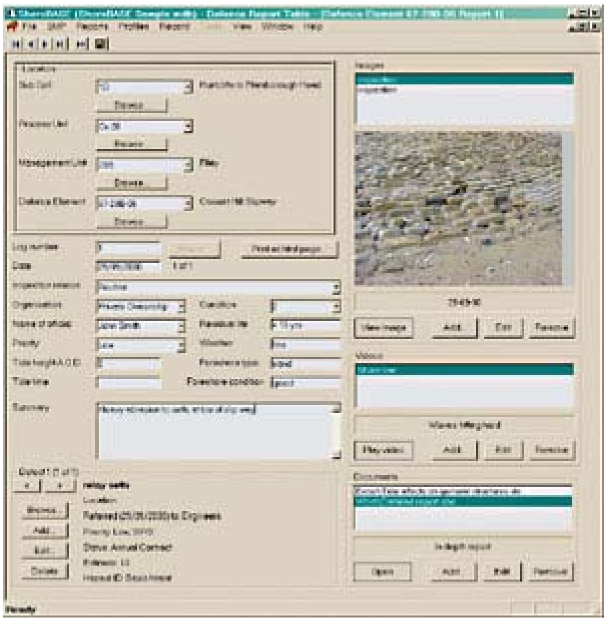
Website: http://www.roundaboutdesign.com/products/keyshore.shtml

KeySHORE is a coastal GIS which combines Autodesk Map, KeyTERRA-FIRMA and ShoreBASE coastal database software. It aims to enable the development of Shoreline Management Plans (SMPs). The tool combines a number of features, including:

- **Input of survey data.** Information from beach profiles, topographic surveys and hydrographic surveys can be input in a variety of formats, including manual entry of profile co-ordinates. Other features (e.g. cliff lines) can be recorded.

- **Beach profiles.** AutoCAD software is used to draw beach profiles. Analysis options include the comparison of historical data to highlight trends in beach profile development and generation of longitudinal sections. As well as traditional profiles, beach data in the form of spot levels can be entered.
- **Ground modelling.** Drawing of contours in AutoCAD is enabled, and volume calculations and diagrams indicating accretion or erosion produced.

Further abilities include mapping software using Autodesk Map to create and edit maps. This is fully linkable with the other tools and databases.



Tyndall Centre Coastal Simulator

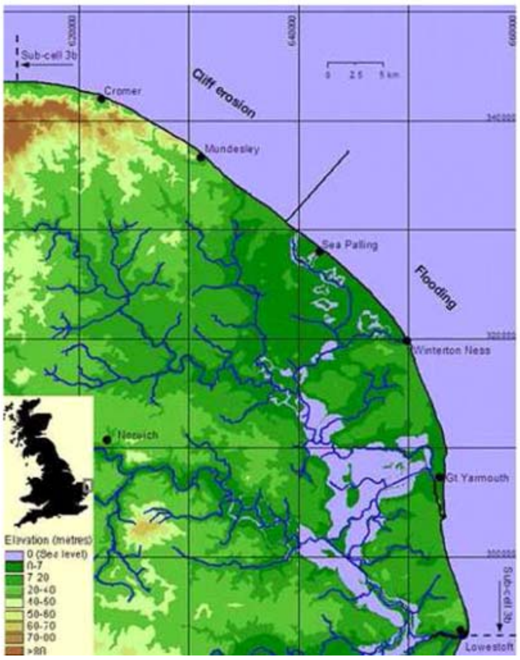
Website: http://www.tyndall.ac.uk/content/tyndall-centre-coastal-simulator

See also *The Tyndall Centre coastal simulator,* Tyndall Centre Briefing Note 18 (Tyndall Centre 2008).

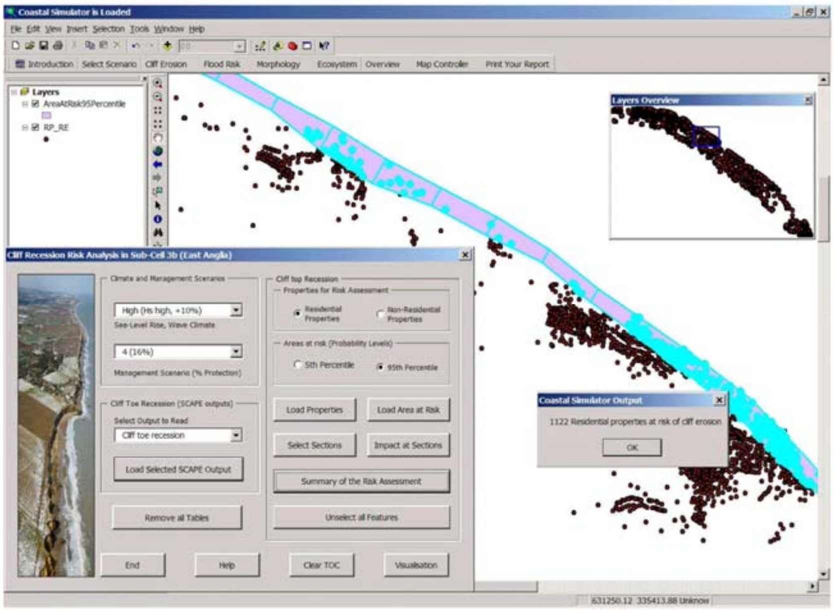
The Tyndall Centre for Climate Change Research has developed the Coastal Simulator in partnership with the Environment Agency in order to aid the development of SMPs. The simulator predicts future coastal evolution under different scenarios based on shoreline management options, and climate and socio-economic features. Sub-cell 3b has been used as a case study, but the method is intended for wider use.

Global scenarios are directly linked with local wave climates and regional climate scenarios to enable the development of predictions. Other features included in the simulator are climate, hydrodynamics, morphology, ecosystems, societal resources, scenarios of shoreline management and flood and erosion risks.

Downscaled Global Climate Models enable development of regional scenarios of future climate change including sea level rise, wave climate change and storm surges. These feed into the SCAPE model (Soft Cliff and Platform Erosion), which predicts shoreline evolution and profile development and is integrated with a model predicting cliff top change. A linked flood model then undertakes a flood and erosion risk assessment. These processes can be repeated for the relevant scenarios.



Sub-cell 3b
620000
640000
660000
0 2.5 5 km
Cromer
Cliff erosion
Mundesley
340000
Sea Palling
Flooding
320000
Winterton Ness
Norwich
Gt Yarmouth
Elevation (metres)
0 (Sea level)
0-7
7-20
20-40
40-50
50-60
60-70
70-80
>80
300000
Sub-cell 3b
Lowestoft



Coastal Simulator is Loaded
File Edit View Insert Selection Tools Window Help
Introduction
Select Scenario
Cliff Erosion
Flood Risk
Morphology
Ecosystem
Overview
Map Controller
Print Your Report
Layers
AreaAtRisk95Percentile
RP_RE
Layers Overview
Cliff Recession Risk Analysis in Sub-Cell 3b (East Anglia)
Climate and Management Scenarios
High (Hs high, +10%)
Sea-Level Rise, Wave Climate
4 (16%)
Management Scenario (% Protection)
Cliff Toe Recession (SCAPE outputs)
Select Output to Read
Cliff toe recession
Load Selected SCAPE Output
Remove all Tables
Cliff top Recession
Properties for Risk Assessment
Residential Properties
Non-Residential Properties
Areas at risk (Probability Levels)
5th Percentile
95th Percentile
Load Properties
Load Area at Risk
Select Sections
Impact at Sections
Summary of the Risk Assessment
Unselect all Features
End
Help
Clear TOC
Visualisation
Coastal Simulator Output
1122 Residential properties at risk of cliff erosion
OK
631250.12 335413.88 Unknow

RACE and NCERM

In April 2006, Halcrow was commissioned to undertake the National Coastal Erosion Risk Mapping (NCERM) programme. This project aimed to map predicted erosion risk while taking account of current defences and management activities.

The project has developed software that utilises techniques developed in the Defra-funded 'Risk Assessment of Coastal Erosion' project (RACE, FD2324) (Halcrow 2007). The RACE methodology is a robust probabilistic method for assessing the hazard and risk of coastal erosion. The method utilises data and information from monitoring programmes and risk-based inspections, and is compatible with the RASP (Risk Assessment of flood and coastal defence for Strategic Planning) method used for flood risk assessment.

The objectives of the NCERM project were to:

- identify appropriate means to develop coverage in order to model and map the risks from coastal erosion;
- identify appropriate means of making this information publicly available.

The project had two audiences:

- local authorities – to provide information to inform the planning process;
- the general public – to complement the Environment Agency's 'What's in Your Back Yard' flood maps and allow them to see the levels of erosion risk in their area of interest.

Questions that the project sought to address include:

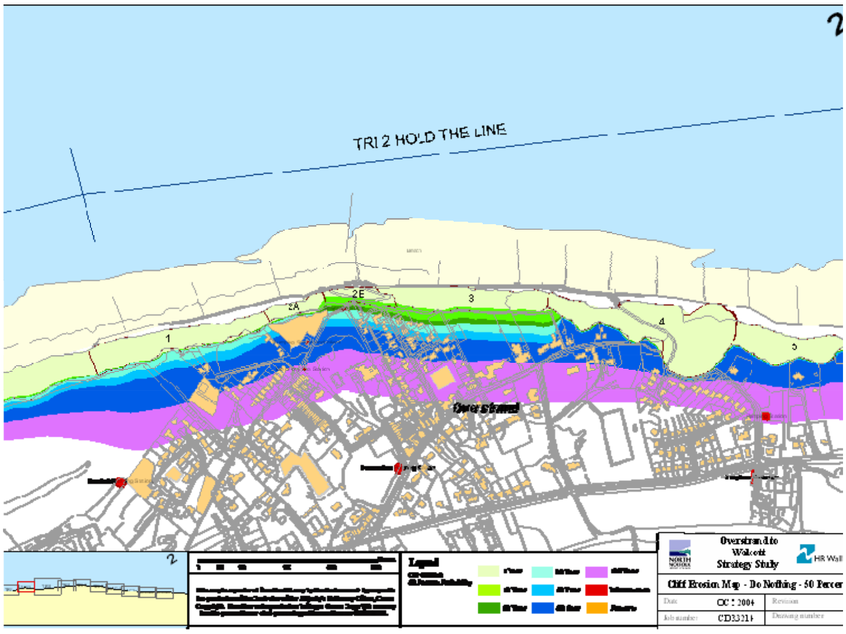
- To what extent are coastal assets (built and natural) at risk from erosion?
- How does risk change over time?
- What is the level of uncertainty associated with this prediction?
- What sort of intervention is likely to be required to manage risk to an acceptable level?
- How sensitive are predictions to probable changes in key assumptions, such as climate change?
- When is intervention likely to be necessary if assets are to be protected?
- To what degree should local planning accommodate likely future scenarios?

Questions that the public will potentially seek from the project outputs include:

- What is the risk to my property now and in the future?
- Should I proceed with a purchase of assets in a potential risk zone?
- What is the degree of uncertainty associated with these decisions?

Regional bespoke analysis – Overstrand to Walcott strategy approach and methodology

A bespoke approach to the prediction of the response of the shoreline (cliff toe) on the north Norfolk coast to changes in coastal management and other long-term coastal changes (e.g. climate change) was adopted by HR Wallingford (HR Wallingford 2005). This stochastic model used predictions from the CliffSCAPE model together with information from cliff surveys to generate a probabilistic prediction of cliff location which was then used in the appraisal of strategic coastal management options.



CliffSCAPE is a model of the process of shore platform lowering and cliff toe recession that governs the retreat of soft coastlines and their response to coastal management interventions. As well as representing the in situ platform and cliff toe, CliffSCAPE models the mobile beach, its role in protecting or abrading the platform, and the contribution that cliff and platform sediments make to the mobile beach. A regional-scale version of CliffSCAPE (CliffSCAPE-RS) is available to model long sections of coast for strategic assessment purposes. The local-scale version can better resolve the effects of individual beach control and coast protection structures.

MDSF

Website: http://www.mdsf.co.uk

From *Development of DSS for long-term planning: review of existing tools*, FLOODsite project report number T18-06-01 (Schanze et al. 2007)

MDSF (Modelling and Decision Support Framework) was created to support the implementation of Catchment Flood Management Plans (an initiative of Defra, the Welsh Assembly Government and the Environment Agency), although the tool is also suitable for use with Shoreline Management Plans.

The model uses source terms and pathway and receptor modules along with management response and decision-support modules to aid decision-making.

Source terms are model results such as water levels or flood areas imported into the framework, with the pathway module predicting flow by modelling it over a Digital Terrain Model (DTM) and including effects of any defences.

Receptor modules include consideration of population, land use and social vulnerability indices. These functions may be manipulated by the user to represent the proposed options. Changes such as the inclusion of sluice gates in the external hydraulic models may be implemented.

The framework rests within a GIS system enabling easy use and visual interpretation.

MDSF may be used for a wide range of applications and is not restricted by spatial or temporal scales. Flood risk may be assessed in terms of economic impact and impact on the local population through tools that enable:

- average annual economic damage to be estimated for individual properties;
- flood risk to be calculated in terms of the number of people at risk from flooding;
- the most vulnerable people within the flood zone to be identified (using a Social Flood Vulnerability Index).

The tool is widely used in the UK, though the target end users are the Environment Agency, their consultants developing CFMPs and SMPs, and local authorities.

SANDS

Website: http://www.halcrow.com/sands/default.asp

SANDS (Shoreline and Nearshore Data System) is a monitoring and analysis suite developed over the last 18 years by Halcrow for asset managers, engineers, researchers and scientists. It enables the analysis of both geospatial and temporal data to establish links between forcing and response. Both climate and shore data may be inputted, stored, inspected and compared. Other functions include the storing, retrieving and analysis of a wide range of asset data, survey reports and records.

Data analysis tools contained within SANDS include tools for:

- extremes analysis;
- storm analysis;
- tidal harmonic analysis;
- wave energy analysis;
- sediment transport analysis.

Specialist tools are available for the processing of metocean data collected during monitoring. Transformation of wave data is also possible via upload of the appropriate coefficients.

Survey data collected during routine monitoring can be comprehensively analysed; typically volumetric calculations, slopes, contours and trends over time can be examined.

Information is stored centrally and referenced to a mapping system which can be inspected, edited and compared on a synchronised timescale allowing sets of data to be viewed simultaneously.

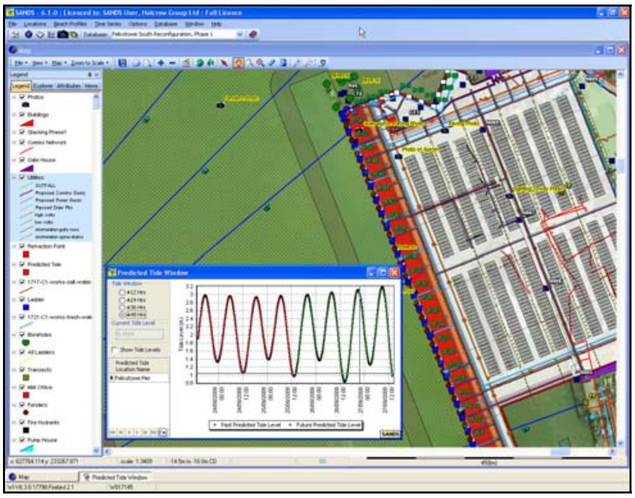
SANDS databases may be used for numerous different applications and have been used for situations including:

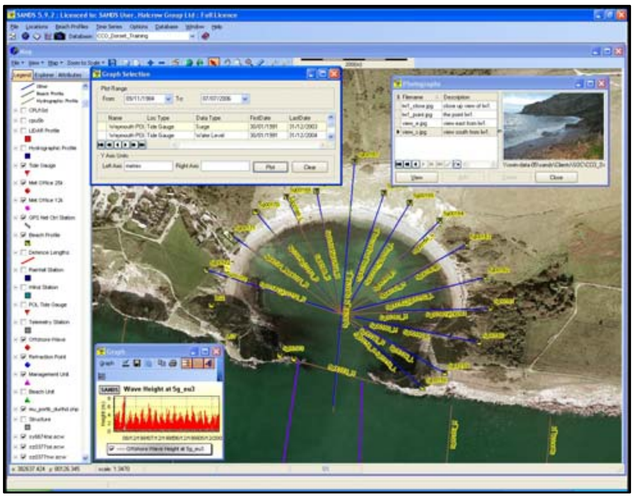
- coastal regional monitoring programmes;
- port asset management;
- asset management of marine structures;
- Shoreline Management Plans;
- environmental studies.

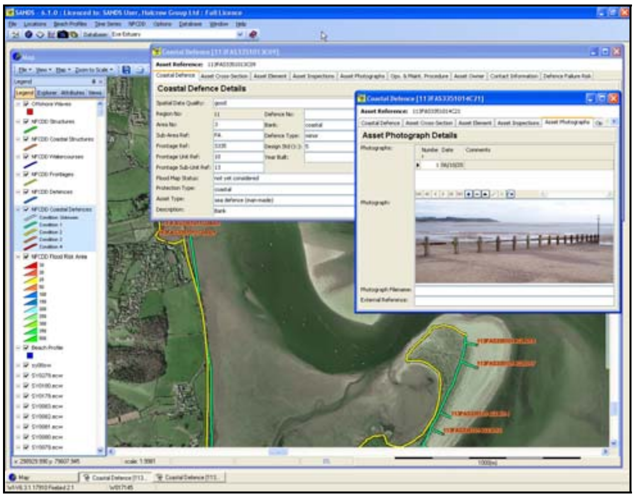
SANDS can also be customised to load data from other sources; for example, an export facility in the UK National Flood Coastal Defence Database (NFCDD) exists to upload and display its mapping and inspections into SANDS. Indeed, any data can be linked directly into SANDS including drawings, calculations, reports, spreadsheets and hyperlinks.

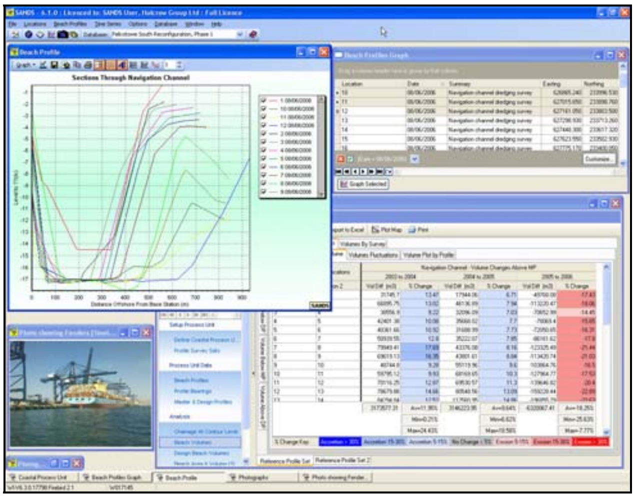
The software is widely used both within Halcrow on a global scale and by independent users such as local authorities, universities, overseas government organisations and the Environment Agency nationally.

Much of the past development, and indeed future planned developments, are driven directly from the SANDS user requirements; the well-established SANDS user group has proved invaluable in this respect.









CDAMD (Coastal Defence Asset Management Database)

Bespoke yet simple asset management databases have been in use for a number of years. One such example is the database used by the Public Services Department of the Government of the Island of Jersey (illustrated below). This simply stores:

- information on defence structures and frontages;
- information on the environment;
- details of events such as storms or maintenance activities;
- inspection records;
- drawings and photographs.

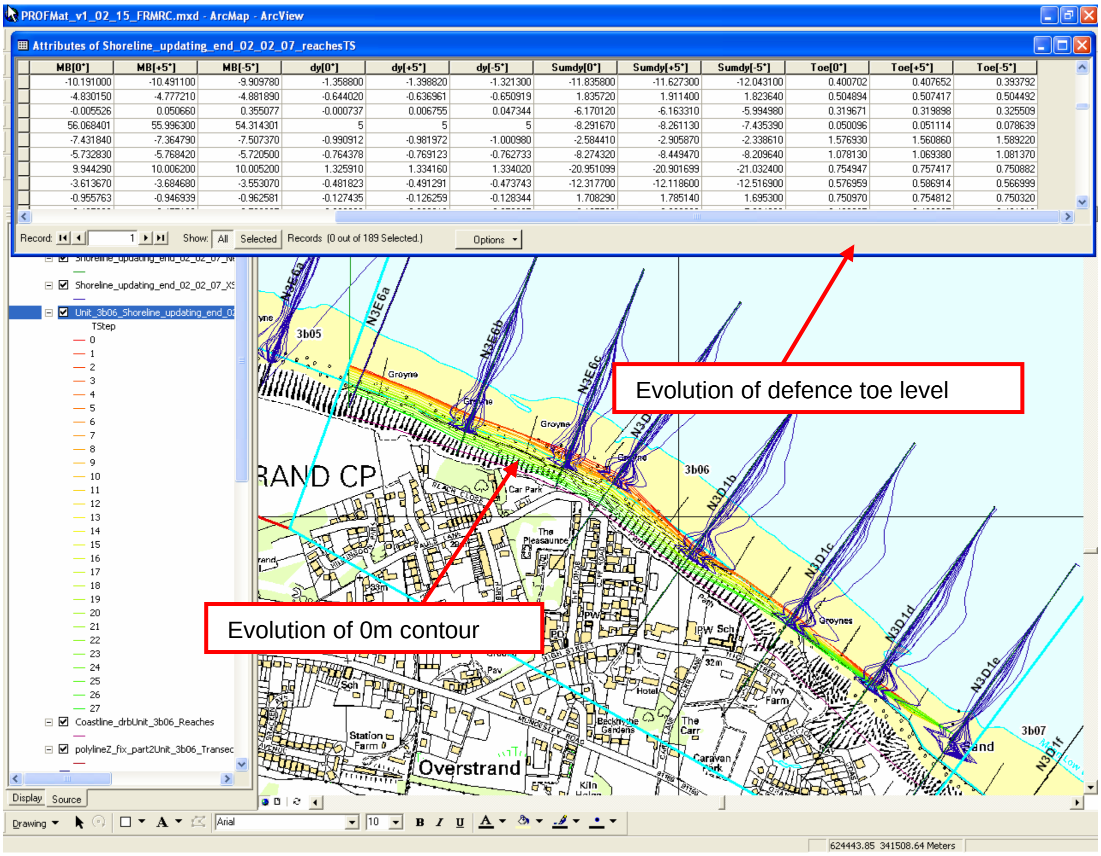
The database can be queried to produce reports and information stored.

GTI-SEAMaT

GTI-SEAMaT (Stripling et al. 2007) is a rapid process-based (shoreline) megascale numerical modelling suite. The suite relies on existing numerical models that have been found to be robust and reliable through extensive application in research and consultancy to provide representations of the processes involved.

Nearshore rapidly changing variations in the seabed are accounted for by determining the wave climate at each transect within a one-line model. The impact of the tide on wave propagation is also accounted for by the existing software. Climate change is dealt with by examining the sensitivity of longshore drift to the mean direction of wave propagation and the effects of sea level rise can be incorporated by periodically increasing the water depth in the wave propagation model.

Seasonal variation in the beach profile is accounted for in the model, albeit rather crudely, by deriving a probability distribution of the beach levels at the backshore (e.g. at the toe of a cliff or sea wall). This refinement does, however, serve to enhance the assessment of flood and erosion risk. The modelling framework readily lends itself to the incorporation of overtopping, flood spreading, and social/economic impact models, thus facilitating the development of a complete numerical tool representative of the RASP source–pathway–receptor model. The modular nature of the suite allows the incorporation of ongoing and future research into flood and erosion-risk assessment.



Broad-scale shoreline evolution and toe level at defence within GTI-SEAMaT.

The linking of the numerical models through considerable development within proprietary GIS software has elevated the software above a simple data management and visualisation role. Numerical modelling is conducted within the GIS software package itself and the numerical models contribute towards the building of the database. This type of application is unusual in that data ordinarily have to be input to the GIS, rather than the GIS generating its own datasets.

As a result of building the megascale morphological model within a GIS framework, the data management capabilities of the GIS software are exploited. In addition, much of the spatial tracking required and ordinarily managed within numerical models through coding is dealt with by the GIS, thus allowing considerable spatial control and model 'awareness'. The linking of the numerical models to other databases (e.g. NFCDD) is performed easily through the GIS.

EUROTAS

From *Development of DSS for long-term planning: review of existing tools*, FLOODsite project report number T18-06-01 (Schanze et al. 2007)

The EUROTAS (European River Flood Occurrence and Total Risk Assessment System) decision-support tool provides a framework for assisting in catchment studies through information management. The project aims to ensure that:

- river management studies can be undertaken in a quality assured manner;

- decisions made and their predicted consequences are recorded.

The tool is organised using the source–pathway–receptor system.

- Sources are obtained from external models.
- Pathways are represented by cross-sections, digital terrain models and a flood spreading algorithm for water levels.
- Receptors are represented as vulnerability layers indicating potential consequences at a given location.

A management module enables the construction of queries and specification of catchment conditions. River engineering scenarios can be tested, along with land use change and external drivers such as climate change.

Scenarios are specified, exported to external simulation models such as ISIS, and the results re-imported back into the model for analysis.

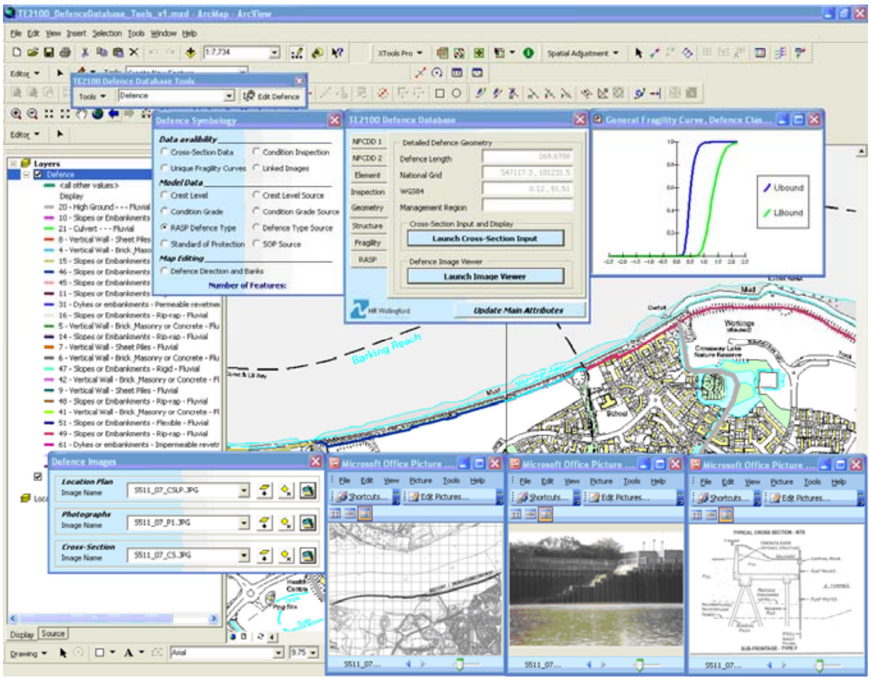
The tool was designed exclusively for the project and is not intended for commercial distribution. However, dissemination of the knowledge and tool has occurred. Further development would be required before the tool is made commercially available.

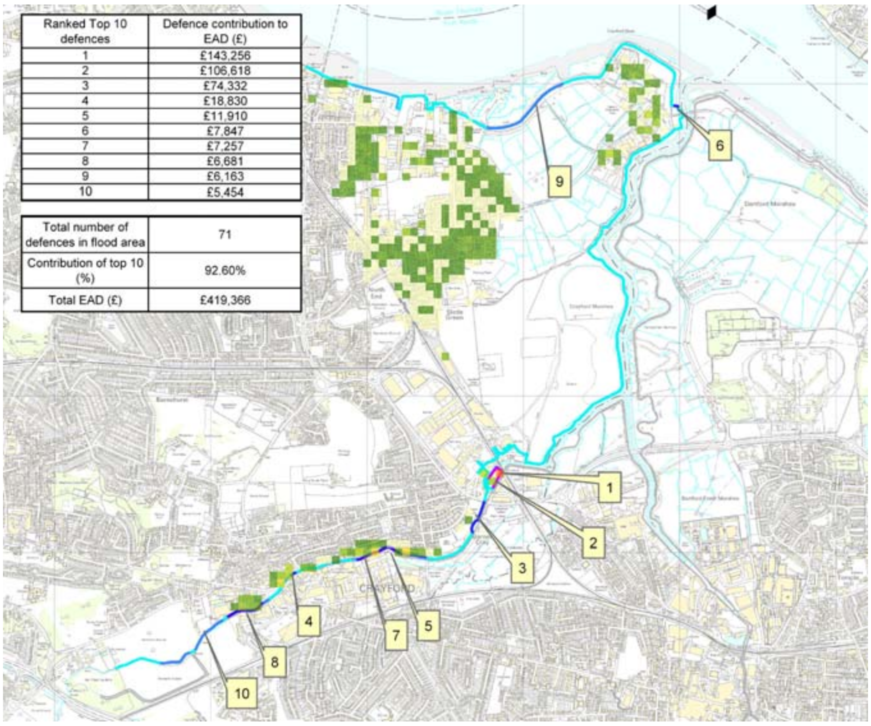
Thames Estuary 2100 project

What might be described as an integrated asset management tool was developed for the Thames Estuary 2100 (TE2100) project.[40] Often described as a PAMS 'type' tool, it carries all the asset information, draws on other databases (such as NPD) and stores other look-up SQL tables for use in running the RASP HLM+ and Rapid Flood Spreading methodologies. This proved to be a very useful and powerful tool for the assessment of future flood risk along the Thames under different management scenarios.

The project also utilised a new methodology for attributing flood risk to particular defence lengths, together with associated estimated annual damages to receptors in the flood affected area. Risk attribution is a crucial tool for asset management as it enables direct comparison of costs and benefits of different intervention options under different modelled scenarios.

[40] See http://www.environment-agency.gov.uk/homeandleisure/floods/104695.aspx





Ranked Top 10 defences	Defence contribution to EAD (£)
1	£143,256
2	£106,618
3	£74,332
4	£18,830
5	£11,910
6	£7,847
7	£7,257
8	£6,681
9	£6,163
10	£5,454

Total number of defences in flood area	71
Contribution of top 10 (%)	92.60%
Total EAD (£)	£419,366

Coastal morphology tool (project SC060074)

Website: http://www.coastalgeomorphology.net

See also *Characterisation and prediction of large scale, long-term change of coastal geomorphological behaviours*, Science Report SC060074/SR1 (Whitehouse et al. 2009).

This project produced a practical framework and methodology for creating new models capable of predicting long-term and large-scale geomorphological evolution of the coast. It provides a clear and consistent understanding of coastal geomorphology to support the management of coastal environments supported by practical modelling and analysis techniques for the prediction of long-term coastal evolution, including management interventions.

The process involves expert geomorphological assessment to improve confidence in the system-based models which are set to deliver benefits in the next round of Shoreline Management Plans (SMP3).

The analysis techniques were also assessed and fall into four broad types:

- **Behavioural models of coastal change** – historical trend analysis and future change extrapolation, the Bruun rule and equilibrium planshape.
- **Process-based models** – one-line models, coastal profile models and area models.
- **Change of state models** – shingle and barrier inertia models for the breaching of barrier beaches and inlet stability tools.
- **Systems-based models –** such as SCAPE (Soft Cliff and Platform Erosion) and ASMITA (Aggregated Scale Morphological Interaction between a Tidal inlet and the Adjacent coast).

All were shown to be worthy of further application and development.

InfoNet™

Website: http://www.wallingfordsoftware.com/uk/products/infonet/

InfoNet™ is an asset and data management system for the management of water and wastewater infrastructure including water networks, water supply, water distribution, wastewater collection, sewers and storm water.

The system enables network data to be inputted, integrated, validated and analysed in one database system. Data can be viewed in a range of GIS and database applications, and imported directly into InfoNet. Data can also be managed, interrogated, manipulated and analysed in order to make effective water infrastructure management decisions. Mapping and aerial photography can be imported in order for data to be understood and interpreted on a spatial basis. InfoNet can be used independently or within an existing GIS system.

Planning Kit

Website: http://www.wldelft.nl/cons/area/wqe/krw/explorer.html

The Planning Kit was developed by Delft Hydraulics (now Deltares) to enable flood management along the Rhine branches. It was created in response to the 1998 Netherlands Parliament policy of 'providing room for the river', which addresses the prospect of higher future river discharges and the increasing need for river restoration. In terms of the Rhine, this meant allowing the increased discharges without being required to heighten the levees.

Stakeholder engagement resulted in 700 individual river improvement measures being proposed to contribute to this policy including:

- removal of hydraulic obstacles;
- excavation of flood plains;
- setting back of levees;
- construction of side channels.

Deciding which of these to implement required substantial public consultation and the need for a method of predicting the effects of combinations of measures on flood levels. It was to enable this that the Planning Kit was developed.

The Planning Kit allows a selection of potential measures to be made and the result of specific combinations of methods to be modelled and their effects visualised. This is achieved through a database containing the results of time-consuming and detailed hydraulic models. Additional information is included for each measure such as aerial photographs, design sketch, cost estimates and ecological impacts. This further enables rapid comparison of options.

DESIMA

From *Development of DSS for long-term planning: review of existing tools*, FLOODsite project report number T18-06-01 (Schanze. et al. 2007)

DESIMA (Decision Support for Integrated Coastal Zone Management) was developed under a European Commission project led by Matra Systems & Information (France) in 1998. It aimed to enable decision-makers to develop operational and integrated coastal zone management by assisting decision-making and the effective management, protection and the development of the coastal zone.

DESIMA is a framework made up of various data inputs and models, providing real-time access to them through a map-based user interface. Typical datasets include:

- bathymetry, wind and wave data;
- tidal levels;
- sea defence data;
- joint probabilities;
- economics.

It enables various measures and instruments to be introduced into the system such as climate change modules, topographic data or sea level rise. Photographs and diagrams can be uploaded enabling presentation alongside model results.

The tool is targeted to authorities and consultants involved in the development of operational and integrated coastal zone management.

RAMFLOOD

Website: http://www.cimne.upc.es/ramflood/

RAMFLOOD (Decision Support System for Risk Assessment and Management of Floods) was a 24-month project co-funded by the 5th Framework Programme of the European Community. It aimed to develop and validate a DSS for risk assessment and the management of emergency scenarios caused by flooding and to provide communication tools among users. The tool utilises environmental and geophysical data from a variety of sources including earth observation, satellite positioning systems, in situ sensors and georeferenced information. Qualitative methods based on simple models and computer simulation models are used to analyse and visualise these data. An artificial neural network (ANN) based decision model that uses Monte Carlo simulation tools enables decision-making and assists the user in the design of emergency scenarios. It aims to enable risk and damage assessment of floods and improve decision-making at all stages of planning, flood management and post-flood recovery.

EBM tools

Website: http://www.ebmtools.org/

EBM tools (Ecosystem-Based Management) is a network of management tools to address the challenges posed by human activities affecting coastal and marine systems such that their ability to fulfil their natural functions are compromised. The whole ecosystem is considered, and the interaction of humans with the environment. EBM tools allow ecosystem-based management by providing models of ecosystems or key ecosystem processes, enabling the generation of scenarios to illustrate the consequences of different management decisions on natural resources and the economy. Through these tools stakeholder involvement in the planning process can be aided. Tools incorporated within EBM tools include:

- data collection tools;
- data processing tools;
- conceptual modelling tools;
- modelling and analysis tools (for example, watershed models, marine ecosystem models, dispersal models, habitat models, socioeconomic models, and model development tools);
- scenario development tools;
- decision support tools (e.g. coastal zone management tools, fisheries management tools, conservation and restoration site selection tools, land use planning tools, and hazard assessment and resilience planning tools);
- project management tools;

- stakeholder communication and engagement tools;
- monitoring and assessment tools.

Appendix 4 Coastal practitioners forum report

A practitioner's forum was held at the Defra Innovation Centre, Reading, on Thursday 29 January 2009 to which coastal managers, local authority coastal engineers, Environment Agency coastal managers, coastal consultants and contractors were invited. This document records and reports the products of this event, which will further inform the project scoping report in which the issues raised will be discussed in further detail.

The purpose of the forum event was to enable coastal practitioners to discuss various issues in groups and to elicit responses to questions posed. It sought to:

- identify the requirements of practitioners;
- identify existing best practice;
- inform any recommendations for future scientific work aimed at filling gaps (that could be identified) and contributing to improved procedures and decision-support tools

Table A4.1 lists the 32 delegates and their organisation.

Table 4.1 Delegates attending the forum.

Name	Organisation
Andy Bradbury	Channel Coastal Observatory
Jackie Banks	Environment Agency
Geoff Boyd	Environment Agency
Jonathan Croft,	Environment Agency
Uwe Dornbusch	Environment Agency
Jaap Flikweert	Royal Haskoning
Peter Frew	North Norfolk District Council
Ben Hamer	Halcrow
Jenny Harcourt	Halcrow
David Harlow	Bournemouth Borough Council
Zoe Hutchison	Mouchel
Ben Hughes	Environment Agency
David Lowsley	Chichester Council
Nick Lyness	Environment Agency
Rob McInnes	Southern Coastal Group
Terry Oakes	Suffolk Coastal District Council
Clive Older	Environment Agency
Jonathan Simm	HR Wallingford
Roger Spencer	Arun District Council
Paul Sayers	HR Wallingford
Owen Tarrant	Environment Agency

Name	Organisation
Dick Thomas	Halcrow
Ian Thomas	Pevensey Coastal Defence Ltd
Emma Thomson	Environment Agency
Anne Thurston	Environment Agency
Keith Tyrrell	Suffolk Coastal District Council
Mike Wallis	HR Wallingford
Roland Wallis	Canterbury City Council
Paul Warner	Environment Agency
Philip Welton	Environment Agency
Richard Whitehouse	HR Wallingford
Andy Wilson	Environment Agency

The event was organised into three sessions:

1. A ‘best practice’ brain dump (individuals)
2. ‘Effective’ decision-making issues (pairs and group participation)
3. A ‘What do we need?’ discussion (group participation)

Session 1 ‘Best practice’ brain dump

Following a context setting introduction in which representatives from local maritime authorities and the Environment Agency gave their perspectives, delegates were asked to record their experience of, and suggestions for, best practice in coastal management on ‘post-it’ notes. These contributions were then ‘processed’ by members of the project team to:

- collate similar points under the following headings:
  - tools
  - best practice
  - life cycle and performance
  - monitoring
  - communication and engagement
  - funding
  - data
- translate the points made within the various headings into three further categories structuring them as statements or questions:
  - We could …
  - How might we …
  - Will it …

This resulted in the following.

We could …

- Develop performance specifications for all structures and compare with actual performance (e.g. bank levels).
- Use fixed point photography during inspections to aid and inform trend analysis (beaches).
- Monitor particle size distribution (PSD) of beach material and identify trends.
- Measure levels of beaches regularly/simply (using dips) and identify trigger levels for intervention.
- Use GPS to monitor beaches and foreshores more regularly and after storm events.
- Undertake frequent periodic monitoring coupled with post-storm surveys.
- Replace the National Flood and Coastal Defence Database with something more useful.
- Create a GIS-based asset inventory (linked to datasets).
- Collect comprehensive information to create historic datasets (and use them!).
- Review and use historic data and information on past events to extend knowledge about the response of assets.
- Check regional and national data carefully against local knowledge and common sense.
- Plan more effectively and be more pro-active in our maintenance activities.
- Treat every beach uniquely (and in context) and develop bespoke solutions.
- Keep more systematic asset-specific records of capital and maintenance spend.
- Link funding of schemes geographically and over time to provide more security.
- Intervene in a 'little and often' manner.
- Develop life cycle plans for performance of structures (including cost and maintenance).
- Involve local people and stakeholders as much as possible (including dissemination).
- Learn from previous experience and communicate our own problems.
- Liaise frequently with the Environment Agency and with local authorities.
- Rely on best practice.

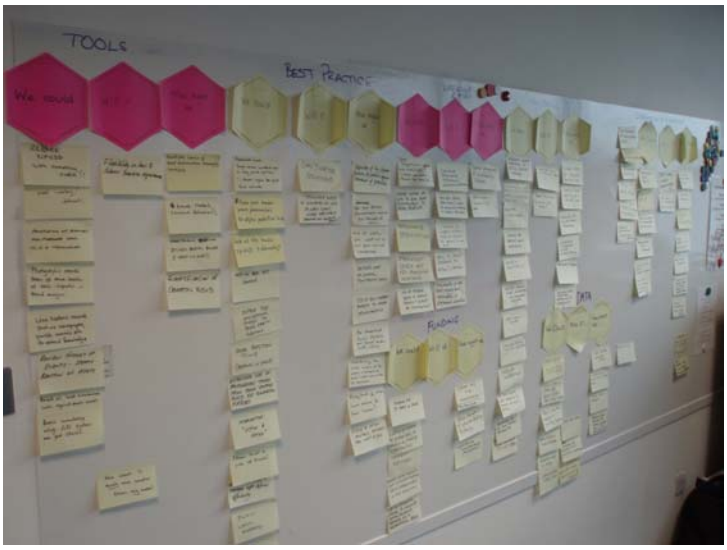
How might we …

- Better record and use data to improve coastal understanding and trigger action?

- Monitor beaches and structures during storm events?
- Gain a better understanding of natural processes and apply this to beach management?
- Measure long-term beach performance and rate of change?
- Investigate causes of asset deterioration in a quantifiable way while recognising uncertainty?
- Evolve understandable models that link coastal processes and assets, and quantify risk?
- Engage and communicate effectively with coastal communities?
- Ensure regular and meaningful communication between local authorities and the Environment Agency?
- Better co-ordinate and fund spatially connected schemes?
- Better secure funds for maintenance? (grant aid, ring fencing?)

Will it …

- Avoid imposing solutions on us?
- Allow data to be shared?
- Ensure models include estuarine shorelines as well as open coasts and deal with boundaries?
- Allow flexible design that allows ‘works’ to encompass change in coastal processes and service requirements?
- Allow a combination of judgement, validation and honesty with respect to uncertainty (i.e. in models)?



Session 2

Delegates were asked to consider a number of questions related to coastal management and to respond – either with answers to the question directly or with other questions or concerns they may have related to the issue posed. The following five questions were asked:

1. What improvements are needed in the measurement/assessment and recording in data systems of the state of existing defences?
2. What improvements are needed in the understanding of how breakwaters, groynes and sea walls influence beach behaviour (as new and as they deteriorate)?
3. What life-cycle issues are important to you about the management of beaches and of coastal structures of various types?
4. What improvements are needed in the assessment of flood and coastal erosion risk? (i.e. benefits available for intervention)
5. What other criteria influence the way you manage your coastal structures and beaches?

All delegates considered these questions placed at stations in the room in turn and added their responses to others on prepared wall posters. Delegates then split into groups to attend whichever station they felt they would like to contribute to further discussion on and collated the comments and compiled lists of five ‘messages’, three ‘recommendations’ and one ‘concern’ on these issues for reporting and feedback.

The lists returned were as follows:

Question 1

What improvements are needed in the measurement/assessment and recording in data systems of the state of existing defences?

Messages:	1. What is the desired outcome?
	2. Targeted data gathering (including historic)
	3. Keep it simple
	4. Standardisation: collect, store, access
	5. Use [data] more effectively for decision-making
Recommendations:	1. Better data management
	2. Better data sharing
	3. Standardisation
Concern:	Linking data with decision-making through the whole life of an asset and regular reviews

The discussion group provided further considerations on this question including:

- Could we not ‘match’ what would be required in a contract?
- Allow the involvement of local people?
- Will ‘standardisation’ lose local knowledge?
- Will ‘the system’ acknowledge the wide range of capabilities and broad range of responsibilities?
- Will it avoid ‘lowest common denominator’?
- [Will it] be practical?
- [Will it] recognise multiple uses of assets?
- We could manage assets to slightly higher standard to minimise damage.
- We could act as soon as damage occurs.

Question 2

What improvements are needed in the understanding of how breakwaters, groynes and sea walls influence beach behaviour (as new and as they deteriorate)?

Messages:	1. Importance of knowledge transfer to ensure we do not reinvent the wheel 2. Understand and link the whole system to individual structures 3. Better understanding of how groynes behave under <u>all</u> conditions (type, deterioration, alignment). 4. We are uncertain as to whether the numerical (e.g. planshape) and physical models are validated. 5. Keep it simple
Recommendations:	1. Ensure design takes account of concern no.1. 2. Information management – facilitate access to written (and other) material [ref message no.1] 3. Take a broad view, listen to local knowledge, conduct post-project appraisal and publish R&D (failures as well as successes)
Concern:	How to get information on an asset (or range of assets) when they are most under stress

Question 3

What life-cycle issues are important to you about the management of beaches and of coastal structures of various types?

Messages:	1. Phasing of interventions 2. Funding technical versus security 3. Better understanding of life-cycle costs 4. Dealing with change (e.g. climate) 5. Optimisation of intervention
Recommendations:	1. Prepare for change 2. Accept change (will happen) 3. Be brave to follow ‘optimal’ scheme
Concern:	Suboptimal solutions [adopted] due to funding uncertainties [and] rules.

Question 4

What improvements are needed in the assessment of flood and coastal erosion risk? (i.e. benefits available for intervention)

Messages:	1. Better technical understanding – particularly of beach response 2. More comprehensive approach to assessment of benefits 3. Capturing and understanding the full scope of risks to be encountered 4. Target data collection 5. Cautionary approach to the use of output from models – ensure sound validation.
Recommendations:	1. Further development of multi-criteria analysis (MCA) to benefit assessment 2. Maintenance – improve appraisal techniques 3. Improve understanding of 'do-nothing' consequences
Concern:	Inadequacy of models to deliver reliable outcomes

Question 5

What other criteria influence the way you manage your coastal structures and beaches?

Messages:	1. Politics – national, local and internal 2. Funding available at the right time 3. Engaging the public 4. Health and safety 5. Hierarchy of plans and strategies.
Recommendations:	1. Fund when funding is needed 2. Consistent approach to benefits (flooding/erosion/all) 3. Include the public
Concern:	Security of funding to deliver long-term plans

Each group in turn presented the agreed responses to the questions in a feedback session to the rest of the delegates.

Session 3

Following another short briefing, the delegates were posed with a further three broader questions in order to capture requirements or issues that possibly would not have come to light from the previous five (more focussed) questions put to them in Session two.

The following three questions were asked:

1. Given the responses to the above (from Session 2), what improvements are needed in the capacity of models to represent the performance of coastal structures and beaches?

2. What additional tools and techniques are needed to support the management of coastal structures and beaches?

3. What could help to improve collaboration between coastal authorities and the Environment Agency on the management of coastal structures and beaches? Consider potential improvements in the following five categories:

- data and information;

- roles and responsibilities;

- processes and procedures;
- enabling technologies;
- audit procedures.

These questions were considered in groups by round table discussion and responses were recorded – although delegates did not have to agree with each other, or on any prioritisation ranking or level of importance. The responses have been collated and are listed as follows:

Question 1: Given the responses to the above (from Session 2), what improvements are needed in the capacity of models to represent the performance of coastal structures and beaches?

Use and management of models

- Important to validate models with experience, whether post-project to inform future works, or as a model calibration exercise using historical data.
- Need to disseminate uncertainties and limitations of specific models and their applications. There tends to be a perception – both by the client and the wider public – that models provide 'the answer' whereas in reality this is not the case and it is simply a prediction which is as accurate as the data you put in to it.
- It was suggested that modelling should inform a management decision in combination with other tools rather than be used alone – and with due regard to the uncertainties and limitations described above.
- The cost-effectiveness of models was questioned, with acknowledgement made of the large amounts of money traditionally spent on modelling. It was questioned whether the benefits gained were worth the amounts spent or whether monitoring was of more use.

Specific model limitations

- Models are most accurately used in terms of comparisons of different scenarios rather than looking to provide a definitive prediction of beach change. An example suggested was comparing the effects of different numbers of groynes.
- Models currently in use are unable to accurately represent mixed beaches and indeed our understanding of them is similarly limited. Processes are

not understood properly. It was pointed out that as most of the UK comprises mixed beaches; this is a significant issue.

- It was suggested that models (particularly planshape models) should use observations of the natural beach as a starting point rather than solely modelled reality. This at least means that there is an accurate starting point.
- A useful project suggested was a comparison of different models and their effectiveness. Obviously this would have to be confined to models of a similar type (e.g. beach planshape models), but would provide useful information when choosing a model for a specific purpose.
- Interaction with structures is a major feature that is not well-represented in models, with at best an estimation of the response of generic structures included. Different materials are not generally differentiated between.
- Directional wave data is an area where model representation could be improved. This is a factor that can significantly affect model results, particularly where longshore transport is simulated.

Question 2: What additional tools and techniques are needed to support the management of coastal structures and beaches?

- Discussion centred on whether there was a need for additional tools and techniques, but it was thought that perhaps there was a greater need to better apply and understand existing tools and methods.
- The importance of capturing knowledge from local experts was recognised and it was questioned how this could effectively done. Historically coastal engineers learnt through apprenticeship and thus knowledge was passed down. Modellers are not always able to benefit from this local expertise, often not knowing the area and not having the time to capture this information.
- The ability to turn data into useful knowledge was also flagged to ensure that the data are used and interpreted correctly.
- Emphasis was placed on the need to understand the appropriateness of models and their use (e.g. ensuring the correct people are involved in the process), and that models are used for the right purposes. Consistency is important nationally; however, it was noted that this should be with due regard to consistency to apply appropriate levels of management and considerations for conditions at particular sites. Emphasis was also given to the need to understand the tools and what purposes they are appropriate for when embarking on a new project.
- Again, the need to understand the limitations of models was stressed; for example, they are unable to model the uncertainties that actually might be more useful for the borough engineers such as when a storm event will occur that will cause a specific section of sea wall to fail. Other limitations included the calculation of risk and residual life.
- Finally, in terms of improvements to tools and techniques, it was recognised that it is difficult to articulate what tools would like before they have been developed – rather it is easier to identify where improvements would be useful.

Question 3: What could help to improve collaboration between coastal authorities and the Environment Agency on the management of coastal structures and beaches?

Problems

- One of the major difficulties in establishing good relationships was the difficulty of maintaining contacts with the Environment Agency; high staff turnover and frequent restructuring made it difficult to maintain relationships.
    - A single point of liaison was recommending as a way of dealing with this difficulty, with people developing a working relationship with a single Environment Agency member of staff and turning to them first.
    - Detailed organisation maps of staff should be available on the Environment Agency website and updated regularly to help find appropriate contacts.
- Different aims and objectives in terms of management were highlighted. The Environment Agency looks at what is best for the environment and the asset itself, whereas local authorities have other priorities and have to manage for the local community and their needs. This can lead to differences of opinion and thus make relationships difficult.
- Barriers were felt in terms of information sharing; these included the form-filling that the Environment Agency requires but which is not necessarily easy to do. Computer systems in place for knowledge sharing were not felt to make it easy either. A more open, transparent relationship where useful information can be shared would improve matters.

Potential solutions

- Integration of neighbouring local authority and Environment Agency staff was recommended so that they can work together and share lessons learnt, etc. Often schemes are effectively repeated on adjacent stretches of coast and more integrated working would be useful.
- Successor planning within the Environment Agency or secondment to local authorities would enable working relationships to be transferred to the next generation of staff.
- As it is still under development, it was suggested that the planned new Environment Agency Asset Management IT system could be designed to include some of the requirements of local authorities as well as fulfilling the Environment Agency's objectives.
- The benefit of regular series of aerial photographs was recognised – and its place alongside GPS surveys emphasised – to offer an insight into beach behaviour that surveys are unable to provide.
- It was suggested that Environment Agency and local authority staff should aim to provide a united front to the wider community, with any disputes resolved internally, rather than widening the gap by publicly coming from different perspectives.

Appendix 5 Data requirements for PAMS and RACE

PAMS

Source: *PAMS MSF 5: Primary and Secondary Data Requirements* (Defra/Environment Agency 2009b)

No.	Data item	In PAMS?	P/S	Data source	Measurement technique(s) and accuracy
Source					
1	In-river water levels/loads	Y	P	External models, NaFRA, other	Model/source dependent
2	Coastal water levels/ loads	Y	P	External models, NaFRA, other	Model/source dependent
3	Flood depth grids	N?	P	External models, NaFRA, derived from flood contours and DTM	Model/source dependent
Pathway					
Flow path (river)					
4	River centre lines	Y?	P	New Environment Agency Detailed River Network (DRN) (ready in 12 months)	Derived from OS MasterMap rivers data
5	Channel blockage – CG	Y	P	Will be NFCDD	Visual inspection
6	Channel vegetation – CG	Y	P	Will be NFCDD	Visual inspection
Flow path (floodplain)					
7	Ground model	Y	P	Environment Agency Twerton	GPS derived (± 1 cm); survey (± 10 cm); LiDAR (± 25 cm), NextMap SAR (± 75 cm); OS profile-derived (± 2.5 m to ± 5 m); hand-held GPS (± 5 m to ± 10 m)
8	Extent of natural floodplain	Y	P	Flood Zones, External model, other	Model dependent
9	Valley type	Y?	S		Derived from floodplain width and longitudinal defence slope
10	Floodplain width	Y?	S		Derived from defence location and Flood Zone 2 boundary
Linear assets					

No.	Data item	In PAMS?	P/S	Data source	Measurement technique(s) and accuracy
11	Defence type	Y	P	NFCDD	Derived from asset data e.g. type, sub type, material, revetment
12	Crest level	Y	P	NFCDD	LiDAR, SAR, detailed survey, inferred from SoP
13	Standard of protection	Y?	P	NFCDD	Subjective assessment, design standard
14	Condition grade	Y	P	NFCDD	Visual inspection
15	Toe level	Y	P	NFCDD	In situ measurement, remotely sensed (± 1m)
16	Ground level (at defence)	Y	S	Populated from the ground model	As for ground model
17	Location (spatial)	Y?	P	NFCDD	Off-set from the river centreline
18	Defence length	Y?	P	NFCDD (includes straight lines)	Captured from the length of the defence spatial data
Non-linear assets (in-line/off-line)					
19	Spatial location	Y	P	NFCDD or similar database	
20	Asset type	Y	P	NFCDD or similar database	
21	Relevant properties for reliability and system analysis e.g. CG, CL, GL, SoP, width, height, shape, length, etc.	Y	P	NFCDD or similar database	
Receptor/Consequence					
Property data					
22	Spatial location 1	Y	P	NPD, Environment Agency Twerton, Address Point	Derived from OS MasterMap TOID, represents letterbox
23	Property type (RP/NRP)	Y	P	NPD, Environment Agency Twerton	
24	Local authority code	Y	P	NPD, Environment Agency Twerton	Derived from an OS boundary dataset defining local authorities
25	Postal area field	Y	P	NPD, Environment Agency Twerton	
26	Floor level, e.g. basement, upper	Y	P	NPD, Environment Agency Twerton	Derived from OS MasterMap

No.	Data item	In PAMS?	P/S	Data source	Measurement technique(s) and accuracy
27	MCM code (for NRP)	Y	P	Middlesex MCM tables	
28	Damages (£/m^2 floor area)	Y	P	Middlesex MCM tables	
29	Saline uplift with depth	Y	P	Middlesex MCM tables	
30	Floor area	Y	P	OS MasterMap	Mastermap polygon
31	Spatial location 2, e.g. letterbox	Y	P	OS MasterMap	Derived from TOID of polygon = Address Point, represents letterbox
32	VO Code (for establishing NRP and bulk class)	Y	P	Valuation Office database	
33	Spatial location 3 (point)	Y	P	Valuation Office database	
34	Property ground level	Y	S	Populated from the ground model	As for ground model
35	Property threshold level	Y	S	Vertical reference frame used within MCM tables. Based on ground model + threshold value.	As for ground model + previous analysis (ref Anglian analysis - J Chatterton, 29/05/2006) has shown the average property threshold to be 0.28m. For NaFRA 2006, ESG agreed to use a value of 0.25m.
Other impact data (examples)					
36	Population data for census ED	N?	P	Environment Agency	Population census
37	Flood SVI for census ED	N?	P	Environment Agency	
38	Agricultural Land Use Classification	N?	P	Defra, Agricultural Land Classification	Inundation damages in £/ha/year have been defined for each land class, assuming a single flood event lasts one week in duration. This is captured at a scale of 1:250,000.
39	Infrastructure damages	N	P	Exist? (some disruption costs in MCM Chapter 6)	
40	Ecological damages	N		Exist?	

Notes CG = Condition Grade; CL = crest level; ED = enumeration district; GL = ground level; MCM = Multi-Coloured Manual (Flood Hazard Research Centre tables); NRP = non-residential property; P = primary, RP = residential property; S = secondary, SAR = synthetic aperture radar; SVI = Social Vulnerability Index; TOID = topographic identifier, VO = Valuation Officer.

RACE

No.	Data item	Data source	Measurement technique(s) and accuracy
Source (for each cliff unit)			
Geotechnical conditions			
1	Recession potential (annual)	Futurecoast database	Assessment of recession potential for coastline of England and Wales
2	Recession potential (landslip)	Futurecoast database	
3	Recession frequency (landslip)	Futurecoast database	
4	Initial year (landslip)	Futurecoast database	
5	Likelihood of recession event	Futurecoast database	
6	Catch-up erosion rate	Local authorities	Source dependant
7	Catch-up erosion duration	Local authorities	Source dependant
Structural conditions			
8	Defences present	NFCDD, local authorities	Visual inspections leading to completion of a standard pro-forma, defence type, condition and geometry, foreshore levels and conditions; local knowledge/ updates
9	Condition	NFCDD, local authorities	
10	Structure type	NFCDD, local authorities	
11	Foreshore dependency	NFCDD, local authorities	
12	Crest level	NFCDD, local authorities	
13	Toe level	NFCDD, local authorities	
Hydraulic conditions			
14	Waves	NFCDD, local authorities	Source dependent
15	Water level	NFCDD, local authorities	Source dependent
16	Beach level	NFCDD, local authorities	Source dependent
17	Beach composition	NFCDD, local authorities	Source dependent
18	Beach volatility	NFCDD, local authorities	Source dependent

No.	Data item	Data source	Measurement technique(s) and accuracy
19	Beach action level	NFCDD, local authorities	Source dependent
20	Exposure	NFCDD, local authorities	Source dependent
Pathway (for each cliff unit)			
21	Defence failure curve	RACE techniques	
22	Curve of erosion distance over time	RACE techniques	
23	Combined statistical methods model	RACE techniques	
Receptor (for each cliff unit)			
24	Mapping of predicted resultant erosion for worst, average and best cases over time	RACE techniques	

Appendix 6 Conclusions from ‘Understanding barrier beaches’ (scoping study)

Source: *Understanding barrier beaches*, R&D Technical Report FD1924/TR (Stripling et al. 2008). Available from: http://sciencesearch.defra.gov.uk/Document.aspx?Document=FD1924_7426_TRP.pdf

This appendix highlights the gaps in understanding that became apparent through the review and consultation carried out in this scoping study. The gaps reflect the current poor understanding of barrier beach processes and are all issues which affect efficient flood-risk assessment. As a result, effective management strategies are difficult to define.

Uncertainties

Relating to reliability

The following points are raised in relation to the short-term response of barrier beaches. Many of these can be viewed in the light of fragility (i.e. what is the probability of failure under a particular loading).

- What conditions will cause a barrier beach to overtop?
- How much overtopping will occur?
- What conditions will cause a barrier beach crest to be lowered?
- How is a breach likely to form?
- How does the beach material (and its grading) affect the profile change?
- How might permeability change as a result of management?

Relating to resilience

The following points are raised in relation to the short-term response of barrier beaches. Many can be viewed in the light of resilience (i.e. the ability of the barrier to ‘self-heal’, or otherwise).

- How is a breach likely to form and be sustained?
- Will a breach remain open if no active management is taken?
- If the crest of the beach is breached will it reform and how quickly will that be?

Relating to deterioration

The following points are related to the long-term behaviour of barrier beaches.

- How quickly will a barrier beach migrate?
- What factors affect the rate of barrier beach migration?
- What factors will cause the barrier beach to migrate more quickly?
- How does the underlying geology affect the beach evolution?
- What is the impact of rising/falling land on the migration rate?
- How does longshore sediment supply/rate impact on beach performance?
- How will anticipated sea level rise affect the barrier evolution?
- How will the anticipated increases in the height and/or frequency of extreme wave events affect the barrier evolution?
- How might anticipated changes in mean wave direction affect the barrier evolution?

Pathway management tools

The following issues all relate to tools that may or may not be at the disposal of managers. They highlight the need for improved understanding and communication.

- Predictive tools: what are available, are they robust, and are they appropriately applied?
- Can breaching or through-flow events be forecast?
- How does engineering work affect beach performance?
- What will happen if breach/crest lowering is not repaired?
- What management options are available?
- Is beach scraping or re-profiling a sound management practice?
- Why do beaches form steep seaward faces following re-grading (or re-profiling)?
- How can water be removed quickly if a breach occurs?
- Monitoring (see below).

Receptors

Although not examined in great detail by this scoping study, the report touches upon several issues which are of relevance in the source–pathway–receptor model.

- Will overtopping or breaching events be damaging to land or property?
- Will they affect other human needs/desires such as access, safety, amenity, aesthetics, water quality?

- How will the local habitats to landward be altered by an increasing frequency of overtopping, overwashing and roll-back?

Monitoring

The current drive towards improved monitoring of assets (including source, pathway and receptor components) is recognised as a step towards achieving improved knowledge and understanding. Research into best-practice for monitoring methods is not addressed in detail in this scoping study as this topic is dealt with elsewhere in relation to the coastal environment in general. Nevertheless, some issues are raised here which are specific to barrier beaches.

- What should be monitored?
- How often should monitoring be carried out?
- What are the most appropriate monitoring techniques?

Recommendations for future research

Shortfalls in the understanding of processes relating to barrier beaches (and, in some instances, all beaches) are apparent. The scoping study highlights the gulf in understanding between those processes occurring on sandy coastlines and those occurring on coarse- and mixed-sediment coastlines. Since the majority of barrier beaches around England and Wales consist of these coarser sediments, recommendations are focused solely around these barrier types.

Evidence from the case histories and issues raised through review and consultation indicate that the basic understanding of pathway component processes is not in line with ‘end user’ requirements. Therefore, it is suggested that a future research programme be established which concentrates on examining the processes of barrier beaches through experiment and monitoring. As a result of such a research programme, it is expected that a second phase of research into developing robust and reliable numerical predictive tools would be embarked upon. A consequence of this proposed research would be the evolution of a sound set of management guidelines.

The following sections identify topics suitable for investigation in the short- to medium-term. These topics are ordered in terms of perceived priority rather than relating directly to the discussion of perceived weaknesses presented above.

Phase 1: Improving pathway component process understanding

Physical modelling

Physical model investigations of barrier beach processes are required to develop reliable flood forecasting tools that are able to estimate flooding arising from overwashing and through-flow, and also the processes influencing the evolution of the barrier crest such that the onset of breaching can be better understood. These investigations should ideally be undertaken at large scale in order to examine the response of shingle and mixed shingle and sand barrier beaches, which are the commonest. Experiments conducted in scale models could reasonably be expected to enhance understanding of reliability through improved fragility curves.

Other advantages of increasing the available dataset of concurrent morphodynamic response and associated hydrodynamic forcing conditions include the value that these add to the development and range of applicability of parametric and deterministic predictive tools.

Monitoring

There is considerable merit in establishing a national database – perhaps allied to the National Flood and Coastal Defence Database (NFCDD) – containing details of barrier beaches including beach profiles, aerial surveys and LiDAR. Simultaneous measurements of forcing conditions (waves and tides), through-flow, permeability and overtopping would also be required. Subsequent analysis of data could be based on procedures adopted by the Channel Coastal Observatory for beach management in southern England and in context with the framework provided in the report.

There is generally a shortfall of data relating to specific storm events. Hydrodynamic data describing barrier performance under extreme conditions (e.g. measurement of volumes of water overtopping or flowing through barriers) should be obtained. Information regarding waves and tides corresponding to overtopping and through-flow events should be gathered simultaneously. A broad study including many sites is necessary in order to provide detail at sites where the geometry and grain size are wide ranging and where conditions are variable. The case history sites studied illustrate this variability.

The nature of barrier beach evolution is such that storm events are episodic and planning of a short-term field-based programme would not guarantee results within a defined timescale. The rarity of such data, however, means that obtaining records during just a single event could be regarded as a success. Existing field monitoring programmes (funded by Defra) could be refined to provide appropriate levels of data. Ongoing data collection as part of the south-east and south-west regional coastal monitoring programmes could provide appropriate site-specific data to assist in this particular research objective. The long-term deployment of waverider buoys and tide gauges can provide hydrodynamic input to this programme.

Considerable raw data are becoming available that could enable a description of the performance of barriers to be developed at both decadal scales and, to a lesser extent, storm event scale. Much of this data has not been analysed previously in context with barrier performance or management. A considerable proportion of these data are already held by the Channel Coastal Observatory (for southern England).

Data obtained by through-storm measurement of nearshore waves and gravel beach morphology (e.g. using shallow angle LIDAR) would prove pioneering and provide valuable insight into the behaviour of barrier beach faces. A research programme such as this would benefit from support by the Environment Agency and contribute to further understanding some of the processes active on barrier beaches.

Such investigations could usefully be combined with laboratory tests under controlled conditions to focus on testing and development of more robust and wide-ranging predictive techniques.

Phase 2: Improving pathway component prediction tools

Numerical modelling

The data collection and analysis research (Phase 1) is intended to lead to improved understanding of the pathway component processes. It is expected that the datasets and the improved understanding gleaned through analysis of the data will contribute to improved predictive tools. As these tools develop, so too will process understanding.

Predictive tools are currently very limited in scope and application. Tools that are actively applied consist of Powell's SHINGLE model (1990) and Bradbury's dimensionless barrier inertia model (2000). Other tools, which are not in routine application, include the OTTP-1D process-based numerical model developed by HR Wallingford as part of the ANEMONE suite with funding under MAFF commission FD0204. The only tool designed specifically for prediction of barrier beach performance under extreme conditions is Bradbury's Inertia Framework (2000). These could form the basis for future investigations, which might sensibly be conducted in large-scale physical model tests supported by field investigations.

Bradbury's dimensionless barrier inertia model provides a first approximation for the prediction of overwashing threshold conditions; this can be refined further by the selective testing of conditions close to the overwashing threshold under more closely controlled conditions, with minimal spatial variability (of the barrier profile). Near prototype-scale random wave-flume studies would:

- aid the development of confidence in the modelling methodology;
- minimise the scale effects;
- provide confirmation of the functional relationships over the lower part of the barrier profile (these cannot be measured, practicably, in the field).

The influence of shingle grading on barrier crest evolution should also be examined. Future development should be supported by the large-scale physical model tests and field investigations suggested as part of the Phase 1 research.

Other empirical frameworks developed for sand beaches could be examined further, but these are generally even less sophisticated.

Although not strictly applicable to barrier beaches, the SHINGLE model could nevertheless be augmented by the proposed monitoring. This model is simple to use and is currently being applied to solve barrier beach problems. Therefore, developing this rapid spreadsheet model would be a justifiable task with the potential to offer a low-cost solution to some of the problems faced during flood risk assessment.

Development would include giving the model the ability to be run repeatedly for a variety of different loadings, with increased capacity to represent the overwashing process derived from physical modelling tests and monitoring – essentially deriving a probabilistic risk-based method of assessing the performance of barrier beaches. Output from the model could be expected to consist of an improved expression of the fragility of the barrier, which could then be used to better inform RASP-type flood inundation analysis.

The focus of the short-term future numerical model development is therefore based on using Bradbury's barrier inertia framework or Powell's SHINGLE model as a starting point. However, there is no reason to disregard the possibility of the development of a process-based numerical model over the medium-term. The basis for such a model could, for example, be the OTTP-1D model developed by HR Wallingford. The OTTP-1D model was built to simulate surf-zone hydrodynamics over porous beaches; it provides predictions of overtopping rates assuming an immobile beach and accounts for permeable structures.

To further develop this model (or even the 2D version, OTTP-2D) towards full morphodynamic capability would enable detailed process-based deterministic assessment of barrier beach design in relation to standards of flood defence. While this implies considerable time and resource investment, it is nevertheless considered a worthwhile task and would result in a generic industry standard tool for assessment of likelihood of breaching of barrier beaches.

The feasibility of the 2D option predicting the development and spatial variation of the planshape of a shingle barrier beach due to the combined influence of longshore transport and overtopping should be investigated. The sensitivity of the barrier profile response to spatial variation of the barrier geometry should be examined in the systematic assessment of three-dimensional response; this would require an extensive test programme to provide statistically valid data.

The longer term aim should be focussed on the development of a methodology to represent barrier beaches within a broad-scale systems model (such as that being developed under the FLOODsite and FRMRC research programmes) so that longshore connectivity and cross-shore processes are considered in tandem. Useful tools and concepts developed under the RASP methodology (e.g. fragility and resilience) could serve to enable such a model development while maintaining practical computational effort and user operability.

Providing effective and efficient management guidelines for the pathway component

Although it would be convenient to label the provision of management guidelines as a ‘Phase 3’ research programme (i.e. to wait for a significant advancement in understanding before issuing guidance), the reality is that there is an urgent need for advice and methods in the short term. It is suggested that first research need is a ‘best practice’ document which focuses on the use of existing methods and understanding, including monitoring practice. Tools for the development of site-specific schemes of management are adequate for shingle beaches (physical models), but there is no generic guidance available that assists with the design of suitable beach geometry to enable the beach evolution to be controlled adequately.

The fundamental difficulty is to assess the volume of water passing over/through a barrier beach under a given scenario (i.e. defined wave/ tide conditions and perhaps an assumed future beach profile). Over a longer term it may be necessary to judge when a barrier beach will retreat over an important hinterland asset such as a coastal road. The former will need the ‘predictive tools’ mentioned above which will involve the acquisition of information on past events that caused problems, together with the database resulting from the proposed monitoring. The second issue can be addressed through analysis of beach profiles, maps and any data on the episodic nature of crest retreat with some degree of success.

In many cases, the first thing coastal managers will want to do is assess the need to manage a barrier beach. This will typically require a flood risk assessment (more rarely an erosion risk assessment), which will provide an indication of the requirement to ‘manage’ or otherwise.

Given a good reason to manage the beach, i.e. showing that it needs maintaining or improving to reduce flood risk (or more precisely at this stage to improve defence standards), then one can turn to deciding what to do. It is unlikely that much can be done about the source, although improved wave/tidal prediction can be made with site-specific data collection. Similarly, the receptor could be improved so that it could accommodate greater flood/erosion risks (e.g. move the asset out of harm's way), but source and receptor behaviour are beyond the remit of this scoping study.

To improve the management of the pathway component it is proposed, as a first step, to improve the knowledge of the pathway. This step is aimed at providing more detailed data collection (Phase 1) and modelling (Phase 2); for example, short-term intensive measurements of beach response to validate predictions of morphological changes under 'normal', rather than extreme, forcing conditions enabling 'weak points' along the barrier to be identified.

The next option is to consider intervention methods. These include:

- recycling beach material from over-stocked to under-stocked areas;
- beach re-profiling – but ideally recovering material from the landward side rather than scraping the front face upwards;
- adding temporary or permanent crest level enhancement (gabions, etc.);
- adding a sea wall or rock revetment partly buried in the crest or to the rear;
- adding beach sediment – either small-scale trickle charging using construction or excavation waste or large-scale operations.

These methods would be examined alongside the enhanced predictive tools discussed above, with due consideration of the whole life costs and environmental impacts. These might include compensating for coastal squeeze if the barrier is prevented from retreating.

A revised 'best practice' guide would evolve. This guidance is something that might be best published in Beach Management Manual II.[41] There may be a need for short-term review of such schemes before then, which could be undertaken as part of the Defra/Environment Agency scoping study for Beach Management Manual II. Revisiting the online consultation method initiated as part of the present scoping study would provide assistance.

Delivery tools

A dedicated website (mapping and pooling UK experience) has been established as part of this scoping study. Findings from this research programme will be made available on the website (http://www.barrierbeaches.org.uk).

During the course of the scoping study, managers and academics (together with other interested parties) were invited to contribute to a pooling of experience of barrier beach management around England and Wales. A proforma to ease the provision of information was made available. In the event, there was poor response to the request for information with only one form being returned completed. A more effective method of obtaining the required information was found to be through meeting those managers with direct experience of barrier beach management.

[41] The review of the Beach Management Manual is underway at the time of writing (April 2009). Any further developments of best practice guidance for barrier beaches would have to await some future revision.

Appendix 7 Recommendations from 'shingle and mixed beaches' study

Source: *Influence of permeability on the performance of shingle and mixed beaches*, R&D Technical Report FD1923/TR (She et al. 2007). Available from: http://sciencesearch.defra.gov.uk/Document.aspx?Document=FD1923_7402_TRP.pdf

Matrix of recommendations (Table 8.1, She et al. 2007).

Type of study	Most relevant for user groups, including Defra/Environment Agency	Most relevant for researchers
Laboratory experiments	• Permeameter measurements to investigate the effects of sediment grading and increasing sand content on the hydraulic conductivity • Experiments on the effect of sand fraction and other factors on cliffing • Experiments on the optimum design profile to reduce cliffing • Experiments on sediment transport and beach profile evolution using a range of sediment mixtures, with concurrent measurements of hydraulic conductivity • Experiments on effects of compaction	• Permeameter measurements of hydraulic conductivity with a range of sediment mixtures • Experiments on initiation of motion using a range of sediment mixtures • Experiments on initiation of motion, sediment transport and beach profile evolution with infiltration/exfiltration • Experiments on kinetic sorting using a range of sediment mixtures • Experiments on reflection on mixed beaches • Measurements of porosity, packing, pore diameter distribution, particle shape, capillary effects
Field experiments	• Monitor newly recharged beaches to identify times when cliffing occurs; collect sediment samples at these times to test hypotheses about causes of cliffing • Experiments on placement of coarse material on upper beach • Measurements of adjacent sites with normally placed and selectively placed recharge material • Continue measurements of groundwater on recharged beaches, or develop new sites for similar measurements	• Detailed measurements of sediment size distributions, sand content, in-situ hydraulic conductivity, water-table elevation, moisture content, hydraulic gradients • Short-term tracer experiment to identify sediment transport paths on recharged beaches • Cliffing and sediment size distribution of natural beaches

Numerical modelling	• Test predictions of existing profile evolution models against data from mixed beaches	• Development of new models for mixed beaches
Recharge	• Monitor and quantify effects of recharge delivery systems and recovery techniques • Monitor sediment sorting following a recharge • Assess economic and technical viability of obtaining smaller volumes of coarse sediment from other sources for placing on upper beach	
Other	• Ensure that regional monitoring programme receives information on recharge and recycling times and locations • Collect data on total amount of sand and gravel available from licensed sites • Collect data on future capital recharge programmes for existing schemes to define remaining life of currently licensed resource • Investigate the possibility of setting aside certain areas of coarse sediment for beach recharge rather then other aggregate uses	• Development of standard methodology to characterise bimodal sediments

Notes All recommendations are in suggested order of priority within each category:
red = overall highest priority
blue = relatively low cost
purple = high priority and relatively low cost
green = long-term

Appendix 8 Conclusions and recommendations from 'sand dune processes and management for flood and coastal defence' project

Source: *Sand dune processes and management for flood and coastal defence. Part 1: Project overview and recommendations*, R&D Technical Report FD1302/TR (Pye et al. 2007). Available from:
http://sciencesearch.defra.gov.uk/Document.aspx?Document=FD1302_5395_TRP.pdf

Coastal sand dunes are of considerable coastal flood defence significance in several parts of England and Wales, as well as being of importance for nature conservation, recreation and other reasons. If current predictions regarding acceleration of future sea level rise prove to be correct, the areal extent and possibly the continued existence, of some systems (especially narrow, fringing and non-climbing systems) will be placed under severe threat.

Wherever possible, natural processes should be allowed to take their course so that dune systems can evolve to achieve a new equilibrium with the forcing factors. This may involve a reduction in dune area and loss/reduction of some important habitats in certain areas, but there is likely to be partial compensation by development of new dune habitat elsewhere. A reduction in the natural flood defence value of some dune systems is also likely unless remedial works are undertaken, including large-scale beach nourishment, dune re-profiling and vegetation planting (as has been done for many years in the Netherlands). Whether or not such action can be justified and considered environmentally acceptable will depend on local circumstances.

In order to provide a better basis for informed decision making, it is recommended that a geomorphological evaluation study (GES) should be undertaken for each of the dune sites or appropriate group of sites identified in this report. These studies should seek to quantify more precisely:

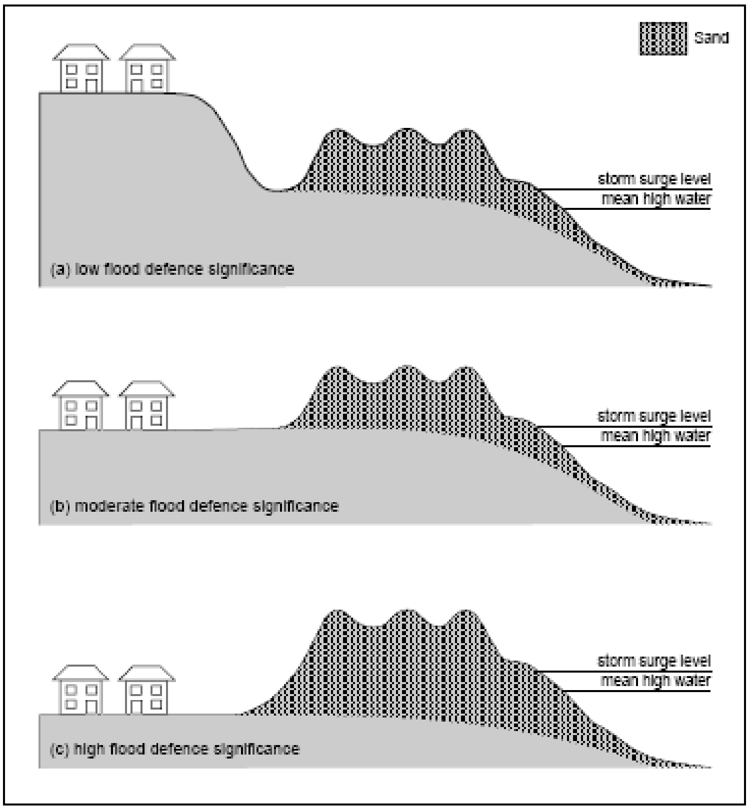
- the beach and dune sand volumes present above various datum levels;
- the rates of recent morphological change;
- the nature of the frontal dune vegetation and degree of sand mobility;
- the area at risk from flooding behind the dunes;
- the standard of existing flood defence provided by the dunes;
- the standard of defence which is desirable given the commercial and environmental asset value of the protected land.

These assessments should also consider the nature of morphology and process regime in the adjoining nearshore and offshore areas in order to develop predictive models of the likely three-dimensional evolution of each beach–dune system in the short, medium and long term. The GES for each dune site should be co-ordinated by the relevant authority responsible for flood and coastal defence. It should take into account other existing studies and plans including Shoreline Management Plans (SMPs) and Local Biodiversity Action Plans (LBAPs), but its outputs should seek to inform and guide the next generation of such plans rather than be governed by them. The scale of study required will clearly vary from area to area, depending on such factors as:

- the size of dune system;
- current and potential future coastal flood defence significance;
- habitat significance.

Monitoring of all dune systems should be seen as a high priority in order to provide early warning of potentially significant changes and to allow sufficient time to consider and design appropriate responsive strategies. Some dune systems are already covered by comprehensive physical and biological monitoring programmes (e.g. the Sefton coast), but this is not true everywhere and steps should be taken to improve the position where required. LiDAR and kinematic GPS ground-based surveys now provide rapid and cost-effective methods of acquiring the necessary physical information from large areas.

Monitoring data should be collected and stored in a standard and easily accessible format (e.g. Microsoft® Excel files) which can be exported for centralised analysis. Many local authorities and other organisations concerned with sand dune management are now moving to establish databases able to store large amounts of environmental information which can be readily interrogated. This should be viewed as good practice which is to be encouraged. However, such local databases should be accessible so that relevant data can be exported in order to allow centralised analysis of regional and national trends. The possibility of creating a higher level, national beach and dune morphological database – similar to those operated in the Netherlands and Australia to inform both strategic and operational management planning – should also be explored.



Schematic diagram showing degrees of significance of dunes for coastal defence.

Appendix 9 Conclusions and recommendations from 'characterisation and prediction of large-scale, long-term change of coastal geomorphological behaviours' project

Source: *Characterisation and prediction of large-scale, long-term change of coastal geomorphological behaviours,* Science Report SC060074/SR1 (Whitehouse et al. 2009) Available from: http://publications.environment-agency.gov.uk/pdf/SCHO0809BQVL-e-e.pdf

1. Predictive capabilities are the essence of a versatile approach to understanding how the coastal system will evolve. At present, a wide range of tools and techniques are available for coastal managers to explore historical coastal developments and predict future change. The large volume of disparate tools and information highlights the need for a systems-based approach linking behavioural and process models to reconcile the different spatial and temporal scales. A range of coastal features and elements was brought forward in this project to provide a basis for describing coastal systems in a consistent fashion.

2. Using these features and elements provides progresses understanding and prediction of change in coastal geomorphological behaviour. In particular, the framework described in the report provides a basis for the use of different to investigate different elements of large-scale, long-term behaviour. It is strongly recommended that the strengths of this framework and its constituent components are further disseminated to the wider industry.

3. Systems mapping was developed as a method for gaining understanding and explicitly capturing the system features and elements and how they interact, including the effects of human interference. It provides an excellent base for sharing knowledge and building consensus when used in a workshop environment. Training among coastal managers in the use of such approaches is recommended.

4. The systems mapping approach could be developed in areas such as chemical and biological systems (within the context of the Water Framework Directive) and using different thematic canvasses such as economics and recreations (within the context of the broader Integrated Coastal Zone Management).

5. Quantified development of other coupled elements (e.g. dunes and beaches, hard rock cliffs and rocky shore platforms, tidal flats and salt marshes) is recommended. Such modules could be built into the linked approaches developed here in a similar manner as for SCAPE and ASMITA. The fine sediment fraction also needs to be tracked and developments will be required to achieve this.

6. Existing geomorphological methods evaluated in the study provide valuable insights into different elements or links of the overall system. Further

development of these methods is recommended for their inclusion in future modelling.

7. The study has confirmed that current practice involving taking outputs from a range of appropriate tools (e.g. systems mapping, modelling and geomorphological methods) and integrating them within the context of expert geomorphological assessment (EGA). This situation is not expected to change in coming years, but this research should help to refine and integrate these tools and methods. To support EGA into the future, it is recommended that dissemination and skills training are carried out.

8. The results of this project should help shape future development of risk-based coastal management techniques and Integrated Coastal Zone Management, Shoreline Management Plans, strategy studies and project appraisal. Potential links to RASP (Risk Assessment for Strategic Planning) and NaFRA (National Flood Risk Assessment) are presented in the report. These will also apply to other versions of quantified risk assessment.

Appendix 10 Goals and tasks of Phase 2 of 'assessment and measurement of asset deterioration including whole life costing' project

Source: *Assessment and measurement of asset deterioration including whole life costing*, Science Report SC060078/SR2 (Brommer et al. 2009). Available from: http://publications.environment-agency.gov.uk/pdf/SCHO0509BQAV-e-e.pdf

Phase 2 of the project is intended to set up the long-term programme of data gathering from pilot sites in Phase 3 and also produce a number of user-focused deliverables.

The main goals of Phase 2 are:

- To improve the fundamental understanding of the processes of deterioration of common material and components in key FRM assets through a targeted data collection and monitoring programme. Wherever possible this will involve developing quantified or quantifiable models of deterioration processes.
- To investigate, further develop and test robust methods and models for assessing the deterioration of high risk FRM asset types in order to provide improved estimates of deterioration and residual life.
- To develop and test robust cost models to establish criteria for determining the optimum and/or most cost-effective time and type of intervention in the deterioration process and their effects on whole life costs.
- To provide practical updated guidance to ongoing flood defence asset management in relation to deterioration and whole-life costs.

A long-term programme of research based on monitoring and evaluation of selected pilot sites will be required to achieve these goals. Extension of the monitoring and data collation scheduled for Phase 2 into a long-term data collection programme (Phase 3) is recommended, carried out primarily by the Environment Agency and other operating authorities (or their contractors).

The R&D project will also provide support to the further development of other projects such as:

- the follow-on to the PAMS Phase 2 project – the R&D recommended by this study should be seen as an integral part of the PAMS programme;
- the new Environment Agency Asset Management supporting system– by suggesting which data on asset deterioration should be included;
- ongoing projects related to maintenance works – by providing practical support on developing decision-making criteria for Operations Delivery managers selecting a particular maintenance standard and estimating the whole-life ownership costs.

The proposed work packages for Phase 2 are:

- WP 1: Developing and conducting a focussed data collection and monitoring programme (0–36 months)
- WP 2: Developing and testing robust methods and models for assessing asset deterioration of key FCRM asset types (12–24 months)
- WP 3: Developing and testing robust methods and models for assessing whole life costs under different maintenance regimes for selected asset types (12–24 months)
- WP 4: Developing improved guidance on determining asset deterioration and assessing the effects of different maintenance regimes (24–36 months)

Appendix 11 Conclusions and future research needs from ‘a new perspective on the sea defence value of saltmarshes’ project

Source: *Quantifying saltmarsh vegetation and its effect on wave height dissipation: results from a UK East coast saltmarsh* (Möller 2006)

A field study has, for the first time, quantified wave energy dissipation over a UK saltmarsh and has confirmed that marshes can act as efficient wave buffers. Relationships between water depths, marsh surface elevations, incident waves and wave attenuation have been established. This study also illustrates, however, that if naturally or artificially created saltmarshes are to be included in sea defence assessments or new coastal management schemes, the role of marsh surface topography and vegetation type has to be adequately quantified. In addition, to ensure the long-term sustainability of marsh (re)creation schemes, there is now a fundamental need to increase our understanding of marsh stability in the face of increasing sea levels and storm frequencies. A study of wave attenuation over open coast salt marshes in Essex is currently underway to address some of these issues.

Appendix 12 Outcome Measures

Source:

Defra website
(http://www.defra.gov.uk/environment/flooding/policy/strategy/outcomemeasures.htm)

Extending Outcome Measures (Environment Agency/Royal Haskoning 2009)

Outcome Measures is a structured system of scoring economic, environmental and flood risk criteria. The system requires:

- flood risk to property to be reduced by a degree that is commensurate with the density of population;
- sites of environmental significance (nationally and internationally) to be protected or appropriate mitigation to be put in place;
- the proposed scheme costs to be in line with Treasury expectations on return on investment and annual expenditure budgets.

The Outcome Measures system has yet to be fully implemented and it continues to be refined for practical use. Of the nine Outcome Measures (OMs), seven apply to both flood and coastal erosion risk and two to flood risk only.

1. Overall benefits

This shows the benefits of flood and coastal erosion risk management activities in monetary terms. Where possible, aspects of the natural and historic environment and social benefits are included. In time the costs and benefits of protecting properties, infrastructure, transport links, the environment and so forth will be identified separately as well as the total benefits.

2. Households at risk

The number of households at risk from flooding or from coastal erosion is shown by this measure. Households at risk of flooding are placed in one of four bands which describe the probability of flooding (very significant, significant, moderate or low). For households at risk of erosion, the time before the property is expected to be lost to erosion is used. The number of households in each of four time bands is counted, from the short-term (erosion likely within 10 years) to long-term (erosion likely between 50 and 100 years).

3. Deprived households at risk

This measure enables the level of flood and coastal erosion risk reduction to the most deprived communities to be targeted. It uses an established ranking of deprived areas (the Index of Deprivation rank for Super Output Areas), combined with the risk bands for flooding and erosion described above to indicate the risk to deprived communities.

4. Nationally important wildlife sites

This measure records, through liaison with Natural England, the delivery of flood, water level and coastal management remedies which contribute to the government target to have 95 per cent of Sites of Special Scientific Interest in favourable condition by 2010.

5. UK Biodiversity Action Plan habitats

Flood and coastal erosion risk should improve the natural environment as well as reducing the risks to people and property. This measure records the overall increase in Biodiversity Action Plan habitat achieved through flood and coastal erosion risk management activities.

6. Flood warning (flood risk only)

Flood warning allows those living and working in areas that can flood to take action to reduce risks, particularly to people. This measure records the proportion of households and businesses in high risk areas that are offered the Flood Warnings Direct service and have registered to receive warnings. There is no equivalent measure for coastal erosion.

7. Contingency planning (flood risk only)

The Environment Agency works with other bodies in Local Resilience Fora to plan for different types of emergency. This measure shows the percentage of Local Resilience Fora emergency response plans that are considered by the Environment Agency to satisfactorily address flood risk. There is no equivalent measure for coastal erosion.

8. Inappropriate development

This shows the number of households covered by planning consents which have been granted despite Environment Agency objections on flood risk grounds. A similar measure for coastal erosion will be used when national maps showing erosion risk are available.

9. Long term policies and action plans

For the first few years of the Outcome Measures system, this measure will ensure that sustainable, high-level plans for managing flood and coastal erosion risks are developed. It will show the percentage of Catchment Flood Management Plans and Shoreline Management Plans that have been signed off by Environment Agency Regional Directors.

Appendix 13 Spatial planning at the coast

The Planning and Compulsory Purchase Act 2004 (PCPA 2004) amended the forward planning aspects of the town and country planning system. Table A13.1 list the main elements of the system.

Table A13.1 Key elements of the planning system.

Central government	**Planning policy statements (PPS)**
Regional planning bodies (RPBs)	Regional Spatial Strategy (RSS)
London	Spatial Development Strategy (SDS)
Local planning authorities (LPAs)	Local Development Frameworks (LDF) of local development documents (LDD) as set out in Local Development Schemes (LDS) made up of: • Development plan documents (DPD); • Supplementary planning documents (SPD).

Coastal risk is an increasingly important issue which affects future development and land use at regional level, particularly in relation to major redevelopment and regeneration areas that are low lying. Shoreline Management Plans (SMPs) provide a major source of information for such policy. Bringing together RSSs and SMPs allows scientific and technological information to inform regional spatial policy. The RSS also provides an opportunity for public examination of resulting policy.

Policies set out in local development documents need to cover a number of different aspects and issues related to coastal risk. Table A13.2 summarises these requirements.

Since flood and coastal defence legislation in England and Wales is permissive, it does not confer a right to protection except in very limited circumstances. For flood defence works funded by the taxpayer, decisions on where to invest or continue to invest should be made in the light of the dangers to life, potential damage to assets measured in national economic terms and legal requirements – the aim being to maximise the public benefits within the available budget.

Table A13.2 Required contents for LDD policy development.

Policies concerning development in areas of risk	• Indicate that long-term, sustainable approaches to managing risk are sought in the face of expected impacts of climate change. 'Safe' use of development relates not only to the site but also to emergency access. • Draw attention to the sequential test of Planning Policy Guidance 25 (PPG25) and indicate the response to different categories of development. • Indicate how applications will be dealt with, the need for flood risk/stability assessments and the need for consultation. • Indicate the significance of the SMP and the defence options (advance the line, hold the line, no active intervention, managed realignment) for development proposals.
Policies where planning permission may be granted in areas of risk	• Indicate that planning applications in risk areas must be accompanied by a flood risk/stability assessment indicating how risk is to be mitigated. • Indicate that new development must not generate immediate or long-term demand for public spending on defence works and that works required must be paid for by the developer. • Set out the contexts (including for emergency access) in which defence works are provided through planning contributions. These will establish where and how prescribed means and relevant requirements will apply. • Link the 'life' of permission to the life of existing defences to avoid granting permission for development in perpetuity which leaves people and property at risk in the longer term future.
Planning policy for coastal defence development	• Establish the scope of policy for renewal of existing defences and for provision of new coastal protection and sea defence works. • State that the need for conformity with SMP will be a consideration. • Provide a reminder of potential impacts on European sites for nature conservation (SPAs and SACs) and long-term implications for mitigation and/or compensation (to be cross-referenced to nature conservation policies). There should be similar reminders of impacts on man made heritage. • Establish criteria for environmental acceptability – appearance, design, materials. • Highlight the opportunities for public access. • Highlight the potential need for signage.

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