Predicting large scale coastal morphological change – from fiction to fact

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Relevance of the new findings to coastal management

A new practical framework and methodology for creating new models capable of predicting long-term and large-scale geomorphological evolution has been developed. The outputs enable clear and consistent understanding of the geomorphology to support the management of complex coastal environments. This is supported by an evaluation of selected practical modelling and analysis techniques for the prediction of mid to long-term coastal geomorphological evolution including management interventions.

The report (Reference 1) describes how the results of geomorphological studies can be incorporated through the process of Expert Geomorphological Assessment (EGA) to improve the confidence in the decision making process. Recommendations were made on how to include the results in future rounds of SMP development.

How you can benefit from this research

- Access to a modular description of coastal geomorphology
- A description of how to involve Expert Geomorphological Assessment in coastal management
- A new and usable approach to system mapping of coasts
- Coupled modelling of coast and estuary management scenarios

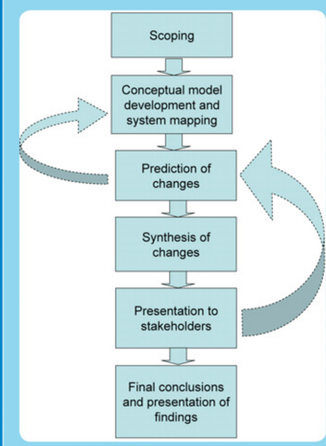
Research drivers

The strategic role of the Environment Agency with respect to coastal erosion and flood risk management requires the delivery of appropriate and sustainable management of coastal erosion and marine flood risk, particularly over long timescales and within large scale systems. Evaluations of complex coastal systems, such as those that include open coasts and inlets, a coast and estuary or coast and offshore banks require the flow and sediment interactions to be determined for a realistic assessment of likely future change.

Illustration of two adjoining coastal geomorphological features

Including Expert Geomorphological Assessment (EGA)

The proposed framework for geomorphological studies can be applied in a consistent fashion to coastal and estuary management.



Framework for studies

Expert Geomorphological Assessment (EGA) provides a sound basis for evaluating past, present and future behaviour within testable conceptual models. The interpretation and integration of the results from geomorphological studies is undertaken through the process of EGA. EGA allows the full range of management issues to be considered, from those with precedent to those which are bespoke and not governed by historic analogues.

The research has provided a wider awareness of the role of EGA in understanding coastal behaviour so that coastal managers can ensure the use of appropriate techniques to assess large scale and longer term changes.

1. Problem Definition
   - Study objectives
   - Limits of study area
   - Timescale
2. Collation and analysis of Existing Background Data
   - Desk Study
   - Site visit
3. Development of preliminary Conceptual Model
   - Identify gaps in knowledge
4. Additional Data Collection
   - Remote sensing
   - Field Surveys
   - Sediment sampling and analysis
   - Computer modelling
5. Data synthesis and refinement of Conceptual Model
6. Explanation/Prediction
7. Recommendations

The seven stages in Expert Geomorphological Assessment

The geomorphological basis for coastal behaviour and management

The description of geomorphological features and elements provides a common basis of understanding and for assessing the role of management interventions.

Analysis of behaviour is underpinned by a conceptual model which provides a hypothesis that can be tested thus adding rigour to the evaluation. In order to quantify the geomorphological evolution of a stretch of coastline, it is necessary to analyse the state of the system in terms of:

- the present day nature of the coastline and its composition;
- its origins and past state;
- its controlling and forcing mechanisms; and,
- its behavioural characteristics.

A standardised approach to the description and analysis of coastal features was included in Reference 1 and 2.

The features are built from geomorphological elements which are the building blocks of any assessment. 17 elements were defined and used in the system mapping.

These elements are well known but those marked with * have been described in a standardised format for the first time in Reference 2.

The representation of management techniques and interventions in coastal systems has been described based on analogues of natural processes in Reference 1. This is a helpful way of thinking about management since it puts the natural behaviour and management techniques on a compatible basis.

Features defined in Reference 1

Offshore, Open coast, Headland, Bay, Spit, Cuspate foreland, Inlet, Tombolo, Barrier island, Estuary, River, Updrift coast, Downdrift coast

Elements defined in Reference 1

Sea cliff, Coastal dune*, Coastal lagoon*, Beach*, Shore platform*, Tidal flat*, Saltmarsh*, Channel*, Inlet-associated bank*, Headland-associated bank, Offshore bank*, Beach ridge, Offshore reef, Seabed sand, Seabed gravel, Low ground, High ground*

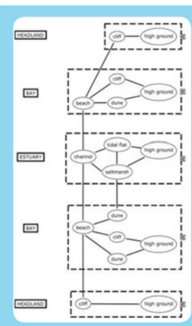
Management techniques related to type of management and shoreline management policy

Shoreline Management Policy DEFRA (2006)	Management technique: Hard defence	Soft defence	No interference
Hold the existing line	Long terminal groynes Short groynes Seawalls and revetments Breakwaters and reefs	Recharge Recycling Bypassing Beach re-profiling	
Advance the existing defence line	As above, plus Reclamation embankments	Recharge	
Managed realignment	Different engineered breach mechanisms and embankments	Use of fine grain dredged material (form of recharge)	No maintenance
No active interference			No maintenance

Using system mapping to support coastal management

System mapping provides a clear and consistent basis for formalising understanding, for sharing information and having debate amongst stakeholders about common areas of understanding and resolving areas of disagreement. It also provides a basis for analysing the degree of connectivity of the coastal system. The research has delivered a practical approach for considering coastal geomorphology in a consistent fashion by developing a system map as a basis for the consolidation of knowledge and formulation of a conceptual model.

Box A *The methodology envisages coastal system mapping as a two stage process. The first stage involves conceptualisation of the coastal system in terms of a set of discrete components and the representation of the interactions between these components in diagrammatic form. The features and elements provide the basis for these components. This could be undertaken as a pencil and paper exercise. However, construction of system diagrams is easily accomplished with the aid of specialist computer software and, to this end, we utilised CmapTools (available as freeware from: http://cmap.ihmc.us). The second stage involves the analysis of connectivity between the components.*



Example of coastal system mapping – a geographical map and a linear representation of the same system (built using Cmap tools – see Box A)

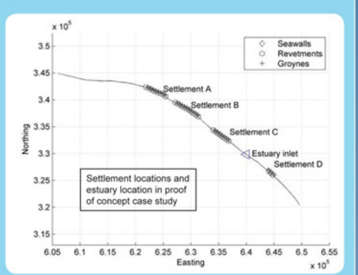
Coupled coast and estuary modelling

Behavioural systems models have been implemented to proof of concept level for a fictional but realistic coupled coast and estuary system (Reference 4).

The system map based conceptual model was developed and formalised into numerical model form. It is a good example of how (with adequate follow-on research) systems models could be used to support the difficult problem of long-term management of a changing coastline.

This study used existing systems-based behavioural models (SCAPE and ASMITA), linked through the exchange of sediment.

It demonstrated the benefits of a coupled modelling approach to evaluate geomorphological behaviour at SMP timescales (up to 100 years), including sea level rise and management interventions.



Evaluation of analysis techniques

A range of analysis techniques has been evaluated by the project (Reference 1). For each technique a description, summary of metadata, and example applications have been provided. The techniques described fall broadly into four types:

1. Behavioural models of coastal change: Historical Tend Analysis and future change extrapolation, the Bruun rule and equilibrium beach shape.
2. Process-based models: one-line models, coastal profile models and coastal area models.
3. Change of state models: Shingle and barrier inertia models for the breaching of barrier beaches and tidal inlet stability tools.
4. Systems-based models: e.g. SCAPE and ASMITA.

The range of existing behavioural models of coastal change, process-based models and change of state models, and associated analysis techniques, have been assessed and are shown to be worthy of further application and development.

Analysis techniques evaluated in Reference 1

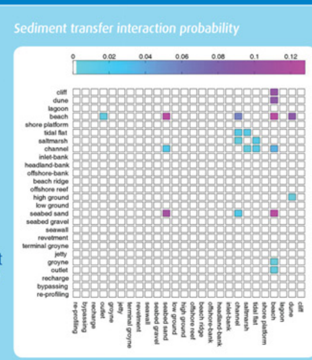
Historical Trend Analysis and Future Change Extrapolation
Bruun rule and related methods
Equilbrium bay shape
One line models
Coastal profile models
Coastal area models
Breaching of shingle barrier beaches
Tidal inlet stability
Reduced complexity systems models

Case study applications

Three systems mapping case studies were produced (Reference 1), these were:

1. The 73 km stretch of the Suffolk coastline between Lowestoft and Landguard Point (i.e. coastal sub-cell 3c).
2. Alnmouth Bay in Northumberland which, showed how the system mapping approach can be applied at a smaller scale (approximately 15 km).
3. Cardigan Bay in Wales was used to demonstrate the application of the approach to a 267 km stretch of coast that encompasses the entirety of coastal cell 9 (with two sub-cells).

Sediment transfer interaction probability



The systems mapping approach described in Reference 3 provides a means of developing systems-based models from the conceptual models used by geomorphologists. It will also deliver benefits in the next round of Shoreline Management Plans (SMP3).

Coupled modelling to address management questions

The results of coupled modelling were used to inform the answers to practical coastal management questions:

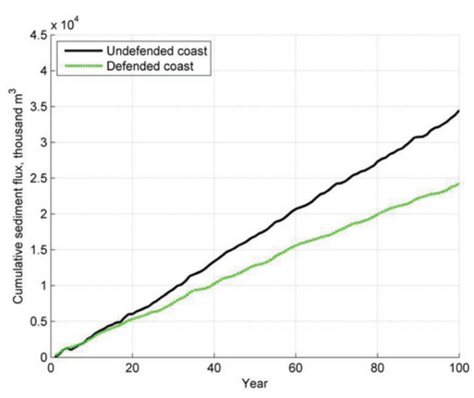
1. If existing structures fail at settlement A, how much cliff recession will occur over the next century?
2. If present management policy (defend) is continued at settlement A, how will the shore platforms evolve over the next century?
3. If present management policy (defend) is continued at settlement A, how will wave loading on the existing structures change over the next century?
4. If settlements A, B, and C are defended for one century, will this affect sediment flux to the estuary? – **See Box B**
5. If 380 hectares are reclaimed from the estuary what will be the resulting loss of intertidal habitat?
6. If 380 hectares are reclaimed from the estuary and simultaneously settlements A, B and C are defended what will be the resulting loss of intertidal habitat?
7. Would such interventions affect the downdrift shoreline at settlement D?
8. Which of the options (1) retreat estuarial seawalls or (2) retreat estuarial seawalls and allow coast protection structures to fail causes least flooding?

Outputs from similar modelling exercises will enable better planning of coastal works and improve understanding of the consequences of not intervening. The modelling involved description of elements including cliffs, beaches, shore platforms, intertidal flats, channels and ebb tidal deltas. New modules are required to describe other elements such as dunes, spits, marshes and nesses.

The systems-based behavioural modelling approach offers a means of developing predictive capacity at the broad scales required by coastal managers.

Box B

If settlements A, B, and C are defended for one century, will this affect sediment flux to the estuary?



Answer: Defence construction and maintenance will, over the course of the century, reduce sediment supply to the estuary by approximately ten million cubic metres.

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A project website is also available: **www.coastalgeomorphology.net**