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Dealing with geomorphological concepts and broad scale approaches for estuaries

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DEALING WITH GEOMORPHOLOGICAL CONCEPTS AND BROAD SCALE APPROACHES FOR ESTUARIES

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Abstract

This paper describes the outcomes of Defra project FD2116 which has developed a framework for Expert Geomorphological Assessment (EGA) including the systematic development of conceptual models of estuarine systems which can form one basis for prediction. This approach relies upon collation, synthesis and interpretation of various types of data from estuaries; key issues associated with data have been reviewed. The paper summarises the review of the use and application of the "top-down" class of assessment methodologies that may be considered for use in developing EGA approaches. The study has developed the assessment of tools first carried out in the EMPHASYS study; these include:

- Historical Trend Analysis (HTA);
- Regime theory and relationships;
- Estuary translation or Rollover model;
- Entropy-based relationships;
- Tidal asymmetry analysis and relationships;
- Analytical methods and solutions;
- Sediment budget analysis and modelling;
- Geological methods for estuarine studies; and,
- Intertidal profile form.

The application of the assessment tools has been illustrated using a variety of case studies and, where possible, guidance in the use of the particular assessment tools in terms of their applicability, data requirements, and outputs has been developed. The project has been completed as part of the joint Defra/Environment Agency R&D Programme.

Introduction

The study of Estuary Geomorphologyi includes the need to study cause and effect at many different time-scales:

- Geological (millions of years) – geology of estuaries;
- Holocene (thousands of years) – creation of estuaries as we know them;
- Anthropogenic history (in the UK , effectively since Roman times) – land reclamation and the impact of agriculture;
- Near history (100-200 years) – quantitative recorded data, impacts of industry and of major engineering schemes in estuaries such as dredging and training wall schemes;

- Decadal (post-war) – more accurate data, impacts of dredging and port-development, salt-marsh loss; and,
- Years – changes in estuary sub-systems, mudflats, creek systems, etc.

Additionally many underlying physical processes within estuaries occur on much smaller time scales with some, relatively speaking, being instantaneous in that the characteristic time of action ranges from seconds to a spring-neap cycle. The investigation of these underlying processes will involve a consideration of these smaller time-scales. Improved understanding of Estuary Processes has been delivered recently by the EstProc project FD1905 (EstProc Consortium, 2004; www.estproc.net).

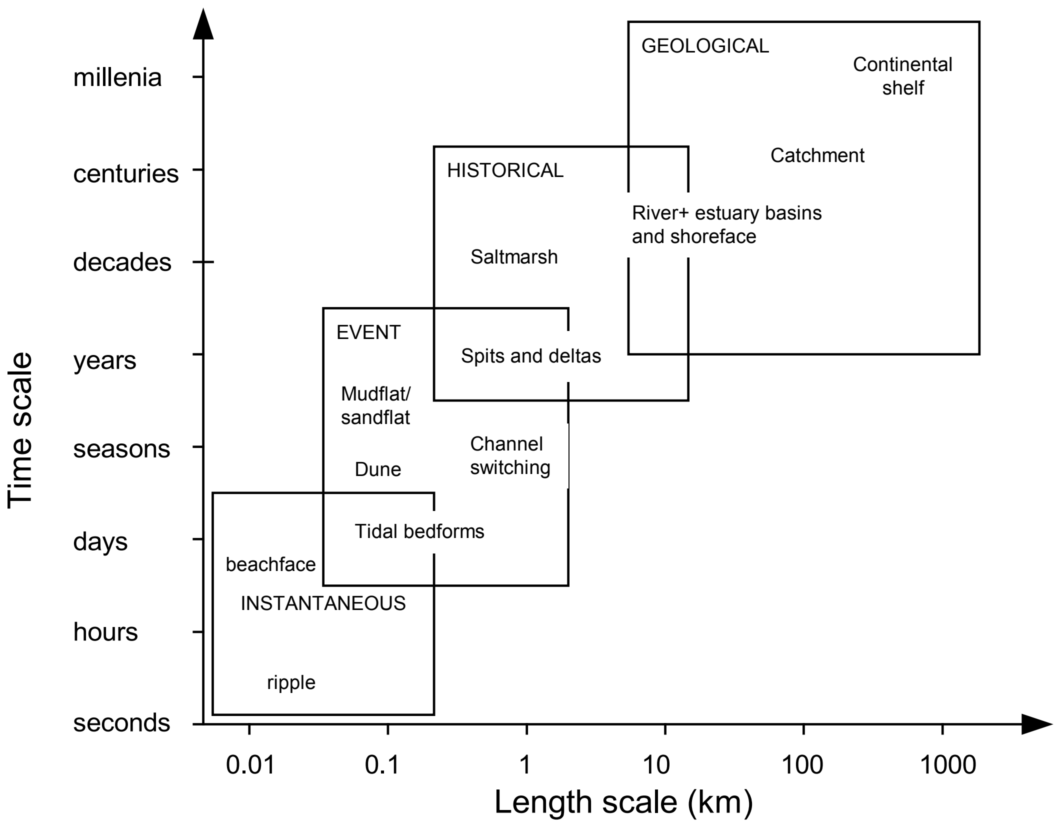

Figure 1 Definition of spatial and temporal scales involved in hydro-geomorphological evolution (after Cowell and Thom, 1994)

For the case of studies supporting estuary engineering and management decisions the time-scales of interest relate to the Event and Historical time-scale (Figure 1), and exceptionally in the case of very large schemes time-scales verging on the Geological time-scale. It is clear that the study of estuary morphology over the whole spectrum of time scales is helpful in understanding the behaviour of any particular system. However, the dominance of the days, seasons, years and decades as the key time-scales in implementing management techniques means that the emphasis in estuary geomorphological studies has to be towards tools and techniques that can work at the Event, Historical and Geological time and space scales. Knowledge of geological or historical geomorphology aids the understanding of a system so as to improve the quality of the geomorphological studies.

The paper contains sections which indicate the continuity and context of the research that has been completed in FD2116, the framework for EGA studies, a discussion of EGA and the HTA methodology, data and predictive tools.

Continuity of research

One of the over-riding aims of the Estuaries Research Programme (ERP) is to meet the needs of users and managers through the provision of appropriate technical and decision-support tools (French et al, 2002). Phase 1 of the ERP (ERP1) benchmarked the current level of understanding and capabilities for predicting morphological change in estuaries (EMPHASYS, 2000a, b). A range of tools and models were applied during that project (top-down, hybrid and bottom-up models – see below) and the performance assessed against common datasets. The research recommendations (EMPHASYS, 2000c) delivered by the ERP1 included a recommendation to strengthen and formalise the use of top down modelling approaches and concepts currently used in Expert Geomorphological Analysis (EGA) and Historical Trend Analysis (HTA). This same recommendation was highlighted in the Estuaries Research Programme Phase 2 Research Plan as a core project (French et al, 2002).

Townend (2000) observed that this does not merely mean the provision of new tools but the translation of model outputs and the interpretation of data into information that can inform the decision-making process. Though much of the ERP is targeted towards development of new tools a need was identified to bridge the gap between current scientific understanding of the applicability of the presently available geomorphological tools and the practical needs of estuary managers. In particular the need to strengthen and formalise the use of top down modelling approaches and concepts currently used in EGA and HTA was highlighted in EMPHASYS (2000a,b) and re-iterated by French et al (2002) as a core project in the Research and Development Plan.

The programme of research undertaken in FD2116 has delivered a rigorous approach to EGA and HTA, which has potential to lead directly to improvements in the quality and effectiveness of morphological studies associated with flood defence and estuarine impact. The research follows a strand of continuity, in terms of ideas and personnel, from the consistent approach taken in the Estuaries Research Programme Phase 1B Guide (EMPHASYS, 2000c). This work was produced by the EMPHASYS consortium (led by HR Wallingford and including ABPmer and John Pethick) and by HR Wallingford in the Phase 2 Uptake Project (FD2110). The output from both these projects highlighted the benefits of a rigorous approach to the use of data and modelling techniques and the need for careful construction of a robust conceptual model. The research approach developed by the project team has extended this rigorous scientific approach within the Defra Broad Scale Modelling Theme.

A framework for expert geomorphological assessment

The EMPHASYS (2000a) guide set out a basic framework for assessment and prediction of morphological change within estuarine systems as have Townend (2000) and Dearnaley et al (2004), amongst others. Any impact assessment of a particular project in an estuary system will consist of a scoping exercise, analysis of the way the system works, prediction of impacts, and discussion with client and regulator about the conclusions of the study. This may lead to further clarification of the issues arising from the project, and additional work leading to refined conclusions and presentation of the study outcomes.

These components of an impact assessment are summarised in Figure 2. The structure of Figure 2 is not definitive but is typical of the broad nature of estuarine studies to support estuary management. We have used Figure 2 as a representative template for estuarine studies, and briefly explain the different components presented in the figure.

Scoping is where the objectives and methodology of the project are mapped out. This includes consideration of the potential effects resulting from a man made project or natural change on local or estuary-wide morphology, evaluation of the availability of and the potential requirement for new data, and the identification of the needs of the client and regulator. In practice this component overlaps with the next component, *Conceptual Model Development*. The correct application of EGA is heavily dependent on an understanding of the system being studied, often referred to as a conceptual model (Box 1). The stages in developing a conceptual model are schematised in Figure 3 which is intended to guide, if the necessary inputs are available, the development of a robust model. As indicated in Box 2, the quality and quantity of data is important in this process.

Box 1 What is a conceptual model?

A conceptual model is a formal explanation of how the system (or sub-system) functions, including the key controlling mechanisms and their relative importance, of the reasons for the historic development (if relevant over the defined model area and time-scale) of the system (or sub-system) and of the reasons for present trends within the system (or sub-system).

An incomplete or poorly focussed conceptual model may lead to incorrect assumptions about the system, poor utilisation of predictive approaches and incorrect assessment of impact. Therefore the characteristics of available data and the conceptual model are very important to the integrity of any study (Box 2).

Box 2 Summary of approach to data

Quality (and quantity) of data

↓

A **robust** conceptual model

↓

Confidence in the results (certainty)

The next component in the overall framework is the implementation of predictive assessment (*prediction of impacts)*. Having a firm and correct understanding of the system will form the basis for the correct choice of predictive methods and will enhance confidence in the conclusions of the study. If one or more model approaches are implemented then some formal synthesis of the results will be required (*synthesis of impacts*). New insights may lead to an adjustment of the conceptual model and further predictive assessment. The *initial conclusions* arising from the synthesis will be explored during *discussions with the client and regulator* and these discussions may lead to some clarification of the issues and the requirement for further predictive work may be highlighted. Finally, when all the outstanding issues have been addressed the *final conclusions* of the assessment can be formally presented (*presentation*).

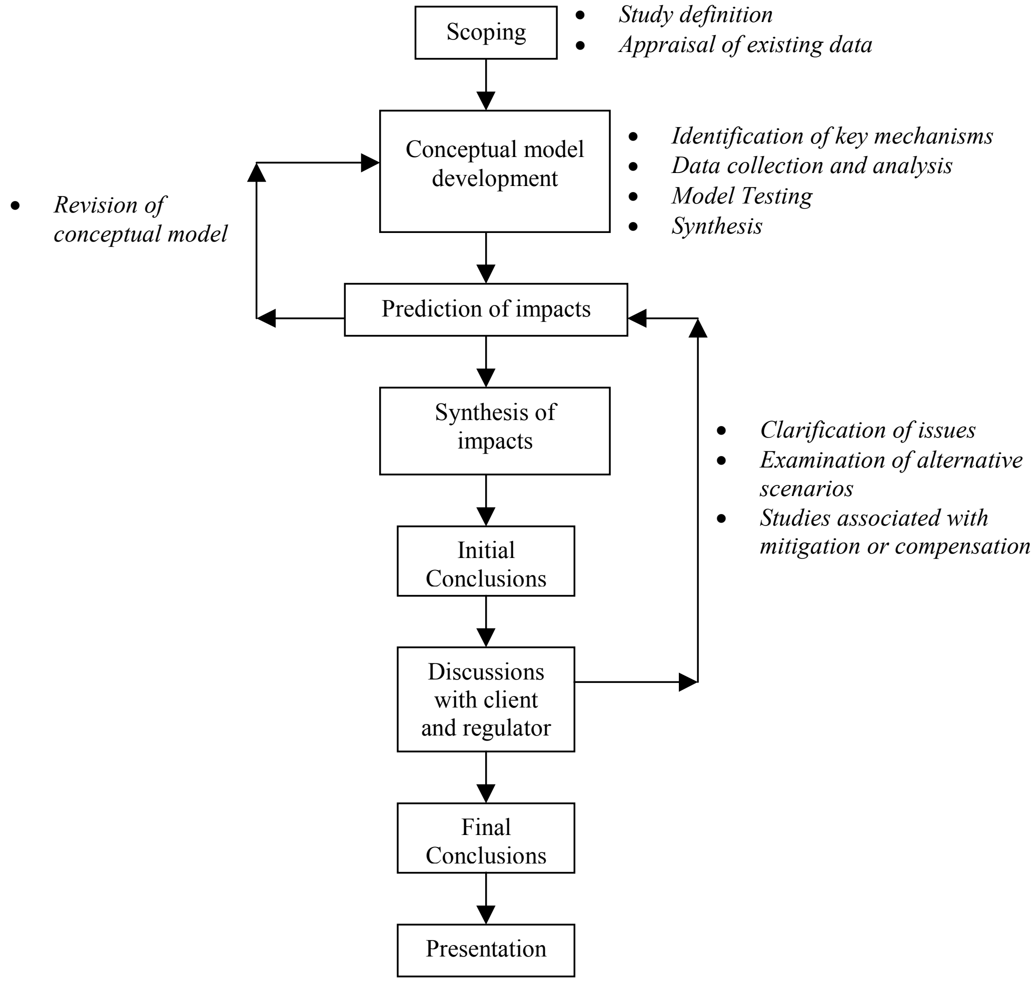

Figure 2 Summary of stages in EGA studies

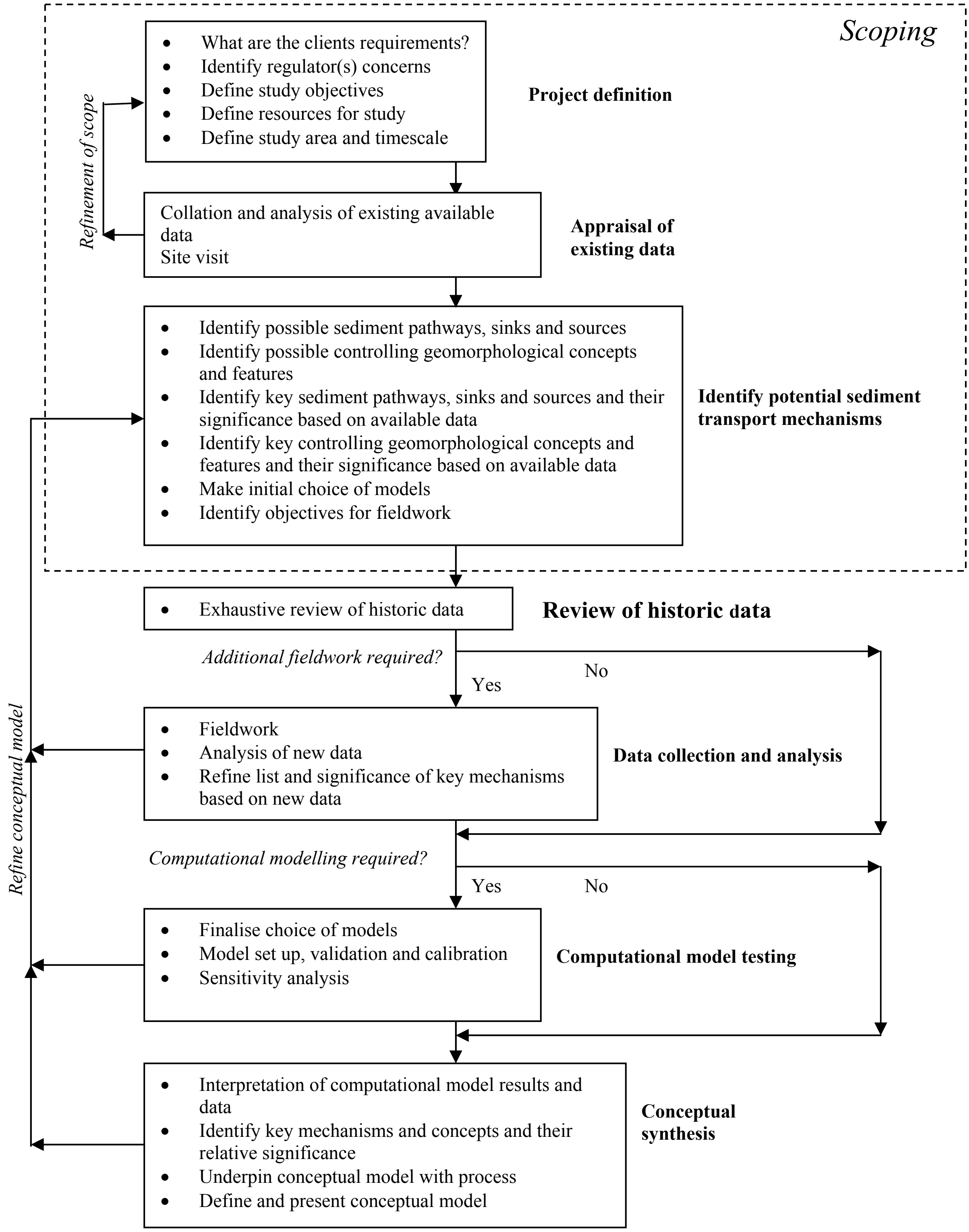

Figure 3 Stages in the development of the conceptual model

Background to EGA and HTA

EGA is a term attributed to Pye and Van der Wal (2000) who coined it during the EMPHASYS project. EGA describes those activities undertaken in geomorphological assessment which were not directly associated with either computational or physical modelling or field measurement, i.e. the assessment activities concerning top-down concepts and background experience in both an estuary system and the discipline of geomorphology. In practice EGA is an imprecise term because it can be applied to geomorphological assessment undertaken without accompanying modelling/field studies but also to activities that take place within modelling/field studies as a pre-cursor to, or overall framework for, such modelling and fieldwork. EGA encompasses the use of HTA and other geomorphological tools but also uses knowledge and/or modelling of estuarine process, usually physical but also chemical and biological, to establish an understanding of the underlying functioning of the system. This understanding is then used as the basis for predicting quantitatively or qualitatively the impacts of natural or man-made change using the relevant geomorphological tools.

HTA is a geomorphological tool involving the analysis of time series data to identify trends and features in estuarine process and/or evolution. HTA can be used for all types of data (e.g. tidal levels, wind or wave records) but more frequently is used to evaluate the past and current trends in morphology. The key issues associated with HTA are described in Table 1, which includes a summary of the limitations of the method. The application of the HTA method has been examined within six case studies in the report, for the estuaries listed in Table 1.

Table 1 Key issues summarised from the review of Historical Trend Analysis

Issue	Historical Trend Analysis
Description	Assessment of data from different periods in time in order to identify directional trends and possibly rates of change of morphological features or physical processes within an estuary
Temporal Applicability	Past 1-200 years, depending on data availability
Spatial Applicability	Whole estuary or specific geomorphological features/geographical locations within an estuary, depending on data availability
Links with Other Tools	• Complements longer-term geological analysis approaches. • Can provide useful data to inform 'regime analyses'. • Provides key input to establishing a conceptual understanding of the longer-term estuary behaviour during 'synthesis of results' (or Expert Geomorphological Assessment (EGA)).
Data Sources	Newspaper articles, published papers, parliamentary records, land registry archives, anecdotal evidence, maps and charts, aerial photography, topographic and bathymetric surveys, remote sensing imagery
Necessary Software Tools / Skills	• Identifying, collating and reviewing relevant data/information sources • GIS/image processing software/photogrammetry • Cartography/digital ground modelling • Geomorphological interpretation of output (EGA)
Typical Analyses	1. Changes in shoreline position (e.g. MHW, MLW) 2. Changes in channel/bank morphology or position 3. Changes in sediment volumes above certain datums 4. Identification of areas of 'cut' and 'fill' or erosion/recession and deposition/progradation over time

Limitations	• Availability of historic data can be limited in some areas • Accuracy of some historic datasets can be questionable • Different measurement techniques, specifications, datums, units, density of data points in successive datasets • Identifies net change between successive datasets, but not the scale of variability over shorter timescales • Need information on anthropogenic intervention which is often not well documented • Many estuaries can exhibit long relaxation (lag) times before changes are manifest, making cause-consequence assessments difficult
Example Applications	• Humber Estuary • Ribble Estuary • Mersey Estuary • Stour Estuary • Southampton Water • Chichester Harbour

EGA and HTA can be summarised as the analysis and application of data together with a knowledge of estuarine processes and specific geomorphological tools blended by experience. The processes and techniques are often well known but can be misapplied, either because the technique is misunderstood or the data for which the technique is employed has shortcomings. Moreover, the assessment of uncertainty in prediction, a vital part of evaluating risk in estuary management, is often lacking from EGA studies. Experience plays an important role in allowing the investigator to reduce the misapplication of EGA techniques, but the end user is not always aware that they are benefiting from this attribute. The formalisation of the process in a clear framework provides the end user with an opportunity to appreciate such benefits.

Data

The range of data that might be available for a morphological study is outlined in Box 3.

With existing data the issue of data quality is even more important than for field data because there is no control and often no appropriate description over how the existing data was collected. This is particularly true of historic data. It is therefore important to check the quality of data, datums and projections.

Box 3 What data might be available?

- Bathymetry/coastline/topography
- Dredging/disposal records
- Tidal levels, waves, currents, salinity, water quality
- Seabed sediments, suspended sediments, bedforms
- Sedimentary characteristics
- Biota, vegetation
- Geological

For long-term assessments of morphological change there are additional data requirements to the data outlined above:

- Climate change data;
  - sea level change
  - history of the wind and wave climate
- Synoptic historical data sets;
- Bedrock and surface geology; and,
- Feedback between biology/vegetation and morphological change.

Over long periods of time the extent of sea level rise becomes significant and needs to be incorporated into any hindcasting or forecasting of change, as do changes in the wind and wave climate. Hindcasting of morphological change is aided considerably by synoptic historical data sets of hydrodynamics and bathymetry, which, though rare, do exist for some estuary systems.

For future predictions of morphological change it is essential to know how the evolution of the estuary may be constrained by geology. This aspect has been addressed in FD2116. As important, is the role of biology and vegetation in controlling morphological change. At present there is very little scientific knowledge regarding the morphological feedback from biology and vegetation, although some recent advances have been made (EstProc Consortium, 2004). The absence of this feedback in a morphological prediction results in additional uncertainty. The conclusions relating to data drawn in FD2116 are as follows:

1. Data is paramount to EGA studies and the use of data should be carefully managed in such studies to enhance confidence in the assessment;
2. Data is by its nature site-specific and a full range of data is not always available;
3. Collection and collation of data is time-consuming and can be expensive;
4. Collection of data is not the end of the problem - each type of data has sources of error associated with its collection which need to be understood;
5. Understanding of the technical aspects of collection and the use for which the data is being collected will reduce the level of uncertainty in the data collected;
6. Review and analysis of data are essential (and also time-consuming and expensive);
7. There is a requirement in every study to maintain some flexibility in the project and budget for actions arising from review of data; and,
8. There is a requirement to understand how uncertainty in the data feeds through to the conclusions.

Predictive tools for estuary morphology

There is a range of tools available to investigate estuary process and morphology, as described for example in EMPHASYS (2000a). Two approaches have generally been taken to predicting morphological change in estuaries: (1) "bottom-up" or process-based approaches and (2) "top-down" or systems approaches.

The "bottom-up" approaches employ models which are based on a representation of physical principles (processes) and give short-term predictions of morphological change. The credibility of these types of approach is increased with calibration and validation using appropriate site specific measurements of relevant processes. The value of bottom-up models is the explicit representation of hydrodynamic and sediment transport processes, leading to morphological change, within the system. However, the long-term predictive capacity of these methods is not always sound as numerical errors, and errors from uncertainty in the description of physical processes, can accumulate with long model run times. Methods to improve the application of process-based models to medium to long term morphological prediction have been investigated in the Defra funded EstProc project (EstProc Consortium, 2004).

The "top-down" approaches employ models which do not in general predict the sediment transport process directly to reach a prediction of morphology. Instead they take more general conceptual or systems based approaches to determining the relationship between forcing variables and the resulting characteristic morphology; a good example is the regime type approach which is based on empirical correlations between a measure of the capacity of the system to move sediment (e.g. tidal prism) and a characteristic feature such as cross-section area at the mouth of the estuary. However, whilst there are many features of top-down models which make them attractive for examining the state and response of a particular estuary morphology, the conceptual nature of the methods means they are more appropriate usually for general rather than detailed assessments.

Results from both bottom-up and top-down approaches require careful analysis, validation and expert interpretation.

There is a third category of methods, the so called "hybrid" approach. This is the combined use of "bottom up" and "top down" techniques. The bottom-up component provides an understanding of forcing processes and the top-down component provides information on the system state and how that wants to change as the forcing is changed.

The present study has examined the use and application of assessment methodologies and tools that may be considered for use in EGA, building on the top-down methodologies investigated in the report "Modelling Estuary Morphology and Process" (EMPHASYS, 2000b). Those covered in FD2116 are:

- Historical Trend Analysis (discussed above);
- Regime theory and relationships - this involves the characterisation of the link between hydrodynamics and estuary morphology in terms of a simple empirical formula(e) which can be used to describe both the estuary equilibrium (or quasi-equilibrium) and its subsequent evolution following disturbance to the system. The theory is applied in two distinct forms – application to estuary and tidal inlet entrances and application throughout estuary systems. New work in the project has examined the theoretical bases for these approaches;
- Estuary translation or Rollover model – this is a concept regarding a general tendency of estuary response to sea level rise which can be then quantified using application of other top-down approaches such as regime theory. The approach simulates the process by which the estuary transgresses longitudinally landwards and vertically upwards thus keeping its position in the tidal frame;
- Entropy-based relationships – this is a method of characterising the most probable state of an estuary by minimising entropy production in an open system, which is closely linked to minimising or maximising energy dissipation. New work has been completed in the present project which enables the state of development of these methods and their limitations to be described, building on the work done in EMPHASYS (2000a, b);
- Tidal asymmetry analysis and relationships – this can be used as a means of evaluating historical changes in estuary functioning and to evaluate physical impact arising from development. Asymmetry relationships focus on the effect of estuary morphology on tidal propagation in order to identify trends in net sediment transport and thus to identify future morphological changes;
- Analytical methods and solutions – these group of mathematical expressions, often derived from first principles resulting from a simplification of estuary systems, can be utilised to gain insight into the functioning and potential changes within an estuary system;
- Sediment budget analysis and modelling – this consists of the evaluation of sediment fluxes, sources and sinks from different mechanisms within a control volume (e.g. a section of a coast or an estuary) in order to gain a better understanding of the functioning of the estuary system;
- Geological methods – estuarine morphology is a response to energy inputs from tides, waves and river flow acting on a suite of materials embracing inherited geology and ongoing sediment inputs to the coastal system. The geological component of this interaction embraces the topography as well as the lithology[ii] and structure of the rock that encompasses the estuary. Although all estuaries share a common set of dynamic driving forces, the morphology of each estuary will display a unique set of adjustments to its inherited geology and topography. This inherited topography is referred to as the 'accommodation space' of an estuary (EMPHASYS, 2000b); and,
- Intertidal profile form – the intertidal zone provides the morphological transition between the subtidal channel of the estuary and the shoreline with its natural features, such as saltmarsh, or man-made coast protection or flood defence works. Various methods are

available relating the equilibrium profile to the prevailing forcing by tides and/or waves.

The applicability of the models for estuary morphology modelling is summarised in Table 2. This aids in method selection for different studies. Confidence in the obtained results is maximised through the process presented in Box 4.

In HR Wallingford (2005) a detailed review of each method is presented. Owing to the limited space in the paper only two of the reviews have been presented in more detail, the HTA approach, described above, and that based on Regime theory described below.

Regime approach

The basis of regime approach to estuary assessment and prediction has been taken further in the project by reviewing the physical basis. The approach based on entropy considerations and sediment transport for both sandy and muddy estuaries are described. The key issues are summarised in Table 3.

Box 4 Building confidence in model results

The Guide (EMPHASYS, 2000a) suggests some key ways to enhance the computational modelling results and build confidence in them and the resulting conceptual model:

Bottom-up models

- Expect site specific calibration and validation and a measure of accuracy of the key variables.
- Seek to understand the difference between model results and measurement. Don't assume either is right – they both contain uncertainty.
- Seek to calibrate sediment transport models against sedimentation patterns (bathymetric changes and/or dredging records).
- Where at all possible validate against historic records.

Top-down models

- It is unlikely that site-specific calibration is possible for top-down approaches although it is possible that generic applicability may be demonstrable.
- It is important to ensure that there is a physical basis for morphological change predicted by top-down models.
- Are the results consistent for those of other similar estuaries?
- Are the results consistent with other top-down approaches?
- Be aware of the scope for error in the method.
- Where possible, validate against historic records.

Table 2 Summary of generic models applicable to different causes of change in estuaries (modified from Pontee and Townend, 1999)

			Data Analysis Methods			"Top down" Methods						Hybrid Methods	
Cause of change	**Spatial scale**	**Temporal Scale**	Accommodation Space	Histroical Trend Analysis	Sediment Budget Analysis	Regime Relationships	Analytical methods	Tidal Asymmetry Analysis	Intertidal Form Analysis	Estuary Translation (rollover)	**Process Based "Bottom up" Methods**	**Regime based**	**Energy/Entropy based**
Freshwater	Xt	Lg		x		x		x				x	x
	Xt	S/M					x				x		
Tide	Xt	S/M					x				x		
	Xt	Lg		x		x		x				x	x
Sea level	Xt	Md					x				x		
	Xt	Lg	x	x	x	x		x		x		x	x
External waves	Xt	S							x		x		
	Xt	M							x		x		
	Xt	Lg				x						x	x
Local waves	Lc	S							x		x		
	Es	S/M									x		
	Es	Lg										x	x
Sediment inputs	Xt	S			x				x		x		
	Xt	M			x				x		x		
	Xt	Lg	x	x	x	x						x	x
Barrage	Lc	Fx								x	x		
	Es	Fx				x	x	x			x	x	x
Barrier	Lc	Fx									x		
	Es	Int					x	x			x		
Deepening	Lc	S		x	x						x		
	Es	M/Lg		x	x	x		x		x	x	x	x
Fauna	Lc	M									x		
	Es	M									x		
Flora	Lc	M									x		
	Lc	Lg											
Intake/outfall	Lc	Fx									x		
	Es	Fx									x		
Jetty or pier	Lc	Fx									x		
Reclamation	Lc	Fx									x		
	Es	Fx				x		x		x	x	x	x
Sea defences	Lc	Fx									x		
	Es	Fx				x		x		x	x	x	x
Training works	Lc	Fx									x		
	Es	Fx				x					x	x	x
Managed realignment	Lc	Fx							x		x		
	Es	Fx	x	x	x	x		x		x	x	x	x
Intertidal recharge	Lc	S							x		x		
	Es	S		x	x	x		x			x	x	x

KEY:

Spatial scale of action		*Time scale of action*	
Local	Lc	Short-term (days to month)	Sh
Estuary	Es	Medium term (seasons to a decade)	M
External	Xt	Long-term (decades to a century)	Lg
		Intermittent	In
		Fixed (in human terms)	Fx

Table 3 Regime theory: Summary of Key Issues

Issue	Regime Theory
Description	Characterisation of the link between hydrodynamics and estuary morphology in terms of a simple empirical formula (or formulae) which can be used to describe both the estuary equilibrium (or quasi-equilibrium) and its subsequent evolution following disturbance to the system
Temporal Applicability	Years to a century
Spatial Applicability	Whole estuary or estuary entrance
Links with Other Tools	• Often utilises HTA bathymetric analysis as a basis for the method • Can be used on a number of levels ranging from top-down approach to hybrid model • Can provide input to deciphering historic behaviour during conceptual model development
Data Sources	*Bathymetry*: maps and charts, aerial photography, topographic and bathymetric surveys, remote sensing imagery *Discharge/Tidal prism*: As bathymetry and/or the results of flow modelling *Littoral drift*: Wave models and/or observed wave data and littoral drift models *Suspended sediment concentration*: field measurements at several places within the estuary *Sediment type*: analysed grab samples, water samples, Admiralty Chart sediment information
Necessary Software Tools / Skills	Regime theory covers a range of skills depending on the complexity of the application. At its simplest level the skills required are similar to those of HTA, i.e.: • Identifying, collating and reviewing relevant data/information sources • GIS/image processing software/photogrammetry • Cartography/digital ground modelling • Basic understanding of estuarine process and sediment transport • Geomorphological interpretation of output At its most complex level Regime Theory becomes a hybrid method with the following necessary skills/tools: • Flow model (1D is usually satisfactory but 2D can be used) • Programming/IT skills to link flow model results with regime relationships • Thorough understanding of estuarine process and sediment transport • Experience of predictive modelling in estuarine environments • Geomorphological interpretation of output (EGA)
Typical Analyses	• Prediction of estuary evolution or estuary/inlet entrance evolution following disturbance • Assessment of stability of estuary/inlet entrances (using Escoffier theory)
Limitations	*Estuary/Inlet Entrance Regime Theory* • No underlying analytical basis except (potentially) for inlet or estuary entrances which can be characterised by a balance between littoral drift and ebb-tide transport • The empiricism of this method results in considerable uncertainty, which can limit the applicability of the method • As applied in a predictive sense the method is best suited to tidal inlets. This is because it is often possible to approximate the tidal flows in the inlet by an analytical model, unlike estuary entrances where a flow model will be necessary, and moreover the evolution of estuary entrances will be affected by changes within the estuary as a whole *Estuary-wide regime theory* • Not all estuaries can be described by the type of empirical relationships that this method uses • The form of regime theory commonly implemented does not represent estuary evolution well • Validation data is scarce • Method works best where impacts of a disturbance are 1-dimensional in their effect. Where impacts are 2-Dimensional method works less well • To be used effectively in a predictive sense the technique usually requires the use of a flow model and data relating to sediment and/or sediment transport.

Conclusions

This paper has described some of the outcomes of the FD2116 study into estuary geomorphology. The main objectives of the study were:

1. To review critically the current geomorphological understanding and concepts related to the medium (month-year) to long term (decade-century) behaviour of estuaries; and,
2. Through formalisation of Expert Geomorphological Assessment (EGA) and Historical Trend Analysis (HTA), to provide a resource for the end user so that he/she can substantially increase the quality of their analysis.

The paper has discussed the relevant scales to be considered, issues surrounding the formation of a conceptual model based on data and understanding, and the application of predictive models. These have been achieved and a consistent and formalised approach to the use of geomorphological based methodologies in estuarine prediction has been established (HR Wallingford, 2005). This has the potential to benefit the quality and effectiveness of studies associated with flood defence and estuarine impact.

Additionally the project has linked and integrated with the Broad Scale Modelling Theme projects FD2107 and FD2117. The results of FD2116 have contributed to the development of the hybrid model envisaged in FD2107 and to the development of the estuary simulator, which is the focus of FD2117.

Acknowledgement

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References

Cowell, P.J. and Thom, B.G. (1994). Morphodynamics of coastal evolution, In: Carter R.W.G. and Woodroffe C.D. (Eds.), Coastal Evolution: Late Quaternary shoreline morphodynamics, Cambridge University Press, Cambridge, UK, pp. 33-86.

Dearnaley, M.P., Baugh, J.V. and Spearman, J.R. (2004). Modelling sediment transport and sedimentation. Proceedings of the Maintenance II Conference, Institute of Civil Engineers, London.

EMPHASYS (2000a). A guide to prediction of morphological change within estuarine systems, Version 1B, produced by the EMPHASYS consortium for MAFF project FD1401, Estuaries Research Programme, Phase 1, December 2000. Report TR 114, HR Wallingford.

EMPHASYS (2000b). Modelling Estuary Morphology and Process, produced by the EMPHASYS consortium for MAFF project FD1401, Estuaries Research Programme, Phase 1, December 2000. Report TR 111, HR Wallingford.

EMPHASYS (2000c.) Recommendations for Phase 2 of the Estuaries Research Programme, produced by the EMPHASYS consortium for MAFF project FD1401, Estuaries Research Programme, Phase 1, December 2000. Report TR 113, HR Wallingford.

EstProc Consortium (2004). Integrated research results on hydrobiosedimentary processes in estuaries. Final Report of the Estuary Process Research Project (EstProc). R&D Technical Report prepared by the Estuary Process Consortium for Defra and Environment Agency Joint Flood and Coastal Processes Theme. Report Nos. FD1905 (3 volumes).

French, J., Reeve, D. and Owen, M. (2002). Estuaries Research Programme, Phase 2 Research Plan FD2115, Report prepared for Defra and the Environment Agency, April 2002.

HR Wallingford (2005). Review and formalisation of geomorphological concepts and approaches for estuaries. Report FD2116/TR2 produced for Defra by HR Wallingford, ABPmer, Prof J Pethick.

Pontee, N.I. and Townend, I.H. (1999). An estuary cause-consequence model. In: 34th MAFF Conference of River and Coastal Engineers, MAFF, London, pp. 5.2.1-5.2.17.

Pye, K. and Van der Wal, D. (2000). Expert Geomorphological Assessment (EGA) as a tool for long-term morphological prediction in estuaries. Paper 15 in EMPHASYS 2000b.

Townend, I. (2000), Marine Science for strategic planning and management: the requirement for estuaries, Journal of Marine Policy.

[i] In science morphology consists of the study of form and shape. In the context of estuaries "morphology" is commonly used as a noun relating to the characteristic form or bathymetric shape of an estuary, although the word can also relate to the study of such changes in form over time, hence "geomorphology" (EMPHASYS, 2000b). The JNCC Estuaries Review has categorised the characteristic forms of estuaries: Fjord, Fjard, Ria, Coastal Plain, Bar Built, Complex, Barrier Beach (*with inlets*), Linear Shore, Embayment.

[ii] Lithology is the source rock type

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