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defra
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Environment Agency

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Geomorphological concepts and broad scale approaches for estuaries

(Defra R&D project FD2116)

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Paper 06A.5

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"Review and formalisation of geomorphological concepts for estuaries"

- Research team:
- HR Wallingford
- ABPmer
- Prof J Pethick
- Project duration 15 months

Estuaries Research Programme (ERP) Phase 2, Broad Scale Modelling Theme

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Why?

Engineering studies use a range of predictive methods to assess estuary morphological behaviour and response

At a range of time and space scales

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EMPHASYS (2000) characterised methods:

- Bottom Up
- Top Down
- Hybrid

✓ ERP recognises and extends all methods

(EstProc FD1905 – extension to process understanding and algorithms -> Bottom Up methods)

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- **Method selection matrix (Table 2 of paper)**
- **Spectrum of approaches**
- **BU, TD, H**
- **Integrated application**

Cause of change	Spatial scale	Temporal Scale	Data Analysis Methods			"Top down" Methods					Process Based "Bottom up" Methods	Hybrid Methods	
			Accommodation Space	Histroical Trend Analysis	Sediment Budget Analysis	Regime Relationships	Analytical methods	Tidal Asymmetry Analysis	Intertidal Form Analysis	Estuary Translation (rollover)		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

Local	Lc
Estuary	Es
External	Xt

Time scale of action

Short-term (days to month)	Sh
Medium term (seasons to a decade)	M
Long-term (decades to a century)	Lg
Intermittent	Int
Fixed (in human terms)	Fx

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Overarching EGA approach…..

EGA - Expert Geomorphological Assessment

- **The analysis and application of data together with a knowledge of estuarine processes and specific geomorphological tools blended by experience**

After: Pye and Van der Wal (2000), EMPHASYS

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How?

- ✓ **FD2116 concentrated on Top Down methods**

1. **<u>Review critically</u> the current geomorphological understanding and concepts related to the medium (month-year) to long term (decade-century) behaviour of estuaries**

2. **F<u>ormalise</u> approaches to Expert Geomorphological Assessment (EGA) and Historical Trend Analysis (HTA)**

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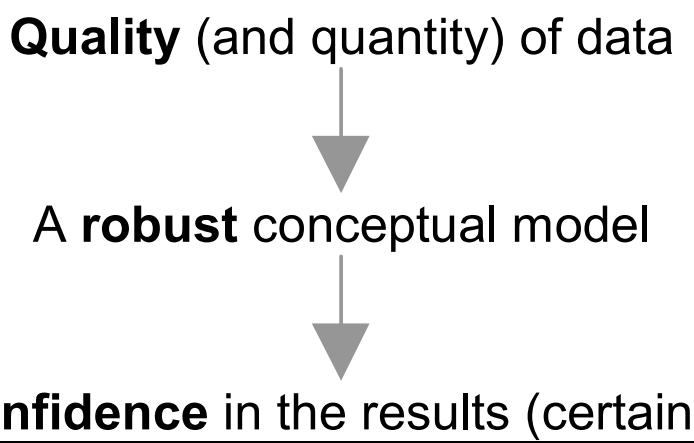
Reducing uncertainty

Conceptual model of how the system (or sub-system) functions and data

Box 2 Summary of approach to data



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FD2116 team has developed the assessment of the following methods within EGA framework:

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

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1. Historical Trend Analysis (HTA);

- **Geomorphological tool dealing with the analysis of time series data to identify *trends* and *features* in estuarine process and/or evolution**
- **Many types of data (for example)**
  - tidal levels, wave records, morphology

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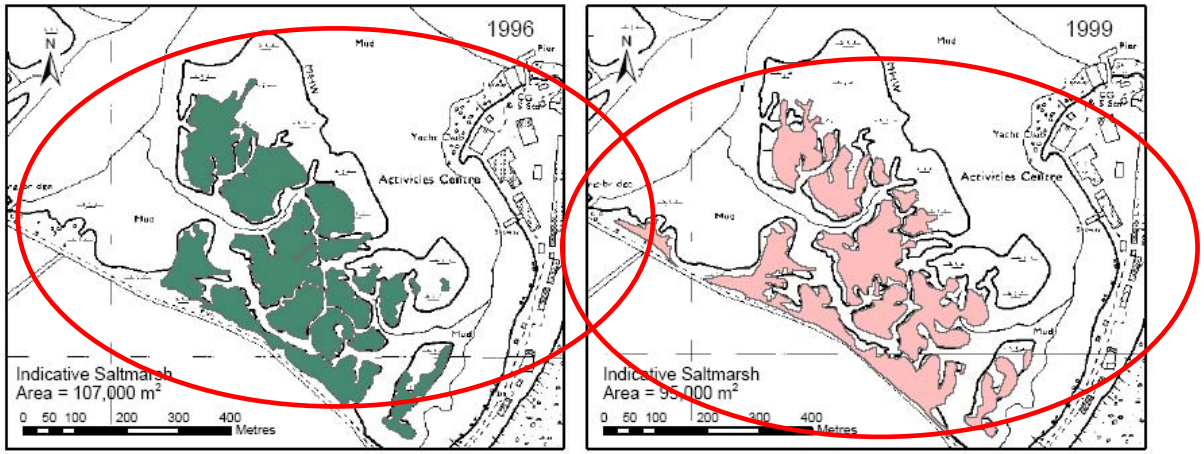
- **Analysis of trends (and rates of change)**
- **Plan Form Changes (e.g. Calshot marsh)**



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2. Regime theory and relationships;

- **Characterising the *link* between hydrodynamics and estuary morphology**
  - E.g. tidal prism and cross-section area
- **Simple empirical formula to describe the estuary *equilibrium* and its subsequent *evolution*, following disturbance to the system**
- **New work in the project has examined the theoretical bases for these approaches**

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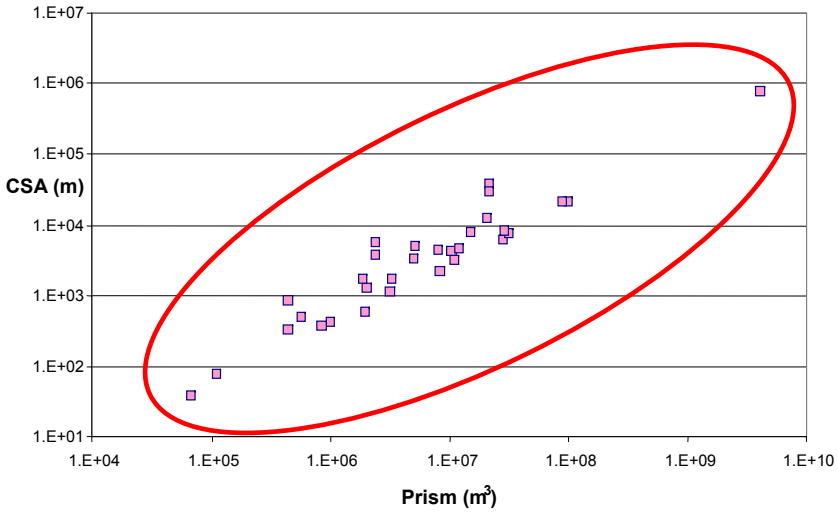
Critique of the traditional theory

- Prism-area relationships can be developed for groups of estuaries/inlet entrances
  - Understand errors
- Previous work has shown that other factors besides discharge and area are important, and need to be incorporated into the regime relationship for estuaries eg:
  - Waves
  - Fluvial flow (e.g. Dyer, EstProc)
  - Sediment type



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So…

- Analysis was undertaken for FD2116 which showed the following:
  - The forms of regime relationship commonly used do not describe the long term sediment transport well enough in estuaries
  - The forms of "appropriate" regime relationships for sandy and muddy estuaries are different

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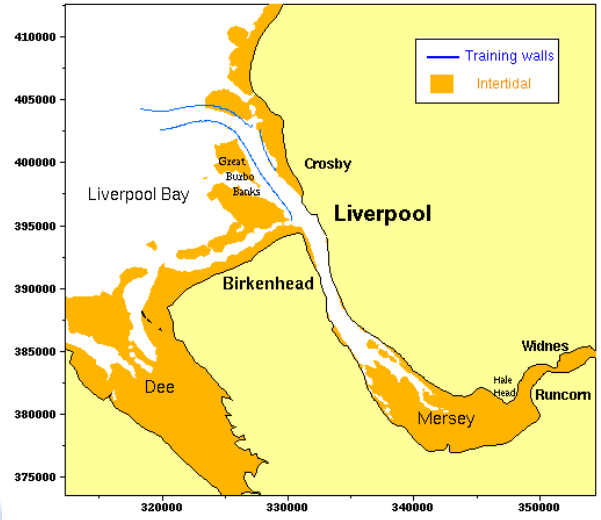
To illustrate the implications of the limitations of the old regime relationship

we used the example of the Mersey Estuary

- Considerable morphological change in 20th Century
- Training walls at estuary mouth in 1911….



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Benefits of a change in the regime formula?

- The old regime theory could not reproduce the observed morphological change because the initial change in hydrodynamics within the estuary was small
- Use of more appropriate formula takes account of:
  - the increase in sediment supply,
  - producing accretion in the estuary,
  - which in turn causes the observed enhancement of ebb-dominance,
  - leading to reduction of sediment import, and
  - attainment of a new equilibrium.

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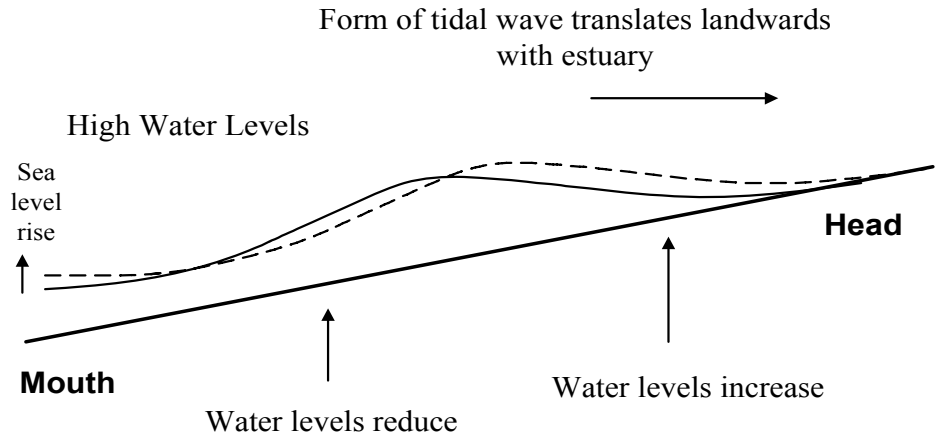
3. Estuary translation or Rollover model;

- **Based on the concept regarding a general tendency of estuary response to sea level rise**
  - Allen
  - Pethick



  - Requires sediment supply

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4. Entropy-based relationships;

- **Characterising the most probable state of an estuary by minimising entropy production in an open system**
- **New work has been completed**
  - Describes the state of development of these methods and their limitations, building on EMPHASYS
  - At present a diagnostic tool for most probable state
  - Focus of ongoing research

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5. Tidal asymmetry analysis and relationships;

6. Analytical methods; and,

7. Sediment budget analysis.

->Aids to understanding functioning of estuary systems

- **Important to know about uncertainty in data**
- **Important to understand applicability of relationships**

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8. Geological factors for estuarine studies;

- **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***
- **Topography as well as the rock type (lithology)**
- **Inherited topography is referred to as the 'accommodation space' of an estuary (EMPHASYS, 2000)**
- **Understand constraint on estuary evolution**

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Inherited topography

The estuary geological frame or

'Accommodation space'

How well does the estuary equilibrium morphology fit this space?

What are the constraints?

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Length can be a constraint

Depth can be a constraint

Width can be a constraint

- e.g. incised into "rock"

- excess width: salt marsh infill

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10. Intertidal profile form;

- **Intertidal is the *morphological transition* between the subtidal channel of the estuary and the shoreline**

  - natural features (e.g. saltmarsh)
  - man-made coast protection or flood defence works

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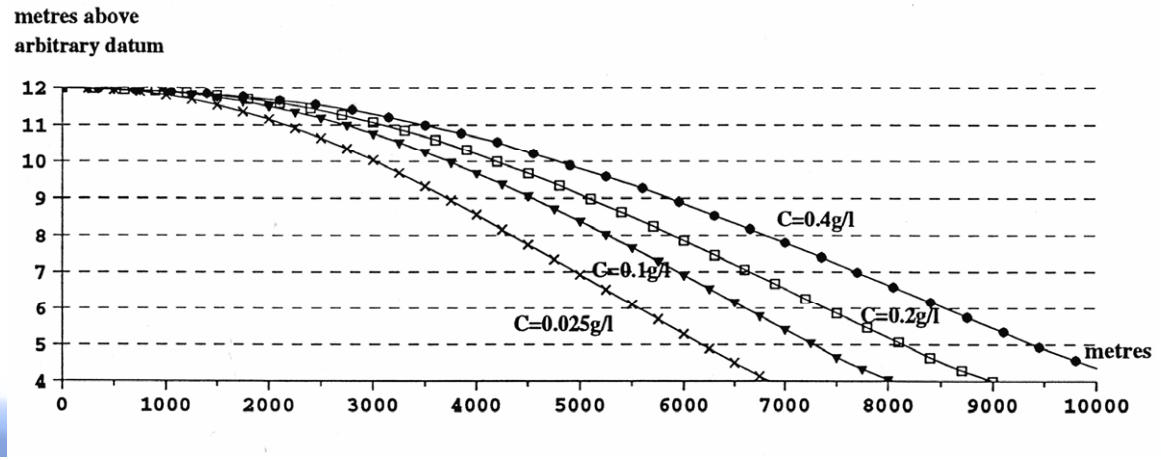
Intertidal profile form (builds on earlier Defra/EA R&D);

- **Tides ->long term prediction**
- **Equilibrium profile shape for prevailing forcing by tides and/or waves, sed conc, SLR**

$$\int_{t^-}^{t^+} deposition(x,t)\,dt = \int^{t^+} erosion(x,t)\,dt$$



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In summary, for those using such methods, project has produced a catalogue format output:

- **Background to method**
- **Overview of method**
- **Data issues, experience, applications**
- **Examples, best practice**
- **Conclusions, recommendations**
- **References**

Method Indicator		
Bottom-Up	**Hybrid**	**Top-Down**
		YES

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And it has:

- **Clarified framework for EGA**
- **Highlighted importance of**
  - Data
  - Conceptual model
  - Appropriate selection of method(s)
  - Cross-checking between methods
- **Provided inputs to continuing ERP research**

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Thank you

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