BEST PRACTICE IN ESTUARY STUDIES:

Short term modelling

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Contents

- Introduction
- The Guide and the generic approach
- The aims of short term modelling
- Developing a conceptual model
- Calibration of process models
- Predictive testing - “what if ..?”
- Blackwater Case Study
- Mersey Case Study
- Conclusions

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Estuaries Research Programme, Phase 1
MAFF Contract CSA 4938

EMPHASYS Consortium

A Guide to Prediction of Morphological Change within Estuarine Systems

Version 1B

Research by the EMPHASYS Consortium for MAFF Project FD1401

December 2000

MAFF

ENVIRONMENT AGENCY

ENGLISH NATURE

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Generic approach

- Scoping
- Analysis of existing data
- Collection of new data
- Application of predictive method(s) (calibration, validation, sensitivity and scenario testing)
- Synthesis and development of conceptual model
- ‘What-if’ testing
- Presentation of results

} ***Short** (and long) **term modelling***

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The aims of short term modelling

- To help develop a conceptual model for the system
- To estimate the initial impacts of a scheme
- As a guide to the effectiveness of predictions of long term evolution

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Confidence and Credibility

- Quality (and quantity) of data

- A robust conceptual model

- Confidence in the results (certainty)

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Development of the conceptual model

- The conceptual model:
  - must explain the system adequately (and where relevant, its history)
  - must be consistent with observations/modelling
  - should synthesise available data and model results
  - should normally contain the components of the sediment budget and how those components interact
  - should allow for uncertainty in model results/field data
  - must convince the regulator
- This is a necessary and time consuming process

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Choice of modeller

- Models are only as good as the people who use them
- Lots of people can use a model - not many people know how to use them to answer your problem
- Most estuary studies are non-trivial
- Get someone you can trust to do your modelling
- Consider use of an independent review team

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Choice of models

Flow models

- Is the system well-mixed or stratified?
  - Is there high fluvial flow?
- Are secondary currents important?
- How much resolution do I need?
  - Is there complex bathymetry in the system?
  - Will all the important features be resolved?

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Choice of models

Wave models

- The application of the right wave model is a technical subject
- Different wave models represent different processes
- Make sure yours has the right processes for your study:
  - refraction
  - shoaling
  - diffraction
  - reflection
  - irregular waves
  - variable energy spectrum, … etc ...

Choice of models

Sediment transport models

- The same considerations as for flow models apply, *but*,
- Sediment tends to hang about near the bed so the 3D structure can be important even in a “well-mixed” system

Boundary conditions

- Put your boundary a long way away from the estuary mouth
  - allows modelling of interaction of estuary with the offshore system
  - avoids effects from boundary condition in impact results
- The right choice of boundary conditions greatly add to the accuracy of the model

Calibration of short (and long term) models

- Expect site specific calibration
- Understand differences between model and measurement (both contain uncertainty)
- The standard of calibration required depends on the the nature of the problem
  - Are long term trends important?
  - Are we choosing between a number of management options or establishing a magnitude of impact which may make or break a scheme?
- Where data is lacking then sensitivity and scenario testing can overcome ***some*** of the problems and reduce uncertainty

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Calibration of flow models

- In most cases this will be the main basis for assessing impact
- Flow results will “drive” most of the other models that could be used for prediction
- The other model results (in most cases) can only be as good as the flow model
- You don’t have to believe the modeller when he says, “the model reproduces the results well”

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Calibration of wave models

- This is not often undertaken on a site specific basis
- Most wave models are calibrated generally on a variety of test data sets

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Calibration of sediment transport models

Mud

- If there is "***enough" "good"*** concentration data the concentration patterns can be matched accordingly
  - THIS IS NOT BY ITSELF SUFFICIENT
- The parameters relating to erosion/deposition ***also*** have to be calibrated
  - OTHERWISE THE UNCERTAINTY IN THE PREDICTED DEPOSITION WILL BE LARGE
- Obervations of accretion/erosion are required - dredging records or changes in morphology

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Calibration of sediment transport models

Sand

- Sand transport models, given an appropriate d_{50} , will probably predict the right sort of *potential* transport
- However, in practice sand transport is limited by the sediment availability and the presence of mud
- Sand transport and erosion/deposition have to be calibrated
  - OTHERWISE THE UNCERTAINTY IN THE RESULTS WILL BE LARGE
- Obervations of accretion/erosion are required - dredging records or changes in morphology
- Sand transport algorithms are only reliable to within a factor of three!

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Predictive "'What-if?'" testing

- The "conceptual model" can be tested to examine how the system responds to imposed change
- This requires rerunning some of the models used in establishing the conceptual model
  - Relative merits of different options can be investigated
  - Quantification of impact can be sought
- Further assumptions may need to be made to provide answers for decision making

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Demonstration Projects

Choice of projects

- Funders decided that best practice should be disseminated through demonstration projects
- These demonstration projects were to be chosen through consultation with end-users
- Consultation with Blackwater stakeholders resulted in the choice of Managed realignment in Salcott Creek as a demonstration project

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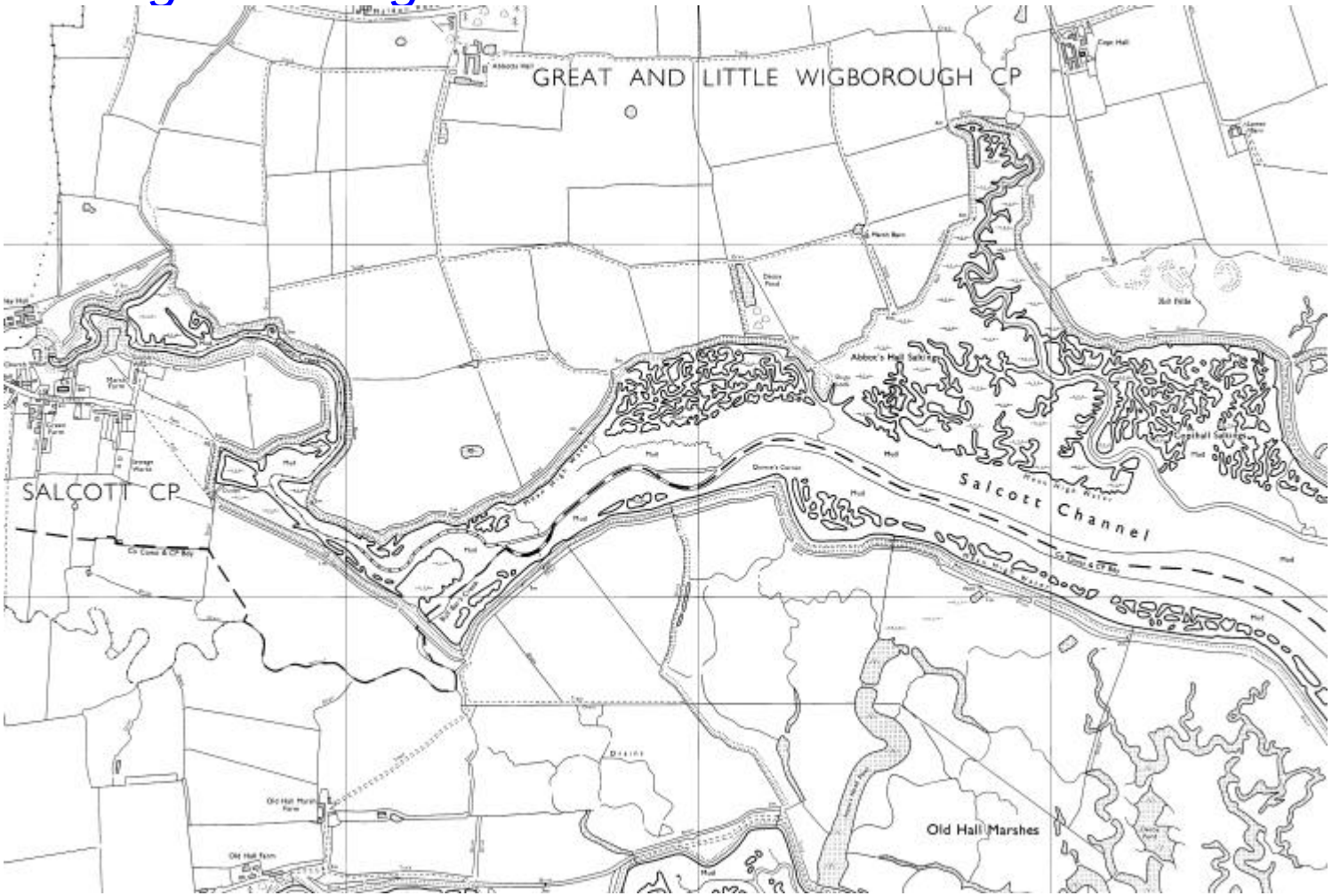
Blackwater Demonstration Project

Managed Realignment in Salcott Creek



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Blackwater Demonstration Project

Introduction

- Real case (ongoing project) of a study of the impacts of five breaches on the nearfield and farfield morphology of Salcott Creek
- Aim to take audience through the process
- Highlight importance of good quality data

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Blackwater Demonstration Project

Development of the conceptual model

The task:

- To build an understanding of the present estuary regime
- To reproduce the main processes with numerical models

The tools available:

- Analysis of field data
- Short-term process modelling
- Long-term modelling (to follow)

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Blackwater Demonstration Project

Development of the conceptual model

Understanding of the present estuary regime

- Experience from other projects
- Processing and analysis of field data
- Running numerical models for existing conditions

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Development of the conceptual model

Experience from other projects

- Orplands Managed Retreat
- Tollesbury Managed Retreat
- Trimley Marsh Managed realignment

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Development of the conceptual model

- Processing and analysis of field data
  - ADCP
  - Tidal levels
  - Bathymetric surveys
  - SSC measurements
  - Waves
  - Sediment type
- Quality check the data. Don't really know how good it is until you use it.

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Development of the conceptual model

So, prior to running a model, what are we expecting to happen?

- Tidal prism to go up
- Velocities to increase
- Change to tidal propagation?
- Local impacts at each breach
- Dispersion of eroded material

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Blackwater Demonstration Project

Development of the conceptual model

Numerical modelling

- 2D flow modelling. This is the main tool in this case. Changes to morphology inferred from changes to the flow regime.
- 2D suspended sediment transport modelling. To determine the effect of the breaches on SSC levels.

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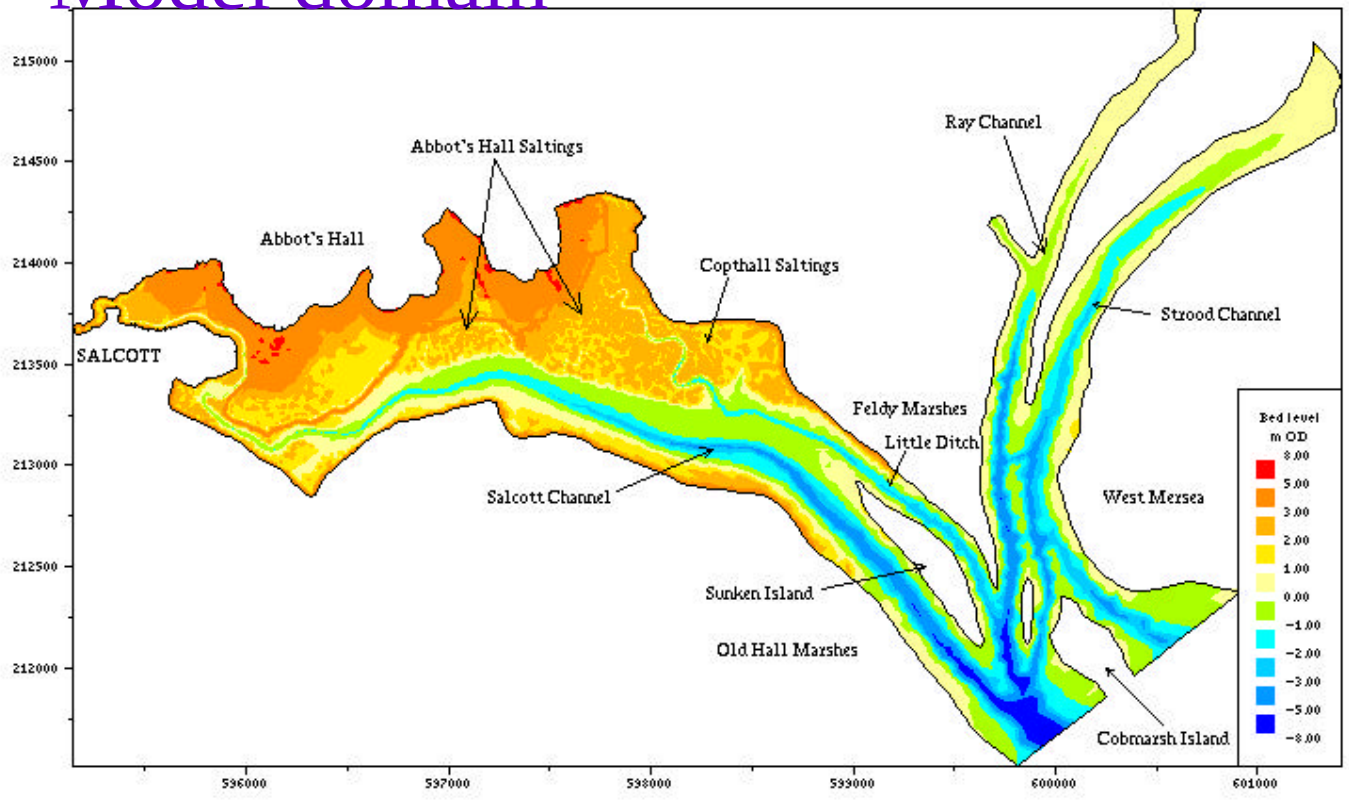
Baseline flow modelling

Model domain



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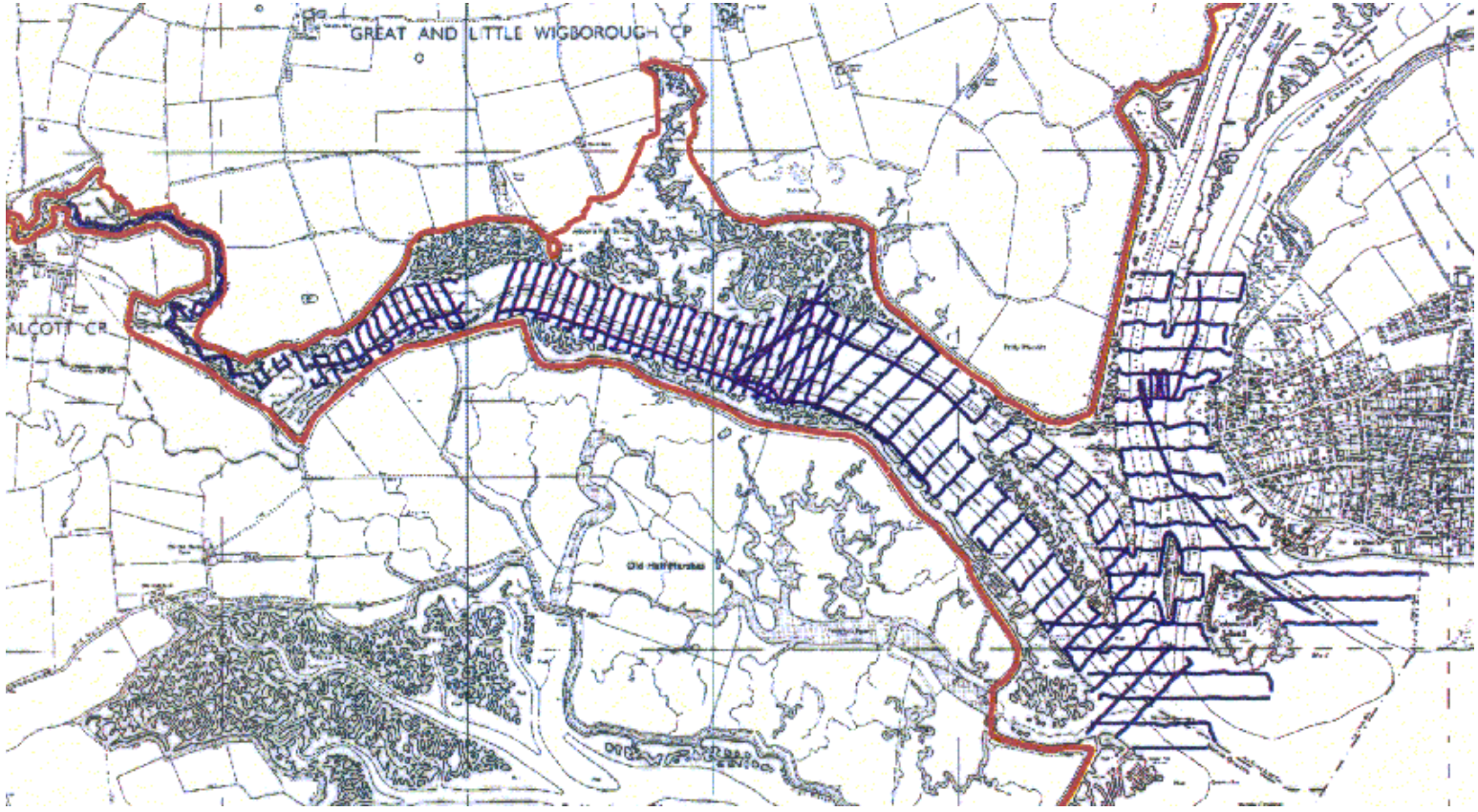
Baseline flow modelling

Model bathymetry



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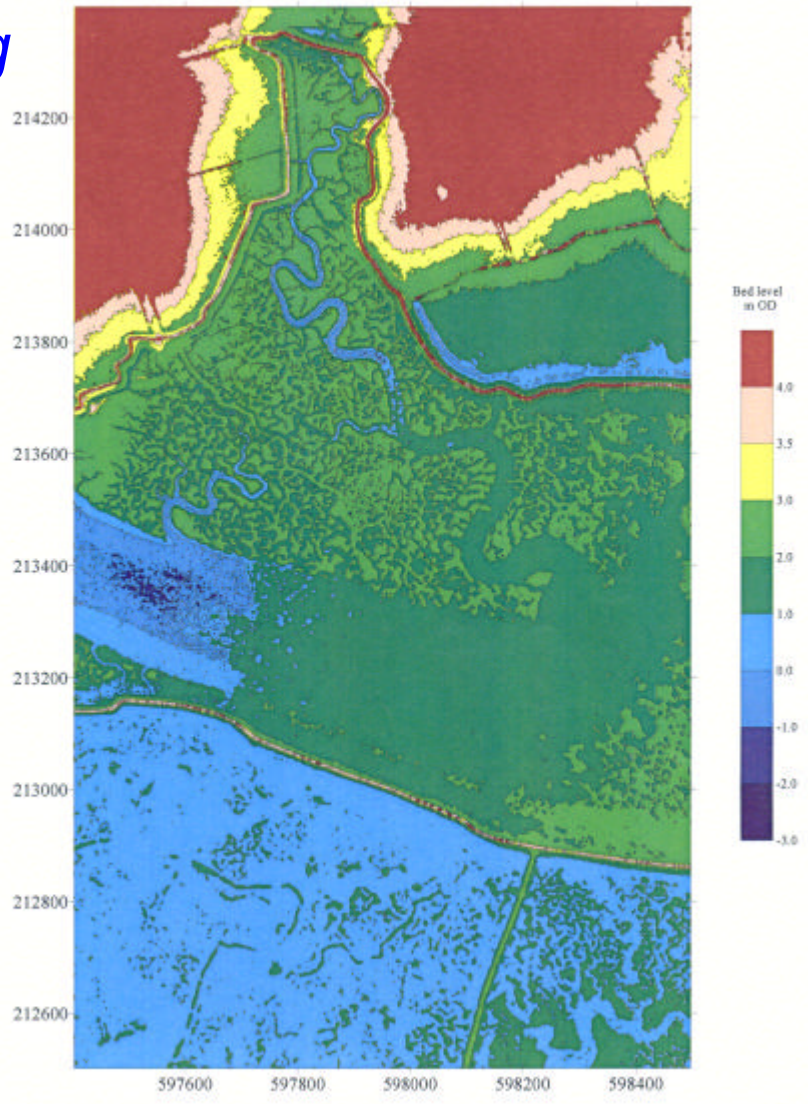
Baseline flow modelling

LiDAR data



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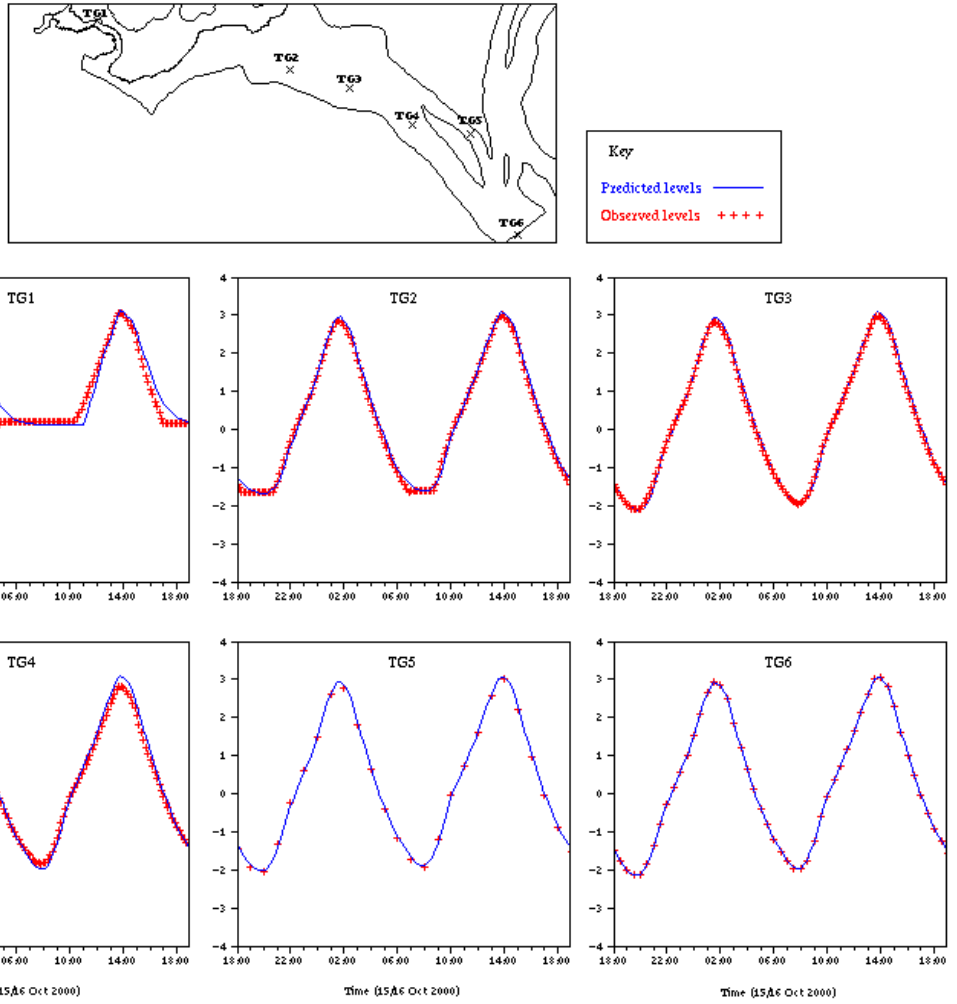
Baseline flow modelling

Calibration of water levels



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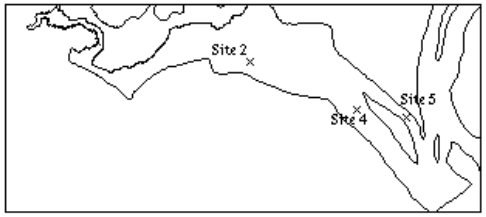
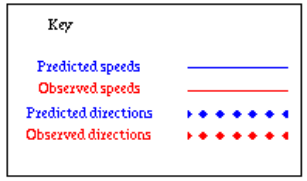
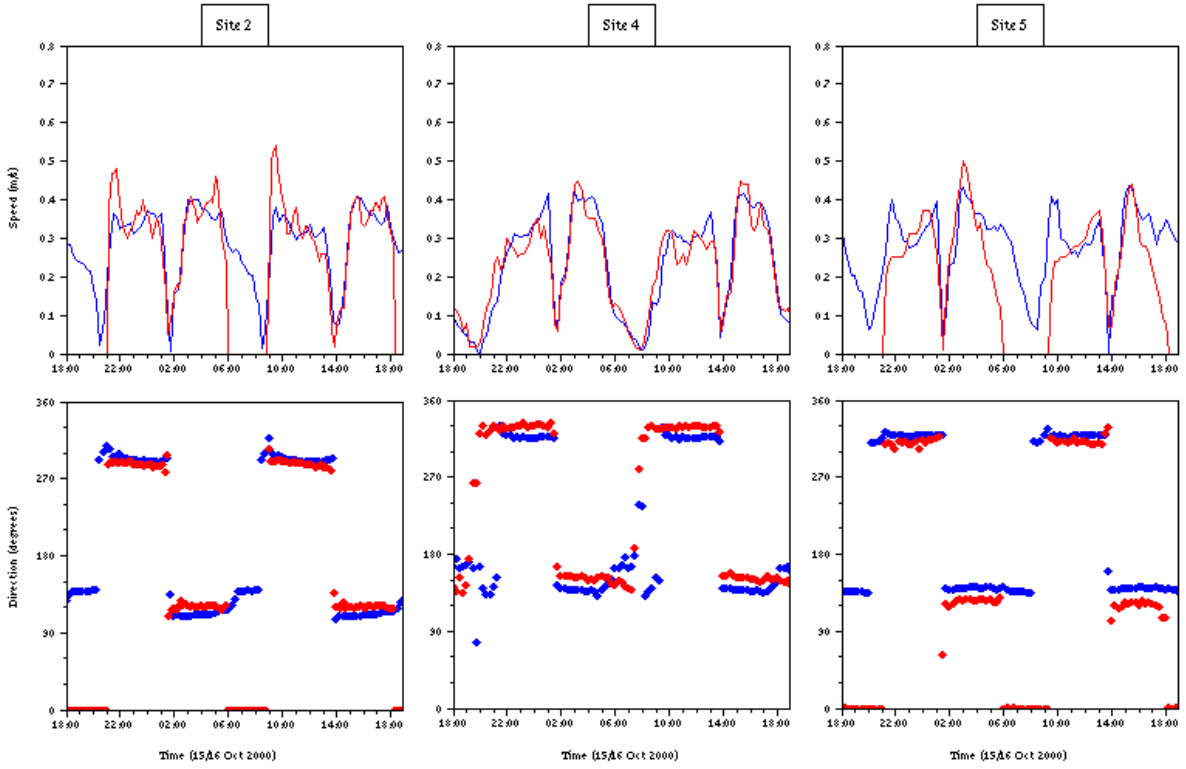
Baseline flow modelling

Calibration of tidal currents







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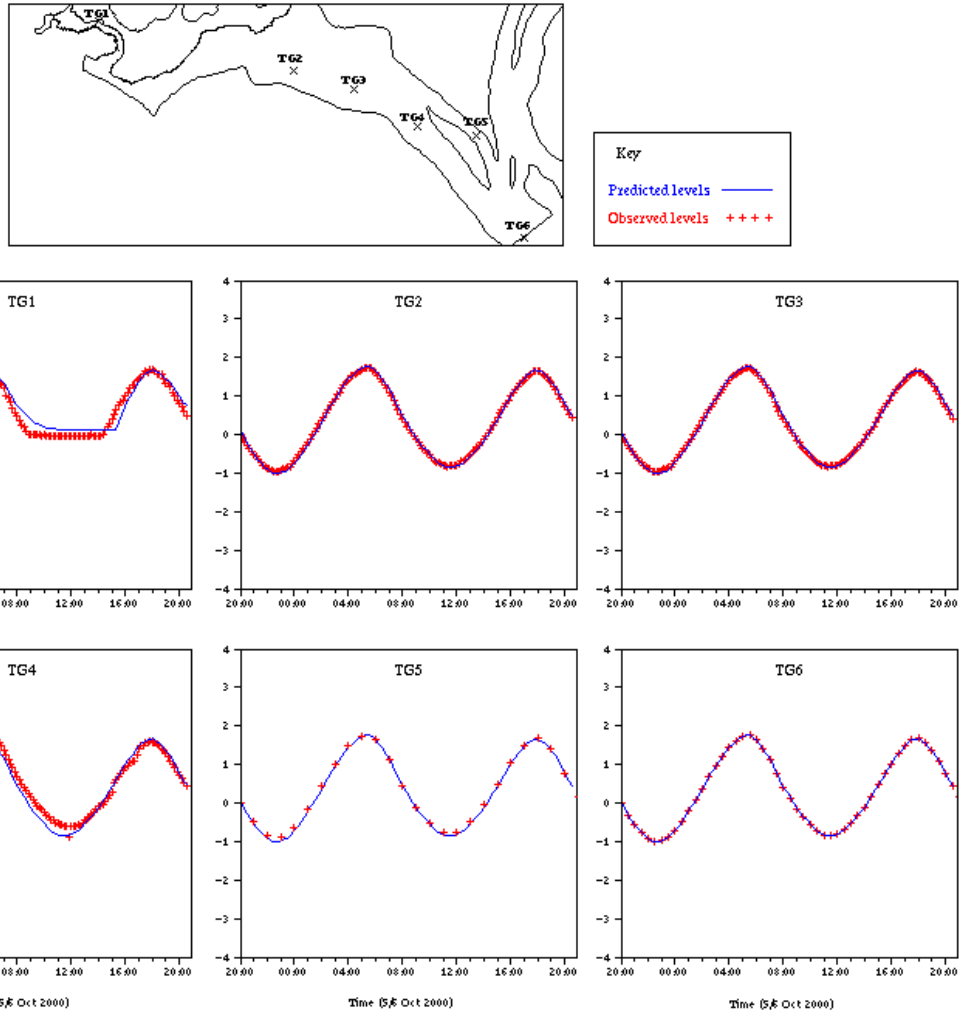
Baseline flow modelling

Validation of water levels



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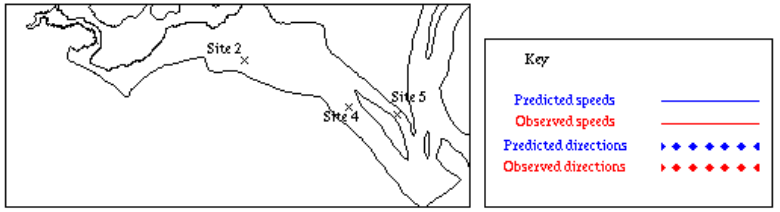
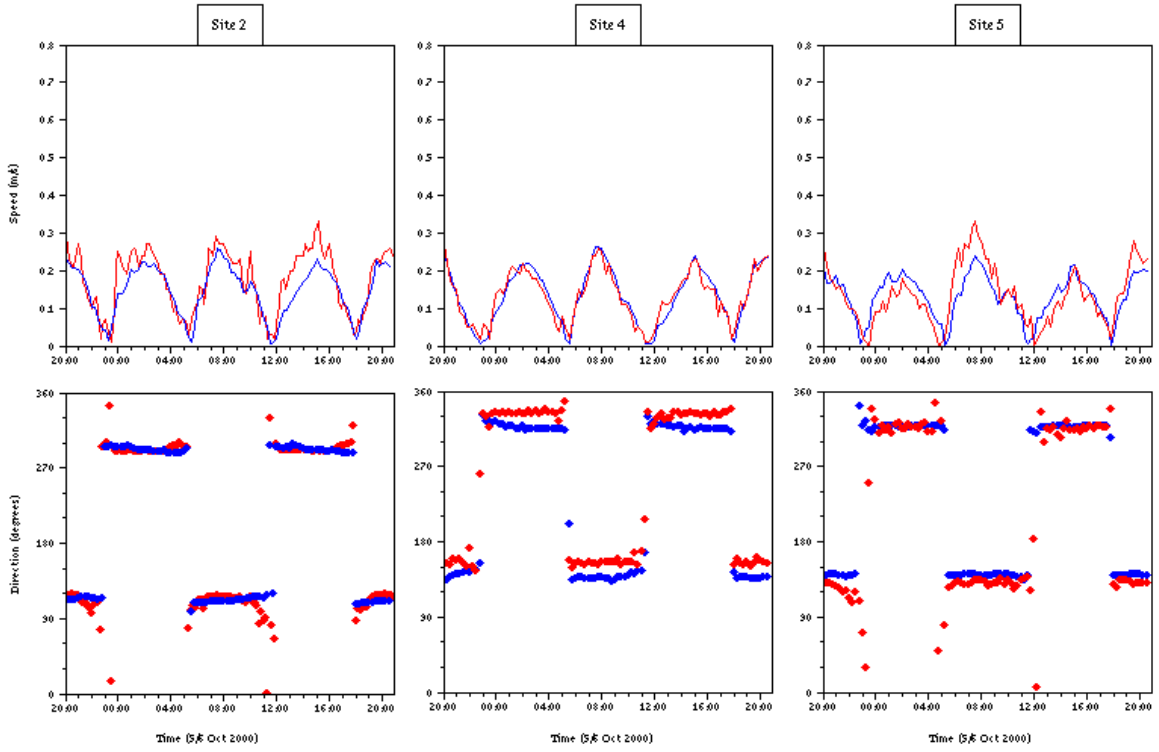
Baseline flow modelling

Validation of tidal currents





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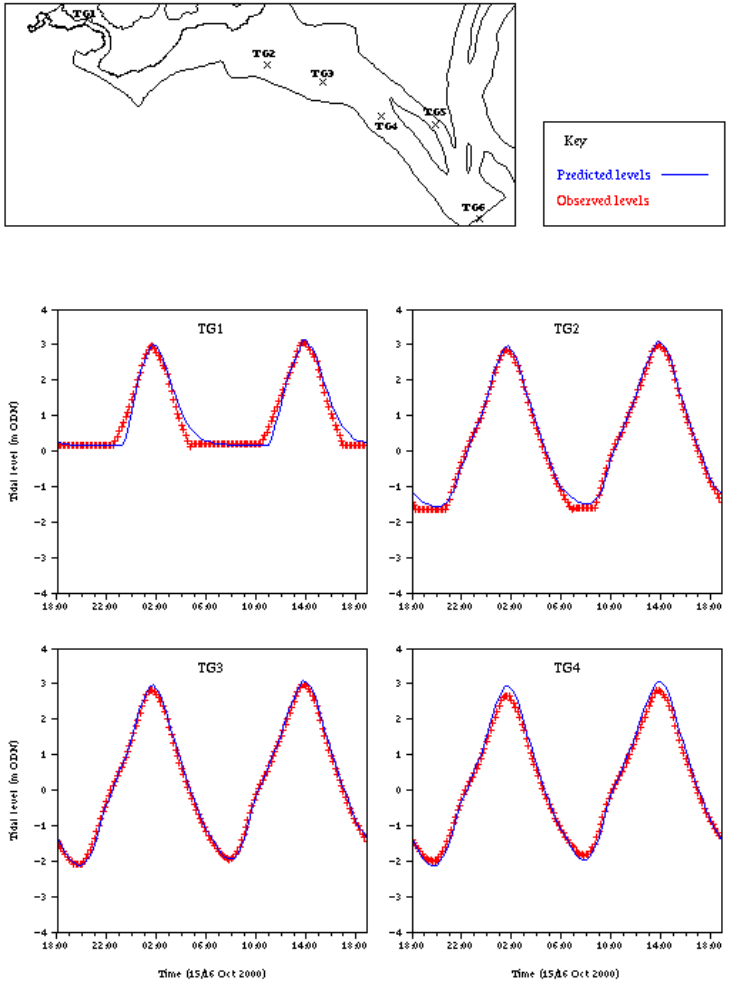
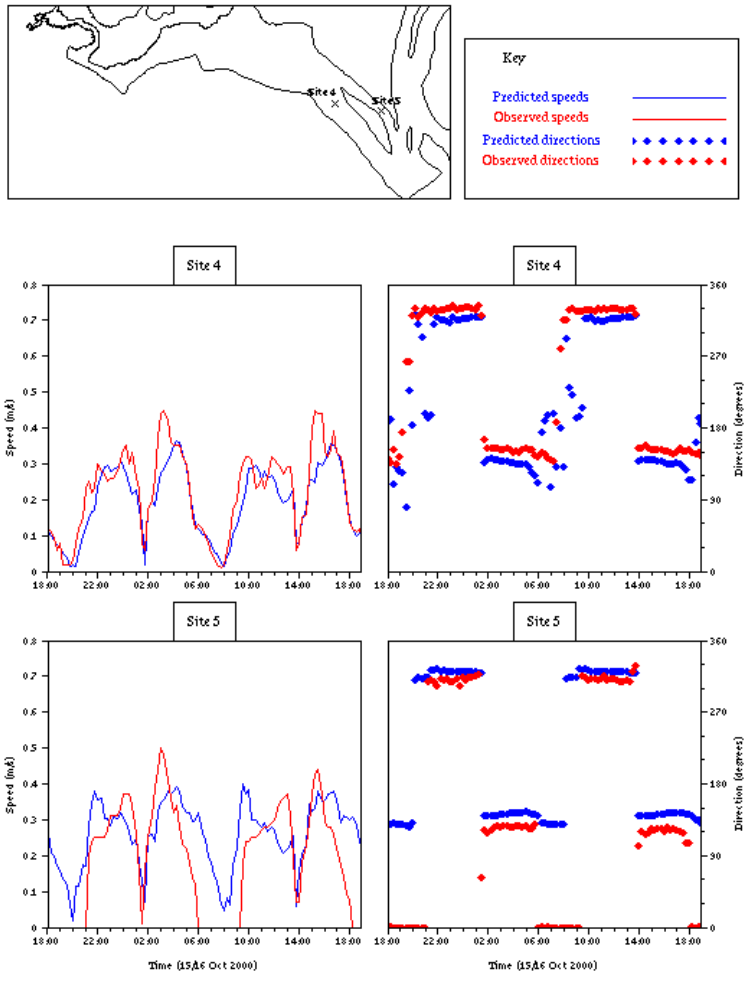
Baseline flow modelling

Suppose no LiDAR data?





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Baseline flow modelling

? A robust conceptual model has been established

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Impact of the proposed scheme

Now we can start investigating the impact of the proposed scheme

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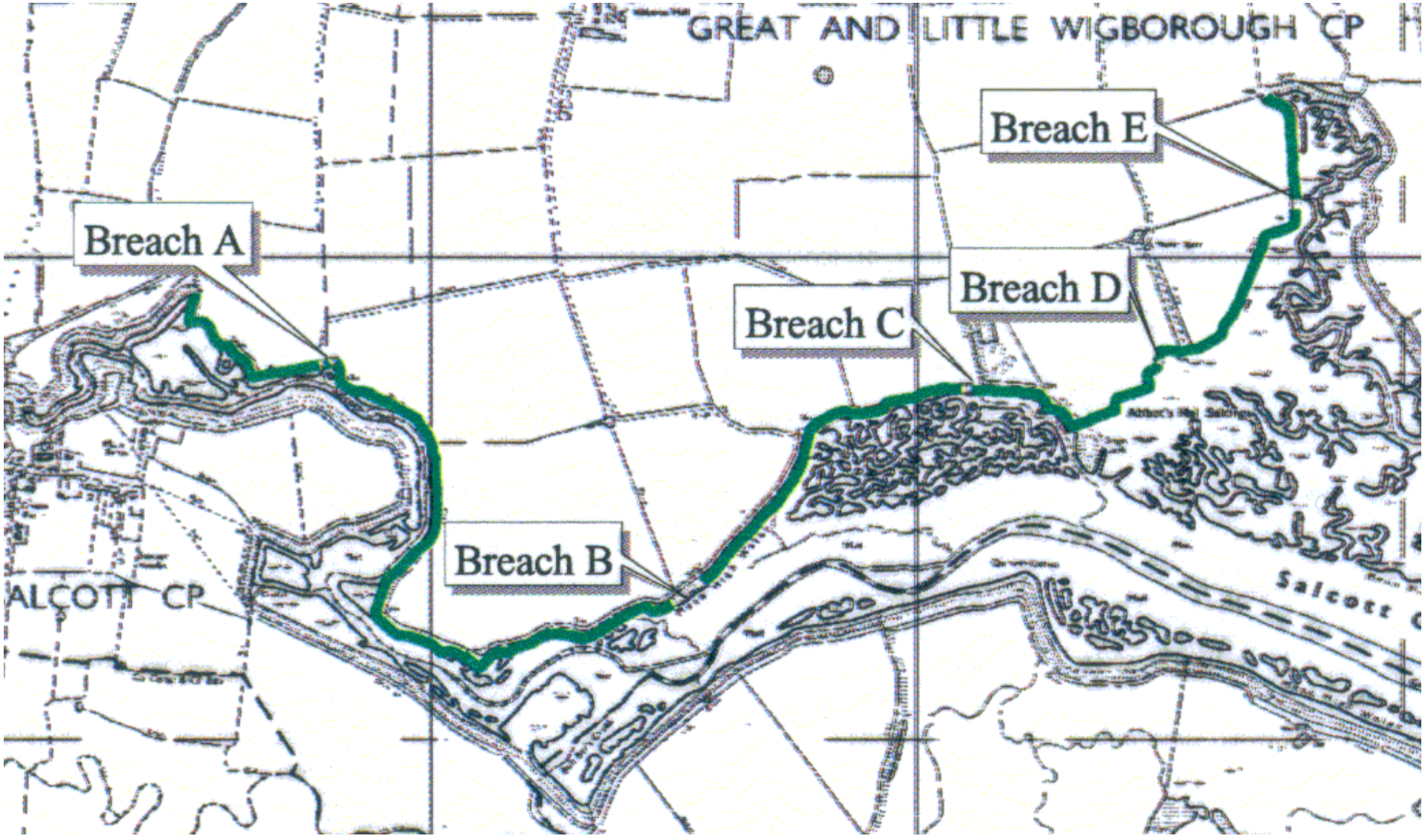
The scheme



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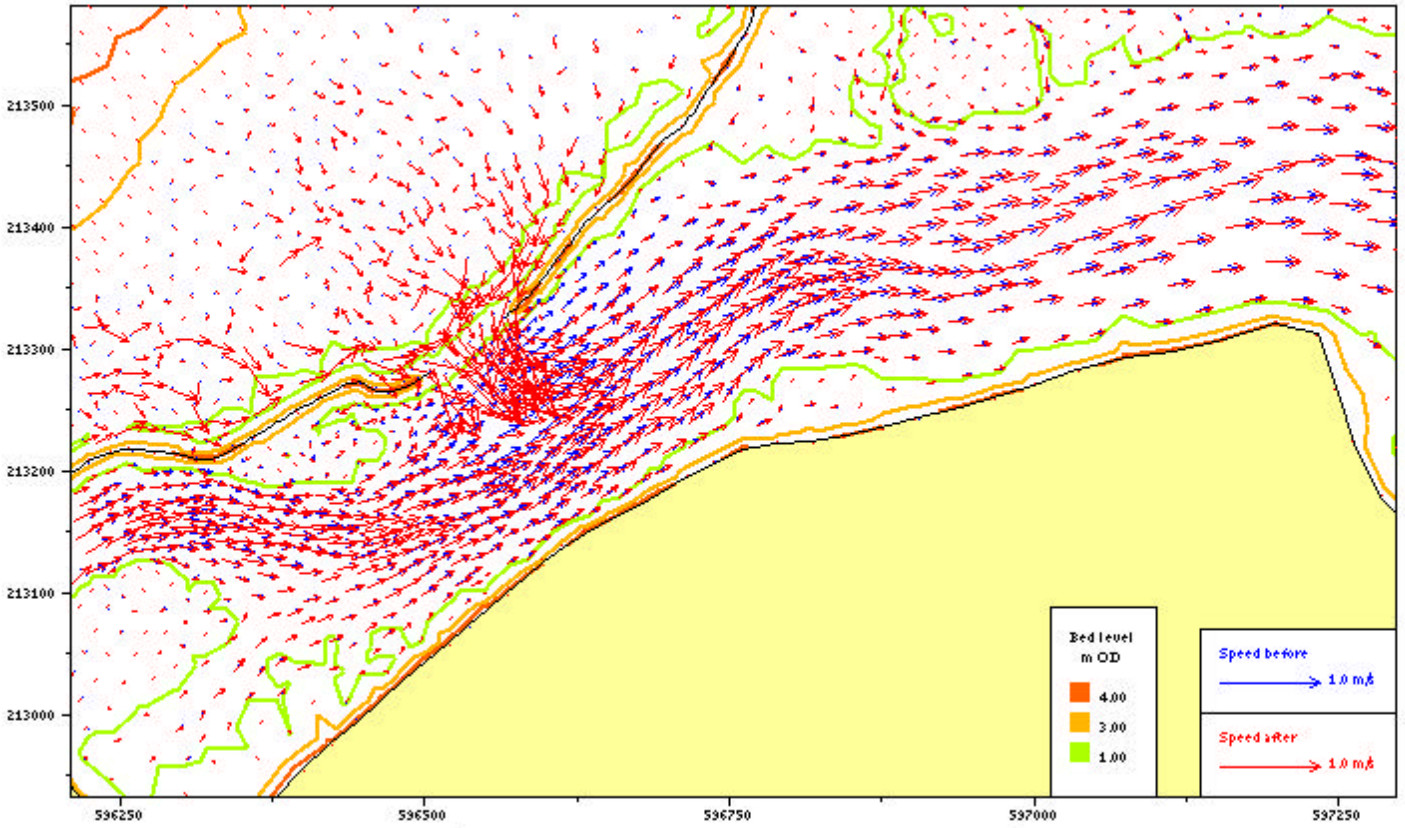
Impact of the proposed scheme



Peak ebb differences – HW + 1.75 hrs – Breach B – spring tide

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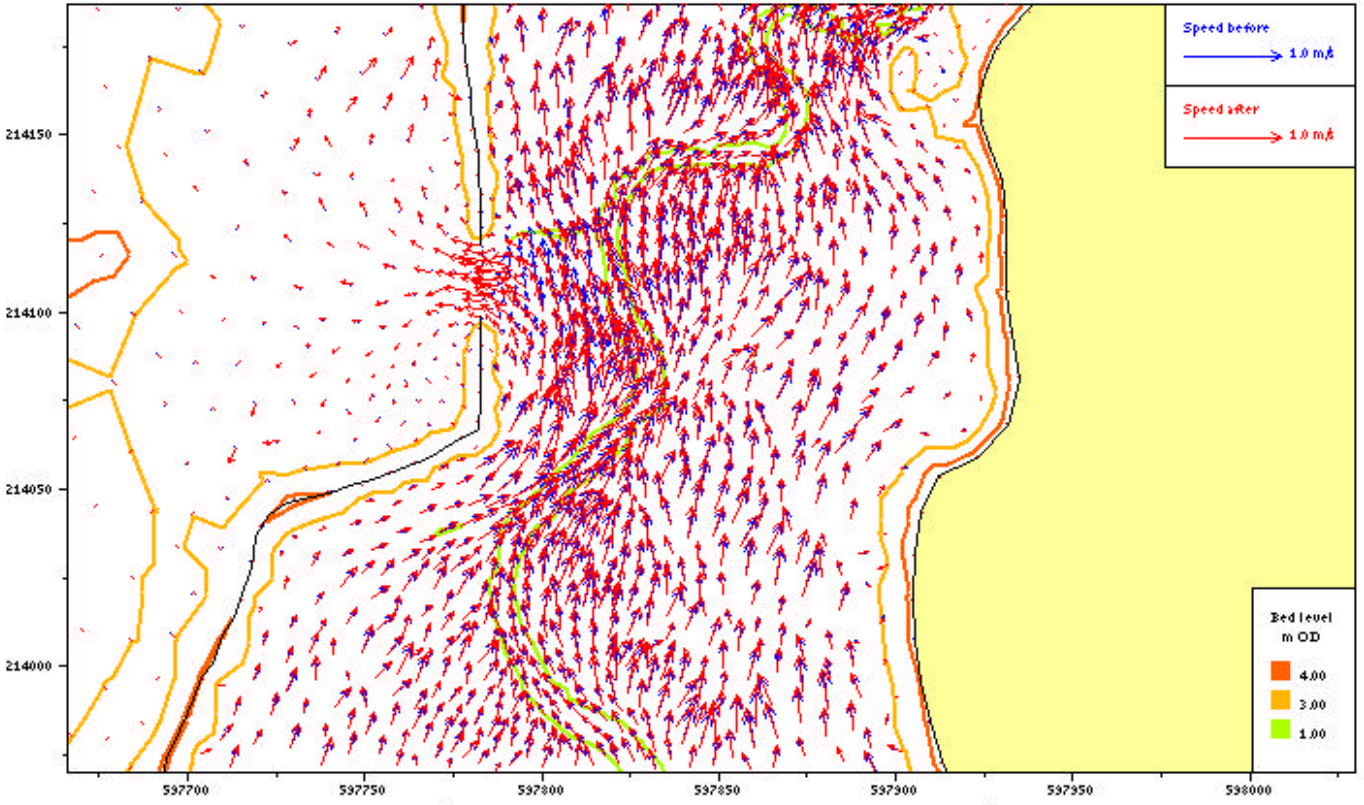
Impact of the proposed scheme



Peak flood differences – HW–0.25 hrs – Breach E – spring tide

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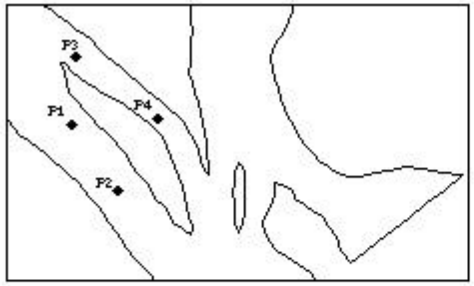
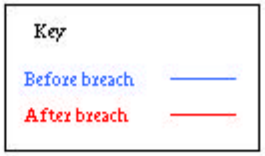
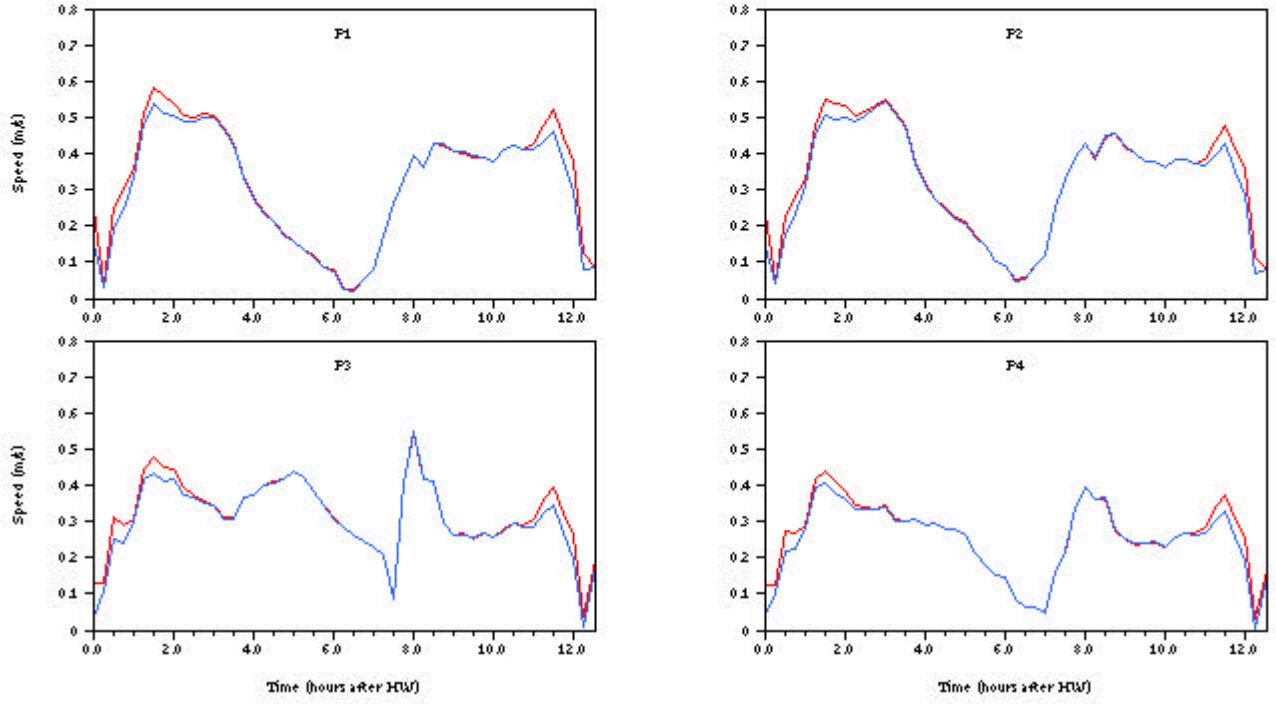
Impact on farfield flows







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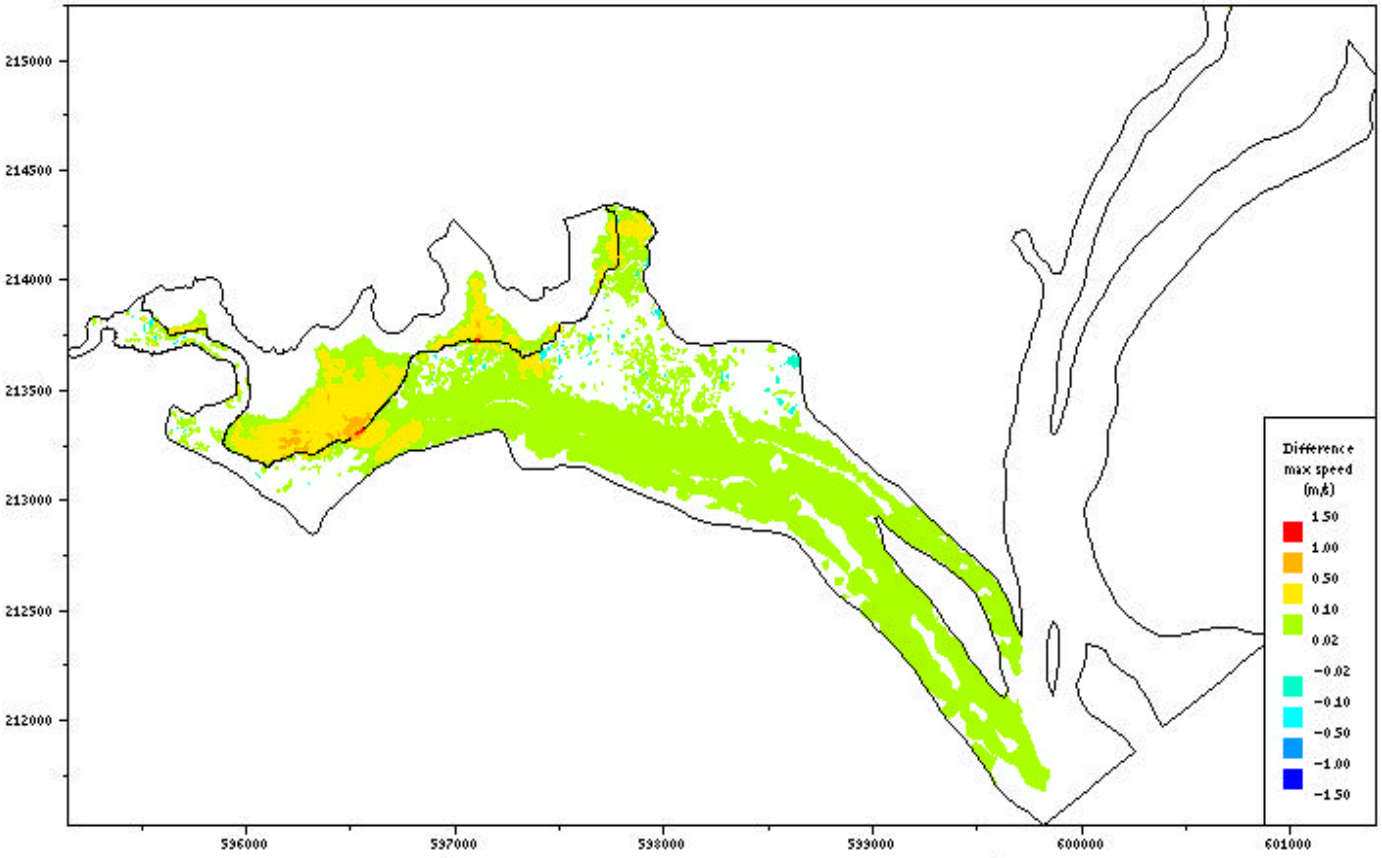
Impact on farfield flows



Maximum speed differences before and after breach – spring tide

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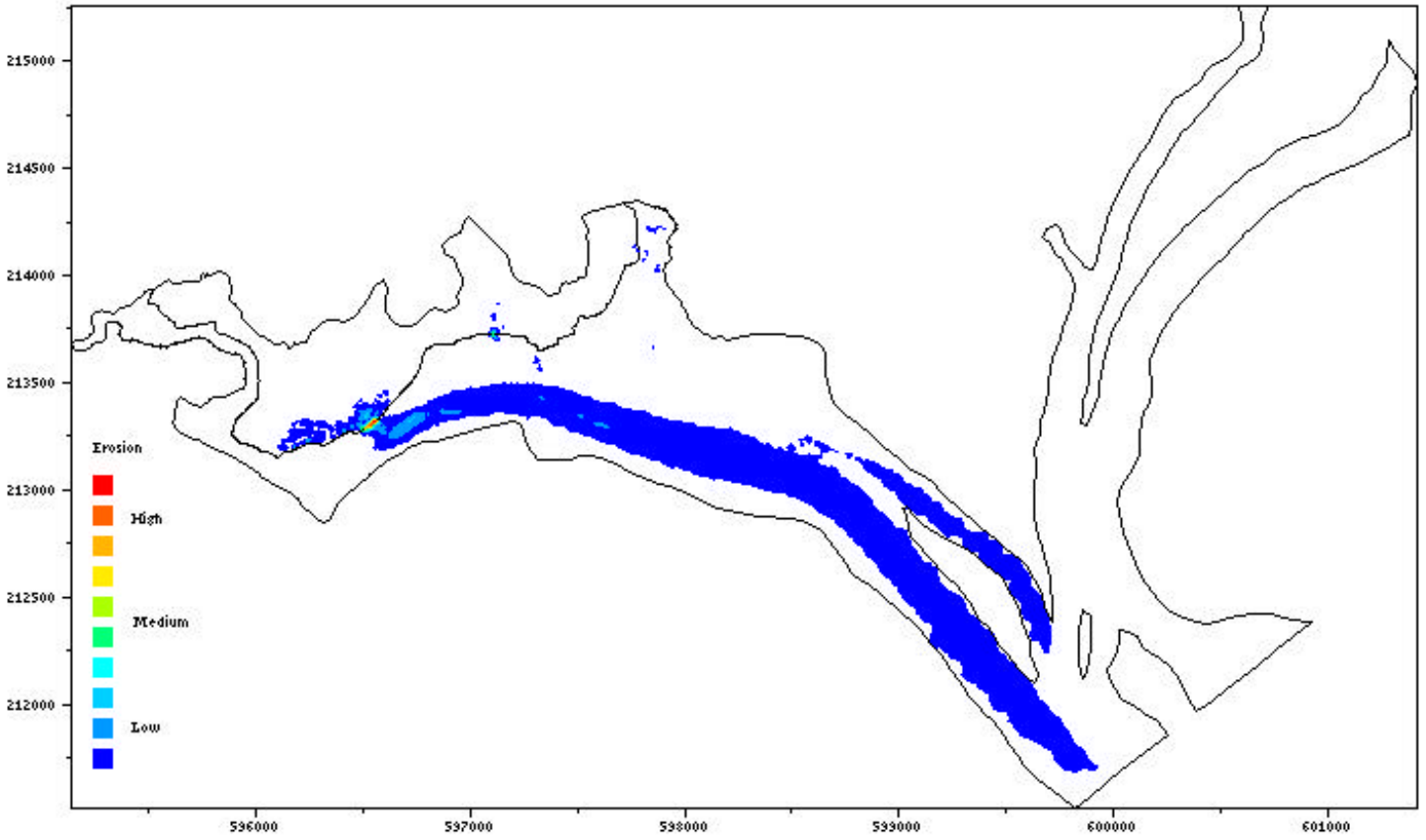
Impact on estuary morphology



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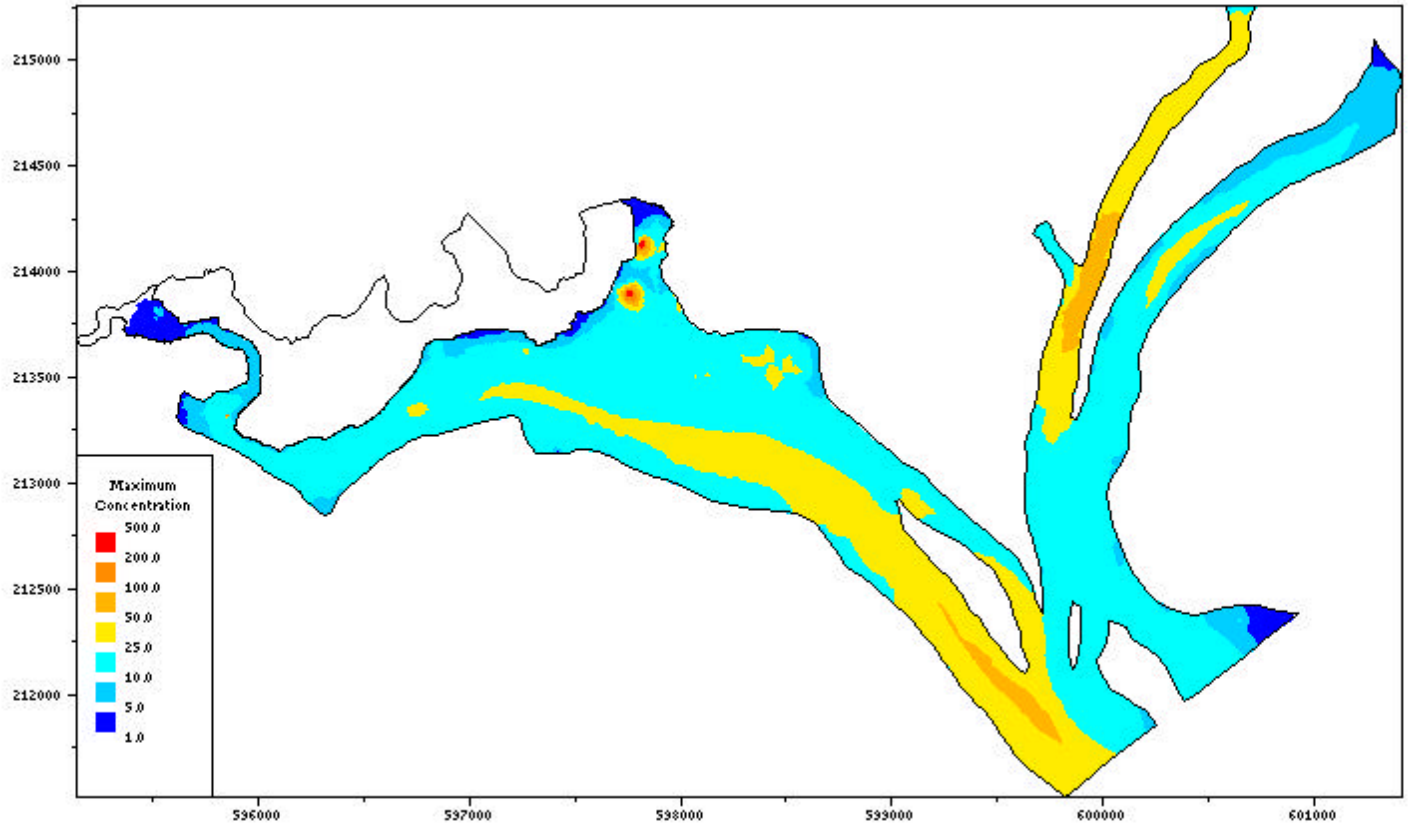
Impact on suspended sediment concentrations



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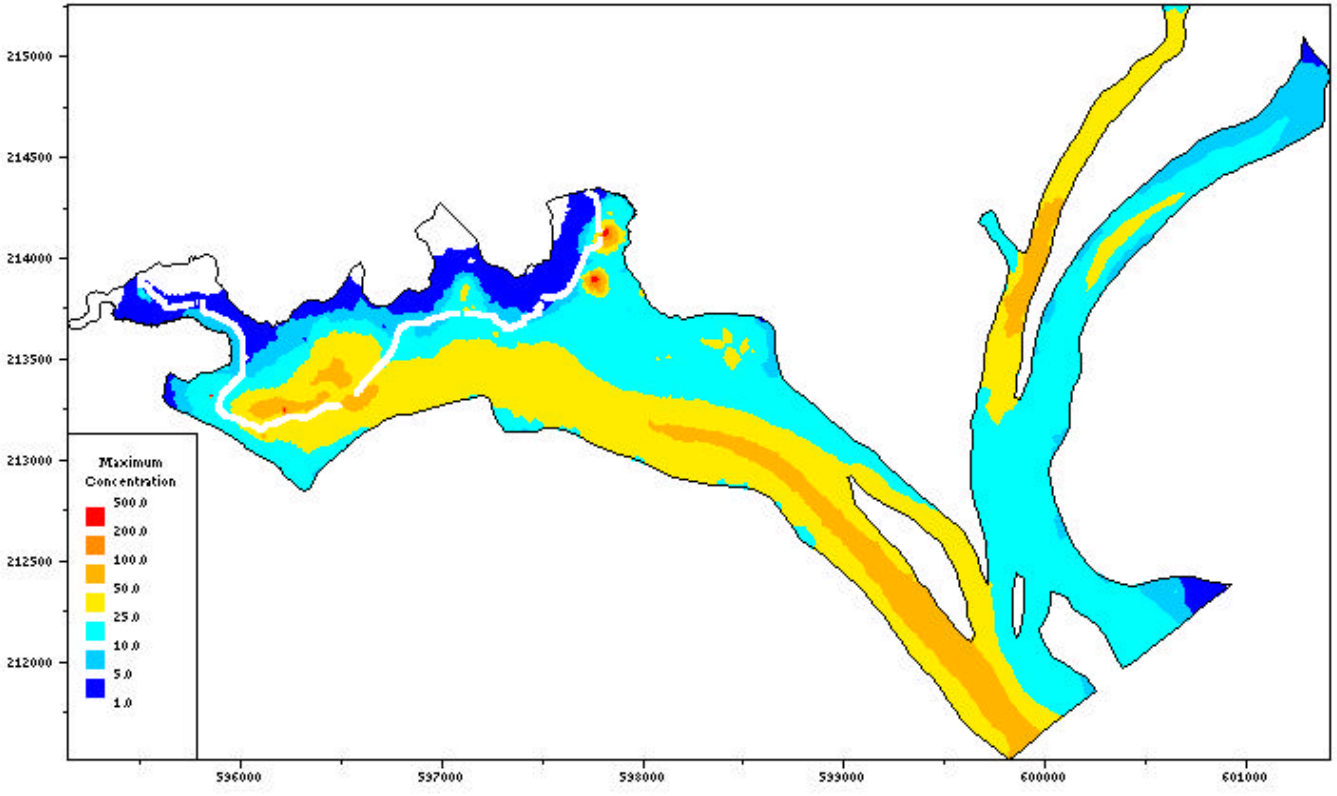
Impact on suspended sediment concentrations



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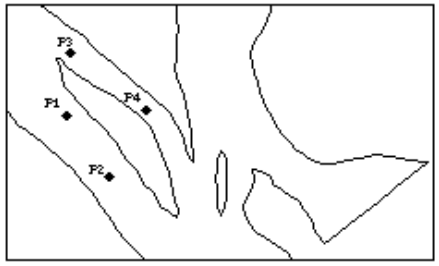
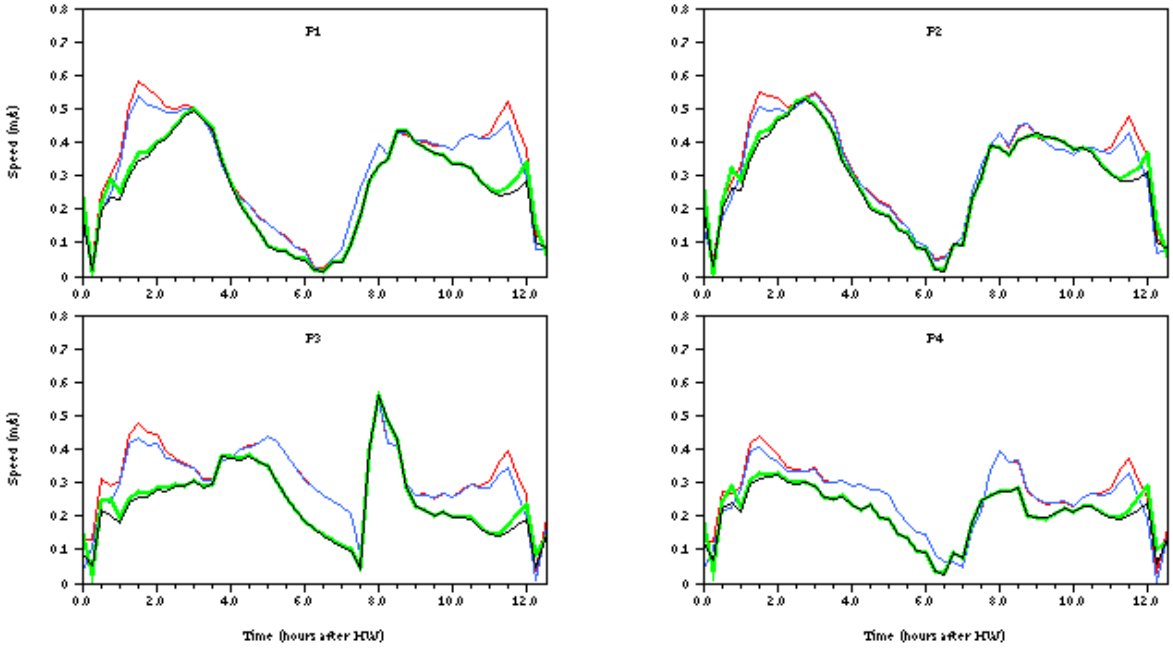
What of the effect of lack of LiDAR?





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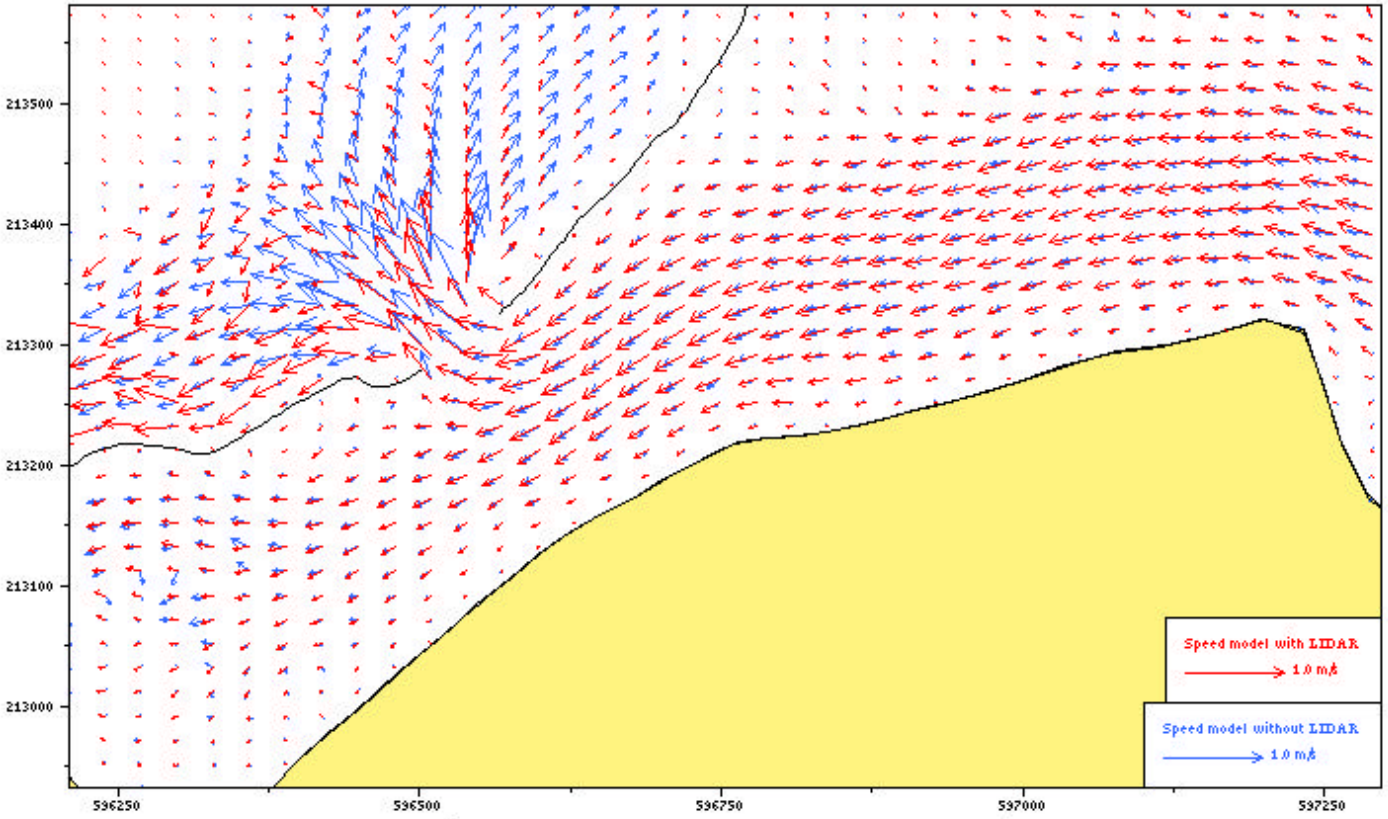

Peak flood differences – HW – 1.0 hrs – Breach B – spring tide

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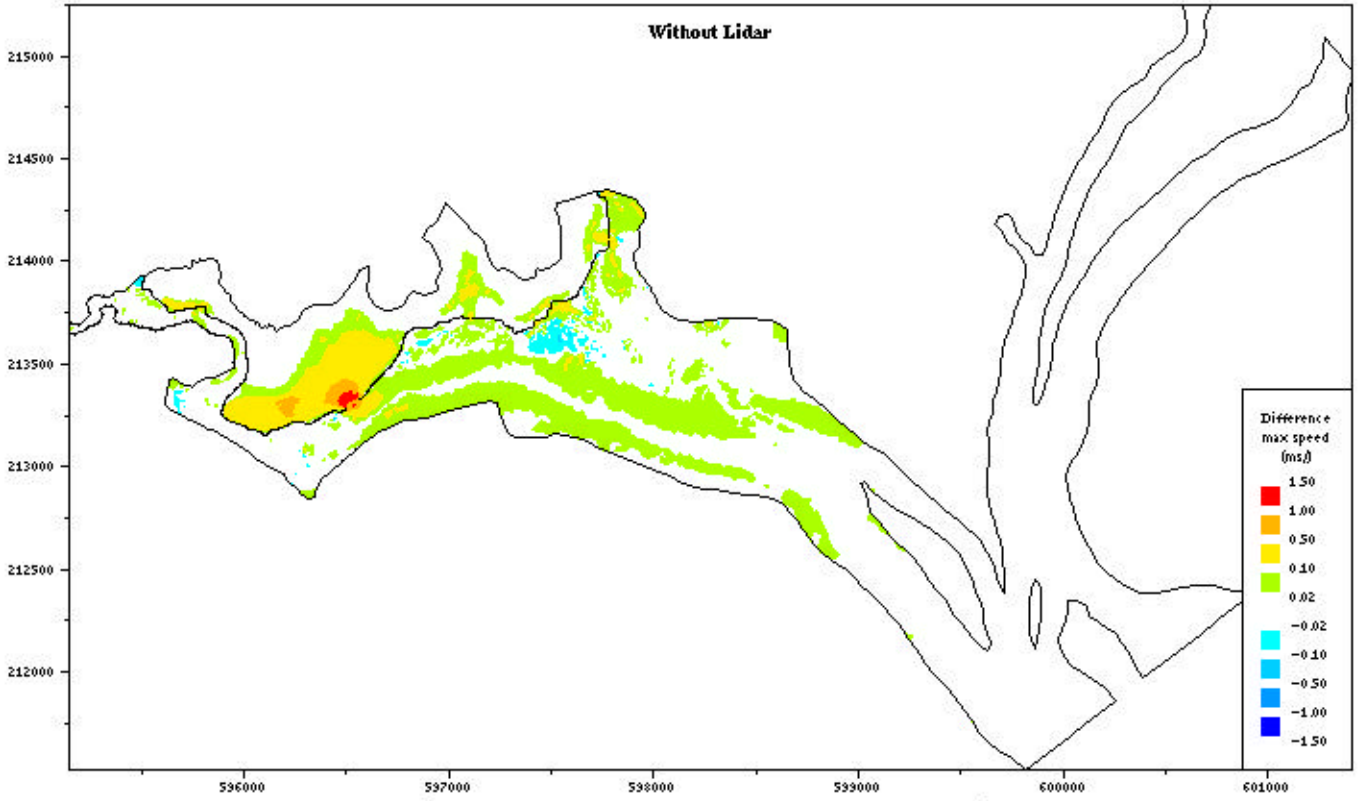
What of the effect of lack of LiDAR?



Maximum speeds differences before and after breach – spring tide

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Blackwater Demonstration Project

Conclusions drawn

- Use of LiDAR data important
- Locally, there will be an impact on flows, and consequential scour
- Due to the increased tidal prism, there will be increased currents, and in some areas this increases the peak tidal current
- Small scale erosion of the channel, and increased turbidity is expected until a new regime is established
- Consultation with stakeholders led to the redesign of one of the breaches (helps buy-in)

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Mersey Demonstration Project

Introduction

- As previously stated, consultation with Mersey end-users resulted in the choice of “removal of the training wall” as a project
- Some comments are necessary about this choice:
  - The training walls are now embedded in shoals and removing them would constitute significant and extensive dredging
  - It is extremely unlikely that this would occur
  - Removal of “just” the training walls (e.g. from decay) might not cause a huge effect
  - For this reason a more limited (part) training wall removal has been considered

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Mersey Demonstration Project

Introduction

- Scenario simulated:
  - Removal of part of training wall on west side of approach channel, close to Mersey entrance
  - Seabed levels also reduced as a means of representing some initial evolution after the training wall removal (when the impact becomes large enough to make a difference)
- Though this type of scheme is not relevant for most estuaries the demonstration project should be viewed as typical of major works near the mouth of an estuary

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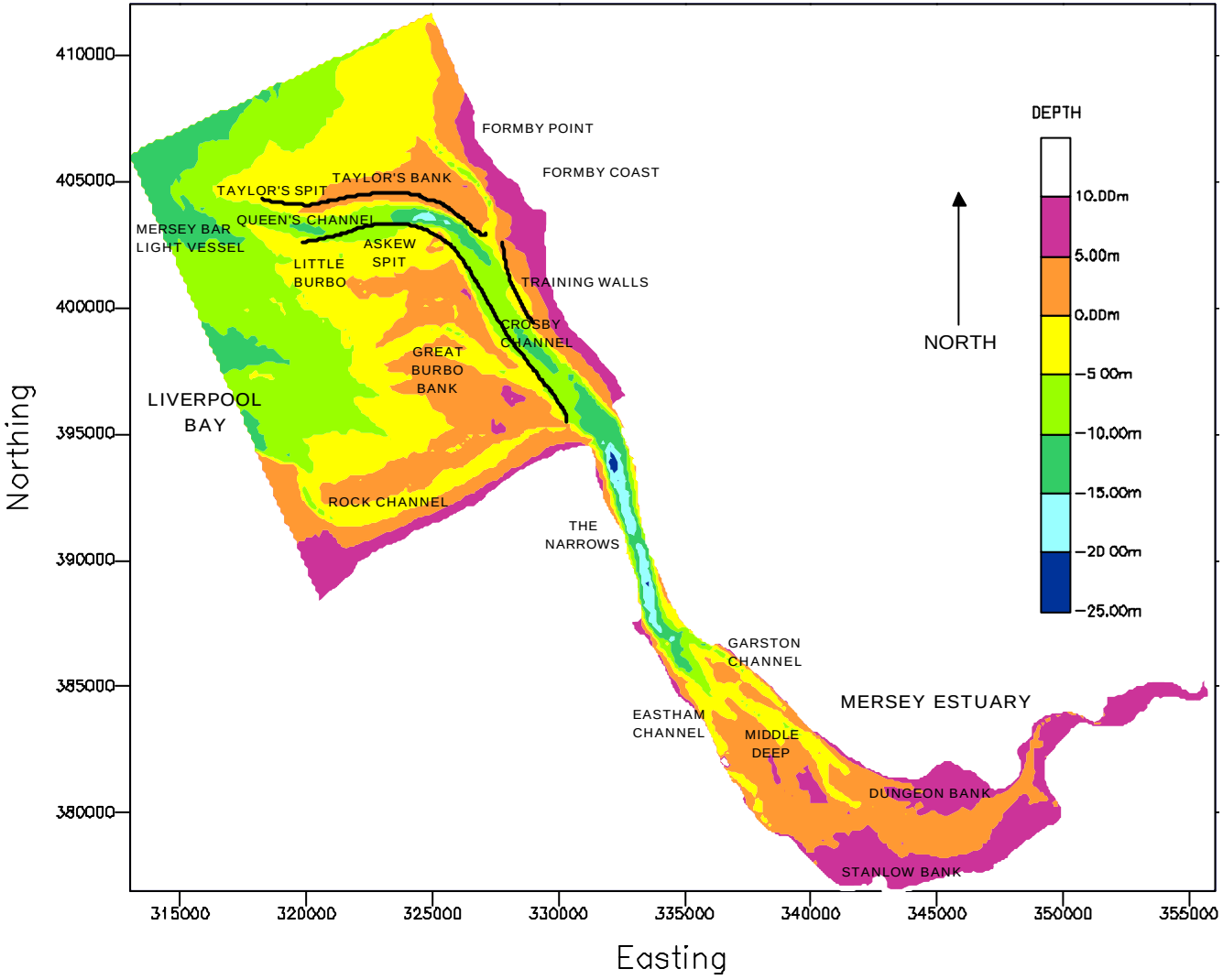
Mersey Demonstration Project

The Mersey Estuary



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Mersey Demonstration Project

Introduction

- This demonstration project will consider the:
  - Development of conceptual model
  - Short term impact of the demonstration scheme
  - Other studies that would be required if the project were carried out “for real”

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Mersey Demonstration Project

Development of the conceptual model

The task:

- To be able to explain the historical changes in the Mersey/Liverpool Bay
- To reproduce these effects with numerical models

The tools available:

- Analysis of existing data
- Analysis of field data
- Short term modelling

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Mersey Demonstration Project

Development of the conceptual model

Analysis of existing data

- Historical surveys
- Dredging data
- Previous studies
  - Cashin (1949)
  - Price and Kendrick (1963)
  - Liverpool University studies
  - Mersey Barrage Studies
  - Mersey Conservator Reports
  - OBU/HRW Research (Chris Thomas PhD)

(For the real study there would of course be a lot more studies to consider)

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Mersey Demonstration Project

Development of the conceptual model

Analysis of field data

- used to calibrate any flow or sediment transport models used
- Sometimes this data itself reveals information which is important to the understanding of the system

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Mersey Demonstration Project

Development of the conceptual model

Short term modelling

- 3D flow modelling
- 3D sand transport modelling
- Particle tracking (not illustrated here)

Mud transport modelling not required *AT THIS STAGE* since the vast majority of the important historical changes have been due to sand transport

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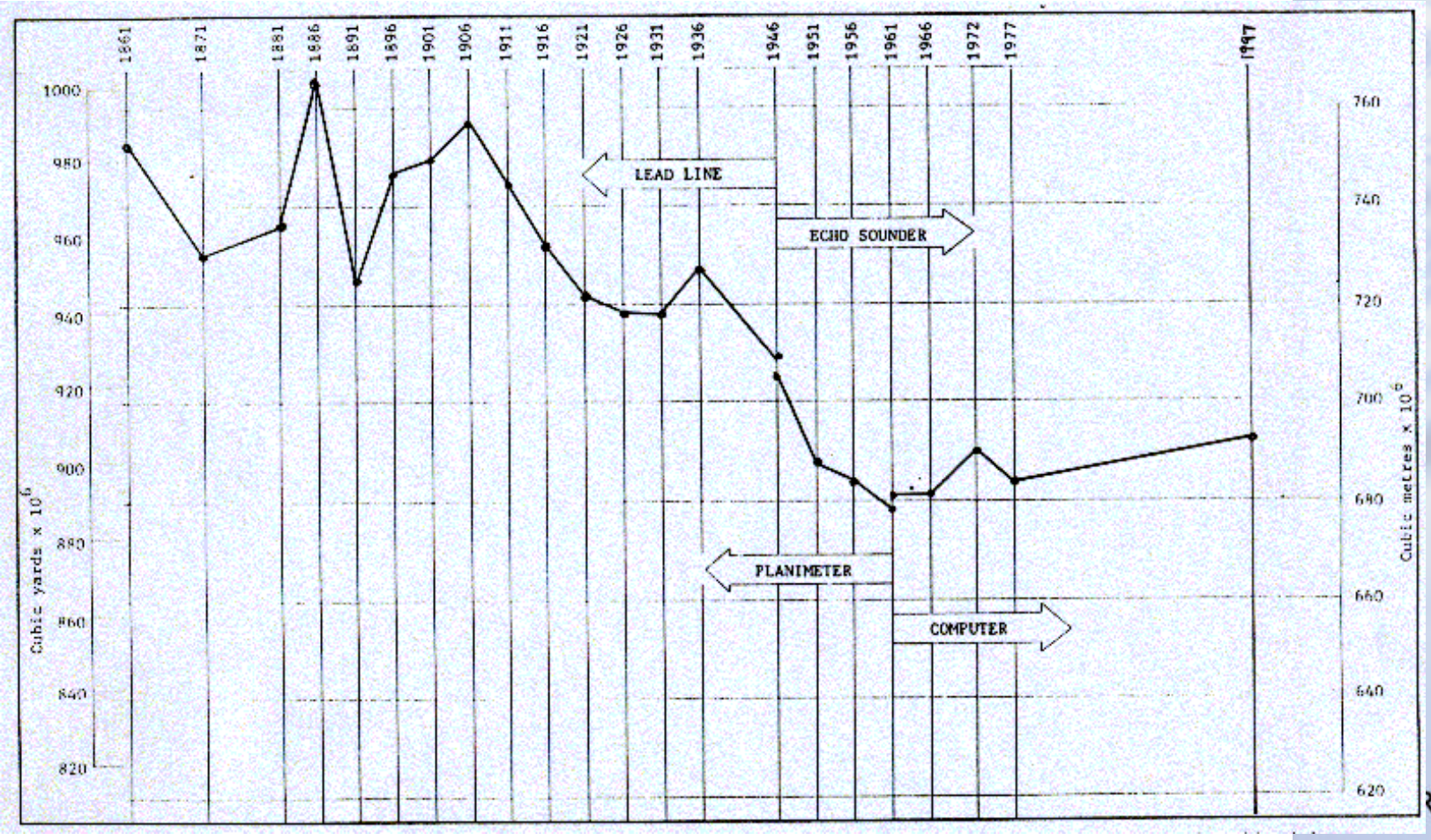
Mersey Demonstration Project

Development of the conceptual model

History of changes to the Mersey Estuary



Mersey Demonstration Project

Development of the conceptual model

Mersey Sediment Budget

Period	Total Volume Change (Mm^3)	Volume Change due to Reclamation (Mm^3)	Material Dredged from Mersey (Mm^3)	Disposal Of Dredged Material in Mersey (Mm^3)	Net Annual Sediment Flux (Mm^3)
1871-1906	23.3	-6.8	9.3	n/a	-0.59
1906-1936	-30.2	-4.5	39.8	n/a	2.18
1936-1956	-24.4	-6.4	19.9	n/a	1.75
1956-1977	-14.5	-2.3	29.3	0.2	1.97
1977-1997	11.2	0	8.8	1.5	-0.2

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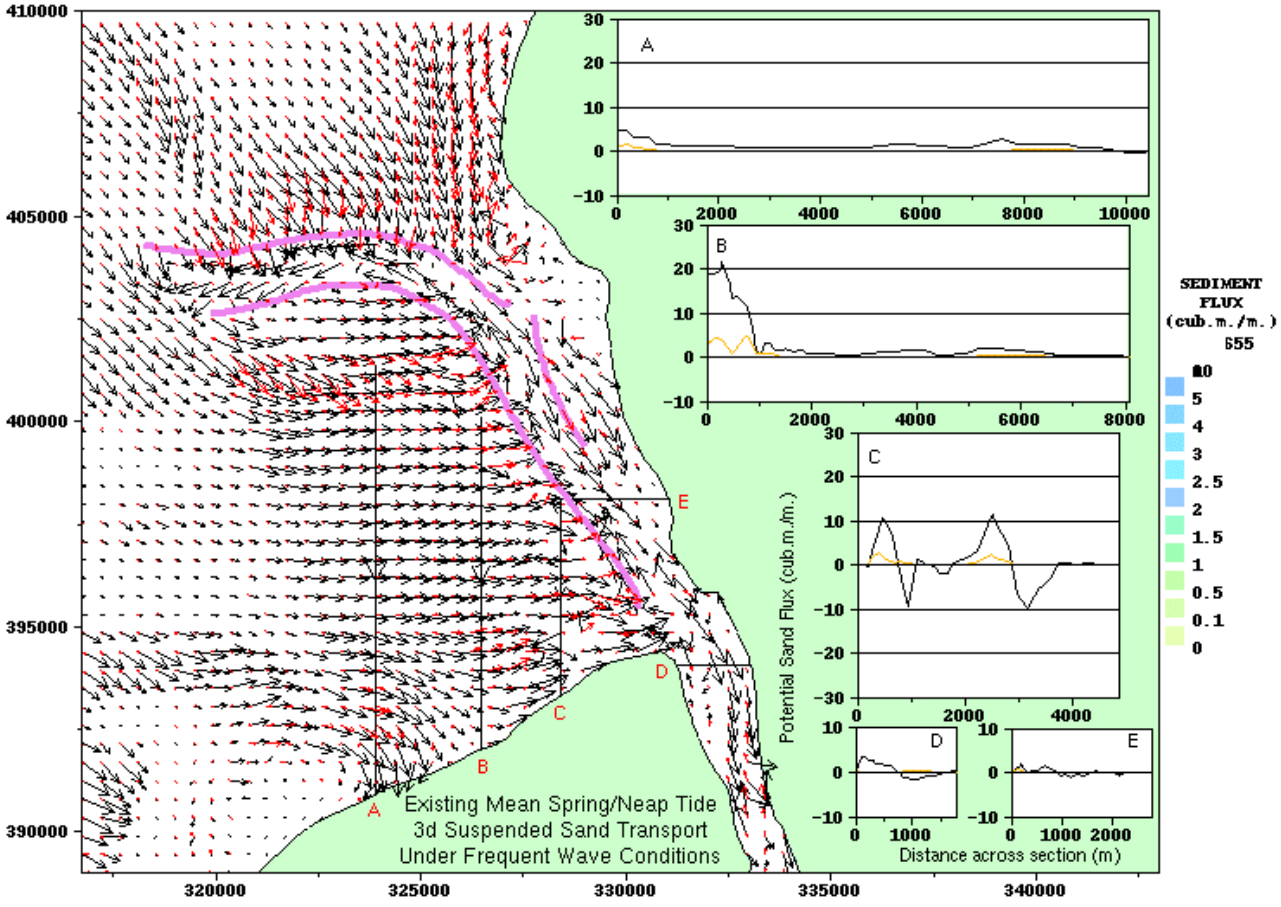
Mersey Demonstration Project

Development of the conceptual model

Effect of tidal range



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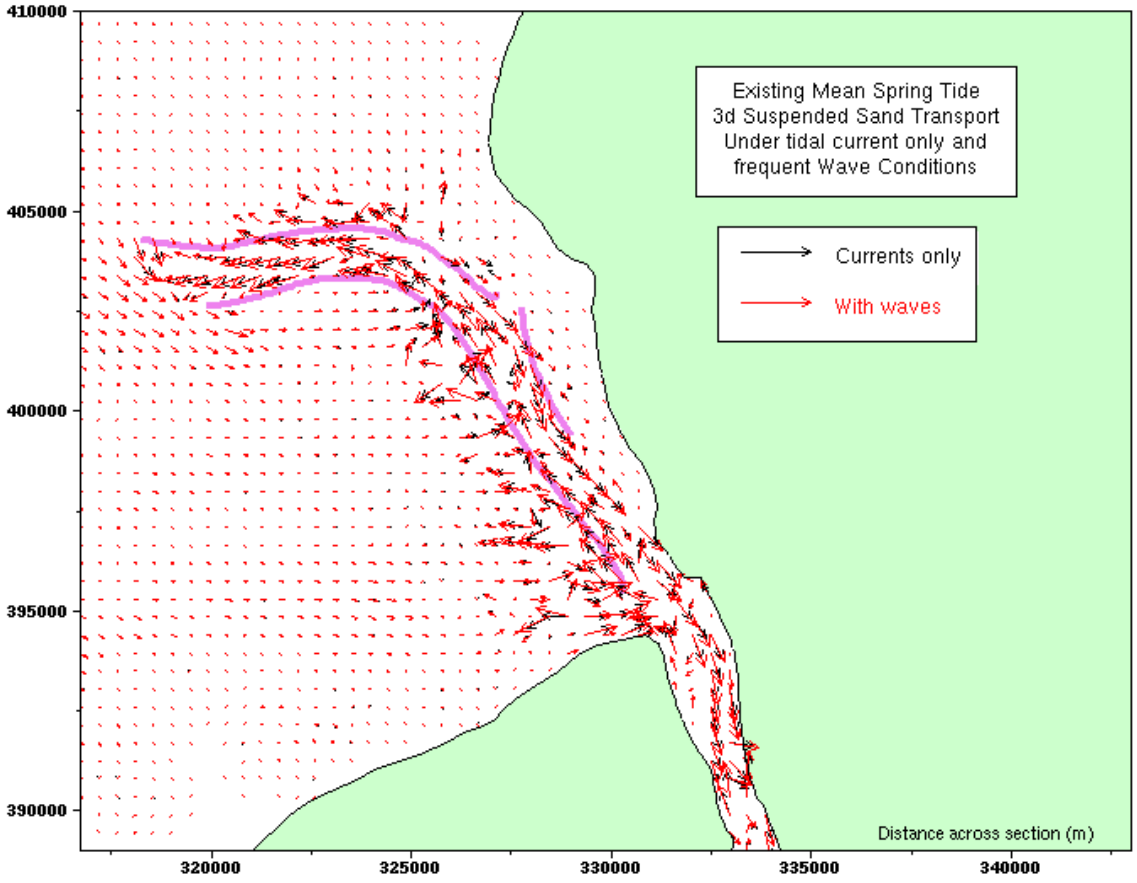
Development of the conceptual model

Effect of waves



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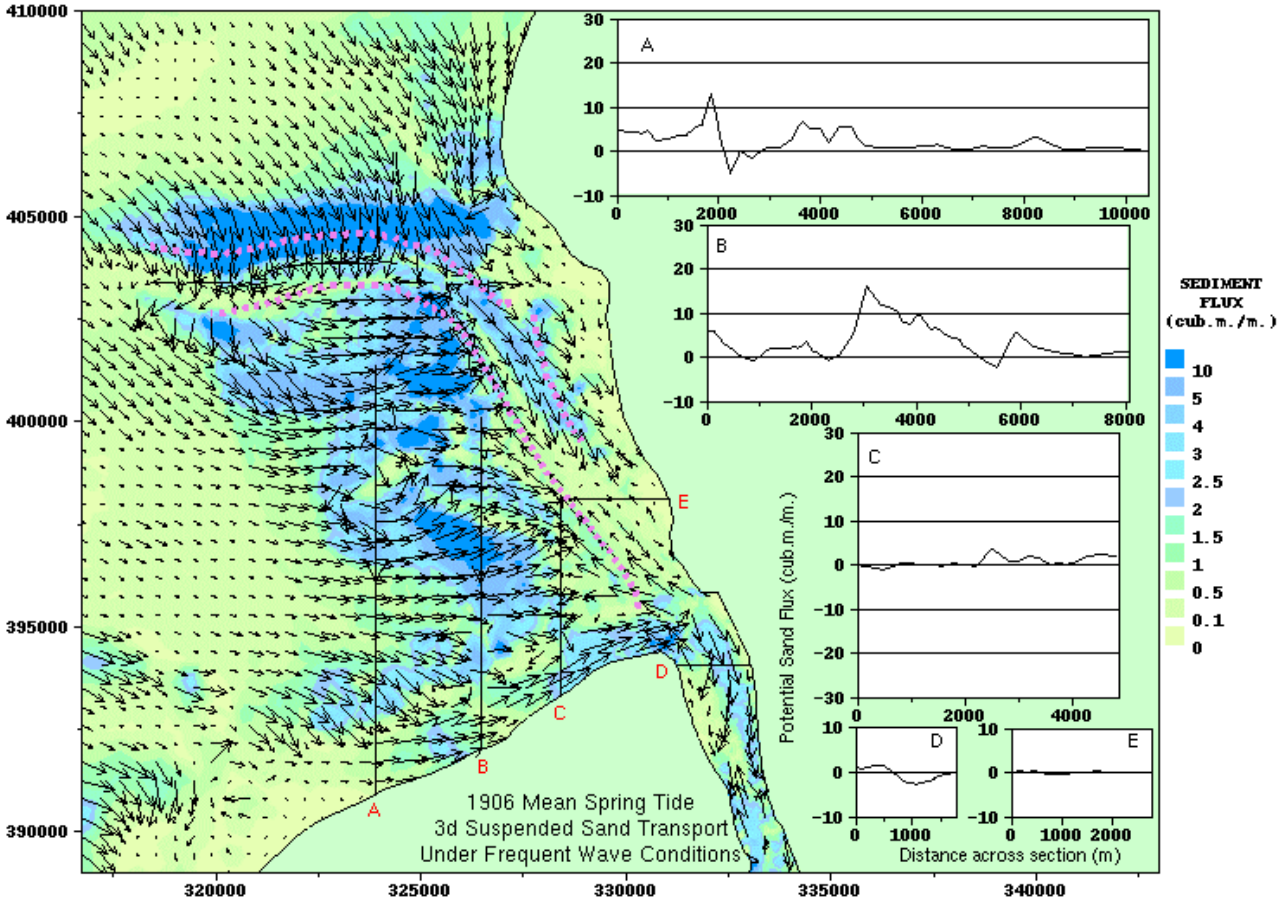
Development of the conceptual model

Sand transport 1906



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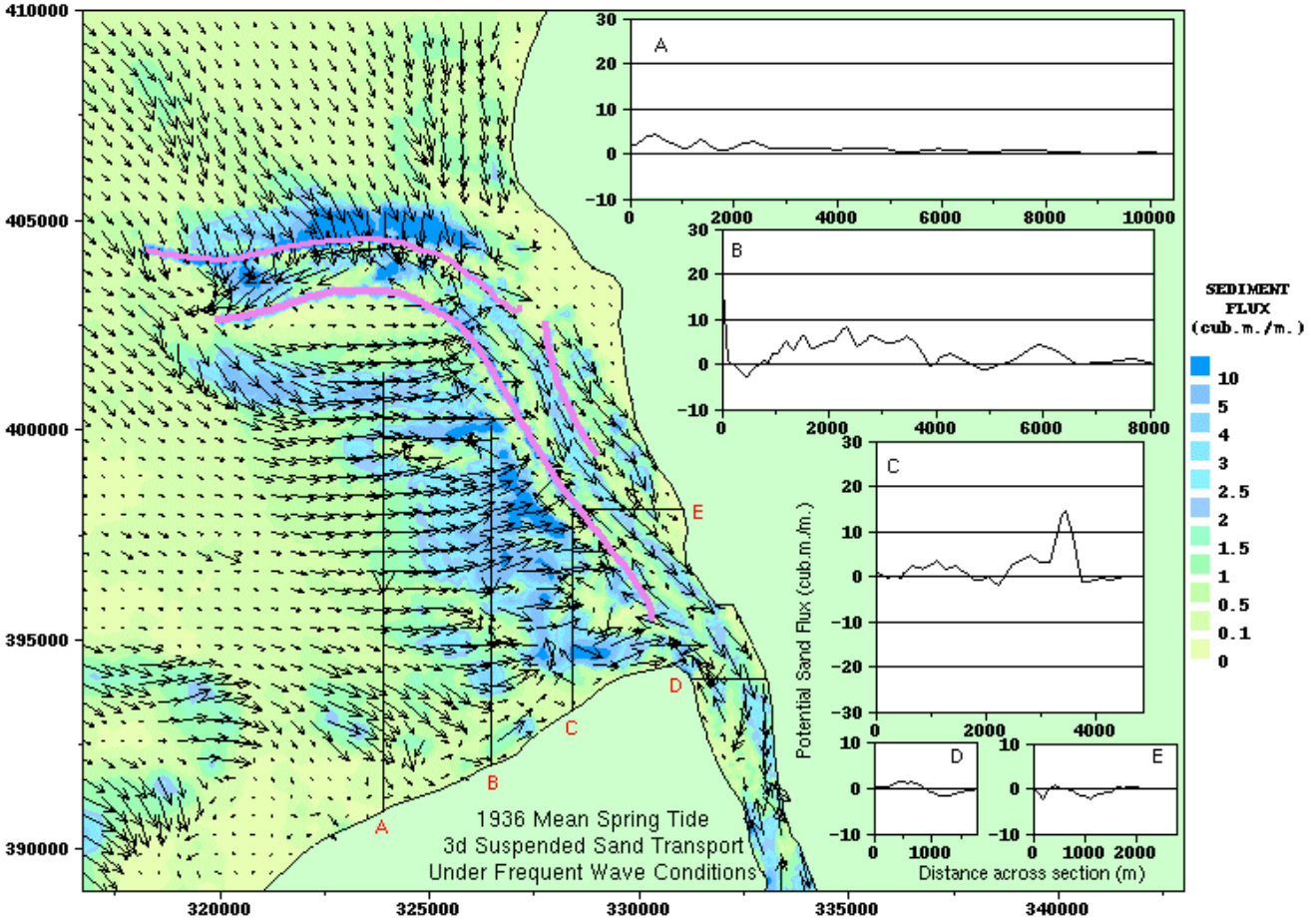
Development of the conceptual model

Sand transport 1936



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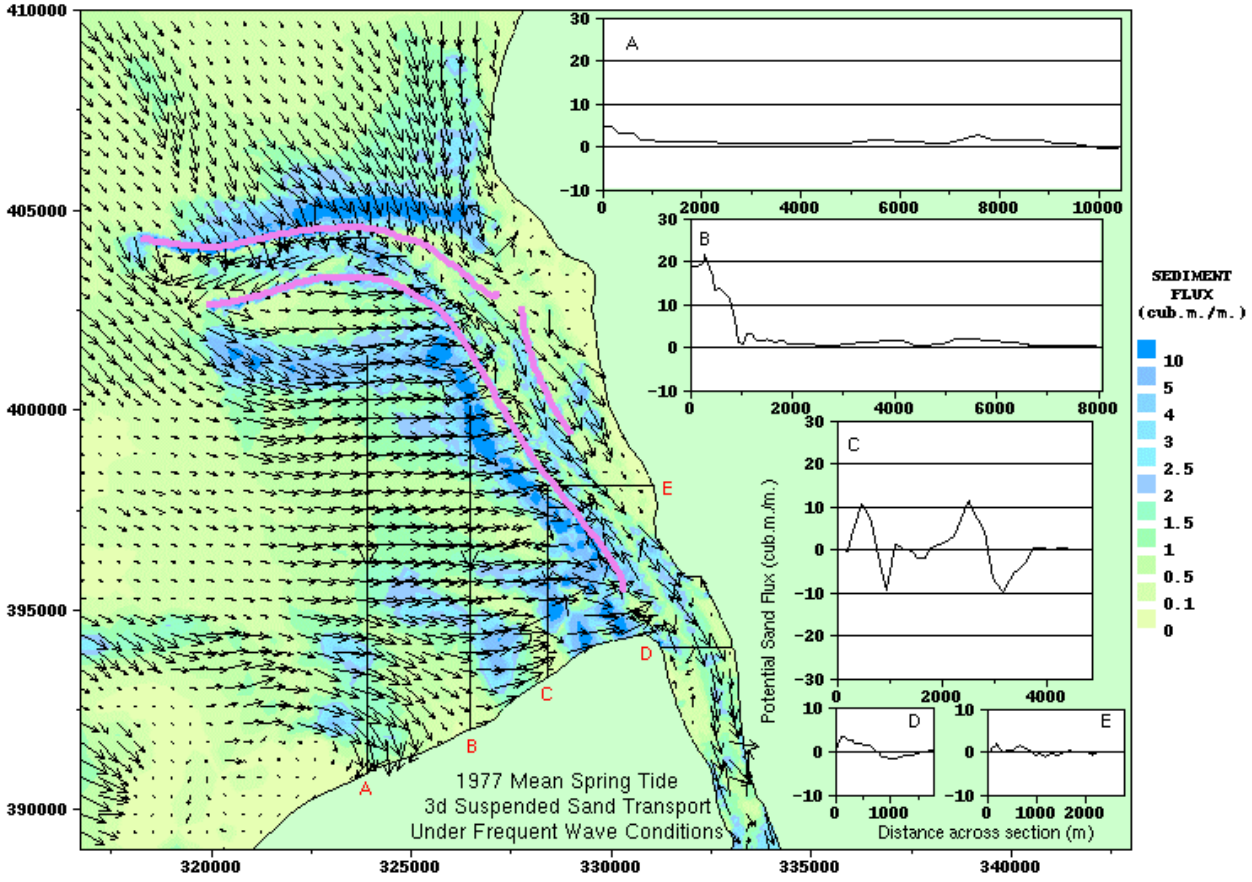
Mersey Demonstration Project

Development of the conceptual model

Sand transport 1977

animation



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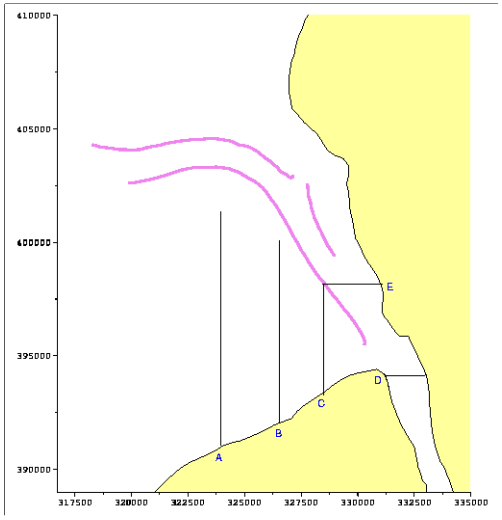
Development of the conceptual model

Changes in Sediment flux 1906-1977



Year	Net sediment flux across transects					
	A	B	C	D	E	C+E
1906	2.69	3.22	0.09	0.53	0.04	0.13
1936	1.6	1.98	2.22	0.24	0.37	2.60
1977	2	4.28	-2.43	-0.15	-0.17	-2.60

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*Development of the conceptual model - **summary***

- The sedimentation in the Mersey in the 20th century is a response to:
  - the influx of sediment into Liverpool Bay from offshore
  - the construction of the training walls
- This is broadly confirmed by:
  - Sediment budget analysis
  - Short-term modelling

? A robust conceptual model has been established

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Impact of the proposed scheme

Now we can start investigating the impact of the demonstration scheme

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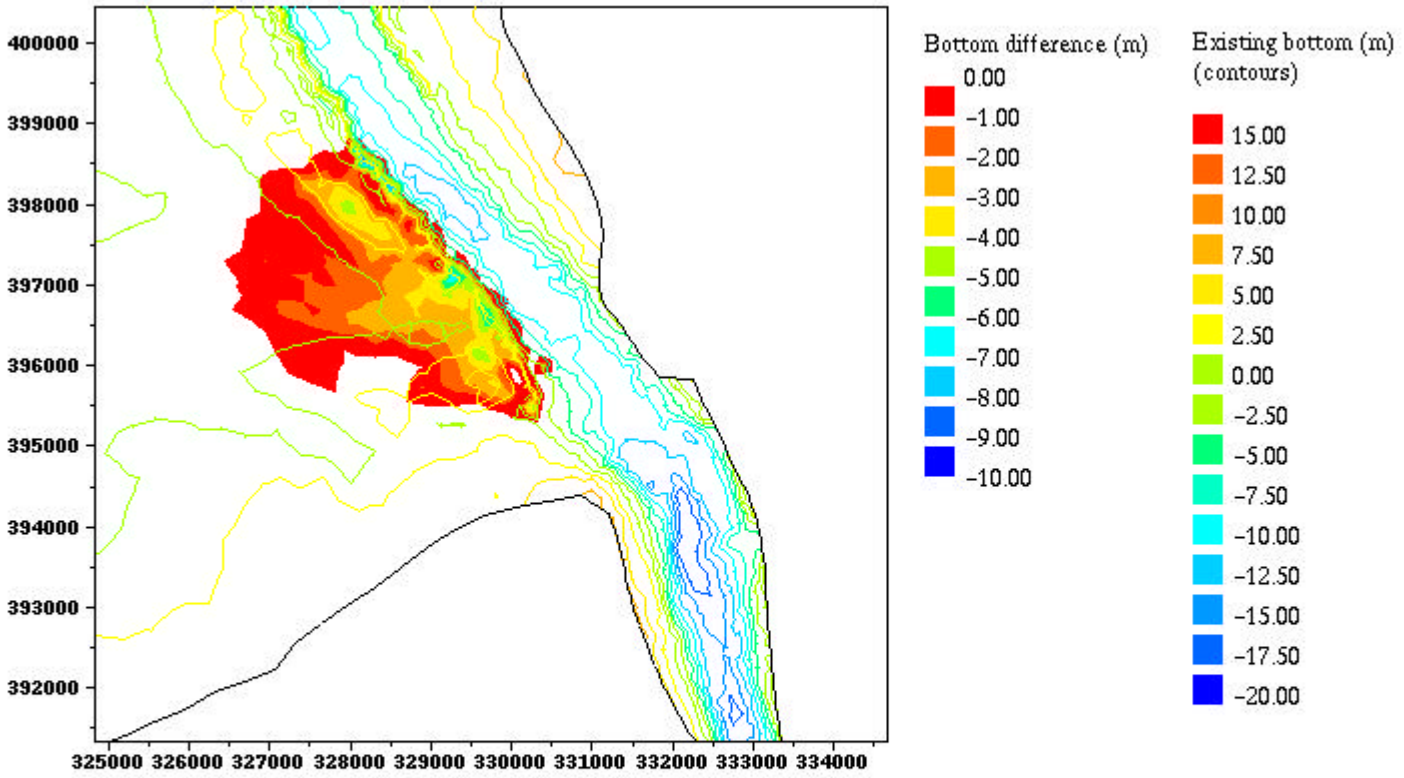
Impact of the proposed scheme - change in bathymetry



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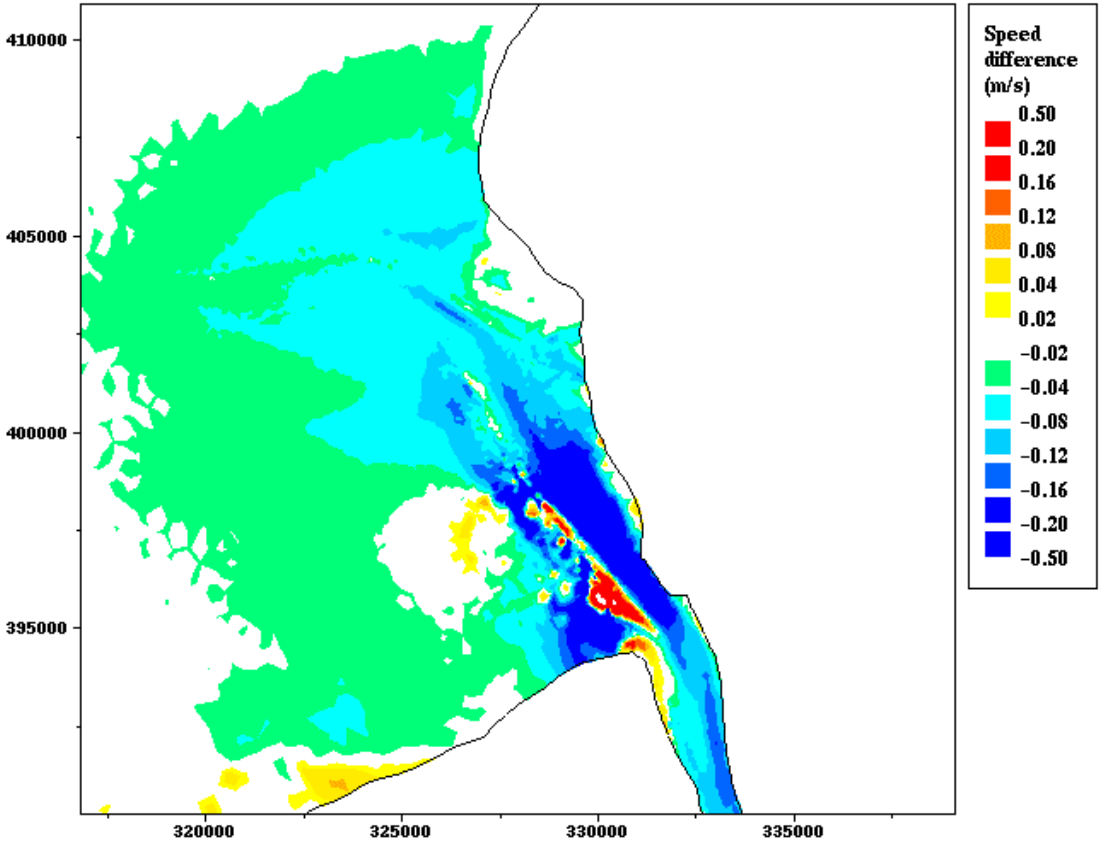
Impact of the proposed scheme on tidal flows

Change in near bed current speed on flood tide



Speed difference at peak flood.

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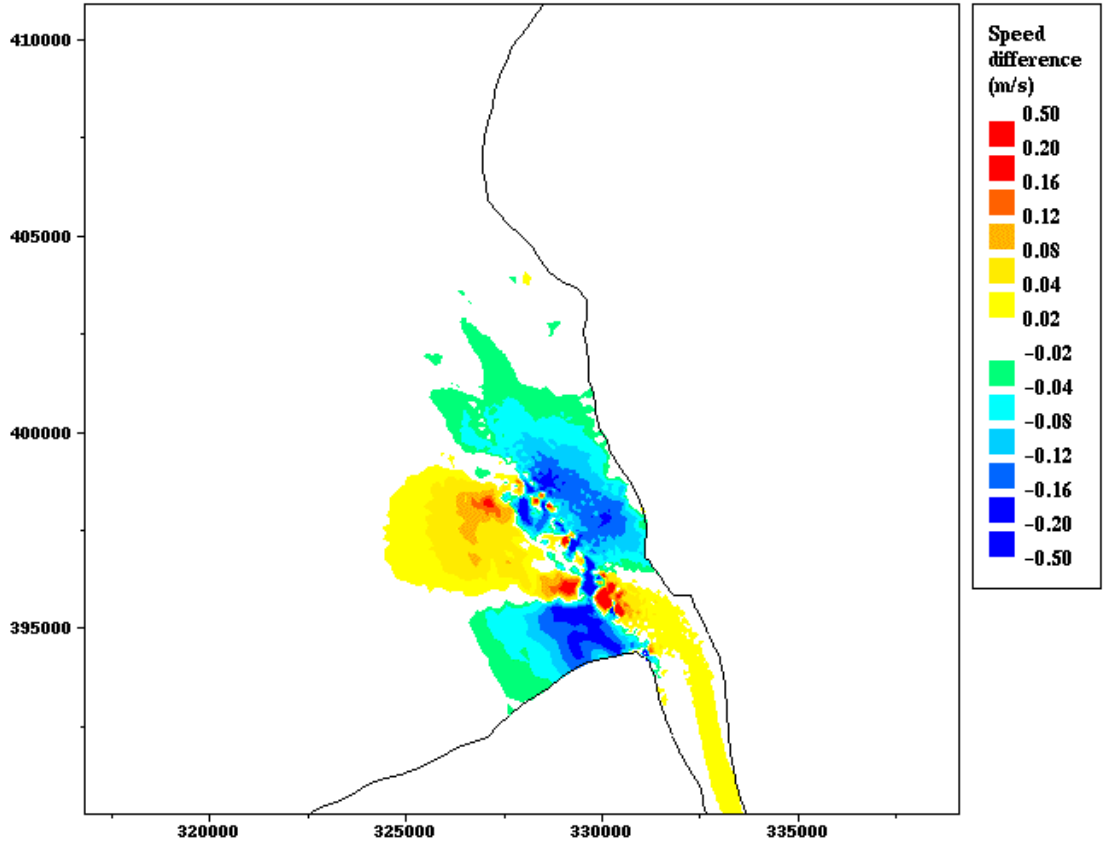
Impact of the proposed scheme on tidal flows

Change in near bed current speed on ebb tide



Speed difference at peak ebb.

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Impact of the proposed scheme on tidal flows

- Scheme influences flows over much of Liverpool Bay
- Impact of scheme extends into the Mersey
- Near bed ebb tide flows increased in Mersey and reduced on flood tide

  ? enhanced ebb-dominance
- Erosion suggested on Great Burbo Bank
- Accretion suggested along coasts either side of entrance

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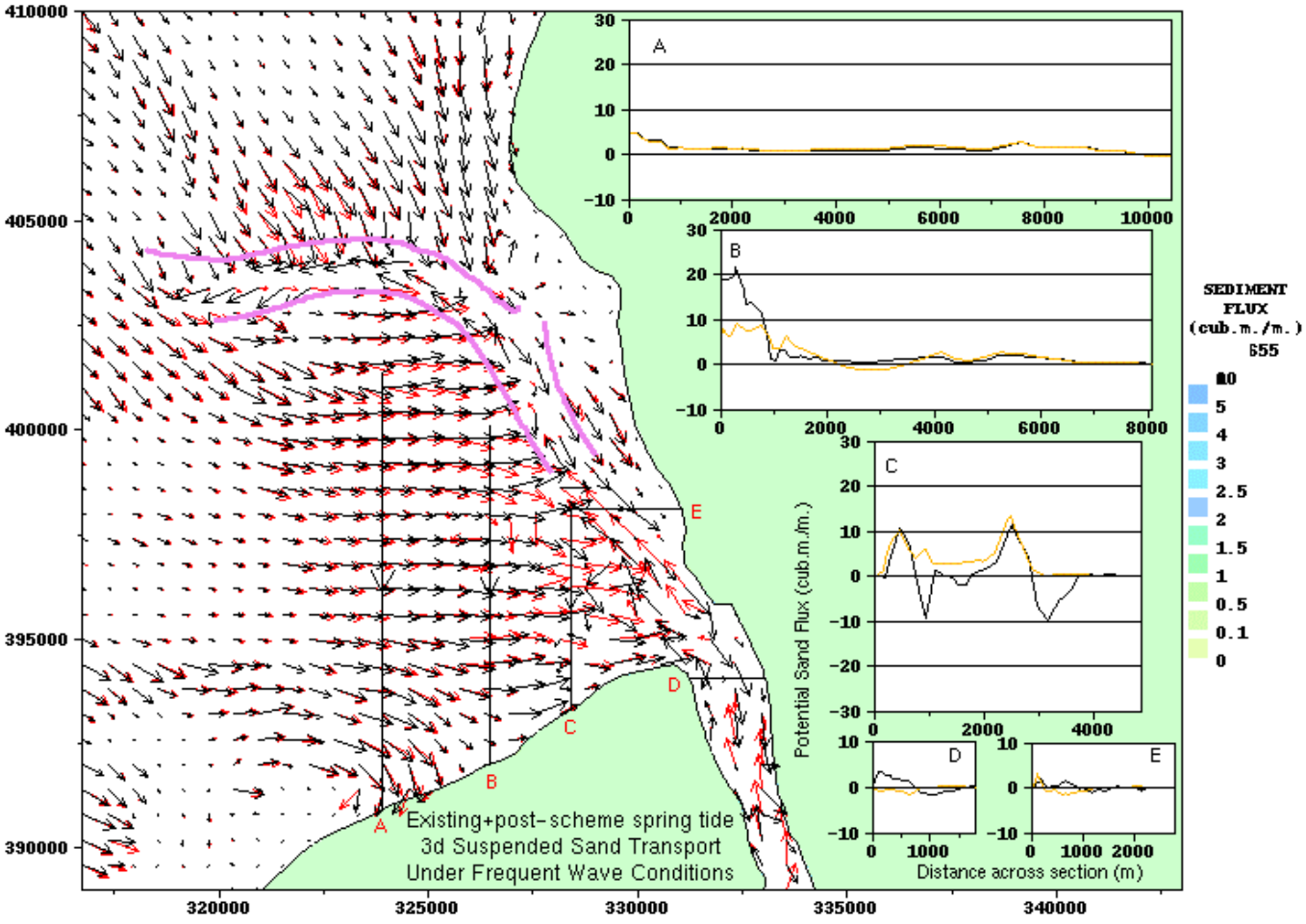
Impact of the proposed scheme on sediment transport

Annual spring tide transport



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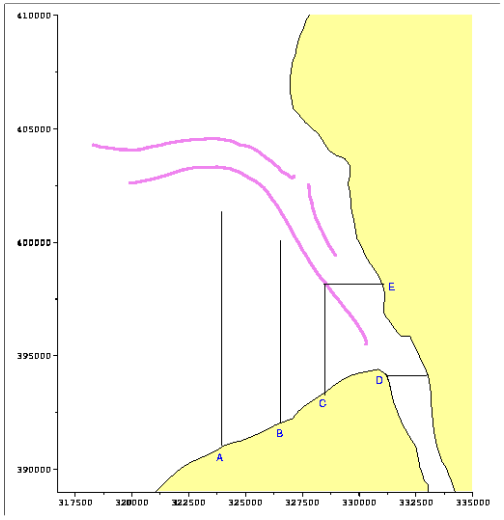
Impact on sediment exchange with Mersey Estuary



Year	Net sediment flux across transects					
	A	B	C	D	E	C+E
Existing	2	4.28	-2.43	-0.15	-0.17	-2.60
Scheme	2.47	1.28	2.70	-0.68	-0.18	2.52

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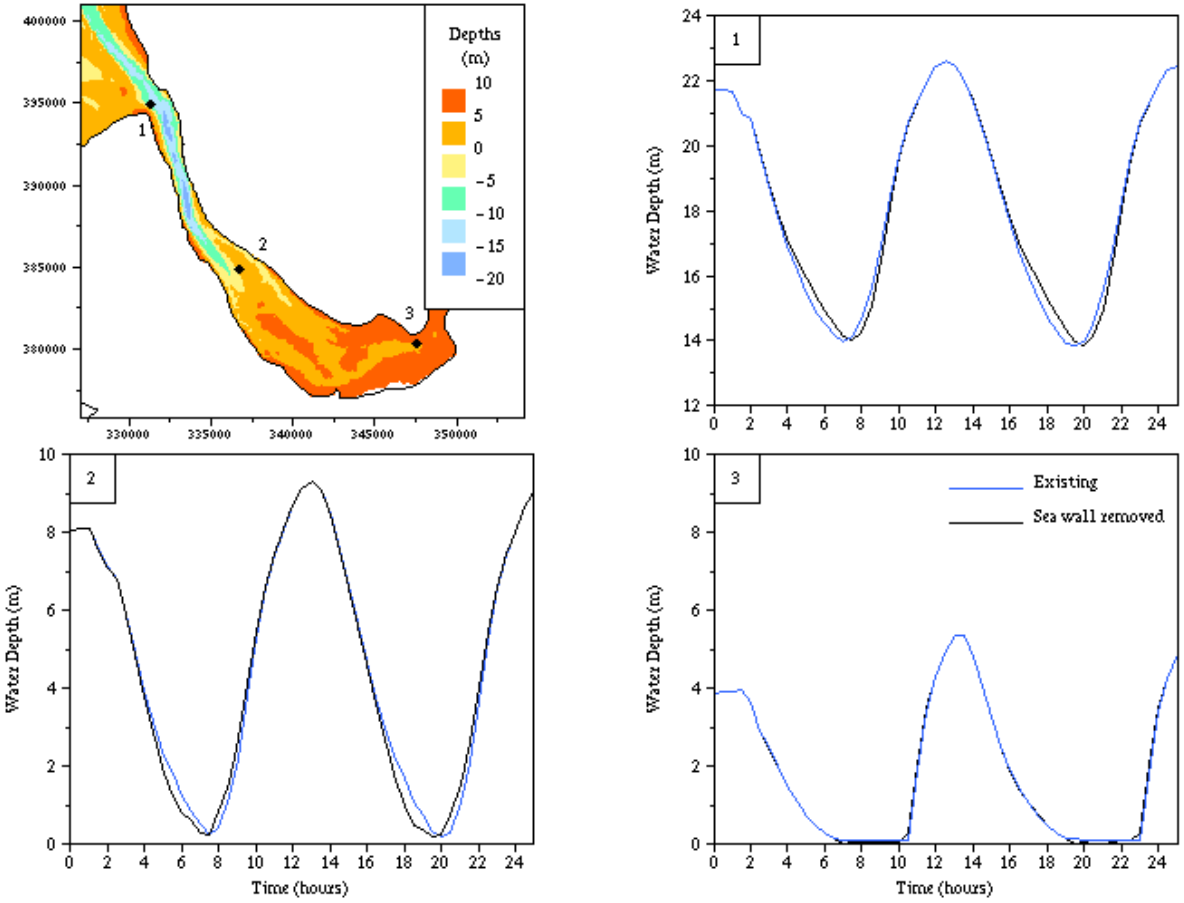
Impact on water levels in the Mersey Estuary



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Further studies needed for the "real" impact assessment

If impact is identified then:

- 3D Mud transport in the Mersey Estuary will be required including:
  - Changes to maintenance requirement within the estuary
  - Evaluation of changes in deposition/erosion on intertidal areas
  - Will the enhanced ebb dominance in the lower estuary reduce concentrations over the longer term?

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Further studies needed for the "real" impact assessment

- Wave modelling including:
  - An assessment of the importance of wave driven currents in the sediment transport in Liverpool Bay
  - Area wave modelling throughout Liverpool Bay and Mersey Estuary
  - Changes in wave action along coast and littoral drift study
  - (If wave changes are large) An extreme water level study

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Further studies needed for the "real" impact assessment

- Longer term morphological evolution of Liverpool Bay and the Mersey Estuary
  - 3D system so use of top-down and hybrid by themselves may be open to criticism
  - May need to use a 3D process-based approach
  - This is difficult, costly and time consuming
  - No one has yet done this successfully

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Conclusion

- Studies of this type are clearly complex and costly and may include elements of research
- Consider undertaking a “pilot” study to identify the possible scope of impact and aid the design of the programme of work
- Consider use of an independent review team to appraise progress and results of studies

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Short-term modelling

Overall conclusions

- Don’t underestimate the magnitude of the task
- Apply the systematic approach identified in the Guide
- Estuary modelling studies are technically complex - use experienced organisations
- Build a robust conceptual model first before you undertake impact modelling
- The two demonstration projects show that each project is different and the scope of work/data requirements/accuracy required may be on different levels

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