IMPACTS OF MARINE ENERGY ON COASTAL SEDIMENTATION

DAVID PRANDLE

A) MARINE ENERGY – PRACTICALITIES?

B) TIDAL POWER

C) COASTAL SEDIMENTS

D) GRAND CHALLENGES

MARINE ENERGY – PRACTICALITIES ?

Is it competitive?

$$\frac{\text{energy produced} \times \text{availability factor}}{\text{capital cost} \times \text{interest rates}}$$

versus

oil
gas
coal
nuclear

costs

ONLY WITH A CARBON TAX/SUBSIDY

Is it competitive?

$$\frac{\text{energy produced} \times \text{availability factor}}{\text{capital cost} \times \text{interest rates}}$$

versus

oil
gas
coal
nuclear

costs

LIKELY SCENARIO ?

10-20 year 'window' for bitter 'proof' of GCC

Renewable Energy Research Requirements:

Assess scale & nature of availability

Engineering designs for extraction

Assess associated environmental impacts*

*differentiate from concurrent GCC impacts

B) TIDAL POWER – BARRIER CHARACTERISTICS

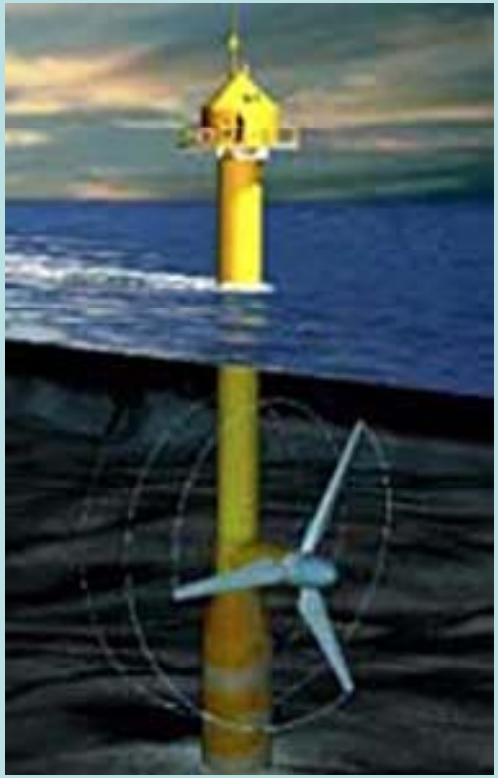
- Net energy yield ~ 27% of 'maximum' (one-way)
- ~ 37% (two-way

- Sea levels in impounded basin ~ msl to HW
- Flushing rate reduced ~ 50%

- 10 year construction period
- No energy production until completion

Tidal energy

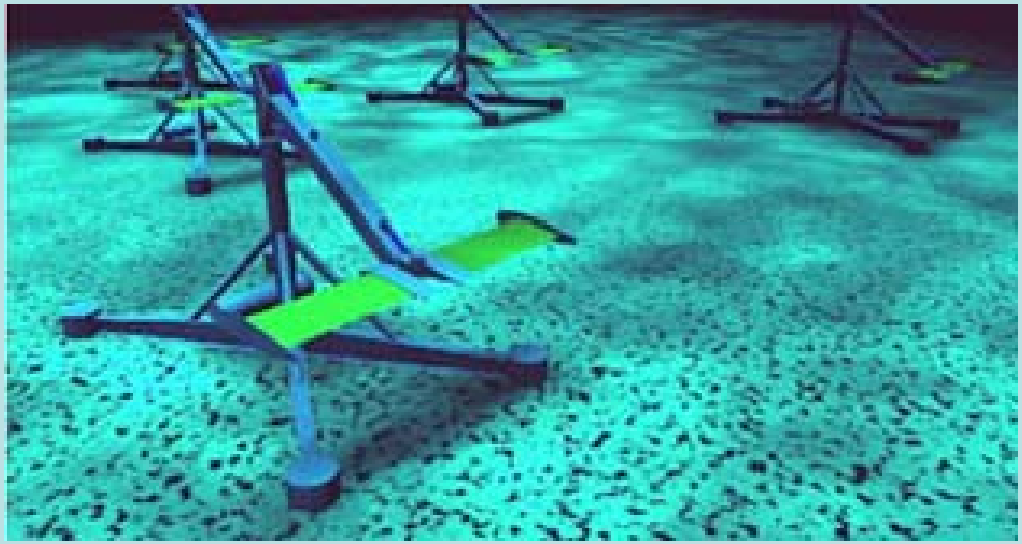
La Rance **tidal barrage**



Tidal stream devices

Marine current turbines e.g. Seaflow (left)

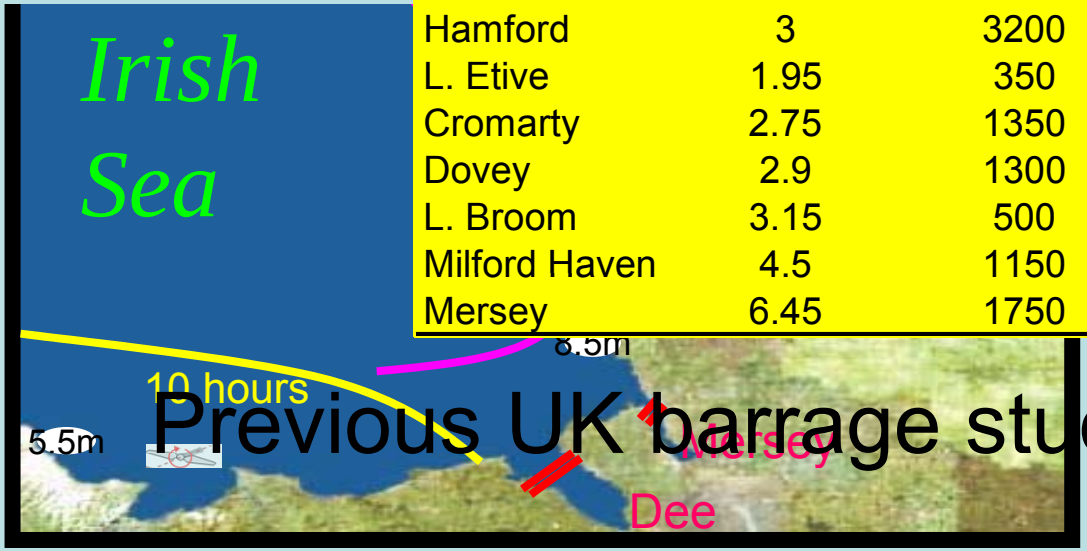
Stingray (below)



al Power Potential of the Eastern Irish Sea

	Range (m)	Length (m)	Capacity (MW)	Output (GWh)
Severn	7	20000	15000	22000
Morecambe	6.3	16600	4000	5400
Solway	5.5	30000	5580	10050
Dee	5.95	9500	800	1250
Humber	4.1	8300	1200	2010
Wash	4.45	19600	2760	4690
Thames	4.2	9000	1120	1370
Langstone	3.13	550	24	53
Padstowe	4.75	550	28	55
Hamford	3	3200	20	38
L. Etive	1.95	350	28	55
Cromarty	2.75	1350	47	100
Dovey	2.9	1300	20	45
L. Broom	3.15	500	29	42
Milford Haven	4.5	1150	96	180
Mersey	6.45	1750	620	1320

Tidal barrage or

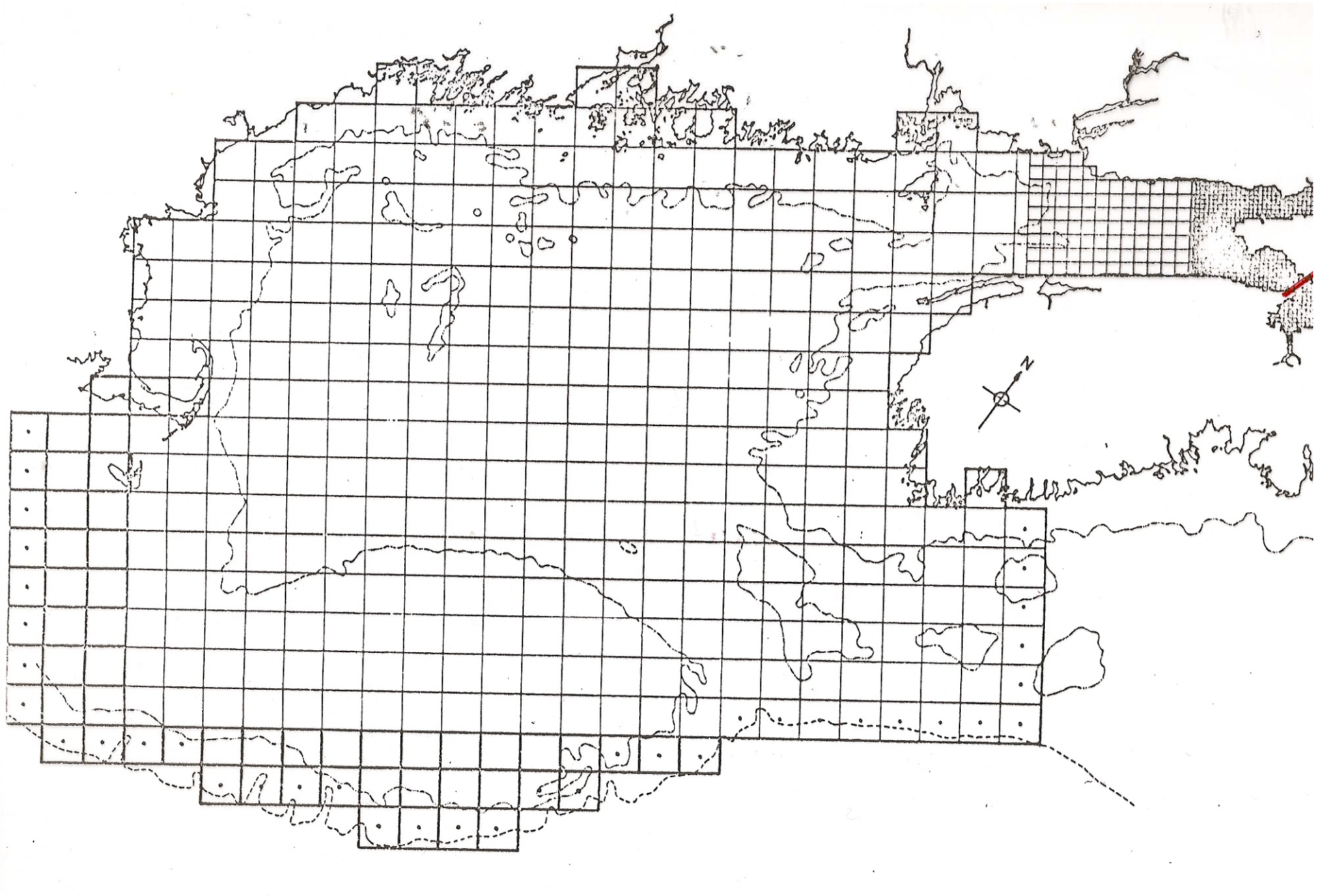


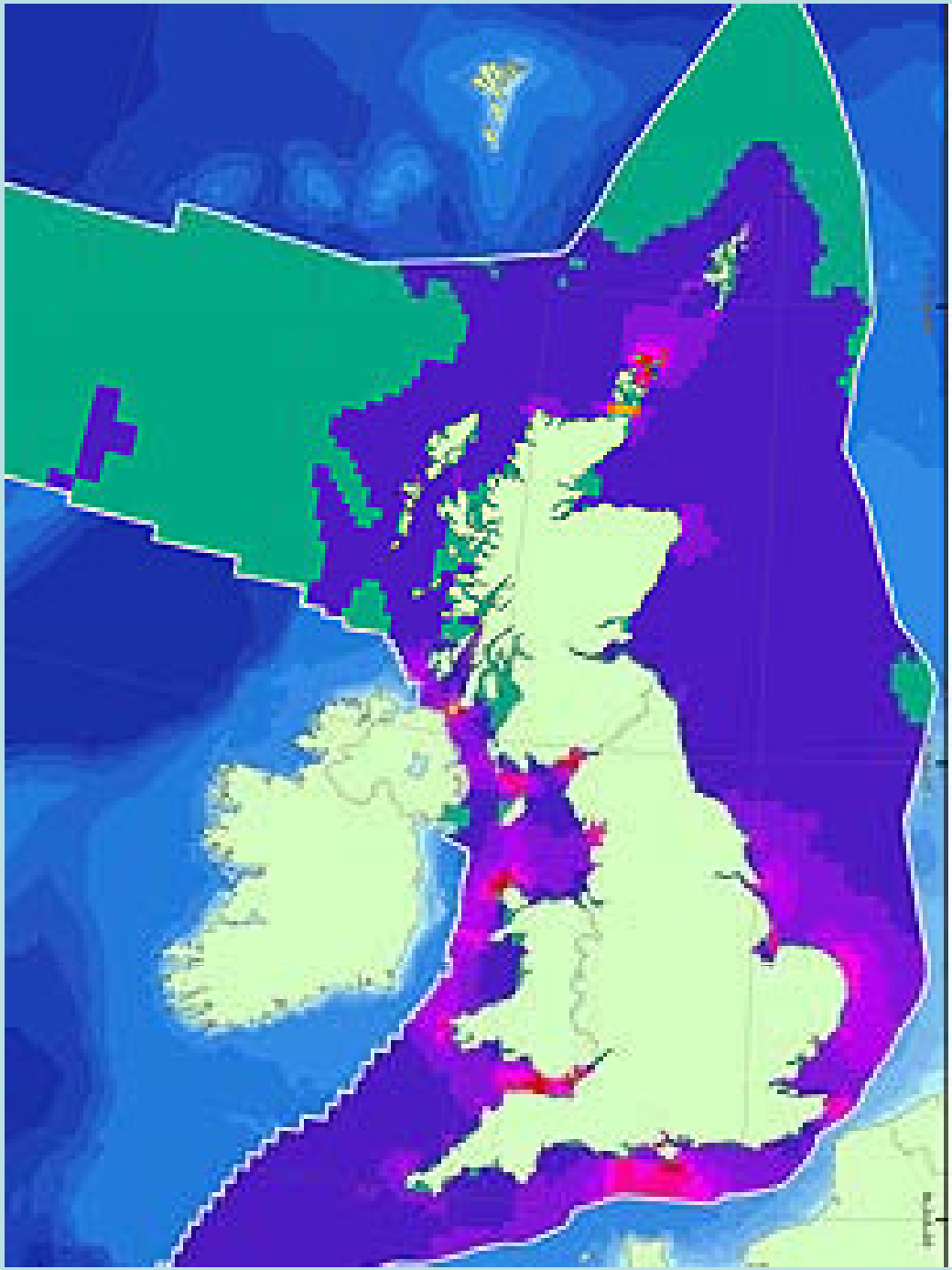
Previous UK barrage studies

Spring tidal range

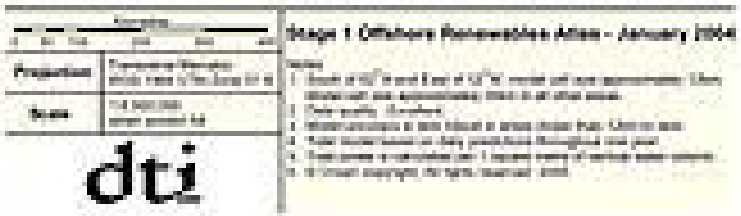
OPERATIONAL, UNDER CONSTRUCTION, DESIGNED BARRIER SCHEMES

PARAMETER	THEORY	LA RANCE	KOREA	FUNDY	BRISTOL CHANNEL	
SURFACE AREA		22	56	86	420	Km^2
TIDAL A AMPLITUDE		4.25	4.0	5.0	4.0	m
EMAX= $4\rho gA^2S/P$		350	360	1900	5900	MW
Actual Output	27	16	17	20	19	%
Rated Head, h	1.2	1.3	1.4	1.3	2.2	h/A
Rated Flow, q	0.4	0.5	0.2	0.4	1.9	q/Q





Average Annual Tidal Power



Average Tidal Power
(kW / m^2 of vertical water column)

- < 0.01
- 0.01 - 0.04
- 0.05 - 0.12
- 0.13 - 0.25
- 0.26 - 0.41
- 0.42 - 0.59
- 0.60 - 0.82
- 0.83 - 1.19
- 1.20 - 1.63
- 1.64 - 2.17
- 2.18 - 2.50
- 2.51 - 2.90
- > 2.91
- Land
- UK Continental Shelf

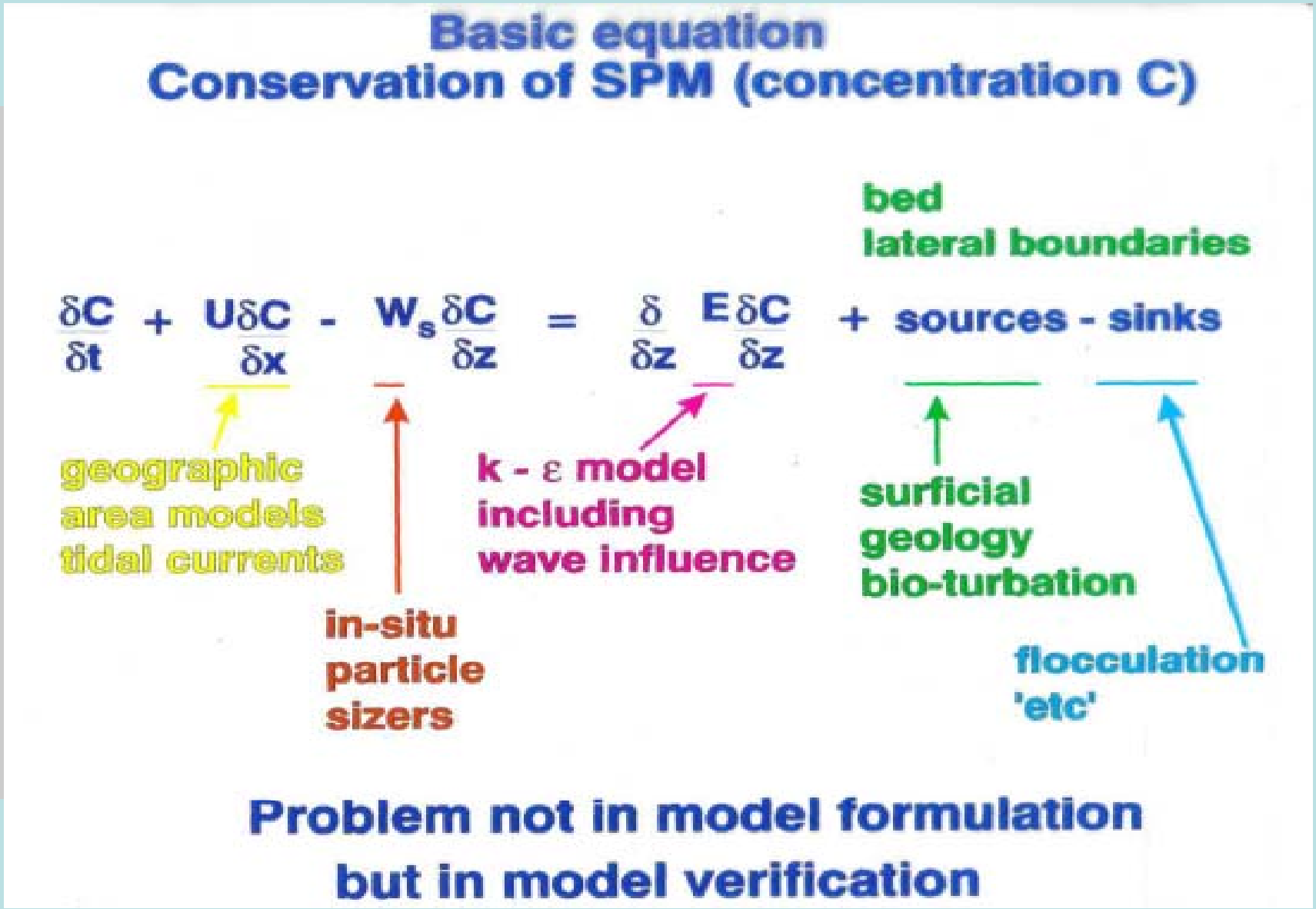
C) COASTAL SEDIMENTATION

FORCING
(tides,waves,storms)

SEDIMENT TRANSPORT ↔ MORPHOLOGICAL EVOLUTION

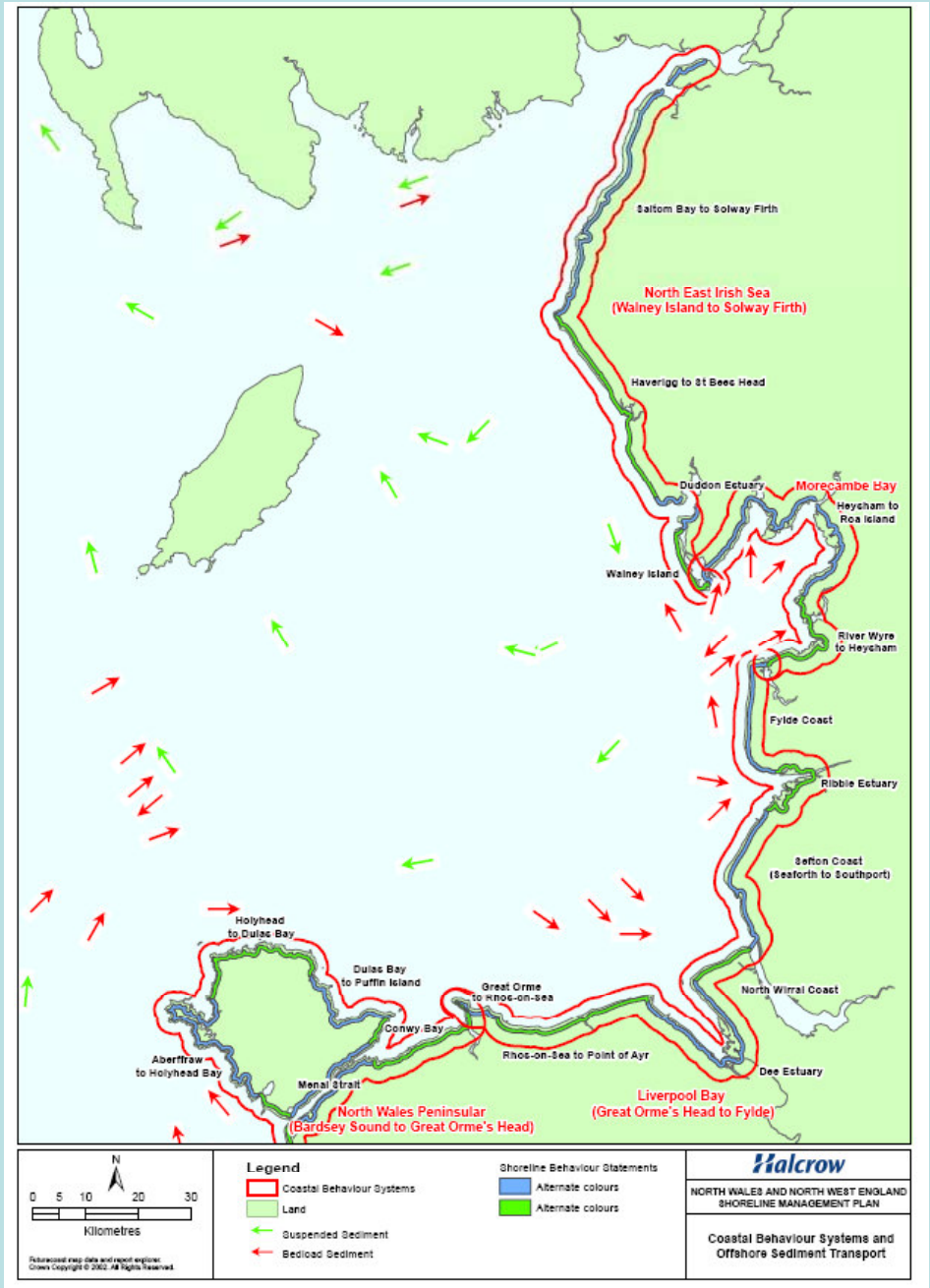
all 3 closely inter-dependent at the coast

Sediment transport – conservation eqn. with problems



NEAR-FIELD localised scour/sedimentation

FAR-FIELD exchange of sediments on scales of :
tides
storms
seasons
climate events
glacial cycles


Saltom Bay to Solway Firth
North East Irish Sea
(Walney Island to Solway Firth)
Haverigg to St Bees Head
Duddon Estuary
Morecambe Bay
Heysham to
Roa Island
Walney Island
River Wyre
to Heysham
Fylde Coast
Ribble Estuary
Sefton Coast
(Seaforth to Southport)
Holyhead
to Dulas Bay
Dulas Bay
to Puffin Island
Great Orme
to Rhos-on-Sea
North Wirral Coast
Conwy Bay
Rhos-on-Sea to Point of Ayr
Aberffraw
to Holyhead Bay
Menai Strait
Dee Estuary
North Wales Peninsular
(Bardsey Sound to Great Orme's Head)
Liverpool Bay
(Great Orme's Head to Fylde)
N
0 5 10 20 30
Kilometres
Legend
Coastal Behaviour Systems
Land
Suspended Sediment
Bedload Sediment
Shoreline Behaviour Statements
Alternate colours
Alternate colours
Halcrow
NORTH WALES AND NORTH WEST ENGLAND
SHORELINE MANAGEMENT PLAN
Coastal Behaviour Systems and
Offshore Sediment Transport

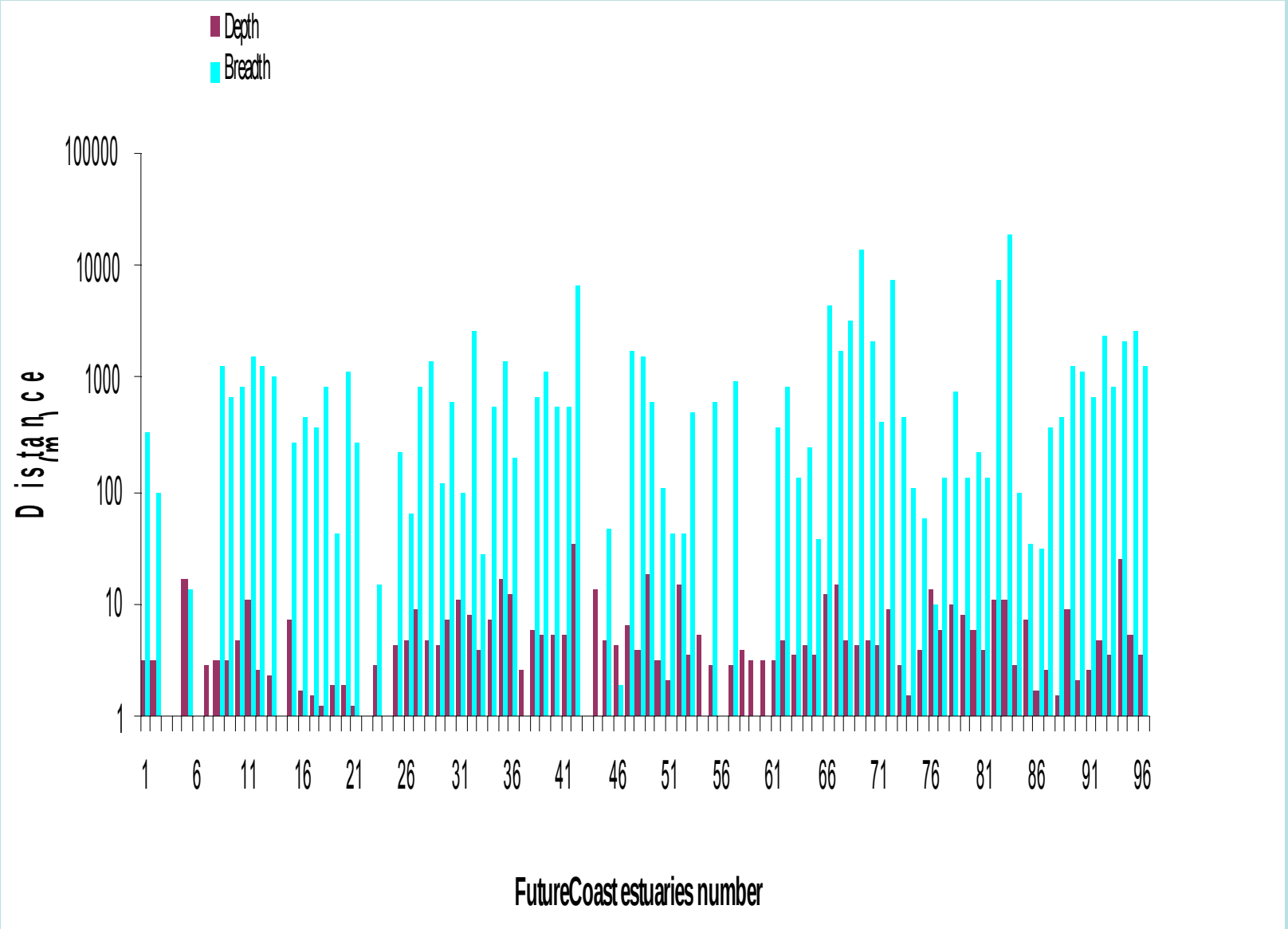
IMPACTS OF MARINE ENERGY ON SEDIMENTS

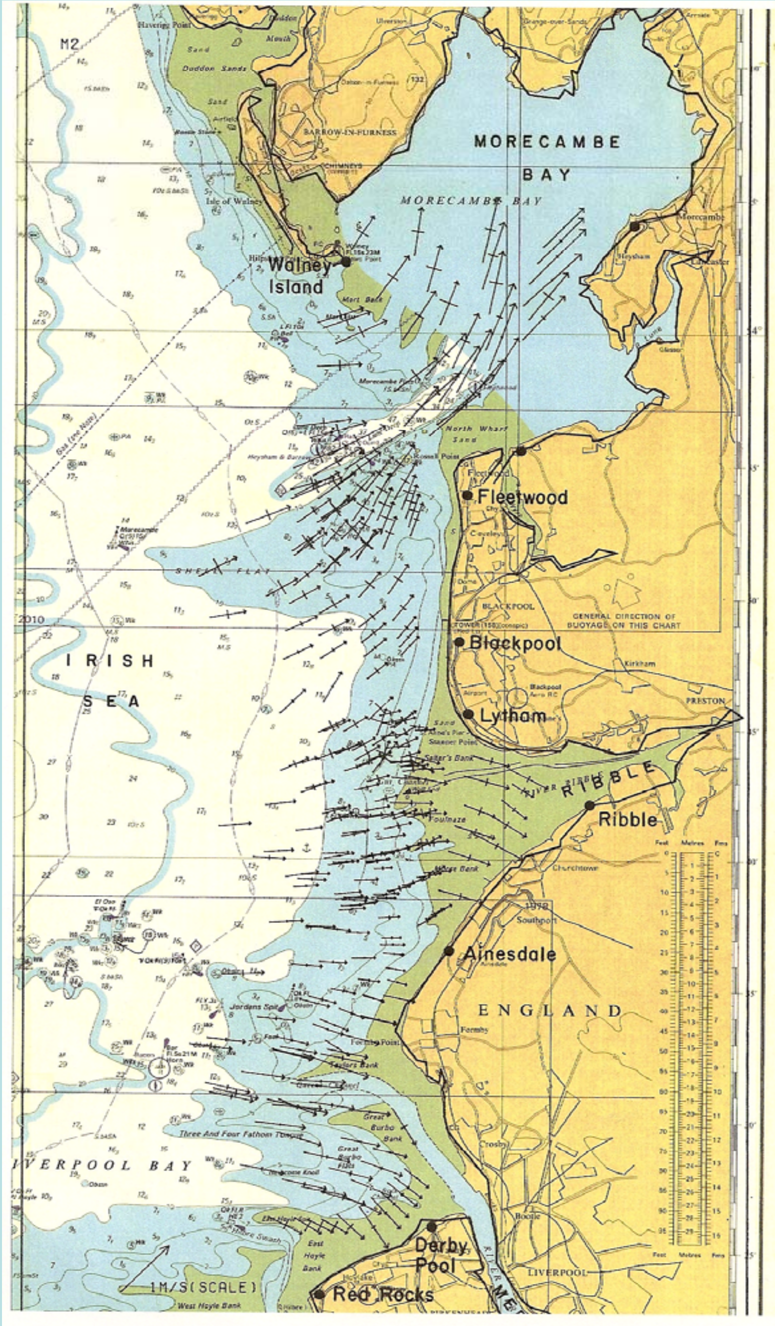
Wind 'Mills' – local/small effect on wave climate

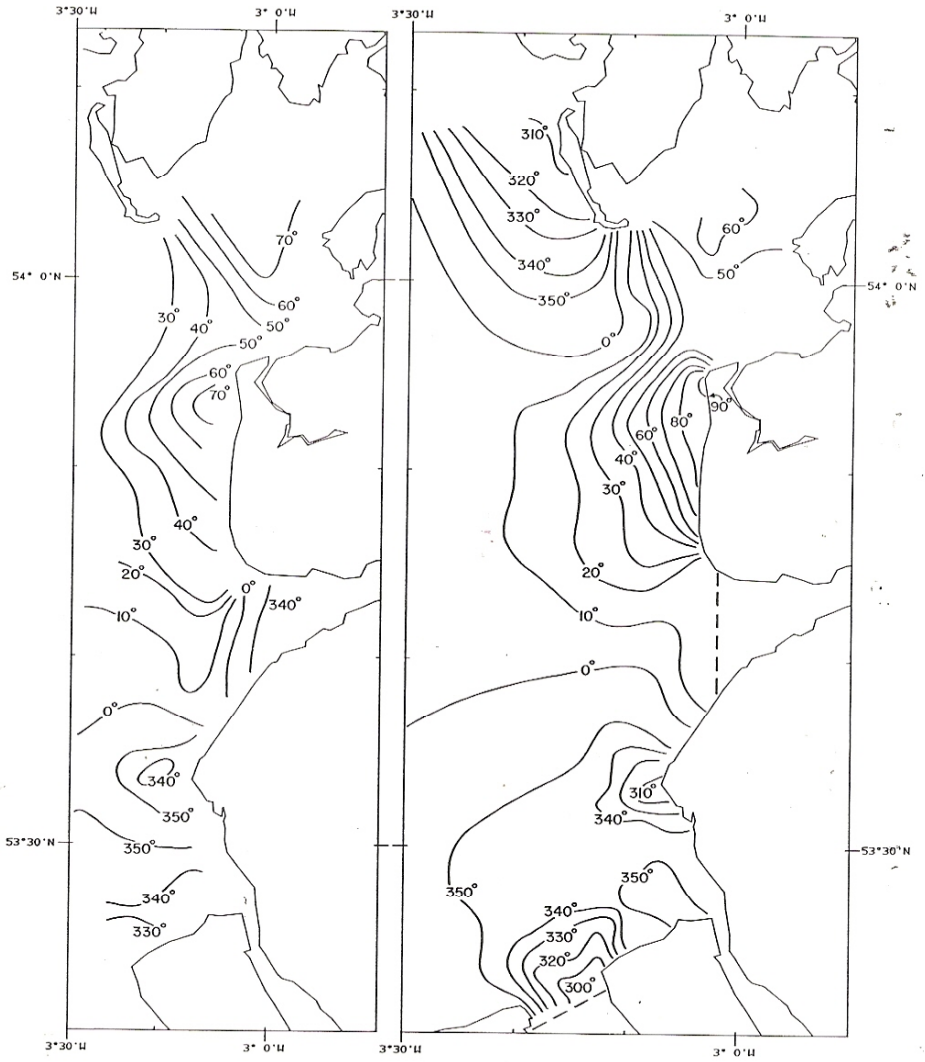
Tidal Barriers - 'settling pond'
large-scale shift of tidal patterns

Tidal Streams – interruption of sediment pathways

Wave - potential changes in magnitude and direction of longshore drift


Depth
Breadth
100000
10000
1000
100
10
1
Distance (m)
1
6
11
16
21
26
31
36
41
46
51
56
61
66
71
76
81
86
91
96
FutureCoast estuaries number


MORECAMBE
BAY
Walney
Island
Fleetwood
Blackpool
Lytham
RIBBLE
Ribble
Ainesdale
ENGLAND
IRISH
SEA
Derby
Pool
Red Rocks
1M/S(SCALE)
M2



7. M_2 current ellipse parameters obtained from H.F. Radar (left) observations and the 1km grid model (right).

(c) direction

Challenges for coastal sedimentation

IMPROVE DESCRIPTIONS OF:

1) SINKS & SOURCES
coast/estuary

2)EROSION & DEPOSITION
cohesives/mixed

3) FORMATION OF MESO-SCALE MORPHOLOGY
dunes/saltmarsh/channels/banks

4)EFFECTS OF 'INTERVENTIONS'
training walls/dredging/railways/offshore energy

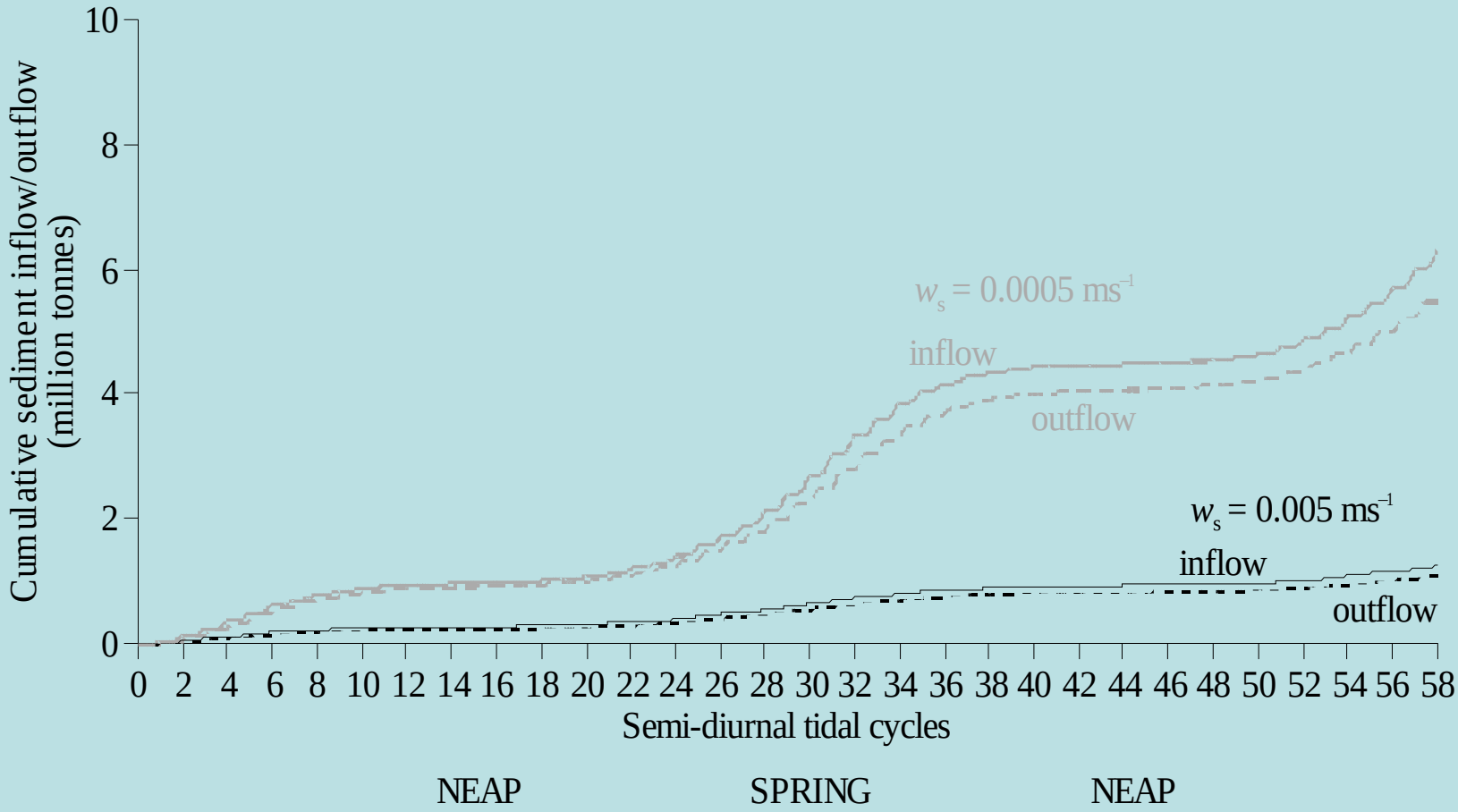
GRAND CHALLENGES

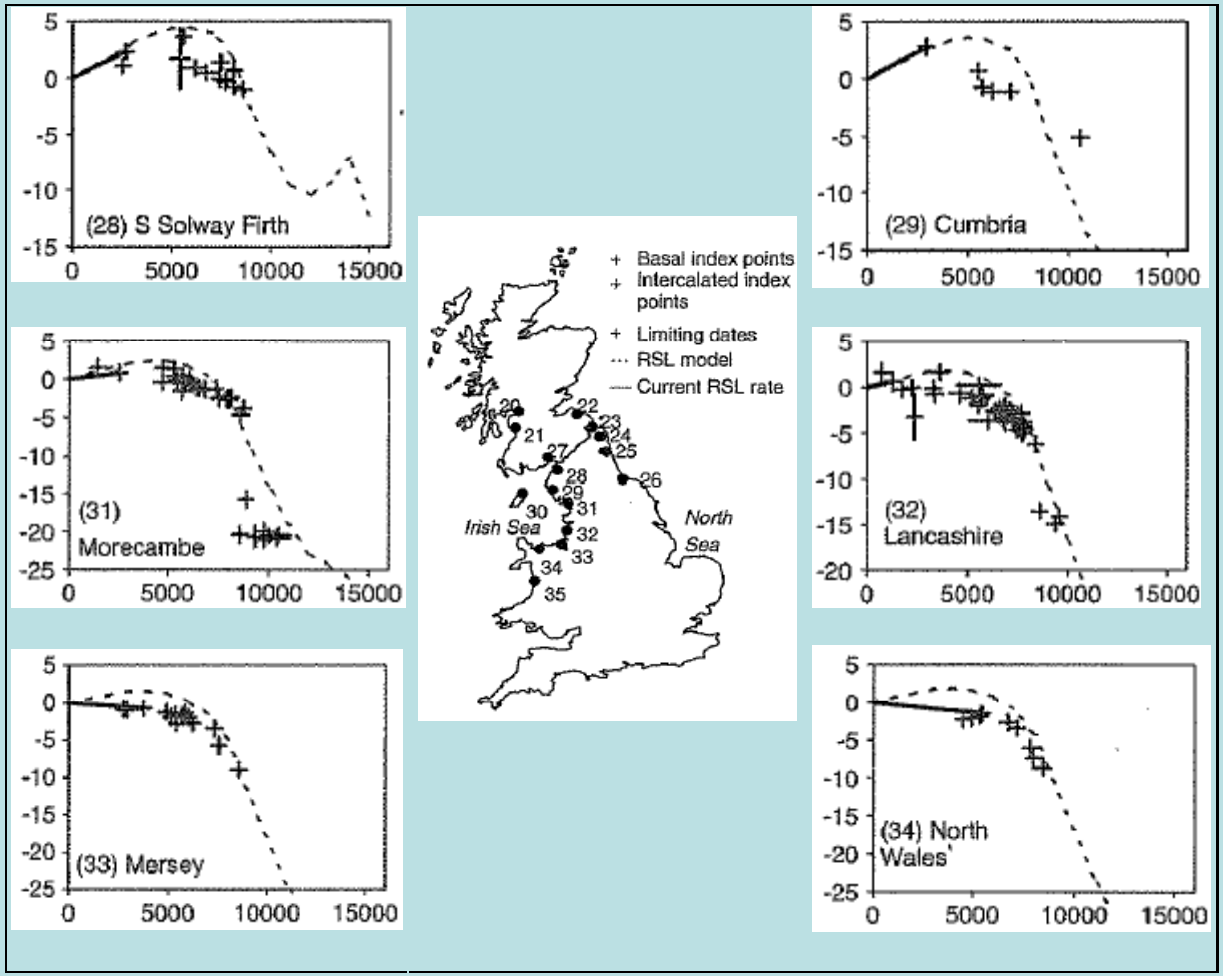
COASTAL SEDIMENTATION

sensor
instrument development
platform

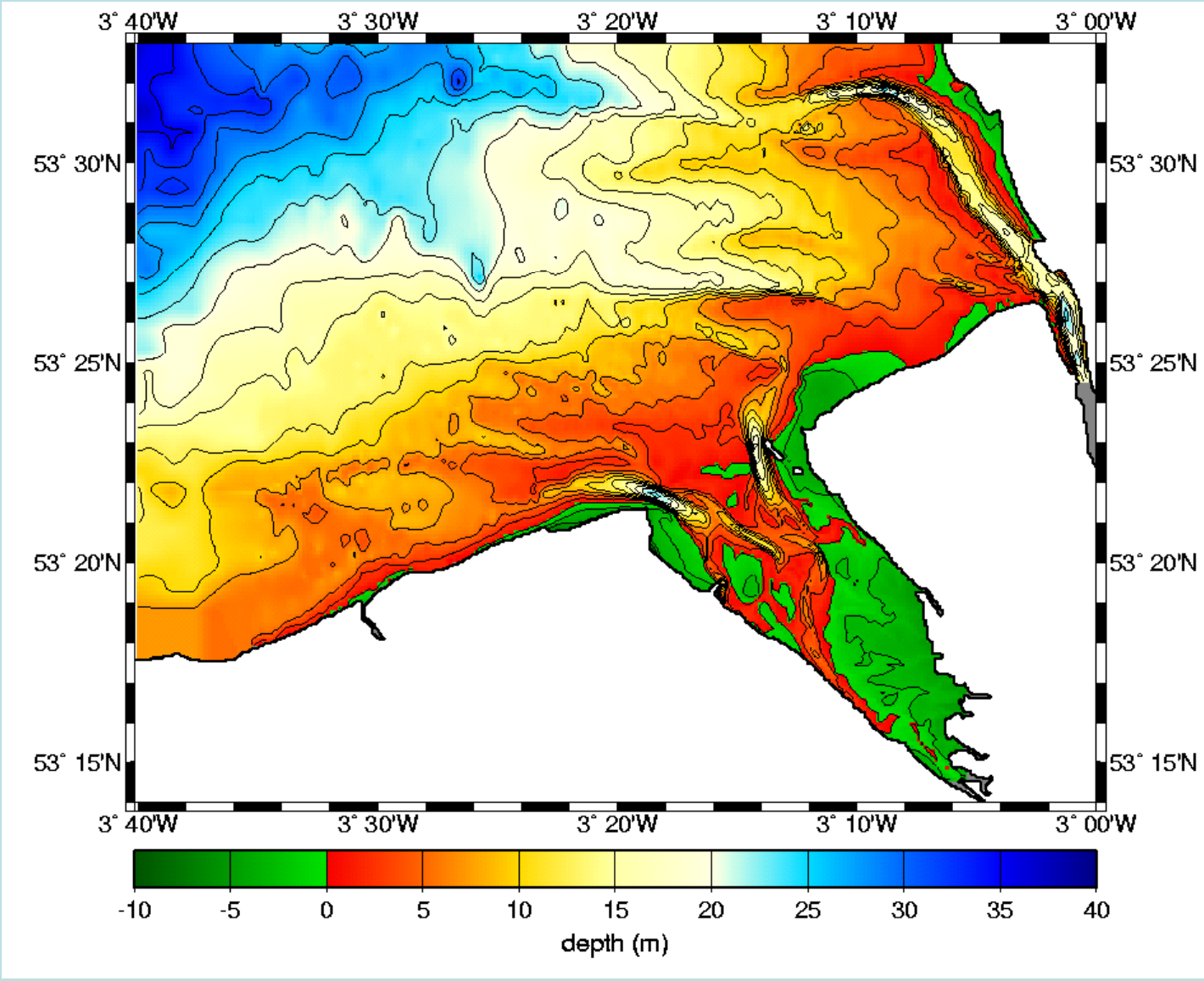
flume experiments
modelling
coastal observatory

forecasting morphology
seasonal/post-event/long-term


Cumulative sediment inflow/outflow (million tonnes)
10
8
6
4
2
0
w_s = 0.0005 ms^{-1}
inflow
outflow
w_s = 0.005 ms^{-1}
inflow
outflow
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48 50 52 54 56 58
Semi-diurnal tidal cycles
NEAP
SPRING
NEAP


(28) S Solway Firth
(29) Cumbria
(31) Morecambe
(32) Lancashire
(33) Mersey
(34) North Wales
+ Basal index points
+ Intercalated index points
+ Limiting dates
··· RSL model
— Current RSL rate
Irish Sea
North Sea
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
5
0
-5
-10
-15
-20
-25
0
5000
10000
15000

High resolution Liverpool Bay/Dee coupled model
EA LIDAR/sonar survey, 2003, Dee Experiment



Model grid:

1/400 degree longitude by 1/600 degree latitude ~200m resolution

267*187 grid points

Repeated 1-month process studies including observations of waves, currents, turbulence, suspended sediment and bottom profile measurements are being made

PhD project on morphodynamic evolution

Tides
Surges
Waves
Sed supply
Biol/chem
events

Geology
morphology

coastal protection
habitat conservation

turbulence
erosion/deposition
bed & coastal features

Impacts of
GCC
'interventions'