Fig 1

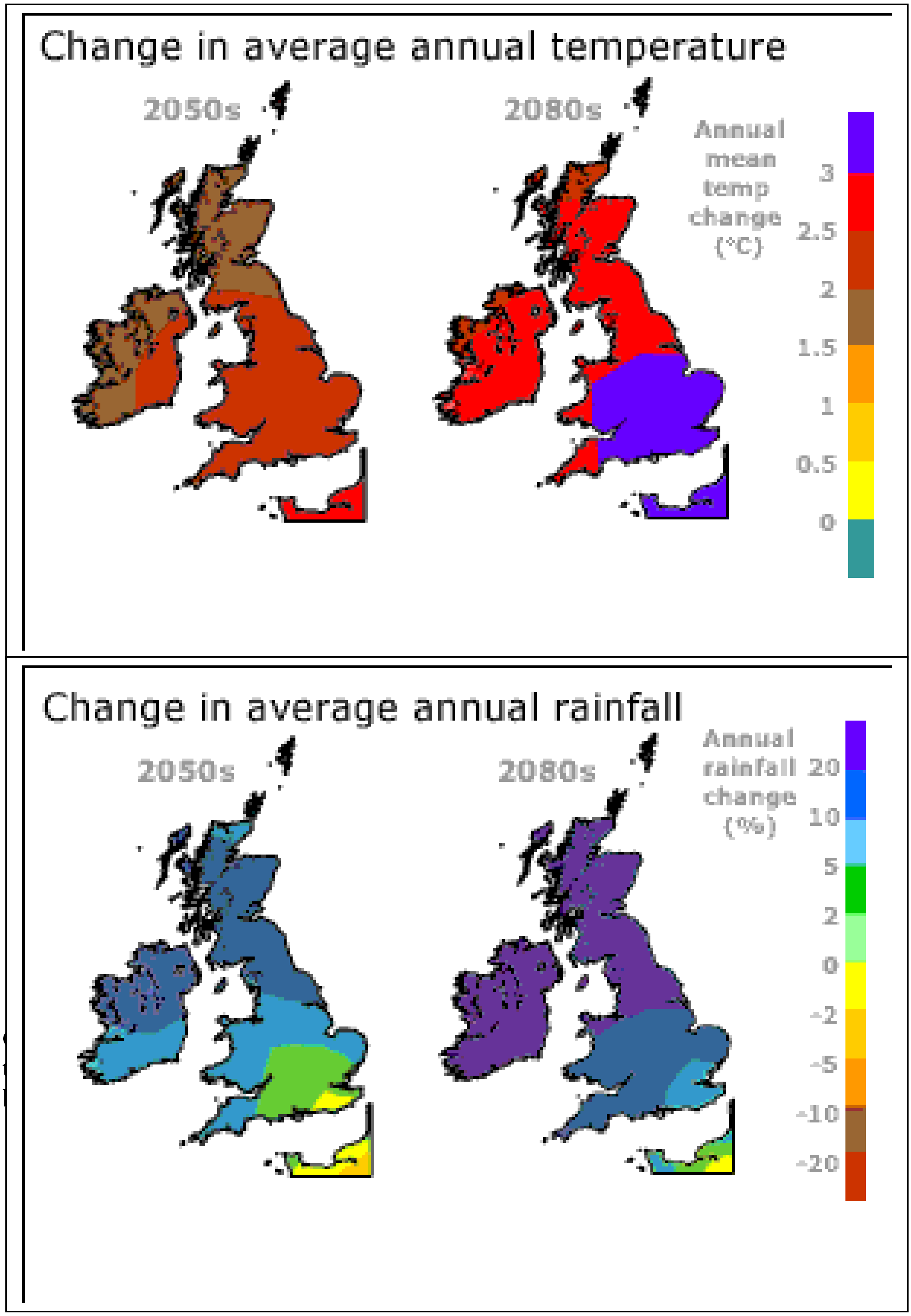


Figure 1 - Source : Climatic Research Unit – East Anglia, UK.
Two scenarios of Temperature and Precipitation changes in the UK for 2050 and 2080 - showing the level of changes by area.
The model is based on the highest sensitivity and 1% per annum concentration growth of greenhouse gases

Fig 2a

Photograph showing the dynamic movement of barrier islands in response to changes in sea-level and sediment supply

Assateague Island, (Ocean City) Virginia, USA. The northern part has remained with shoreline in the position when storms breached the island and sea-defences were installed 1933. The southern (un-walled) section has moved shoreward in response to changes in sediment supply and sea level. It is now aligned with the 1933 shoreline as defined by the mainland defences protecting the City . Ref" Against the tide" – Cornelia Dean. P78

Fig 2b **Fig 2c**

Morris Island – (Charleston light), Folly Beach, South Carolina, USA. Standing 400 metres from the present day shoreline and demonstrating the dynamic movement of coastline with time.

Originally built 1300 metres from its current position
http://www.bansemer.com/nc-lighthouses/morris_island_lighthouse.htm

Fig 3 a, b, c

A montage of Environment Agency 'Flooding risk maps' for the eastern and south-eastern counties of the UK illustrate the large area of Norfolk that is at serious risk of flooding (Fig 3a). (approx. 8-15 EA individual maps have been included to create each of the composite maps shown here)

Not only are areas across the south and east liable to flooding but with extremes of increased precipitation likely - possibly following extremes of drought, there is a greater likelihood of run-off swelling rivers to levels at which river flooding would occur.

If this condition coincided with an abnormally high tide or storm surge then local flooding would be greatly increased. Buoyancy flows (see Tmczak, S (2000) - (http://oceanografia.cicese.mx/cursos/sco/chapter04,html) resulting from the difference in density values of the fluvial and marine waters may also exacerbate the conditions

The South coast map (Fig 3b) shows local flooding risk areas including the Dungeness shingle-spit on which Dungeness power station is sited. (See also Fig 17 Main appendix)

Fig 3c Shows the lessening extent of coastal areas at risk of flooding in the South-west (and reflects the nature of the lithology with some sections more resistant to erosion) with hazard and risk concerns shifting more to land-movement and slides.

See pages :

Fig 3a	Appendix to Report - Page 4
Fig 3b	Appendix to Report - Page 5
Fig 3c	Appendix to Report - Page 6

Fig 3a

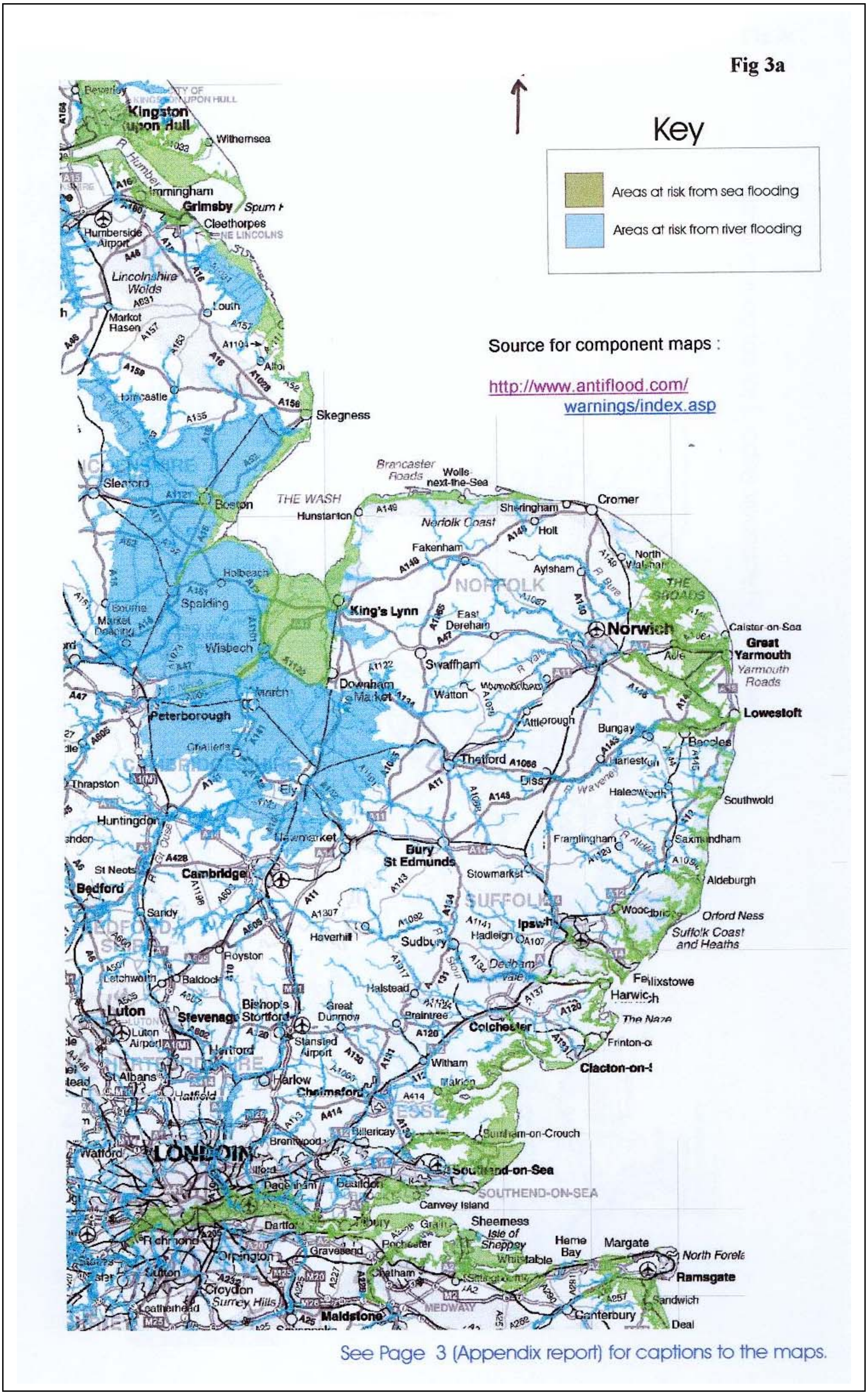
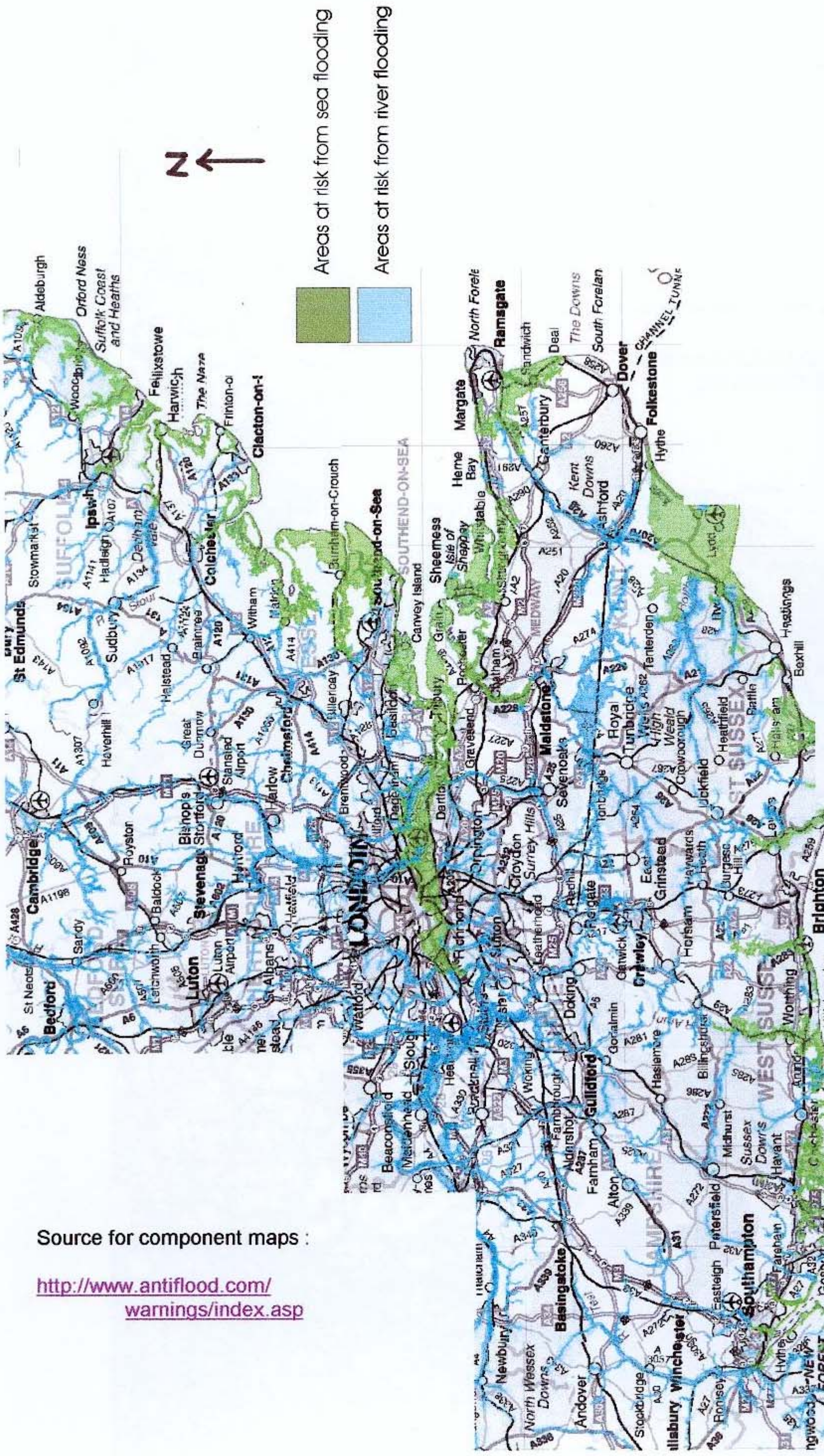


Fig 3a
Key
Areas at risk from sea flooding
Areas at risk from river flooding
Source for component maps :
http://www.antiflood.com/warnings/index.asp
Kingston upon Hull
Withernsea
Immingham
Grimsby
Cleethorpes
Humberside Airport
Lincolnshire Wolds
Louth
Market Rasen
Skegness
Sleaford
Boston
THE WASH
Hunstanton
Brancaster Roads
Wells-next-the-Sea
Sheringham
Cromer
Norfolk Coast
Holt
Fakenham
Aylsham
North Walsham
NORFOLK
Holbeach
Spalding
King's Lynn
East Dereham
Norwich
Caister-on-Sea
Great Yarmouth
Yarmouth Roads
Wisbech
Swaffham
Downham Market
Watton
March
Peterborough
Attleborough
Bungay
Lowestoft
Beccles
Thetford
Diss
Thrapston
Ely
Halesworth
Southwold
Huntingdon
Newmarket
Bury St Edmunds
Framlingham
Saxmundham
St Neots
Cambridge
Stowmarket
Aldeburgh
Bedford
SUFFOLK
Sandy
Haverhill
Sudbury
Hadleigh
Ipswich
Orford Ness
Suffolk Coast and Heaths
Royston
Dedham Vale
Felixstowe
Letchworth
Baldock
Halstead
Harwich
Luton
Stevenage
Bishop's Stortford
Great Dunmow
Braintree
The Naze
Luton Airport
Hertford
Stansted Airport
Colchester
Frinton-on
Witham
Clacton-on-
St Albans
Harlow
Hatfield
Chelmsford
Maldon
Brentwood
Billericay
Burnham-on-Crouch
Watford
LONDON
Southend-on-Sea
SOUTHEND-ON-SEA
Basildon
Canvey Island
Dartford
Tilbury
Sheerness
Isle of Sheppey
Richmond
Gravesend
Rochester
Herne Bay
Margate
North Foreland
Orpington
Whitstable
Chatham
Ramsgate
Sutton
Croydon
Surrey Hills
Maidstone
MEDWAY
Canterbury
Sandwich
Deal
See Page 3 (Appendix report) for captions to the maps.

Fig 3b



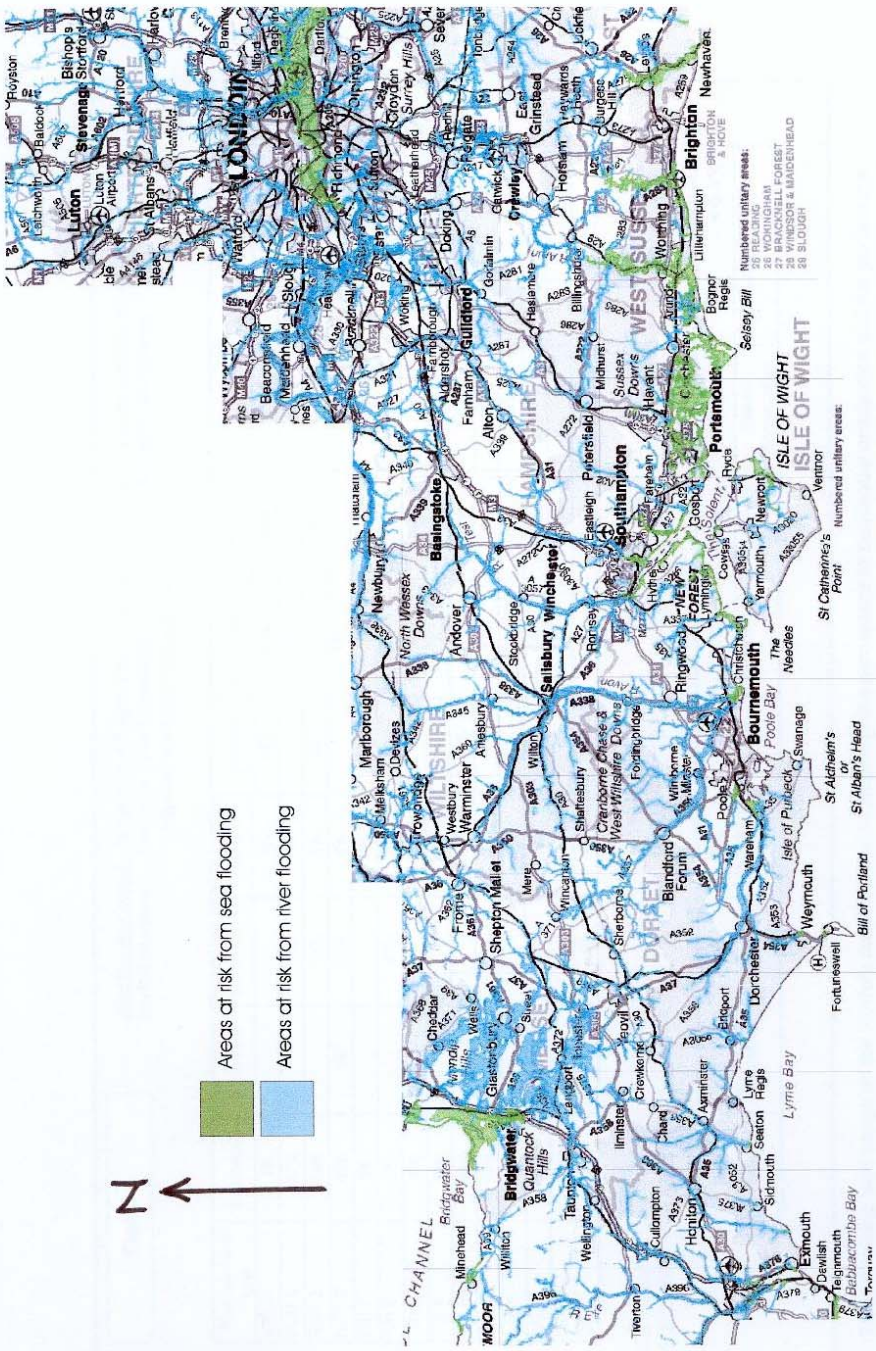
See Page 3 (Appendix Report) for captions to maps

Source for component maps :

http://www.antiflood.com/warnings/index.asp

Fig 3c

Fig 3c



See Page 3 (Appendix Report) for captions to maps

Source for component maps :

http://www.antiflood.com/warnings/index.asp

Figure 4

Adapted from data in "Valuation of Coastal Land" – un-numbered table in section covering useage of land on the Norfolk coastline. Document 1 - An Introduction to the North Norfolk Coastal Environment
http://www.northnorfolk.org/coastal/doc1.html

Datapoint	Management Unit	Residential	Industrial	Commercial	Public	Tourism	Recreational	Agricultural	Nature Conservation	Open Land	MOD
1	Unit 1	1%			1%	15%	24%	53%	3%		3%
2	RUN 1	67%		7%	1%		14%		6%	5%	
3	RUN 2	14%		<1%	8%	40%	7%	19%	7%	5%	
4	RUN 3	63%	1%	12%	8%		13%			3%	
5	TRI 1	2%			1%	10%	42%		38%	7%	
6	TRI 2	57%		<1%	3%	6%	8%	6%	20%		
7	TRI 3	4%					3%	72%	21%		
8	TRI 4	26%			1%			46%	21%	4%	3%
9	TRI 5	19%				22%		39%	17%	3%	
10	TRI 6	74%		1%	2%	5%	5%	10%	3%		
11	BAC1					16%		71%	10%	3%	
12	BAC 2	29%	19%	<1%	<1%	7%	3%	39%		3%	
13	SEA 1	3%					3%	94%			
14	SEA 2	22%		<1%	6%	4%		68%			
	Accumulated % →	381%	20%	20%	31%	125%	122%	516%	146%	33%	6%
	from 14 data sets →	1400%	1400%	1400%	1400%	1400%	1400%	1400%	1400%	1400%	1400%

Percentage of total

27%	1%	1%	2%	9%	9%	37%	10%	2%	< 0.5%
Residential	Industrial	Commercial	Public	Tourism	Recreational	Agricultural	Nature Conservation	Open Land	MOD

Table showing land usage on the Norfolk coastline and highlighting the percentage of residential occupation and the percentage of agricultural land exposed to the effects of both erosion and exposure to flood disruption.

Fig 5

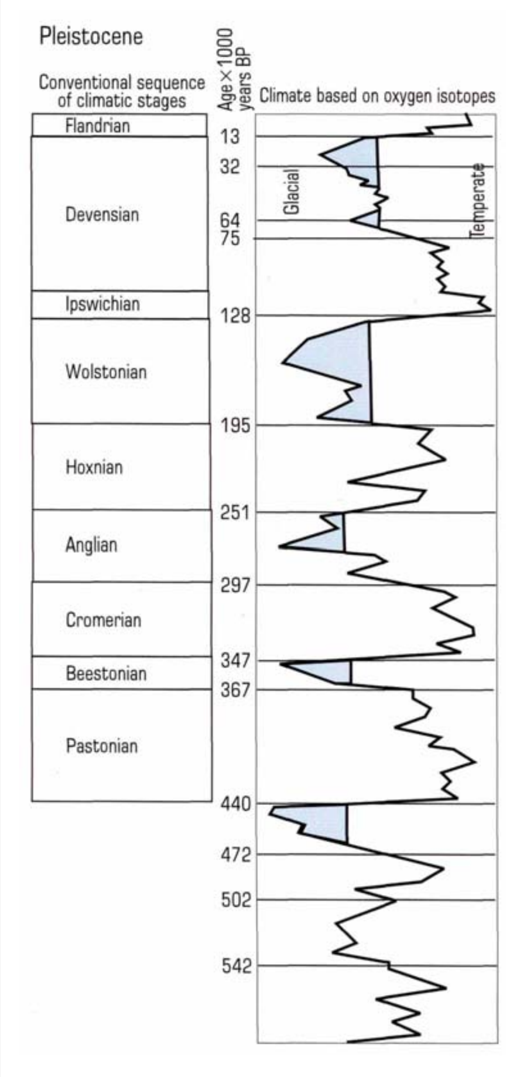


Fig 5 (see left)

Oxygen isotope data used to display the temperature during climatic ages including the Anglian, Wolstonian and Devensian stages.

The Geology of Britain, Toghill, Peter.
Figure 156 (page 171) diagram a. After Boulton, G.S. In "Geology of England and Wales" Duff, P.D. and Smith, A.J. 1992 Geological Society of London.

Fig 6 (below)
Oxygen isotope incorporated with data obtained from beetles and used to display the temperature during the Late Devensian / Holocene boundary during which the most recent tills of East Anglia were deposited.

Fig 6

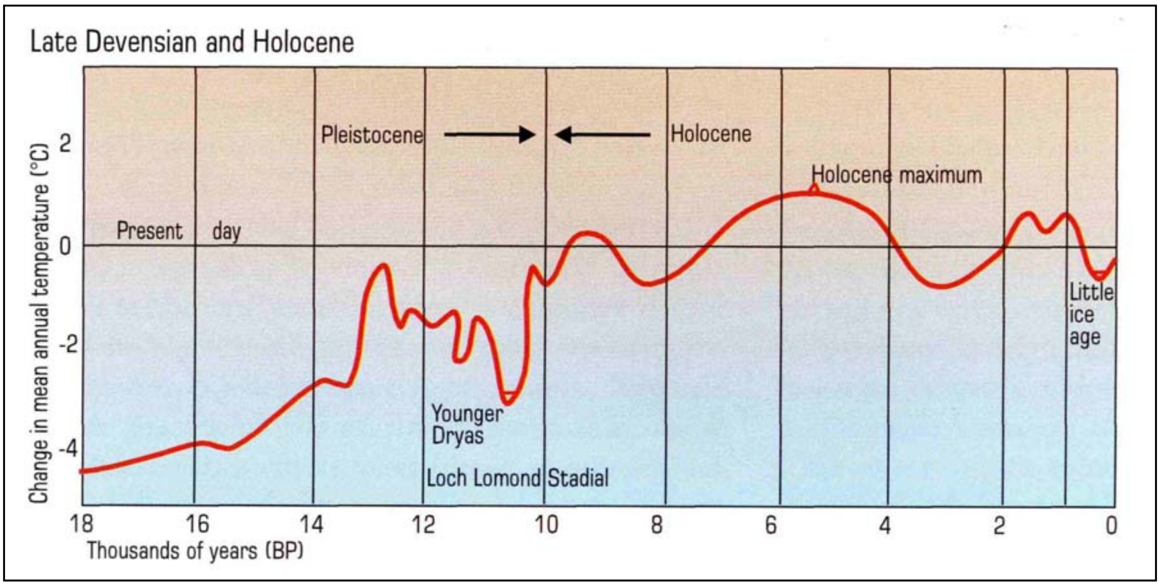
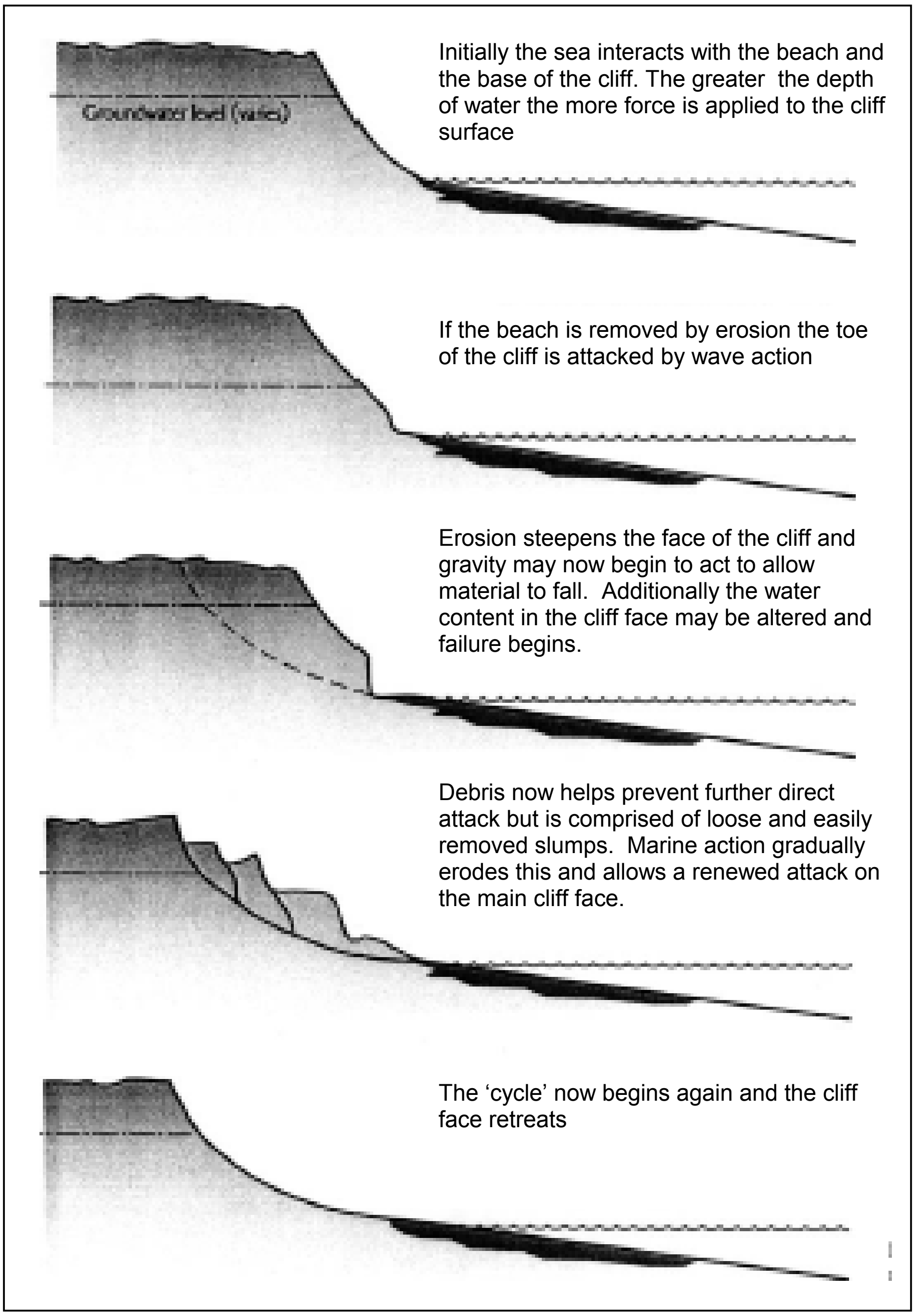


Fig 7



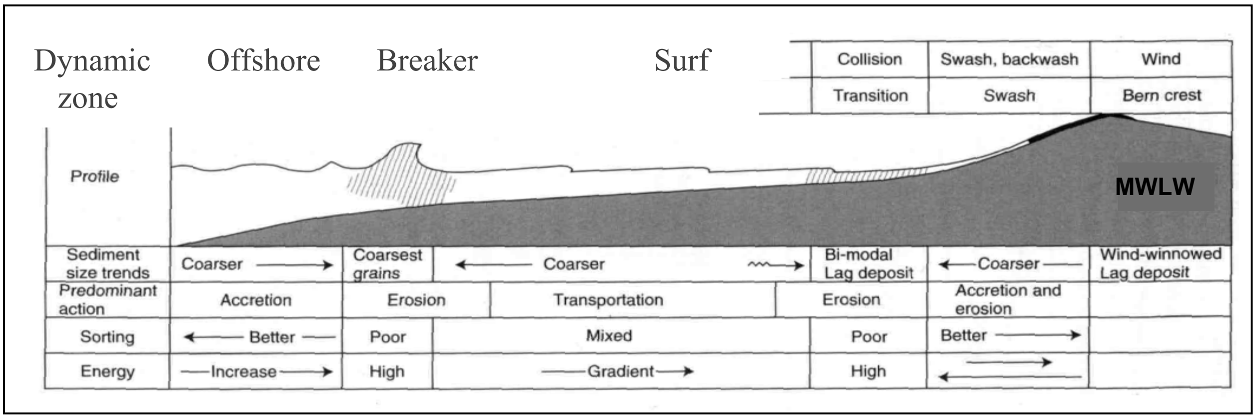
Sectional view of the toe-erosion of cliffs by wave action.

Lee, E.M. Meadowcroft, I.C. Hall, J.W. Walden, M.
Coastal landslide Activity: A Probabilistic simulation model (2002)
Fig 2 P. 350

http://www.cen.bris.ac.uk/civil/staff/jwh/Publications/BEGE61.pdf

Fig 8
Wave action on foreshore and beaches

Bell, Fred G. (1999)
"Geological Hazards: Their assessment, avoidance and mitigation"
ISBN 0-415-31851-3 publisher : Spon Press 7.4 'Coastal Erosion' p 301



The four major dynamic zones of the beach environment are illustrated in this diagram. The shaded areas are those in which high concentration of suspended grains are found. Experiments using fluorescent sand (and its dispersal) and electro mechanical measurements showed that two high energy zones could be identified, one either side of the surf zone. These have been labelled the 'Breaker' zone and the 'Transition' zone.

MWLW = Mean water Low water. Bell 1999 (Fig 7.4 p 301)
(The diagram is based on Ingle 1966)

Fig 9 (Table I)

Table 1. *Eastern England, sediment budget*

Supply		tonnes a^{-1}	
F	Yare system	4 000	
L			
U	Suffolk Rivers	1 600	
V		5 600	≈100 kt
I			
A	Wash Rivers (Wilmot & Collins)	≈100 000	
L			
	River Humber (Veenstra)	≈100 000	100 kt
C	Norfolk Cliffs	665 000	785 kt
L	Covehithe/Easton	45 000	
I	Dunwich	60 000	
F	Walton	15 000	
F			
S			
	Holderness	1 400 000	1400 kt
Total			≈2500 kt
Deposition			
N Norfolk Marshes		104 100	104 kt
Breydon water		7 500	≈100 kt
Blyth		5 000	
Alde		6 300	
Deben		17 000	
Orwell		8 800	
Stour		37 000	
Hamford Water		17 800	
Wash (with progradation; Evans & Collins)		(1 600 00)	
Wash (vertical accretion only)		790 000	790 kt
Humber mudflats		63 400	127 kt
N Lincs. marshes		63 400	
Total			≈1100 kt

Fig 10

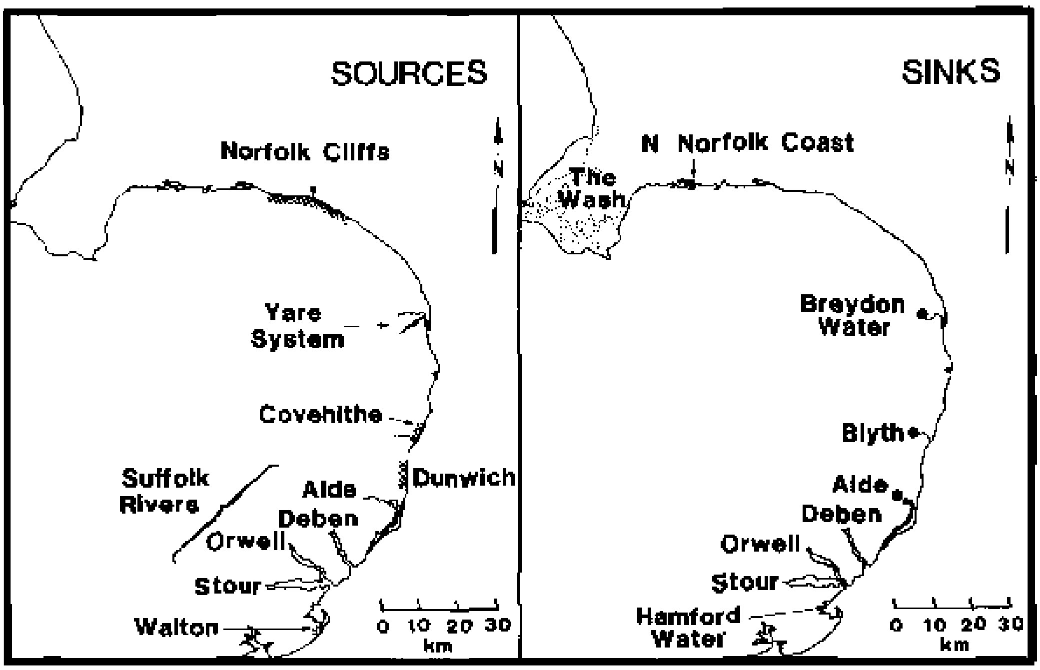
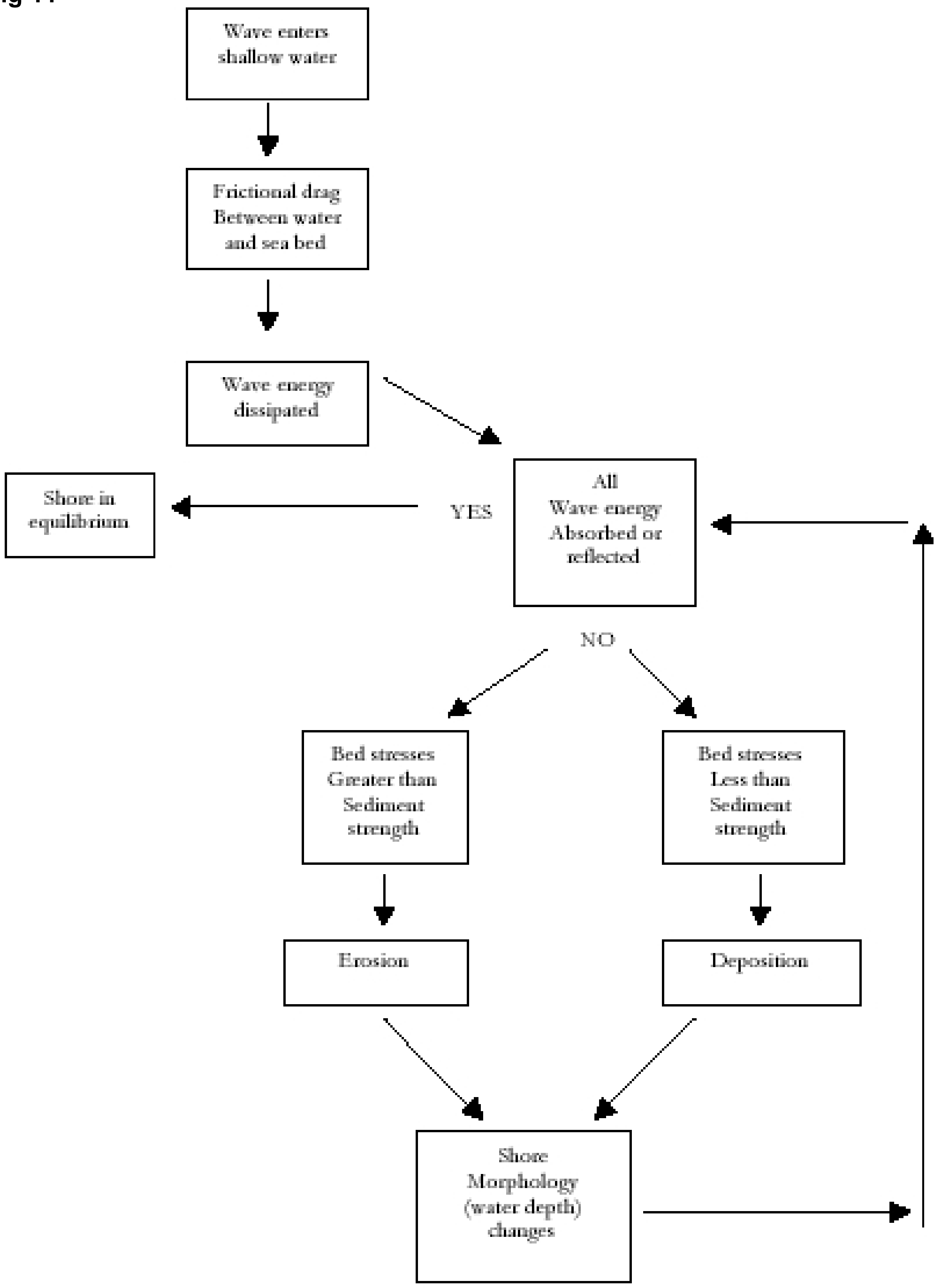


Fig. 2. Location of sources and sinks of fine grained sediment around East Anglia.

McCave, I.N. (1987) **Fine sediments sources and sinks around the East Anglia Coast (UK)**
Department of earth sciences, University of Cambridge. Journal of the geological society London. Vol 144 p149-152
Table 1 p.150 (Fig: 8) and Fig 2 p 150 (Fig: 9)

Fig 11



"Safeguarding our Coasts" LOIS (Land Ocean interaction Survey)
Study of East and Norfolk coasts. (2001)

www.nerc.ac.uk/loiscoast (2001)

Page 9 Diagram illustrating the relationship between sediment transport and shore morphology.

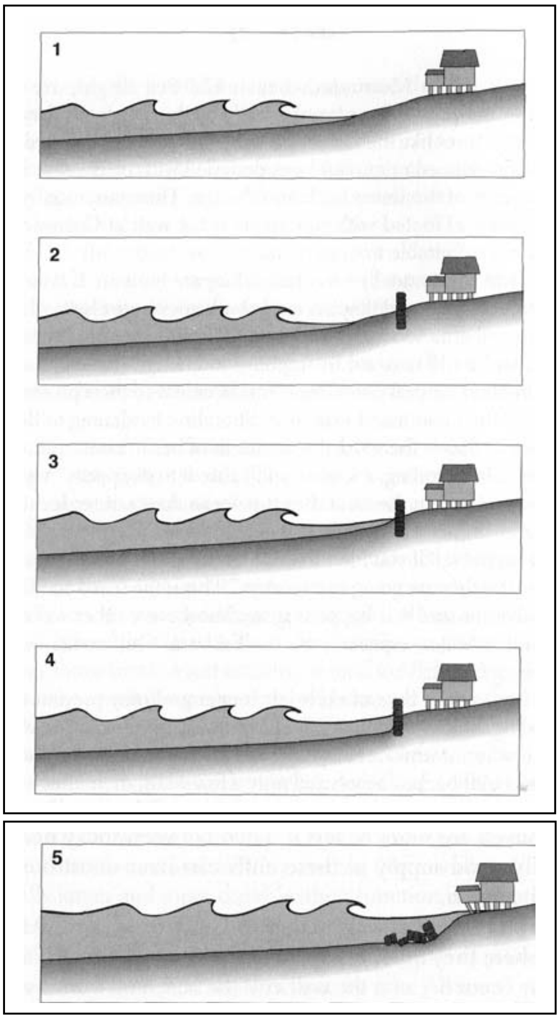
Fig 12

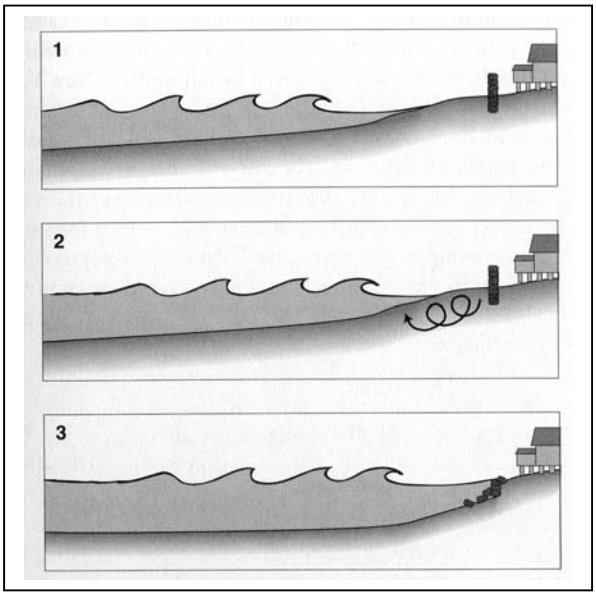
Hornsea, UK

Erosion of cliffs shown to be taking place through sediment starvation at Hornsea, Eastern England.

The terminal groyne traps downdrift sediment movement and the cliff line is now offset.

Fig 13





Dean, Cornelia, Against the Tide (1999)
Columbia University Press ISBN 0-231-08419-6
P54 – 55 (No figure number)

If erosion is taking place on a shore line both Dean and Pilkey (in "The Corps and the Shore") argue that the building of a sea wall will destroy the beach. First of all the beach will reduce in size and then as the waves begin to strike the wall the turbulent water ensuing erodes deposits at the base of the wall – ultimately causing the wall's destruction. Additionally the lack of surface interaction with incoming waves across a shallow beach profile also denies the chance of energy dissipation.

For structural defences see figs 13a, 13 b (LOIS Charts)

Fig 13 a Coastal defence Charts – Lois Study “ Coastline 2000” – Appendix F

Type	Diagram	Description	How it works	Advantages	Disadvantages
Gabions		A mesh of steel cages containing boulders or rubble. Usually found at the back of a beach.	Gaps between boulders and cages absorb wave energy.	Moderate cost and maintenance. Gabions become part of the beach as they break down.	Not as strong as a sea wall.
Revetment		Timber or concrete posts driven down into the beach with connecting boulder and concrete infill.	Energy is reduced as waves pass through the boulder or concrete infill.	Average capital and maintenance cost for a ›hard‹ defence. Scouring reduced at the back of the beach.	Not as strong as a seawall. Short lifespan.
Rip-rap		Large blocks of rock forming a permanent ramp.	Largest rocks dissipate wave energy.	Moderate capital and maintenance cost.	Must be large enough to work. Interrupts longshore drifts.
Beach enrichment		Level of beach maintained by feeding material from offshore locations.	Beach is built up to provide a mobile buffer. Beach absorbs wave energy.	Low cost. Builds on existing beaches maintaining natural appearance of coast.	Unpredictable behaviour of foreign material & effects of long-term dredging. Beach vulnerable to extreme wave action.
Natural beach		Changes in coastal system allowed to take their course	No direct costs. Unprotected eroding shore provides sediment for system	Compensation to owners of lost land. Not generally a socially accepted option.	No initial outlay but possible hidden costs.

Fig 13 b **Coastal defence Charts – Lois Study** **" Coastline 2000" – Appendix F**

Key: Very high cost > £600,000 High cost > £300,000 Average cost > £100,000 Moderate cost <£100,000 Low cost <£10,000

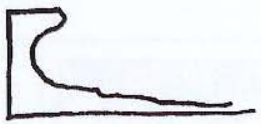
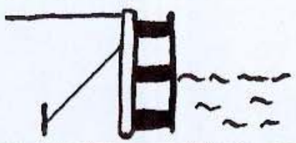
Type	Diagram	Description	How it works	Advantages	Disadvantages
Seawall		Vertical or curved wall made of masonry blocks which reflect the waves. Ramp absorbs energy evenly. Base design prevents undercutting.	Presents a barrier against the sea to deflect wave energy. Prevents nearby areas from flooding.	Effective dissipation and / or reflection of wave energy. Able to withstand severe wave action. Provides reassurance against risk of flooding and storm damage.	Very high cost. Requires regular costly maintenance. Overtopping is a risk. Wall or ramp may be undermined as waves scour away the beach or saltmarsh.
Breakwater		Solid masonry faced concrete capped artificial island. Base keyed into rock.	Protects area on lee side providing a local low energy area	Slows long shore drift and encourages sediment accumulation.	High capital and very high maintenance cost. Overtopped at high tide.
Embankment		Bank of earth usually covered with grass, built up to form a wall.	Raised bank protects the surrounding land from flooding.	Relatively low cost and cheap to maintain.	Structures are usually low and easily breached. Once breached large areas of land are at risk of flooding.
Bulkhead		In-filled structure, often of old tyres, oil drums etc. protected with a shield of steel and wood.	Beach provides main defence against waves.	Moderate capital cost and maintenance for a solid structure.	Cannot survive serious wave attack.
Groynes		Timber barriers or concrete walls running at a right angle to the shore.	Beach material builds up between the groynes and absorbs wave action.	Moderate capital and maintenance costs. Conserves the beach.	Short life span. Interrupts longshore drift.

Fig 14 Slapton Sands – South Devon **Fig 15**

	
Shingle Beach – June 1990	Shingle Beach – August 2002 – Showing eroded beach level and stabilisation solution adjacent to the road.

http://www.english-nature.org.uk/livingwiththesea/project_details/good_practice_guide/shingleCRR/shingleguide/Annexes/Annex02Slapton/Index.htm

Fig 16

Map showing location of Slapton Sands

Fig 17

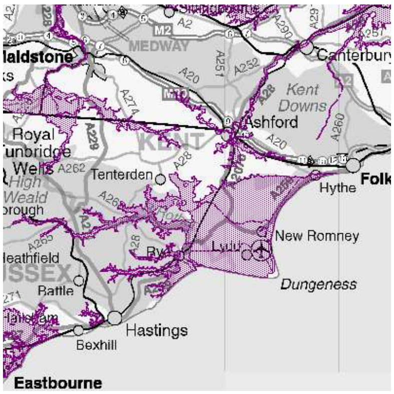


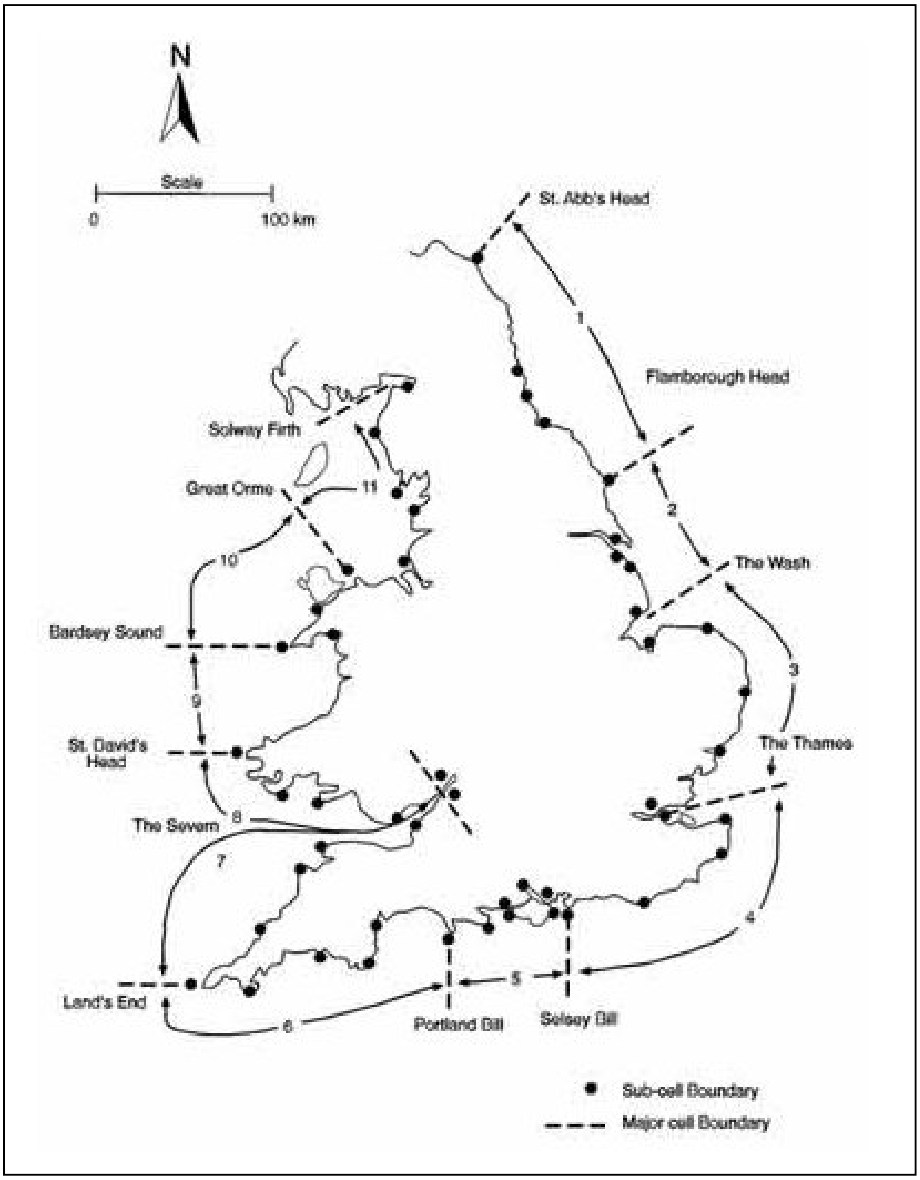
Fig 18

Fig 19

Aerial photography used as simple reference record of geological processes of accretion bands on Dungeness spit, Essex adjacent to nuclear power station. Beach feeding removes material from the NE and deposits it on the SW coastline.
Source: Multimap

http://www.multimap.com/map/photo.cgi?client=public&x=383000&y=80000&scale=25000&gride=0&gridn=0

Fig 20



Map showing 'Sediment cell divisions' for Regional Management zones controlling coastal defences in the UK (HR Wallingford 1993)

Example images of coastal LIDAR records

Readily accessible aerial maps used for initial review of areas and showing geomorphological features for reference (see Review reference 52)
http://www.multimap.com/map/photo.cgi?client=public&x=609000&y=117000&scale=50000&width=700&height=

Images taken between 1997 and 1998 – Washington shoreline -
Brown and red tones indicating accretion whilst green indicates erosion

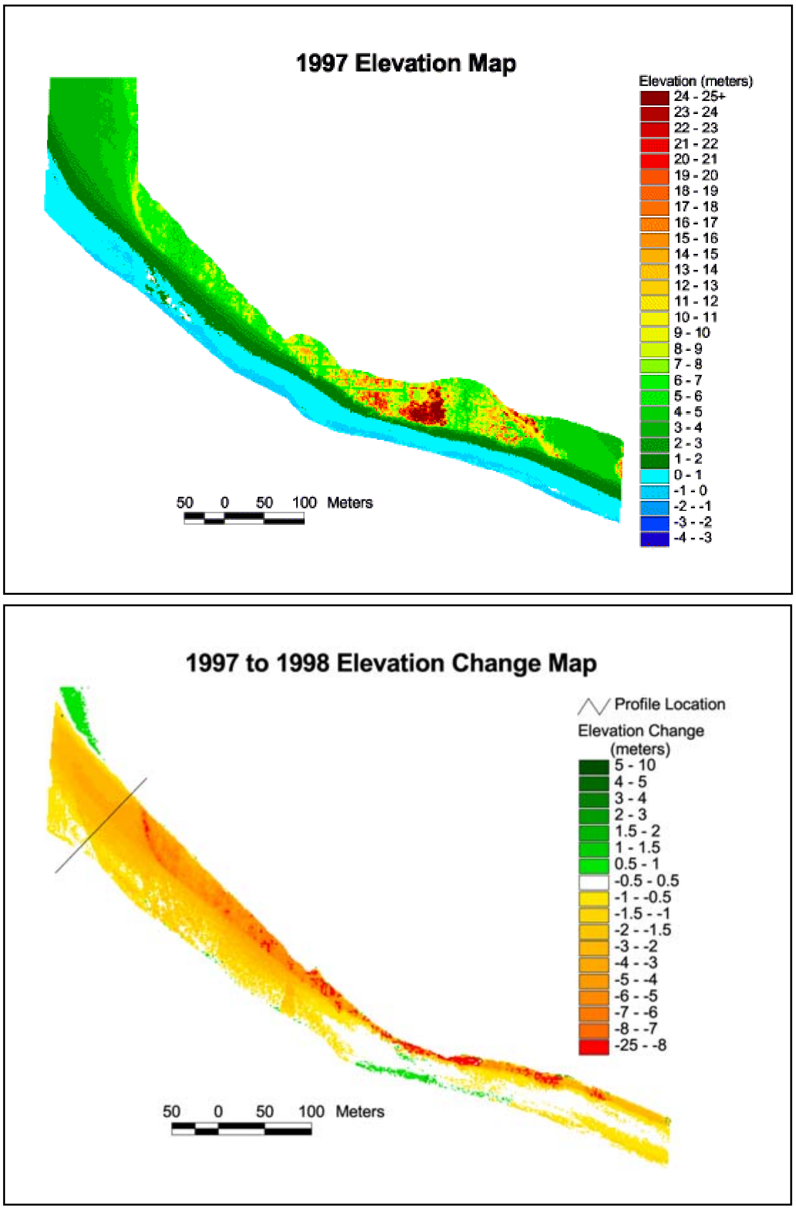


Fig 21

“About LIDAR” - includes other detail of technology and equipment associated with LIDAR
www.csc.noaa.gov/beachmap/html/intlidar.html
(accessed 21-06-03)

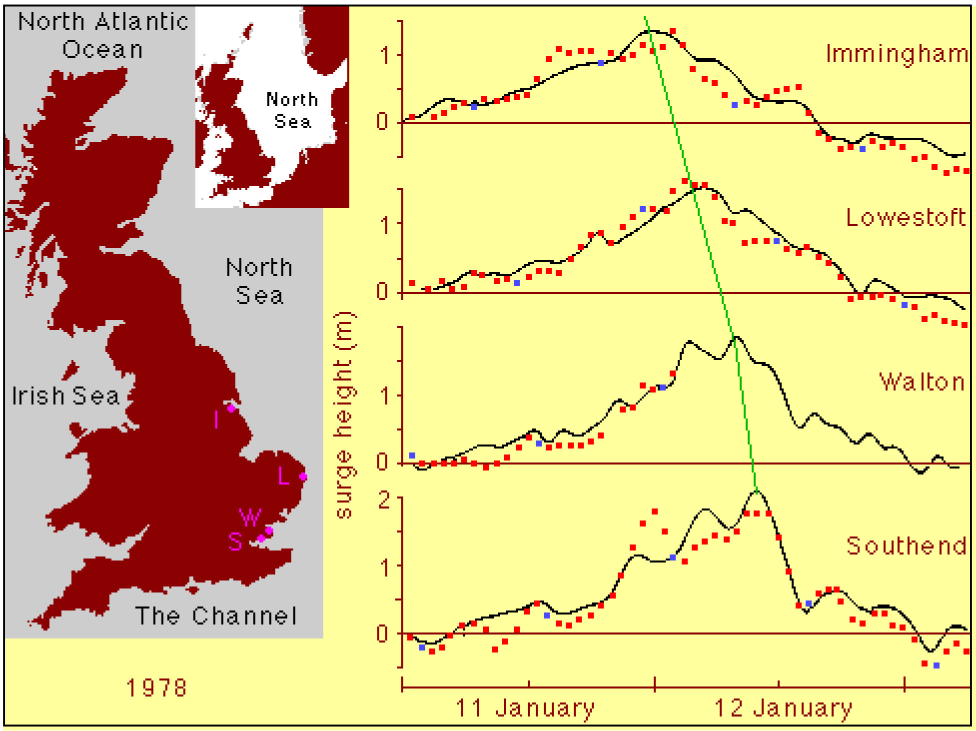


Fig 22

http://oceanografia.cicese.mx/cursos/sco/figures/fig4a1.html
"A storm surge in the North Sea. The curves are predictions from the storm surge warning system, the squares are observations. The tide is subtracted from the data, so only the effect of the wind surge is shown; this has to be added to the tide to obtain final sea level. Blue squares indicate local high water.

The storm surge enters from the North Atlantic Ocean and builds up as the water is pushed into the North Sea and towards the narrow Channel between England and France. Notice the increase in surge height from 1.5 m at Immingham (I) to 1.7 m at Lowestoft (L) and 2m at Walton (W) and Southend (S). The green line indicates that it takes the surge about 11 hours to travel from Immingham to Southend."

Quoted Caption from site (accessed 01-07-03)

Map and Diagrams sourced as above