NRA - Conservation 14

SALTMARSH RESEARCH SEMINAR

ABSTRACTS

28 November 1995

CBI Conference Centre

London

SALTMARSH RESEARCH SEMINAR

28th November 1995, CBI Conference Centre, London

PROGRAMME

10:00 **<u>Opening Address</u>**
Nick Stevens, NRA South Western Region, NRA R&D Saltmarsh Management for Flood Defence Project Leader.
Brief overview of ongoing research programmes in the UK including NRA, MAFF, English Nature, etc.

<u>Session 1: Ongoing NRA Research Projects</u>
Chairman: Nick Stevens

10:10 **Dr K Carpenter, HR Wallingford**
"Maintenance and enhancement of saltmarshes" and "Historic changes in saltmarshes"

10:30 **Dr Jeremy Lowe/Prof John Pethick, University of Hull**
"Sedimentation processes under managed retreat"

10:50 **Prof John Lester/Dr Cecilia MacLeod/Richard Emmerson, Imperial College**
"Pollutant study of managed retreat"

11:10 **Paul Rampling, University of Wales at Bangor**
"Contemporary and Holocene sediment dynamics of the Walton Backwaters, north-east Essex"

11:25 **Dr Tom Spencer, University of Cambridge**
"Wind wave attenuation over saltmarshes"

11:40 **Coffee**

<u>Session 2: Other Research Projects</u>
Chairman: John Morgan, NRA Southern Region

12:00 **Prof Ken Pye, University of Reading**
"Geographical and temporal variations in saltmarsh sediment properties; implications for erosion rates and long-term stability of saltmarsh regeneration schemes"

12:10 **Prof Tony Dexter, Silsoe Research Institute**
"The strength and stability of muds and sediments"

12:20 **Dr John Hazelden, Cranfield University**
"Soils and managed retreat at Tollesbury, Essex"

12:30 **Dr Jon French, University College London**
"Optimal design of saltmarsh channel networks"

12:40 **Dr John Coosen, Ministry of Transport, Public Works & Water Management, Netherlands**
"An overview of salthmarsh research in the Netherlands"

12:50 **Dr Winifred Wood/Prof Mike Baines, University of Reading**
"An exploratory numerical model of sediment deposition over tidal saltmarshes"

13:00 **Lunch**

Session 3: Open Session

14:00 **Chairman: Daniel Leggett, NRA Anglian Region**

This open session will allow anyone to speak about their research or to comment on any previously presented topics. The session will open with:

Andy Swash/Tony Polson, MAFF
and Richard Leafe, English Nature

who will speak about the research being funded by their organisations. Following this the chairman will invite others to talk for a maximum of 5 minutes each. Anyone wishing to speak should register their name before lunch.

Discussion

15:15 **Tea**

Session 4: Practical Applications of Research/Case Studies

Chairman: Nick Stevens

15:30 **Ken Allison, NRA Northumbria and Yorkshire Region**
"Humber Estuary, the need to understand geomorphology"

15:40 **Karsten Jensen, Strukturdirektoratet for Landbrug og Fiskeri**
"Establishment of sedimentation fields in the Danish Wadden Sea"

15:50 **Dr P De Wolf, Afdeling Waterwegen Kust**
"Preservation of the Het Zwin nature reserve"

16:00 **Dr Hofstede, Landesamt fur Wasserhaushalt und Kusten**
"Saltmarsh management in the Federal State of Schleswig-Holstein"

16:10 **Andrew Bradbury, New Forest District Council**
"Western Solent saltmarsh study"

16:20 **Mark Dixon, NRA Anglian Region**
"Operational managed retreat at Orplands"

16:30 **Discussion, Summing Up and Closing Address**
Mark Dixon, NRA Anglian Region and Nick Stevens

17:00 **End of Seminar**

SALTMARSH RESEARCH SEMINAR
28th November 1995, CBI Conference Centre, London

List of attendees (alphabetical order by surname)

Ken Allison	-	NRA Northumbria & Yorkshire Region
Prof Mike Baines	-	University of Reading
Dr Charles Beardall	-	NRA Anglian Region
Ian Black	-	English Nature
Dr Laurie Boorman	-	Institute of Terrestrial Ecology
Andrew Bradbury	-	New Forest District Council
Dr Alan Brampton	-	HR Wallingford
Fiona Burd	-	IECS, University of Hull
Alan Burrows	-	NRA South Western Region
Dr Kathryn Carpenter	-	HR Wallingford
Dr J Coosen	-	Ministry of Transport, Public Works and Water Management, Netherlands
Dr Mike Dearnaley	-	HR Wallingford
Prof Tony Dexter	-	Silsoe Research Institute
Mark Dixon	-	NRA Anglian Region
Dr Pat Doody	-	JNCC
Judith Dunderdale	-	Silsoe College, University of Cranfield
Richard Emmerson	-	Imperial College
Caroline Fletcher	-	HR Wallingford
Rachel Fowler	-	Sir William Halcrow & Partners Ltd
Dr Jon French	-	University College London
Dr John Hazleden	-	Cranfield University
Dr J Hofstede	-	Landesamt fur Wasserhaushalt und Kusten, Germany
Nick Holden	-	NRA NCIMS
Louise Hopkins	-	Binnie, Black & Veatch
Andrew Huckbody	-	Sir William Halcrow & Partners Ltd
Kadir Ishak	-	University of Wales, Bangor
Karsten Jensen	-	Strukturdirektoratet for Landbrug og Fiskeri
Sue King	-	Imperial College
Dr Bob Kirby	-	Ravensrodd Consultants Ltd
Ir Arie Kraak	-	Rijkeswaterstat, Netherlands
Richard Leafe	-	English Nature
Prof John Lester	-	Imperial College
Dr Jeremy Lowe	-	IECS, University of Hull

Dr Cecilia MacLeod	-	Imperial College
Dr Roger Maddrell	-	Sir William Halcrow & Partners Ltd
John Morgan	-	NRA Southern Region
Dr Ken Norris	-	Royal Society for the Protection of Birds
Siobhan O'Rielly-Wiese	-	Imperial College
Dr Michael Owen	-	NRA C6 Topic Advisor
Dr Mike Partridge	-	EPSRC
Prof John Pethick	-	IECS, University of Hull
Tony Polson	-	MAFF
Prof Ken Pye	-	University of Reading
Dr Paul Rampling	-	University of Wales, Bangor
Carol Reid	-	English Nature
Jo Sawyer	-	Flood Hazard Research Centre, Middlesex University
Mark Scrimshaw	-	Imperial College
Nick Stevens	-	NRA South Western Region
Andy Swash	-	MAFF
Dr Tom Spencer	-	Cambridge University
Ian Townend	-	Associated British Ports Research and Consultancy
Stuart Walley	-	University of Wales, Bangor
Mike Whiley	-	NRA Anglian Region
Dr Winifred Wood	-	University of Reading

Session 1: Ongoing NRA Research Projects
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Prof John Lester, Richard Emmerson and Siobhan O'Rielly-Wiese, Imperial College
"Pollutant study of managed retreat"

Paul Rampling, University of Wales at Bangor
"Contemporary and Holocene sediment dynamics of the Walton Backwaters, north-east Essex"

Dr Tom Spencer, University of Cambridge
"Wind wave attenuation over saltmarsh surfaces"

Kathryn E Carpenter
HR Wallingford

Maintenance and enhancement of saltmarshes

- The role of monitoring and data interpretation in coastal management decisions
- Overview of maintenance and enhancement techniques in current use - their effectiveness, location, applicability and environmental impact
- The value of the detailed case study approach for coastal managers
- Example case study
- Guide to aid the selection of appropriate management action

John Pethick & Jeremy Lowe
Institute of Estuarine and Coastal Studies, Hull University

Sedimentary processes under managed retreat

This paper describes the results of laboratory based research on basic sedimentary processes under salt marsh vegetation and compares this work with field studies of the same processes in managed retreat sites in the Blackwater estuary. The laboratory work stressed the importance of the vegetation roughness length to deposition and re-erosion processes under tidal flows and waves respectively. The work also demonstrated the critical nature of the length of flow over the marsh surface to deposition rates and therefore the role of creek density in the efficient distribution of sediments. Field results from both the Northey Island and the Tollesbury experiments have confirmed that seasonal vegetation changes do play a major part in sedimentation rates so that assessment of net deposition requires a medium term (>1<10 year) data base. The variability of sedimentation over the surface of each site means, however, that no spatial correlation with creek proximity can be observed at present. An analytical method for dealing with the spatial variance is described and its application to 5 years of data from the Northey Island site is presented.

The paper concludes with some suggestions for methods of increasing the net deposition rate on managed retreat sites. These include:

- Increasing sediment available to the site at optimal periods.
- Increasing the efficiency of sediment delivery within the site.
- Increasing the sediment trapping efficiency of the surface.

It is proposed that field experiments to evaluate these methods are introduced into the managed retreat experimental programme.

John N Lester, Cecilia L MacLeod and Richard Emmerson
Dept of Civil Engineering, Imperial College of Science, Technology and Medicine, London

Pollutant study of managed retreat

Within an estuary fine grained sediments are deposited at the saline/freshwater interface to create low lying inter-tidal mud flats which may subsequently become colonised with halophytic vegetation. Such salt marshes are of immense environmental and economic importance, particularly for flood defence since their presence reduces the impact of waves at the shore line. Such marsh habitats along the UK Essex coastline are, however, in decline which is putting increasing pressure upon coastal defences, escalating both the construction and maintenance costs of flood protection schemes. Pollution has been cited as a potential cause for the decline of these fragile ecosystems. Heavy metals, herbicides, insecticides and organochlorine compounds within the salt marsh environment could potentially have a deleterious effect upon salt marsh vegetation and invertebrates, ultimately leading to marsh erosion.

A case study of salt marsh and mud flat environments in Essex and the Blackwater estuary defines the magnitude, spatial and temporal distribution of contaminants within these inter-tidal sediments. Research at Orplands and Tollesbury seeks to demonstrate how an appreciation of sediment processes and pollutant input pathways, transportation routes and contaminant sinks, may aid the management of flood defences. Results of an analysis of salt marshes within the Blackwater estuary indicate widespread low level contamination by a range of anthropogenic contaminants from historical as well as contemporary sources. The magnitude, distribution and availability of contaminants is dependent upon a number of inter-related biological, chemical and physical processes. These interrelationships demonstrate the need to consider different disciplines and management needs to create integrated approaches to coastal management.

Paul Rampling
University of Wales, Bangor

Contemporary and Holocene sediment dynamics of the Walton Backwaters, north-east Essex, England

The Walton Backwaters is a shallow, mesotidal embayment on the north-east Essex coast connected to the southern North Sea through a poorly-defined, transitional tidal inlet. It is currently the subject of national conservational interest due to an apparent long-term breakdown and erosion of the saltmarsh and deterioration of the inlet. Previous research and surveys confirm significant morphological changes within the last 150 years.

This research looks at the hydrodynamics and sediment transport, and rates of sedimentation through time. The tidal regime is predominantly ebb-dominated although more pronounced in the inlet than the embayment resulting in a characteristic ebb delta. Preliminary calculations of tidal prism/inlet cross-sectional area relationships suggest that the inlet is adjusting to a new equilibrium profile due to reduction in the tidal prism caused by recent (last 300 years) reclamation works.

Monitoring of saltmarsh accretion/erosion shows that very little sediment is being deposited and that erosion is in the form of cliff-retreat with sediment being released from the saltmarsh to the tidal channels and mudflats.

Historical engineering works in the form of land reclamation, seawalls, groynes and dredging appear to have combined to produce an unstable system that is in the process of readjusting to a new dynamic equilibrium.

Tom Spencer, Jon R French[*] and I Moeller
Department of Geography, University of Cambridge
[*] Department of Geography, University College, London

Wind wave attenuation over saltmarsh surfaces: results from Norfolk, England

A large proportion of European saltmarshes are exposed to significant incident energy from wind-generated waves. Recent monitoring of intertidal profiles on foreland coasts with extensive mudflats and more landward saltmarshes suggests that they can be usefully viewed as a low-energy analogue of beach profile adjustment to varying nearshore energy conditions. This energy-buffering function, and its manifestation in the reduction of wave heights across marsh surfaces, has engineering significance since it permits the relaxation of design criteria for flood defence embankments where these are fronted by saltmarsh. Scale physical model experiments undertaken in the UK during the 1980s suggest a wave height reduction of approximately 40% over an 80m wide saltmarsh from shoaling and breaking processes and from frictional losses but these results were not validated by complementary field observations.

Between September 1994 and May 1995, an array of three bottom-mounted pressure transducers, placed ca. 200m apart along a shore-normal transect centred on the sandflat/pioneer marsh transition, was used to measure changes in wave characteristics at Stiffkey, North Norfolk coast, UK. Pressure readings were taken at a frequency of 5Hz over periods of 5 to 7 minutes at different times of the tidal cycle over a range of tidal inundations. Pressure time-series were corrected to offset attenuation with depth of the high frequency fluctuations; a comparison of surface waves computed in this way with observations made using video camera/frame grabbing techniques showed a highly significant positive correlation. Analysis of 54 records showed a consistent energy decrease of between 47.4% and effectively 100% across the saltmarsh section of the transect. This differed significantly from the much lower energy reduction (1.9-55.3%) across the sandflat section of the transect. Reduction in wave energy and significant wave heights was only weakly related to water depth across the sand flat but more strongly related to water depth across the saltmarsh for the tidal cycles monitored. It is hoped to extend these measurements over a further field season to sample a wider range of water depths and incident wave energies.

Session 2: Other Research Projects
Chairman: John Morgan, NRA Southern Region

Prof Ken Pye, University of Reading
"Geographical and temporal variations in saltmarsh sediment properties; implications for erosion rates and long-term stability of saltmarsh regeneration schemes"

Prof Tony Dexter, Silsoe Research Institute
"The strength and stability of muds and sediments"

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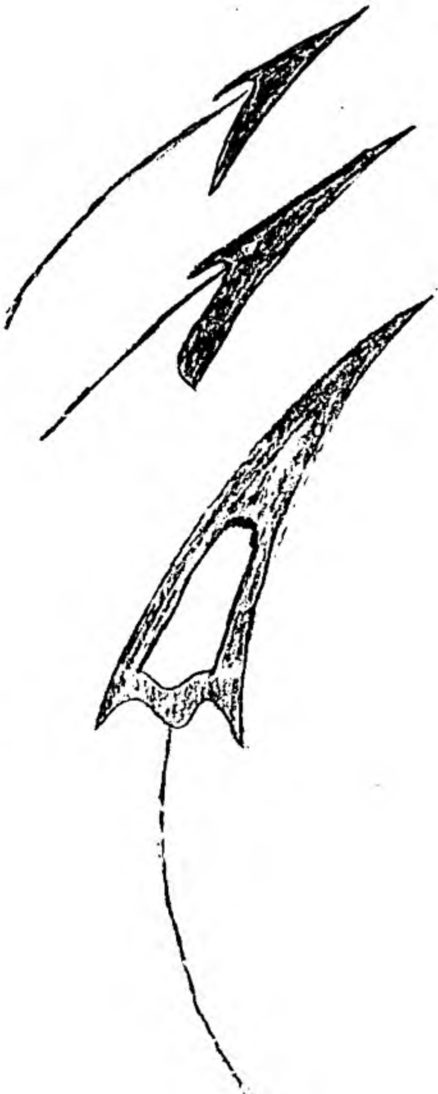
Dr Winifred Wood/Prof Mike Baines, University of Reading
"An exploratory Numerical model of sediment deposition over tidal saltmarshes"

Ken Pye
Postgraduate Research Institute for Sedimentology
The University of Reading

Geographical and temporal variations in saltmarsh sediment properties: implications for erosion rates and long-term stability of saltmarsh regeneration schemes

The presentation will consider (1) the ways in which the textural, mineralogical and chemical characteristics of saltmarsh sediments control their geotechnical behaviour, the morphological development of saltmarshes, and rates of erosion/accretion, and (2) the implications of these relationships for the long-term stability of regenerated marshes on different parts of the British coast. Examples will be drawn from several recent and ongoing research projects at the University of Reading.

Tony Dexter
Silsoe Research Institute



The strength and stability of muds and sediments

The strength and stability of granular materials, such as muds, sediments and soils, controls their ability to withstand erosive forces. This is true irrespective of whether the erosive forces come from raindrops, flowing water, wave action or from anthropogenic actions. Ultimately, the stability of the material depends on the ability of the granules of which they are composed to remain bound or attracted together.

The binding forces between particles are influenced by a large number of factors including the mineralogy, the types of ions adsorbed on the surfaces of the particles, the ionic composition of the pore water, the degree of saturation, and the pore water pressure. Additionally, biological factors such as the binding action of roots or cementation by exudates from various organisms can modify stability. Some of these effects are being studied on the Tollesbury experimental set-back site.

Before the sea wall was breached at the Tollesbury site, soils on five experimental plots were characterized intensively. Following the breaching on 4 August 1995, the changes in soil mechanical, physical and physical-chemical properties are being monitored.

Before breaching, the soil on the former agricultural land was relatively stable. That is, the particles did not disperse (fly apart) spontaneously in fresh water. After breaching, the immediate effect would have been that the pore water would have changed from fresh to saline, and this would have increased the stability of the soil. However, with time, the soil became increasingly sodic (ie sodium ions replaced the calcium and magnesium ions adsorbed onto the surfaces of the soil particles). When the soil became sodic (exchangeable sodium percentage greater than 3), the soil was no longer stable in fresh water and the particles spontaneously repelled and dispersed into suspension.

The effects of this are illustrated with values of exchangeable sodium percentage, water retention characteristics, hydraulic conductivity and soil stability measured with both sea water and fresh water.

This work was sponsored by MAFF Flood and Coastal Defence Division.

John Hazelden
Soil Survey and Land Research Centre, Cranfield University

Soils and managed retreat at Tollesbury, Essex

In setting back sea walls, the intention is to reestablish salt marsh on land where such plants may not have grown for perhaps 500 years since reclamation. The soils have been altered both chemically and physically during this time, and some of these changes are irreversible.

Soil salinity, measured as electrical conductivity (EC), has been monitored at the Tollesbury experimental site, following trial flooding with sea water in November 1994 and in February 1995, and following breaching of the sea wall in August 1995.

At Northey Island and North Fambridge in Essex, agricultural land reverted to salt marsh following breaches in the sea walls in 1897. At both sites, there is a buried soil surface at 0.6 to 1m below the current marsh surface, and these buried topsoils have a mush higher bulk density. Density and porosity are important parameters which influence the water release characteristics of a soil. Sediments overlying these buried soils have accumulated rapidly over the past 98 years and have much higher available phosphorus levels than those on nearby 'natural' salt marshes.

Today both these sites show drainage patterns apparently inherited from the buried agricultural land surface. The drainage pattern at the time of initial flooding clearly exerts strong control on the pattern that develops with further sedimentation, even once the old land surface becomes deeply buried. It is likely that some of the artificial drainage lines now visible at Northey Island and North Fambridge were originally little more than narrow grips, a few centimetres deep. This would suggest that a creek network could be created on a 'retreat' site by digging relatively small and shallow creeks simply to get the drainage flowing as required.

Jon French & Tom Spencer
Department of Geography and Jackson Environment Institute, University College, London
Department of Geography, University of Cambridge

Optimal design of saltmarsh channel networks

Saltmarsh channel networks are clearly important in terms of both tidal exchange and sediment supply. Our work on tide-dominated saltmarshes has shown that networks evolve under the influence of strong form-process feedbacks, which incorporate both 'internal' and 'external' controls. *Internally,* the hydrodynamic interaction between channel and marsh surface water movements typically results in a locally ebb-dominated flow regime to which channel morphology adjusts. At the same time, the marsh surface functions as a very effective sediment trap. Hydraulic gradients adjacent to channels define the spatial pattern of sedimentation at tidal time-scales, and surface elevation determines the frequency of flooding and therefore the sedimentation rate at annual time-scales. *Externally,* the saltmarsh presents a dissipative morphology to incident tidal and wave energy. Larger scale feedbacks occur as tidal prism is altered by the changing vertical and lateral extent of saltmarsh.

From this perspective, a number of distinct channel network functions are identified: i) *supply* (i.e. introduction and dispersion of fine sediment); ii) *removal*(i.e. surface drainage and substrate dewatering); and iii) *dissipation* (of tidal energy input). There is evidence to suggest that in natural salt marshes, channel morphology is to some degree optimised with respect to each of these criteria. However, the mechanics of this adjustment remain only partially understood. Knowledge of this behaviour would greatly aid the effective restoration of saltmarsh as part of managed 'setback' of flood defences. Work currently in progress aims to determine the extent to which these natural channel functions can be reproduced at minimal cost within restored saltmarshes.

John Coosen
National Institute for Coastal and Marine Management
The Netherlands

Overview of the saltmarsh research in the Netherlands

The topics are:

- saltmarsh defence methods;
  experiments have been done with "soft engineering" (clay and brushwood groynes) as well as hard solutions (stone walls). A review of methods has been made

- depoldering or managed retreat;
  in the Waddenzee as well as in the Delta area (SW) large schemes are in preparation to be performed in the near future. A small example (100 ha) of saltmarsh development in a former polder is monitored since 1991

- new management options for the accretion fields in the Waddenzee are developed;
  the artificial drainage system in the former "land-gain projects" is redesigned and the functions are critically evaluated.

Winifred Wood & Mike Baines
Department of Mathematics
Reading University

An exploratory numerical model of sediment deposition over tidal saltmarshes

This presentation describes an exploratory numerical model of sediment transport and deposition on an idealized tidal salt marsh. The mass transport equation is simplified to make it hyperbolic in one space dimension and time. The box scheme is used for the numerical solution and this is satisfactorily checked against an exact solution for a particular case. Difficulties encountered in the numerical solution for the flood and ebb tides are discussed. The results from using the programme on sediment made up of a population of different sized particles are in qualitative agreement with observations on the Severn Estuary (Allen, 1992) and the Lincolnshire and Norfolk coasts (Hartnall, 1984; French & Spencer, 1993).

Session 3: Open Session

Chairman: Daniel Leggett, NRA Anglian Region

This open session will allow anyone to speak about their research or to comment on any previously presented topics. The session will open with:

> **Andy Swash/Tony Polson, MAFF**
> **Richard Leafe, English Nature**

who will speak about the research being funded by their organisations. Following this the chairman will invite others to talk for a maximum of 5 minutes each.

Session 4: Practical Applications of Research/Case Studies
Chairman: Nick Stevens

Ken Allison, NRA Northumbria and Yorkshire Region
"Humber Estuary, the need to understand geomorphology"

Karsten Jensen, Landbrugs- og Fiskeriministeriet, Denmark
"Establishment of sedimentation fields in the Danish Wadden Sea"

Dr P De Wolf, Ministerie van de Vlaamse Gemeenschap, Belgium
"Preservation of the Het Zwin nature reserve"

Dr J Hofstede, Landesamt für Wasserhaushalt und Küsten, Schleswig-Holstein
"Saltmarsh management in the Federal State of Schleswig-Holstein"

Andrew Bradbury, New Forest District Council
"Western Solent Saltmarsh Study"

Mark Dixon, NRA Anglian Region
"Operational managed retreat at Orplands"

Ken Allison
National Rivers Authority, Northumbria and Yorkshire Region

The Humber Estuary: the need to understand geomorphology

The Humber Estuary plays a critical role within the UK economy. The growing Humber ports are a significant component of this economic activity, relying increasingly on artificially dredged navigation channels.

Much of the estuaries' intertidal area is designated an SPA under the EC Habitats and Bird directives in addition to being designated under the RAMSAR convention. Hence any development proposals which may impact on this intertidal area must be strictly controlled.

400000 people, extensive agricultural, urban and industrial areas rely on the protection afforded by tidal defences. Year on year sea level rise and land sink are combining with natural deterioration of these defences to increase the risks of catastrophic failure to unacceptable levels. The long term strategic planning for tidal defence provision must consider ALL options including do nothing, re-align, retreat, maintain etc.

The adjoining Holderness coast is eroding at 1-3 metres every year.

If:

- the Humber ports are to continue to grow,
- the internationally important SPA is to be protected,
- an informed long term tidal defence strategy is to be formulated, encompassing all options,
- informed decisions are to be made regarding the Holderness coast,
- that is :- a genuinely Holistic approach to the management of the estuary is to be taken,

then:

- we must improve our understanding of the geomorphological processes at work.

This is a major task which would best be tackled through a 'partnership' approach. This partnership is vital if a common understanding of the processes at work is to be achieved.

Karsten Jensen
Landbrugs-og Fiskeriministeriet

The work the Danish Ministry of Agriculture and Fisheries carry out in the Danish part of the Wadden Sea

The presentation will comprise a short description of the extension of the Danish Wadden Sea and the saltmarshes and a description of the methods used when building up new saltmarshes including:

Establishment of sedimentation fields

1 Brushwood groynes
2 Drainage systems
3 Observations of plant immigration and sedimentation rate

The presentation will be illustrated with slides showing the different procedures in the work and the different stages of development in the sedimentation fields.

Peter D Wolf
Ministerie van de Vlaamse Gemeenschap.

Preservation of the Nature Reserve "Het Zwin"

"Het Zwin" is an area of saltmarsh and mudflat, which is situated on the Dutch-Belgian border.

I intend to clarify the management measures that have already been taken in order to conserve this area's mudflat and saltmarsh character, as well as possible future management measures that are still in consideration.

J Hofstede
Schleswig-Holstein Ministry for Food, Agriculture, Forests and Fisheries, Kiel, Germany

Saltmarsh management in the federal state of Schleswig-Holstein (Germany)

The configuration of the North Sea coast of Schleswig-Holstein is highly irregular. In front of the mainland extensive tidal flat areas, interrupted by large tidal gullies and islands, the Wadden Sea, exist. The mainland coastline measures about 564 km, 398 km of which are protected by sea walls. Of a total area of 2750 km^2 about 100 km^2 of the Wadden Sea of Schleswig-Holstein are occupied by saltmarshes. Most of these saltmarshes lie in front of sea walls and are anthropogenic, they developed through management techniques (saltmarsh works).

In the middle of the nineteenth century, man started to build artificially drained brushwood groyne fields in front of the dikes in order to enhance marsh accretion. This relatively simple technique became known as the "Schleswig-Holstein Method" and soon spread along the entire Wadden Sea coastline. With minor modifications this method is still being applied today.

Until about 1950, the main purpose of saltmarsh works was to create new land which could be diked and cultivated. Changes in agricultural conditions later made this unprofitable and the main argument for saltmarsh works became coastal protection (State Water Act). In 1994 the State Environmental Act was adopted. Accordingly saltmarshes have a high ecological value and natural processes must be allowed to take place. In other words, saltmarsh works should be abandoned. However, as most of the anthropogenic saltmarshes nowadays lie in an unnatural high energy position, it is likely that giving up the saltmarsh works would lead to their disintegration. The expected increase in sea level rise would even accelerate this development.

Being aware of this fact, coastal defence and environmental authorities agreed that existing saltmarshes must be preserved, if necessary with management techniques. Investigations on how to optimize these techniques in an ecological as well as economical sense are in progress.

Andrew P Bradbury
New Forest District Council

Western Solent saltmarsh study

Recent concerns have been expressed at the perceived high rates of erosion of the Western Solent saltmarshes, by environmental agencies, local authorities and the NRA.

A series of parallel studies, which commenced in 1992, has been designed and implemented to examine processes, rates of erosion and possible environmentally acceptable methods of reducing erosion or regenerating saltmarsh. These studies include:

a) historical review of saltmarsh evolution;
b) geochemical analysis of marsh and river sediments;
c) hydrographic surveys of the intertidal zone (to the marsh edges);
d) annual aerial photography of the marshes;
e) digital photogrammetric mapping of the marshes;
f) installation of a weather station to monitor wind speed and direction, tidal levels and barometric pressure;
g) production of a local wave climate from wind records, using numerical models;
h) investigation and field trials of novel edge protection methods; and
i) investigation of the possibility of recycling dredged silts to recharge the marshes.

The programme has focused on data collection to date. An initial qualitative assessment of the data indicates that high quality records have been achieved for most areas of the programmed research. The aerial photography, photogrammetry, hydrographic surveys and weather records have provided particularly interesting data. The data collection programme is scheduled to continue and the analytical phase, which has been designed to focus on the response of the intertidal zone to physical processes, is about to commence.

Further collaborative work to increase the ecological content of the programme, to include habitat mapping, is planned with local conservation organisations.

NATIONAL RIVERS AUTHORITY

Managing Coastal Re-Alignment

Case Study at Orplands Sea Wall
Blackwater Estuary, Essex

A M Dixon
Senior Engineer

and

R S Weight
Higher Technician

OCTOBER 1995

MANAGING COASTAL RE-ALIGNMENT

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Managing Coastal Re-alignment

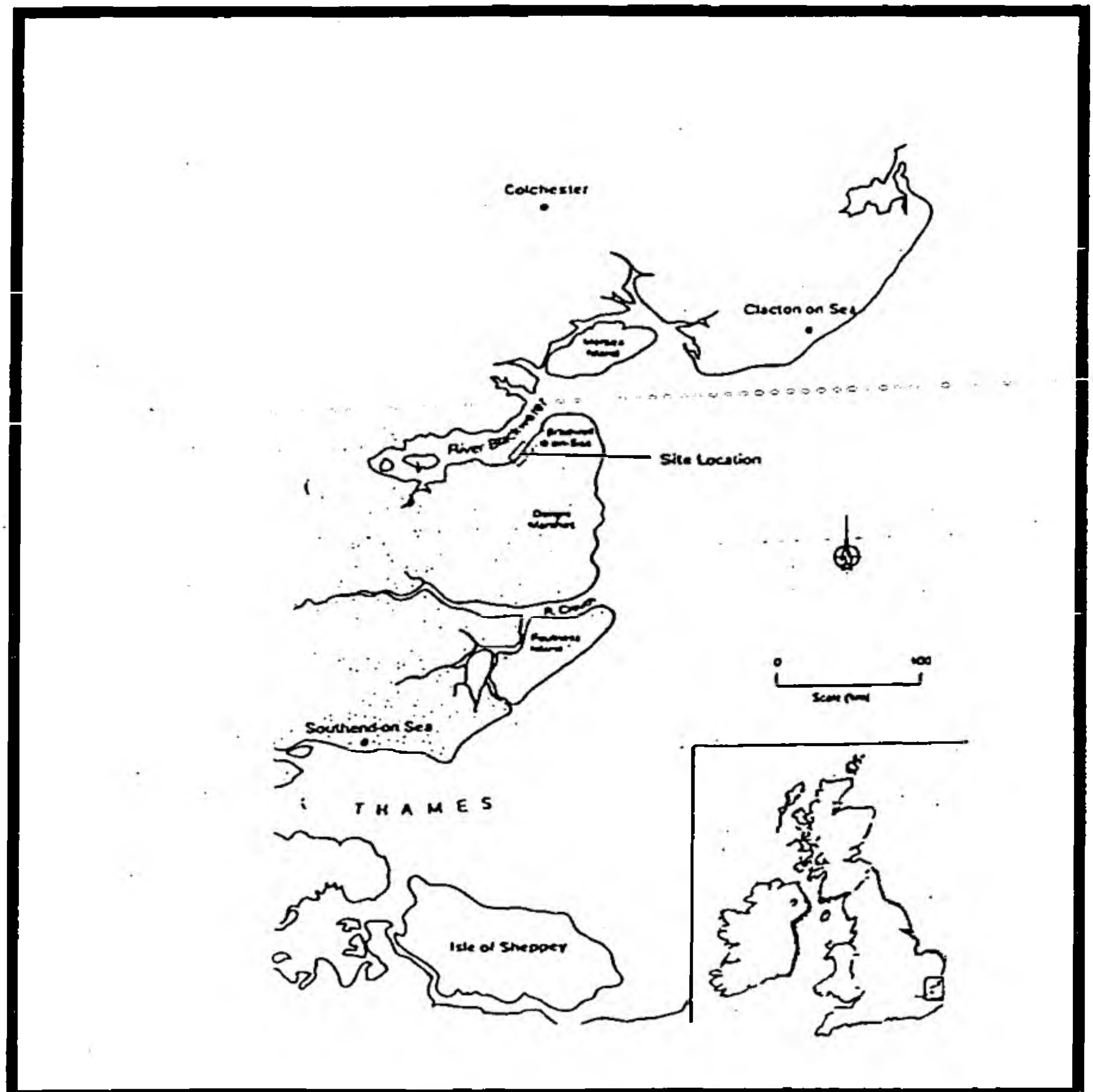
Case Study at Orplands Sea Wall, Blackwater Estuary, Essex

A M Dixon and R S Weight
National Rivers Authority

1. ABSTRACT

Rising relative sea levels, declining national agricultural economic benefits and loss of inter-tidal habitats have combined problems that have created a requirement for holistic management for flood defence issues and solutions. This paper examines the problems of a 2 km length of flood embankment on the Essex coast and the practical management requirements and consequences of managed retreat.

Figure 1:- Site Location



2. SUMMARY

The Orplands sea wall frontage covers 2 km of coastline, part of St Lawrence Bay on the south shore of the Blackwater estuary in mid Essex (Figure 1). The sea defence flood wall was originally constructed in the C18 between 1740 and 1820 (Reference 1), at the end of the Mini Ice Age that England was then experiencing. The old pictures of oxen being roasted on the Thames were a true depiction of the climate at that time. Such cold periods cause sea levels to fall and the majority of sea walls in Essex were built to keep out high "surge" tides, tides that drowned large flocks of sheep and cattle for which the coastal land was renowned. The defences were small earthen structures; a low wall, dug by hand, and protected by a natural fronting salting, cheap to build and cheap to maintain (Reference 2).

But the Mini Ice Age ended and sea levels continued to do what they have been doing for thousands of years; a gradual rise, year after year: the average for Essex has been 300 mm per century, but has accelerated to almost double this figure since the 1930's and, as sea levels rise, so the open coast and estuaries of Essex have to adjust to ever increasing forces that tides produce; they have to roll back inland to give the sea a larger flood plain in which to "lose" all that increase in tidal energy.

A salt marsh, or salting, fronting a sea wall breaks up wave action and reduces the tide's energy by its great length of meandering creeks, the same as a strong gale can be reduced inside the middle of a forest, all those trees and branches and leaves dissipating the gale's strength until the floor of the forest is always in calm. The increase in tidal force from a rising sea level erodes the mudflats, foreshores and saltings; Essex is losing 2% of its saltings every year (Reference 3). Of the 50,000 hectares of marsh that the Essex coast had in the 16th century only 4,500 hectares remain; 40,000 have been enwalled and are now mainly agricultural land and the remainder is being eroded by natural forces.

By 1993 the Orplands sea wall had lost almost all of its protecting salt marsh and the concrete block and ragstone face was no longer adequate to stop wave damage, nor was the wall high enough to prevent the big surge tides overtopping and scouring the landward back face. To reinstate the existing damage would have cost £350,000; to improve the wall to prevent overtopping and future damage over the next 20 years required an additional £250,000. The land protected (Figure 2) was only some 38 hectares in total; ie. it would have cost £16,000 per hectare to protect land with a market value of only £3,700 Ha. Such a level of expenditure is uneconomic.

The NRA had no sustainable economic option but to regenerate the old salt marsh behind the existing Orplands sea wall and recreate a natural flood defence that will have the following advantages.

[1] It will create a saline flood control zone that will reduce the effects of storm tides by reducing wave action and relieve tidal pressure.

[2] It will create a new high level marsh that will be of great importance to both overwintering and summer breeding birds.

[3] It will provide (by footpath diversion) a new public access route for quiet recreation with considerable landscape enhancement.

[4] It will assist (as do all marshes) in reducing pollution levels by storing and natural treatment via the new plants and invertebrates.

[5] It will reduce projected local public expenditure by saving £525k on conventional flood defence techniques.

The scheme was designed by Hydraulics Research Limited, one of the foremost international specialists in coastal engineering (Reference 4). Figure 3 shows a breach in each "compartment"; the most northern of 50 m wide and the southern of 40 m, to enable tidal entry and egress.

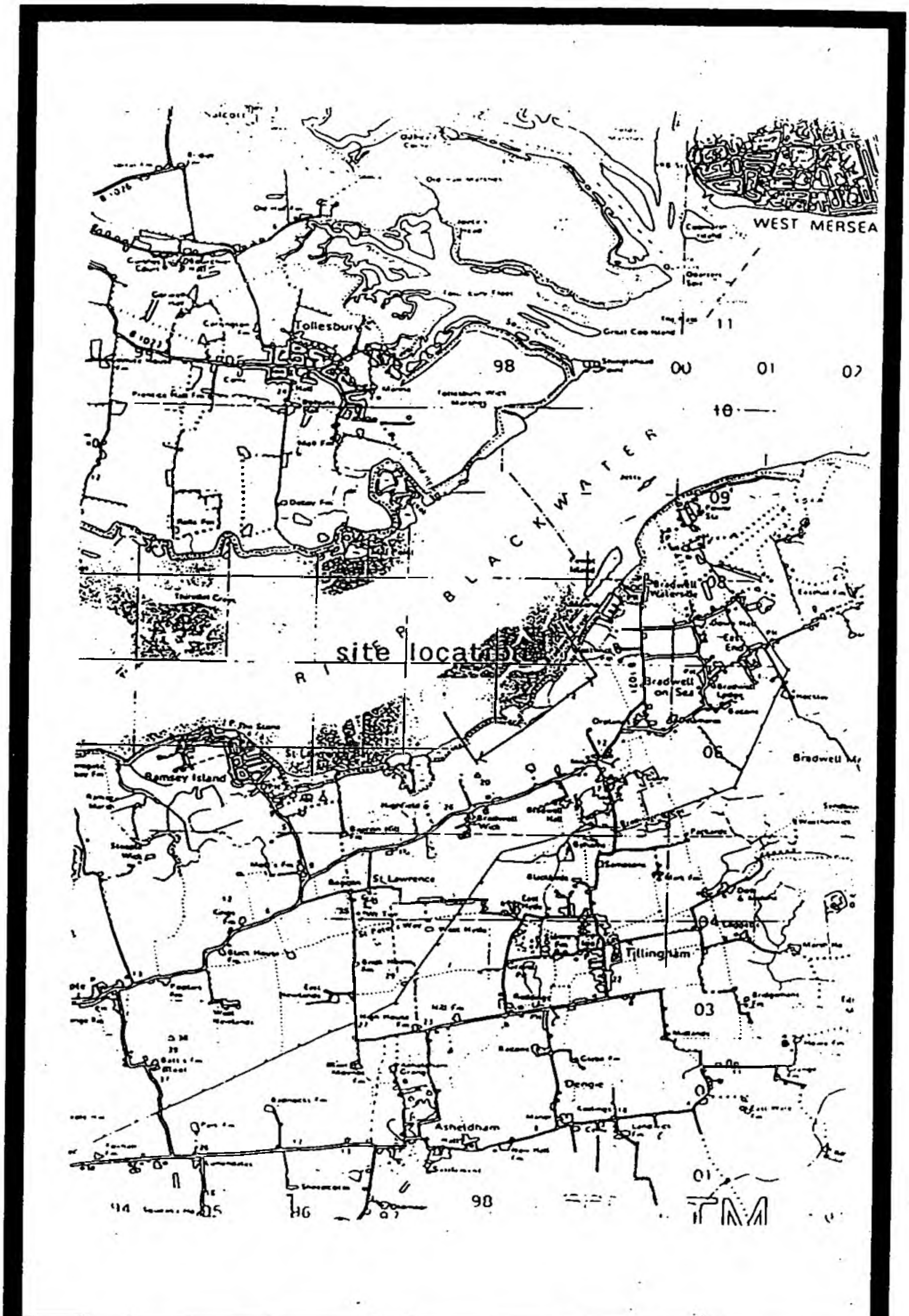
New artificial feeder creeks were excavated to carry silt onto the new marsh. The material excavated from these creeks was placed to one side to form temporary wavebreaks whilst the new plants establish themselves.

A new ditch was dug at approximately the 3 m contour line to give continuity to land drainage on the existing fields, the material from this ditch placed to "seaward" to form the route of the new footpath which can be walked at any state of the tide.

A new pond has been created to assist land drainage and provide a fresh to brackish habitat for birds, insects and plants.

The total scheme construction cost was £65,000, with a further £35,000 for design and staff management.

Figure 2


WEST MERSEA
Tollesbury
RIVER BLACKWATER
site location
Bradwell Waterside
Bradwell on Sea
Ramsey Island
St Lawrence
Tillingham
Asheldham
Dengie
Bradwell Wick
98
00
01
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06
03
TM

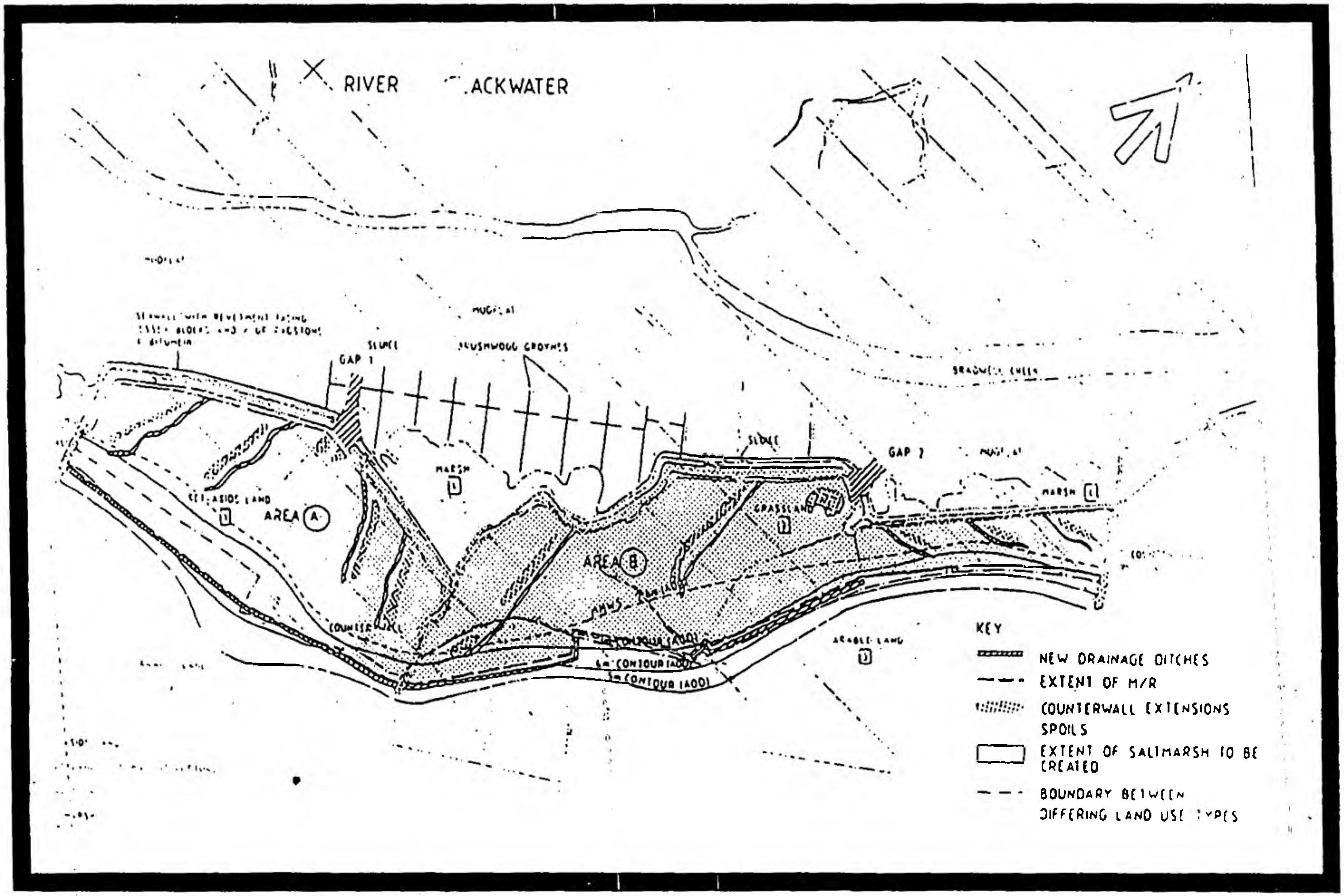

RIVER
ACKWATER
GAP 1
SLUICE
GAP 2
SLUICE
MARSH
AREA A
AREA B
GRASSLAND
ARABLE LAND
KEY
NEW DRAINAGE DITCHES
EXTENT OF M/R
COUNTERWALL EXTENSIONS
SPOILS
EXTENT OF SALTMARSH TO BE CREATED
BOUNDARY BETWEEN
DIFFERING LAND USE TYPES

Figure 3

3. INTRODUCTION

Aristotle wrote in 300 BC "The same regions do not always remain sea or always land but all change their condition in the course of time". This question of relative sea level so vexed him that it is claimed he drowned himself because he failed to find a satisfactory answer. Sea levels have been rising since the last Ice Age ended 10,000 years ago and terrestial habitats have been migrating landward as the sea has risen (see Figure 4). There was a brief period between the 13 and 19 centuries when a "Mini Ice Age" allowed a reduction in this advance and man attempted to halt the inevitable by constructing sea walls to claim salt marsh and inter-tidal areas for initially agricultural and latterly industrial development (Reference 2). Many of the early sea walls failed during episodic tidal surges; the defence line could not be sustained and the land regenerated back to its original habitat and function. The finance of the Medieval to Victorian flood walls were largely driven by a growing population requiring food production within reasonable transport distance of population centres; private investment in low cost earth walls provided a sufficient viable economic return. Rising construction and maintenance costs became associated with increasing heights of surge tides and by the end of the last century many defended areas became unviable (Reference 2). The 1906 - 1911 Royal Commission on Flood Defences of the British Isles concluded that public money should not be used for defending small rural areas of agricultural land such "as is found in the Counties of Kent, Essex and Suffolk".

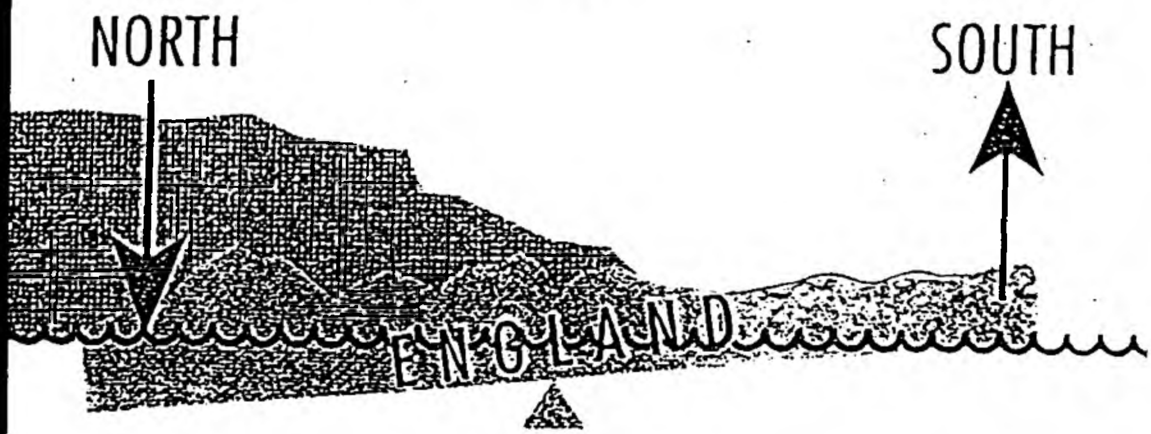
Following the Great War of 1914 - 1918 government policy was formulated to enable Britain to be self-sufficient in food as part of its defence strategy. Lord Bledisloe was appointed to chair a commission to increase agricultural production and reported to the House in 1927. His recommendations included the improvement to fluvial land drainage to "keep water out". The question was later raised in the Upper House if this included saline water and the debated reply was in the affirmative. This policy was pursued until the flood of 1953 when the Government instigated a full inquiry into the cause, effect and remedy of surge tide flooding. Amongst the findings and recommendations of this, the 'Waverley' Report were:-

[1] It was uneconomic to prevent future flooding to some agricultural areas.
[2] The construction of large sluices to vacate over-topped walls.
[3] Research into natural defence systems.
[4] Landowners to financially contribute toward construction and maintenance costs.
[5] Improved protection to existing urban areas.
[6] No further development below the 5 m contour line.

Not all of these recommendations were accepted and between 1953 and 1993 £200 million had been spent improving and maintaining agricultural sea walls in Essex, equivalent to £14700 per hectare of land protected. During this period rising sea levels and consequent increased tidal and wave energies had continued the erosion process to fronting mudflats and saltings requiring additional maintenance to some distinct lengths of sea walls, with equivalent 1995 costs of over £40k per hectare of land protected.

Figure 4

During the Ice Age



Weight of ice causes Scotland to 'sink' and Southern England to rise

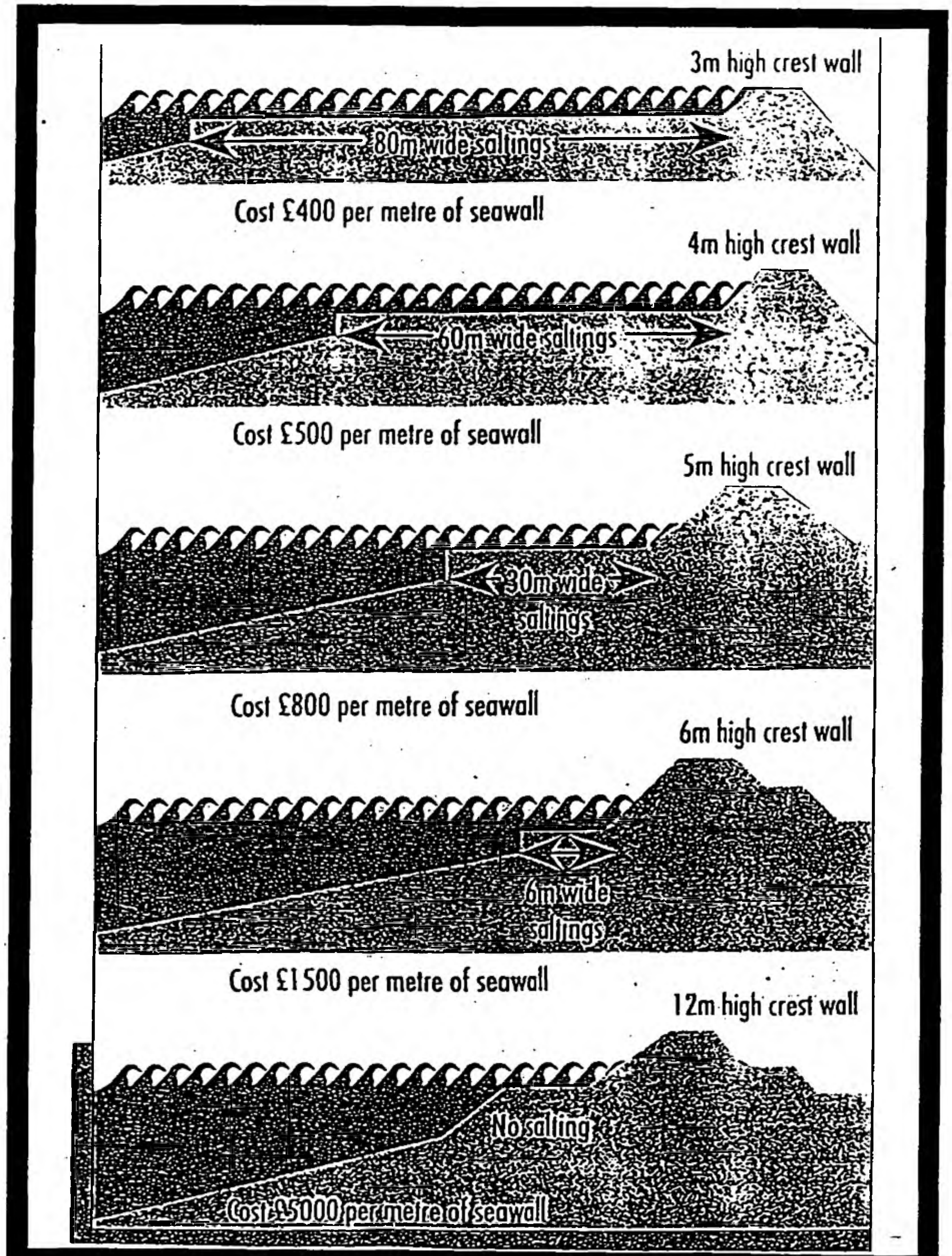
End of Ice Age

As ice melts so land adjusts back to level

4. EROSION MANAGEMENT

An holistic management approach has been developed for the salt marshes in Essex (Reference 5). In this County the consequences of erosion have wide implications. Of the 440 km of sea walls that protect the Essex coast, 320 km rely on a fronting salt marsh to reduce wave energy and protect the toe, see Figure 5 below.

Figure 5 - Effectiveness of saltings in coastal defence



Essex saltings are being reduced by erosion at a rate of 2% per annum (Reference 3) and projected costs to combat this problem are in excess of £400 million for the next 50 years if existing levels of protection are to be maintained. The basic management structure can be condensed to:-

[1] Monitor what is happening

[2] Define the problem

[3] Assess alternative solutions

[4] Define chosen solution

[5] Action that solution

[6] Monitor and assess the effects

4.1 Results of Monitoring

R&D and monitoring of Essex Saltmarsh was instigated in 1985 (Reference 6) only those results pertinent for the purposes of this report are given below.

Figure 6

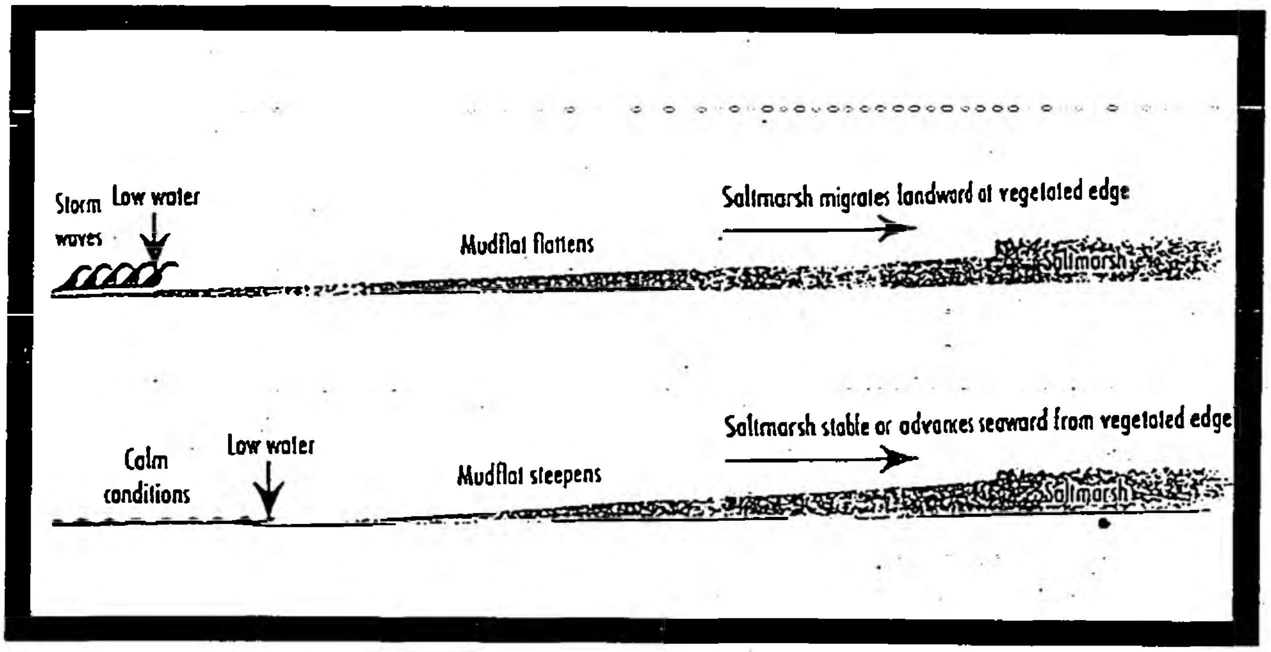


Figure 6 above demonstrates the behaviour and importance of fronting mudflat and salt marsh ie. a self-adjusting natural mechanism for removing storm energy, acting in the same way as a shingle beach.

4.2 Problem Definition

As a result of previous R&D and monitoring on the Essex coast (Reference 6) defining the problem at Orplands was simple; rising sea levels had provided the mechanisms to remove the protecting salt marsh and undermined the seaward toe causing revetment collapse. Increased wave energy had further removed concrete and ragstone blocks and caused overtopping of the wall causing extensive crest and backslope scour to defined lengths of the 2 km frontage.

4.3 Alternative Solutions

Under the NRA's project management system a small team comprising of a catchment based Operations Technician, an area based Conservation Officer, a regionally based Coastal Geomorphologist were lead by an area Senior Engineer with input from water quality and pollution control as required. The teams objectives were to produce a cost-effective sustainable solution; the team leader to undertake the management of the recommendations; quality review was by Senior Area and Regional staff. The team met on four occasion to assess information presented by the team leader/project manager.

The findings are summarised below in Figure 7.

Figure 7

Option Description NB: Revenue Costs are for 10 years	COSTS			BENEFITS		NET NPV £k
	CAP £k	REV £k	TOTAL NPV £k	VALUE £k	NPV £k	
1. Managed Retreat	100	-	100	96	96	4
2. Do Nothing	30	150	180	31	31	149
3. Repair existing damage	210	110	320	40	40	280
4. Improve revetment and toe	480	50	530	40	40	490
5. Rock armour toe/wavebreak	220	70	290	40	40	250

(Price base 23 November 1993)

The use of foreshore recharge techniques were dismissed due to lack of water depth for dredger operation. This option was, however, costed and found to be uneconomic.

4.4 Solution Definition

Managed retreat (Figure 8) was the preferred economic and environmental soluton with the following qualifications:-

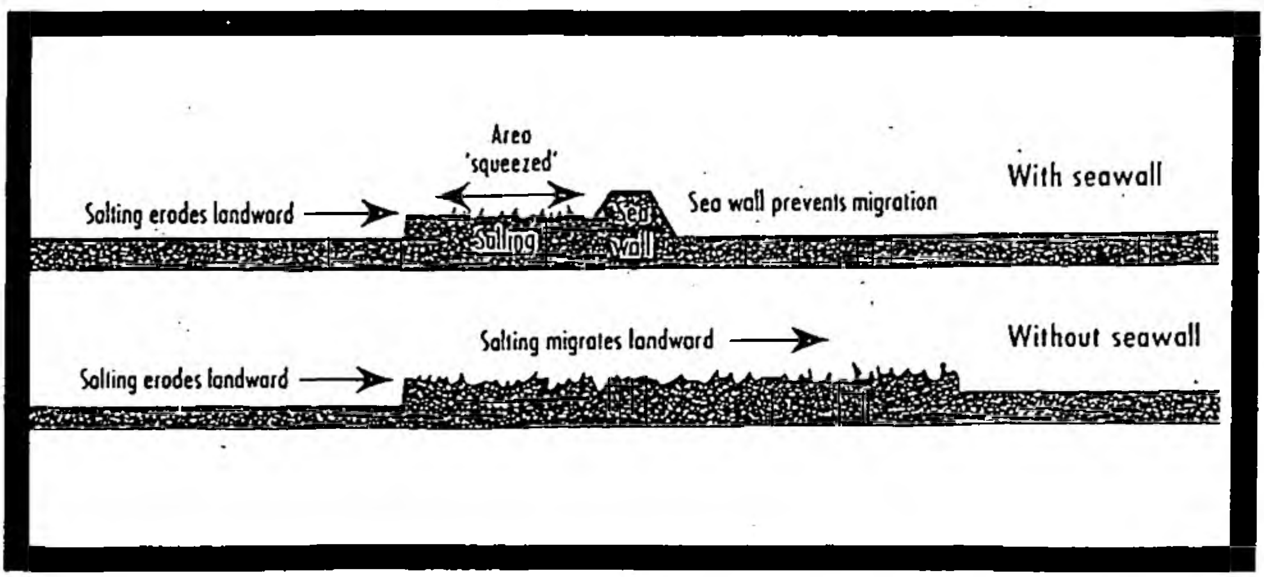
4.4.1 OBJECTIVES: "To produce a 40 hectare natural salt marsh that will act as a maintenance free flood defence, allow natural coastal process to operate and meet the national requirement of habitat creation on wetlands as specified by NRA, MAFF and the RAMSAR convention".

4.4.2 PRODUCTS: "To achieve the objectives, products must include an environmental assessment, hydraulic and coastal process study, an economic engineering solution report and satisfy customer/landowner requirements".

4.4.3 JUSTIFICATION/BENEFITS: "The scheme must be undertaken as soon as possible to avoid sea wall collapse and consequent environmental and flood defence damage both uptide and downtide of the frontage. Considerable financial savings will be made on avoiding short and medium term maintenance estimated at £400k over 10 years. Do nothing or delay will cause considerable environmental damage or may result in litigation for neglect".

4.4.4. RISKS, CONSTRAINTS, DEPENDENCIES: "Design must be correct to ensure compatibility with estuary hydraulics. Major constraint is that the scheme must be on the NRA Capital Programme by January 1994 for completion in financial year 1994/95".

Figure 8



4.5 SOLUTION ACTION

Contracts were let to produce-

4.5.1 A hydrodynamic/EA assessment of the effects of managed retreat at this location on the estuary processes and habitats. The final report to include an outline design to enhance natural sediment accumulation. The salt marsh seaward of the existing flood wall is at an average height of +2.5 m ODN with a landward level range from 0 to 4.0 m ODN.

4.5.2 An engineers report to meet MAFF grant-aid criteria to be based on 4.5.1 above and include full tender documents.

4.5.3 Pre-works geoarchaelogical evaluation to include an assessment of possible damage to any relevant findings by a managed retreat option.

Whilst these reports were being prepared landowner and local and national interest groups were approached for negotiation and information purposes. Landowner requirements were met by the MAFF habitats salt marsh payments of £525 per hectare for arable and £195 per hectare for pasture, per annum for a period of 20 years. Half of the land was SSSI grazing freshwater marsh and the remainding arable section was purchased by a local wildfowling club on the condition that managed retreat would be undertaken. The pasture section remains in the original private ownership. Local pressure groups eg. yachting, fishing, adjacent landowners, schools, parish and district council, etc. attended illustrated talks and site visits organised by the project manager. Governmental organisations requiring consents and licences included:-

[i] MAFF Fisheries for F.E.P.A licence

[ii] Crown Estate Marine for future ownership definition

[iii] District and County Councils for planning consent and footpath diversion

[iv] English Nature, Countryside Commission, English Heritage for consent/licence

[v] British Pipeline Agency for underground services

[vi] ADAS for landowner habitat payments and management conditions.

All reports, consents, licences, etc were finalised by December 1994 and the contract for construction was let in February 1995 for completion by mid April 1995.

5. DESIGN and CONSTRUCTION (see Figure 3 and 9)

To ensure continuity of existing land drainage a new 'V' shaped ditch was dug at the landward boundary at between the 3 and 4 metres contour, spoil from the excavation placed and shaped but uncompacted to the immediate seaward of the ditch to form the new footpath route for the 2 km length of the site. Simple flapped 300 mm pipes allowed egress of freshwater from the 'V' ditch and onto the new salting.

Two new counter walls were built to the north and south of the site to define saline flooding and provide protection to adjacent areas. The counter walls would benefit from the new salt marsh created by the managed retreat option and were therefore simple un-reveted clay walls. An existing relict counter wall was extended to separate the site into two distinct compartments to encourage silt accumulation.

A series of nine meandering vertically sided 'creeks', one metre deep, were put across the site to allow access and egress of tides to the new marsh. Their meandering shape and 'rough' finish are designed to remove tidal energy and allow side slumping and movement to enable natural adjustments to changing energies within the site as it develops. The new creeks connect up to the old 'borrow pit' or 'delph ditch' that runs immediately to landward of the old sea wall; the delph ditch being the main route for the tide from the breach locations to the new marsh.

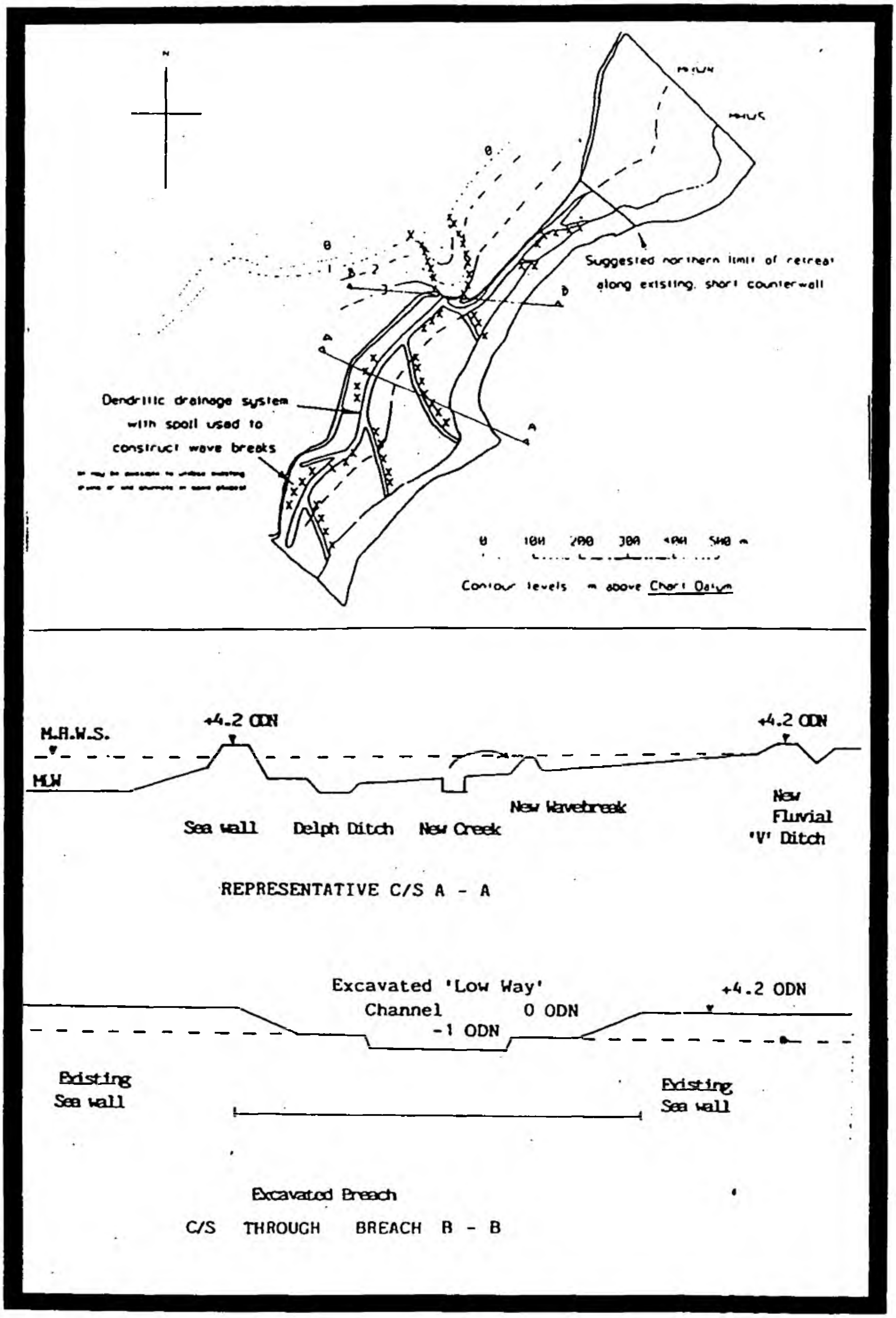
Two breaches were made to the existing wall to feed each compartment, their width reflecting the volumes of water to flood the site during variable tidal conditions, with the design criteria of each breach remaining relatively stable and erosion resistant. It is important, however, that no 'hard' engineering is used to artificially prevent either breaches or new creeks from eroding and hence preventing future natural adjustments being made as tidal forcing alters with marsh and estuary development.

The only construction equipment required on this subtly complex but simple design was 4 hydraulic excavators and 1 dozer; no concrete was required, the tide flap valves being sleeved and bolted onto the drain pipes. Breach excavation was achieved over four days during neap tides. The material excavated from the breaches was placed to landward to prevent external estuarial wave energy entering the site, and material from the new creeks placed 5 m to one side in a continuous line to limit internal wave generation whilst halophytic plants establish.

Principal quantities were 13,000 m^3 of excavation and placing, 30 m of pipework and 1 km of fencing.

Day to day site management was contracted out to a site engineer reporting to the project manager.

Figure 9 - Scheme Details



6. POST SCHEME ASSESSMENT

Monitoring of all flood defence schemes is essential to ensure scheme compliance with objectives. As Orplands was the first managed retreat solution undertaken as a flood control structure in the UK a pre and five year post construction monitoring contract was let. Items covered include for the site, plus a control site:-

6.1 Vertical accretion/erosion rate on both foreshore and salting.

6.2 Lateral erosion/progradation rates.

6.3 Physical characteristics of sediment

- cohesive strength
- density profiles
- particle size composition
- organic content

6.4 Chemical characteristics of sediment

- redox potential
- pH
- sulphide concentration
- heavy metal concentration (in sediment)
- nutrient content (of sediment)

6.5 Dissipation of wave energy and current speeds landwards over the marsh surface during exceptionally high tides.

6.6 Changes in salt marsh morphology (signs of creek lengthening, cliffing of salt marsh edges, areas of plant die-back leading to pan formation).

6.7 Plant vigour - productivity (related to accretion via peat formation and reduction in erosion)

- % species cover (roughness and efficiency at binding the sediment varies between species).

- Plant height (related to extent to which surface water flows will be effected).

- Plant community - species list, % cover, abundance

6.8 Value of vegetation to grazing birds and other secondary producers - above ground biomass, nutritional value of grazed material.

6.9 Composition, abundance and biomass of invertebrates, bivalves, crustacean, fish, mammals and birds.

Total cost is £50,000 including annual and final reporting.

Further contracts have been let under the NRA's National R&D budget to assess local and estuarial effects on tidal hydrodynamics and agri-chemcial pollution soak potential benefits.

At the time of this paper no official reports have been published, but early results have indicated a 3 mm gain in sediment, widespread halophytic plant colonisation, embryo invertebrate and crustacean use, extensive utilisation by birds and mammals, widespread approval of the general public.

It is important to stress that the degree of monitoring is a balance between the cost-benefit of the results obtained for flood defence and information required for other locations. Future managed retreat schemes should require less extensive monitoring as results are analysed and conclusions accepted.

7. THE FUTURE OF MANAGED RETREAT

7.1 IMPLICATIONS

The importance of salt marsh to both flood defence and conservation of rare habitats cannot be over stressed. Figure 10 illustrates the extent of their imporatnce and their range in East Anglia, with Essex stocks at 4500 hectares, Suffolk 1300, Norfolk 3000, Lincoln 4200; total UK area is 44400 hectares (Reference 7). As a natural flood and erosion control they prevent wave generated potential damage reaching sea walls, their miles of meandering creeks remove tidal current energies, their seaward physical weight stabilises sea wall structures and their relative area acts as a flood plain to lessen the effects of tidal storm surges.

As a conservation asset they provide a habitat for rare and endangered plants and insects, the fine silts of which they are composed hold vast numbers of invertebrates; one square metre of mud can support 15000 hydrobia snails on its surface and up to 2000 invertebrates below the surface (Reference 8). This biomass provides food for the 2.6 million waders and wildfowl that over-winter on the European Atlantic coast, of which over ½ million use the UK east coast saltings (Reference 9). The sheltered water created by the maze of creeks act as vital fish nurseries for fry of bass, mullet, flatfish and eels whilst the annual yield of dead vegetation inputs ½ tonne per hectare per annum of natural nutrients to feed bivalve molluscs and associated commercial fisheries (Reference 10).

Extensive navigation and recreation for both commerical use and private pleasure exist because of salt marsh. A massive leisure industry employing thousands of people and creating millions of pounds to the national wealth of the Country rely on the conditions created by estuaries and their associated salt marsh.

The ability of salt marsh to absorb, store and naturally treat anthropogenic pollutants is as yet an unquantified financial asset to improving coastal water quality (Reference 11).

7.2 LIMITATIONS

7.2.1 Managed retreat is not a no-cost option, with the majority of sea walls cheaper to maintain than to retreat.

7.2.2 High value land cannot be considered for the managed retreat option, including urban and industrial development and large agricultural areas.

7.2.3 Depending on the site location within the estuarial coastal cell, managed retreat could be at the detriment to adjacent coastal areas or to the estuarial long term stability.

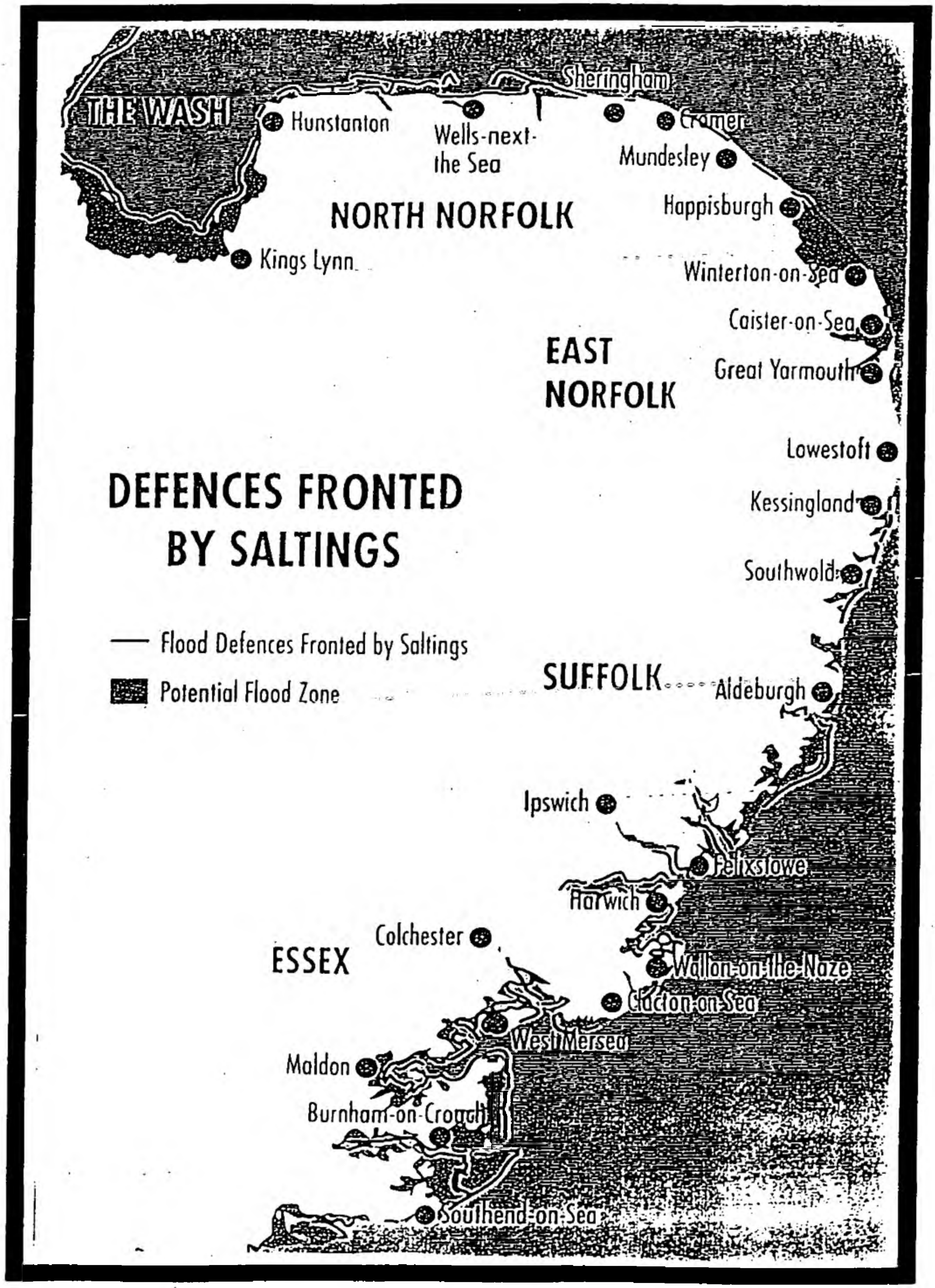
7.3 BENEFIT TO FLOOD DEFENCES

7.3.1 Better use of available flood defence funding by reducing expenditure on high cost walls to benefit lower cost walls e.g 2% of sea wall requiring 15% of the maintenance budget.

7.3.2 Regenerated salt marsh by managed retreat will create natural flood zones to remove tidal and wave energy with minimal maintenance costs.

7.3.3 Potentially could create a saline 'safety valve' flood washland to remove the peaks of tidal surges to the benefit of upstream areas. Breaches on the Deben estuary during the 1953 surge tide altered the tide height which was +4 m ODN at the mouth but only +3 m ODN at Woodbridge located at the 'top' of the estuary, saving the town from flooding (Reference 2).

Figure 10


THE WASH
Hunstanton
Wells-next-the Sea
Sheringham
Cromer
Mundesley
Happisburgh
NORTH NORFOLK
Kings Lynn
Winterton-on-Sea
Caister-on-Sea
EAST NORFOLK
Great Yarmouth
Lowestoft
DEFENCES FRONTED BY SALTINGS
Kessingland
Southwold
Flood Defences Fronted by Saltings
Potential Flood Zone
SUFFOLK
Aldeburgh
Ipswich
Felixstowe
Harwich
Colchester
ESSEX
Walton-on-the-Naze
Clacton-on-Sea
West Mersea
Maldon
Burnham-on-Crouch
Southend-on-Sea

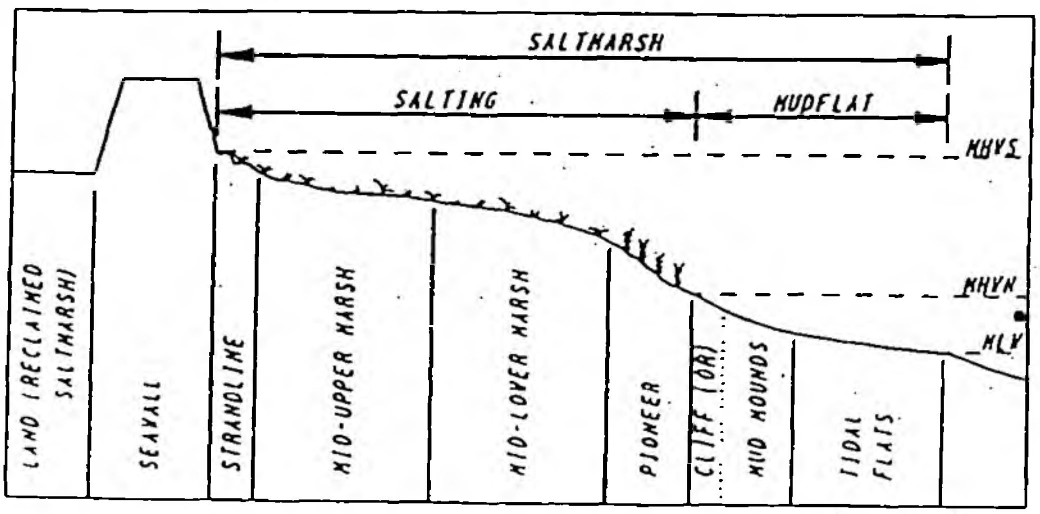
7.4 DISCUSSION - THE WAY FORWARD

Attempting to prevent relative sea level rise is like trying to prevent winter. The MAFF initiative toward Shoreline Management Plans, the NRA's Catchment Management programme and English Nature's Estuary Management Plans will eventually develop a concensus view on future potential managed retreat areas for salt marsh recreation. Salt marsh definition will need to become widely adopted to ensure effective communication between specialists and interest group (see Figure 11 and Reference 12).

Figure 11

<u>WHAT IS A SALTMARSH?</u>

STRICTLY SPEAKING A SALTMARSH IS THE AREA OF 'LAND' BETWEEN MEAN HIGH WATER SPRINGS and MEAN LOW WATER SPRINGS, and INCLUDES NOT ONLY THE VEGETATED SURFACE and DRAINAGE CREEKS BUT ALSO THE FRONTING MUDFLAT. THEY ARE FORMED BY MUDDY SEDIMENTS BEING DEPOSITED UNDER LOW ENERGY CONDITIONS. TIDAL FLATS FORM THE MOST EXTENSIVE PART OF A SALTMARSH, BUT AT THEIR UPPER LIMIT THEY HAVE EITHER LOW CLIFFS OR SLOPING MUD MOUNDS THAT DEMARCATE BETWEEN THE VEGETATED and NON-VEGETATED SURFACES. THE AREA WITH VEGETATION and ASSOCIATED CREEKS IS COMMONLY, IN ESSEX, CALLED A SALTING.



Definition of saltmarsh zones on the Essex coastline

From a coastal zone or flood defence management perspective what is required is to embrace the entire inter-tidal zone ie. from low water springs to + 1 metre above H.A.S. ie. the area subject to extreme surge events, the area that an estuary or coast requires to best lose tidal energy during episodic surges.

Coupled with this required definition is greater flexibility in the existing habitats payments conditions to allow new salt marshes to be utilised for a wider range of activities and uses eg. low density moorings or oyster cultivation on low level areas or sheep grazing and hay cropping to high levels.

And most of all what will be required is a robust education of the general public, governmental agencies and departments in the formation, use and abuse of these wilderness areas, areas capable of regenerating themselves for the benefit of all, if given the room to do so.

8. ACKNOWLEDGEMENTS

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