WESTERN SOLENT SALTMARSH STUDY

AP BRADBURY

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ANDREW BRADBURY BSc

New Forest District Council

Abstract

The design, implementation and preliminary analysis of a monitoring programme for the Western Solent saltmarshes is discussed. The study forms an integral part of the Western Solent and Southampton Water Shoreline Management Plan. A series of surveys have been carried out across the whole of the saltmarsh system, extending from the high water mark landward of the marshes, beyond the intertidal flats and into deep water. The study, which was designed in 1992, comprises a series of interactive elements including measurement of hydrodynamic forces, aerial surveys and hydrographic surveys. It also includes short term studies of small scale processes. Detailed baseline surveys and repeat surveys have been completed and the study has provided meaningful quantitative measurements of short term rates of change within the system. Hydrodynamic records of tidal levels and wind speed/direction have provided the basis for the compilation of a local wave and water level climate. Sufficient data to provide the basis of an outline management strategy for the saltmarshes is now available.

Future work will comprise detailed data analysis and the application of theoretical process models to the data. The next stage of the study will address the need for marsh protection schemes and will if necessary examine and field test the most appropriate environmentally acceptable solutions.

1 Introduction

The western Solent saltmarshes provide natural protection from wave action to approximately 10 kilometres of low lying shoreline and form the natural harbours within the Lymington and Keyhaven Rivers. There is clear evidence from map based data, that the saltmarsh system is evolving rapidly, both ecologically and morphologically. Significant losses to the area of intertidal flats have occurred during the past few years, resulting in exposure of the shoreline and sea defences to wave action. The perceived increase in erosion rates and the annual losses of large areas of saltmarsh have resulted in local concerns for the long term survival of the marsh system. These concerns have, together with a requirement to provide quantitative input to the Western Solent and Southampton Water Shoreline Management Plan, resulted in the development of a saltmarsh research and monitoring programme. The objectives of this programme are listed below.

1 Provide detailed quantitative measurements of changes to the morphology of the saltmarsh system
2 Provide quantitative measurements of hydrodynamic forces acting on the saltmarsh system
3 Analyse the interaction of the forces and responses of the saltmarsh system, for both short term storm events and evolution over periods of several years

4. Provide guidance on the management of the saltmarsh system, as an integral part of the Western Solent and Southampton Water Shoreline Management Plan
5. Assess the effectiveness and appropriateness of alternative methods of marsh protection and enhancement, carrying out field trials where appropriate.

2 Research Programme

The research programme is broken down into the following elements:

1. Historical Review
2. Design and implementation of a monitoring programme
3. Quantification of rates of change
4. Analysis of hydrodynamic forces and shoreline responses
5. Review and field trials of alternative protection schemes
6. Application of the results and theoretical models of detailed processes and ecological studies, using local field data for calibration

3 Historical Review

An initial historic review was commissioned from the University of Southampton, Department of Oceanography (Ke and Collins 1993) and this has formed the basis for the design of the programme of field work. This study considered the historical development of the saltmarsh system, patterns of sediment and water movement and examined present day rates of erosion and accretion.

The historical review has identified an average loss of saltmarsh at a rate of 3.6x10 4 m2 per year, from the western Solent saltmarsh system. By contrast the saltmarsh surface is accumulating sediment at a rate of 2-5mm per year. The study indicates a net loss of fine sediments from the intertidal system due to the strong dominance of the ebb tide.

4 Design of the monitoring programme

Previous research on management of saltmarsh systems was reviewed prior to deciding on the content of the monitoring programme. It became apparent that most studies had focused upon the performance of small scale process elements, of what are large and complex systems.

Monitoring programmes which address the interrelationship of the elements that make up the system from deep water to the high water line are rare. Similarly, many of the solutions to saltmarsh erosion problems appeared to address the symptoms of the problems, without detailed knowledge of the interrelationship of other potentially important variables. There appears to be particularly little information available about the interaction of hydrodynamic conditions with changes to the morphology of the intertidal zone, seaward of the marsh edges. This is not perhaps surprising since this zone presents considerable measurement difficulties.

Whilst it is acknowledged that many of the small scale processes are extremely important, forming an integral part of the saltmarsh response system, monitoring information is needed across the whole range of hydrodynamic influence. Saltmarsh monitoring programmes must be of a sufficiently broad basis, within the context of shoreline management, to provide a clear breakdown of the key forces and responses of the whole of the system. This study sought therefore, to provide information across the whole of the zone of potential hydrodynamic influence, on both the responses of the saltmarsh system and the hydrodynamic forces.

The importance of the understanding of the small scale individual elements of the saltmarsh system has not been ignored however. Results and theoretical applications of small scale process studies have been considered and applied where appropriate within this monitoring programme. As the programme develops further, it is hoped that the sites discussed might provide an appropriate location to test the applicability of some of the theoretical process studies carried out previously at other locations. The effects of ecological changes in particular the migration and evolution of different marsh species such as Spartina were also acknowledged to be important. Independent studies which would provide information to this study were also set up in coordination with local conservation agencies.

The quality of the baseline information is an important factor in the programme design. A series of peripheral studies were designed to provide background baseline information, which would supplement the regular monitoring and provide the flexibility for meaningful comparative studies at a later stage, if necessary. The frequency and density of regular monitoring measurements can be modified, if any temporal trends are identified, as the programme develops.

The timescale of the monitoring programme is important, if meaningful management decisions are to be made. The monitoring programme was initially planned for major review after a period of 5 years, with provision for extension and modification after analysis of the data collected. It was hoped that this initial monitoring programme would provide adequate data to identify temporal variations which would form the basis for future management strategies.

The evolution of saltmarsh systems is very rapid by comparison with many other coastal processes and their fragile environment appears to be very sensitive to small changes in environmental conditions. Management decisions need to be made therefore, with considerable caution. They should ideally be made with sufficient knowledge of the potential effects of any actions that are taken, both within the system and in terms of the effects that any decisions may have on the adjoining coastal systems. The saltmarsh monitoring programme was designed, therefore to integrate with the monitoring programme for the remainder of the coastal cell.

A series of short term studies were also designed and implemented to supplement the baseline information. These included:

Topographic surveys of the marsh surface
Geotechnical measurements of soil strength
Measurement of heavy metal concentrations in sediments
Analysis of the fine grained sediment budget
And
Measurement of accretion on the saltmarsh surface

5 Hydrodynamic measurements

High quality hydrodynamic data is fundamental to a coastal process study and an environmental measurement system was designed at an early stage in this project, to monitor the key hydrodynamic variables:

Wind waves
Water levels
And
Tidal currents

A permanent environmental measurement system has been installed at an excellent site on an offshore platform, close to the mouth of the Lymington River (Figure 2). Tidal elevations, barometric pressure, wind speed and direction are all telemetered in virtual real time to a PC data logger at the Council offices in Lymington. The system was first installed in 1992 and has operated with few interruptions ever since, providing data of high quality. Typical time series data from the logging system are shown in Figure 3.

Wind data has been used to synthesise hindcast wave conditions following storms, using the JONSEY wave prediction programme. Maximum deep water conditions have been calculated, resulting in local significant wave heights of 1.06 metres, with a mean wave period of 3.3 seconds. Subsequent analysis of the wave data has been carried out in conjunction with tidal data and intertidal profiles, provided from the hydrographic surveys. A one line model of wave transformations (WENDIS) has been used to calculate the distribution and magnitude of wave conditions at the marsh edges. Statistical analysis of the wind records will provide a regional wave climate, when sufficient data is available to provide statistically valid prediction of the distribution and magnitude of extreme events.

Similarly, a harmonic analysis of the tidal data will provide local tidal predictions and continued long term records of water levels will provide valuable data about the frequency and magnitude of the surge component of water levels. The tidal range at the site is only 2.5m on spring tides. An extreme tidal surge may increase the tidal range by approximately 50% of the maximum tidal range. The combined effects of wave activity and extreme water levels are particularly important at this site.

The environmental monitoring system has excellent potential for examination of the response of the intertidal zone to individual storm events and the research programme will be extended to examine the response of selected areas to such extreme conditions.

Ebb tidal currents dominate the area. Tidal flows have been recorded at several strategic locations and the results of current meter deployments will be used in conjunction with a numerical model of tidal flows, to examine sediment transport within the system.

6 Hydrographic surveys

Historical information has been drawn from Admiralty surveys and surveys commissioned by the Lymington Harbour Commissioners. Unfortunately the inter tidal zone, which is of particular interest for shoreline management purposes, is not surveyed in detail during surveys that are primarily designed to provide information for navigation and the data from these surveys is of very limited value.

Technological advances in both position fixing accuracy and computer controlled data capture methods have enabled a programme of detailed and accurate digital hydrographic surveys to be designed and carried out at reasonable cost. Surveys are carried out over high water spring tide periods, when the marsh surface is immersed, allowing the survey vessel to run across the intertidal zone to the edge of the saltmarsh surface. Detailed profiles are surveyed across the intertidal flats and in to relatively deep water. The surveys have been carried out with survey tracks spaced at intervals of approximately 10m, providing detailed spatial coverage of the intertidal areas. Soundings have been recorded with a Raytheon DE719B echo sounder linked via an MDS4 digitiser producing soundings which are realistically accurate to approximately +/-0.1m. Surveys are carried out during very calm periods when survey accuracy is maximized. Position fixing has been carried out with Trimble 4000SE differential GPS, providing positional accuracy to approximately 1 metre. HYPACK data processing and data acquisition software has been used to process the data and tidal control is provided by the tide gauge at the mouth of the Lymington river. Survey data is subsequently analysed using DGM3.8 digital terrain modeling software and FASTCAD drawing package.

Digital hydrographic surveys were initially carried out within the Lymington river in 1992 and development of both the survey techniques and the analysis of the survey data has been focused on this area since then. Repeat surveys have demonstrated that ground modeling techniques can be used to provide both reliable and accurate data and also confirm that there are significant measurable quantities of change in the intertidal zone within periods of 1 year, particularly at the edges of the saltmarshes (Figure 4). The hydrographic surveying programme has since been extended to cover the nearshore zone between Hurst Castle and Pitts Deep (Figure 1), covering the whole of the 10 kilometre saltmarsh frontage. It is expected that this will permit an evolution model of the whole of this saltmarsh system to be developed, in parallel with the aerial survey programme and the hydrodynamic measurements.

The hydrographic surveys have provided several valuable data sets:

(i) quantification and location of erosion and accretion
(ii) detailed profiles perpendicular to the marsh edges extending from the saltmarsh edge into deep water
(iii) navigational charts and volumetric analysis of dredging requirements within the harbour

7 Aerial surveys

Vertical aerial photography of the marshes has been carried out from aerial surveys since 1990 and the photography has been used to provide detailed assessment of the plan shape changes of the marsh edges. The surveys are carried out from a range of elevations, according to the analysis requirements. Low level aerial surveys carried out at a contact scale of 1:2500 provide detailed photographs which are used for visual interpretation of the evolution of morphological features within the marsh system. Features such as creek systems, vegetation cover and marsh edge cheniers can be identified and investigated particularly effectively from photography at this scale. Higher level surveys at a scale of 1:8000 are used to provide overviews of larger areas of the marsh system. Digital mapping of the Lymington river saltmarsh system, carried out in 1992 and 1994, was mapped from 1:3400 scale photography. This scale was selected for optimization of vertical accuracy and provision of adequate ground control. This is a particular problem in marsh areas where fixed ground control can be very difficult to achieve. Significantly more detail is provided from this mapping than is available from the Ordnance Survey 1250 scale mapping. Ground control for the surveys was carried out using Trimble DGPS and digital photogrammetry was carried out by Cartographical Services Ltd.

The vertical accuracy of surveys has been confirmed at the 0.1m level by comparison of the 1992 aerial survey, which was carried out at low water spring tide, with the hydrographic surveys carried out over high water, thus providing a significant overlap. The two independent surveys provide a remarkable level of consistency indicating that accuracy might be even better than the target +/- 0.1m.

The digital aerial survey mapping is separated into a series of layers to aid manipulation within the software mapping and analysis packages. The aerial survey mapping identifies features such as marsh edge cheniers, as well as providing considerable detail on the morphology of marsh creek systems and the intertidal flats.

A series of 3 dimensional profiles across the marshes are measured on each survey. These are used to identify comparative changes in the marsh and intertidal surface profiles. The degree of change in the surface elevations of the marsh is not yet at a measurable level, over the two year timescale of the investigations. Changes in the marsh surface levels are smaller than the accuracy of the surveys. However, the data recorded to date will provide a good baseline for future long term measurements. Field measurements of marsh surface levels have been recorded to supplement the levels derived from the aerial surveys. These indicate that there is accumulation on the marsh surface at a rate of a few millimeters per year. The marsh surface is generally quite flat although there are a few areas which are notably lower than other areas. The marsh levels vary by only approximately 0.4m across the entire study area.

Plan shape changes of the marsh edge are analysed by registering coordinated surveys on each other. Figure 6 demonstrates plan shape changes during the course of a two year period, along the most exposed section of the marsh frontage.

8 Preliminary Analysis

The preliminary analysis has focused on quantification of plan shape changes to the marsh edges, and the location and quantification of erosion and accretion within the intertidal zone. Digital terrain modeling has provided the basis for quantification of changes and the high density of survey information has enabled accurate measurement of changes to be made within the intertidal and submerged zones. Erosion is focused at the mouth of the Lymington River and maximum erosion rates of the marsh edges of 8m per year have been measured at isolated locations. The average erosion rate along the open face of the marshes was 3m per year between 1992 and 1994 (Figure 6).

There is a very strong correlation between exposure to wind wave attack and the rate of erosion. The presence of vegetation appears to have little effect. Those areas which have suffered losses in vegetation do not appear to be eroding any faster than those with densely rooted vegetation, even when subject to the same exposure of wave attack.

Wave attack and erosion within the Lymington River is more limited, due to the shorter fetches, but ship wash and draw down generates waves of significant magnitude to induce erosion of the marshes over the upper part of the tidal cycle.

Low relief cheniers, comprising a mixture of sands, gravels and shells are forming along the saltmarsh edges from Keyhaven Lake to Lymington. These features are characteristic of environmental change, from an environment of tidally dominated deposition, to one of wave dominated erosion. The cheniers at the mouth of the Lymington river lie along stretches of saltmarsh which are eroding more slowly than areas without cheniers, but with a similar exposure to wave attack. The original gently sloping faces of the cheniers have now steepened, which is further evidence of an increasingly severe environment. Whilst the cheniers provide additional protection to the marsh edges, vegetation cover is destroyed due to smothering by sand and shingle. Similarly, narrow fringing sand and gravel beaches have developed in places and the marshes erode more slowly in these areas.

The varied shape of the profile within the intertidal zone if particularly interesting. The upper intertidal zone is characterized typically by steep clifflets and a strong concave upward profile within the upper part of the intertidal zone (Figure 5). The seaward cliffs vary in height but are typically 0.7-1.5 metres high. The marsh surface varies in level by only about 0.4m. Whilst the cross section profiles have changed due to erosion of the marsh edges, the geometry of the profiles has remained fairly constant, with parallel recession of the profiles. The profiles occasionally become flatter, but in most cases the profile of the intertidal zone is largely unchanged.

Whilst analysis of the data is at a very early stage, there is clear evidence that the essentially concave upwards non-dimensionalised hypsographic profile, referred to by Kirby (1992) is evident within this saltmarsh system. This has been developed by calculation of the relative constant level areas, based on contours at 0.2m intervals from both the hydrographic and aerial survey data. Preliminary qualitative analysis of the shape of the intertidal non-dimensionalised profiles along the eroding coastline appears to be consistent with the theories suggested by Kirby. Further quantitative analysis of the intertidal profiles will seek to extend the validity of the theoretical analysis of the stability of the intertidal zone, by the use of hypsographic profiles, within an area of low mesotidal range.

9 Management Strategy

The monitoring data has provided the basis for an interim review of the saltmarsh management strategy, which to date has involved no protection works. It is clear that the saltmarsh system is reducing in size at a rapid rate, but there is evidence that current sea defences and coast protection works are not yet vulnerable, except at the eastern end of the marsh system. If the fastest measured erosion rates are used as the basis for planning, economically justifiable coast protection works may be needed in this area within 5-15 years. The areas of high economic value within the Lymington River are not yet threatened, but economically justifiable coast protection works may be needed within the Lymington River within 30 years. There is clear evidence however, that the Hurst Spit shingle beach is crucial to the survival of the Keyhaven Marshes and to the performance of the sea defences in this area. The current management strategy is reliant on the implementation of the proposed large scale beach recharge scheme, which is needed to maintain the level of protection afforded by Hurst Spit.

The issue of natural losses from an area of high conservation value needs to be addressed. The balanced view of the conservation organizations seems to favour a management strategy which allows the marshes to evolve naturally, despite the rapid losses of valuable saltmarsh areas. Continued monitoring is strongly supported. Additional environmental studies, including vegetation mapping, have been suggested to supplement the hydrodynamic studies.

The monitoring programme is now beginning to provide high quality data which can be used as an effective management tool. The dynamic nature of the saltmarsh system is subject to temporal and spatial changes and the monitoring programme is crucial to a clear understanding and the formation of a coherent long term management strategy.

Whilst there is at present no obvious need for protection works, the opportunity should be taken now to examine alternative methods of protection should these eventually be required. A range of options for long term active management of the marsh system has been considered:

Defend the marsh edges
Raise levels of the marshes
Or allow recession to continue

These options will continue to be addressed. The beneficial use of dredged materials from the local marinas is one potential option which is being addressed seriously, both in the context of raising the level of the marshes and by recharging the intertidal zone. There are serious concerns about the development of artificially generated marsh surfaces, in the context of the development of the indigenous marsh species and the migration of species across the tidal profile, and also in the quality of sediments derived from the dredging programme. The use of hard defences such as rock armouring and concrete aprons will present significant problems, particularly if short sections of work are constructed. Such solutions would not be environmentally acceptable at this site. A small monitored trial of staked fibre rolls, carried out within the relatively benign environment of the Lymington River, has demonstrated that this technique is unlikely to be suitable at this site.

The natural fringing sand and shingle beaches and cheniers help to slow the rate of erosion of the marsh edges and also provide another habitat within the system. The concept of beach recharge within the system may present an attractive environmentally beneficial long term possibility, providing a protection system which is both dynamic and will not become outflanked. This will be examined in more detail but is likely to be an expensive option, unless beneficial use of waste materials from other sources can be utilized. A trial site for this type of protection will be examined and a small trial carried out, if a suitable site and source can be identified.

10 Conclusion and Recommendations

1 Monitoring of hydrodynamic forces and shoreline response should continue
2 Further investigation of innovative shoreline recharge methods should be pursued
3 Suitable areas for trial sections of shoreline recharge should be identified

4 Coast protection works are unlikely to provide cost effective short term solutions to marsh edge erosion at this site
5 Functional coast protection works could only be constructed at considerable seriously environmental expense
6 Short stretches of hard coast protection works would become outflanked within 2-3 years of construction

11 Acknowledgements

The research programme is funded by New Forest District Council, with contributions from Hampshire County Council. Aerial and hydrographic survey data for 1992 was provided by the Lymington Harbour Commissioners. Hydrographic surveys were carried out by Andrew Colenutt (NFDC) and John Cross (University of Southampton).

12 References

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Kirby R 1992 Effects of Sea Level Rise on Muddy Coastal Margins, Coastal and Estuarine Studies; Dynamics and Exchanges in Estuaries in the Coastal Zone, American Geophysical Union, Vol 40, pp313-334.

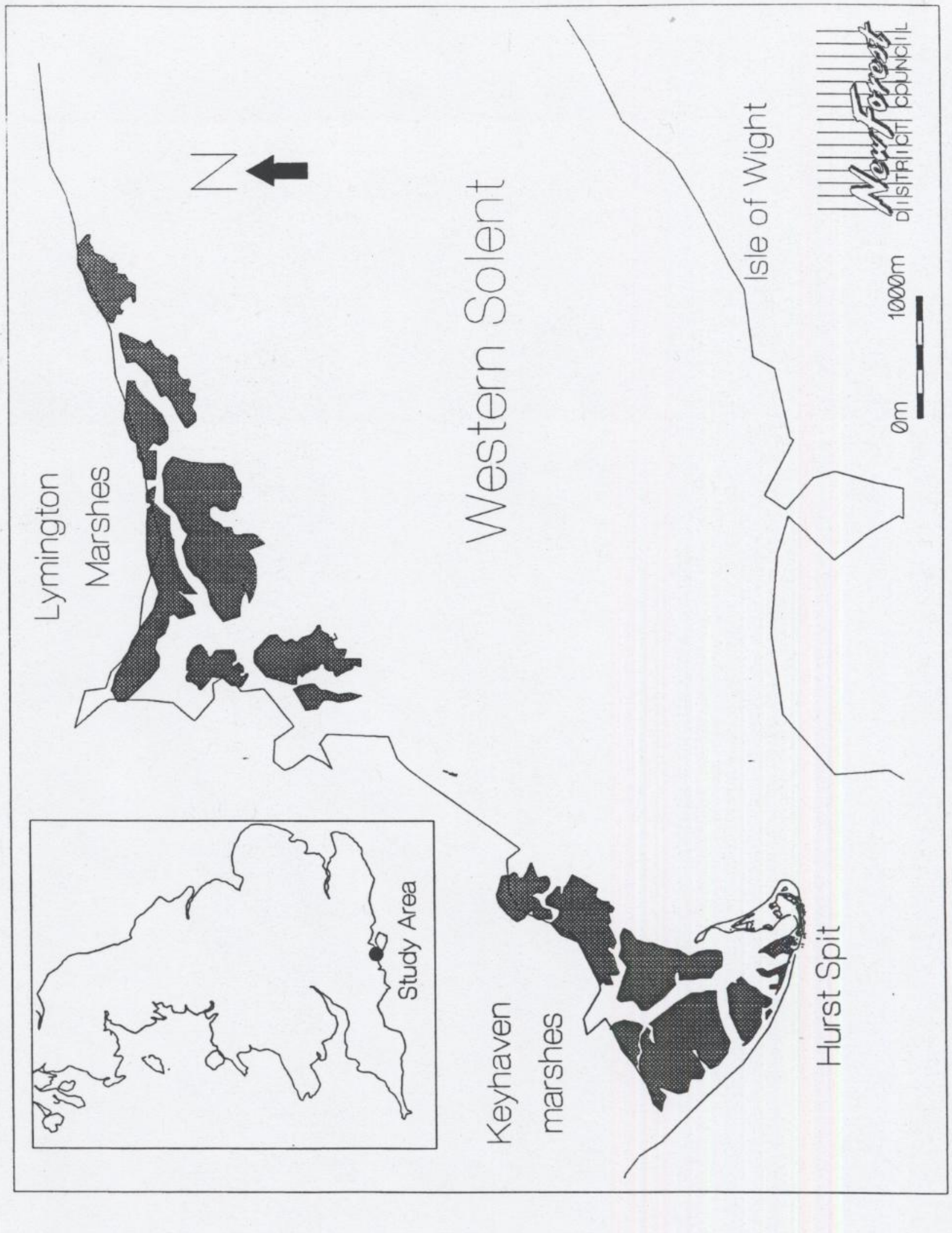

Figure 1. Location maps of study area

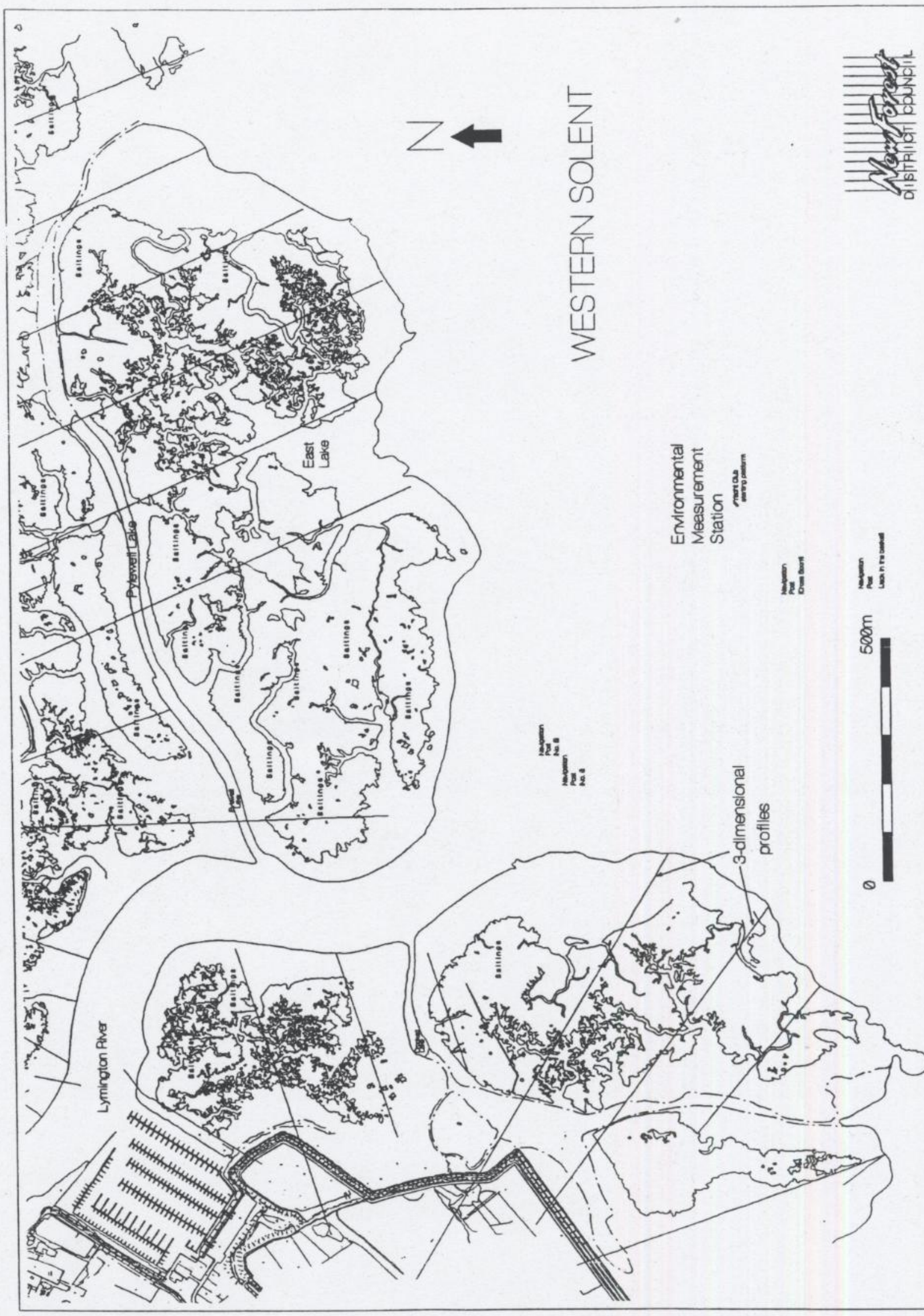

Figure 2. Location of environmental measurement station

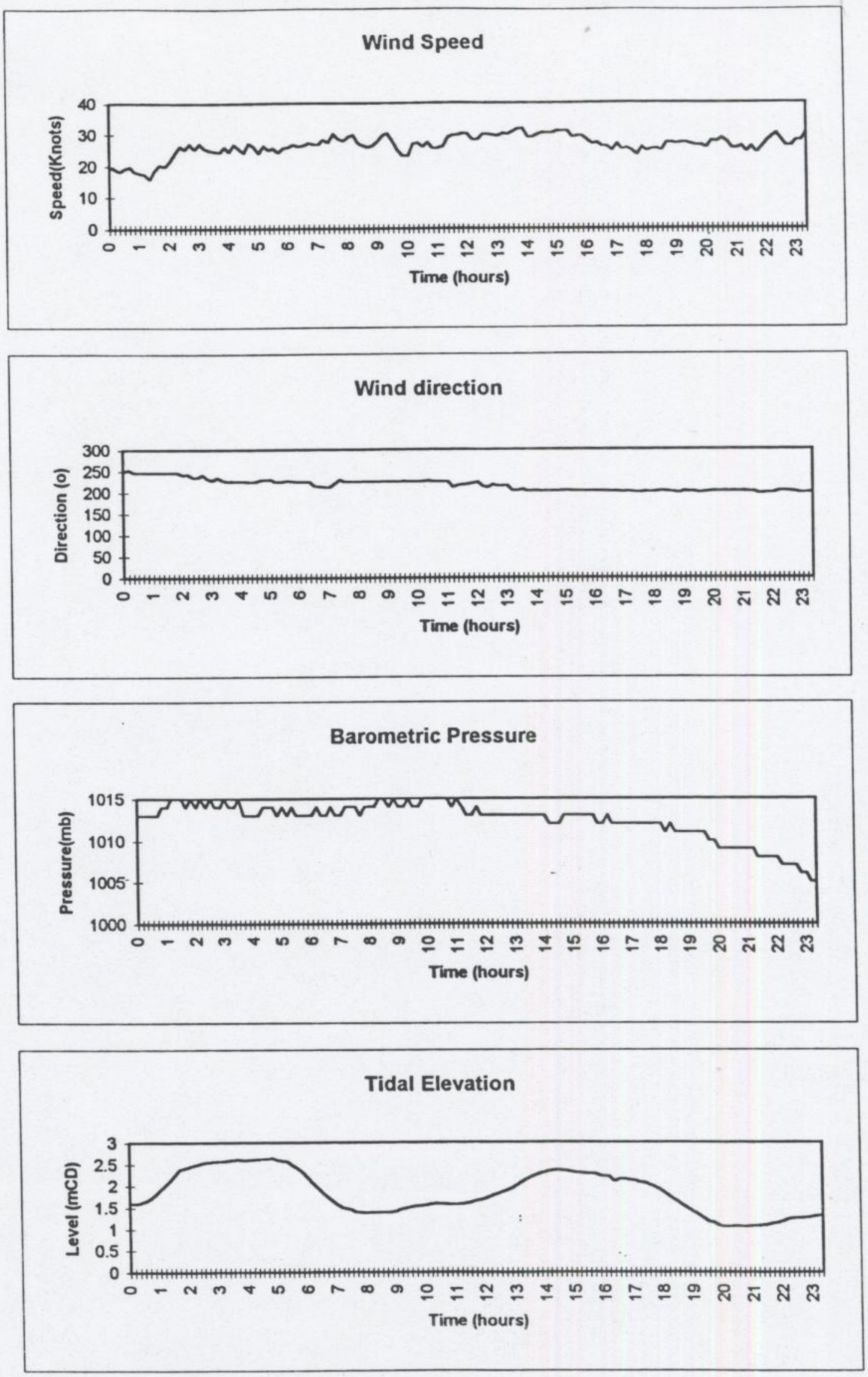

Figure 3. Time series data from environmental station

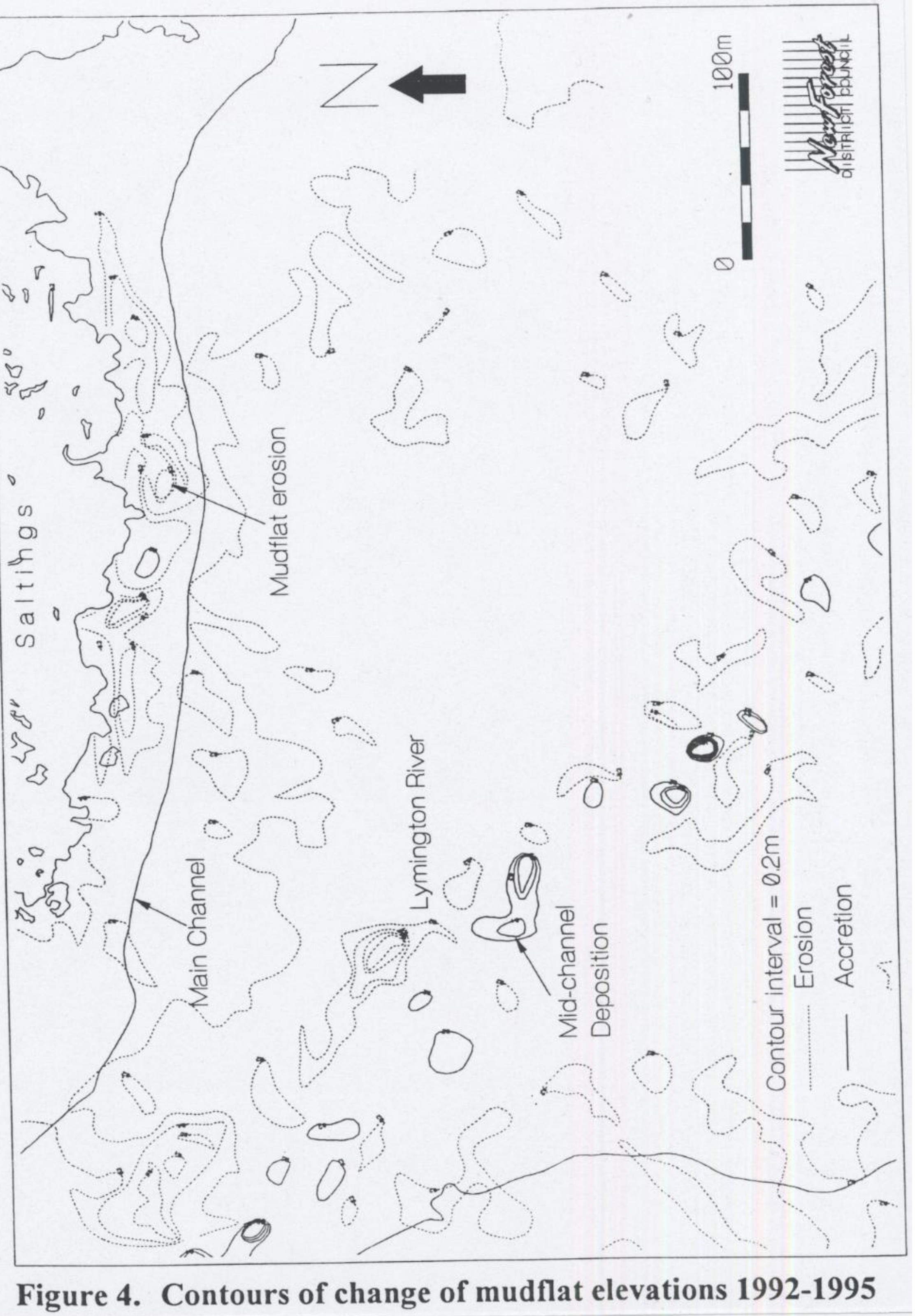

Figure 4. Contours of change of mudflat elevations 1992-1995

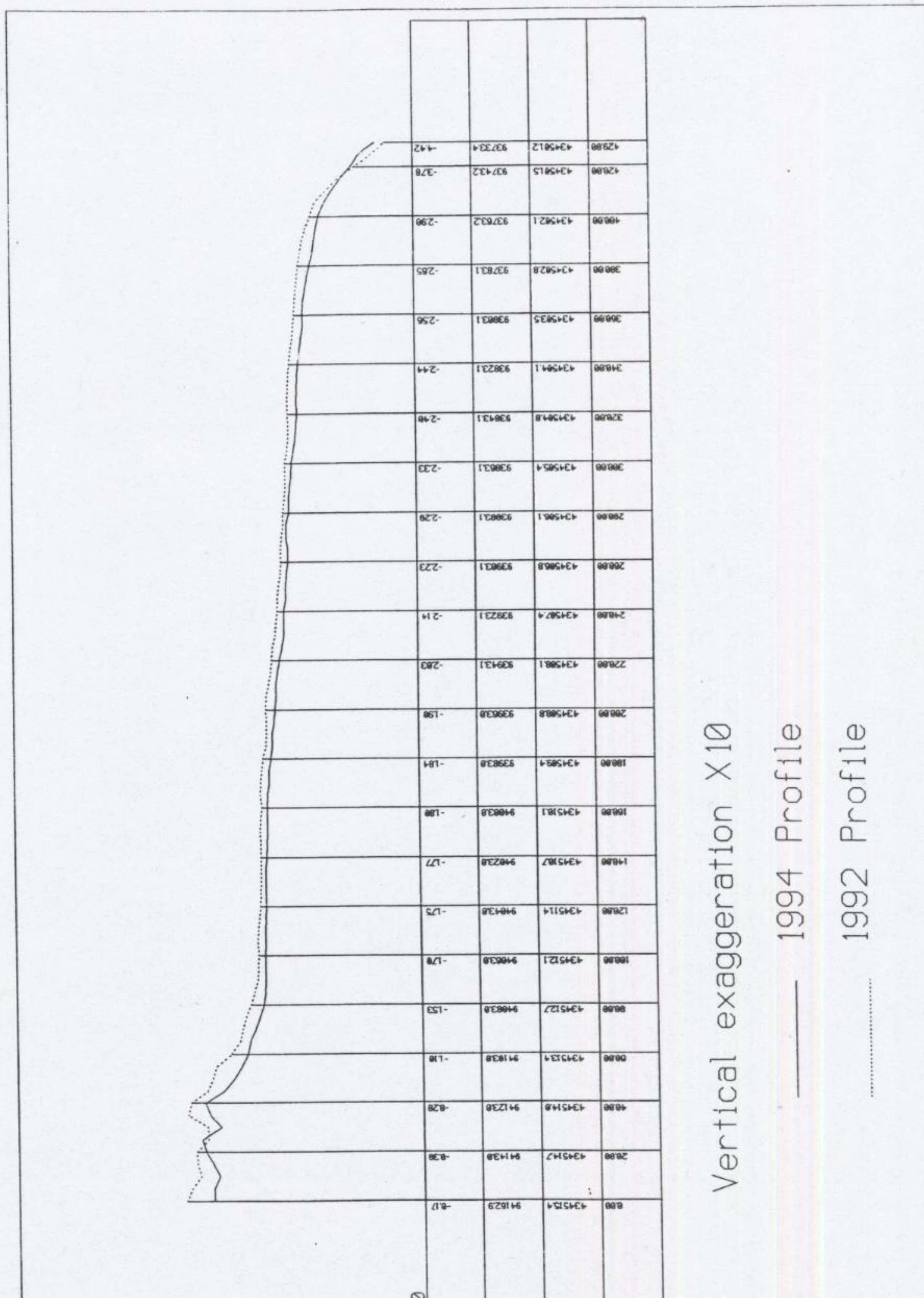

Figure 5. Changes to the intertidal profile 1992-1994

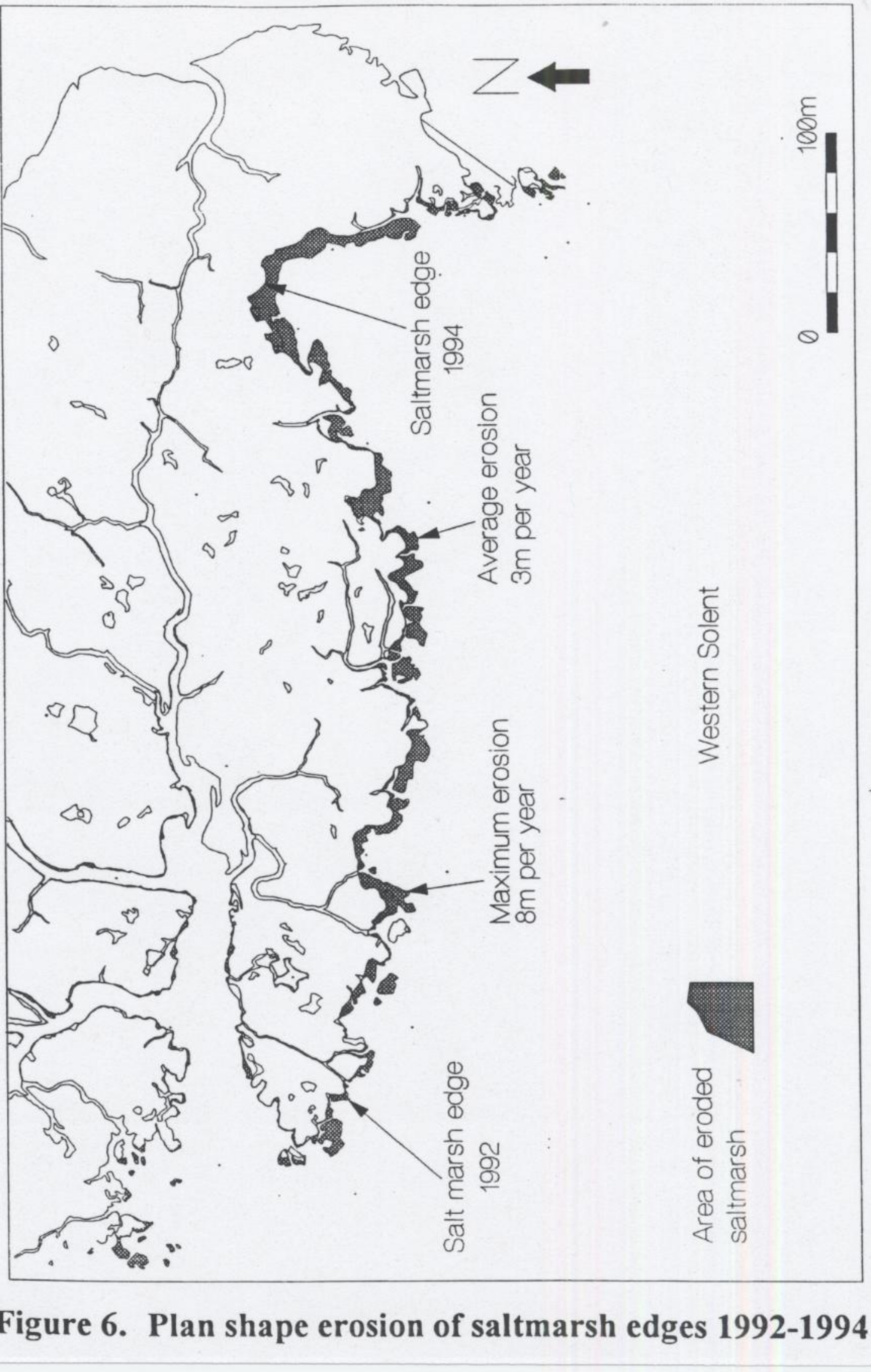

Figure 6. Plan shape erosion of saltmarsh edges 1992-1994