CCPEM Centre for Coastal Processes Engineering and Management

UNIVERSITY OF Southampton School of Civil Engineering and the Environment

CENTRE FOR ENVIRONMENTAL SCIENCES

# Scoping Study

*Site analysis for potential beneficial dredge spoil use for restoration and recharge of intertidal soft sediment resources within the Solent*

**F.A.O Stephen Blythe, Rhian Edwards and Tim Holzer**

**31/03/2009**

**Scoping Study**

*Site analysis for potential beneficial dredge spoil use for restoration and recharge of intertidal soft sediment resources within the Solent*

**For:**
Stephen Blythe HCC
Email: stephen.blyth@hants.gov.uk
Rhian Edwards HCC
Rhian.edwards@hants.gov.uk
Tel: 01962 846777

Tim Holzer Environment Agency
Tel: 01962 764830
Email: tim.holzer@environment-agency.gov.uk

**From:**
Miss Elizabeth Williams
ecrw104@soton.ac.uk
Dr. Simon Bray s.bray@soton.ac.uk
Dr Dafydd Llloyd Jones
dlj@noc.soton.ac.uk
Dr Ilse Steyl ilse.steyl@btinternet.com
Dr Malcolm Hudson mdh@soton.ac.uk
Professor Robert J Nicholls
R.J.Nicholls@soton.ac.uk
Tel. 023 80595000 (Switchboard)
University of Southampton

CCPEM Centre for Coastal Processes Engineering and Management

University of Southampton School of Civil Engineering and the Environment

Centre for Environmental Sciences

## Executive Summary


Discussions were undertaken between Hampshire County Council, the Environment Agency and the University of Southampton, School of Civil Engineering and the Environment (Centre for Environmental Sciences). These established a need to investigate the viability of using dredge spoil for saltmarsh restoration and mudflat creation in the Solent (central southern UK).

A literature review of current natural and anthropogenic threats to saltmarsh longevity in the UK and worldwide was undertaken. This also considered the potential impact of dredging activities and considered the potential value of keeping sediments within the geomorphological systems. The value of saltmarsh as a habitat, sediment sink, source of nutrients and provider of natural coastal protection was considered. The status of Solent salt marshes, particularly in relation to their conservation value, their source of sediment and wave erosion trends was identified. Both passive and active methods of saltmarsh restoration tried in the UK and worldwide were considered. In particular the use of dredge spoil and methods for its placement and retention were investigated.

An overview of legislation in relation to Environmental Impact Assessment and Appropriate Assessment and planning issues was given. Furthermore the matter of trace elements and pollutants potentially associated with dredge spoil, and as a result its suitability for restoration works, was also considered. This was complemented by comment form the main regulatory agencies (the Environment Agency and Natural England) who kindly gave their opinion on procedures and processes that may lead to a Solent saltmarsh restoration trial.

This background material was then considered in relation to nine saltmarshes, owned by Hampshire County Council, where restoration may be viable. This was coupled with a further eleven sites identified through the Solent Dynamic Coast Project (SDCP) where use of dredge spoil may be feasible to convert mudflat to saltmarsh. A tool was developed which utilised recommended physical conditions, coupled with conservation designations and socio-economic considerations. GIS analysis showed erosion trends, sediment amounts required, marsh slope and height. In addition analysis considered sediment amounts required to restore marsh/convert mudflat and identified marsh erosion trends (useful to identify sites naturally accreting). A Multi Criteria Analysis (MCA) "*traffic light*" system combined the above factors and highlighted marshes/mudflats which appear most suitable for restoration.

For saltmarsh restoration, based on the MCA of the Hampshire County Council sites, results indicate that Gutner Point, Keyhaven and Calshot show a positive balance of criteria for trial dredge spoil recharge. For mudflat recharge the MCA analysis indicated that West Northney, Farlington and Pagham South show the most positive balance of criteria. Of these three sites West Northney would require the least sediment to be introduced to the system. The availability of dredge spoil for restoration projects was considered with regard to regularity of dredging, possible contaminant concentrations (against EA Action Levels).

It is recommended that site visits and consideration of local knowledge be employed to indicate the most suitable restoration method of those identified in section three. Furthermore it is highly recommended that a robust experiment design and program of trials through research should be used to monitor changes in accretion or erosion.

Whilst not exhaustively considered, the likely issues associated with a potential Environmental Impact Assessment were highlighted to inform regulators and decisions makers of potential processes necessary before restoration trials and full restoration, could be undertaken.

Finally at all times through any proposed restoration trial in the Solent System, it is strongly recommended that close liaison with stakeholders and interested parties is undertaken to ensure all concerns are addressed. The University recommends trials in the region not least to offset historic marsh loss, however these must be undertaken with the precautionary principle in mind.

## Contents

*Preface* ... 1
1. Introduction ... 2
1.1 Value and Loss ... 2
1.2 Sea Defence ... 3
1.3 Beneficial Use and Managed Realignment ... 4
1.4 Drivers and Possible Opportunities for Solent Beneficial Use ... 5
1.5 Solent Overview ... 6
1.5.1 Introduction ... 6
1.5.2 Description ... 6
1.5.3 Wave Climate ... 7
1.5.4 Sediment Patterns ... 8
1.5.5 Conservation and Sensitive Habitats ... 9
1.6 Potential Restoration Areas ... 11
1.7 Aims and Objectives ... 12
2 Saltmarsh Dynamics, Restoration, Success and Failure ... 13
2.1 Overview of Accretion and Erosion Physical Processes ... 13
2.2 Saltmarsh Restoration Background ... 13
2.2.1 Introduction ... 13
2.2.2 Saltmarsh Restoration – Brief Overview ... 14
2.2.3 Solent Scope ... 17
2.3 Success and Failure ... 18
3 Saltmarsh Restoration Techniques ... 20
3.1 Introduction ... 20
3.2 Reduction of Erosive Potential ... 20
3.2.1 Wavebreaks ... 20
3.2.2 Vegetation Planting ... 21
3.2.3 Retention of Sediment ... 23
3.3 Sediment Settling ... 23
3.3.1 Sedimentation Fields/Polders ... 23
3.4 Sediment Augmentation ... 24
3.4.1 Introduction ... 24
3.4.2 Direct Placement of Dredged Material ... 26
3.4.3 Trickle Charging ... 27
3.5 Managed Realignment ... 28
3.5.1 Introduction ... 28
3.5.2 Techniques ... 28
4 Legislation Maze – Barrier or Opportunity ... 29
4.1 Context ... 29
4.2 Saltmarsh Selection Process ... 29
4.3 Dredge Spoil Consideration ... 30
4.4 AA, EIA and Planning ... 32
4.4.1 Introduction ... 32
4.4.2 Appropriate Assessment (AA) ... 32
4.4.3 Environmental Impact Assessment (EIA) ... 33
4.4.4 Planning Requirements ... 34
4.5 Regulatory Agency Comments ... 35
4.5.1 Introduction ... 35
5. Suitability Criteria: Site Selection for Potential Intertidal Recharge ... 38
5.1 Introduction ... 38
5.2 Key Factors for Site Selection ... 38
5.3 Method for identifying sites ... 39
5.3.1 Outline ... 39
5.3.2 Historic Rates of Saltmarsh Loss ... 39
5.3.2 LiDAR and Tidal Level Interpretation ... 39

5.3.3 Dredging Data .... 41
5.4 Results: Hampshire County Council Sites .... 41
5.4.1 Keyhaven: Introduction .... 42
5.4.3 Keyhaven: Volume Requirements for Mudflat Recharge .... 44
5.4.4 Keyhaven: Multi Criteria Analysis .... 46
5.4.5 Pennington: Introduction .... 47
5.4.6 Pennington: Historic Saltmarsh Change .... 47
5.4.7 Pennington: Volume Requirements for Mudflat Recharge .... 49
5.4.8 Pennington: Multi Criteria Analysis .... 51
5.4.9 Calshot: Introduction .... 52
5.4.10 Calshot: Historic saltmarsh change .... 52
5.4.11 Calshot: Volume Requirements Mudflat Recharge - Calshot .... 54
5.4.12 Calshot: Multi Criteria Analysis .... 56
5.4.13 Mercury: Introduction .... 57
5.4.14 Mercury: Historic Saltmarsh Change .... 57
5.4.15 Mercury: Volume Requirements for Mudflat Recharge .... 60
5.4.16 Mercury: Multi Criteria Analysis .... 62
5.4.17 Hacketts Marsh: Introduction .... 63
5.4.18 Hacketts: Historic saltmarsh change .... 63
5.4.19 Hacketts: Volume Requirements for Mudflat Recharge .... 65
5.4.20 Hacketts: Multi Criteria Analysis .... 67
5.4.21 Bunny Meadows: Introduction .... 68
5.4.21 Bunny Meadows: Introduction .... 68
5.4.22 Bunny: Historic saltmarsh change .... 68
5.4.23 Bunny Meadows: Volume requirements for mudflat recharge .... 70
5.4.24 Bunny Meadows: Multi Criteria Analysis .... 71
5.4.25 Hook Marshes: Introduction .... 73
5.4.26 Hook: Historic Change .... 73
5.4.27 Hook: Volume Requirements for Mudflat Recharge .... 74
5.4.28 Hook: Multi Criteria Analysis .... 76
5.4.29 Hayling (West): Introduction .... 77
5.4.30 Hayling (West): Historic saltmarsh change .... 77
5.4.31 West Hayling- Volume requirements for mudflat recharge .... 79
5.4.32 West Hayling: Multi Criteria Analysis .... 81
5.4.33 Gutner Point: Introduction .... 82
5.4.34 Gutner Point: Historic Saltmarsh Change .... 82
5.4.35 Volume Requirements for Mudflat Recharge .... 84
5.4.36 Gutner Point: Multi Criteria Analysis .... 86
5.4.37 Conclusions for Hampshire County Council Sites .... 87
5.5 Results: SDCP Sites .... 89
5.5.1 Introduction .... 89
5.5.2 Saltgrass Lane .... 89
5.5.2 Salt Grass Lane: Multi Criteria Analysis .... 90
5.5.3 Lymington Reed Beds .... 91
5.5.4 Lymington Reed Beds: Multi Criteria Analysis .... 92
5.5.5 Gillies .... 93
5.5.6 Gillies: Multi Criteria Analysis .... 94
5.5.7 Farlington .... 95
5.5.8 Farlington: Multi Criteria Analysis .... 96
5.5.9 Stoke .... 97
5.5.10 Stoke: Multi Criteria Analysis .... 98
5.5.11 West Northney .... 99
5.5.12 West Northney: Multi Criteria Analysis .... 100
5.5.13 North Common .... 101
5.5.14 North Common: Multi Criteria Analysis .... 102

5.5.15 Nutbourne ... 103
5.5.16 Nutbourne: Multi Criteria Analysis ... 104
5.5.17 West Wittering ... 104
5.5.18 West Wittering: Multi Criteria Analysis ... 105
5.5.19 Medmerry ... 106
5.5.20 Medmerry: Multi Criteria Analysis ... 107
5.5.21 Pagham South ... 108
5.5.22 Pagham South: Multi Criteria Analysis ... 109
5.5.23 Conclusions for SDCP Sites ... 111
5.6 Conclusions ... 112
5.6.1 Site Recommendations ... 112
5.6.2 Monitoring Requirements for Chosen Sites ... 112
5.7 Potential Locations of Dredged Material ... 113
5.8 Restoration Methods ... 118
6 Possible Environmental Issues for Solent Saltmarsh Restoration ... 119
7 Conclusions ... 121
References ... 122

## Figures

Figure 1.1 Overview of Solent and national / international conservation designations 6
Figure 1.2 Solent significant wave height exceedence (m), for the given percentage 7
Figure 1.3 Mean monthly significant wave heights, Lymington, Western Solent 2003-2008 8
Figure 1.4 Solent SACs 9
Figure 1.5 North Solent SPAs 9
Figure 1.6 HCC sites identified for potential restoration 11
Figure 1.7 SDCP sites identified for recharge following managed realignment 11
Figure 3.1 Design for sedimentation polder 24
Figure 4.1 Suggested saltmarsh selection process 30
Figure 4.2 Suggested process of identifying dredge spoil disposal or re-use routes 31
Figure 4.3 Consideration of development affecting internationally designated sites 33
Figure 4.4 Overview of the EIA process 34
Figure 5.1 Profile of tidal flat to saltmarsh progression in North West Europe 40
Figure 5.2 Calculating volumes of sediment to convert mudflat to saltmarsh 41
Figure 5.3 Historic saltmarsh change - Keyhaven 42
Figure 5.4 Saltmarsh extents 1971-2007 - Keyhaven 43
Figure 5.5 Heights of the Keyhaven site relative to OD 44
Figure 5.6 Area selected for potential mudflat recharge- Keyhaven 44
Figure 5.7 Existing saltmarsh and potential saltmarsh buffers - Keyhaven 45
Figure 5.8 Sediment volume to convert mudflat to saltmarsh - Keyhaven 45
Figure 5.9 Mean slope (%) for Keyhaven saltmarsh site 46
Figure 5.10 Historic saltmarsh change - Pennington 47
Figure 5.11 Saltmarsh extents 1971-2007 - Pennington 48
Figure 5.12 Heights of Pennington saltmarsh relative to OD 49
Figure 5.13 Area selected for potential mudflat recharge - Pennington 49
Figure 5.14 Existing saltmarsh and potential saltmarsh buffers – Pennington 50
Figure 5.15 Sediment volume to convert mudflat to saltmarsh - Pennington 50
Figure 5.16 Mean slope (%) for Pennington saltmarsh site 51
Figure 5.17 Historic saltmarsh change - Calshot 52
Figure 5.18 Saltmarsh extents 1946-2007 - Calshot 53
Figure 5.19 Height of Calshot Marshes relative to OD 54
Figure 5.20 - Area selected for potential mudflat recharge- Calshot 54
Figure 5.21 Existing saltmarsh and potential saltmarsh buffers - Calshot 55
Figure 5.22 Sediment volumes to convert mudflat to saltmarsh - Calshot 55
Figure 5.23 Mean slope (%) for Calshot saltmarsh site 56
Figure 5.24 Saltmarsh change 1946-2007 - Mercury 57

FIGURE 5.25 HISTORIC SALTMARSH CHANGE - MERCURY 58
FIGURE 5.26 SALTMARSH EXTENTS 1946-2007 – MERCURY 59
FIGURE 5.27 HEIGHT OF MERCURY MARSH RELATIVE TO OD 60
FIGURE 5.28 AREA SELECTED FOR POTENTIAL MUDFLAT RECHARGE- MERCURY 60
FIGURE 5.29 EXISTING SALTMARSH AND POTENTIAL SALTMARSH BUFFERS - MERCURY 61
FIGURE 5.30 SEDIMENT VOLUME TO CONVERT MUDFLAT TO SALTMARSH - MERCURY 61
FIGURE 5.31 MEAN SLOPE (%) FOR MERCURY SALTMARSH SITE 62
FIGURE 5.32 HISTORIC SALTMARSH CHANGE – HACKETTS 63
FIGURE 5.33 SALTMARSH EXTENTS 1946-2007 –HACKETTS 64
FIGURE 5.34 HEIGHT OF HACKETTS MARSH RELATIVE TO OD 65
FIGURE 5.35 AREA SELECTED FOR POTENTIAL MUDFLAT RECHARGE - HACKETTS 65
FIGURE 5.36 EXISTING SALTMARSH AND POTENTIAL SALTMARSH BUFFERS - HACKETTS 66
FIGURE 5.37 VOLUME OF SEDIMENT TO CONVERT MUDFLAT TO SALTMARSH - HACKETTS 66
FIGURE 5.38 MEAN SLOPE (%) FOR HACKETTS MARSH SITE 67
FIGURE 5.39 SALTMARSH EXTENTS 1946-2007 –BUNNY MEADOWS 68
FIGURE 5.40 SALTMARSH EXTENTS 1946-2007 – BUNNY MEADOWS 69
FIGURE 5.41 HEIGHTS OF THE BUNNY MEADOWS SITE RELATIVE TO OD 70
FIGURE 5.42 AREA SELECTED FOR POTENTIAL MUDFLAT RECHARGE-BUNNY MEADOWS 70
FIGURE 5.43 EXISTING SALTMARSH AND POTENTIAL SALTMARSH BUFFERS- BUNNY MEADOWS 71
FIGURE 5.44 SEDIMENT VOLUME TO CONVERT MUDFLAT TO SALTMARSH – BUNNY MEADOWS 71
FIGURE 5.45 MEAN SLOPE (%) FOR BUNNY MEADOWS SALTMARSH SITE 72
FIGURE 5.46 SALTMARSH EXTENTS 1946-2007 - HOOK 73
FIGURE 5.47 HEIGHT OF HOOK MARSH RELATIVE TO OD 74
FIGURE 5.48 POTENTIAL MUDFLAT RECHARGE AREA - HOOK 74
FIGURE 5.49 EXISTING SALTMARSH AND POTENTIAL SALTMARSH BUFFERS 75
FIGURE 5.50 VOLUME OF SEDIMENT TO CONVERT MUDFLAT TO SALTMARSH - HOOK 75
FIGURE 5.51 MEAN SLOPE (%) FOR HOOK SALTMARSH SITE 76
FIGURE 5.52 HISTORIC SALTMARSH CHANGE – WEST HAYLING 77
FIGURE 5.53 SALTMARSH EXTENTS FOR 2007 LTEI ANALYSIS AND HPI FOR 2005 - WEST HAYLING 77
FIGURE 5.54 SALTMARSH EXTENTS 1946-2007 – WEST HAYLING 78
FIGURE 5.55 HEIGHT OF WEST HAYLING SITE RELATIVE TO OD 79
FIGURE 5.56 POTENTIAL MUDFLAT RECHARGE AREA - WEST HAYLING 79
FIGURE 5.57 EXISTING SALTMARSH AND POTENTIAL SALTMARSH BUFFERS - WEST HAYLING 80
FIGURE 5.58 VOLUME OF SEDIMENT TO CONVERT MUDFLAT TO SALTMARSH – WEST HAYLING 80
FIGURE 5.59 MEAN SLOPE (%) FOR WEST HAYLING SALTMARSH SITE 81
FIGURE 5.60 HISTORIC SALTMARSH CHANGE – GUTNER POINT 82
FIGURE 5.61 SALTMARSH EXTENTS 1946-2007 – GUTNER POINT 83
FIGURE 5.62 HEIGHT OF THE GUTNER POINT SITE RELATIVE TO OD 84
FIGURE 5.63 AREA SELECTED FOR POTENTIAL MUDFLAT RECHARGE- GUTNER POINT 84
FIGURE 5.64 EXISTING SALTMARSH AND POTENTIAL SALTMARSH BUFFERS – GUTNER POINT 85
FIGURE 5.65 VOLUMES OF SEDIMENT TO CONVERT MUDFLAT TO SALTMARSH – GUTNER POINT 85
FIGURE 5.66 MEAN SLOPE (%) FOR GUTNER POINT SITE 86
FIGURE 5.67 MANAGED REALIGNMENT SITE SALT GRASS LANE 89
FIGURE 5.68 HEIGHT OF THE SALT GRASS LANE SITE RELATIVE TO OD 90
FIGURE 5.69 MEAN SLOPE (%) FOR SALT GRASS LANE SITE 90
FIGURE 5.70 MANAGED REALIGNMENT SITE LYMINGTON REED BEDS 91
FIGURE 5.71 HEIGHT OF THE LYMINGTON REED BEDS SITE RELATIVE TO OD 92
FIGURE 5.72 MEAN SLOPE (%) FOR LYMINGTON REED BEDS SITE 92
FIGURE 5.73 MANAGED REALIGNMENT SITE GILLIES 93
FIGURE 5.74 HEIGHT OF THE GILLIES SITE RELATIVE TO OD 94
FIGURE 5.75 MEAN SLOPE (%) FOR GILLIES SALTMARSH SITE 94
FIGURE 5.76 MANAGED REALIGNMENT SITE FARLINGTON 95
FIGURE 5.77 HEIGHT OF THE FARLINGTON SITE RELATIVE TO OD 96
FIGURE 5.78 MEAN SLOPE (%) FOR FARLINGTON SITE 96
FIGURE 5.79 MANAGED REALIGNMENT SITE STOKE 97

FIGURE 5.80 HEIGHT OF STOKE SITE RELATIVE TO OD 98
FIGURE 5.81 MEAN SLOPE (%) FOR STOKE SITE 98
FIGURE 5.82 MANAGED REALIGNMENT SITE WEST NORTHNEY 99
FIGURE 5.83 HEIGHT OF WEST NORTHNEY SITE RELATIVE TO OD 100
FIGURE 5.84 MEAN SLOPE (%) FOR WEST NORTHNEY SITE 100
FIGURE 5.85 MANAGED REALIGNMENT SITE NORTH COMMON 101
FIGURE 5.86 HEIGHT OF NORTH COMMON SITE RELATIVE TO OD 102
FIGURE 5.87 MEAN SLOPE (%) FOR NORTH COMMON SITE 102
FIGURE 5.88 MANAGED REALIGNMENT SITE NUTBOURNE 103
FIGURE 5.89 HEIGHT OF THE NUTBOURNE SITE RELATIVE TO OD 103
FIGURE 5.90 MEAN SLOPE (%) FOR NUTBOURNE SITE 104
FIGURE 5.91 MANAGED REALIGNMENT SITE WEST WITTERING 105
FIGURE 5.92 HEIGHT OF WEST WITTERING SITE RELATIVE TO OD 105
FIGURE 5.93 MEAN SLOPE (%) FOR WEST WITTERING SITE 106
FIGURE 5.94 MANAGED REALIGNMENT SITE MEDMERRY 107
FIGURE 5.95 HEIGHT OF MEDMERRY RELATIVE TO OD 107
FIGURE 5.96 MEAN SLOPE (%) FOR MEDMERRY SITE 108
FIGURE 5.97 MANAGED REALIGNMENT SITE PAGHAM 109
FIGURE 5.98 HEIGHT OF PAGHAM SOUTH RELATIVE TO OD 109
FIGURE 5.99 MEAN SLOPE (%) FOR PAGHAM SOUTH SITE 110
FIGURE 5.60 ANNUAL TONNAGE SEDIMENT DISPOSAL FOR SOLENT AREA (2002-2007) 113
FIGURE 5.61 MONTHLY TONNAGE SEDIMENT DISPOSAL FOR SOLENT AREA (2006-2007) 113
FIGURE 5.62 DREDGE LOCATIONS WITHIN THE SOLENT 114

## Tables

TABLE 2.1 INDICATIVE TIMESCALES INVOLVED IN CREATING MANAGED REALIGNMENT SCHEMES .......... 17
TABLE 4.1 RELEVANT MARINE PLANNING CONSENTS (ACTIVITIES BELOW MHWS) ............................ 34
TABLE 5.1 TIDAL DATA FOR THE SOLENT REGION ........................................................................ 40
TABLE 5.2 HISTORIC SALTMARSH CHANGE - KEYHAVEN ............................................................... 42
TABLE 5.3 SEDIMENT VOLUME TO CONVERT MUDFLAT TO SALTMARSH - KEYHAVEN ........................... 45
TABLE 5.4 SEDIMENT VOLUME TO RE-ESTABLISH SALTMARSH - KEYHAVEN ...................................... 46
TABLE 5.5 HISTORIC SALTMARSH CHANGE - PENNINGTON.............................................................. 47
TABLE 5.6 SEDIMENT VOLUME TO CONVERT MUDFLAT TO SALTMARSH - PENNINGTON......................... 50
TABLE 5.7 SEDIMENT VOLUME TO RE-ESTABLISH SALTMARSH - PENNINGTON.................................... 51
TABLE 5.8 HISTORIC SALTMARSH CHANGE - CALSHOT..................................................................... 52
TABLE 5.9 SEDIMENT VOLUMES TO CONVERT MUDFLAT TO SALTMARSH – CALSHOT .......................... 55
TABLE 5.10 SEDIMENT VOLUME TO RE-ESTABLISH SALTMARSH - CALSHOT ....................................... 56
TABLE 5.11 HISTORIC SALTMARSH CHANGE AT MERCURY.................................................................. 57
TABLE 5.12 SEDIMENT VOLUME TO CONVERT MUDFLAT TO SALTMARSH - MERCURY .......................... 61
TABLE 5.13 SEDIMENT VOLUME TO RE-ESTABLISH SALTMARSH - MERCURY ...................................... 62
TABLE 5.14 HISTORIC SALTMARSH CHANGE AT HACKETTS ............................................................... 63
TABLE 5.15 SEDIMENT VOLUME TO RE-ESTABLISH SALTMARSH AREAS - HACKETTS ............................ 66
TABLE 5.16 SEDIMENT VOLUME TO RE-ESTABLISH SALTMARSH - HACKETTS...................................... 67
TABLE 5.17 HISTORIC SALTMARSH CHANGE – BUNNY MEADOW ....................................................... 68
TABLE 5.18 SEDIMENT VOLUME TO CONVERT MUDFLAT TO SALTMARSH – BUNNY MEADOWS .............. 71
TABLE 5.19 HISTORIC SALTMARSH CHANGE - HOOK ......................................................................... 73
TABLE 5.20 VOLUME OF SEDIMENT TO CONVERT MUDFLAT TO SALTMARSH - HOOK ............................ 75
TABLE 5.21 HISTORIC SALTMARSH CHANGE – WEST HAYLING .......................................................... 77
TABLE 5.22 SEDIMENT VOLUME TO CONVERT MUDFLAT TO SALTMARSH – WEST HAYLING .................. 80
TABLE 5.23 SEDIMENT VOLUME TO RE-ESTABLISH SALTMARSH - WEST HAYLING................................ 81
TABLE 5.24 HISTORIC SALTMARSH CHANGE – GUTNER POINT.......................................................... 82
TABLE 5.25 SEDIMENT VOLUME TO CONVERT MUDFLAT TO SALTMARSH – GUTNER POINT................... 85
TABLE 5.26 SEDIMENT VOLUMES TO RE-ESTABLISH SALTMARSH - GUTNER POINT.............................. 86
TABLE 5.27 TOTAL MUDFLAT AREA – SEDIMENT VOLUME TO INCREASE MUDFLAT HEIGHT TO MHWS... 87

TABLE 5.28 TOTAL MUDFLAT AREA – SEDIMENT VOLUME TO INCREASE MUDFLAT HEIGHT TO MHW ..... 87
TABLE 5.29 TOTAL MUDFLAT AREA – SEDIMENT VOLUME TO INCREASE MUDFLAT HEIGHT TO MHWN... 87
TABLE 5.30 MCA SUMMARY FOR HAMPSHIRE COUNTY COUNCIL SITES ........................................... 88
TABLE 5.31 SURFACE AREA OF MANAGED REALIGNED MUDFLAT REQUIRING SEDIMENT INPUT ........... 111
TABLE 5.32 TOTAL MUDFLAT AREA – SEDIMENT VOLUME TO INCREASE MUDFLAT HEIGHT TO MHWS . 111
TABLE 5.33 TOTAL MUDFLAT AREA – SEDIMENT VOLUME TO INCREASE MUDFLAT HEIGHT TO MHW ... 111
TABLE 5.34 TOTAL MUDFLAT AREA – SEDIMENT VOLUME TO INCREASE MUDFLAT HEIGHT TO MHWN . 111
TABLE 5.35 MCA FOR SDCP SITES ........................................................................................ 112
TABLE 5.36 ACTION LEVELS FOR DREDGED SEDIMENT AS DEFINED BY CEFAS ................................. 115
TABLE 5.37 DREDGE SITE CONTAMINANT DATA COMPARED WITH CEFAS ACTION VALUES ................ 116
TABLE 5.38 APPROXIMATE SEDIMENT QUANTITIES FROM PROPOSED SOUTHAMPTON WATER DREDGE ........................................................................................................................ 117
TABLE 6.1 SALTMARSH RESTORATION SCHEMES POTENTIAL ENVIRONMENTAL ISSUES SUMMARY ...... 120

## Preface

*Hampshire County Council (HCC), the Environment Agency and the University of Southampton undertook discussions on the potential use of dredge spoil for restoration of Solent saltmarshes and creation of mudflat. The University of Southampton were subsequently asked to investigate Solent saltmarsh/mudflat sites suitable for restoration or recharge with dredged material. This has been achieved through a Scoping Study of sites considering their physical factors, conservation status and related legislation issues; this lead to conclusions on potential suitability.*

*The Scoping Document identifies that marsh migration and change is dynamic and can be a natural process. It contains a literature review on current threats both natural and anthropogenic and identifies that that restoration using dredged material may not be appropriate for certain locations. This is accompanied with a review of suitable techniques for inter-tidal recharge. Although not exhaustively, also considered is the regulatory framework under which any such project would occur. To summarise the Scoping Study:*

- *i) Considers the intrinsic value of saltmarshes;*
- *ii) Investigates the current status of recent and relevant saltmarsh restoration research;*
- *iii) Investigates restoration methods;*
- *iv) Identifies relevant legislation and procedures associated with the proposal;*
- *v) Identifies potentially suitable sites within the Solent system (delineated for this purpose by Hurst Spit to the west, and the HCC boundary to the east and*
- *vi) Develops a system to identify suitability of candidate sites;*
- *vii) Recommends suitable sites based on data analysis;*
- *viii) Identifies potential sources of dredged material and risks associated with this (e.g. levels of trace elements*
- *ix) Provides an outline of what may be necessary within any associated EIA or AA process.*

# 1. Introduction

## 1.1 Value and Loss

In sheltered, low wave exposure coastal and estuarine areas there is a sensitive balance between economic and ecological interests (e.g. Jensen and Mogensen, 2000; Winn *et al.,* 2003; Morris, 2007). Estuary systems are generally benign and can, if of sufficient size, be dredged to provide a sheltered commercial harbour, used for fisheries and recreation and may have associated areas of urban industrial and residential development. Human activities pressurise these highly productive areas, which can be habitats for feeding and over wintering birds, pelagic and benthic marine species, estuarine reduced salinity specialists and wetlands such as mangroves (in tropical climes), saltmarshes and intertidal mudflats. These wetlands may be sinks and sources of sediments and nutrients and can have pivotal roles in local marine ecosystems and natural coastal protection.

The value of coastal wetlands has, however, only relatively recently been recognised. Mangroves in particular were cleared as a nuisance species in favour of residential developments and shrimp farms, but are now appreciated for their coastal protection and fishery habitat value (Bennett and Reynolds, 2004). Latterly costs benefit approaches have highlighted the important 'ecosystem service' of wetlands from social and economic aspects (Spurgeon, 1999; Hansenn, 2005). These factors are highlighted in recent studies applicable to the Solent, where it is recommended that saltmarsh loss, and its implications, are included in spatial planning decisions (BRANCH Partnership, 2007). In addition, for the natural environment greater study has identified saltmarsh value and importance to marine ecosystems from the supply of nutrients, to spawning and nursery grounds (e.g. Cleary, 2003; Bloomfield and Gillanders, 2007).

Direct human impacts on saltmarshes have been suggested as responsible for exacerbating loss. Current debate on vessel wash impacts on these habitats is prevalent in the Solent and has been shown to be influential in saltmarsh erosion elsewhere (e.g. King and Lester, 1995). For vessel movements maintenance of waterways through dredging has caused concern regarding the draw down of intertidal sediment. This may enhance marsh erosion and as dredged material is commonly disposed off at offshore benthic sites it is lost to the local geomorphological system (e.g. Pontee, 2004). Development pressures in sheltered coastal areas, for both residential and industrial purposes, can lead to infrastructure which may directly and indirectly impact saltmarshes and mudflats. This can occur, for example, through the direct loss of marsh and sediment during construction and potentially through subsequent hydrodynamic change altering local sediment dynamics (e.g. Bozek and Burdick, 2005). In addition these installations may require protection using either hard or soft engineering structures which may lead to coastal squeeze thus preventing saltmarsh (and other intertidal biotopes) from landward migration (Wolters *et al.,* 2005). Conversely, changes in coastal priorities leading to managed retreat may result in saltmarsh creation in suitable low lying areas (Lee, 2002).

Worldwide saltmarsh and other coastal wetland area loss may be attributable to a variety of factors other than direct anthropogenic influences outlined above. These 'natural' pressures which, research suggests, may be exacerbated by human activities, include sea level rise leading to enhanced coastal squeeze and increasing severe weather patterns (Winn *et al.,* 2003; Bertness *et al.,* 2004; Wolters *et al.,* 2005). However, some research discounts coastal squeeze stating that in addition to wave erosion, saltmarsh loss may be exacerbated by increased biopeturbation by polychaete worm species (Hughes and Paramor, 2004). This, however, is questioned by Wolters *et al.,* (2005) who state that there is a need for long term field studies to support this suggestion. Finally, in addition to coastal erosion from wave action, the south east coast of the UK in particular, is experiencing increased sea level rise due to isostatic (post glacial rebound of land mass) (see: Shennan and Horton, 2002) recovery which adds to the recognised erosive processes associated with climate change.

Finally in addition to the recognised natural physical and less well understood faunal influences on saltmarsh stability, the dieback of plant communities is a significant factor. Zonation (distribution of plant species across the up shore gradient of the marsh) in saltmarsh plants is normally clear unless erosion has changed elevation. A pioneer species normally found low on the marsh or close to the toe is *Spartina* spp. *Spartina* can be instrumental in marsh creation through pioneer colonisation, subsequent modification of local hydrological conditions allowing fine sediment to settle and thus providing suitable habitat for secondary colonisers. However, *Spartina* in the Solent and elsewhere has suffered extensive dieback (Goodman *et al.,* 1959; Johnson, 2000) which has been implicated in exacerbating saltmarsh decline in the region.

Between 1992 and 1998 UK saltmarsh loss was estimated to be a total of 600 ha and annually was approximated to be in the region of 100 ha (UKBAP, 1999). In recognition of this significant loss saltmarsh is designated as a Priority Action Habitat under the UK Biodiversity Action Plan (UKBAP) and is a target habitat under the Hampshire, Eastleigh and Isle of Wight Local Biodiversity Action Plans (LBAPs). Marking the concern over the loss of intertidal wetlands The UKBAP states that there should be "*no further net loss of extent of intertidal sediment ecosystems*". In addition, "*by the year 2015 3,600 ha of intertidal sediment should be created to offset historical losses (of which 90% should by in England and 10% in Wales)*".

In the Solent from 1956 to 2001, net saltmarsh loss has been as high as 72% in Langstone Harbour and 63% in Portsmouth Harbour (Baily and Pearson, 2007). Based on marsh erosion rates between 1971 and 2001, the Solent Coastal Habitat Management Plan predicted an intertidal habitat loss of some 730 to 830 ha for the North Solent and the Isle of Wight over the next 100 years (2001-2100); this is around 10% of the existing resource, (Bray and Cottle, 2003).

The recognition of saltmarsh (and mudflat) value as a resource for coastal defence, natural habitats and ecosystems and their intrinsic aesthetic value, particularly recognisable in the Solent region, has heightened research efforts. These have sought to clarify and quantify the above outlined roles and to establish where saltmarsh may be stabilised from further loss or, of more relevance to this report, restored or natural accretion promoted.

### 1.2 Sea Defence

The relatively recent realisation of saltmarsh and other wetland habitat value is exemplified in their natural sea defence role. Removal or reduction of saltmarsh area has heightened realisation the role of saltmarsh buffer zones in protecting terrestrial infrastructure and assets.

Saltmarshes act as an important two-tier sea defence by absorbing and dissipating wave energy. In addition they can enhance the effectiveness of onshore man-made protection works by dissipating incoming wave energy. However, due to isostatic recovery and the impacts of global climate change, relative sea level rise creates increased tidal energies which may erode soft coastlines, including saltmarshes, in the Solent and elsewhere. Responsible for flood protection measures in the UK, the Environment Agency (EA) recognises two solutions. Either building bigger sea walls at an exceptional cost, which increasingly may be contrary to national shoreline management priorities, or via promoting sustainable sea defence through managed realignment or maintaining current natural sea defences (Bolam *et al.,* 2002).

If the 2,000 km of saltmarsh protecting the UK were to erode, it would be necessary to strengthen and raise embankments to prevent overtopping at exceptional expense. Thus it was recognised that an environmental priority and action is to continue to incorporate (intertidal wetland) habitat creation into flood defence capital schemes (Environment Agency, 2000). Shoreline Management Plan guidance further recommends that operating authorities plan for a dynamic coast, and carefully consider nature conservation objectives, including biodiversity targets set under the EU Habitats and Birds Directives, Ramsar Convention and DEFRA High Level Target 4 (DEFRA and the Environment Agency, 2005).

Of the 354 km of highly developed coastline of the North Solent, approximately 283 km (80%) are protected from flooding or coastal erosion. The majority of these defences are fronted by intertidal areas with national and/or international (Natura2000) designations. Partly due to the reduction in fronting intertidal areas, many of the Solent coastal defences require repairing or upgrading to provide an adequate level of protection. The Solent Dynamic Coast Project (Cope *et al.,* 2007) found that a length of 178km of coastal defence will need replacement intertidal habitat to offset future coastal squeeze to fronting Natura2000 sites. It is estimated that of these 178km of coastal defence, over half will come to the end of their useful life in the next 20 years. Under the Habitats and Birds Directive, replacement habitat must be secured to offset coastal squeeze resulting from new flood defence schemes, in addition, as discussed, the UKBAP stipulates no further net loss of these areas. In the North Solent, schemes such as Eastoke and Selsmore were delayed for over two years due to the inability to find replacement habitat.

With habitat legislation requiring restoration, offset or creation of wetland areas as natural habitat, but with a concurrent need to manage coastal areas for flood defence, where feasible a mutually beneficial solution would be an ideal. The removal of dredge spoil from soft sediment geomorphological systems has been implicated in draw down and erosion of intertidal habitats (Pontee, 2004; Van der Wal and Pye, 2004; Rowe, 2008) thus exacerbating wetland loss. Suggestions, research and trials in the USA (e.g. Smith *et al.,* 1975), Europe (Boorman *et al.,* 2002) and on the UK east coast (Bolam and Whomersley, 2003) have investigated the recharge of saltmarshes and creation of mudflats using spoil. This is aimed to achieve both mitigation of habitat loss and to maintain natural coastal defence; due to numerous factors to date a substantial trial of such a scheme has not yet been achieved in the Solent.

### 1.3 Beneficial Use and Managed Realignment

Dredging to maintain existing channels and berths, or to create new ones, is essential if UK ports are to be kept accessible and competitive with new markets (Fletcher, 1992). With a total of approximately 40 million wet tonnes of sediment disposed of annually, in terms of quantity maintenance spoil far outweighs all other materials disposed of in the marine environment (Bolam *et al.,* 2006). There are over 150 specified sites designated for dredged material disposal around England and Wales (Bolam *et al.,* 2006); primarily chosen as the most economic method. However, due to escalating world-wide concerns over potential environmental consequences of dredge spoil disposal, it is becoming increasingly important to minimise impacts and investigate alternative methods (Bolam and Rees, 2003).

It is a requirement under the London Convention (1972), the Oslo Paris Convention and a statutory requirement under the UK's Food and Protection Act that in considering whether to licence disposal at sea, the Licensing Authority has regard to any alternative means of disposal (Csiti and Burt, 1999). DEFRA, the Licensing Authority, considers all dredged material to be a potential resource rather than a waste material and licence applicants are required to consider alternative uses of dredged material (Colenutt, 2001). Recently there has also been considerable pressure from bodies such as Natural England, the House of Commons Environment Committee on Coastal Zone Protection and Planning, and others to use dredge material in a beneficial way (Csiti and Burt, 1999). By considering dredged material as a resource, a dual objective can be achieved in that the material can be disposed of with minimal environmental damage, and benefits can accrue from its use.

The nature of dredge spoil can vary from soft silts to boulders or crushed rock however, the majority consists of finer material (CEFAS, 2003). Through intertidal recharge fine material from maintenance dredge works can be used to raise mudflats to levels suitable for saltmarsh development. This is achieved by introducing sediment onto or adjacent to intertidal areas to mitigate for deficits in estuarine sediments (DEFRA and Environment Agency, 2005). In the US, dredged material has been successfully used to create new mudflats and saltmarshes, which effectively act like natural systems (Posey *et al.,* 1997, Ray, 2000, Streever, 2000). However, in the UK less than 1% of the 40-50 million $m^3$ of dredged material produced is used beneficially (Bolam and Whomersley, 2005). As discussed, concerns over the eventual fate of the material, and the ecological consequences of placing fine-grained material onto intertidal habitats, have limited this practice to small-scale trials. To enable dredged material to be used beneficially methods must be identified which do not destroy other valuable habitats, harm residential wildlife, reduce water quality, or cause unacceptable consequences in terms of erosion or deposition. Through understanding factors limiting beneficial use scheme success in intertidal habitat creation, the success of future trials within the Solent will be greatly increased.

Managed realignment is one of the methods through which intertidal habitat can be created. In the UK, particularly on the east coast, it has been used with some effect through both, intentional realignment of sea defences to allow flooding and intertidal habitat development (Leggat and Dixon, 1994; Boorman *et al.,* 2002) and sediment augmentation (e.g. Bolam and Whomersley, 2003). Since 1992 about 750ha of intertidal habitat have been created in the UK, about half of which was for compensatory habitat and virtually all was created through managed realignment. With reference to the Solent, the Solent Dynamic Coast Project (Cope *et al.,* 2007) combined topographic and tidal elevation data with site suitability questionnaires to identify 11 sites for potential managed realignment. This was to compensate for intertidal loss from coastal squeeze, potentially providing a potential intertidal area of 552ha. The study concluded that even with managed realignment, there would only be a near balance between gains and losses of intertidal habitat from coastal squeeze alone across the north Solent (Cope *et al.,* 2007). This emphasises the need for additional methods of habitat creation such as the beneficial use of dredge spoil to raise intertidal profiles too low to develop vegetated saltmarsh.

### 1.4 Drivers and Possible Opportunities for Solent Beneficial Use

Predicted intertidal area changes across the north Solent were estimated by the Solent Dynamic Coast Project (Cope *et al.,* 2007) to be +60ha for mudflat and -812ha for saltmarsh over the next 100 years (2005-2105). Coastal squeeze of the intertidal zone resulting from maintenance of existing sea defences was estimated to be 5ha of mudflat and 495-595ha of saltmarsh (Cope *et al.,* 2007). There appears to be a need for saltmarsh creation of to offset losses within the Solent and to achieve the goals of the UKBAP for this habitat.

Potential benefits of intertidal habitat creation include increasing diversity, maintaining biological productivity and optimum populations and increasing habitats for endangered species. The beneficial use of dredged material can increase saltmarsh areas by:

1) Increasing existing mudflats height to a tidal level suitable for the growth of saltmarsh species where insufficient sediment supplies have led to historic saltmarsh loss; and,
2) By raising the intertidal profile at managed realignment sites to encourage the development of new saltmarsh areas

Through research, Hampshire County Council has identified existing saltmarsh areas under their ownership to be considered for offsetting historic saltmarsh loss. Furthermore the Solent Dynamic Coast Project (SDCP) (Cope *et al.,* 2007) proposed intertidal areas within the Solent identified for possible managed realignment; identified as sites where sediment augmentation may raise mudflat height to promote saltmarsh growth.

To further highlight that this subject is increasingly topical, Associated British Ports are proposing to dredge the main shipping channel of Southampton water and approaches (see: http://www.southamptonvts.co.uk/files/dredgescopingreport.pdf). However, it has been noted that much of this material may not be suitable for beneficial use (Solent Forum, 2008) and will be "*dumped at the Nab* [Tower dump site]".

In addition to the planned dredging of Southampton Water, the Isle of Wight have, for some time, been investigating beneficial use of dredged material. Specifically "*the Isle of Wight Estuaries Project is involved in the development of sustainable dredging plans for the Medina and the Western Yar estuaries and takes an interest in the activities in the Island's other estuaries*" (Hawley, pers com., 2008).

Hawley (2008) noted that through dredging, loss of sediment to the Medina system and its associated effects on habitats were major concern thus beneficial use was proposed. Concerns were raised following the proposal, however, which broadly reflect similar matters raised for wider Solent sites a summary of these includes:

- Trace elements associated pollutants (heavy metals, TBT etc.);
- Guidance re sediment contaminant levels and whether, if OK for disposal at sea, it would be ok to use further up an estuary;
- Suspended sediments and possible effects regarding the Water Framework and Shellfish Water Directives;
- Concerns over the volume of material available actually suitable for beneficial recharge (similar to the Southampton water example);
- Need to use specialist equipment not readily available within Medina;
- Sporadic nature of sediment supply;
- Sediment type unsuitable thus may change benthic/associated habitats possibly infringing Habitats Regulations (Appropriate Assessment clarification necessary);
- No framework for stakeholders to buy into whole project – so what's in it for them?

The EA have apparently rejected one Medina beneficial use scheme due to Shellfish Directive implications. Hawley (2008) stated that clear guidance regarding all the interactions of conservation objectives needs to be given in terms of beneficial use projects.

Despite the concerns raised above, it is apparent that there is a drive to utilise managed realignment and beneficial use opportunities in the Solent region. However, here as elsewhere there are sensitive matters to consider which have been concluded as potential barriers, not least the inherent habitat value of the pre-existing saltmarshes.

## 1.5 Solent Overview

### 1.5.1 Introduction

The Solent is a widely studied region thus detailed descriptions are available in a variety of documents, e.g. the Standing Conference on Problems Associated with the Coastline (SCOPAC) (http://www.scopac.org.uk/) for the Solent region. Furthermore more detailed information on habitat designations and sediment/geomorphological characteristics are available in the Solent Coastal Habitats Management Plan (CHaMP) (see: http://www.english-nature.org.uk/livingwiththesea/champs/pilots.asp) and an overview of relatively recent scientific research can be obtained in Collins and Ansell, 2000). However, to place the Solent region into context for this report, a short overview is presented here.

### 1.5.2 Description

Separating the Isle of Wight from mainland UK, the Solent is approximately 30 km in length and ranges between 1-8 km wide (Fig. 1.1); it has been suggested as being formed through the tidal inundation of a river valley (the Solent River) following the demise of the last ice age, glacial melting and subsequent runoff. Today there are major estuaries within the Solent and the region is recognised for its tidal regime (four a day). This is ascribed to localised oscillations (dictated by constrictions such as bed form) adding to the normal English Channel ebb and flood.

The Solent sees significant shipping from Portsmouth and Southampton Docks. In addition the south coast has the UK's highest recreational boating activity. This is particularly intense throughout the Solent (RYA pers. com. 2003). Amongst others, these factors place pressure on the sensitive, but industrially and socially valuable Solent.

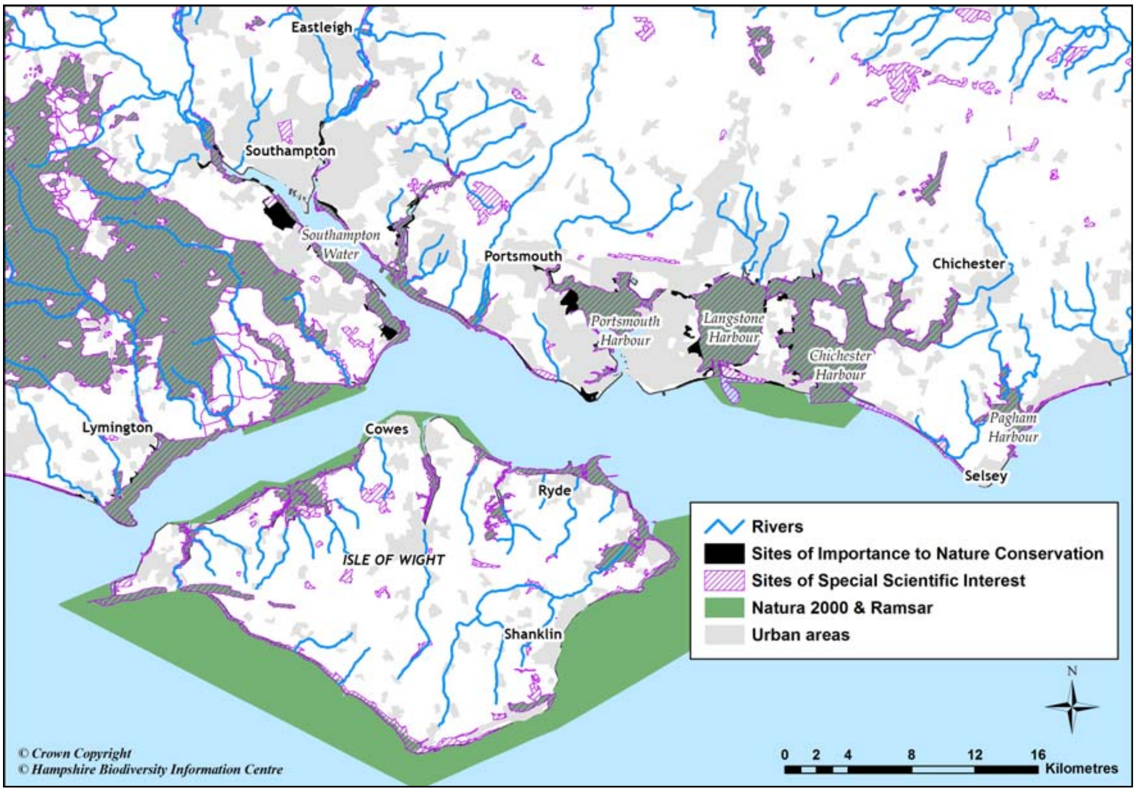


**Figure 1.1 Overview of Solent and national / international conservation designations**

1.5.3 Wave Climate

Solent waves are fetch-limited, with the largest associated with the longest (east-west) fetch in the waterway (Fig. 1.1). Consequently the Solent is subject to less wave energy than many other UK south coast shores. This has resulted in the formation of sheltered intertidal habitats such as saltmarsh, mudflats, dunes, soft cliffs and lagoons. Saltmarshes and mudflats can enhance this shelter providing protected areas behind which, in many cases, urbanisation has occurred. This, amongst other factors, has led to considerable development of shoreline defences.

Strategic consideration of defence from seaward erosion is detailed in the North Solent Shoreline Management Plan (SMP) (under development) for which the frontage is 340 km in length. Of this "*approximately 80% is defended or has active beach management*". Of the defences "*54%* [are] *owned/maintained by Private individuals, companies, or County Councils where public funding is not available for maintenance or improvements to existing defences* (Colenutt, pers com., 2008).

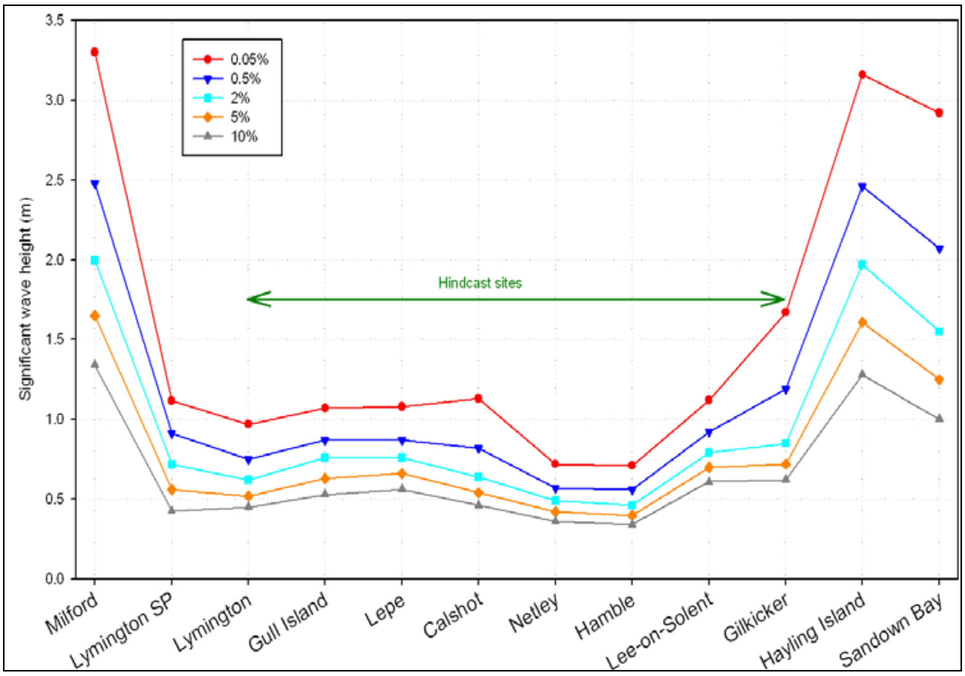


**Figure 1.2 Solent significant wave height exceedence (m), for the given percentage**
(Draft North Solent SMP, in preparation)

The dominant wave direction is from the south-west, though significant south and south-east waves do occur. Waves within the Solent itself are significantly less damaging than those occurring in Christchurch bay to the east and Hayling to the west. This is because of the shelter supplied by the Isle of Wight (Fig. 1,2) and is particularly the case in the western Solent and Southampton Water where shelter is also given by Hurst Spit and the morphology of the estuary respectively (Draft North Solent SMP, in preparation).

The Channel Coastal Observatory (http://www.channelcoast.org/) are continuing to monitor the Solent. This is vital in establishing the changing wave climate and implications for "*loss of sediment feeding beaches and erosion of saltmarshes* [and] *is essential for measuring and assessing the performance and life expectancy of existing coastal defences*" (Draft North Solent SMP, in preparation). However, it should be noted that though "*the quality of the wave climate data is high from the four sites* [recording Solent] *wave climate, it is not yet possible to discern a trend of increased storminess linked to climatic change, due to the short length of the dataset*" (Draft North Solent SMP, in preparation).

Continued monitoring of changing wave climates, however, is particularly relevant to sites such as Lymington. Here, although wave energies may be less than elsewhere in the Solent (Figs. 1.2 and 1.3), there has been marked saltmarsh erosion and restoration strategies have been considered for some time (e.g. LRDC International Ltd, 1993; Colenutt, 1999; Johnson, 2000).

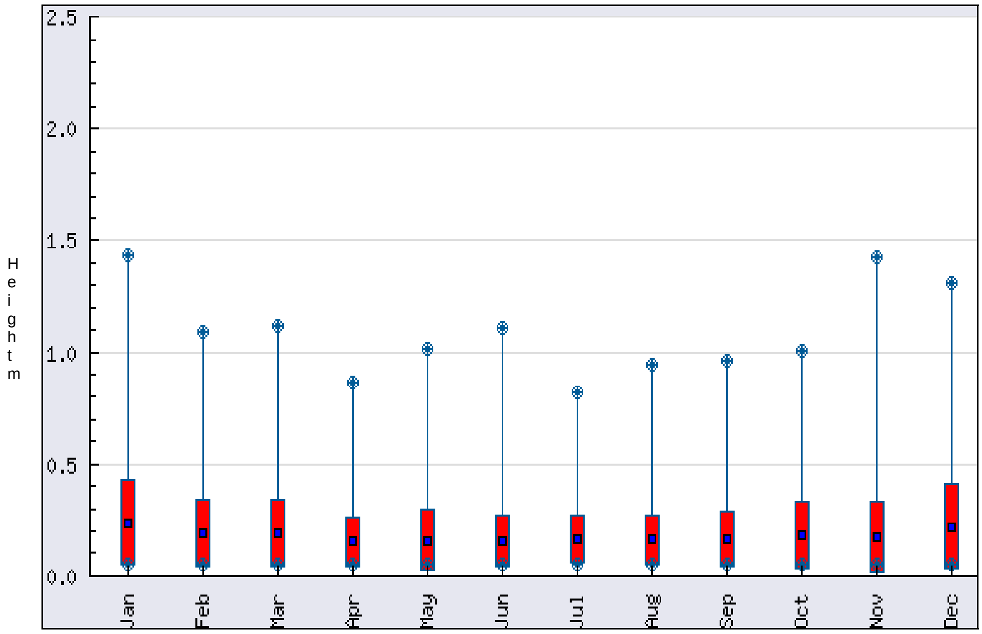


**Figure 1.3 Mean monthly significant wave heights, Lymington, Western Solent 2003-2008**
(Modified from: Channel Coastal Observatory, 2008)

Overall changing wave climate in the Solent due to weather patterns, sea level rise and isostatic recovery may, in the long term, create a feedback mechanism (i.e. as saltmarsh erodes, this loss of protection may exacerbate further saltmarsh erosion and mudflat creation). This may have significant implications for saltmarsh longevity and/or restoration potential. In addition to these 'natural' factors, there has been some interest in how the changes in shipping traffic lanes for vessels entering and leaving major Solent harbours may also affect soft sediment shores. Data on this matter are not readily available and enquiries revealed no current definitive opinion. This is, however, potentially a significant factor particularly with possible plans for larger shipping to operate in the region. The implications that dredging for such craft, and the wash created by their passage, are factors which may require further research and consideration.

1.5.4 Sediment Patterns

The Solent comprises geomorphological units. These are: "*erosional cliff coasts* associated with *the Isle of Wight* [and] *Solent approaches*; *barrier beach coasts found mainly with the tidal inlets of Hurst* [Spit], *Calshot* [Spit] and *Portsmouth, Langstone and Chichester Harbours* (areas of coarse grained sediment accumulation) and *intertidal flat/saltmarsh coasts, mainly behind barriers and protected parts of the coastline*" (Velegrakis, 2000).

Sediment transport pathways in the Solent are complex and tidally dominated. Although the focus of much research Velegrakis (2000) commented that there were many unanswered questions about Solent sediment transport patterns; for example, it was "*not yet clear why the East and West Solent are so different in terms of surfical sediment distribution*". Bray *et al.,* (2000) identified that cliff erosion and beach replenishment are important sediment sources and that pathways showed sediment transported west into the eastern Solent. Following this they are distributed within the Solent to the "*beach spit and tidal delta systems*" (Bray *et al.,* 2000).

This is a very brief overview of a complex system which is subject to ongoing study. However, in terms of this research it is important to note that Bray *et al.,* (2000) stated that "*human activities including inshore dredging and coastal stabilisation have significantly affected some* [sediment] *pathways and have contributed to problems of beach erosion*". It was also noted that restoration had been achieved by replenishment schemes (Bray *et al.,* 2000). This, however, was presumably for coarser sediment Solent areas (e.g. Hurst Spit) rather than through use of dredge spoil to recharge eroding marsh or for mudflat creation. Although small schemes have been trialled in the Solent, (e.g. Hythe Marshes; see Colenutt, 1999), to date no large scale project has been achieved.

1.5.5 Conservation and Sensitive Habitats

With respect to conservation, the Solent has designated areas that strongly reflect the varied, diverse and important nature of the region. There are intertidal areas which are protected under international, national and local designations (Fig 1.1). Overall "*76% of the North Solent SMP frontage is covered by European nature conservation designations - including interest features or key habitats in front* [of] *and behind defences* (Draft North Solent SMP, in preparation).

The Solent has two Special Areas of Conservation (SACs) being the Solent and Isle of Wight lagoons and Solent Maritime SACs (Fig. 1.4); designated under the EU Habitats Directive 92/43/EEC. There are four Special Protection Areas (SPAs) (The Solent and Southampton Water, Chichester and Langstone Harbours, Portsmouth Harbour and Pagham Harbour). These are designated under the EU Birds Directive 79/409/EEC (Fig. 1.5) and there are wetlands of international important designated under the Ramsar Convention. Nationally there are there are 15 Sites of Special Scientific Interest (SSSIs) (Fig. 1.1) and local designations (SINCs.

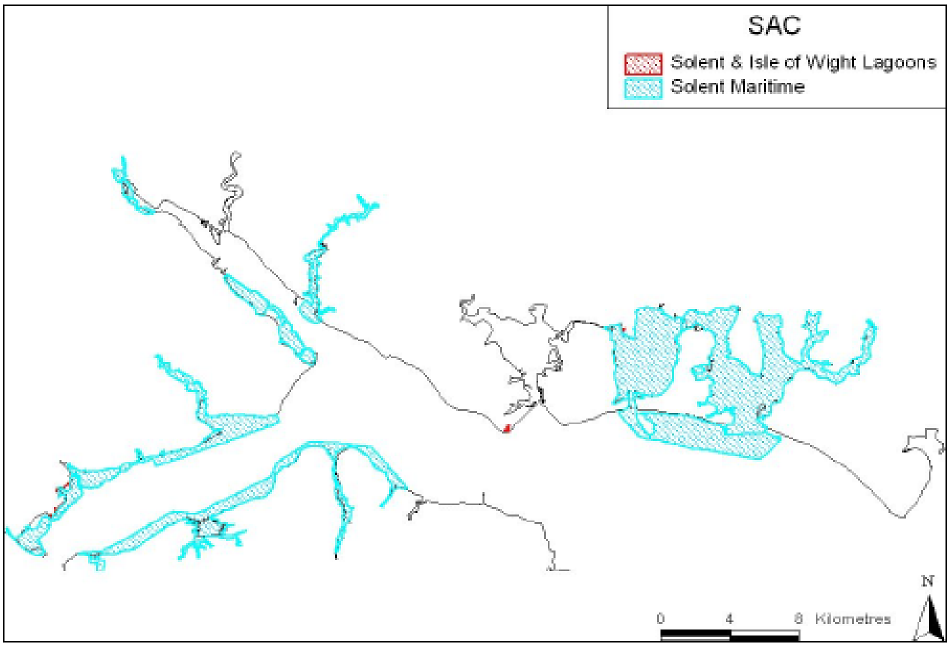


**Figure 1.4 Solent SACs**
(Cope *et al.,* 2007)

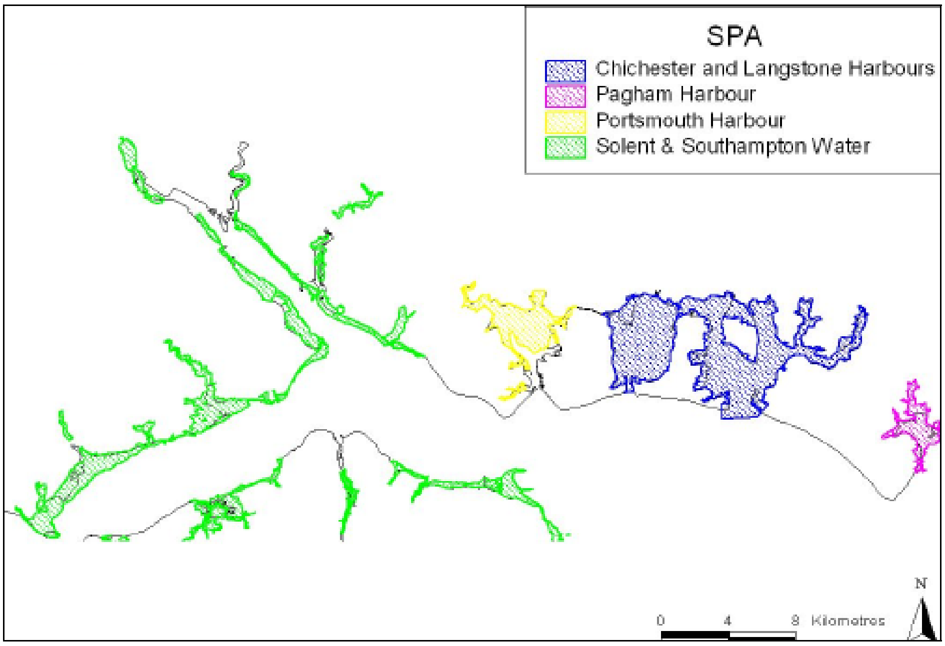


**Figure 1.5 North Solent SPAs**
Cope *et al.,* (2007)

International, EU, national and local conservation designations accurately reflect the importance of the Solent and the sensitivity of its associated terrestrial, intertidal and benthic habitats. Works which may impact European conservation assets may be subject to an Appropriate Assessment (AA) and considered within a related Environmental Impact Assessment (EIA).

Sensitive habitats within the Solent region are covered in detail by the Solent CHaMP (see: http://www.english-nature.org.uk/livingwiththesea/champs/pilots.asp) and Collins and Ansell, (2000) detail biodiversity implications. There are, for example, areas of vegetated shingle, a priority UKBAP habitat (http://www.ukbap.org.uk/UKPlans.aspx?ID=29) and SAC lagoons (see: Johnson *et al.,* 2007). However, of more potential significance to saltmarsh restoration and creation of mudflats, through intertidal recharge, are habitats/species that may be adversely affected, these include:

- Saltmarsh, Mudflat and associated communities: This report's main focus. UKBAP habitats with EA as lead partner (see: http://www.ukbap.org.uk/UKPlans.aspx?ID=33 and http://www.ukbap.org.uk/UKPlans.aspx?ID=34). As with many marine habitats both may be sensitive to smothering and saltmarsh plants can take up re-suspended heavy metals which may bioaccumulate to higher grazing organisms (Weis and Weis, 2004; Suntornvongsagu *et al.,* 2007). In addition mudflats are rich and diverse, particularly with invertebrate species, which may also be susceptible to smothering and contaminant uptake which may bioaccumulate to higher trophic levels (e.g. waders). In addition they may be important feeding areas for fish species such as flounder and sea bass Thus care must be taken when considering possible locations, local hydrodynamics (subject to detailed study) and elements in dredge material for potential beneficial use. Subsequently long-term monitoring of any contaminant uptake may be appropriate;
- Seagrass (*Zostera* spp.): A UKBAP habitat with the Environment and Heritage Service as lead partner (see: http://www.ukbap.org.uk/UKPlans.aspx?ID=35). Highly productive for organic material and as a habitat for associated species. Seagrass beds have significantly declined due to physical disturbance, excess nutrients, smothering and from a wasting disease (see: Hawkins *et al.,* 1999 for an overview of issues); they may also bioaccumulate tributyltin from anti fouling coatings. All Solent seagrass beds are SSSIs (see: http://www.solentforum.org/resources/pdf/natconsv/seagrasses.pdf) and the Hampshire and Isle of Wight Wildlife Trust have produced a comprehensive review of their locations and factors affecting these habitats in the Solent (Chesworth *et al.,* 2008);
- Fish species: The Solent and Southampton Water are important migratory routes for priority BAP fish species including salmon (*Salmo salar*), sea trout (*Salmo trutta*) eel (*Anguilla anguilla*). They migrate "*to and from the Rivers Test, Itchen and Hamble* [amongst other local waterways], *all of which are designated under the EC's Freshwater Fisheries Directive*" (Environment Agency, 2000). Consideration of migration activity is of paramount importance for any works which may impact this, for example it has been shown that salmon smolts migrate move seaward during their spring migration (Moore *et al*., 1998). Though this activity may be mainly nocturnal (Moore *et al*., 1998), suspended sediment from restoration/realignment works may still constitute a significant barrier due to slow settlement rates. It is thus highly likely that the EA will wish to see the aspects of disturbance, bioaccumulation from suspended sediment contaminants, noise etc considered (including synergistic interactions) in any proposed realignment/restoration works potentially affecting migratory and normally resident fish species;
- Shellfisheries: As previously highlighted (§ 1.4) shellfisheries are an important consideration with regard to possible sediment smothering and bioaccumulation of associated contaminants (e.g. see Tay *et al*., 2003). Younger and Kershaw (2004) states that "*the Solent contains the largest native oyster (Ostrea edulis) fishery in Britain*". Historically the economic importance of this industry cannot be underestimated, even in years of low productivity (Jensen, 2000). The fishery extends throughout the region and although previous water quality issues resulted in some 'no take' areas, all Solent oyster fisheries were listed as being of Class A in 2004 (Younger and Kershaw, 2004). With the importance, and distribution of this industry in consideration, and with the knowledge that shellfisheries have been identified as a concern by the EA in respect of the Median saltmarsh restoration plan, potential contamination and compensation issues associated with dredge spoil use close to shellfisheries are important factors.

The above is a brief overview of significant habitats, species and resources. Should plans or trails taking saltmarsh/mudflat restoration/realignment plans proceed in the Solent, these and other local conservation issues will require careful assessment.

## 1.6 Potential Restoration Areas

It is against the background of a dynamic tidal environment, with relatively benign, but possibly changing, wave trends that the use of dredge spoil for potential restoration of Solent saltmarshes and possible creation of managed realignment sites is being considered.

As discussed, sites within the Solent have been identified as having potential for saltmarsh restoration trials or for managed realignment through creation of mudflat areas potentially resulting in saltmarsh development. Such proposals however, require careful assessment to ensure they comply with planning, legal, conservation and water quality goals amongst many factors.

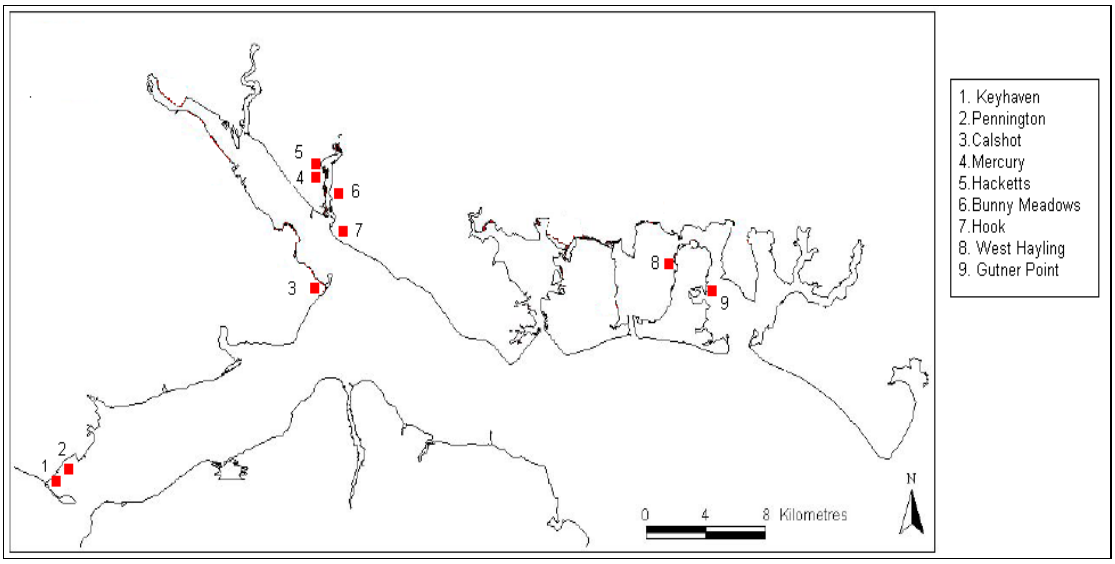


**Figure 1.6 HCC sites identified for potential restoration**

Hampshire County Council (HCC) identified nine existing saltmarsh areas under their ownership potentially suitable for offsetting historic saltmarsh loss (Fig. 1.6). Further to this the EA proposed a further 11 sites intertidal areas within the Solent which had been identified for possible managed realignment, where potential mudflat could be raised to promote saltmarsh growth, by the Solent Dynamic Coast Project (Cope *et al.,* 2007) (Fig. 1.7).

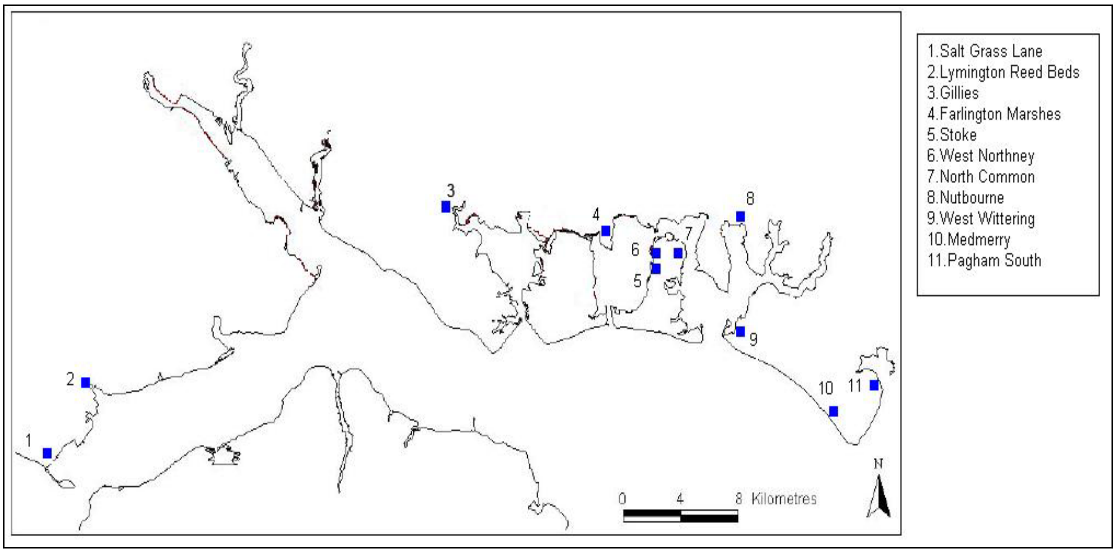


**Figure 1.7 SDCP sites identified for recharge following managed realignment**

### 1.7 Aims and Objectives

Impacts on soft sediment intertidal habitats from both human activities and natural change, coupled with realisation of their inherent value, have focussed efforts to retain wetlands. They have become a target of aims to ameliorate their loss through both restoration and more holistic management. Restoration is increasingly being investigated through the beneficial use of dredge spoil to keep it within a geomorphological system through the recharge of eroded saltmarshes or managed realignment of mudflat areas.

With the detailed benefits saltmarshes and the factors affecting their decline, this project aims to identify sites saltmarsh and mudflat sites potentially suitable for intertidal recharge. From these data the aim is to create a shortlist of potential sites for either restoration (HCC sites), or promotion of saltmarsh creation through managed realignment (SDCP sites). Of the locations given by HCC and through the SDCP, those suitable for intertidal recharge will be clarified through a review of literature to identify a pragmatic set of criteria. In addition Geographical Information System (GIS) analysis will be used to ascertain potential physical suitability and the status of relevant conservation designations. Furthermore the quantification and availability of dredged material within the Solent will be important factors. Finally, although this project does not set out to be a socioeconomic exercise, where feasible factors such as nearby residences, or industry, will also be considered.

Based on the outlined factors, the main aims of this work are:

- To outline natural and social values of saltmarshes and factors affecting their longevity ;
- Through literature review and GIS analysis, to investigate the viability of its beneficial use for saltmarsh restoration and mudflat creation on a targeted list of sites indicated by HCC and the EA (through the Solent Dynamic Coast Project (Cope *et al.,* 2007));
- To provide a brief overview of guidance, legislation and possible limitations in any proposed restoration trials or projects.

These aims will be undertaken through outlining physical processes behind accretion and erosion in saltmarshes, worldwide and UK efforts to identify and reduce saltmarsh loss and to review methods of dredge spoil placement. To follow, legislation and its interpretation through regulatory bodies can be viewed as a barrier to achieving restoration, thus a synopsis of, and guidance for, the regulatory perspective is also given. This is not exhaustive, however, and will require discussion and agreement before any proposed scheme could move forward. This is followed by an overview of limitations and factors which may require consideration in an Environmental Impact Assessment/Appropriate Assessment. The core of the project, site assessment, will be achieved through the GIS analysis of pre-supplied sites complimented by consideration of dredge spoil sources and levels of contamination. This will hone final choices of where saltmarsh restoration and mudflat creation may be viable opportunities in the Solent.

# 2 Saltmarsh Dynamics, Restoration, Success and Failure

## 2.1 Overview of Accretion and Erosion Physical Processes

Similarly to rocky shores, saltmarshes show distinct species distribution in relation to changing environmental gradient (zonation) across their intertidal extent. These habitats consist of a variety of halophyte (salt tolerant) species which colonise mudflats as they rise to a height suitable for plant community establishment. The widespread, but relatively low abundance, UK saltmarshes have formed in low energy environments and are found in eastern England, North West England and Wales and on the south coast, the Solent. Scotland also has a significant number of relatively small saltmarshes (Nottage and Robertson, 2005).

Saltmarsh formation usually follows the development of a mudflat which reduces wave shear stress. This allows deposition on the landward side and subsequent colonisation by pioneer saltmarsh species (e.g. *Spartina anglica*) (Nottage and Robertson, 2005; van Wesenbeeck *et al.,* 2008). Although this is not a linear process, as deposited material can become resuspended, sediment deposition increases over time until final settlement and relative consolidation has occurred. As shear strength increases and dewatering occurs this provides suitable conditions for the continued development of the marsh and for secondary facilitated colonisation, e.g. by *Spartina* species (Proffit *et al.,* 2005).

Saltmarsh erosion occurs when sediment loss outweighs accretion rates, possibly due to increased shear stress (e.g. nearby vessel traffic, increased storminess). A reduction in dewatering (potentially due to sea level rise) can also reduce sediment consolidation and may lead to increased anoxia from hydrogen sulphide processing bacteria. This results in increased sulphide-phytotoxins, subsequent plant and associated root mass loss leading to further sediment erosion (Mendelssohn and Kuhn, 2003) (for a review and overview of accretion and erosion factors see: Carpenter and Pye, (1996); Nottage and Robertson, (2005)).

Significant short-term saltmarsh loss can be due to erosion at the toe which can "*remove a* comparatively *large volume of sedimentary material in one mass wasting event*" (van Proosdij *et al.,* 2006) and may be related to a sediment budget change (Pontee, 2004). A reduction in sediment supply, and enhanced erosion, can occur due to loss of fine material from the geomorphological system potentially associated with capital and maintenance dredging; this may have unpredictable effects. These can include the draw down of intertidal fine material consequently enhancing the erosive processes already occurring (van der Wal and Pye, 2004; Rowe, 2008); this has been noted in the Solent (Pontee, 2004). In addition to physical effects associated with the dredge site, dredging has been found to potentially impact benthic communities at both source and spoil disposal areas (Robinson *et al.,* 2005) and may also be associated with heavy metal and hydrocarbon contamination of sensitive species (Jordaan, 1970; Weichsel *et al.,* 1998; Svavarsson *et al.,* 2001; Santos *et al.,* 2004; Bray, 2005); including sediments from Southampton Water (Rogers, 2002).

For the above reasons, research is increasingly highlighting the desirability of keeping dredged sediment within coastal geomorphological systems and to use it for trials and projects investigating its benefit in saltmarsh restoration (e.g. Fletcher *et al.,* 2001; Hughes and Paramor, 2004; Dearnaley *et al.,* 2007).

## 2.2 Saltmarsh Restoration Background

### 2.2.1 Introduction

Methods of saltmarsh restoration are reviewed in detail (§ 3). As an overview it is widely acknowledged that saltmarshes in the UK and elsewhere have significantly declined (e.g. Wolters *et al.,* 2005[a]), although locally, some sites have accreted sediment both laterally (Haslet *et al.,* 2003) and vertically (Haslet *et al.,* 2001). Vertical accretion can, however, be related to sea level rise (Haslet *et al.,* 2001) and may also result in a community change moving towards a more reed (*Phragmites australis*) dominated, and species poor, habitat (Windham and Lathrop, 1999; Warren *et al.,* 2002).

As discussed, decline may be associated with a variety of factors, but efforts to halt, or reverse saltmarsh loss have increased in line with realisation of their coastal defence, and natural habitat values. Historically man made loss was often associated with impoundment of wetlands to create agricultural or industrial land (Wolters *et al.,* 2005[b]). As sea levels rise and remaining marshes decrease, however, policies have shifted to allow marshes to naturally re-establish through removal of coastal defences in Europe (e.g. Wolters *et al.,* 2005[b]) and North America (Warren *et al.,* 2002; Konisky *et al.,* 2006). Such ideas were formed from an accidental breaching incident in the UK due to storm tides after which saltmarsh communities began to develop (French, 1999).

This initial response to accidental flooding and subsequent deliberate removal of barriers is in contrast with efforts to actively augment saltmarsh stability through promoting retention, accretion or through the use of dredge spoil. The latter and potentially more sustainable approach to saltmarsh management, creation and estuarine foreshore protection, involves the beneficial use of dredged sediment to restore eroding and degrading inter-tidal profiles (Colenutt, 1999; Morris, 2007) and the re-creation of saltmarsh areas. These options are relevant to HCC and EA objectives, but potentially in conflict with Natural England (NE) 'managed retreat' guidelines. Using imported sediment such as clean dredge ('spoil') material to a threshold elevation above which vegetation may naturally gain a foothold, recharge is the beneficial use of sediment, which might otherwise be lost to the geomorphological system (Morris, 2007). This practice has been researched worldwide and in the UK, however the Solent has seen little focus on such a project despite efforts and recommendations to achieve this (e.g. see Johnson, 2000; Colenutt, 2001 and HCC, 2000).

### 2.2.2 Saltmarsh Restoration – Brief Overview

In Australia saltmarsh erosion has been recognised for a considerable period and has been credited to a lack of understanding of reclamation impacts from industry and residential development (Bird, 1987; Laegdsgaard, 2006). Whilst restoration in the UK has been trialled since the 1980s (see: Holder and Burd, 1990), in Australia it is described as a "*relatively new concept*" (Laegdsgaard, 2006) which, similarly to the UK, appears related to the heightened awareness of saltmarsh importance. Passive approaches have been used in a number of projects (allowing flooding, removal of barriers etc.) and active levelling and reprofiling has also been used to allow 'natural' recolonisation. It was noted that soil salinity, dewatering rate and organic content (sometimes requiring additional amounts) were all important in reestablishment of marsh (Laegdsgaard, 2006). A review of readily available literature did not reveal current projects using dredge soil beneficially, but did highlight the impacts of inappropriate dredge spoil dumping near wetlands causing them to become over-heightened) resulting in a changed habitat (Burchett *et al.,* 1998).

Saltmarsh restoration in the USA has followed removal of engineering structures to allow flooding (e.g. Warren *et al.,* 2002; Konisky *et al.,* 2006) and the beneficial use of dredge spoil; the latter being proposed a considerable period before now (e.g. Smith *et al.,* 1975). It is not clear if this wildlife habitats creation project went ahead, legislation was seen as a potential barrier, however it was concluded that there was a "*high potential for achieving this goal*" (Smith *et al.,* 1975). There have been numerous USA projects with varying degrees of success and some that highlight failures or fragilities (e.g. Langis *et al.,* 1991). Suggestions of trials have continued (e.g. Yozzo *et al.,* 2004) and actual projects have been undertaken (Ray, 2000) where mudflat creation showed an acceptable colonisation rate and biodiversity enhancement.

A succinct summary was noted in work by Schrift (2002) where research looked at the use of dredge spoil to restore marshes in Louisiana after a severe decline following a spring-summer drought during 2000. It was found that the height of placed dredged material was significantly different between areas with high, medium and low elevations in comparisons to the pre-existing marsh. High and medium dredge spoil restoration sites did not show saltmarsh recolonisation two years after spoil placement and plant cover was similar to those areas suffering from post drought dieback. After slurry placement good marsh recovery was seen in low elevation sites that broken off marsh remnants settled on and also in vegetated areas that still had some remnant marsh. It was apparent that height was an overriding factor (Schrift, 2002), as was organic content (see also: Laegdsgaard, 2006), and sulphide concentration (see also Mendelssohn and Kuhn, 2003).

The success of de-embankments in north-west Europe to allow flooding has been assessed by Wolters *et al.,* (2004). Results showed variable success with "*many sites* [supporting] *less than 50% or regional target species*" (Wolters *et al.,* 2004); larger areas had higher diversity. It was recommended that clear targets (for diversity in relation to restoration success) be set at an early stage to enable robust monitoring schedules. It was also recommended that management involve grazing (already occurring on some Solent saltmarshes) and mowing regimes as these may enhance diversity (Norris *et al.,* 1998).

In a review of successes and failures Boorman *et al.,* (2002) recognises that European interest in saltmarshes has risen dramatically since seawall loss resulted in marsh development. In relation to the realisation of saltmarshes' role as a natural coastal defence it was noted that coastal marshes can reduce wave energy factor of almost 3, highlighting this ecosystem service. The authors recognised that saltmarsh recreation or passive regrowth was "*clear*" for England and Wales, but that "*this was not going to be an easy or cheap process*" (Boorman *et al.,* 2002). Problems associated with use of spoil included inadequate drainage (in natural systems supplied by the creeks that develop within marshes). Also highlighted was the height of marshes which if too low did not demonstrate full recolonisation. This appears a contrast to findings by Schrift (2002) and highlights the need for case by case assessment of restoration processes.

The first cited intentional saltmarsh restoration through managed retreat in the UK took place in 1991. This was at a small scale - 0.8ha – at Northey Island in Essex where a seawall was deliberately breached. Dagley (1995) showed that by 1993 a pioneer saltmarsh community had developed and by 1994 there were a total of 25 species including the rare *Suaeda vera* and other recognisable communities forming mosaics with the pioneer marsh.

This was followed by a large scale deliberate flooding at Tollesbury where 21 ha were flooded in 1995 (Boorman *et al.,* 2002). This scheme seems to have had little effect on sediment accretion, with the site showing no significant differences in the rate of sediment accretion prior to and following realignment (Defra, 2008). However in contrast the scheme was successful in terms of colonisation by salt marsh plants, with intertidal mudflats being quickly produced and being subsequently colonised by vegetation. These plants do not, however, contain many 'high marsh' species and the Defra report (2008) suggests that it can take decades for plant communities to reach equilibrium with natural conditions. In addition to vegetation it was also found that intertidal invertebrates and birds were also quick to recolonise the site. The site has now been monitored for 13 years and it is worth quoting Defra's general key findings from the program:

- With minimal pre-treatment and management, allowing tidal ingress through a simple, relatively small breach onto low-lying agricultural land will quickly produce intertidal mudflats which are colonised by saltmarsh plants;
- Managed realignment sites in low energy environments, located near natural marshes, should be left to regenerate naturally;
- Future projects should consider leaving vegetation on the site prior to inundation, either uncut or a high cut, if mown;
- Soils that are compacted during construction of managed realignment sites should be lightly cultivated prior to inundation, as compacted soils restrict plant colonisation;
- The development of a creek network appears fundamental to the establishment of saltmarsh vegetation.

(Defra, 2008).

Further trials in Essex also involved sediment retention schemes, with an EA scheme at Hamford Water using a combination of polders (alongside wavebreaks and sediment recharge) to restore areas of foreshore to levels where recolonisation by saltmarsh vegetation might occur (Nottage and Robertson, 2005). In this scheme a line of barge hulks were placed offshore to act as wavebreaks while a polder system was constructed to increase sedimentation and increase the surface elevation of the foreshore in the lee of the wavebreaks. To increase the rate of elevation increase, dredged sediment from a Harwich Haven Authority maintenance dredging programme was pumped ashore, and within 9 months of the placement of sediment the area had been colonised by pioneer saltmarsh vegetation.

Successful creation of saltmarshes through use of dredge spoil has been noted for some period (see: Ray *et al*., 1994). Although schemes in Essex had been underway for some time, in 2003 it was noted that in the UK beneficial use was still "limited to small scale trials" (Bolam and Whomersley, 2003). Concerns related to movement of placed sediment and subsequent legal issues are cited as restricting factors. In addition the rate of invertebrate recolonisation (related to organic matter levels) and resultant possible impact on bird and fish populations, deprived from direct access to productive material, are also concerns for local biodiversity (Bolam and Whomersley, 2003). This is a particular issue as proposed intertidal recharge schemes will be associated with highly productive estuarine ecosystems. This highlights the need for robust trials, not least in the Solent where nationally and internationally important bird populations are dependent on this resource, albeit currently diminishing. Bolam and Whomersley, (2003) investigated a marine dredge spoil placement project in the Crouch Estuary (Essex). Through multivariate data analysis it was found that invertebrate community structure had not recovered to reference site status after three months, but that this may have been related to elevation (as previously discussed) and that a more robust design for control sites may also have influenced results. Colonisation, however, did continue and some densities had fully recovered within 18 months (Bolam and Whomersley, 2003).

A large scale project of spoil placement in the Orwell Estuary, Essex was investigated for Defra by HR Wallingford and the Centre for Fisheries and Aquaculture Science (CEFAS) (Dearnaley *et al*., 2007). The scheme involved the placement of 35,000m$^3$ of sediment and was monitored for habitat value and flood defence enhancement. The site was selected as being in front of a seawall that the Environment Agency were "committed to defend" (Dearnaley *et al*., 2007) and that Natural England viewed it as a "reversible option" which may also trickle charge other nearby areas with fine sediment. Different methods of retaining the material were trialled and the results show that mud placement could create habitats within 6 months and that within 12-24 months there was a high abundance of mud species. It has been reported that around 1.6 ha of saltmarsh has developed around the fringe of the site and along the facing of the new sea wall. The vegetation community is dominated by the pioneer species Salicornia, and appears to be behaving naturally, following distinct seasonal variation in growth and die-back. The conclusion from the first six years of monitoring is that the saltmarsh was developing well and the site supports large numbers of Dunlin and Ringed Plover (Defra and Environment Agency, 2005). Much practical experience was gained in the Orwell project, and other UK trials (see Colenutt, 2001), but despite this it was concluded that "in the five years since the conception of this project little has changed in the terms of UK beneficial use of muddy material" (Dearnaley *et al*., 2007). Dearnaley *et al*., (2007) also went on to say that "*practical delivery of such* [muddy material] *use is developing slowly* [and is] …*undertaken at very small scales*".

A further restoration scheme useful to review is that undertaken at Wallasea Island, Essex which is a project conceived as a compensatory scheme to offset intertidal habitats lost to the ports of Sheerness and Felixstowe. The scheme involved the building of a new sea wall, approximately 400m behind the existing tidal defences which were being eroded by tidal action and breaching of the existing defences to allow flooding of the site (Dixon *et al.,* 2008). The majority of the site was at an elevation half way between Mean Low Water (MLW) and Mean High Water Neap (MHWN) and 550,000m$^3$ of sediment from maintenance dredging of Harwich port were placed on the seaward side of the walls. This sediment was contained by a clay bund and the topography was raised to a level just below the MHWS level.

Monitoring of the scheme is underway with an initial 5 year programme, however it is important to recognise is that this commenced prior to breaching to establish a baseline. Among the monitoring requirements are hydrodynamics and sedimentation; bird populations; benthic, aquatic and terrestrial invertebrates; juvenile fish and saltmarsh vegetation (Dixon *et al.,* 2008).

The Wallasea scheme is useful to review as it gives indications of the regulatory framework, planning and consent issues that a restoration scheme may encounter. During the Planning Application for Wallasea the following regulatory and legislatory issues were investigated:

- Town and Country Planning Act 1990 – Planning permission was required and obtained from Local Authority (purpose: (1) Control of construction to mean low water; (2) Temporary and permanent footpath diversions; (3) Evaluation of archaeological impacts;
- Town and Country Planning Act (EIA) Regulations 1999 (the EIA Regulations) – The proposal was classed as an infrastructure project comprising coastal works capable of altering the coast under Schedule 2 of the EIA Regulations. An EIA was required to accompany the planning application;

- Habitats Regulations 1994 – An Appropriate Assessment was required for impacts on Natura 2000 areas (information required for this assessment was provided in the Environmental Statement);
- Wildlife and Countryside Act 1981 – The EIA included assessments of impacts to species protected under Schedule 5 and impacts on Sites of Special Scientific Interest.
- Land Drainage Act 1991 – Consent from the Environment Agency was required because existing drainage systems and coastal defences were affected. It was agreed with EA that a single Land Drainage application could cover all the works and future maintenance of the seawall;
- Water Resources Act 1991 – Consent from the EA Flood Defence Committee was required for proposed works affecting tidal flood defences. A discharge consent was not required (there will be no discharge from the site to the estuary & the dredged sediments were dewatered entirely within the realignment). A water abstraction licence was not needed because the scheme involved altering the coast to allow "natural" abstraction;
- Highways Act 1980 – Separate consents were needed from the Local Authority for temporary and permanent footpath diversions;
- Harbour Works Licence – The Harbour Authority required details of the plans to provide a works licence under their Crouch Harbour Act 1974 responsibilities;
- Crown Estates – Consent sought to safeguard land ownership (otherwise it reverts to the Crown after breaching). Definitive area maps pre - and post-breaching required;
- Coast Protection Act 1949 (CPA) – It was agreed with the Marine Environmental Consents Unit (MECU) that no consent was needed under Section 34 (as amended by Section 36) of the Merchant Shipping Act 1988 for construction, works below mean high water Springs (MHWS) or for temporary navigation blocking during recharge operations;
- Food and Environment Protection Act 1985 (FEPA) – Agreed with MECU that construction/sediment deposition licences under Part 2 were not needed. With respect to the sediment recharge works, although a formal FEPA consent was not required (because dredged sediments were not deposited below MHW), material quality was still double-checked and subject to FEPA-standard studies, as if consent was sought;
- Waste Management Licensing Regulations (WMLR) (1994) - A waste management licence or an exemption under Regulation 17 of the WMLR (1994) was not required.

Dixon *et al.,* (2008) also suggest indicative timescales for creating managed realignment schemes based on the Wallasea experience (Table 2.1).

TABLE 2.1 INDICATIVE TIMESCALES INVOLVED IN CREATING MANAGED REALIGNMENT SCHEMES
(Based on Wallasea Island scheme) – (Modified from Dixon *et al.,* 2008)

| **Process** | **Timescales** |
|---|---|
| Site selection and purchase | Highly variable and depends on several factors of which the most critical are the availability of strategic flood management guidance; land owner responses/involvement and the views of the local population |
| Site investigations, project design and EIA preparation | 12 months |
| Seeking consents | 12 months (about half of which can be concurrent with EIA) |
| Major earthworks for new coastal defence and recharge bund | 3 months per km |
| Placement of dredged material to elevate ground levels | 4 months |
| Settlement, consolidation and vegetation of walls | 12 months |
| Breaching window | 2 weeks (between top of spring tide and bottom on neap tide) in two separate tranches at Wallasea) |
| Post-breach hydrodynamic studies for impact verification monitoring | 6 months (minimum) to validate hydrodynamic predictions and evaluate channel morphological changes |
| Post-breach hydrodynamic studies for site success monitoring | 5 years (ideal minimum) to confirm the site has met predetermined targets (where relevant) |

### 2.2.3 Solent Scope

Unlike the marshes in Essex and elsewhere, the Solent has seen limited work on saltmarsh restoration through dredge spoil use. Colenutt (2001) highlighted that many techniques have been tried in the USA, but at that time little had been undertaken in the UK. Hampshire County Council was in a group looking at such schemes (see:

http://www.hants.gov.uk/scrmxn/c28960.html) and ABP had suggested saltmarsh restoration as mitigation for the Dibden Bay project.

*Both ABP and the Environment Agency have been involved in production of guidance resources for managed realignment (see: http://www.saltmarshmanagementmanual.co.uk/Index.htm and http://www.abpmer.net/omreg/index.php?option=com_contentandtask=viewandid=16andItemid=58)*

The Solent contains around 4% of the UK's saltmarsh (Bailey and Pearson, 2007) with some of the most important examples of the habitat in southern Britain (Fowler, 2000). Solent marshes have been reported as eroding, with losses as high 72% in Langstone Harbour between 1956 and 2001 and 63% between 1971 and 2001 in Portsmouth Harbour (Bailey and Pearson, 2007). As discussed, and possibly even more the case in the densely populated area around the Solent, possible causes include coastal squeeze through urbanisation, industrial development and sea level rise coupled with *Spartina* die back (Fowler, 2000; Tsuzaki, 2004, Williams (in preparation). In addition, and as highlighted here, there is also the loss of sediment through capital and maintenance dredging (Morris, 2007).

Perhaps due to reasons associated with the recreational boating industry, perceptions about regulatory agencies and the obvious value of internationally important wetland habitats in the Solent, the issues associated with saltmarsh restoration are sensitive. However, with robust design and monitoring of trial sites, it may be hoped that saltmarsh restoration in the Solent can move forward beyond the previously mentioned "*very small scales*" (Dearnaley *et al.,* 2007)

### 2.3 Success and Failure

It is important to set out the goals and objectives of a restoration scheme at the outset. Restoration projects that lack clearly defined goals and objectives are less likely to achieve success, and in many cases it may be impossible to gauge success in the absence of a clearly defined project plan. A successful outcome of any saltmarsh restoration scheme will therefore need to be measured against specific targets. Nottage and Robertson (2005) suggest that these need to accord with the SMART philosophy, i.e. they need to be Specific, Measurable, Achievable, Relevant and Time-bound.

Potential targets for a successful saltmarsh restoration project might therefore include targets such as:

- Accretion of the saltmarsh occurs, creating X ha of sustainable new habitat;
- Alternatively, no further erosion of the saltmarsh occurs from the pre-restoration edge;
- Saltmarsh undergoes no further loss of existing species and habitats;
- Development of a full transition of saltmarsh habitats across the site, particularly mid and upper communities;
- Fulfilment of obligations to provide compensatory habitat when existing habitat is lost.

The key measure of success for each restoration scheme will be site specific and depend on the principle targets identified for each site. A monitoring programme will need to be developed that allows these targets to be measured over a sufficient duration that outcomes can be determined.

Success cannot be guaranteed and failure of a restoration scheme may be deemed to have occurred if the site-specific target(s) for an area are not met. Restoration schemes are, by nature, highly complex, involving an interplay of anthropogenic intervention and natural processes (both physical and biological) and hence a variety of stochastic problems may be encountered which can lead to a restoration failure.

Among the reported issues that can lead to failure of schemes are:

- A significant difference between the organic content of the dredged material and the sediment composing the saltmarsh. Defra (2004) states that, in particular, invertebrate recolonisation of an area is sensitive to the differences in organic content, and that this parameter requires assessment during the FEPA decision making process.

- Changing the marsh structure sufficiently that the ecological functioning of the recolonising marsh communities becomes different from the surrounding natural areas. An example might be where marshes are overheighetned by sediment deposition and the natural plant communities change to be dominated by *Phragmites spp.* (Warren *et al.,* 2002).
- A difference in the availability and cycling potential of nutrients within the dredged sediment compared with the natural system can affect the development of a new marsh community (Langis *et al.,* 1991). In particular Nitrogen is a primary limiting nutrient in many saltmarshes (Howarth, 1988) and a lack of available Nitrogen can affect plant productivity, biomass, diversity, morphology, reproductive potential and abundance of plant species. It has been shown (Broome *et al.,* 1988) that use of slow-release fertilisers on recolonising saltmarsh can enhance plant growth, although this may have its own adverse environmental impacts.
- Insufficient dewatering of placed sediments leading to waterlogging and conditions detrimental to recolonisation. It has been found that waterlogging and decaying of marsh vegetation at a scheme in Essex has caused sufficient anoxia and sodium-enrichment to prevent even strongly salt-tolerant vegetation from re-establishing (Macleod *et al.,* 1999).
- Recolonisation of saltmarsh flora and fauna can be adversely affected by the presence of pollutants in the dredge spoil sediment. Introduction of pollutants such as heavy metals and hydrocarbons can significantly damage saltmarsh communities (Teal, 1986) however some studies (e.g. Anderson *et al.,* 2002) have shown that *Spartina alterniflora* growth is not inhibited by low levels of TBT (up to 250ng/g).

Although a number of issues have been shown to adversely affect the success of schemes, many of these can be mitigated against in advance, e.g. the nutrient, organic and pollutant content of dredged sediments can be measured and analysed prior to any placement of spoil into a saltmarsh restoration scheme. The potential benefits of a successful restoration scheme are such that no presumption of failure should be made in advance of more detailed studies on a site-specific basis.

# 3 Saltmarsh Restoration Techniques

## 3.1 Introduction

Techniques designed to recharge saltmarsh are used to restore and maintain existing sites or prevent erosion of new habitat. Recharge techniques are designed so that marsh coastlines can respond to changes in wind; tide, wave and sea-level conditions (Bray *et al.,* 1992; French 1997). If physical processes within the estuary are suitable for saltmarsh formation, marshes will generally be self-sustaining (Toft and Maddrell, 1995). However factors that influence and adversely affect such processes and conditions, such as sea level rise (Reed, 1990), may necessitate management of the habitat to produce a more appropriate regime (King and Lester, 1995; Hubbard and MacGuire, 1997).

Soft-engineering techniques, such as inter-tidal recharge and marsh restoration can be used to influence the processes that occur naturally and manipulate the development of habitats. Inter-tidal recharge is the term used to describe the artificial raising of inter-tidal and sub-tidal areas with imported sediment (Environment Agency, 1998), such as dredged ('spoil') material. The theory is to raise the level of a managed area to a threshold elevation above which vegetation can naturally gain a foothold, but below a level where the marsh is colonised by upland plants.

Thus the key issue is the post-deposition elevation of the area relative to the tidal frame. This elevation dictates the number of tidal inundations the area will receive. Toft and Maddrell (1995) reported that in the U.K. marsh generation works best at elevations between mean high water neaps and mean high water springs equating to approximately 300-450 tidal inundations per year. At these levels of inundation pioneer marsh plants can colonise and develop. Below 300 inundations per annum low and upper marsh communities can develop, while conversely above 450 inundations per annum mudflats will develop.

A number of techniques have been identified as being suitable for restoration of saltmarsh and enhancing and maintaining intertidal habitats. This chapter will review the differing techniques, and where appropriate, summarise the results of previous research studies where these techniques have been trialled.

The following techniques aim to produce environmental conditions which enhance saltmarsh habitats:

(a) Reduction of erosive potential stabilising existing marsh (e.g. wavebreaks, pioneer vegetation planting);
(b) Retention of sediment (e.g. sedimentation fields/polders, groyne fencing structures);
(c) Increasing sediment supply (e.g. direct placement, trickle charging);
(d) Managed realignment.

The aim of these techniques is to allow saltmarsh to form and develop seawards. It must be remembered that these techniques are not mutually exclusive, but can be used in combination to provide the best local conditions for saltmarsh regeneration (Kesler and Kentula, 1990). This chapter will therefore review some key case studies and research programmes.

## 3.2 Reduction of Erosive Potential

### 3.2.1 Wavebreaks

Commonly saltmarsh deterioration is due to wave erosion at the leading edge of the marsh (Frey and Basan, 1985). This may be exacerbated by associated plant community decline thus losing binding root networks. A relatively simple approach to reducing the amount of wave-driven erosion is the use of wavebreaks which allows reduction of wave energy impacting existing saltmarsh. Moderation of the inshore wave climate can both reduce erosion, and allow sediment to deposit and accrete inshore of the wavebreaks. Wavebreak design and placement needs to be carefully considered to prevent wave refraction or diffraction damaging other areas of shoreline or disrupting any local longshore sediment transport processes (Reise, 2001; Nottage and Robertson, 2005).

Toft and Maddrell (1995) summarise that consideration needs to be given to wave climate, bathymetry, frictional resistance, wave stresses, sea bed stability, abrasion and attrition, aesthetics, navigation and other environmental factors when designing a wavebreak scheme.

Wavebreaks are usually placed some distance offshore of a marsh foreshore. They may provide a barrier to wave progression or simply reduce water depths, causing wave interaction with the seabed and hence reducing wave energy reaching the shoreline. Wavebreaks can be constructed from brushwood, planking, sandbags, geotextiles or novel components such as redundant Thames barges filled with sediment and sunk offshore (Nottage and Robertson, 2005).

Wavebreaks are deployed parallel to the shoreface or perpendicular to the longest fetch and minimise wave energy reaching the shoreline but allow water and sediments to pass through. They also slow currents which may promote sedimentation, and may also delay the departure of the ebb tide (Colenutt, 1999). Geotextile containers have also been successfully used as baffles to reduce wave energy impacting on the shorelines of saltmarsh and to enhance sedimentation and were first used in the 1970s in Galveston Bay, USA (Smith, 1978; Davis and Landin, 1998) where a 9 acre site was established on placed sandy dredged material. The geotextile containers typically consist of tubular-shaped bags, filled with dredged sand (Fowler and Sprague, 1993; Blankenship, 1996) and laid parallel to the shoreline.

In 1984 at Marsh House, on the Dengie peninsula, Essex, sixteen old Thames lighters (barges) filled with silt were towed and sunk in a position seaward of the eroding saltings (Leggett and Dixon, 1994). The barges were positioned some 600m offshore and sunk parallel to the shoreline leaving a gap of 10m between each barge. The silt in each barge was covered with gravel to prevent wash-out (and to provide an area for migrating terns to nest). In 1986/87 two rows of stakes with a fine plastic mesh geotextile cladding were driven in at right angles to the coast to meet the lighters at either side and to enclose the area landward of the lighters (HR Ltd, 1987; Packham and Willis, 1997).

Offshore wavebreaks can also be constructed directly using coarse grained dredged material. Typically the berms of such structures are fully submerged and consist of dredged sand, gravel, clay or a mixture of these (Bray *et al.,* 1997). Colenutt (1999) reports that the practicality of placing dredged material in the correct position will depend on prevailing conditions and the type of dredger available:

- Sediment can be placed by bottom discharge from hoppers over high water spring tides to construct a coarse-grained bund or ridge at the low water mark. This will stabilise and retain fine-grained sediments higher up the inter-tidal profile;
- For chenier enhancement and construction sediment can be ‘rainbowed’ from a dredger positioned further offshore. ‘Rainbowing’ is the technique of spraying sediment from the dredger onto the foreshore using a pumped cannon. This technique is limited by the distances over which the dredged material is to be sprayed and by the accuracy of the placement of the material.

Colenutt (1999) also reports that post-project monitoring of the retained sediment and the gravel bund is essential for both of these techniques.

### 3.2.2 Vegetation Planting

Vegetation planting may have a number of effects on saltmarsh stability and restoration (Pye and French, 1993). Salt-tolerant (halophytic) vegetation can, in itself, be used in the low inter-tidal as a means to reduce wave energies reaching the shoreline – acting as a wave attenuator e.g. a zone of healthy saltmarsh 80 metres wide can reduce wave height by 50% (CERC, 1992).

Vegetation can also be used as a means of increasing wave attenuation and stabilising the saltmarsh surface itself, and also trapping sediments to increase elevation. Finally, a further mechanism by which saltmarsh surfaces can accrete is purely as a result of vegetative growth, and is independent of sedimentation.

Broome *et al.,* (1988) discuss an artificial planting scheme on intertidal creek banks at Ile Grande, France where sprigs of *Spartina alterniflora* and *Halimione portulacoides* were planted at 0.5m spacing. It was found that at this site planting plugs of plants successfully recolonised the area, and that results were enhanced by also incorporating a slow release fertiliser (osmacote). Seneca (1974) and Seneca *et al.,* (1975) suggest that when transplanting, plants should be replanted to a depth that the plants were occurring in naturally. In addition, to ensure maximum survival plants for transplanting should be obtained from as close to the new marsh creation site as possible.

Many saltmarshes were originally used as grazing areas (Bakker, 1985; Jensen, 1985). Andresen *et al.,* (1990) reported on a long term study of grazed saltmarsh at Leybucht, Germany. They found that while grazing retarded sedimentation and decreased litter production and population densities of certain insect species and their predators it actually allowed plants from the lower marsh to spread to higher marsh. In addition when grazing was abandoned species richness of plants declined and halophytic plant species and communities disappeared.

From this it may be hypothesised that when replanting saltmarsh vegetation it may be advantageous to cut plants on a regular basis (to simulate the effects of grazing). Hubbard (1970) suggested that repetitive cutting of *Spartina* led to more uniform, denser and earlier flowering stands and that the effect of one season's cutting persisted for more than one summer.

French (2001) reports that natural vegetation that can tolerate prolonged submergence e.g. seagrass or seaweed, has been used by coastal managers through artificial planting, to increase the bed roughness (and hence the wave energy attenuation) of mudflat fronting saltmarsh shorelines. Fonseca and Cahalan (1992) found that seagrasses could reduce current velocity reaching exposed mud shorelines by up to 40 percent. However, local environmental conditions obviously play a critical part in determining whether artificial planting of vegetation is viable. If areas are vegetation-free because local environmental conditions are inappropriate for vegetation growth then planting/transplanting is unlikely to be successful.

Wave energy at the saltmarsh surface itself is reduced by the increased surface roughness provided by saltmarsh plants. Marsh, colonised with vegetation, has a high bed roughness giving increased frictional drag than a mudflat. Knutson (1998) found that more than half the wave energy and up to 40 percent of the wave height were lost within the first 2.5m of the marsh edge. Through deliberate vegetation planting, particularly *Spartina* (Cord Grass) species, erosive tidal flows can be dissipated by the plant stems with the resultant effects of a decrease in current velocity, increased sediment deposition, and raising the level of the mudflats and marshes. *Spartina sp*. spread rapidly to colonise unvegetated mudflat areas and confines the ebbing water, forming low islands, and allowing these relatively stable areas to develop still further (HR Ltd, 1987).

Increases in marsh elevation due to sedimentation are dependent upon the cumulative stabilising and sediment trapping efficiency effect of saltmarsh plant species. Yang (1998), studying saltmarshes in the Yangtze estuary, China, reported a positive linear correlation between the density of marsh plants and the amount of sediment trapped. Increasing the density of saltmarsh vegetation through planting may therefore increase the amount of sedimentation and increase the elevation of the marsh surface. The use of pre-planted pallets anchored to the marsh of securing young plants in fresh mud whilst they become established and encouraging deposition is a method proposed by LRDC International Ltd (1993). There is, however, a complication – Pethick (1992) argued that the rate of sediment deposition over a marsh is controlled by the availability of sediment within the water column, rather than plant density. Hence, schemes that plant marsh vegetation without considering the local sediment budget may fail because of the lack of available sediment (French, 2001). One way of increasing sediment availability may be to combine planting with trickle charging of the area (see later section).

It is, however, commonly assumed that accretion is only controlled by mineral sedimentation, but in some cases vertical accretion of marsh surfaces can be controlled by the accumulation of organic matter (e.g. Anisfield *et al.,* 1999; Turner *et al.,* 2000; Chmura and Hung, 2004) – in the words of McCaffery and Thompson (1980) "*accretion via vegetative growth*". The vegetative processes that increase marsh elevation include accumulation of detritus from overground plant parts (Rybczyk *et al.,* 1998); insertion of root tissues into sediments (Wolaver *et al.,* 1988); and enhance sediment trapping by litter (Rooth *et al.,* 2003). Therefore to manage marshes which accrete via vegetative growth requires a sound understanding of the mechanisms that promote organic matter accumulation and pore space.

An example of a marsh undergoing vegetative growth accretion has been studied by Nyman *et al.,* (2006). They studied a saltmarsh in Louisiana and showed unequivocally that accretion at this site was unrelated to sedimentation. At their field site, accretion proceeded via the production of aquatic roots that developed into a fibrous network just above the existing marsh surface and that, in time, became indistinguishable from the pre-existing surface. Any intervention in such a system that disrupted the vegetative accumulation would therefore be detrimental to the overall health of the marsh.

#### 3.2.3 Retention of Sediment

A method of stimulating natural deposition rates and processes (MAFF, 1993) is to increase the period of sedimentation during a tidal cycle. One approach to this is by traditional fine-grained sediment-deposition (‘warping’) methods where high tide waters are impounded and sediment settling allowed, before draining the waters off (‘dewatering’) via a sluice gate, or as tide falls. Sediment traps may also be designed where transport velocities are decreased, hence increasing rates of deposition. This can be achieved through the use of groynes, sedimentation polders, breaching dikes or the use of baffle fences (can be made of materials such as brushwood or geotextiles)

### 3.3 Sediment Settling

#### 3.3.1 Sedimentation Fields/Polders

Brushwood can be used to construct simple shore-normal permeable groynes, similar to the brushwood wavebreaks described in Section 3.2.3 above. These are permeable structures that allow water to pass through but impede the passage of waves. In cases of strong long-shore currents, simple shore normal structures will be sufficient to trap fine sediment moving along the coast, whilst allowing water to pass through, albeit at a reduced velocity. Brushwood groynes are often deployed as a double row of vertical wooden stakes driven well into the mudflat between which are woven finer branches (Colenutt, 2001).

Fine-grained sediment has a long settling time, and to enhance the settling of such material requires the construction of large sediment fields, or polders (Figure 13), to permit sufficient time for the fine-grained sediment to settle out (Plate 4). Sedimentation fields can be produced by combining shore-normal brushwood groynes and shore-parallel brushwood wavebreaks (French *et al.,* 2001). Here waters pond on the flood tide and drain more slowly through the permeable brushwood during the ebb, allowing sediment greater time to settle out. Tidal velocities are reduced by the ponding effect and the erosive effects of wave and tide-generated shear stress are diminished, thus allowing the fine-grained fraction of the sediment to settle out. As a result, the sedimentation of suspended matter is enhanced (Hofstede, 1995). This technique has been successfully used at Wallasea Island, Essex, U.K., to build up the mudflat from a degraded saltmarsh edge.

The ‘Schleswig-Holstein method’, originally established and refined in Holland and Germany (but now used more widely) encloses a width of mature upper marsh (showing signs of vegetation loss and erosive damage), together with a similar width of mudflat seaward of the marsh, by the construction of a perimeter fence (MAFF, 1993). Within the fences a regular pattern of shallow ditches are dug to collect the deposited fine-grained sediment. The material excavated to create the ditches is used to build up ridges between the ditches and once sufficient sediment has accumulated is dug out and spread over the area increasing the overall surface elevation of the polder field. This process is repeated with the ditches being re-excavated over a set period (Nottage and Robertson, 2005). The aim is to develop a new area of marsh, which will protect the reclaimed or regenerating area, and which is subdivided into several enclosures or polders.

Gaps in the fencing along the seaward line of each enclosure allow the tidal inflow into a series of channels within the area; these are maintained to control the flow and hence the sediment distribution. The main ditches are dug perpendicular to the coast while other trenches (‘grips’) are dug parallel with it. The main trenches direct the waters of the flooding tide onto the upper areas sufficiently rapidly for them to carry the sediment towards the shore, instead of depositing it further offshore (Colenutt, 1999). The use of polders to create sedimentation fields has been successfully used in the German Wadden Sea to promote saltmarsh creation – here saltmarsh area has increased by approximately 10% over the past decade (Houwing *et al.,* 1999; Rupp and Nicholls, 2002).

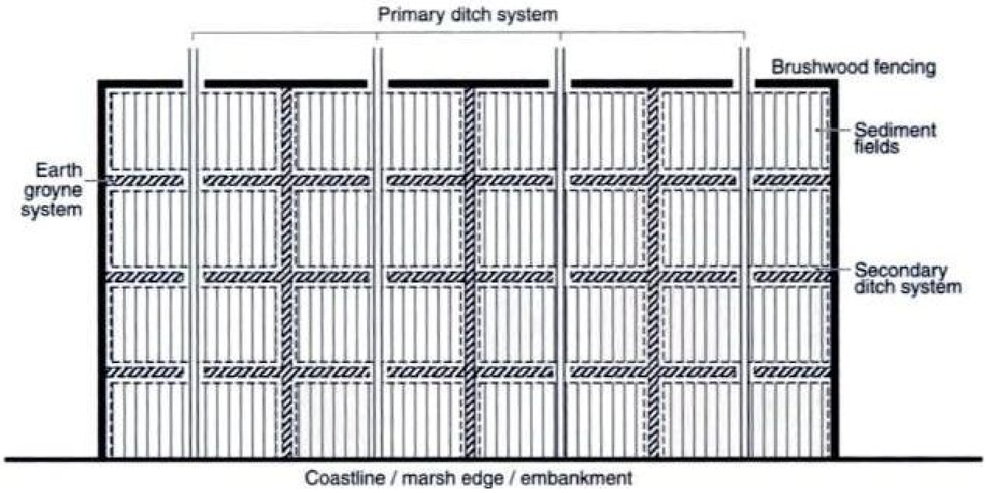


**Figure 3.1 Design for sedimentation polder**
(French, 2001).

Research into the effectiveness of a polder restoration scheme has been carried out by Dausse *et al.,* (2006) in the Bay of Veys, north-west France. It was found that outflowing water from the polder structure showed decreased nitrate concentrations as well as concentrations of total suspended sediment. The polder was therefore acting as a sink for nitrates as well as for particulate material, at least for the duration of the study. French *et al.,* (2001) report on a number of schemes trialled along the Essex coast and argues that those schemes that were most successful were those where there was plentiful sediment availability e.g. polders established on the Crouch and Roach estuaries. French (i*bid.*) also reports on a scheme at Deal Hall, Essex, where two enclosures showed rapid accretion but a third enclosure which lacked the ditches and internal embankments showed little accretion. This emphasises the importance of the internal ditching in the Schleswig-Holstein method.

French (*ibid.*) therefore suggested a series of rules for polderisation based on the Essex examples, which would be of value when assessing similar schemes for the Solent system.

- The sediment budget of the system is critical in that adequate supplies of sediment need to be available (naturally or artificially supplied);
- The ditch/ridge system within the fencing is a key factor in inducing sediment to settle;
- Wave protection by suitably positioned groynes needs to be established in order to preserve the sediment during dewatering and compaction.

Nottage and Robertson (2005) also raise another issue that is of importance when considering polderisation as a potential tool – namely that the repeated re-excavation of ditches means that this is not a quick-fix solution. Indeed the saltmarsh can take many years to become established by this method and will then only do so if there is sufficient sediment availability over that time frame.

A combination of techniques is often used to restore and enhance saltmarsh systems. A method of foreshore accretion and artificial creation of a saltmarsh, developed from Dutch experiences, can typically be divided into three phases. During the first phase, a groyne field is built in order to reduce turbulence and to improve sedimentation. When the elevation of this field is high enough, a system of drainage furrows is dredged (see section 4.2.1) in order to improve aeration and to initiate the growth of pioneer vegetation (see section 4.2.6). At the same time, a second groyne field is built in front of the first and takes over the function of the first (second phase). If the development is successful, a saltmarsh will be generated; if necessary this can then be protected by a third groyne field (phase 3).

## 3.4 Sediment Augmentation

### 3.4.1 Introduction

There are potential opportunities, through environmentally-sensitive soft engineering methods, to recreate self-sustaining soft sediment shorelines in eroding areas (Kirby, 1995) and to maximise environmental benefits (Colenutt, 1999). Inter-tidal recharge is the term used to describe the artificial raising of inter-tidal and sub-tidal areas with imported sediment (Environment Agency, 1998). Placement of fine cohesive sediments on, or in front of, existing marsh can enhance the natural supply of sediment and aid recolonisation of land area by halophytic plants. It has been reported (French, 2006) that estuaries that are well charged with sediments may offer a high probability of marsh regeneration provided such sediments are retained within the system.

One method of increasing the sediment supply to marshes makes beneficial use of 'densified', low-contaminated (clean or treated), low-cost maintenance-dredged sediment ('spoil') as a resource within a sedimentary system, rather than as a problem to be disposed of at offshore dumping sites. The general aim of inter-tidal recharge is to increase the sediment supply on the inter-tidal and sub-tidal areas, thereby promoting natural processes and enhancing coastal stability (Colenutt, 2001).

Technical considerations include the following measures:

- To reduce or reverse the rate of retreat of managed coastal habitats (French, 1997);
- To reduce wave energy, control the tidal velocities and to encourage deposition of the fine-grained sediment fraction;
- To manage and control the rate of either naturally induced, or artificially-enhanced, sedimentation;
- To transform low and concave eroding muddy foreshores into high and convex accreting shores (Kirby, 1995); and
- Ideally, to extend the saltmarsh seawards.

French (2006) identified that the nature of the dredged material can be critical in the outcome of any restoration – with factors such as the moisture content, compaction, grain size, pollutant level and nutrient availability of the material all important. In addition Nottage and Robertson (2005) state that on-going reapplication of sediment, combined with sediment restraining structures, may have to be undertaken.

Although introducing sediment to the system seems a straightforward exercise, there are some challenges. In particular any development of stable substrate is a slow process controlled by the settling, de-watering and consolidation characteristics of the sediments introduced to the area. Nottage and Robertson (*op cit.*) therefore state that the ultimate surface profiles attained, and the timeframes over which consolidation and colonisation occur, cannot be predicted with certainty. The technique is thus mostly empirical and repeat applications of sediment may be required to obtain the desired results.

The benefits of increasing the sediment supply to marshes may also need to be offset with potential detrimental changes that may occur within the soil as a result of the supply. Macleod *et al.,* (1999) report the results of a trial in Orplands, Essex, where tidal waters were allowed to flood previously reclaimed land. Here rapid sedimentation blanketed the previous vegetation which became waterlogged and decayed. This led to the development of a zone of sodium-enrichment, and anoxia – both of which were sufficient to potentially prevent establishment of even the most salt-tolerant vegetation. While these results were from a managed realignment scheme they are analogous to the potential outcome of uncontrolled increases in sediment supply. Further adverse impacts may include the smothering of existing biota, and the potential introduction of contaminants if the dredged material is taken from a polluted source.

Thus is order to be successful, beneficial use projects need to be designed by multidisciplinary teams that includes resource managers, engineers, biologists and other specialists. Ongoing monitoring after any implementation of restoration schemes is needed to make sure the project is effective. Monitoring needs to be focused and must continue for a long enough period to detect any significant changes. These factors often make the beneficial use alternative more costly than other disposal options (Blankenship, 1996), but more environmentally sustainable since sediment within the system is treated as a resource rather than as a problem.

### 3.4.2 Direct Placement of Dredged Material

The aims of direct placement of muddy sediment onto the existing saltmarsh-mudflat profile, without construction of retaining structures, is to restore elevation in subsiding marshes (Wilber, 1992, 1993); to modify the morphology and to make additional sediment available for recycling within the saltmarsh system. Fine cohesive sediment of a grain size similar to that found on existing saltmarsh in the area is required.

This technique is considered to be one of the principal applications of the beneficial use of dredged material (MAFF, 1996). Muddy, low-contaminated, dredged spoil may need to go through a process where its density is increased to achieve the stability necessary for placement on the eroding tidal flat (e.g. a process of dewatering, Colenutt, 1999). Areas where sediment is placed should, with adequate planning, be recolonised by emergent vegetation and if only thin layers of sediment are deposited on the marsh surface the deleterious situation described by Macleod *et al.,* (1999) detailed above should be avoided.

Trailing suction hopper dredgers and cutter suction dredgers are best suited for foreshore recharge where direct placement of material can be achieved through pumping via a pipeline discharge, resulting in a weaker material which is more readily resuspended. The sediment is pumped onto the marsh in a slurry form, with the surplus water draining off and leaving the sediment behind. Another option for placement could be through bottom dumping from a hopper (HR Wallingford, 1999), which requires material to be rehandled by other plant, depending on the site and prevailing conditions. To reduce potentially harmful impacts, special dredging techniques, designed to minimise loss of sedimentary material, may be required.

If barge access is possible near the final disposal or reuse site (Steetzel, 1996), the dredged material can be pumped directly. Trailer dredgers for recharge work usually fitted with a mechanised pipeline retrieval and connection system; many trailer dredgers are unable to pump material over long distances. When sediments are dredged from locations that are far from the final placement area, they must initially be placed in a barge, then transported to an offloading facility and handled separately for transport to the disposal or re-use site.

Alternatively, a shallow-draft hopper may be pump-discharged over the bow by spraying (‘rainbowing’) material onto the foreshore. By jetting sediment slurry using a mudcannon, at low water on spring tides, the sediment can be ‘placed’ high on the foreshore. It may be necessary to spray material behind a containment structure such as behind wavebreaks or bunds, which protect the recharge while it is dewaters. Coarser sediments such as gravels can be used to construct containment structures, and using sediments coarser than those found naturally in the system reduces the chance of the containment structure being transported by local waves and currents.

The force exerted by a spray of sediment can flatten and bury the marsh vegetation, however the thickness of the sediment deposit can control the mechanisms of recolonisation (Ford *et al.,* 1999). Wilber (1993) suggests that deposits less than 15cm thick are recolonised by sprouting of *in situ* vegetation, while deposits greater than 15cm thick will smother and kill existing vegetation and hence require invasion by new plant material. It has been suggested that the introduction of thin layers of dredged material may have a fertilising effect on current vegetation, promoting growth (Ford *et al.,* 1999).

Spray charging was the focus of a study in Louisiana, conducted in 1996, and reported by Ford *et al.,* (1999). In this project dredged sediments were thoroughly mixed and sprayed onto the marsh surface. Coarse and finer sediment fractions remained mixed and did not segregate either during or after deposition and ensured a uniform distribution of grain sizes. The study found that initially, as might be expected, accretion of sediments was an order of magnitude greater at sprayed sites than at reference sites. The force of the spray flattened the emergent plants at the deposition site, although the vegetation recovered to an upright position within a few months. After 20 months there was little difference in the total accretion between sprayed and unsprayed sites, although the elevation of the sprayed site was enhanced but with an increased elevation small enough for the marsh to remain marsh and not become colonised by upland species.

Ford (*op. cit.*) also reported that initially the organic matter content of the sprayed marsh decreased (due to the deposition of dredged material that contained little organic material). However it was found that roots and rhizomes quickly colonised the new sediments, and within 1 year soil bulk density, percentage organic material, root/rhizome biomass and volume of sediment had all returned to, or exceeded, levels measured prior to spraying. It was therefore concluded that spraying of dredged materials had the potential for restoring marshes that had degraded to shallow open-water areas provided that subsequent erosion from wave action could be limited. Where wave action was limited bottom elevations could be sufficiently increased to sustain emergent wetland vegetation where none existed prior to sediment deposition taking place.

It may be useful to estimate the volumes of dredged sediment that would be required in a spray charging campaign. If we assume a hypothetical marsh area 200m wide by 50m deep, then a 15cm thickness of sediment over the whole area equates to a volume of sediment of 1500m$^3$. If loose sand is taken to have a density of 1.4 tonnes/cubic metre then this equates to approximately 2100 tonnes of sediment that would be required for one recharge event.

### 3.4.3 Trickle Charging

The concept of trickle charge is to increase the availability of source material by introducing fine sediment in an unconstrained manner. The energy of the natural system is used to redistribute the dredged material. The natural movement of the sediment to the required areas is promoted, which allows the foreshore to respond naturally to physical processes. Sedimentation is therefore wholly dependent on the natural processes (French and Watson, 1999).

Inter-tidal trickle charge is the approach where material is placed on the inter-tidal zone to disperse. This method requires the strategic placement of small quantities of sediment in sacrificial ‘mud mounds’, at the appropriate level on the inter-tidal zone. Alternatively, a bank of sediment may be deposited from split hopper barges on the spring tide at approximately low water mark. The deposited materials are then eroded and transported by the rising tide to increase the suspended sediment concentration in the inter-tidal zone. The overall effect is to add sediment to the system and allow it to deposit naturally in accretion areas so forming equilibrium morphology without the need for artificial periods of consolidation (MAFF, 1993).

An alternative to this technique is trickle charge via the water column. In this method the dredged material is discharged into the water column at such a rate and dilution that the moving water column is able to carry the recharged material away from the site of introduction. It can be seen that trickle charging has the potential to increase the natural sedimentation, however it may also involve problems. As the sediment is unconstrained it may be re-deposited in areas where accretion is unwelcome, and may then require further management and maintenance. Thus an understanding of the natural transport pathways is required before trickle charging is undertaken, particularly if the saltmarshes to be charged are close to sensitive areas such as shipping channels, marina berths and harbour entrances etc. In addition, as identified (§ 1.5.5) natural assets may be adversely affected by the suspended sediment plume associated with this method. Thus where areas of e.g. seagrass, shellfisheries, fish migration routes and other sensitive habitats and species are known or knowledge is required, a precautionary principle and appropriate research/management or alternatives should apply.

A variation on this technique is agitation dredging, currently not licensed but under review by MAFF (HR Wallingford, 1999). The basic aim of agitation dredging is that material is mobilised from the dredge site by hydraulic action (e.g. water injection). The water injection dredging process aims a high-volume, low-pressure water jet directly above the sediment surface; the jet stream will erode and penetrate the sediment and form a mixture with the suspended sediment. This raises the muddy sediment into a turbid density layer just above the sea bed (HAM, 1994). Unless retained, the density layer will spread out and decrease in height. The natural tidal regime disperses the agitated dredged material from the dredge site (HR Wallingford, 1999). The fine-grained sediment would settle out as a thin layer over a wide area (HAM, 1994), through the deposition and subsequent re-suspension of the sediment within tidal cycles.

## 3.5 Managed Realignment

### 3.5.1 Introduction

Managed realignment is a technique that can recreate marsh habitat, and may be suitable for the SDCP (Cope *et al*., 2007) sites considered in this study. The rationale behind managed realignment is simple, to return land to the sea, and allow intertidal mudflats and saltmarshes to develop landwards of those that are already in existence (Vincent, 1993; Birks, 1993; French, 2006).

Managed realignment may be defined as the deliberate process of relocating the line of defence landwards of its existing position or allowing the coastline to recede to a new line of defence (natural or manmade) accompanied by measures to encourage the development of an environmentally beneficial habitat. This may involve retreating inland from the existing line of flood or coastal defence (CIRIA, 1995), or allowing the natural erosion of the coastline in areas where expenditure on coastal defences cannot be justified, and/or where such defences would have an unacceptable environmental impact (NFDC, 1997). ‘Management’ need not necessarily entail intervention, e.g. in the form of ‘hard’ engineering works, but implies monitoring and provides an opportunity to intervene if appropriate (Brooke, 1993).

### 3.5.2 Techniques

Managed realignment (or ‘set-back’) in low lying areas involves the maintenance of a defence, but along a new line further inland. It is particularly applicable to locations where the fronting saltmarsh and mudflat is eroding and the presence of a defence structure is prohibiting a compensatory movement landwards. Set-back generally encompasses the following:

- Construction of a secondary, usually less expensive inner line of defence;
- Breaching of the old defence;
- Management of the land between the old and new defences promoting the creation of saltmarsh;
- Removing the front sea wall either wholly or partially.

Forms of managed retreat that approximate to setback or to controlled abandonment are most likely to produce mid to low level saltmarsh and / or inter-tidal flat (Radley, 1993).

Managed realignment studies in Pagham Harbour, Sussex, U.K. appear to indicate that saltmarshes regenerate most successfully in areas where marshes had been prior to reclamation (French, 2006). Three possible reasons have been suggested:

(1) Soil geochemistry is most suitable in areas that have previously been marsh;
(2) Those area were relatively sheltered from incident waves;
(3) The surface elevations were immediately suitable for regrowth of marsh vegetation.

In an earlier study French (1999) also suggested that where managed realignment is instated, smaller sites more successfully regenerate saltmarsh, while large sites tend to revert to mudflats. It was suggested that this was because of the potential erosive effects of locally generated wind waves – large sites can have relatively greater ‘fetch’ for wind waves which enhances their erosive potential.

Managed realignment is a useful tool since it allows natural processes to continue, and allows environments to develop in a naturalistic fashion providing flood defence and habitat creation opportunities. It is a useful technique for mitigating the impacts of sea-level rise and environmental degradation, provided there is no issue with development or usage of the hinterland which would be required for flooding. It is therefore not an appropriate technique where there are constraints upon land usage, such as areas where significant natural habitat value, infrastructure or development is in proximity to a proposed restoration site.

# 4 Legislation Maze – Barrier or Opportunity

## 4.1 Context

The legal and planning context of Britain is complex for a number of reasons, including:

- The number of statutory and non-statutory measures;
- The various administrative and enforcement agencies that must be engaged to obtain relevant permissions;
- The constantly evolving framework as existing measures are revised.

It is not the intention of this document to discuss the legislative and regulatory framework pertaining to the use of dredge spoil within marine conservation areas in detail; this would undoubtedly require attention from a planning expert. However, through research, summaries have been identified that assist in clarification of the planning context and provide succinct information. In addition, discussions have been held with Natural England (NE) and the Environment Agency (EA) to identify salient points with which they may have specific concerns, or view as opportunities.

Most of the existing saltmarsh within the UK, as well as areas with the potential for saltmarsh creation, fall under one or other of the European designations (Natura2000 sites). This means that an Appropriate Assessment (AA) undertaken for all plans or projects deemed likely to have a significant affect on the site's features. This requirement is to demonstrate that any development will not adversely impact on the integrity of the site. In addition an Environmental Impact Assessment (EIA) may also be required to support any application for consents and licenses where impact may be apparent on infrastructure other than natural resources. The scope of any assessment will be governed by the nature, magnitude and location of proposed works.

Finally there are planning requirements to be adhered to in relation to dredging and spoil disposal as well as EU Directives, e.g. the Water Framework. However, through discussion, a general attitude of flexibility was identified and a willingness to work towards robust trials in the Solent system would be encouraged, particularly in the light of successful trials UK elsewhere.

The following sections summarise selection, sediment assessment, legislative, planning and consent requirements that could pertain to saltmarsh restoration and provides outlines of, and links to, resources that may aid interpretation.

## 4.2 Saltmarsh Selection Process

To provide context to the whole process and to further compliment work undertaken through this research, a general model (Nottage and Robertson, 2005) of potential saltmarsh site selection is given (Fig. 4.1). This project benefits from the fact that a discrete list of potential sites was previously provided by the EA and HCC on which digital analysis of erosion rates allowed final choices to be established.

The approach in Figure 4.1 is a simple method which allows consideration of physical habitat. It begins to introduce issues associated with why the saltmarsh may be suitable for restoration and under what auspices this may be achieved (e.g. conservation, flood protection, amongst others). Engineering options may be considered to enhance methods where some of the options are suboptimal (§ 3).

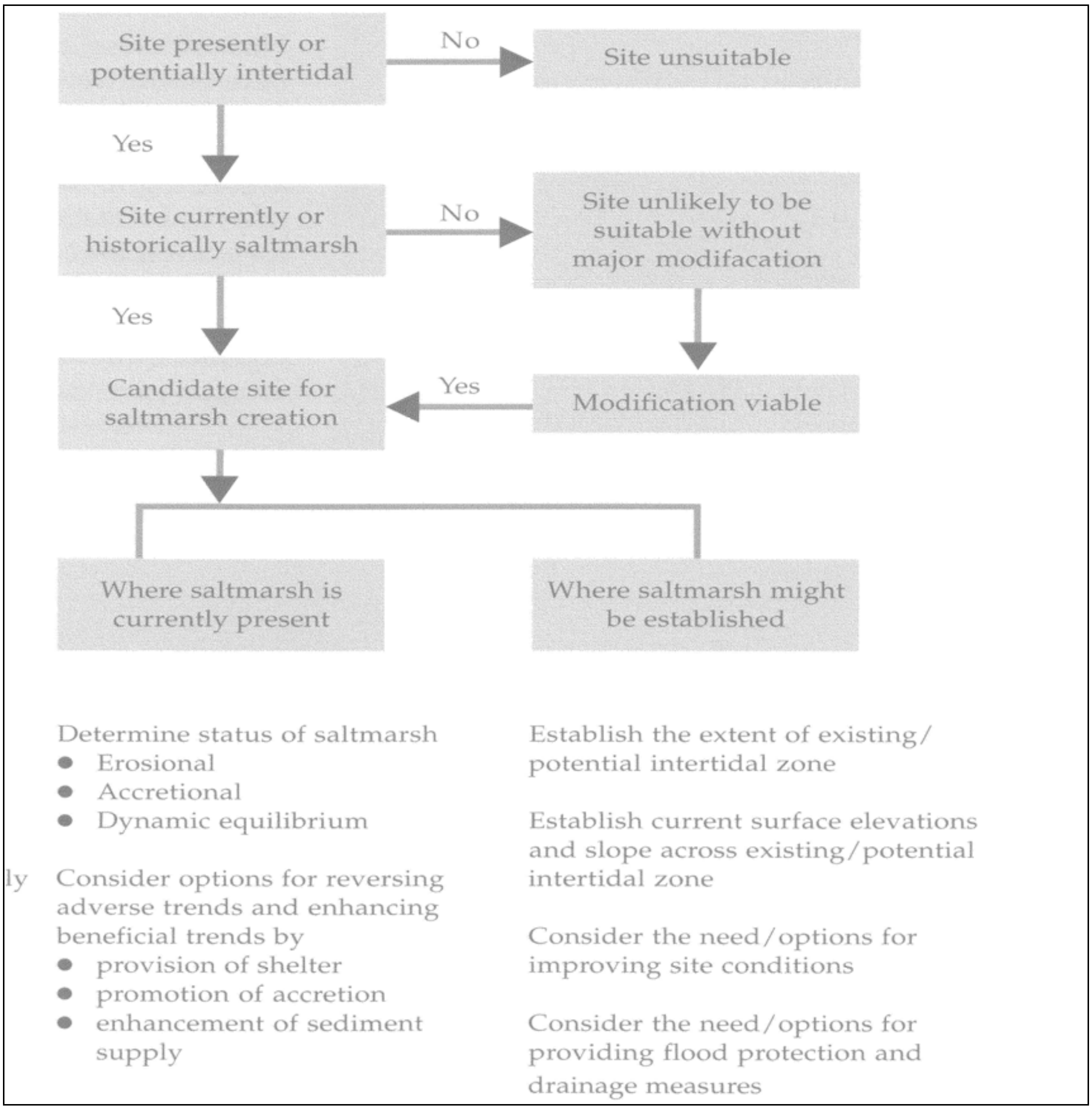


**Figure 4.1 Suggested saltmarsh selection process**
(Nottage and Robertson, 2005)

## 4.3 Dredge Spoil Consideration

Whilst licensing authorities may be viewed as a barrier, some aim to provide opportunities and clarity to beneficial use issues. The Marine Consents and Environmental Unit (MCEU – now the Marine and Fisheries Agency (http://www.mfa.gov.uk/)) was promoting beneficial use of dredged material through the maintenance of a register of sources where the material may be suitable for saltmarsh creation/mudflat recharge (see: http://www.mceu.gov.uk/mceu_local/FEPA/FEPA-beneficial.htm). They also provided a register of material available from potential schemes. To assist with beneficial use aims, MCEU also produced a guidance flow chart (Fig. 4.2). Although the guide was not used in this study (due to pre-selected sites and sediment sources), it may be a useful method for checking the process used to determine dredge spoil disposal and re-use.

Whilst it is envisaged that saltmarsh restoration trials in the Solent will be synchronised with already existing dredging operations (§ 6), dredge operations will still require permissions and licenses to be in place. Where material is dredged and is removed above the waterline, a Food and Environmental Protection Act (FEPA) licence will be required.

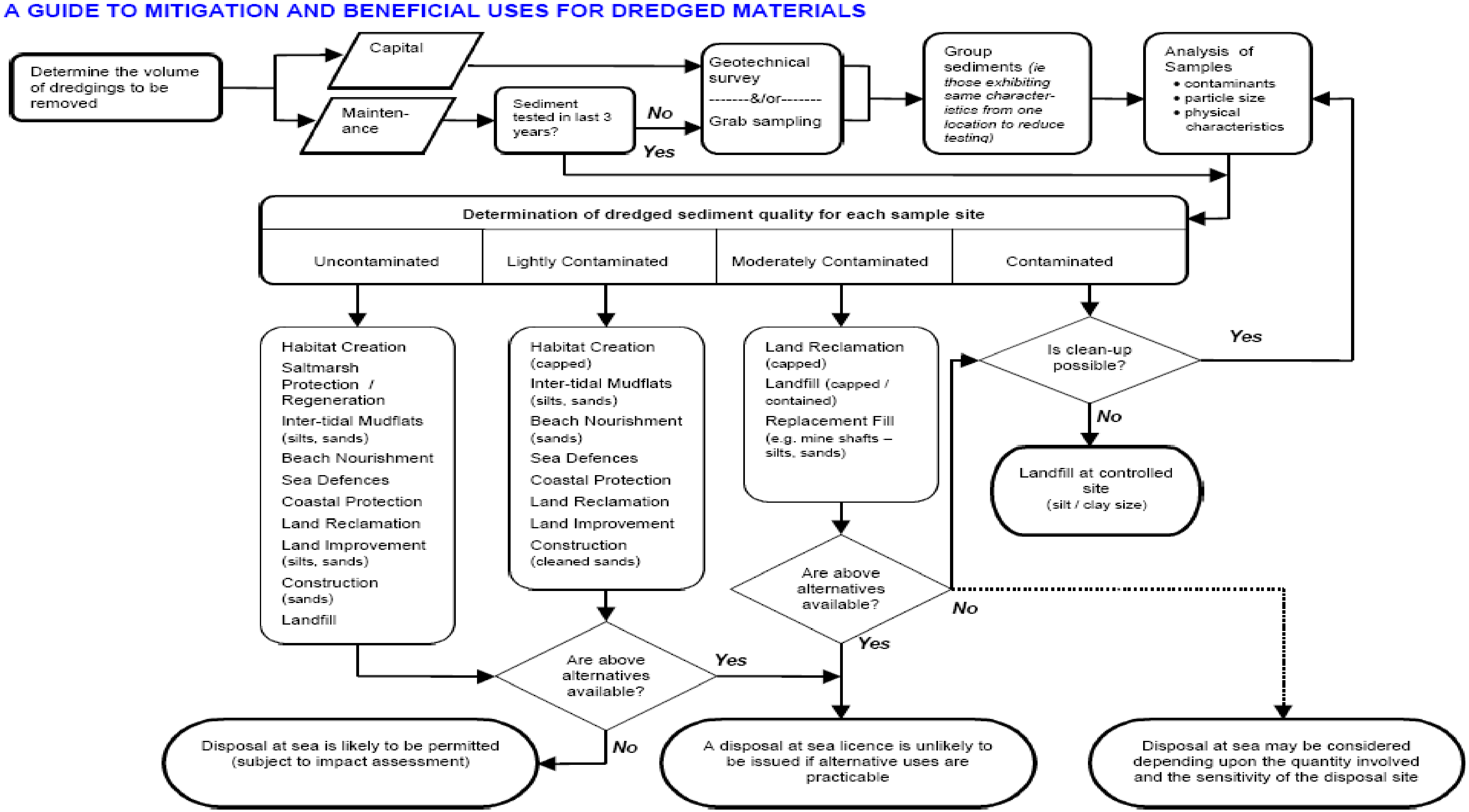


**Figure 4.2 Suggested process of identifying dredge spoil disposal or re-use routes**
(MCEU, 2008)

The MCEU noted that where dredge operations may affect a European site designated under The Conservation (Natural Habitats, &c.) Regulations 1994 (otherwise known as The Habitats Regulations "… *it may be necessary to redeposit dredged material in such a way as to mitigate the adverse impact of the dredging operation to the satisfaction of the relevant competent authorities*" [usually the harbour authority, or ferry operator] (MCEU, 2008). The competent authority will require the support of Natural England/Countryside Council for Wales; a beneficial use licence will possibly also apply and potentially a Coast Protection Act consent (See MCEU, (2008) for more detail).

The above represents what has been interpreted as one of the most significant barriers to saltmarsh restoration, though it is not clear why this is so as the prospect for beneficial use should, if well planned and managed perhaps be regarded as a significant opportunity. Saltmarshes are often encompassed as part of Natura2000 sites for which Natural England is responsible in England. In addition, where not a Natura2000 site, it is likely that other significant conservation legislation will apply. Full details of MCEU guidance to the 1994 Conservation Regulations is available at http://www.mceu.gov.uk/mceu_local/FEPA/conserv-regs.htm.

## 4.4 AA, EIA and Planning

### 4.4.1 Introduction

The beneficial use of dredge material has gained more acceptance from authorities in recent years. The potential environmental benefits of schemes to recharge or recreate intertidal habitats as an offset for harbour development, has been noted by organisations such as Natural England. However, safeguarding the coastal habitats and species of the UK is entailed in a number of regulatory and legislative measures.

### 4.4.2 Appropriate Assessment (AA)

If it has been identified through a screening exercise that works (beneficial use) may have a *significant* effect on the conservation status of a designated (or candidate) Natura2000 site an Appropriate Assessment (AA) will be required (see Regulation 48 of the Habitats Regulations). NB 'Significant effect' is a specific term used by Regulation 48 of the Habitats Regulations, and includes any 'effect' be it adverse or beneficial.

The purpose of an AA is to assess the potential impacts of a scheme on internationally designated nature conservation sites and whether those impacts may be singly or cumulatively significant.

Therefore under Regulation 48, an AA must to be undertaken when any plan or project might:

- either alone, or in combination with other plans or projects, would be likely to have a significant effect on a European Site; and
- is not directly connected with the management of the site for nature conservation

A European Site is any classified Special Protection Area (SPA) and any Special Area of Conservation (SAC) from the point where the Commission and the Government agree the site as a Site of Community Importance. Appropriate Assessment is also required, as a matter of Government policy, for potential SPAs, candidate SACs and listed Ramsar Sites for the purpose of considering development proposals affecting them (English Nature, 1997). In fact the plan or project does not need to be within the designated site. If the project has any potential direct or indirect effect of significance on any European Site then an AA will be required.

In addition, under the Habitats Regulations, no plan or project potentially affecting a European site can be undertaken unless it can be identified that there will be no adverse impact on the integrity of that site, either alone or in-combination with other plans or projects. If this cannot be demonstrated the project may not proceed unless there are no alternative solutions and imperative reasons of overriding public interest. This aims to be a strategic method of identifying impacts and possible mitigation measures order to address the complex issues of in-combination and cumulative impacts.

As a brief guide to AA Figure 4.3 summarises an approach to the consideration of development proposals affecting Natura2000 sites, based on Planning Policy Guidance 9 (PPG9).

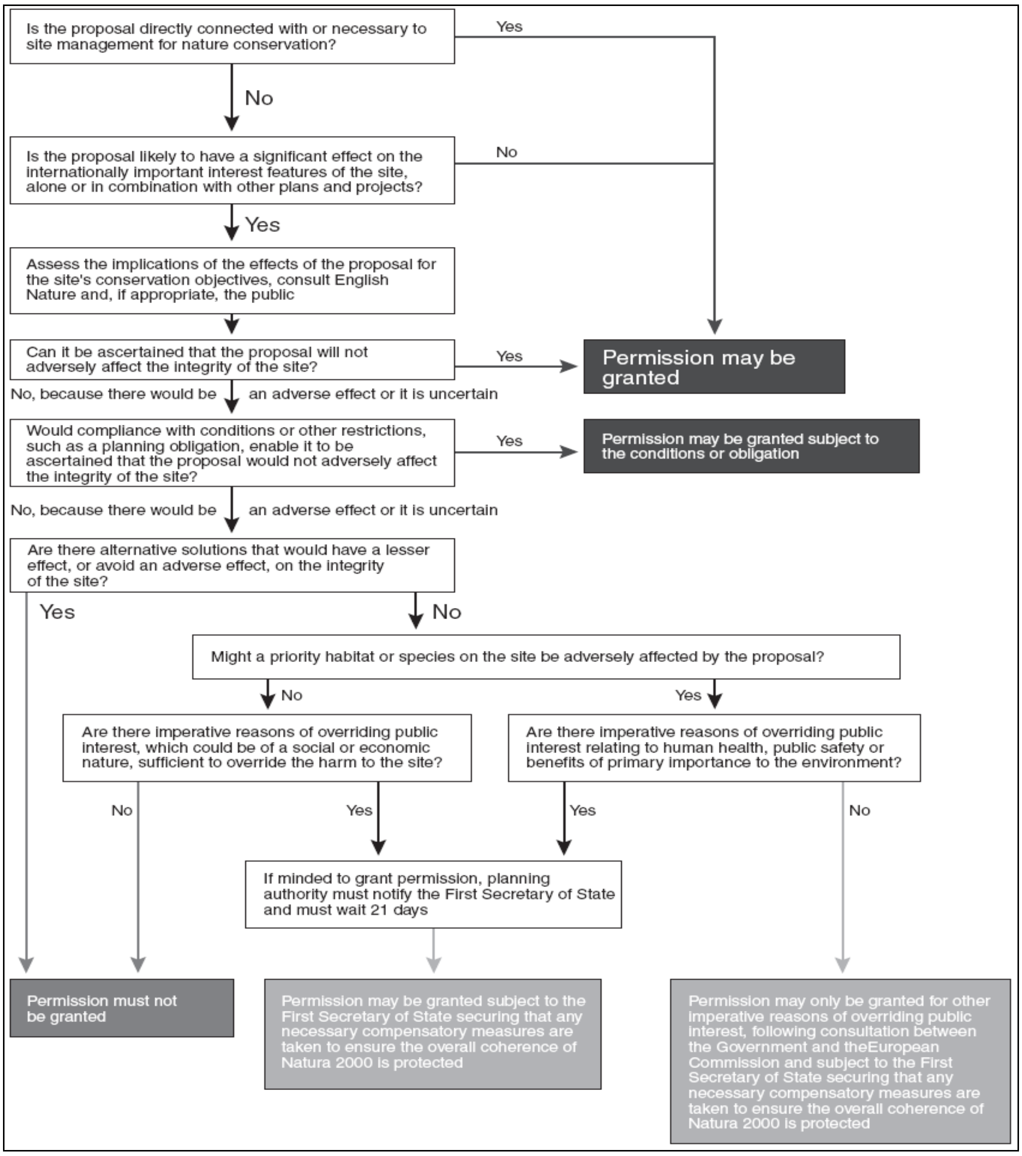


**Figure 4.3 Consideration of development affecting internationally designated sites**
(ODPM, 2005)

### 4.4.3 Environmental Impact Assessment (EIA)

Due to the fact that many saltmarshes and intertidal mudflats are environmentally sensitive, with associated natural assets and local human infrastructure, it is highly likely that in many cases an EIA will need to be carried out prior to commencement of a restoration scheme.

An EIA is an important tool which ensures that the likely effects of any plan or scheme on the environment are understood before the scheme is allowed to go ahead. In cases where the project in question is judged likely to give rise to significant environmental effects, an EIA will need to be undertaken and reported in an Environmental Statement.

The EIA will screen for potentially significant issues, scope out those effects deemed insignificant, then aims to address remaining factors in detail. Information assembled for the EIA can be used when carrying out an Appropriate Assessment under the Habitats Regulations, although the information requirements for EIA and AA are not necessarily the same and each should be scoped separately and then combined if required to achieve efficiencies in data collation. In view of this an English Nature briefing note (1997) suggests that it would be helpful if the relevant EIA clearly identified, under a specific subject heading, the likely significant effects on the internationally important habitats and/or species.

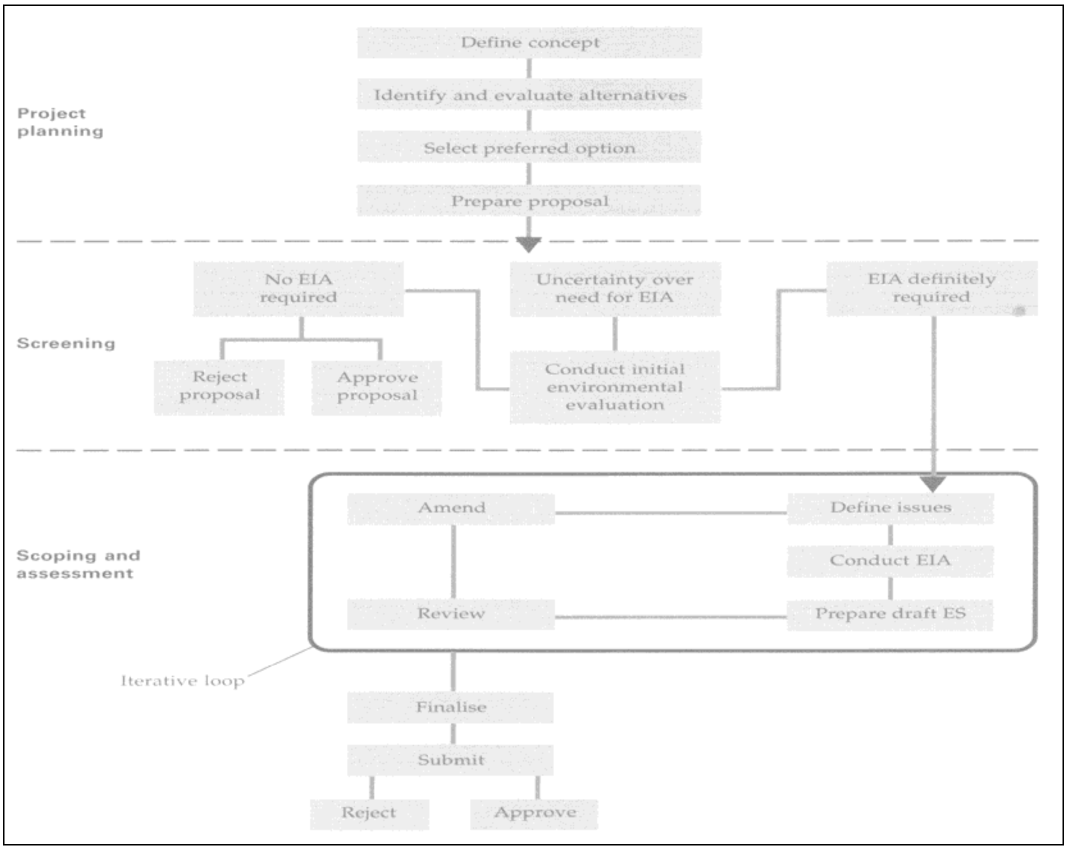


**Figure 4.4 Overview of the EIA process**
Nottage and Robertson, (2005)

### 4.4.4 Planning Requirements

Consideration and integration of relevant planning requirements and licensing is essential to avoid inadvertently undermining the success of saltmarsh creation/restoration projects. In addition to the details given above, the Solent Forum has produced a guide that will assist with specific Marine Consents including beneficial use of dredging (see: ).

A summary of consents applicable to beneficial spoil use is given (Table 4. 1), however it is clearly advised that "*If you are in any doubt, you should always contact the licensing or consenting body for advice, it is far better to do this in the initial stages than find out that you have omitted to gain a consent and cannot carry on with your proposa*l" (Solent Forum, 2006). It is further advised that proposers should remember mitigations and implications associated with the proposal – this will be achieved through formal EIA and AA (where necessary).

TABLE 4.1 RELEVANT MARINE PLANNING CONSENTS (ACTIVITIES BELOW MHWS)
(Modified from Solent Forum, 2005)

| **Activities requiring consent** | **PP[1]** | **PL[2]** | **Land drainage consent** | **Coast protection Act approval** | **Harbour authority consent*** | **PPCP[3]** | **Discharge consent** | **Consent / Licence Additional information** |
|---|---|---|---|---|---|---|---|---|
| Land reclaim | X | X | X | X | X | X | X | |
| Coast protection | X | X | X | X | X | | | |
| Flood defence | X | X | X | X | X | | | |
| Capital dredging | X** | X | X | X | X | | | **Capital and maintenance dredging may be permitted if by Statutory Undertaker or their lessee |
| Maintenance dredging | X** | X | X | X | X | | | |
| Foreshore recharge / beneficial spoil use | X | X | X | X | X | X | | |
| [1]PP - Planning Permission; [2]PL – Planning Licence; [3]PPCP - Pollution prevention/ control permit | | | | | | | | |
| * Harbour authority consent required where the activity takes place in a harbour or the method in the method involved work within the harbour limits. The consent is likely to be in the form of a Works and Dredging Licence. | | | | | | | | |

## 4.5 Regulatory Agency Comments

### 4.5.1 Introduction

During research for this project meetings and discussions were held with the Natural England and the Environment Agency and to highlight specific concerns they may have regarding beneficial use projects. Comments are summarised below.

### 4.5.2 Natural England Responses

On the part of Natural England, the Lyndhurst (Southampton) team expressed interest and encouragement for beneficial use schemes. However, they would wish to see very robust trials undertaken on a research basis for Solent sites. This would be appropriate, as although comments have been made that saltmarsh restoration is advancing at a very slow pace (§ 2.2.2), many of the UK trials that have been undertaken were in Essex and the Solent may demonstrate a significantly different suite of factors. Thus the Natural England team would wish saltmarsh restoration using dredge spoil to be considered on a case by case basis.

Following these comments, further clarification was sought as to what NE would require through a list of targeted questions. It was noted that "*Natural England welcomes consultation on this document and encourages opportunities for habitat creation to conserve and enhance biodiversity and landscapes*" (Natural England, Lyndhust Office, 2009).

Both the questions and the NE responses are detailed below:

1. HCC and the EA requested NE to explain what was meant NE by a "*robust trial"* in the Solent?

   NE stated that *"We need to scope out and develop a trial to ensure that the works will be beneficial and to manage the risks in terms of any potential impacts. We welcome the opportunity to discuss this on a case by case basis, as to the level of detail that will be required*".

2. HCC and EA were pleased that NE are supportive, but would like NE to clarify if beneficial use would constitute as an impact on a Natura2000 site (thus a major stumbling block) or would they take a longer term pragmatic view that beneficial use would be a "management" aim to reverse loss of saltmarsh areas in line with UK and LBAPs - i.e. a more flexible approach?

   NE stated that *"Natural England would look at the specifics of the cases and examine the benefits and risks to the designated sites. We would want to ensure that the risks are managed and we would look at the advantages and disadvantages of each proposal for beneficial use*.

   *"We would prefer a trial study to look at sites where there is minimum risk and maximum benefit. Natural England welcome the opportunity to be involved in a study to look at potential suitable sites, timings and methods with involvement of the Environment Agency, Hampshire County Council and ports industry"*.

3. HCC and EA requested clarification as to if Appropriate Assessment will be necessary in all cases (re Natura2000 sites) or again if point 2 above were feasible, then could the more pragmatic stance be applied?

   NE considered that "*The benefits and disadvantages of a beneficial use project will need to be explored and an Habitats Regulations Assessment is a suitable and necessary way to understand the full impacts of the proposal*".

4. HCC and EA are aware that successful trials and full restoration schemes have been run on East coast [of the UK], so can we clarify what are NE's feelings regarding major stumbling blocks in the Solent.

> NE's opinion is that "*We wish to learn from the lessons of the restoration schemes on the East coast. We look forward to exploring with the Environment Agency, Hampshire County Council and the ports industry* [to discuss] *the opportunities for beneficial use in the Solent and developing a trial investigation*".
>
> "*We recognise the considerable effort that has been given to this project and we would very much like to continue further involvement with this* [work] *as it develops*".

Overall it appears that NE are keen to be a partner in any projects involving dredge spoil restoration trials in the region. They feel that proposals will need to be considered on a case by case basis, that robust trials are undertaken on sites where there is the most minimal feasible risk and that they are mindful of lessons learned from UK East coat projects and how these may be applied to sites in the Solent region.

4.5.3 Environment Agency Responses

Discussions with the Environment Agency (EA) revealed a cautionary approach which highlighted issues regarding water quality, fish passage, biodiversity and flood defence. The EA would have specific concerns with regard to water quality and it is likely that aspects of the Water Framework Directive and the requirements of the Shellfish Waters Directive will apply with sediment possibly being considered as a contaminant. This relates to trace elements/pollutants associated with dredge spoil, and their potential to affect dissolved oxygen levels, bioaccumulate to higher organisms, or to exhibit possible ecotoxilogical effects. In addition trace pollutants may be taken up through saltmarsh plants and if grazed may bioaccumulate to livestock or grazing bird species. These matters would have to be assessed and mitigated where necessary, e.g. through consideration of sediment source (already discussed in this work, § 5.8 and MCEU web site) and appropriate sediment management.

With wider ecology in mind, the EA also wished to highlight noise, turbidity and disturbance impacts on bird populations and migratory fish (e.g. salmon). Careful timing of works often represents appropriate mitigation to avoid such impacts, addressing concerns raised through AA and EIA and making such works acceptable.

It is recognised that the EA is responsible in certain circumstances for flood management and is sensitive to any works that may increase flood risk, particular where human infrastructure may be impacted. Any saltmarsh restoration works would need to demonstrate that such issues had been identified and adequately mitigated in preliminary studies and in agreement with the EA.

Mindful of the Environment Agency's cautionary approach to beneficial use of dredged material in the light of significant constraints such as those outlined above and the need to comply with relevant legislation and policy requirements, it is also a strong advocate of sustainable beneficial use. "*This is particularly so where beneficial use results not only in the protection of existing habitats, but where it can enhance, restore or extend the habitat resource. Indeed the need to create habitat from scratch in order to maintain a status quo where habitat may otherwise be lost through the EA's own activities, may be an essential prerequisite. The EA also has its own targets to create intertidal habitats to meet UK Biodiversity Action Plan (BAP) targets and beneficial use of dredged material may have a vital role to play in the restoration of habitat required under drivers such as the Habitats and Water Framework Directives*" (Holzer, pers com., 2009). As such, the EA wishes to be pro-active in developing the relevant principles, technology, understanding and best practice for beneficial use of dredged material and is a key partner in the current project.

With wider ecology in mind, the EA also wished to highlight noise and disturbance impacts on bird populations and issues regarding fish passage (e.g. salmon) and nursery (e.g. bass) impacts through turbidity, noise and water quality impacts (refer to Water Framework Directive). It is likely that with close cooperation these issues may be ameliorated through timing of works, and could be highlighted in an AA/EIA.

Finally it is recognised that the EA are responsible for flood management and are sensitive to any works that may increase flood risk, particular where human infrastructure may be impacted.

Any saltmarsh restoration works would need to demonstrate that such issues hade been identified and controlled for in preliminary studies and in agreement with the EA.

#### 4.5.4 Other Stakeholders

It has become apparent that Harbour Masters have the difficult poison of finding a balance between the needs of marina/yard operations, boat users/operators and wildlife agencies/regulatory authorities. Preliminary discussions highlighted these sensitive areas and possible legal comeback associated with unwelcome deposition of placed sediment in areas which would leave a Harbour Authority open to legal challenge. Early liaison and full involvement of harbour officials is strongly recommended. This will ensure that their comments and local knowledge are fully encompassed in any proposed trial site. The support and information available from local wildlife officers and wardens who are in a position too have in depth knowledge of many of the Solent sites, is also a valuable resource.

Early collaboration with English Heritage Hampshire and Isle of Wight Trust for Maritime Archaeology would also be highly appropriate as it is recognised that the subtidal and intertidal areas of Solent estuaries may have significant historical association and remains (e.g. Grace Dieu, Hamble River (Friel, 2007)).

Finally it is strongly recommended that general groups who are stakeholders in the use, management (e.g. estuary partnerships) and wellbeing of the Solent region are involved at an early stage. This will promote their backing, give access to a wide knowledge and data resource and provide input on recommended strategies.

# 5. Suitability Criteria: Site Selection for Potential Intertidal Recharge

## 5.1 Introduction

This section outlines the physical criteria for intertidal recharge and the factors which can influence final selection. Potential recharge sites within the Solent between Keyhaven and Pagham will then be identified using these criteria.

Hampshire County Council identified nine potential restoration sites where saltmarshes were currently present. The Environment Agency proposed a further 11 sites, identified by the Solent Dynamic Coast Project (SDCP) (Cope *et al*., 2007) for potential intertidal habitat creation through managed realignment using sediment recharge to increase mudflat height to encourage saltmarsh growth (Figs. 1.6 and 1.7).

## 5.2 Key Factors for Site Selection

The following is a summary of the key factors affecting the success of saltmarsh creation (ABP Research & Consultancy LTD, 1998, Atkinson *et al*., 1998, Atkinson *et al.*, 2001, DEFRA and Environment Agency, 2005, Nottage and Robertson, 2005). The process of saltmarsh creation should ensure that there is no adverse effect on the environment or activities in the surrounding area.

1) **Presence of existing natural saltmarshes** in the proposed area indicates the existence of favourable conditions for saltmarsh creation. This may also supply new sites with saltmarsh propagules and where colonisation is slow, assisted seeding can be considered.
2) **Elevation -** The minimum elevation at the proposed site should be around MHWN, or at a level that would experience 450-500 tidal inundations a year. The elevation of surrounding natural marsh should be considered. In the past the most successful marshes have been approximately 2.1 m OD when breached (or 400-500 tidal inundations per year) with the height of established marsh being 2.34 m OD (<300 tidal inundations). As a general rule, saltmarsh form at site elevations of 2-3 m OD and mudflats elevations of <1 m OD.
3) **Drainage -** Drains increase sediment stability by supplying the marsh surface with sediment and nutrients. This reduces waterlogging, which is detrimental to plant colonisation and survival and dissipating tidal energy. An extensive creek system is required. Experience from the US concluded that sites which are too high do not develop adequate drainage systems and lack habitat diversity (ABP, 1998). The relic creek network should be enhanced. If natural creek development is slow, excavation of a drainage system should be considered. The creation of marsh at the Tollesbury managed realignment site found that creeks did not begin to develop until about 20-30 cm of sediment had accreted on top of an agricultural site surface. This suggests the importance of excavating drainage channels in areas suitable for saltmarsh creation. Therefore, when choosing a site, access for earthmoving vehicles needs to be considered. Without such intervention it is recommended that sites slope gently to level slightly lower than needed for saltmarsh development as natural saltmarsh drainage will form in the accreting sediment, producing marshes of better quality and diversity.
4) **Surface gradient -** Site gradient determines species biodiversity, with more natural slope giving greater habitat diversity. Flat sites may result in poor diversity dominated by pioneer or low marsh species; optimum is 1-2% (<1:50).
5) **Soil grain size -** Sediment grain size, composition and porosity affect drainage characteristics and organic content, and can influence the elevation of species colonisation and the outcome of plant competition. Finer sediments would be best to use in saltmarsh restoration.
6) **Sediment Supply -** Sediment supply needs to maintain an accretion rate sufficient to offset predicted sea level rise. The presence of healthy marshes close to a proposed site would indicate a suitable location in terms of sediment supply.
7) **Contamination -** Areas away from major pollutant sources are preferable.
8) **Land Conservation Value -** Sites selected for saltmarsh creation should not have a high conservation value (such as SSSIs, Ramsar sites etc). Areas designated due to conservation value in the UK are available from Natural England (http://www.english-nature.org.uk/pubs/gis/gis_register.asp).

9) **Local Economic/Recreational Activities -** All current activities such as oyster and mussel farms in the vicinity of the proposed site should be mapped and checked that they are not likely to be adversely affected by the creation of the recharge site. In addition sites may have important recreational/amenity value that will be affected by a recharge scheme. Mitigation measures to offset associated impacts may be expensive. For example, at Freiston, the implications of managed realignment on oyster farms were not considered. Following the breach of the site, large volumes of sediment drained off and caused rapid channel deepening and erosion. Suspended sediment was washed through an oyster farm on to mudflats south of the site causing siltation and burial of oyster racks, which had to be moved at considerable cost (DEFRA and Environment Agency, 2005).
10) **Accessibility -** Sediment retention at disposal sites may be problematic. The behaviour of fine material is difficult to predict unless protected in some way or placed in quiescent locations. When selecting intertidal areas for recharge, consideration of the accessibility and costs for appropriate vessels/plants/machinery to handle the material and the possible indirect ecological impacts of sediment re-suspension must be considered; for example re-suspended material may smother adjacent saltmarsh or shellfish areas.

These criteria will be applied, where possible, to the sites below in a multi-criteria assessment (MCA). The MCA is an appropriate tool since it allows qualitative analysis but can also incorporate quantitative data where it is available. This allows data to be compared and gives a ***framework*** for decision makers to identify potentially suitable sites. A “traffic light” system has been chosen to allow the criteria to be compared. **NB**: the qualitative analysis is therefore highly simplified, and the judgements of the research team should be tested by a stakeholder group before decisions are made.

## 5.3 Method for identifying sites

### 5.3.1 Outline

To rank potential intertidal recharge sites, a number of priority factors were identified. Firstly, it was necessary to identify saltmarsh loss rates and to quantify historic saltmarsh areas, enabling assessment of restoration need. Secondly, existing/potential mudflat areas had to be identified, as well as the sediment requirement to convert these areas to saltmarsh. Each of the sites were then assessed against the key factors summarised in section 5.2. Finally, it was necessary to identify suitable potential sources of sediment from maintenance dredge sites within the Solent to use for recharge.

### 5.3.2 Historic Rates of Saltmarsh Loss

Site saltmarsh change rates driven by local factors such as *Spartina* dieback, wave attack, sea level rise, dredging, reclamation, development and pollution were identified through aerial photography interpretation (Civco *et al*., 1986). The Solent Dynamic Coast Project (Cope *et al*., 2007) quantified saltmarsh loss between the 1940s and 2002 through historic aerial photography interpretation. The aerial photography was obtained from a variety of sources, including the National Monuments Record Centre (NMR) and local authorities. Aerial photographs were scanned, geo-rectified and mosaiced and saltmarsh areas digitised. The majority of aerial photographs were taken between April and September at low tide at a scale of approximately 1:10,000. The average error for the historic photography geo-rectification and digitising was approximately +/- 6 to 12 m (1940’s-1991) and +/- 2.2 m for photography taken after the year 2000. Saltmarsh loss in each location was calculated from these data.

### 5.3.2 LiDAR and Tidal Level Interpretation

The duration and frequency of tidal inundation in relation to land elevation and gradient is one of the most crucial factors promoting mudflat and saltmarsh development. Inappropriate elevations have resulted in the failure of a number of schemes in the USA (Pontee, 2003).

Elevation influences the frequency and duration of tidal inundation, as well as the exposure to wave action, all of which effect primary colonisation (Pontee, 2003). Colonisation of the saltmarsh or mudflats by vegetation can only commence once the surface level has been raised sufficiently high in the tidal frame by physical sedimentation (Joint Nature Conservation Committee (JNCC), 2004). Williams and Lester (1994) found that the intertidal zone in North

West Europe typically showed a distinct landward zonation from mudflats through to low or pioneer marsh, middle marsh, high marsh and on to terrestrial vegetation (Fig. 5.1).

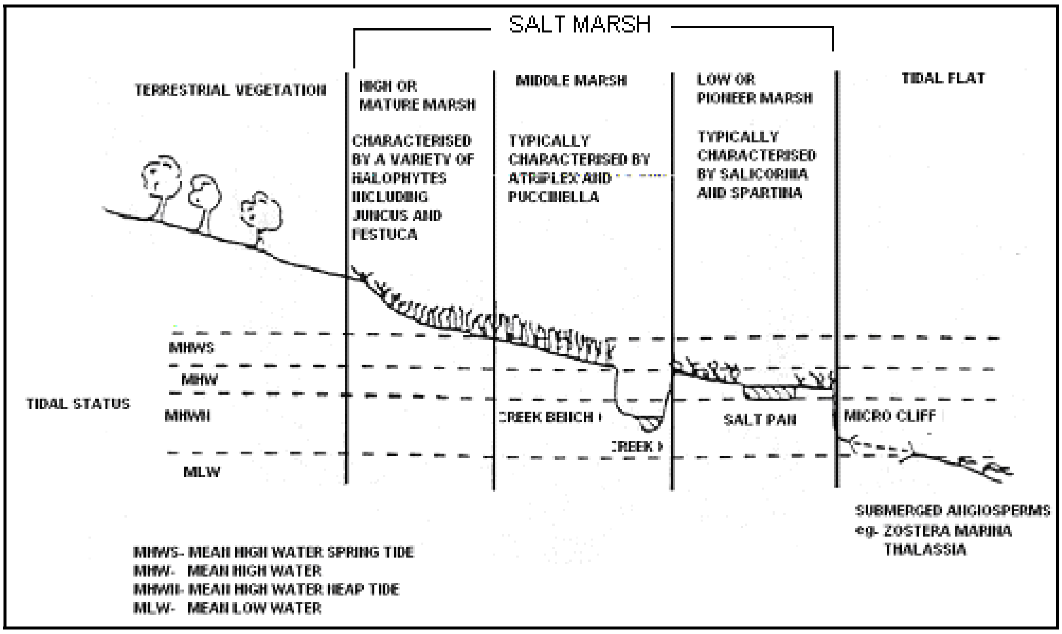


**Figure 5.1 Profile of tidal flat to saltmarsh progression in North West Europe**
(Williams and Lester, 1994)

Mudflat exists between lowest astronomical tide (LAT) and mean high water neap (MHWN), whilst saltmarsh colonise between MHWN and highest astronomical tide (HAT). The range of individual species is a combination of their relative ability to tolerate tidal submergence, or factors related to tidal submergence such as soil anaerobics and competition with increasing elevation (Gray, 1992).

Based on this, LiDAR data were "flooded" to corresponding tidal elevations to determine expected ranges of intertidal habitat coverage. Tidal levels for the region were interpolated for the different saltmarsh areas from 2007 tidal data (Table 5.1).

TABLE 5.1 TIDAL DATA FOR THE SOLENT REGION
(All figures given in metres) (Proudman Oceanographic Laboratory, 2007)

| Port Name | Northing | Easting | HAT | MHWS | "MHW" | MHWN | LAT |
|---|---|---|---|---|---|---|---|
| **Hurst Point** | 431776 | 89089 | 1.06 | 0.87 | 0.67 | 0.47 | -1.55 |
| **Lymington** | 432907 | 96509 | 1.53 | 1.34 | 1.08 | 0.81 | -1.92 |
| **Bucklers Hard** | 441104 | 100274 | 1.73 | 1.41 | 1.06 | 0.71 | -2.51 |
| **Warsash** | 449272 | 105905 | 2.13 | 1.76 | 1.41 | 0.71 | -2.40 |
| **Southampton** | 442203 | 109549 | 2.19 | 1.89 | 1.49 | 1.08 | -2.78 |
| **Calshot Castle** | 449307 | 102198 | 2.19 | 1.76 | 1.36 | 0.96 | -2.44 |
| **Bursledon** | 449237 | 109611 | 2.29 | 1.86 | 1.46 | 1.06 | -2.58 |
| **Lee-on-the-Solent** | 456371 | 100417 | 2.13 | 1.76 | 1.36 | 1.06 | -2.34 |
| **Portsmouth** | 462243 | 100483 | 2.39 | 1.98 | 1.55 | 1.12 | -2.59 |
| **Northney** | 472760 | 104327 | 2.59 | 2.16 | 1.61 | 1.06 | -3.06 |
| **Bosham** | 479801 | 104430 | 2.55 | 2.16 | 1.66 | 1.16 | no value |
| **Dell Quay** | 483352 | 102632 | 2.55 | 2.16 | 1.66 | 1.16 | no value |
| **Itchenor** | 479858 | 100724 | 2.45 | 2.06 | 1.56 | 1.06 | -2.89 |
| **Chichester Harbour** | 475188 | 98801 | 2.51 | 2.05 | 1.61 | 1.16 | -2.53 |
| **Pagham** | 490492 | 97190 | 3.16 | 2.55 | 1.90 | 1.25 | -3.16 |
| **Selsey Bill** | 485852 | 93405 | 2.81 | 2.30 | 1.75 | 1.25 | -3.02 |

LiDAR accuracy was 2 m in the x, y and +/- 15 cm in the z direction. UK, experience has shown that saltmarsh recreation proceeds best between elevations of mean high water neap (MHWN) and mean high water spring tides (MHWS) (Pontee, 2003).

The generated intertidal areas were compared to past and present aerial photography to verify the extent of saltmarsh and mudflat. At potential managed realignment sites, areas were similarly flooded behind the existing defences to determine potential intertidal areas. To calculate the volume of existing mudflat and saltmarsh areas, the intertidal area was converted to a 3D profile using heights from the LiDAR data in ARCView 9.2 from which surface area and volume calculations above a plane (LAT) could be derived. To determine the volume of sediment required to convert the mudflat to saltmarsh, the existing mudflat area was converted to a 3D profile of specified height, the volume above LAT was recorded and the initial mudflat height subtracted. The levels chosen were MLWN, MHW and MHWS as pioneer species establish between MLWN and MLW and mid/upper species between MLW and MHWS. Sediment volumes required to extend marsh edge by 5 m, 20 m, 50 m, and 100 m over the mudflat was calculated to simulate accretion and the required sediment volume calculated (Fig. 5.2). To estimate the volume of sediment required to re-establish previous historic saltmarsh areas, results were interpolated against the historic saltmarsh surface areas, this was achieved by applying a trendline to data, which obtained the r- squared value closest to 1 (perfect correlation). The equation for the Pearson product moment correlation coefficient, r, is:

$$r = \frac{\sum(x-\bar{x})(y-\bar{y})}{\sqrt{\sum(x-\bar{x})^2\sum(y-\bar{y})^2}}$$

*where x and y are the (known_x's) and (known_y's) and $r^2$ is the square of this correlation coefficient.*

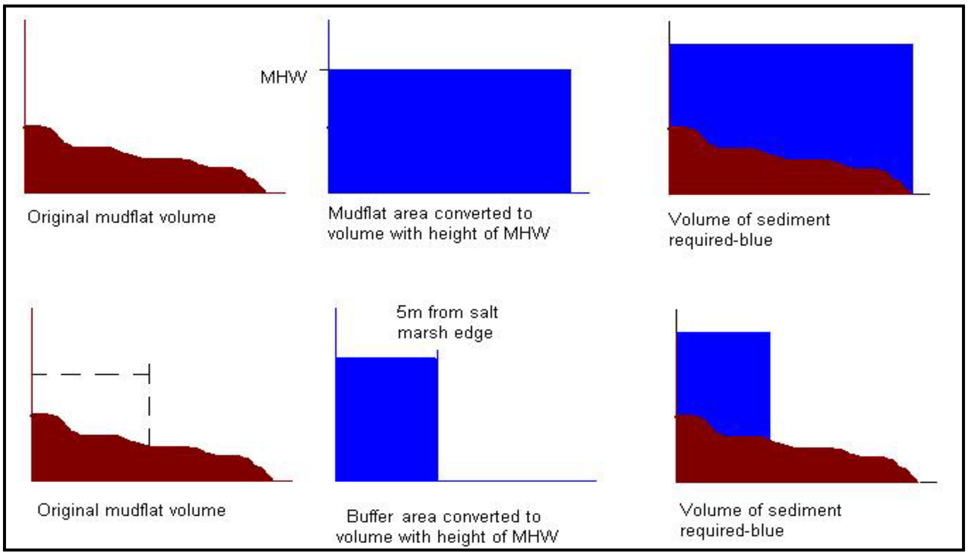


**Figure 5.2 Calculating volumes of sediment to convert mudflat to saltmarsh**

### 5.3.3 Dredging Data

Dredging data were obtained from CEFAS and was provided by licence number and dumping site; a list of the abstraction sites, with latitude and longitude co-ordinates and contaminants, were also provided. Data were combined to give a list of Solent maintenance dredging sites and associated volumes. Recommended sites are defined as those which are experiencing saltmarsh erosion, require a minimum volume of sediment to increase the saltmarsh area and have a nearby source of appropriate dredge material to raise mudflat height to levels suitable for saltmarsh growth.

## 5.4 Results: Hampshire County Council Sites

The results of analysis will now be presented on a site by site basis. Historical rates of saltmarsh are given for Hampshire County Council Sites. This is followed by figures showing the volume of sediment required to increase mudflat heights to a level suitable for saltmarsh growth. These are then interpolated to determine the volume of sediment required to return the saltmarsh to historic levels. All figures are given in $m^2$ rather than hectares to be comparable with dredging data in later chapters (10,000 ha is equivalent to 1 ha). Finally each site will be assessed in an MCA against the 10 factors in Section 5.3.2 (where data are available).

### 5.4.1 Keyhaven: Introduction

The Keyhaven (SU SZ 306 908) marshes consist of intertidal mudflats and Atlantic salt meadows. They are jointly owned by New Forest District Council (NFDC), HCC and private owners. They currently have a medium to high recreational use (Cope *et al*., 2007) with the area being used for walking, bird watching, fishing and bait digging. Numerous rights of way run through the site and NFDC is investigating enhanced site access. The marshes contain archaeological remains of a sea salt industry and also grade 2 listed buildings. The marshes are conservation areas covered by SSSI, Ramsar and SPA designations. Locally there are intertidal berths for both recreational and small commercial users. There are some residential and yacht club properties within 200m of the upper extent of the marsh.

### 5.4.2 Keyhaven: Historic Saltmarsh Change

The total saltmarsh extents for 1971, 1984 and 2001 are shown at Keyhaven. Since 1971 there has been a total loss of 649,497 $m^2$ from saltmarsh at Keyhaven at a rate of 1.27% per year (Table 5.2; Figs. 5.3 and 5.4). Keyhaven lies directly behind Hurst Spit and is prone to edge erosion from south-easterly wave attack, internal desiccation is also clear (Fig. 5.4).

TABLE 5.2 HISTORIC SALTMARSH CHANGE - KEYHAVEN
(Based on HPI)

| Year | Surface Area $m^2$ | Data Source | Period | Total loss $m^2$ | % loss | % loss pa |
|---|---|---|---|---|---|---|
| **1971** | 1,424,545 | Champ/CCO | 1971-2007 | 649,497 | 45.59 | 1.27 |
| **1984** | 1,171,473 | Champ/CCO | 1984-2007 | 396,425 | 33.84 | 1.47 |
| **2001** | 823,197 | Champ/CCO | 2001-2007 | 48,149 | 5.85 | 0.97 |
| **2007** | 775,048 | LTEI | | | | |

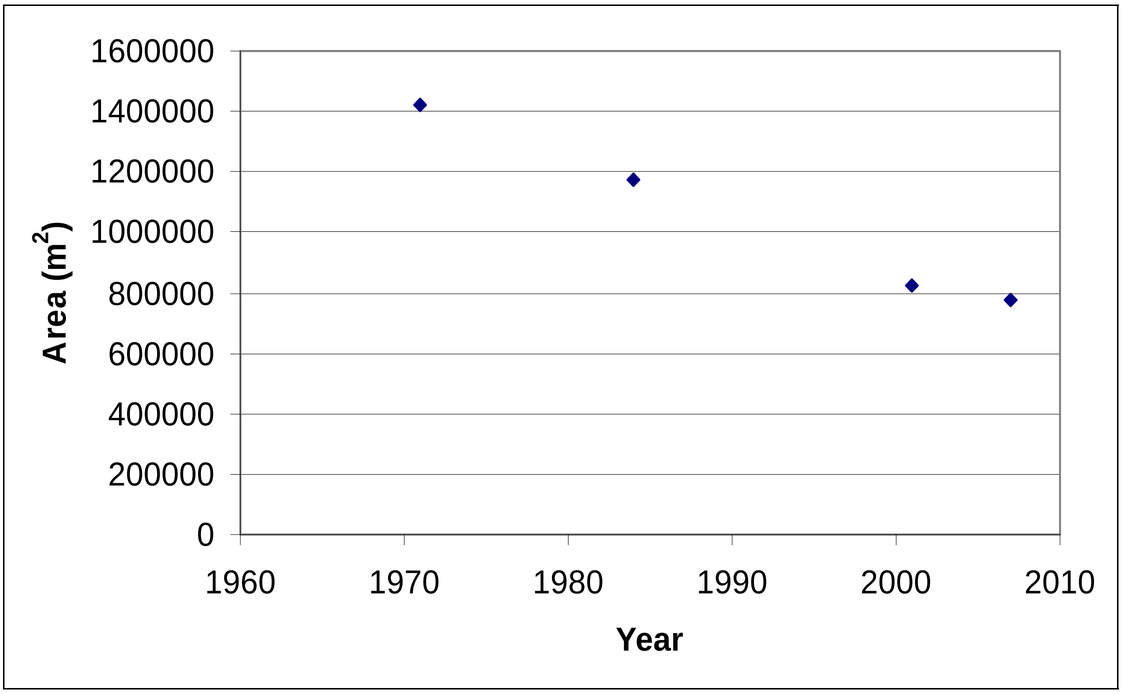


**Figure 5.3 Historic saltmarsh change - Keyhaven**

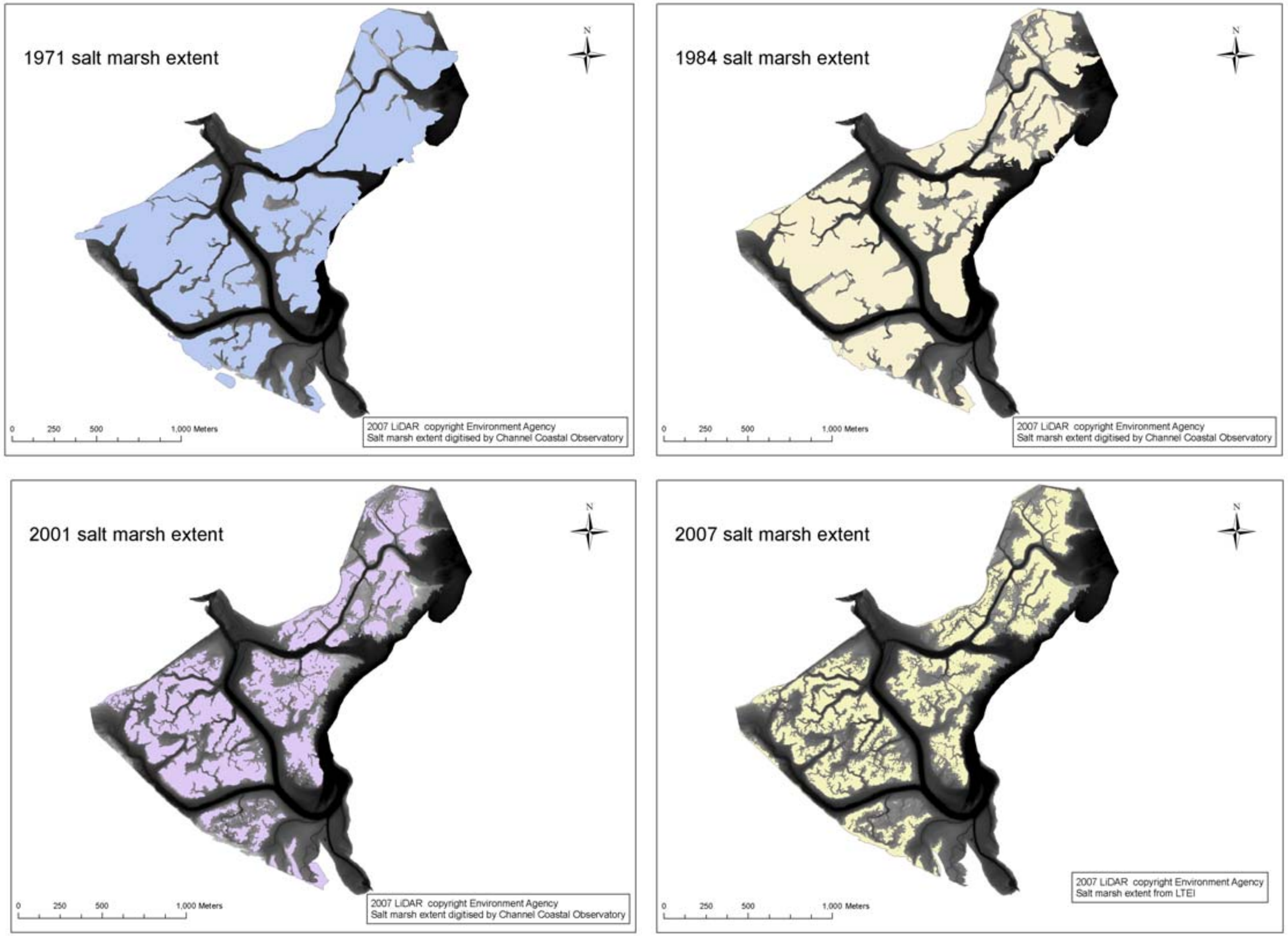


**Figure 5.4 Saltmarsh extents 1971-2007 - Keyhaven**

The majority of the Keyhaven site is at a height of between 0.5 and 2.5 m above O.D (Fig. 5.5).

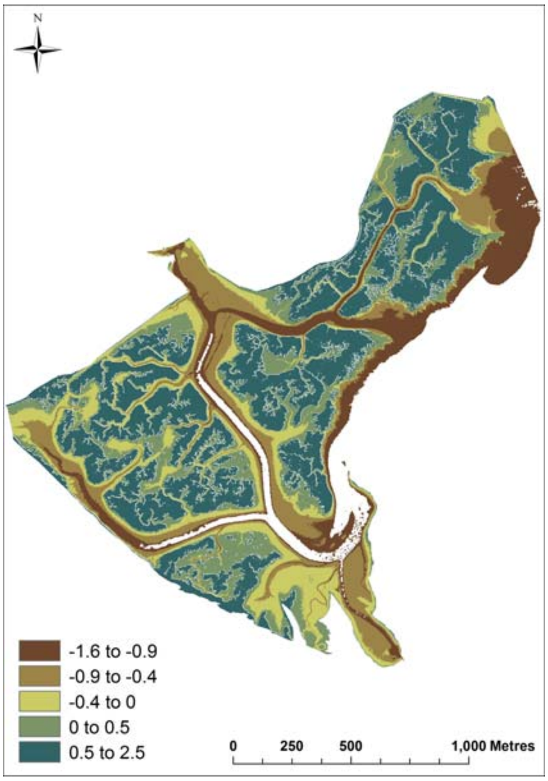


**Figure 5.5 Heights of the Keyhaven site relative to OD**

5.4.3 Keyhaven: Volume Requirements for Mudflat Recharge

The area selected for potential sediment recharge is shown (Fig. 5.6). Saltmarsh and mudflat extent was derived from LTEI (LiDAR Tidal Elevation Interpretation).


**Figure 5.6 Area selected for potential mudflat recharge- Keyhaven**

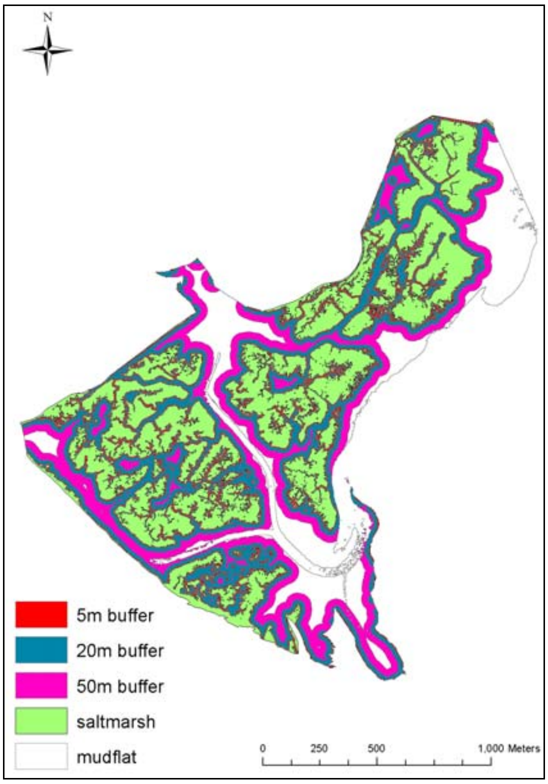


**Figure 5.7 Existing saltmarsh and potential saltmarsh buffers - Keyhaven**

Results show the sediment volumes required to increase the existing mudflat area to a height which would encourage establishment of saltmarsh species. The extent of the saltmarsh buffers to calculate volume requirements is shown in Fig 5.7 and sediment volumes given in Table 5.3.

TABLE 5.3 SEDIMENT VOLUME TO CONVERT MUDFLAT TO SALTMARSH - KEYHAVEN

| | Surface Area $m^2$ | % mudflat surface area converted | Volume of sediment required $m^3$ | | |
|---|---|---|---|---|---|
| | | | mhws | mhw | mhwn |
| **5m** | 198,817 | 15 | 162,357 | 114,641 | 68,913 |
| **20m** | 596,643 | 46 | 569,651 | 426,457 | 289,229 |
| **50m** | 965,077 | 75 | 1,027,904 | 796,285 | 574,317 |
| **mudflat** | 1,287,821 | 100 | 1,545,539 | 1,236,461 | 940,263 |

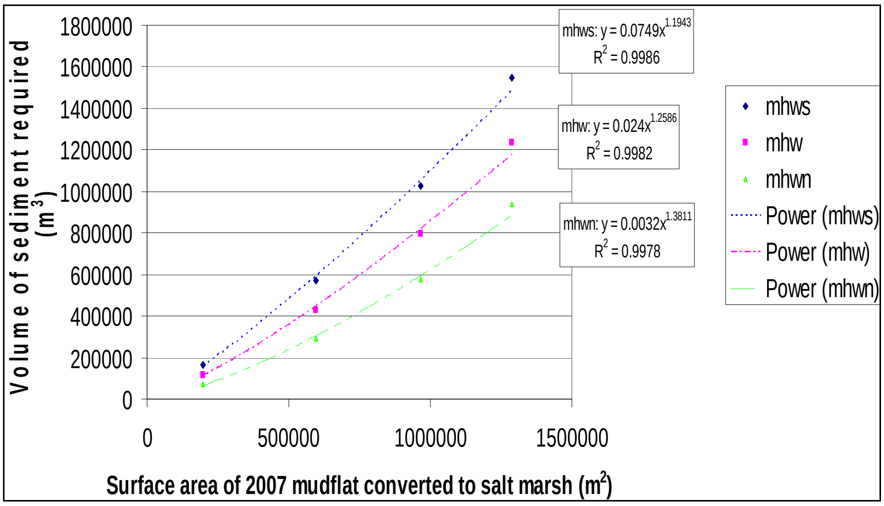


**Figure 5.8 Sediment volume to convert mudflat to saltmarsh - Keyhaven**

Fig 5.8 shows interpolation for volume requirements to re-establish historic saltmarsh for the different years the extents are given in Table 5.4. This indicates that a volume of 344,154 $m^3$ of sediment would be the minimum required to re-establish 1971 saltmarsh areas.

TABLE 5.4 SEDIMENT VOLUME TO RE-ESTABLISH SALTMARSH - KEYHAVEN

| Year | Surface Area $m^2$ | Volume of sediment required $m^3$ | | |
|---|---|---|---|---|
| | | mhws | mhw | mhwn |
| **1971** | 653,682 | 660,350 | 500,532 | 344,154 |
| **1984** | 400,610 | 367,970 | 270,269 | 175,012 |
| **2001** | 52,334 | 32,369 | 20,858 | 10,526 |

5.4.4 Keyhaven: Multi Criteria Analysis

**Presence of existing natural saltmarshes** – indicates the existence of favourable conditions for saltmarsh creation – there are extensive existing saltmarshes immediately adjacent to the site: GREEN.

**Elevation –** most successful marshes have been approximately 2.1 m OD – majority of site between 0.5 and 2.5 m above O.D. (Fig 5.5 above): GREEN.

**Drainage** – an extensive creek system is required – extensive existing creek system: GREEN.

**Surface gradient –** optimum is approximately 1-2% (<1:50) – calculated mean slope for Keyhaven saltmarsh is 2.25% (Fig 5.9): GREEN.

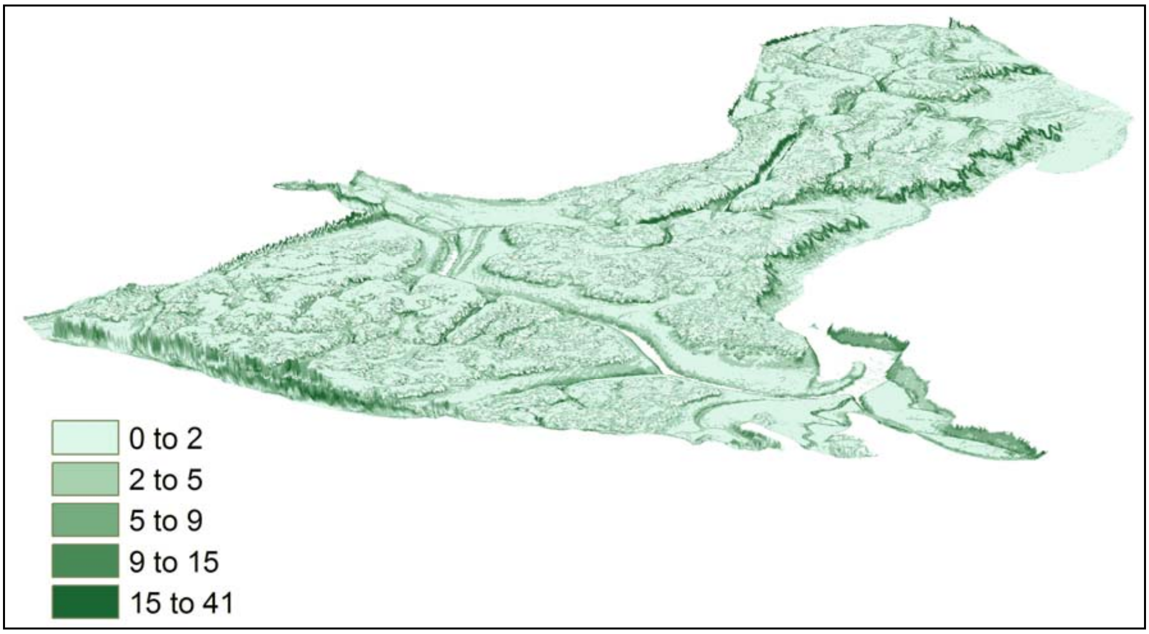


**Figure 5.9 Mean slope (%) for Keyhaven saltmarsh site**

**Soil grain size –** sediment grain size, composition and porosity of the dredge sediments used will affect drainage characteristics and organic content – composition of dredged sediment to be used for recharge is unknown: AMBER

**Sediment Supply –** presence of healthy marshes close to a proposed site would indicate a suitable location in terms of sediment supply – extensive marshes nearby but widespread erosion: AMBER.

**Contamination –** areas away from major pollutant sources are preferable – moderate boating use and a potential for antifouling / hydrocarbons: AMBER.

**Land Conservation Value -** sites selected for saltmarsh creation should not have a high conservation value (such as SSSIs, Ramsar sites etc.) – Keyhaven site designated SSSI, Ramsar, SPA: RED.

**Local Economic/Recreational Activities –** all current activities should be checked that they are not likely to be adversely affected by the creation of the recharge site - potential shellfishery (Ostrea edulis), which may be impacted through sediment drift and high volumes of recreational boating: AMBER.

**Accessibility** – when selecting areas for recharge, consideration of the accessibility and costs for appropriate vessels/plants/machinery to handle the material must be considered – reasonable accessibility for vessels, but poor accessibility for plant / machinery from land side: AMBER.

### 5.4.5 Pennington: Introduction

The Pennington (SZ 328 924) marshes consist of intertidal mudflats and Atlantic salt meadows and are jointly owned by NFDC, HCC and numerous private owners. They currently have a medium to high recreational use (Cope *et al*., 2007) with the area being used for walking, bird watching, fishing and bait digging. Numerous rights of way run through the site and the marshes are subject to SSSI, Ramsar and SPA designations. No residential or commercial properties are within the immediate area of the nearby shoreline, there is, however, a wastewater treatment outfall nearby.

### 5.4.6 Pennington: Historic Saltmarsh Change

There has been rapid erosion of the saltmarsh at Pennington, which has declined in area from 49,028 $m^2$ in 1971 to 107 $m^2$ in 2007 (Table 5.5 and Fig 5.10). Pennington is more exposed to wave action than Keyhaven, which is protected by Hurst Spit (although erosion has increased at Keyhaven due to factors currently unclear). In addition, coastal erosion within the western Solent has resulted in the ability of large waves from Christchurch Bay to enter at Hurst Narrows. Combined with increased wave energy due to the erosion of surrounding saltmarsh, Pennington marsh itself is experiencing increased wave action (RACER, 2004) and shows spatial decline (Fig. 5.11).

TABLE 5.5 HISTORIC SALTMARSH CHANGE - PENNINGTON
(Based on HPI)

| Year | Surface Area $m^2$ | Data Source | Period | Total loss $m^2$ | % loss | % loss pa |
|---|---|---|---|---|---|---|
| **1971** | 49,135 | Champ/CCO | 1971-2007 | 49,028 | 99.78 | 2.77 |
| **1984** | 21,423 | Champ/CCO | 1984-2007 | 21,316 | 99.50 | 4.33 |
| **2001** | 5,613 | Champ/CCO | 2001-2007 | 5,506 | 98.09 | 16.35 |
| **2007** | 107 | LTEI | | | | |

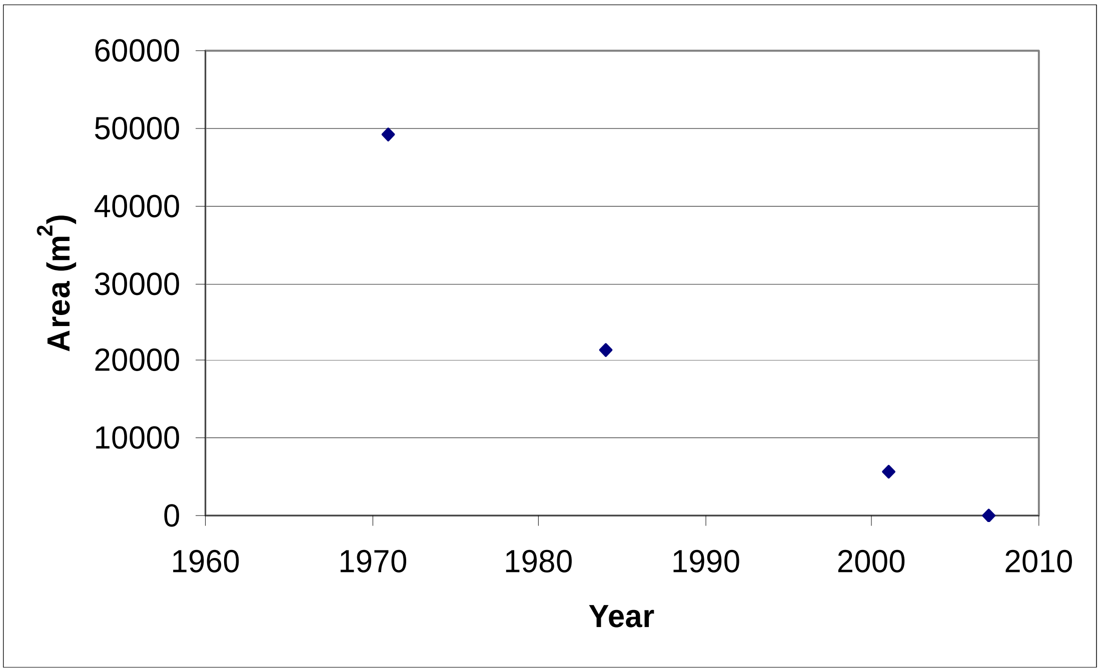


**Figure 5.10 Historic saltmarsh change - Pennington**

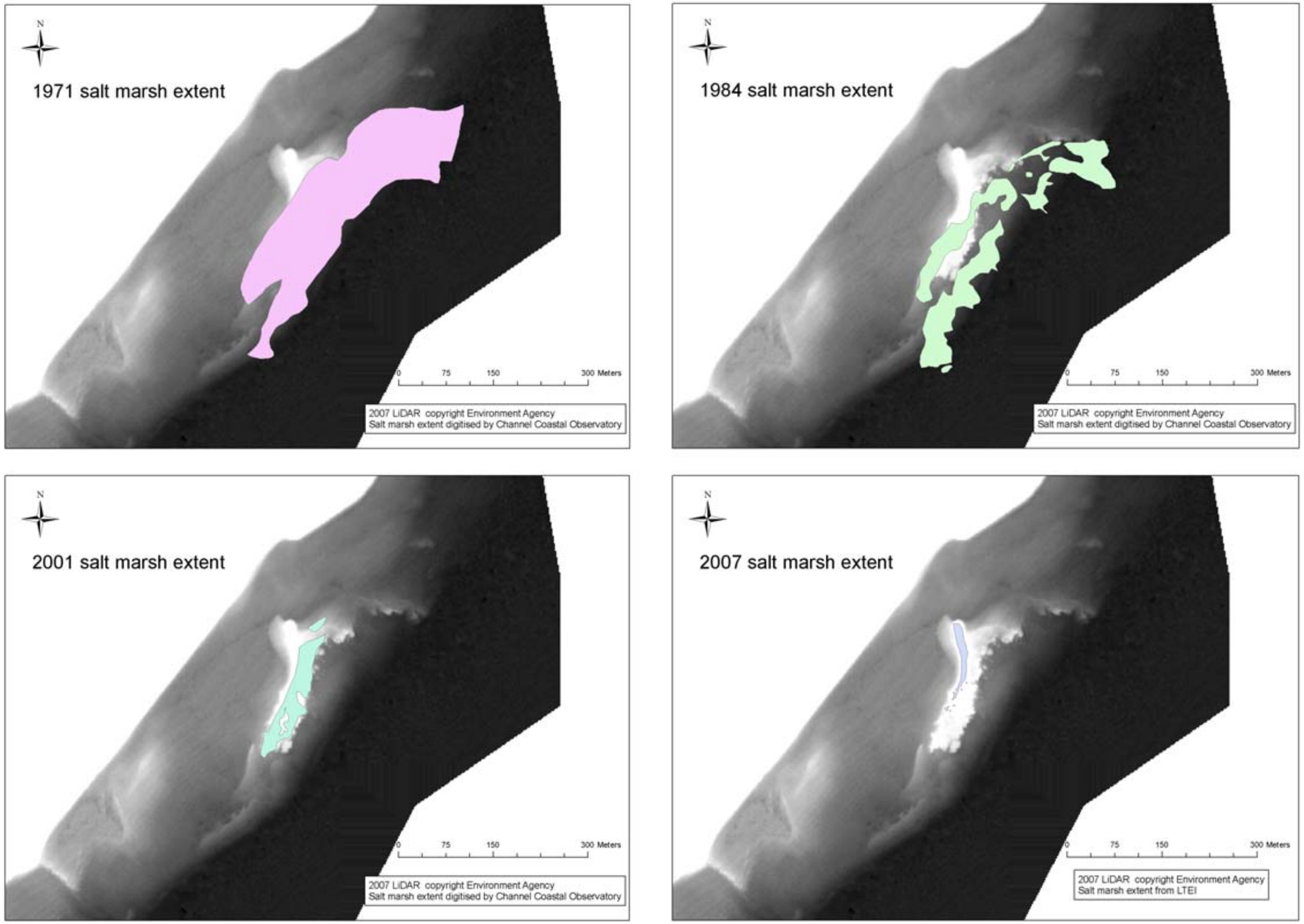


**Figure 5.11 Saltmarsh extents 1971-2007 - Pennington**

The heights of the Pennington saltmarsh are between -1.9 and 1.19m above OD (Figure 5.12).

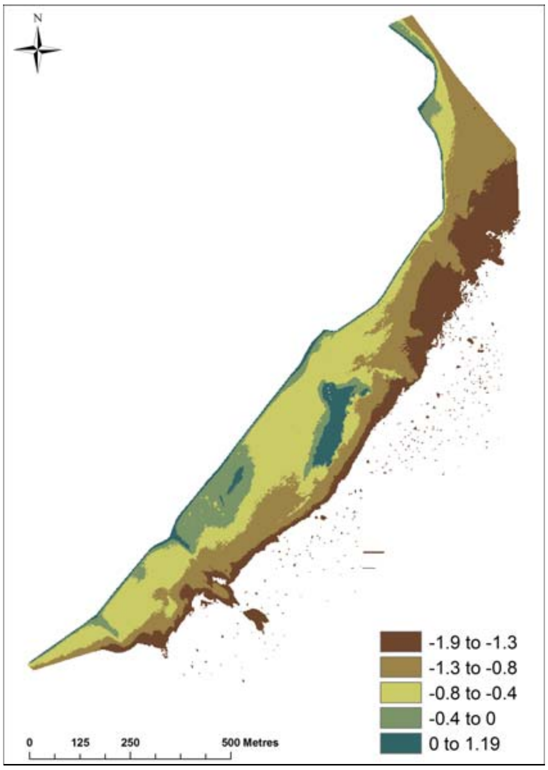


**Figure 5.12 Heights of Pennington saltmarsh relative to OD**

5.4.7 Pennington: Volume Requirements for Mudflat Recharge

The area of mudflat at Pennington is extensive, potentially due to wave exposure, resulting in restriction of the accretion of sediment to levels suitable for the development of saltmarsh (Figs. 5.13 and 5.14). The volume of sediment required to convert the complete area of mudflat at Pennington to a level suitable for saltmarsh growth would be 429,963 $m^3$ (Table 5.6).

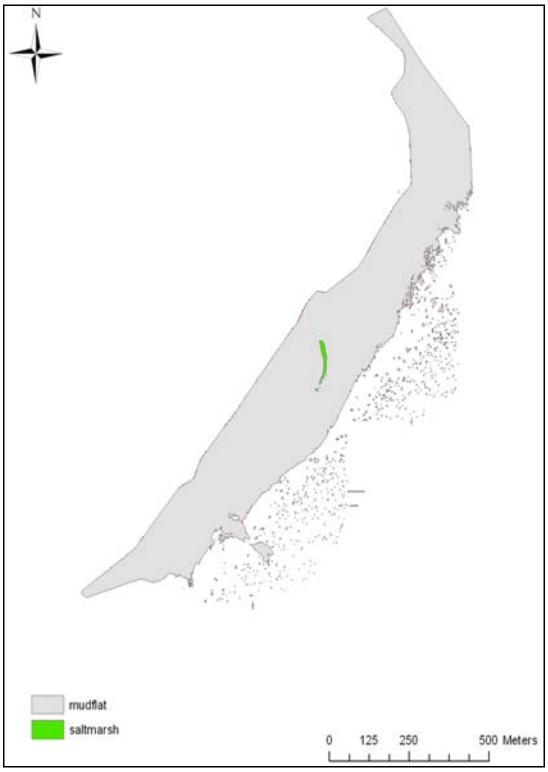


**Figure 5.13 Area selected for potential mudflat recharge - Pennington**

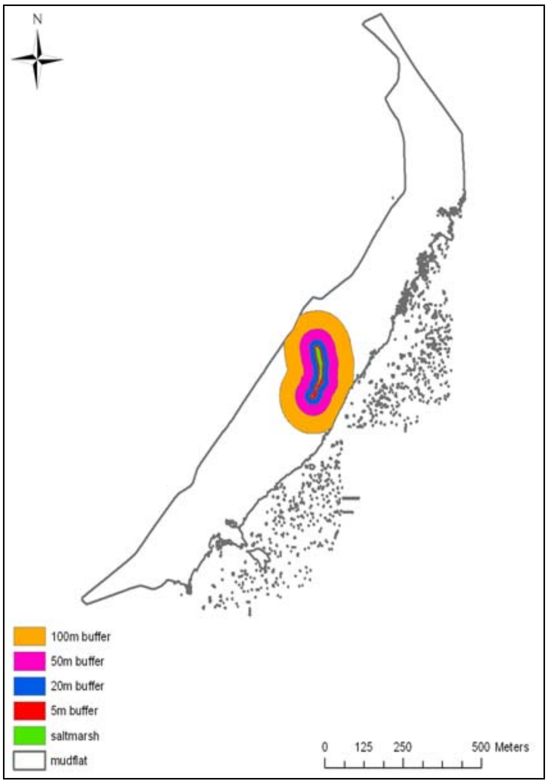


**Figure 5.14 Existing saltmarsh and potential saltmarsh buffers – Pennington**

TABLE 5.6 SEDIMENT VOLUME TO CONVERT MUDFLAT TO SALTMARSH - PENNINGTON

| | Surface Area $m^2$ | % mudflat surface area converted | Volume of sediment required $m^3$ | | |
|---|---|---|---|---|---|
| | | | mhws | mhw | mhwn |
| **5m** | 1,880 | 1 | 1,156 | 705 | 272 |
| **20m** | 7,918 | 2 | 6,711 | 4,810 | 2,989 |
| **50m** | 24,014 | 6 | 27,201 | 21,437 | 15,914 |
| **100m** | 61,029 | 16 | 81,594 | 66,947 | 52,910 |
| **mudflat** | 373,764 | 100 | 605,632 | 515,928 | 429,963 |

Fig 5.15 shows interpolation for volume requirements to re-establish historic saltmarsh for the different years, the extents are shown in Table 5.7. This indicates that to re-establish 1971 saltmarsh areas at Pennington at MHWN, 55,926 $m^3$ of sediment are required (Table 5.7).

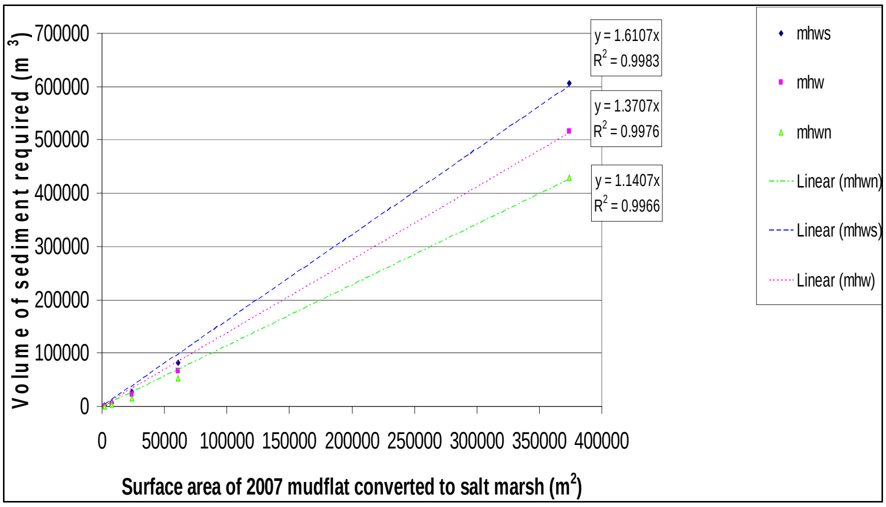


**Figure 5.15 Sediment volume to convert mudflat to saltmarsh - Pennington**

TABLE 5.7 SEDIMENT VOLUME TO RE-ESTABLISH SALTMARSH - PENNINGTON

| Year | Surface Area | Volume of sediment required $m^3$ | | |
|---|---|---|---|---|
| | | mhws | mhw | mhwn |
| **1971** | 49,028 | 78,969 | 67,203 | 55,926 |
| **1984** | 21,316 | 34,334 | 29,218 | 24,315 |
| **2001** | 5,506 | 8,869 | 7,547 | 6,281 |

### 5.4.8 Pennington: Multi Criteria Analysis

**Presence of existing natural saltmarshes** – indicates the existence of favourable conditions for saltmarsh creation – there are existing saltmarshes immediately adjacent to the site, but large areas of bare mudflat: RED.
**Elevation –** most successful marshes have been approximately 2.1m OD – majority of site between -1.9 and 1.2m relative to O.D. (Fig 5.12 above): AMBER.
**Drainage –** an extensive creek system is required – limited existing creek system: AMBER.
**Surface gradient –** optimum is approximately 1-2% (<1:50) – calculated mean slope for Pennington saltmarsh is 2.88% (Fig 5.16): AMBER.

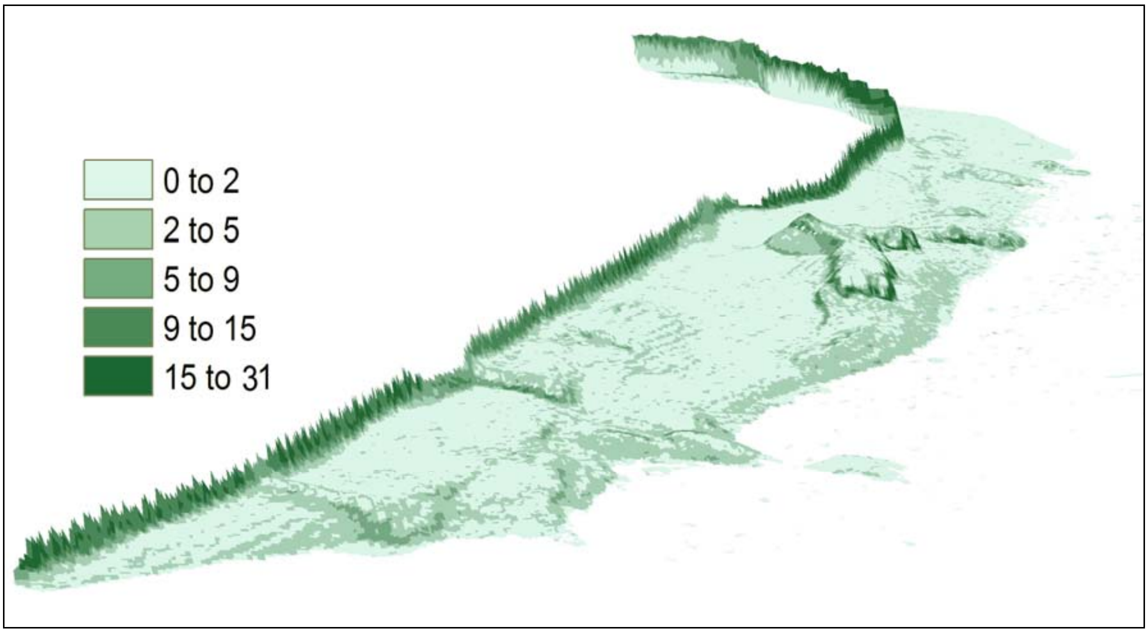


**Figure 5.16 Mean slope (%) for Pennington saltmarsh site**

**Soil grain size –** sediment grain size, composition and porosity of the dredge sediments used will affect drainage characteristics and organic content – composition of dredged sediment to be used for recharge is unknown: AMBER.
**Sediment Supply –** presence of healthy marshes close to a proposed site would indicate a suitable location in terms of sediment supply – potential supply from Lymington River, but this is limited and potentially subject to ongoing change; mudflats and some saltmarsh nearby but widespread erosion: RED.
**Contamination –** areas away from major pollutant sources are preferable – potential pollutants from Lymington River: AMBER.
**Land Conservation Value -** sites selected for saltmarsh creation should not have a high conservation value (such as SSSIs, Ramsar sites etc.) – Pennington site designated SSSI, Ramsar, SPA: RED.
**Local Economic/Recreational Activities** – all current activities should be checked that they are not likely to be adversely affected by the creation of the recharge site – wastewater treatment outfall nearby, as well as local shellfishery and other recreational activities: RED.
**Accessibility** - when selecting areas for recharge, consideration of the accessibility and costs for appropriate vessels/plants/machinery to handle the material must be considered – accessibility for vessels is good, although exposed; however, accessibility for plant / machinery from land side is good: GREEN.

5.4.9 Calshot: Introduction

Close to the Calshot Activities Centre Calshot Marsh (SU 486 017) lies at the entrance to Southampton Water. It consists of saltmarsh and inter-tidal mudflat lying within the shelter of Calshot Spit which, coupled with the influence of the Ilse of Wight, protects the site from the predominately south-westerly waves. Following the opening of the ESSO Oil Refinery in the 1950s Spartina 'dieback' occurred around discharge points. The Marsh is owned and managed by HCC and has a high amenity value with the area used for walking, bird watching, fishing and general recreational activities (Calshot Activities Centre). Numerous rights of way run through the site and the marshes have SSSI, SAC, SPA and Ramsar conservation designations. Fawley Power Station and Calshot Activities Centre are within 600 m of the marsh. There are also numerous beach huts along the spit immediately to the southeast.

5.4.10 Calshot: Historic saltmarsh change

*Calshot LiDAR coverage was not complete, therefore historic saltmarsh changes are given only for the equivalent area. It is recommended future surveys include the complete saltmarsh*.

In 1972 a clean-up operation included the reseeding and replanting of saltmarsh species. Table 5.8 and Fig 5.17 show the decline in the rate of saltmarsh loss in 1984. Figure 5.18 shows the pattern of saltmarsh loss between 1946 and 2007. The marsh has suffered from edge erosion, particularly in the north-west, adjacent to the channel to Fawley Power Station, which is regularly dredged. The internal desiccation of the marsh is evidence of *Spartina* 'dieback (Fig. 5.18).'

TABLE 5.8 HISTORIC SALTMARSH CHANGE - CALSHOT
(Based on HPI)

| Year | Surface Area $m^2$ | Source | Period | Total Loss $m^2$ | %loss | % loss pa |
|---|---|---|---|---|---|---|
| **1946** | 265,601 | ABP | 1946-2007 | 186,651 | 70.27 | 1.15 |
| **1954** | 208,365 | ABP | 1954-2007 | 129,415 | 62.11 | 1.17 |
| **1963** | 162,791 | ABP | 1963-2007 | 83,841 | 51.50 | 1.17 |
| **1971** | 131,336 | Williams, 2006 | 1971-2007 | 52,386 | 39.89 | 1.11 |
| **1984** | 99,192 | Williams, 2006 | 1984-2007 | 20,242 | 20.41 | 0.89 |
| **1991** | 130,197 | Williams, 2006 | 1991-2007 | 51,247 | 39.36 | 2.46 |
| **2001** | 106,504 | Williams, 2006 | 2001-2007 | 27,554 | 25.87 | 4.31 |
| **2007** | 78,950 | LTEI | | | | |

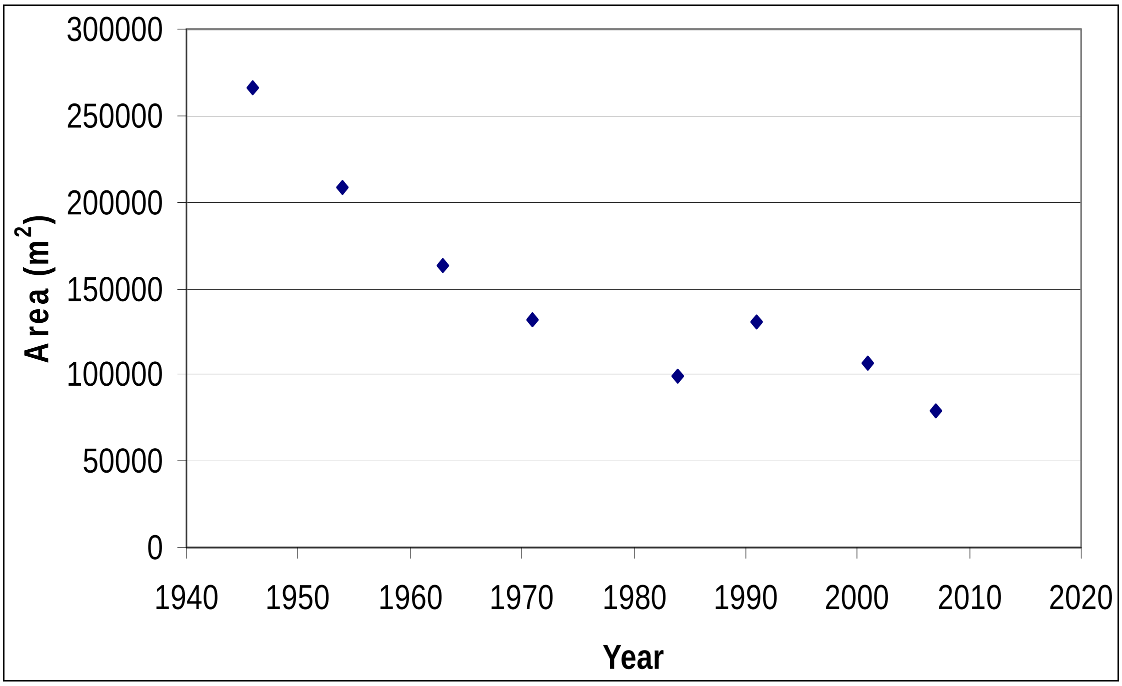


**Figure 5.17 Historic saltmarsh change - Calshot**

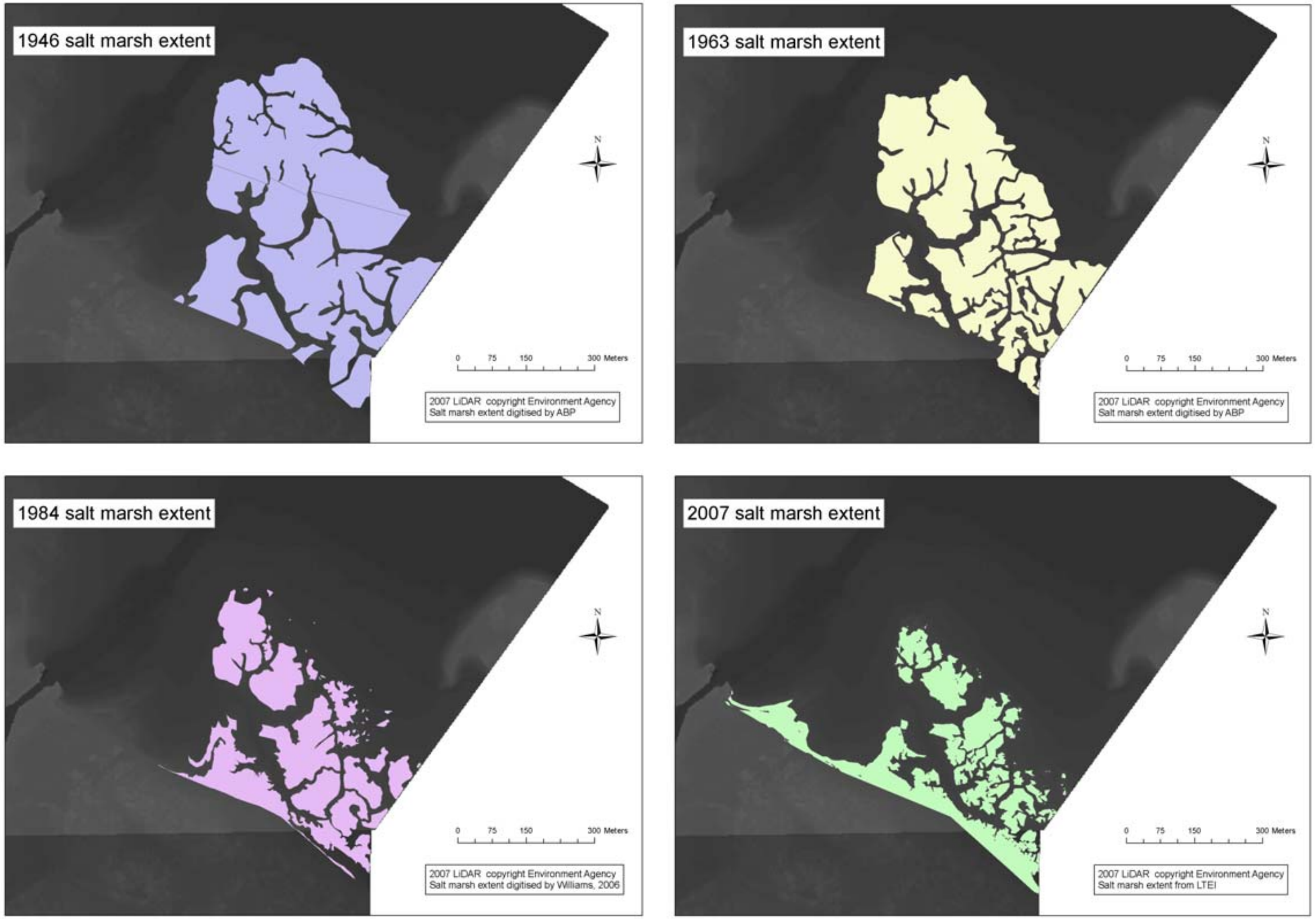


**Figure 5.18 Saltmarsh extents 1946-2007 - Calshot**

The height of the Calshot Marshes is between -2.4 and 2.1m relative to OD (Figure 5.19)

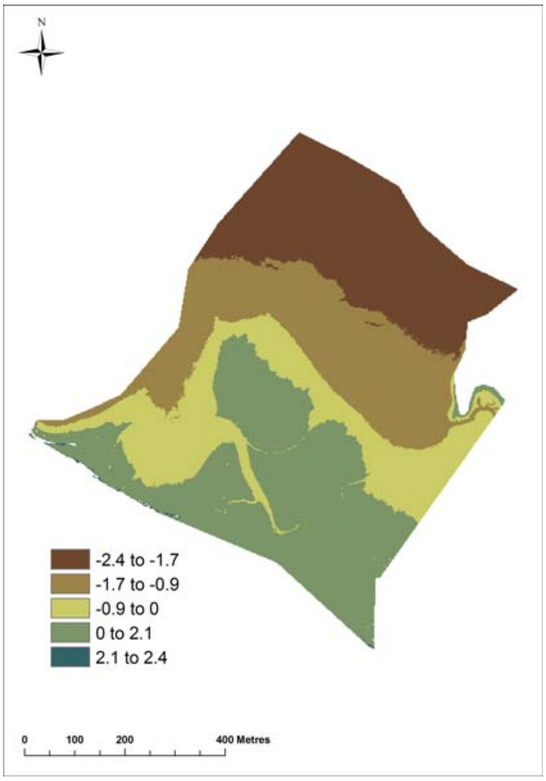


**Figure 5.19 Height of Calshot Marshes relative to OD**

5.4.11 Calshot: Volume Requirements Mudflat Recharge - Calshot
The mudflat area to be potentially raised to a level suitable for salt marsh growth is indicated in Fig 5.20.

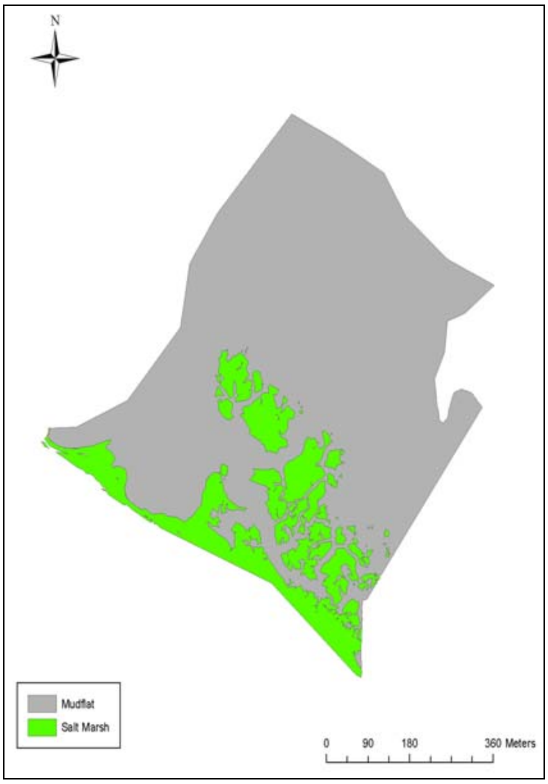


**Figure 5.20 - Area selected for potential mudflat recharge- Calshot**

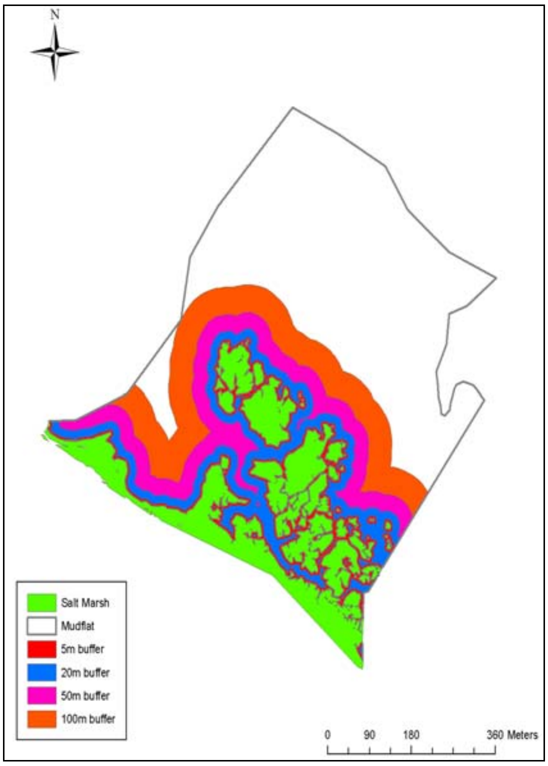


**Figure 5.21 Existing saltmarsh and potential saltmarsh buffers - Calshot**

The extent of buffers used to calculate volume of sediment required to convert the complete area of mudflat at Calshot to a level suitable for saltmarsh growth is given in Fig. 5.21 and would be 535,699 m$^3$ (Table 5.9 and Fig 5.22).

TABLE 5.9 SEDIMENT VOLUMES TO CONVERT MUDFLAT TO SALTMARSH – CALSHOT

| | Surface Area m$^2$ | % mudflat surface area converted | Volume of sediment required m$^3$ | | |
|---|---|---|---|---|---|
| | | | mhws | mhw | mhwn |
| **5m** | 32282 | 8 | 31748 | 18835 | 5922 |
| **20m** | 76026 | 20 | 85053 | 54642 | 24232 |
| **50m** | 122266 | 31 | 159927 | 111020 | 62114 |
| **100m** | 181528 | 47 | 276527 | 203916 | 131305 |
| **Mudflat** | 389825 | 100 | 847560 | 691629 | 535699 |

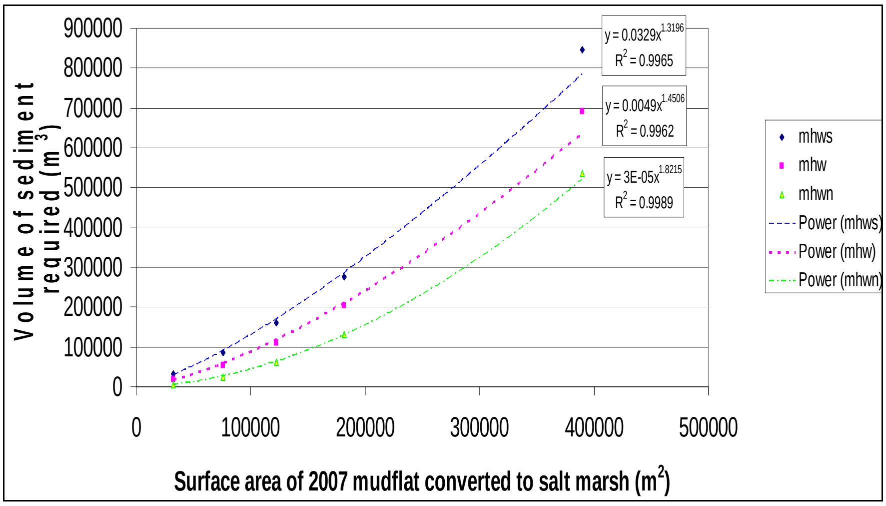


**Figure 5.22 Sediment volumes to convert mudflat to saltmarsh - Calshot**

To re-establish 1971 saltmarsh areas at MHWN, 19,725 m$^3$ of sediment are required (Table 5.10).

TABLE 5.10 SEDIMENT VOLUME TO RE-ESTABLISH SALTMARSH - CALSHOT

| Year | Surface Area m² | Volume of sediment required m³ | | |
|---|---|---|---|---|
| | | mhws | mhw | mhwn |
| **1946** | 186,651 | 297,062 | 216,947 | 199,596 |
| **1954** | 129,415 | 183,219 | 127,538 | 102,435 |
| **1963** | 83,841 | 103,321 | 67,946 | 46,456 |
| **1971** | 52,386 | 55,548 | 34,347 | 19,725 |
| **1984** | 20,242 | 15,839 | 8,647 | 3,490 |
| **1991** | 51,247 | 53,960 | 33,269 | 18,951 |
| **2001** | 27,554 | 23,794 | 13,525 | 6,120 |

5.4.12 Calshot: Multi Criteria Analysis

**Presence of existing natural saltmarshes** – indicates the existence of favourable conditions for saltmarsh creation – there are existing saltmarshes adjacent to the site: GREEN.
**Elevation –** most successful marshes have been approximately 2.1m OD – majority of site between -2.4 and 2.1m above O.D. (Figure X.X above): GREEN.
**Drainage –** an extensive creek system is required – extensive existing creek system. GREEN
**Surface gradient –** optimum is approximately 1-2% (<1:50) – calculated mean slope for Calshot saltmarsh is 3.24% (Figure 5.23): AMBER.

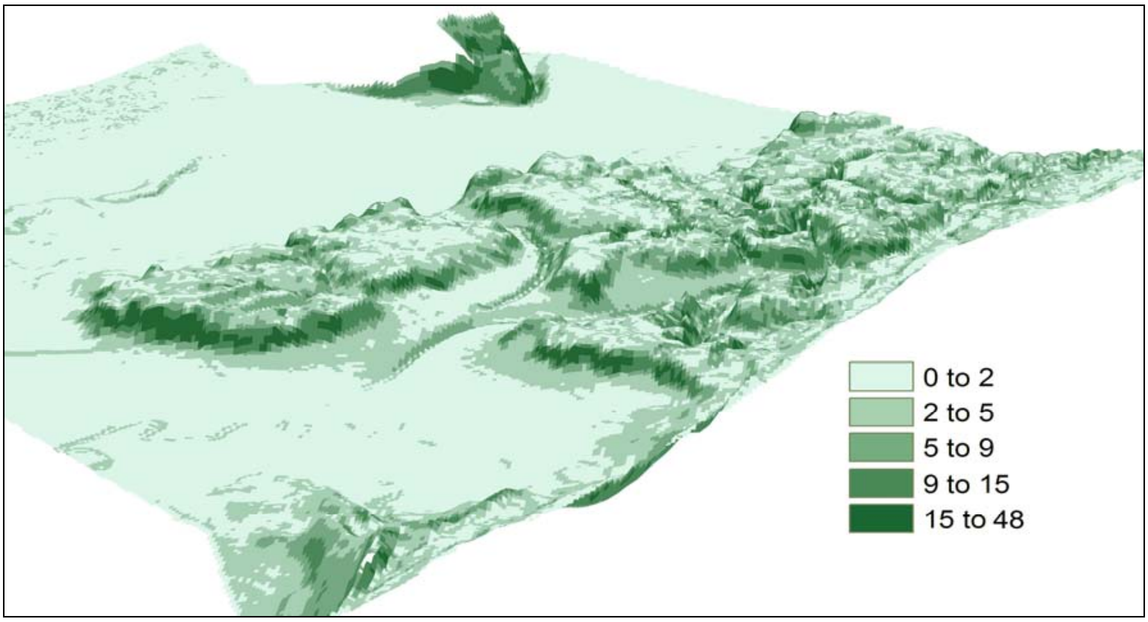


**Figure 5.23 Mean slope (%) for Calshot saltmarsh site**

**Soil grain size –** sediment grain size, composition and porosity of the dredge sediments used will affect drainage characteristics and organic content – composition of dredged sediment to be used for recharge is unknown: AMBER.
**Sediment Supply –** presence of healthy marshes close to a proposed site would indicate a suitable location in terms of sediment supply – large amount of suspended fine grained material carried down Southampton Water: GREEN.
**Contamination –** areas away from major pollutant sources are preferable – potential hydrocarbon pollution from oil refineries in Southampton Water as well as antifouling pollution: RED.
**Land Conservation Value -** sites selected for saltmarsh creation should not have a high conservation value (such as SSSIs, Ramsar sites etc.) – Calshot site designated SSSI, SAC, SPA and Ramsar: RED.
**Local Economic/Recreational Activities** – all current activities should be checked that they are not likely to be adversely affected by the creation of the recharge site – Calshot water sports centre and Power Station water intake: RED.
**Accessibility -** when selecting areas for recharge, consideration of the accessibility and costs for appropriate vessels/plants/machinery to handle the material must be considered – accessibility from marine side for vessels and machinery / plant from land side GREEN.

5.4.13 Mercury: Introduction

Mercury Marsh (SU 485 076) is situated along the western bank of the River Hamble and consists of intertidal mudflats, saltmarsh and reed beds and is under Hampshire County Council and private ownership. The marshes currently have a medium to high recreational use (Cope *et al*., 2007) with the area being used for walking, bird watching, and general recreational activity. Rights of way run through the site and the marshes have SSSI, Ramsar, SAC and SPA designations. Residential areas are less than 100 m from the marsh and large marinas are within 300 m.

5.4.14 Mercury: Historic Saltmarsh Change

Fig 5.24 illustrates saltmarsh area converted to land since 1946 totalling 22,644 $m^2$. It would require removal of 33,523 $m^3$ of sediment to lower the area to HAT; the highest tide where transitional saltmarsh species grow.

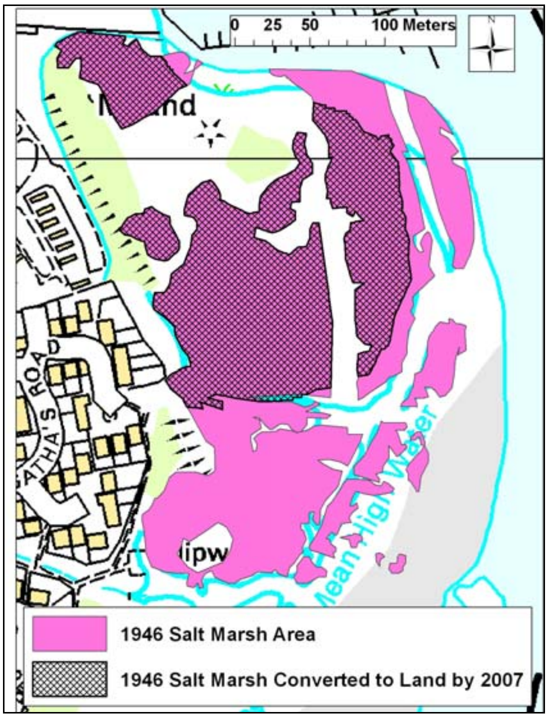


**Figure 5.24 Saltmarsh change 1946-2007 - Mercury**

The rate of saltmarsh decline at Mercury marsh appeared to slow (Table 5.11 and Fig 5.25) between 1946 and 2007, with edge erosion as the dominant process (Fig 5.26). Through a site visit it was noted that the saltmarsh element had largely disappeared and the remainder had accreted to become dominated by *Phragmites. Australis* (reeds), grading to terrestrial habitat. The reduction in loss may be due to the relative consolidation of the sediment by more abundant reed and terrestrial vegetation.

TABLE 5.11 HISTORIC SALTMARSH CHANGE AT MERCURY
(Based on HPI)

| Year | Surface Area $m^2$ | Source | Period | Total Loss $m^2$ | %loss | % loss pa |
|---|---|---|---|---|---|---|
| **1946** | 52,235 | CCO | 1946-2007 | 36,486 | 0.70 | 0.01 |
| **1971** | 38,221 | CCO | 1971-2007 | 22,472 | 0.59 | 0.02 |
| **1984** | 16,363 | CCO | 1984-2007 | 614 | 0.04 | 0.00 |
| **2000** | 12,915 | CCO | 2000-2007 | -2,834 | -0.22 | -0.04 |
| **2007** | 15,749 | LTEI | | | | |

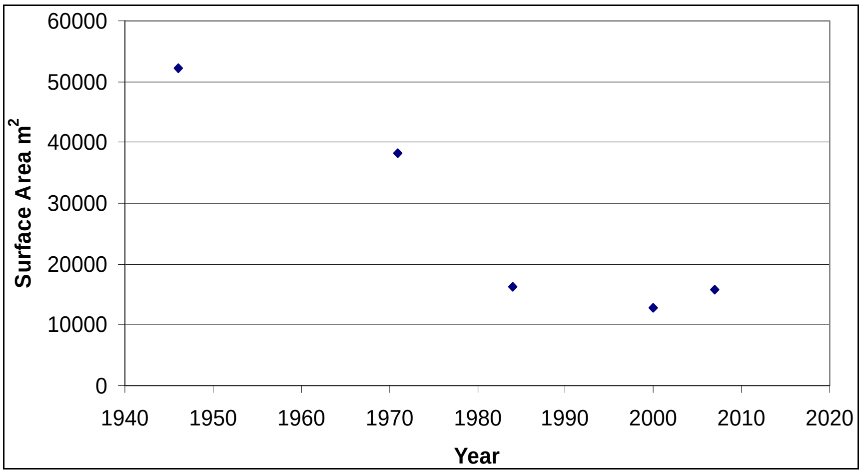


**Figure 5.25 Historic saltmarsh change - Mercury**

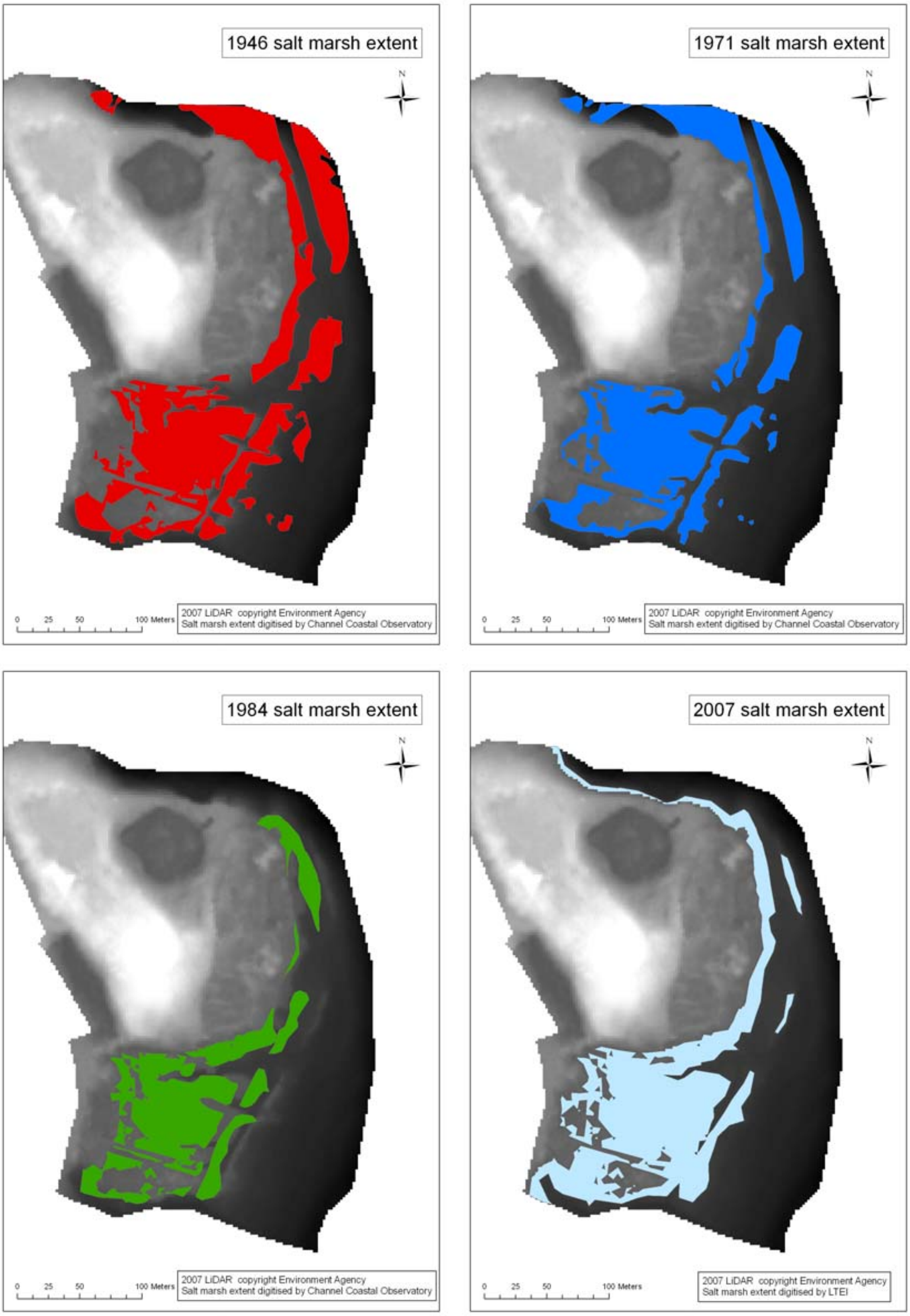


**Figure 5.26 Saltmarsh extents 1946-2007 – Mercury**

The height of the Mercury Marsh site is between -2.5 and 2.1 m relative to OD (Figure 5.27).

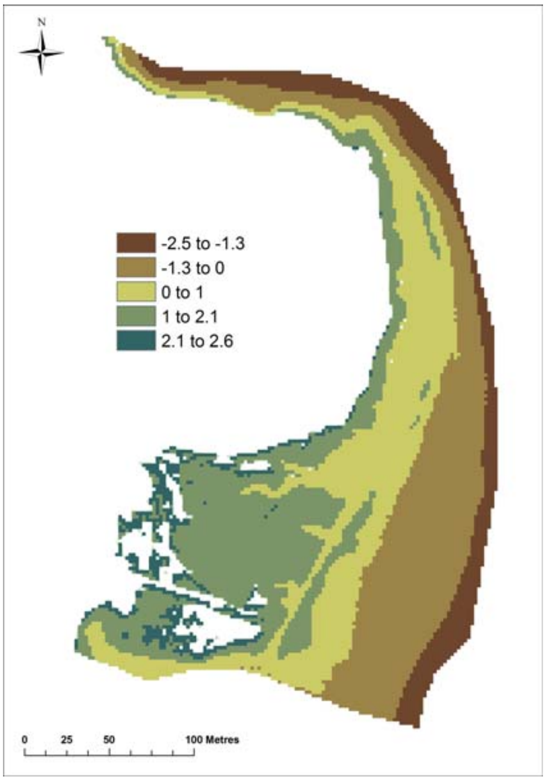


**Figure 5.27 Height of Mercury Marsh relative to OD**

5.4.15 Mercury: Volume Requirements for Mudflat Recharge

The mudflat area for potential recharge is shown in Fig 5.28 and 5.29. The volume of sediment required to convert the complete area of mudflat at Mercury marsh to a level suitable for saltmarsh growth would be 35,863 $m^3$ (Table 5.12 & Fig 5.30).

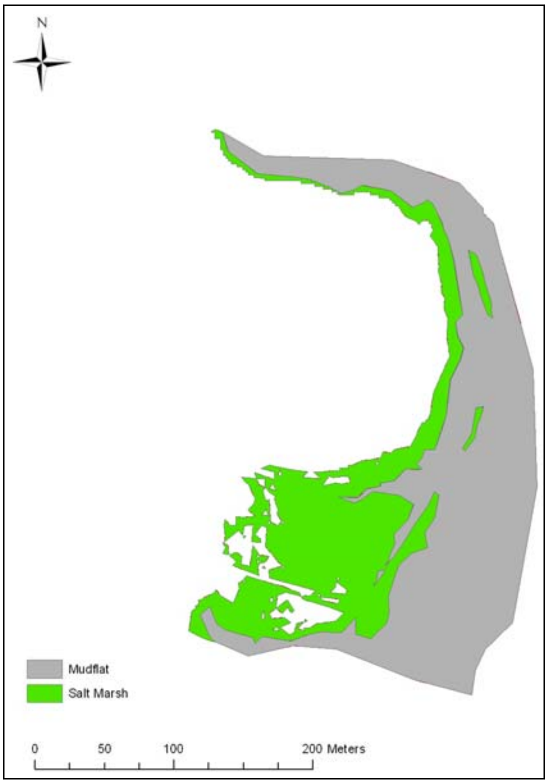


**Figure 5.28 Area selected for potential mudflat recharge- Mercury**

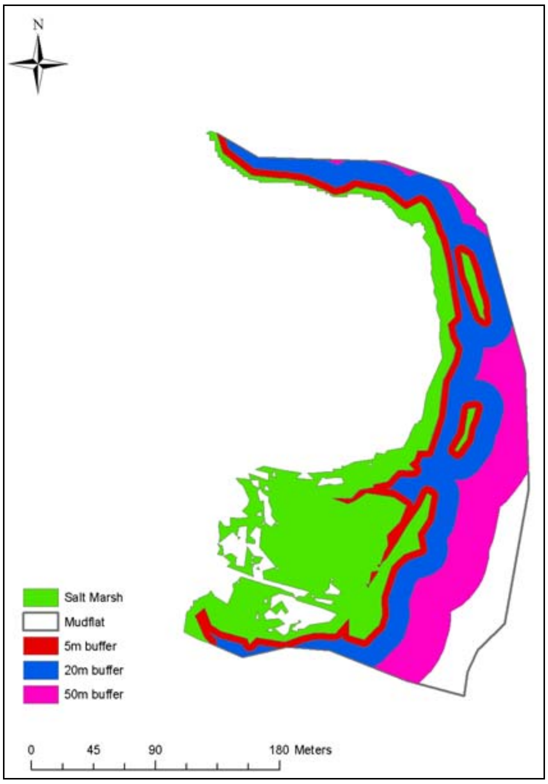


**Figure 5.29 Existing saltmarsh and potential saltmarsh buffers - Mercury**

TABLE 5.12 SEDIMENT VOLUME TO CONVERT MUDFLAT TO SALTMARSH - MERCURY

| | SA | % mudflat SA | Volume of sediment required m³ | | |
|---|---|---|---|---|---|
| | | | mhws | mhw | mhwn |
| **5m** | 198,817 | 15 | 6,348 | 4,306 | 1,949 |
| **20m** | 596,643 | 46 | 25,680 | 19,641 | 12,674 |
| **50m** | 965,077 | 75 | 44,938 | 35,763 | 25,176 |
| **mudflat** | 1,287,821 | 100 | 58,693 | 48,093 | 35,863 |

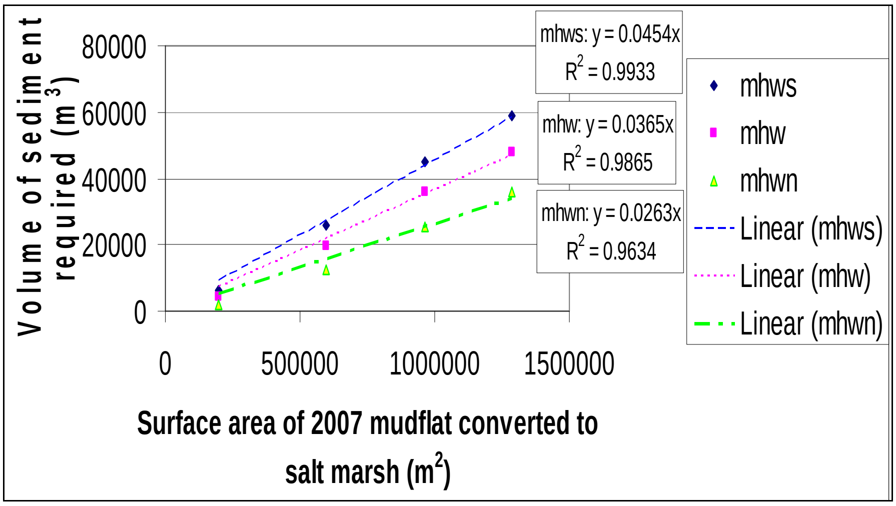


**Figure 5.30 Sediment volume to convert mudflat to saltmarsh - Mercury**

The Volume: Surface Area relationship closely fits a linear trend (Fig 5.30). By interpolating the trend to calculate the volume required to regain Historic levels, it can be seen that in order to re-establish 1971 saltmarsh areas at MHWN, 591 $m^3$ of sediment are required (Table 5.13).

TABLE 5.13 SEDIMENT VOLUME TO RE-ESTABLISH SALTMARSH - MERCURY

| Year | Total Loss $m^2$ | Volume of sediment required $m^3$ | | |
|---|---|---|---|---|
| | | mhws | mhw | mhwn |
| **1946** | 36486 | 1,656 | 1,324 | 960 |
| **1971** | 22472 | 1,020 | 816 | 591 |
| **1984** | 614 | 28 | 22 | 16 |

5.4.16 Mercury: Multi Criteria Analysis

**Presence of existing natural saltmarshes** – indicates the existence of favourable conditions for saltmarsh creation – there are existing saltmarshes close to the site, but Mercury is isolated by marina development: AMBER.

**Elevation –** most successful marshes have been approximately 2.1m OD – majority of site between -2.5 to 2.1m above O.D. (Fig 5.27 above): GREEN.

**Drainage –** an extensive creek system is required – extremely limited existing creek system: RED.

**Surface gradient –** optimum is approximately 1-2% (<1:50) – calculated mean slope for Mercury saltmarsh is 6.7% (Fig 5.31): RED.

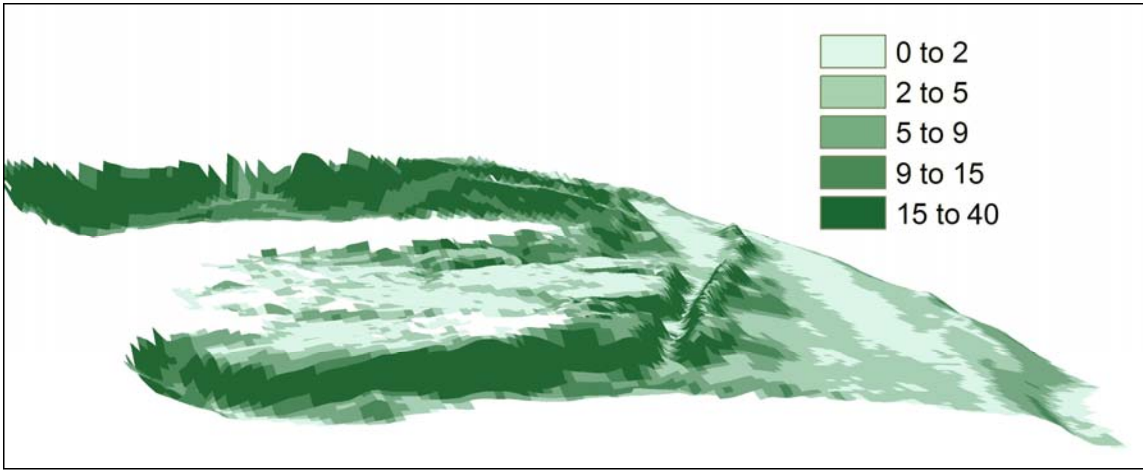


**Figure 5.31 Mean slope (%) for Mercury saltmarsh site**

**Soil grain size –** sediment grain size, composition and porosity of the dredge sediments used will affect drainage characteristics and organic content – composition of dredged sediment to be used for recharge is unknown: AMBER.

**Sediment Supply –** presence of healthy marshes close to a proposed site would indicate a suitable location in terms of sediment supply – saltmarshes nearby, and fine sediment transport within the Hamble River: GREEN.

**Contamination –** areas away from major pollutant sources are preferable – there are very high levels of antifouling pollution: RED.

**Land Conservation Value -** sites selected for saltmarsh creation should not have a high conservation value (such as SSSIs, Ramsar sites etc.) – Mercury site has SSSI, Ramsar, SPA and SAC designations: RED.

**Local Economic/Recreational Activities –** all current activities should be checked that they are not likely to be adversely affected by the creation of the recharge site – very high levels of recreational boating with high economic value of local marinas: RED.

**Accessibility -** when selecting areas for recharge, consideration of the accessibility and costs for appropriate vessels/plants/machinery to handle the material must be considered – accessibility by vessel good but access for plant / machinery from land very poor, due to recreational location: AMBER.

5.4.17 Hacketts Marsh: Introduction

Hacketts Marsh (SU 485 089) consists of intertidal mudflats, salt marsh and grazed agricultural land, and is owned by HCC. It currently has a low to medium recreational use (Cope *et al*., 2007) as the site is closed to the public due to a restrictive covenant order which was inherited with the sale of the property. Access is only available on guided walks or by prior arrangement with site manager. A public footpath runs along the western boundary. The marsh has SSSI, Ramsar, SPA and SAC designations. The site is relatively close to high value residential properties in nearby Old Bursledon village and major marinas on the River Hamble.

5.4.18 Hacketts: Historic saltmarsh change

The historic decline on Hacketts marsh has not been as significant as other areas in the Solent, with only a 21% loss in area since 1946 (Table 5.14, Fig 5.32), compared to other areas such as Calshot (Table 5.8) which has experienced a 70% loss in area during the same period. As Fig 5.33 shows, edge erosion is the dominant process.

TABLE 5.14 HISTORIC SALTMARSH CHANGE AT HACKETTS
(Based on HPI)

| Year | Surface Area $m^2$ | Source | Period | Total Loss $m^2$ | %loss | % loss pa |
|---|---|---|---|---|---|---|
| **1946** | 79,348 | CCO | 1946-2007 | 16,660 | 21.00 | 0.34 |
| **1971** | 73,107 | CCO | 1971-2007 | 10,419 | 14.25 | 0.40 |
| **1984** | 63,791 | CCO | 1984-2007 | 1,103 | 1.73 | 0.08 |
| **2000** | 58,714 | CCO | 2000-2007 | -3,974 | -6.77 | -0.97 |
| **2007** | 62,688 | LTEI | | | | |

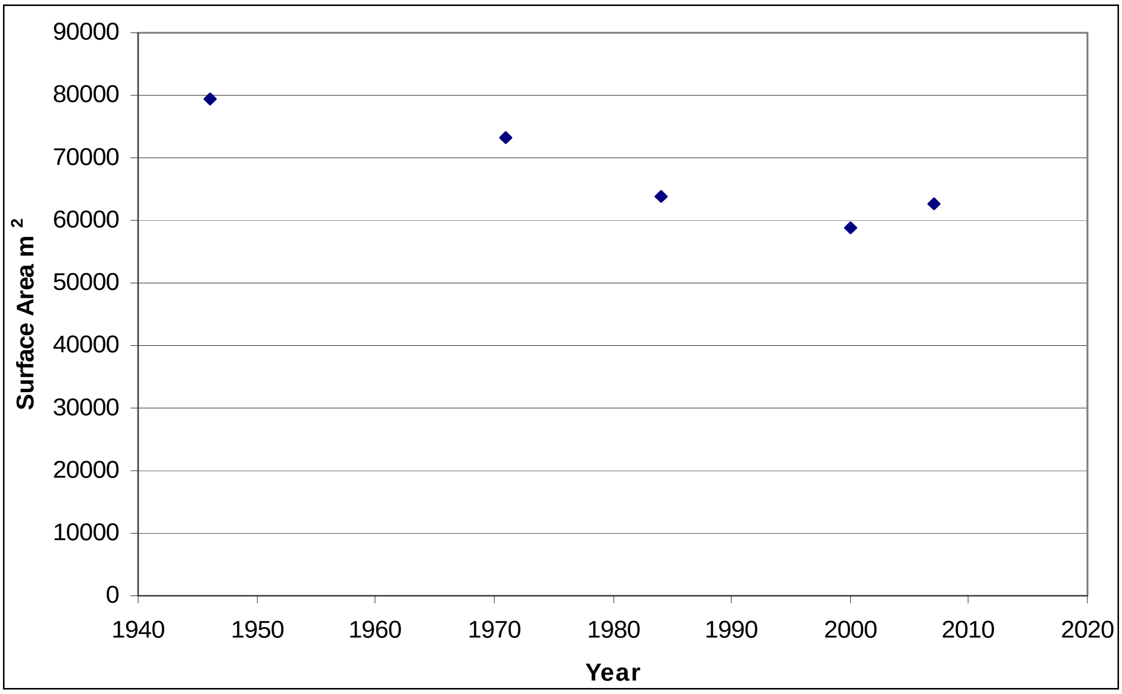


**Figure 5.32 Historic saltmarsh change – Hacketts**

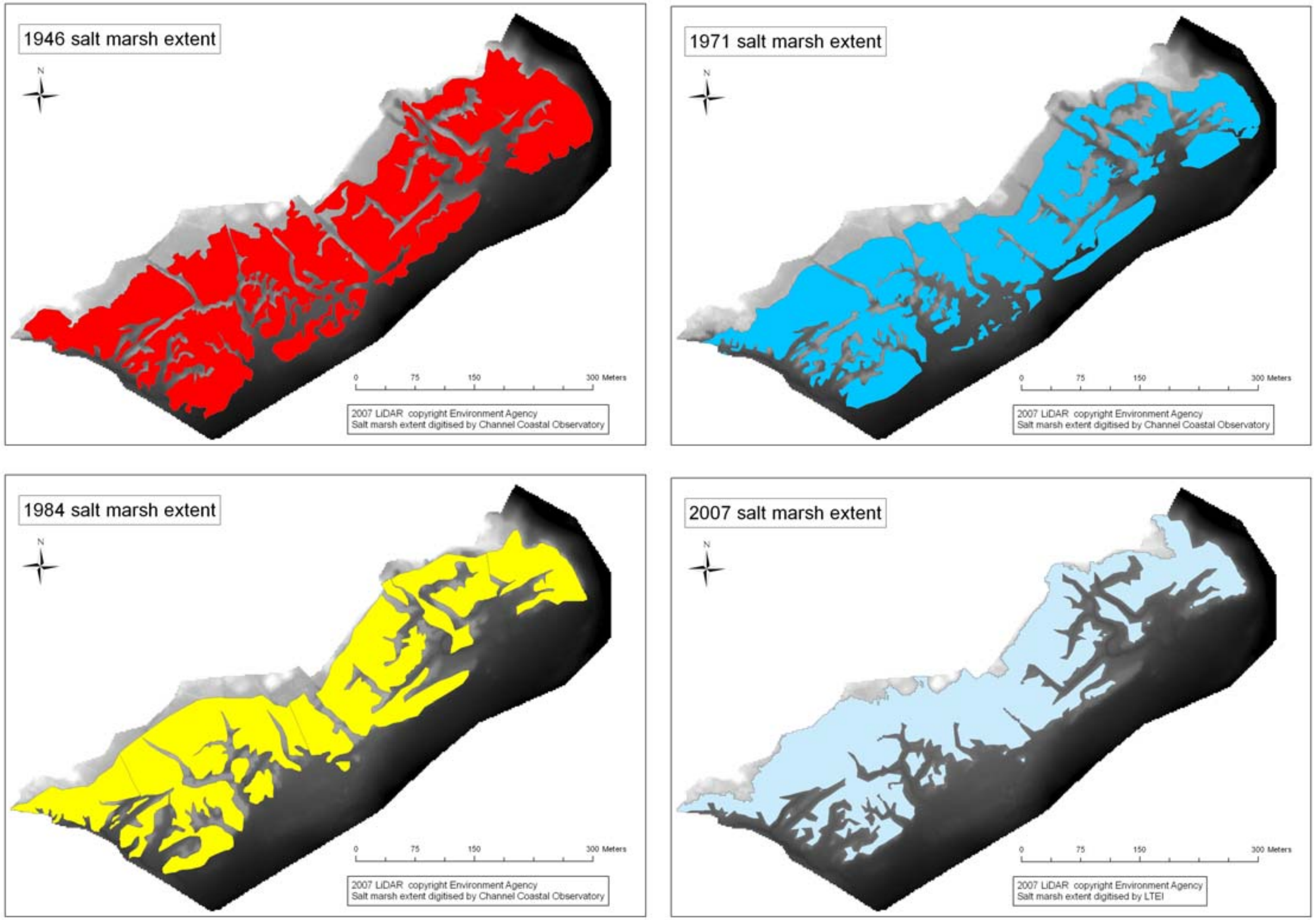


**Figure 5.33 Saltmarsh extents 1946-2007 –Hacketts**

The majority of Hacketts Marsh is between -2.5 m and 2.1 m relative to OD (Fig 5.34).

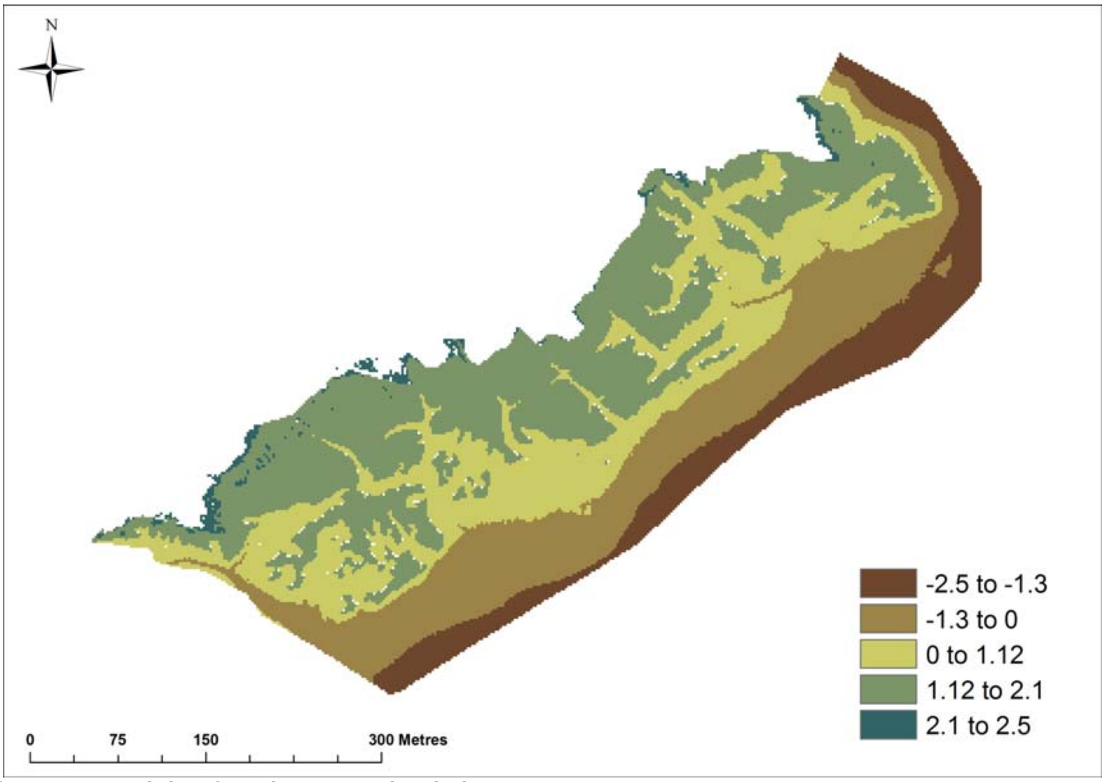


**Figure 5.34 Height of Hacketts Marsh relative to OD**

5.4.19 Hacketts: Volume Requirements for Mudflat Recharge

Figs 5.35 and 5.36 show the area of saltmarsh present at Hacketts marsh in 2007, buffers used to calculate volumes are given in Fig. 5.36.

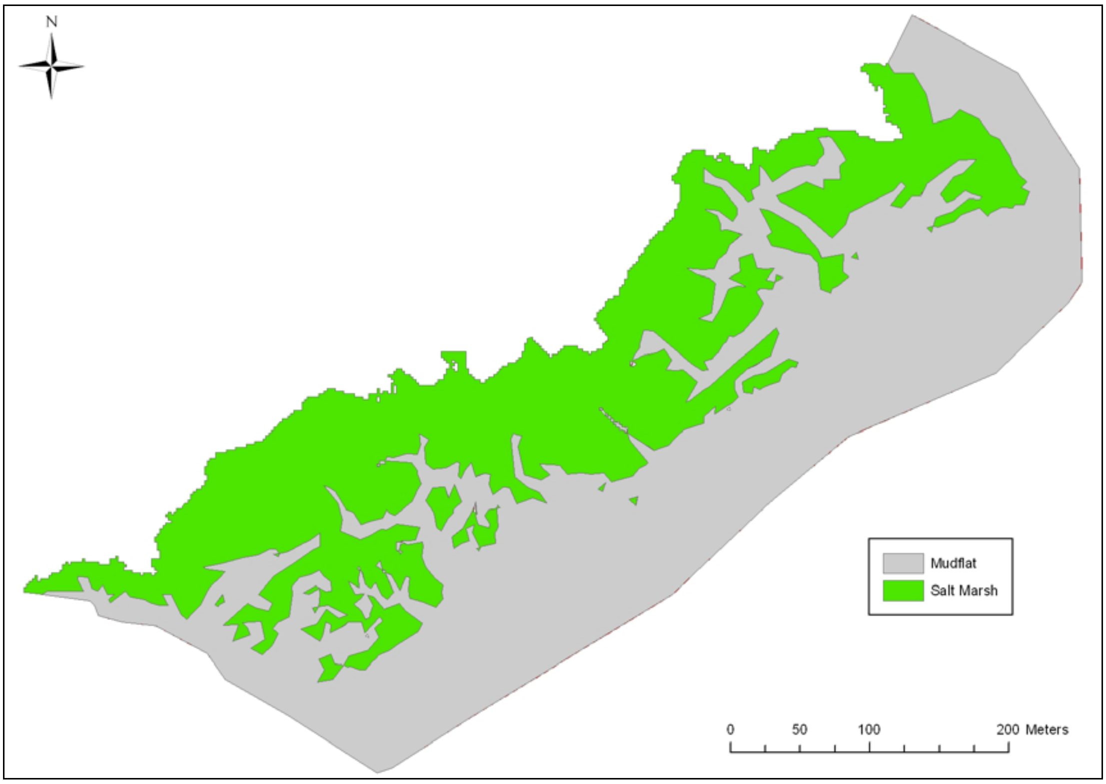


**Figure 5.35 Area selected for potential mudflat recharge - Hacketts**

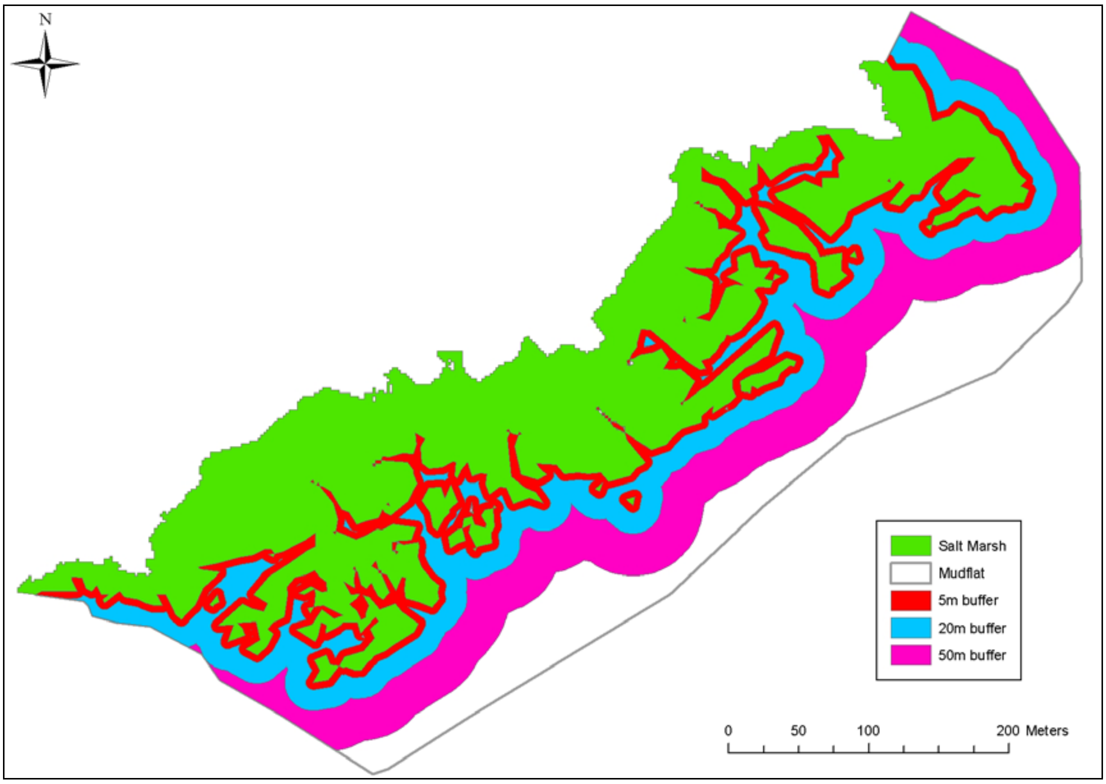


**Figure 5.36 Existing saltmarsh and potential saltmarsh buffers - Hacketts**

As shown in Table 5.15 the total volume of sediment to increase the mudflat area to MHWN level is 99,137 $m^3$.

TABLE 5.15 SEDIMENT VOLUME TO RE-ESTABLISH SALTMARSH AREAS - HACKETTS

| | Surface Area $m^2$ | % mudflat SA | mhws | mhw | mhwn |
|---|---|---|---|---|---|
| **5m** | 19,656 | 22 | 20,328 | 12,662 | 3,817 |
| **20m** | 42,535 | 47 | 52,716 | 36,128 | 16,987 |
| **50m** | 69,718 | 77 | 110,215 | 83,025 | 51,651 |
| **Mudflat** | 90,643 | 100 | 175,277 | 136,926 | 99,137 |

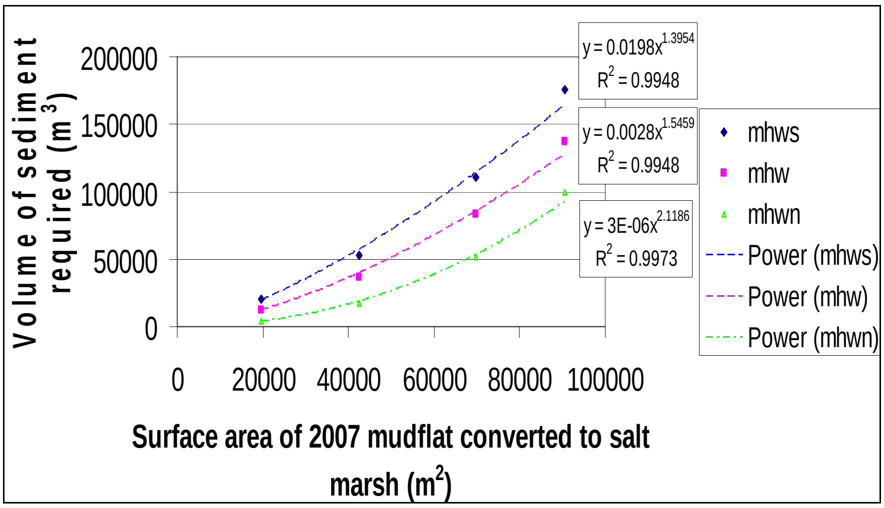


**Figure 5.37 Volume of sediment to convert mudflat to saltmarsh - Hacketts**

The volume required to increase the saltmarsh to regain historic areas is shown in Fig 5.37 and Table 5.16 shows that a relatively small volume of sediment is required to increase the saltmarsh height to adequate levels for pioneer development.

TABLE 5.16 SEDIMENT VOLUME TO RE-ESTABLISH SALTMARSH - HACKETTS

| Year | Total Loss $m^2$ | Volume of sediment required $m^3$ | | |
|---|---|---|---|---|
| | | mhws | mhw | mhwn |
| **1946** | 16,660 | 15,402 | 9,407 | 2,637 |
| **1971** | 10,419 | 8,001 | 4,553 | 976 |
| **1984** | 1,103 | 349 | 141 | 8 |

5.4.20 Hacketts: Multi Criteria Analysis

**Presence of existing natural saltmarshes** – indicates the existence of favourable conditions for saltmarsh creation – there are existing saltmarshes immediately adjacent to the site: GREEN.
**Elevation –** most successful marshes have been approximately 2.1m OD – majority of site between -2.5 and 2.1m relative to OD (Fig 5.34 above): GREEN.
**Drainage** – an extensive creek system is required – extensive existing creek system: GREEN.
**Surface gradient –** optimum is approximately 1-2% (<1:50) – calculated mean slope for Hacketts saltmarsh is 4.46% (Fig 5.38): RED.

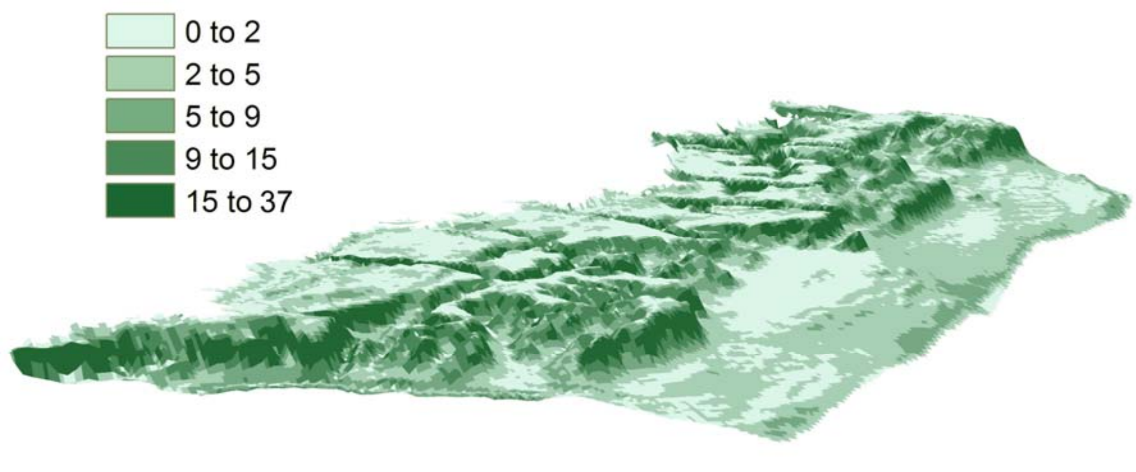


**Figure 5.38 Mean slope (%) for Hacketts Marsh site**

**Soil grain size –** sediment grain size, composition and porosity of the dredge sediments used will affect drainage characteristics and organic content – composition of dredged sediment to be used for recharge is unknown: AMBER.
**Sediment Supply –** presence of healthy marshes close to a proposed site would indicate a suitable location in terms of sediment supply – marshes are present nearby and fine sediment transport in Hamble River: GREEN.
**Contamination –** areas away from major pollutant sources are preferable – there are very high levels of antifouling pollution: RED.
**Land Conservation Value -** sites selected for saltmarsh creation should not have a high conservation value (such as SSSIs, Ramsar sites etc.) – Hackett's Marsh site designated SSSI, Ramsar, SPA and SAC: RED.
**Local Economic/Recreational Activities –** all current activities should be checked that they are not likely to be adversely affected by the creation of the recharge site – very high levels of recreational boating with high economic value of local marinas: RED.
**Accessibility** - when selecting areas for recharge, consideration of the accessibility and costs for appropriate vessels/plants/machinery to handle the material must be considered – accessibility by vessel good but access for plant / machinery from land very poor, due to recreational location: AMBER.

5.4.21 Bunny Meadows: Introduction

Part of the Lee-on-The-Solent to Itchen Estuary SSSI and the Hook with Warsash Local Nature Reserve, Bunny Meadows (SU 489 071) is an area of important intertidal habitat that has become relatively isolated from the main river Hamble flow due to a sea wall which also allowed development of a the Solent Way coastal footpath resulting in high local amenity values. The saltmarsh habitat behind the wall is connected to the river through a series of culverts, however localised failure of the sea wall has resulted in consideration of future sustainability of its management. Repairs on one section in 2004 had a proviso from the EA and NE that they were removable. Covered by SPA, SAC and Ramsar designations, the slowly accreting site is of high conservation value. The gardens of several high value properties run down to the intertidal and a large marina is opposite.

5.4.22 Bunny: Historic saltmarsh change

Historic land claim for agriculture along the River Hamble took place in the early 19th century, particularly at Bunny Meadows. However in ca. 1930 the site was abandoned and the sea wall breached in a number of places to allow the regeneration of saltmarsh and mudflat (Cundy *et al*., 2003). The saltmarsh extent at Bunny Meadows has increased by 168% between 1946 and 2007 following the breach in the sea defences (Table 5.17, Figs 5.39 and 5.40). The rate of growth of the marsh has been 0.61% since 1984 indicating that the natural accretion of the marsh in this location is continuing at a rapid rate and it may be more economical to leave the site to increase naturally.

TABLE 5.17 HISTORIC SALTMARSH CHANGE – BUNNY MEADOW
(Based on HPI)

| Year | Surface area $m^2$ | Source | Period | Total Loss $m^2$ | %loss | % loss pa |
|---|---|---|---|---|---|---|
| **1946** | 62,709 | CCO | 1946-2007 | -105,734 | -168.61 | -1.69 |
| **1971** | 125,421 | CCO | 1971-2007 | -43,022 | -34.30 | -0.34 |
| **1984** | 104,903 | CCO | 1984-2007 | -63,540 | -60.57 | -0.61 |
| **2000** | 105,059 | CCO | 2000-2007 | -63,384 | -60.33 | -0.60 |
| **2007** | 168,443 | LTEI | | | | |


**Figure 5.39 Saltmarsh extents 1946-2007 –Bunny Meadows**

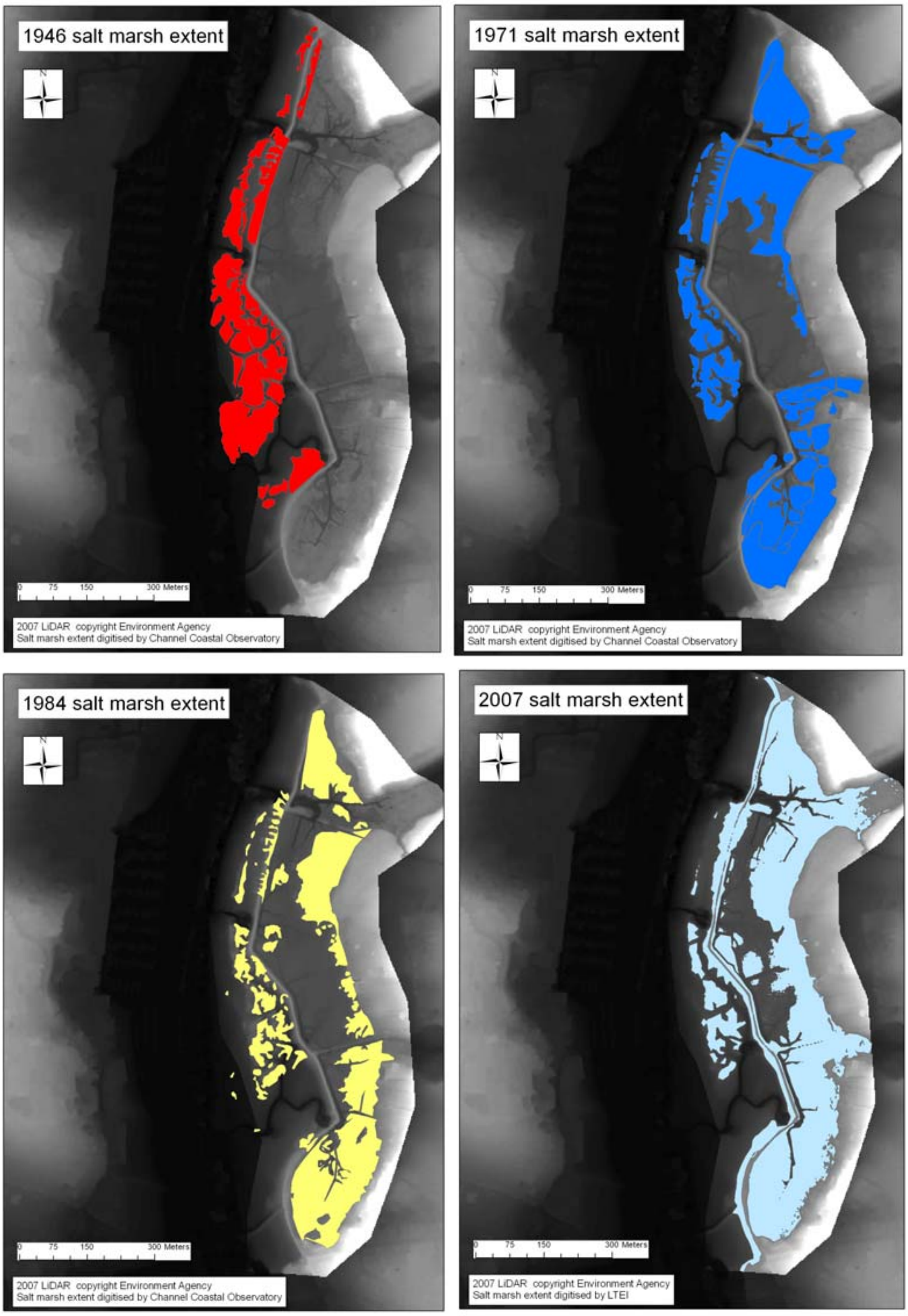


**Figure 5.40 Saltmarsh extents 1946-2007 – Bunny Meadows**

The majority height of Bunny Meadows is between -2.6 and 2.1m relative to OD (Fig 5.41).

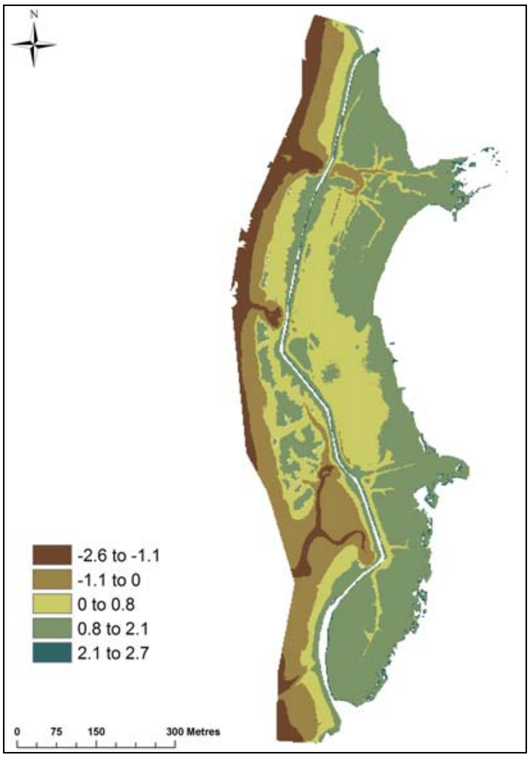


**Figure 5.41 Heights of the Bunny Meadows site relative to OD**

5.4.23 Bunny Meadows: Volume requirements for mudflat recharge

Although the site may be better left to naturally accrete sediment volumes required to increase mudflat height to levels which may promote saltmarsh were calculated. Figs 5.42 and 5.43 indicate potential mudflat recharge areas. These show that a minimum sediment volume of 153,061 $m^3$ would be required to raise the mudflat to MHWN (Table 5.18 and Fig 5.44).

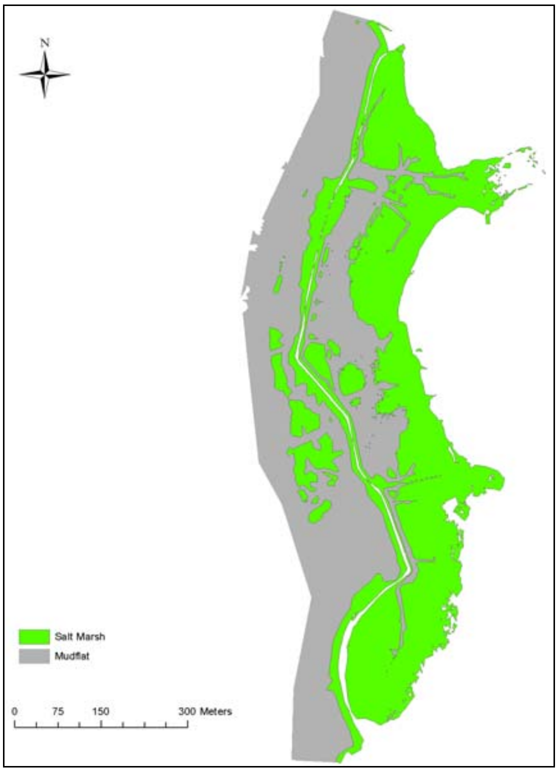


**Figure 5.42 Area selected for potential mudflat recharge-Bunny Meadows**

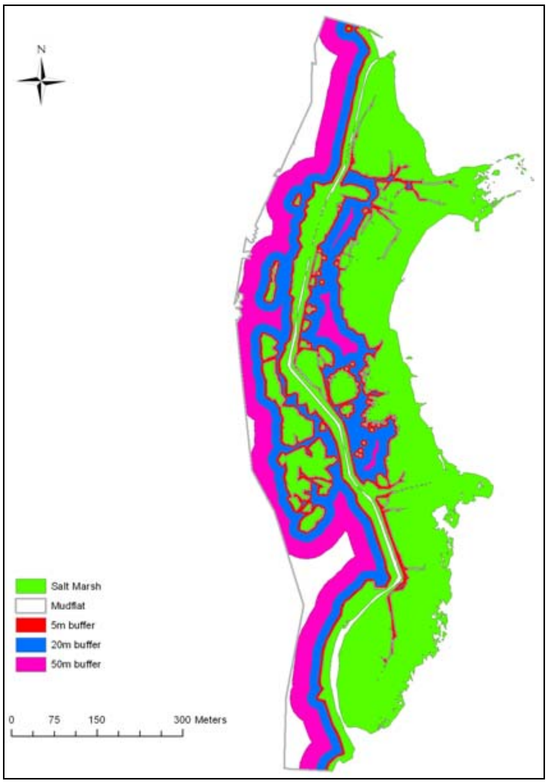


**Figure 5.43 Existing saltmarsh and potential saltmarsh buffers- Bunny Meadows**

TABLE 5.18 SEDIMENT VOLUME TO CONVERT MUDFLAT TO SALTMARSH – BUNNY MEADOWS

| | Surface area m² | % mudflat surface area | Volume of sediment required m³ | | |
|---|---|---|---|---|---|
| | | | mhws | mhw | mhwn |
| **5m** | 39,516 | 23 | 47,482 | 32,071 | 14,288 |
| **20m** | 96,099 | 56 | 125,942 | 88,463 | 45,219 |
| **50m** | 150,914 | 88 | 239,394 | 180,537 | 112,625 |
| **Mudflat** | 172,462 | 100 | 297,929 | 230,669 | 153,061 |

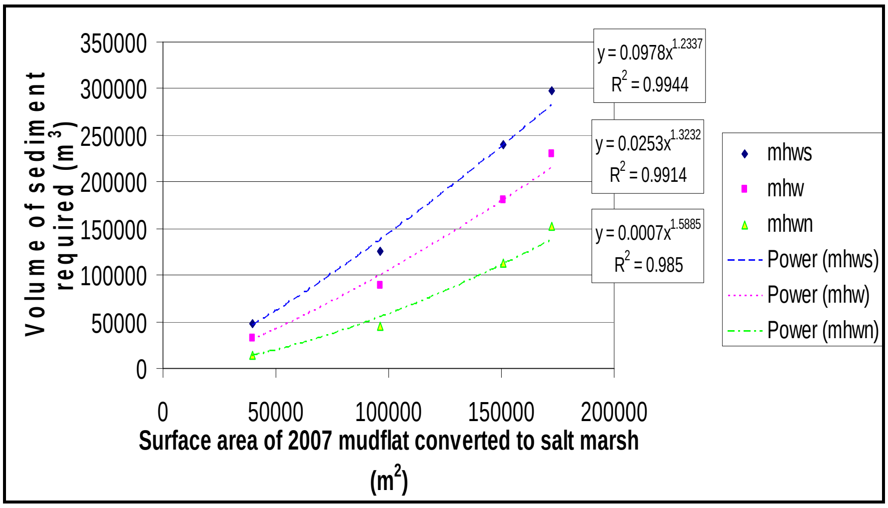


**Figure 5.44 Sediment volume to convert mudflat to saltmarsh – Bunny Meadows**

From historic analysis, the marsh at Bunny Meadows appears to be accreting, therefore volumes of dredge material to regain former salt marsh areas did not require calculation.

5.4.24 Bunny Meadows: Multi Criteria Analysis

The Bunny Meadows site is currently accreting so no introduction of dredged material is recommended. However the MCA for the site is included below.

**Presence of existing natural saltmarshes** – indicates the existence of favourable conditions for saltmarsh creation – extensive existing saltmarshes on opposite side of the Hamble River: AMBER.
**Elevation –** most successful marshes have been approximately 2.1m OD – majority of the site is between -2.6 and 2.1m relative to OD (Fig 5.41): GREEN.
**Drainage –** an extensive creek system is required – remnant existing creek system: RED.
**Surface gradient –** optimum is approximately 1-2% (<1:50) – calculated mean slope for Bunny Meadows saltmarsh is 4.94% (Fig 5.45): RED.

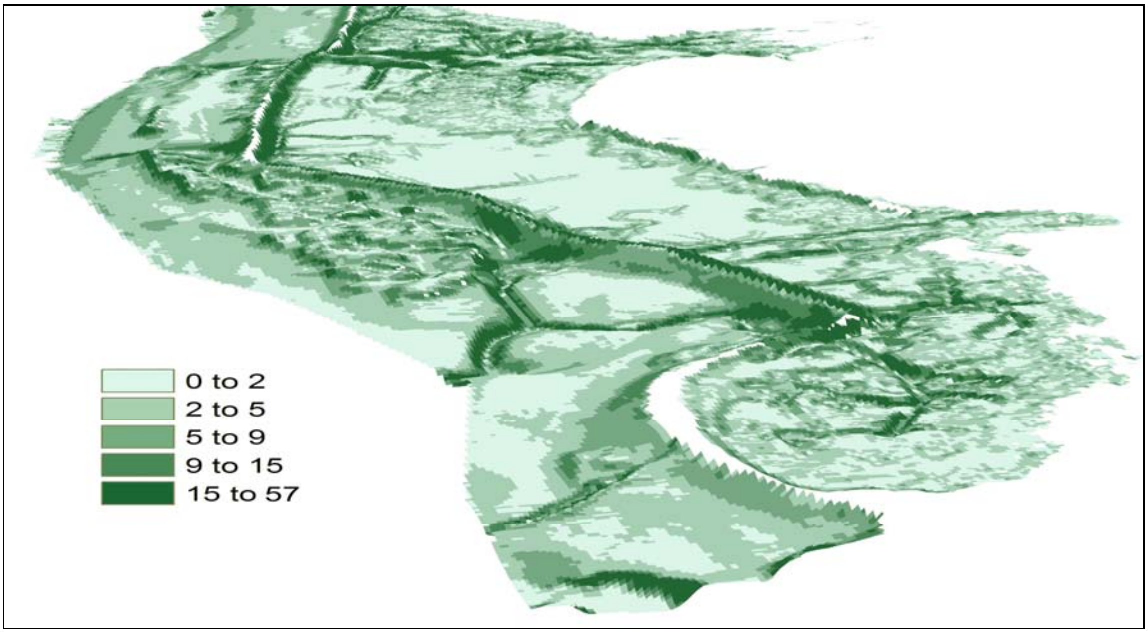


**Figure 5.45 Mean slope (%) for Bunny Meadows saltmarsh site**

**Soil grain size –** sediment grain size, composition and porosity of the dredge sediments used will affect drainage characteristics and organic content – composition of dredged sediment to be used for recharge is unknown: AMBER.
**Sediment Supply –** presence of healthy marshes close to a proposed site would indicate a suitable location in terms of sediment supply – extensive marshes nearby but isolated by the presence of sea wall:. AMBER.
**Contamination –** areas away from major pollutant sources are preferable – there are very high levels of antifouling pollution: RED.
**Land Conservation Value -** sites selected for saltmarsh creation should not have a high conservation value (such as SSSIs, Ramsar sites etc.) – Bunny Meadows site designated SSSI, Ramsar, SPA, SAC: RED.
**Local Economic/Recreational Activities –** all current activities should be checked that they are not likely to be adversely affected by the creation of the recharge site – very high levels of recreational boating with high economic value of local marinas: RED.
**Accessibility -** when selecting areas for recharge, consideration of the accessibility and costs for appropriate vessels/plants/machinery to handle the material must be considered - accessibility by vessel good but access for plant / machinery from land very poor: AMBER.

5.4.25 Hook Marshes: Introduction

Hook (SU 493 051) is again part of the Lee-on-The-Solent to Itchen Estuary SSSI and the Hook with Warsash Local Nature Reserve, it is also SPA, SAC and Ramsar designated. The site is shielded from the main Solent by a small, but growing, spit and has seen slow accretion within the saltmarsh itself and the development of lagoons. It is a Hampshire County Council recreational area and there is relatively close high value housing; the School of Maritime Studies is a short distance NNW in the River Hamble.

5.4.26 Hook: Historic Change

The surface area of natural marsh area at Hook is minimal due to its exposed location at the main entrance to Southampton Water where wave energy is higher than at sites within the River Hamble and at Calshot. The Historic change of the saltmarsh at this location indicates that there was 8,117 $m^2$ of saltmarsh in 1946 and the LTEI indicates an area of 17,546 $m^2$, an area increase of 116%. However, the marsh locations differ and it difficult to differentiate whether the large area indicated by the LTEI is accurate as the location of the marsh lies along a spit (Table 5.19 and Fig 5.46).

TABLE 5.19 HISTORIC SALTMARSH CHANGE - HOOK
(Based on HPI)

| Year | Surface area $m^2$ | Source | Period | Total loss $m^2$ | % loss | % loss pa |
|---|---|---|---|---|---|---|
| **1946** | 8,117 | CCO | 1946-2007 | -9,429 | -116.16 | -1.90 |
| **2007** | 17,546 | LTEI | | | | |

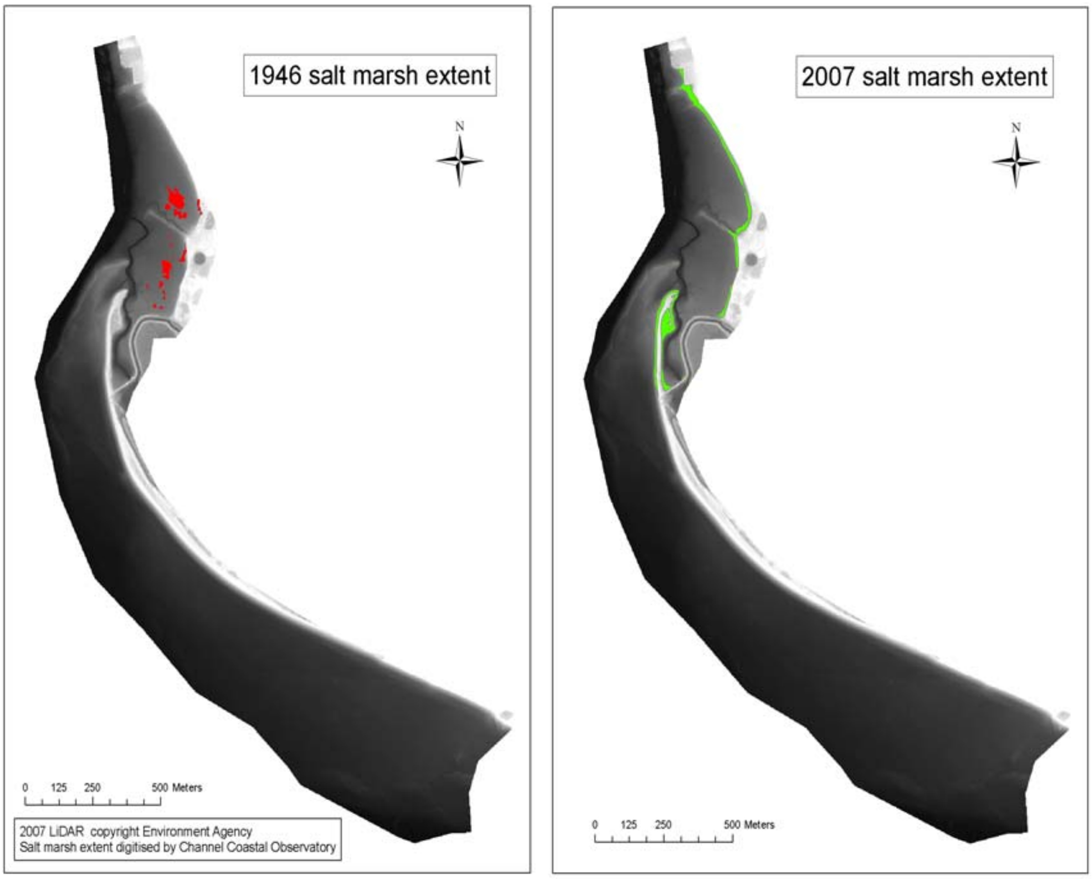


**Figure 5.46 Saltmarsh extents 1946-2007 - Hook**

The majority height of Hook Marsh varies between -2.6 and 0 m OD, with only a small proportion between 0 and 2.1 m OD (Fig. 5.47)

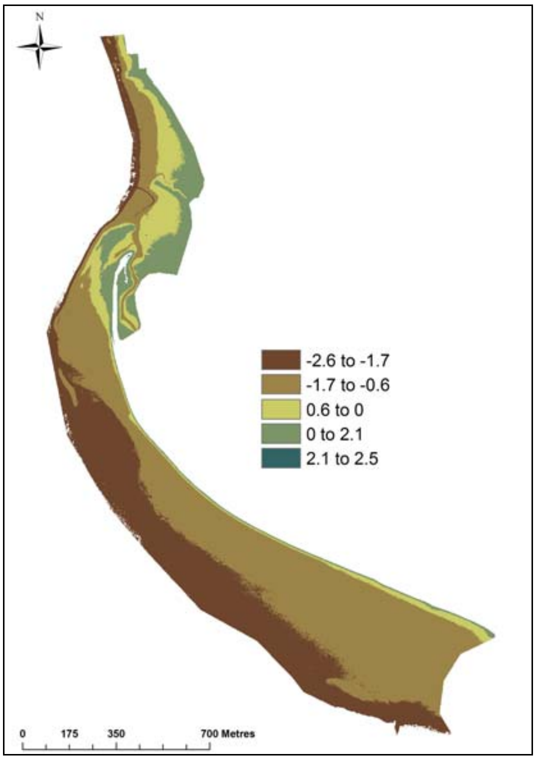


**Figure 5.47 Height of Hook Marsh relative to OD**

5.4.27 Hook: Volume Requirements for Mudflat Recharge

The area of mudflat at Hook is greater than the saltmarsh. This indicates the high energy environment at Hook may be unsuitable for saltmarsh promotion and may require shelter provision to be viable if the site is used for sediment recharge (Figure 5.48 and 5.49).

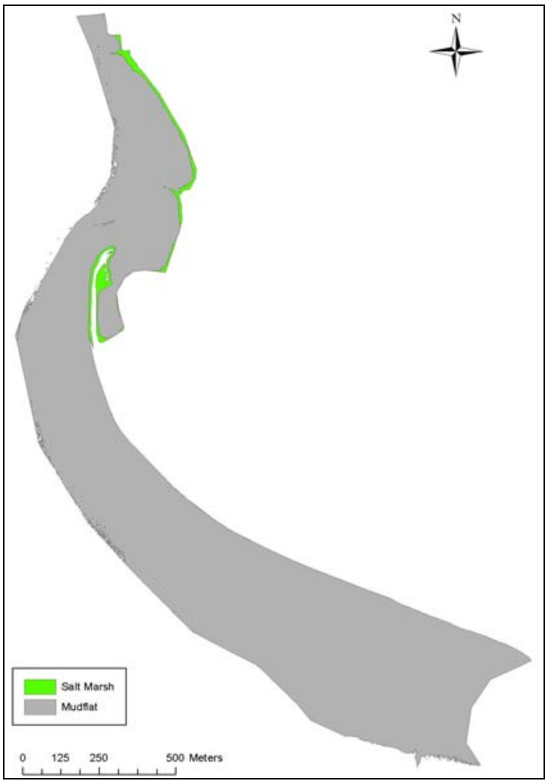


**Figure 5.48 Potential mudflat recharge area - Hook**

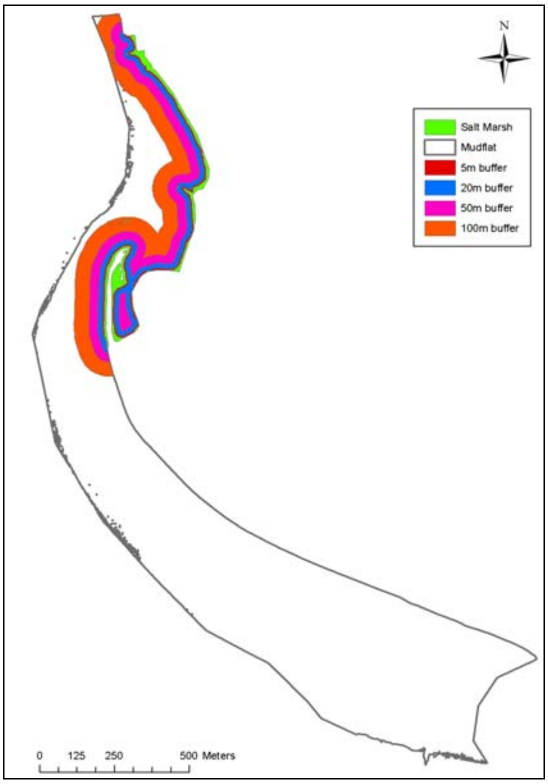


**Figure 5.49 Existing saltmarsh and potential saltmarsh buffers**

Were the 953,886m$^2$ of mudflat to be converted to saltmarsh the minimum requirement of sediment would be 1,379,437m$^3$ (Table 5.20 and Fig 5.50).

TABLE 5.20 VOLUME OF SEDIMENT TO CONVERT MUDFLAT TO SALTMARSH - HOOK

| | Surface area m$^2$ | % mudflat surface area | Volume of sediment required m$^3$ | | |
|---|---|---|---|---|---|
| | | | mhws | mhw | mhwn |
| **5m** | 10,382 | 1 | 12,865 | 9,231 | 1,964 |
| **20m** | 42,791 | 4 | 60,721 | 45,744 | 15,791 |
| **50m** | 99,182 | 10 | 146,022 | 111,308 | 41,880 |
| **100m** | 182,922 | 19 | 312,986 | 248,964 | 120,918 |
| **Mudflat** | 953,886 | 100 | 2,381,017 | 2,047,157 | 1,379,437 |

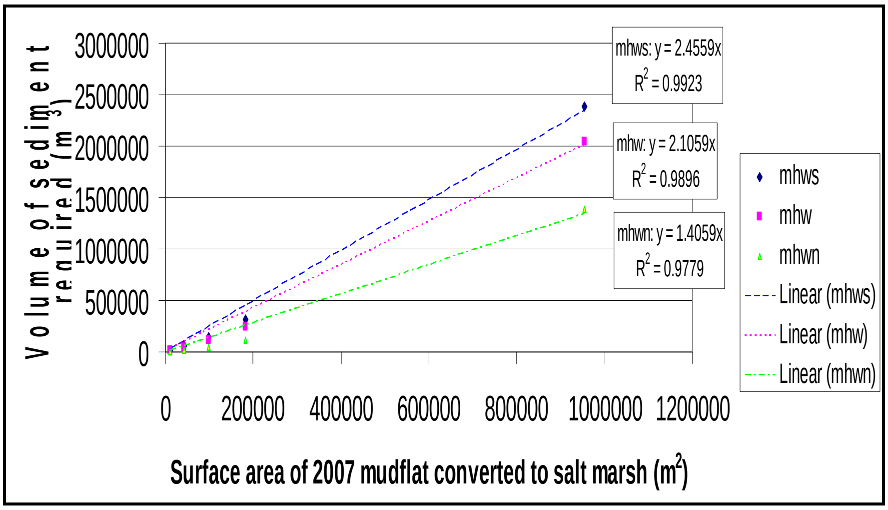


**Figure 5.50 Volume of sediment to convert mudflat to saltmarsh - Hook**

From historic analysis the marsh at Hook appears to be accreting, therefore volumes of dredge material to regain historic salt marsh areas did not require calculation**.**

5.4.28 Hook: Multi Criteria Analysis
The Hook Marsh site is currently accreting so no introduction of dredged material is recommended. However the MCA for the site is included below.

**Presence of existing natural saltmarshes** – indicates the existence of favourable conditions for saltmarsh creation – relatively isolated from other saltmarshes: AMBER.
**Elevation –** most successful marshes have been approximately 2.1m OD – majority of site lies between -2.6 and 0m OD, with only a small proportion between 0 and 2.1m OD (Fig. 5.47): AMBER.
**Drainage –** an extensive creek system is required – remnant existing creek system: AMBER.
**Surface gradient –** optimum is approximately 1-2% (<1:50) – calculated mean slope for Hook saltmarsh is 6.79% (Fig 5.51): RED.

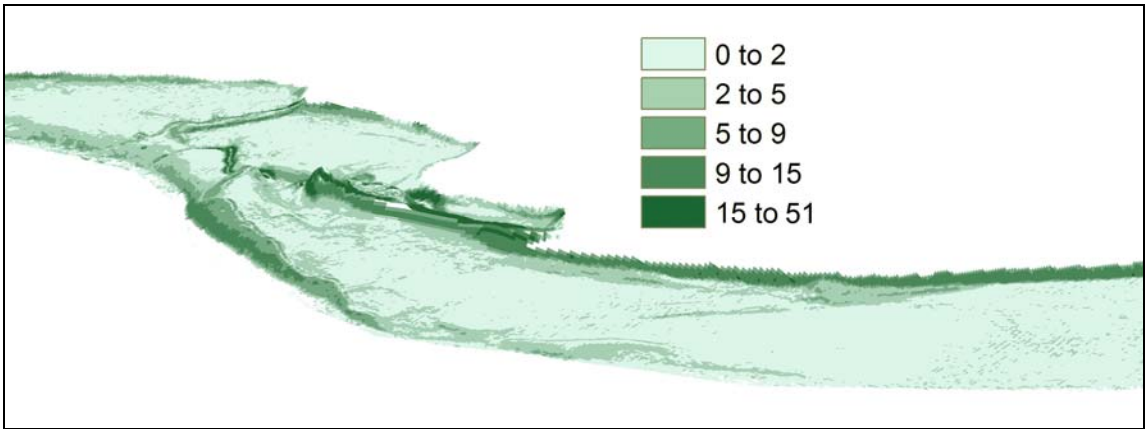


**Figure 5.51 Mean slope (%) for Hook saltmarsh site**

**Soil grain size –** sediment grain size, composition and porosity of the dredge sediments used will affect drainage characteristics and organic content – composition of dredged sediment to be used for recharge is unknown: AMBER.
**Sediment Supply –** presence of healthy marshes close to a proposed site would indicate a suitable location in terms of sediment supply – likely to be interrupted by local spit and man made infrastructure: AMBER.
**Contamination –** areas away from major pollutant sources are preferable – potential hydrocarbon pollution from oil storage facility approximately 1.3 km to the North West, as well as high potential antifouling pollution from the Hamble River: RED.
**Land Conservation Value -** sites selected for saltmarsh creation should not have a high conservation value (such as SSSIs, Ramsar sites etc.) – Hook site designated SSSI, Ramsar, SPA. RED.
**Local Economic/Recreational Activities –** all current activities should be checked that they are not likely to be adversely affected by the creation of the recharge site – low amenity value, however there may be potential impact on the adjacent Warsash Maritime Academy: AMBER.
**Accessibility -** when selecting areas for recharge, consideration of the accessibility and costs for appropriate vessels/plants/machinery to handle the material must be considered – good accessibility for vessels however poor accessibility by road for plant and machinery: AMBER.

5.4.29 Hayling (West): Introduction

Hayling (West) (SU 714 036) marshes consist of mudflats, marsh and pasture land and are jointly owned by Hampshire County Council and a private owner. The pasture land has a low recreational value, but other parts of the site are popular during the summer. A permissive footpath runs along the perimeter of the site. The site contains archaeological interests identified by HCC and West Sussex County Council and is designated under SSSI, SAC, Ramsar and SPA designations. There is residential housing within 500m of the marsh.

5.4.30 Hayling (West): Historic saltmarsh change

Between 1946 and 2007 West Hayling marsh eroded by 48% (Table 5.21, Fig 5.52). However, from CCO data, since 1984 the saltmarsh has increased, however comparison of LTEI coverage and the 2005 extent (aerial photography) indicates a saltmarsh area classification difference; a site visit would enable clarification (Figs 5.53, 5.54).

TABLE 5.21 HISTORIC SALTMARSH CHANGE – WEST HAYLING
(Based on Hpi)

| Year | Surface area $m^2$ | Source | Period | Total Loss $m^2$ | %loss | % loss pa |
|---|---|---|---|---|---|---|
| **1946** | 56,405 | CCO | 1946-1963 | 27,350 | 48.49 | 0.79 |
| **1963** | 32,061 | CCO | 1963-2007 | 3,006 | 9.38 | 0.21 |
| **1984** | 9,252 | CCO | 1984-2007 | -19,803 | -214.04 | -9.31 |
| **2001** | 1,086 | CCO | 2001-2007 | -27,969 | -2575.41 | -429.24 |
| **2002** | 3,589 | CCO | 2002-2007 | -25,466 | -709.56 | -141.91 |
| **2005** | 3,310 | CCO | 2005-2007 | -25,745 | -777.79 | -388.90 |
| **2007** | 29,055 | LTEI | | | | |

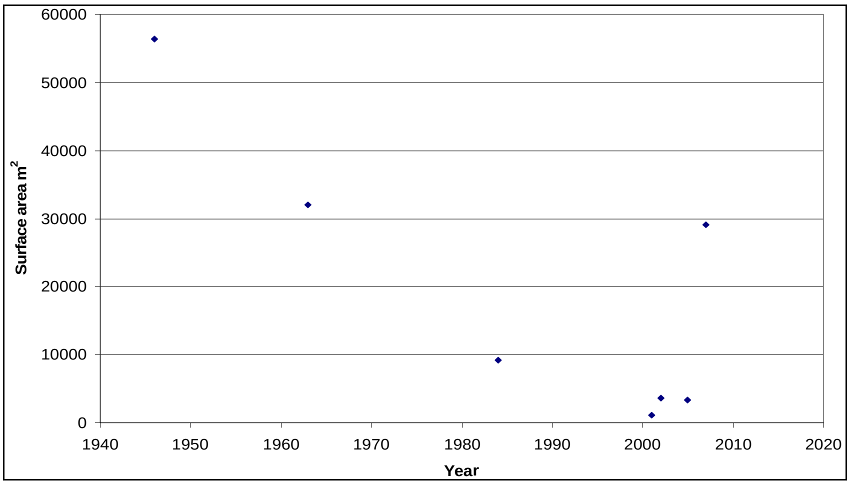


**Figure 5.52 Historic saltmarsh change – West Hayling**

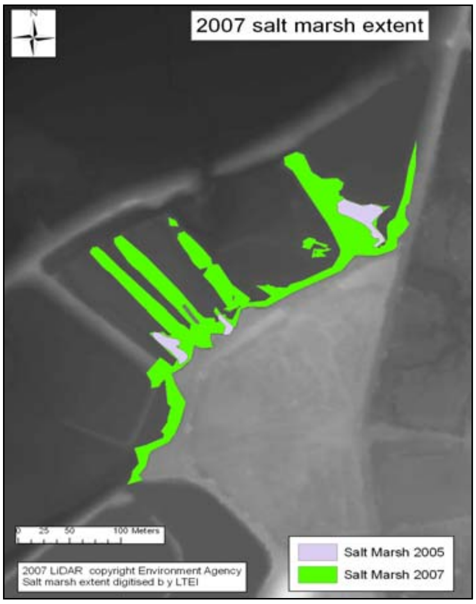


**Figure 5.53 Saltmarsh extents for 2007 LTEI analysis and HPI for 2005 - West Hayling**

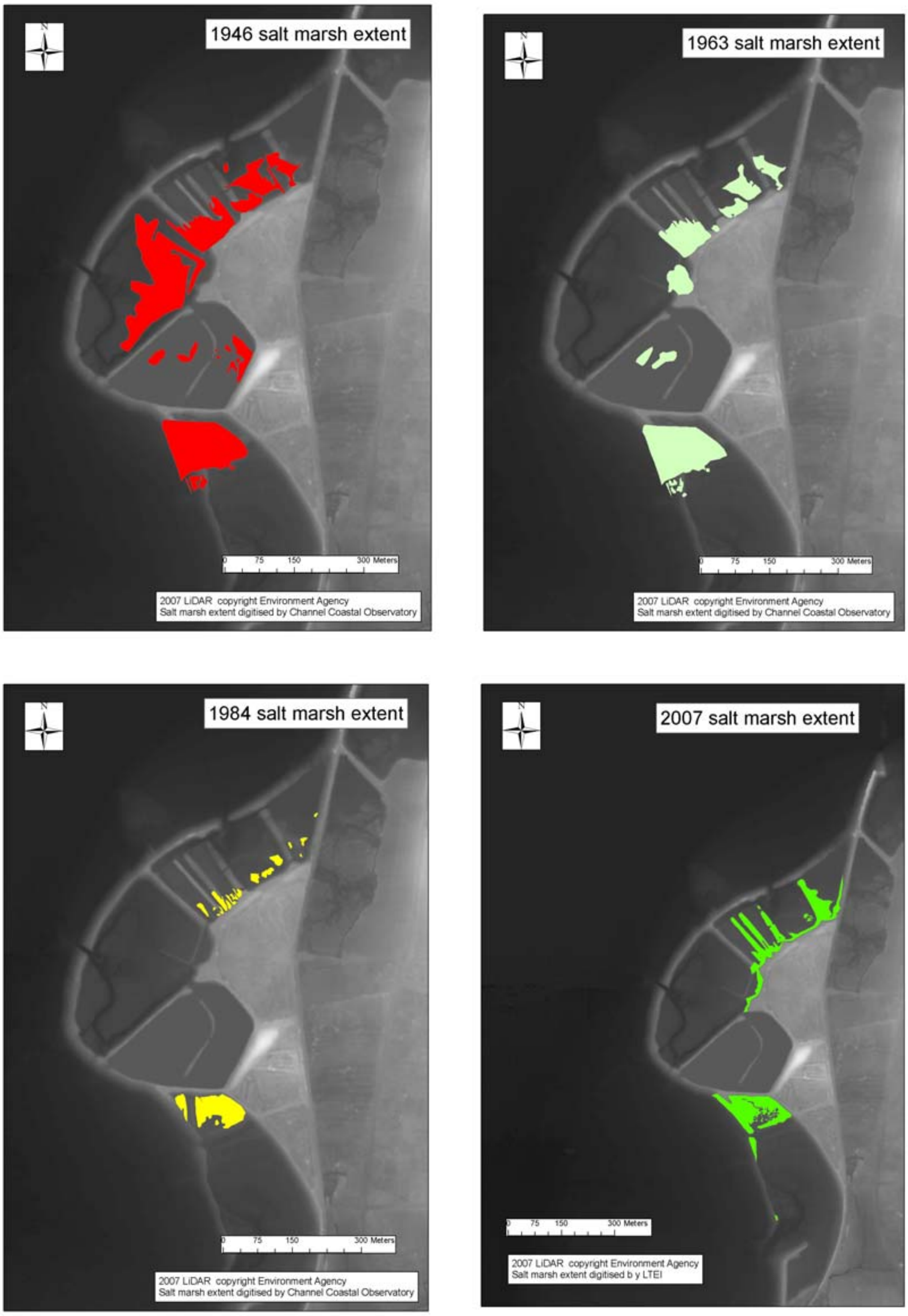


**Figure 5.54 Saltmarsh extents 1946-2007 – West Hayling**

The height of the West Hayling site varies between -2.7 and 0.7m relative to OD. Only small areas were between 0.7 and 2.1m (Fig 5.55).

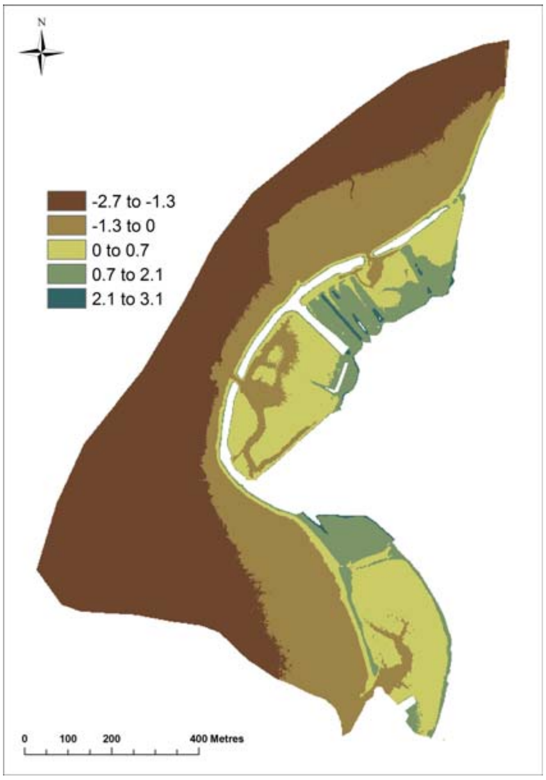


**Figure 5.55 Height of West Hayling site relative to OD**

5.4.31 West Hayling- Volume requirements for mudflat recharge
The extents of mudflat for potential sediment recharge are indicated in Figs 5.45 and 5.46.

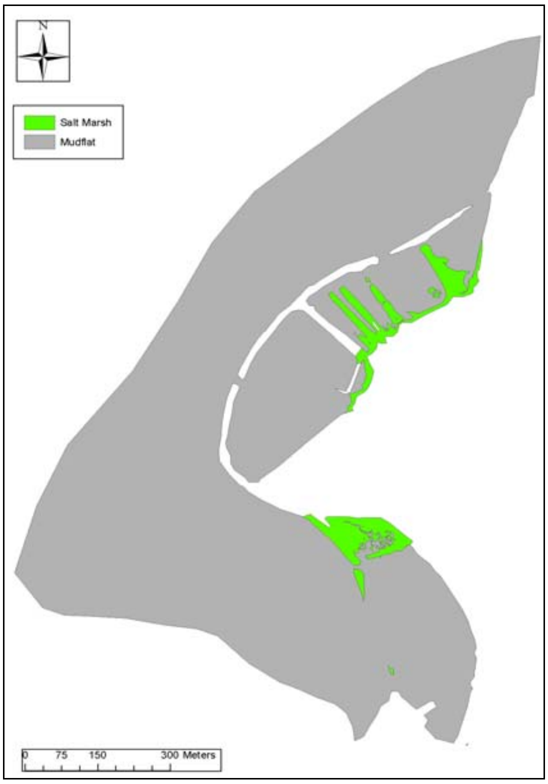


**Figure 5.56 Potential mudflat recharge area - West Hayling**


**Figure 5.57 Existing saltmarsh and potential saltmarsh buffers - West Hayling**

The area of mudflat for potential conversion to saltmarsh is 720,707 $m^2$ which would require a minimum input of 914,232 $m^3$ to convert to pioneer marsh (Table 5.22 and Fig 5.47).

TABLE 5.22 SEDIMENT VOLUME TO CONVERT MUDFLAT TO SALTMARSH – WEST HAYLING

| | Surface area $m^2$ | % mudflat surface area | Volume of sediment required $m^3$ | | |
|---|---|---|---|---|---|
| | | | mhws | Mhw | Mhwn |
| **5m** | 13,416 | 2 | 14,889 | 8,584 | 2,144 |
| **20m** | 39,751 | 6 | 48,448 | 29,765 | 10,685 |
| **50m** | 87,229 | 12 | 119,922 | 78,924 | 37,054 |
| **100m** | 179,133 | 25 | 283,275 | 199,082 | 113,098 |
| **mudflat** | 720,707 | 100 | 1,598,689 | 1,260,063 | 914,232 |

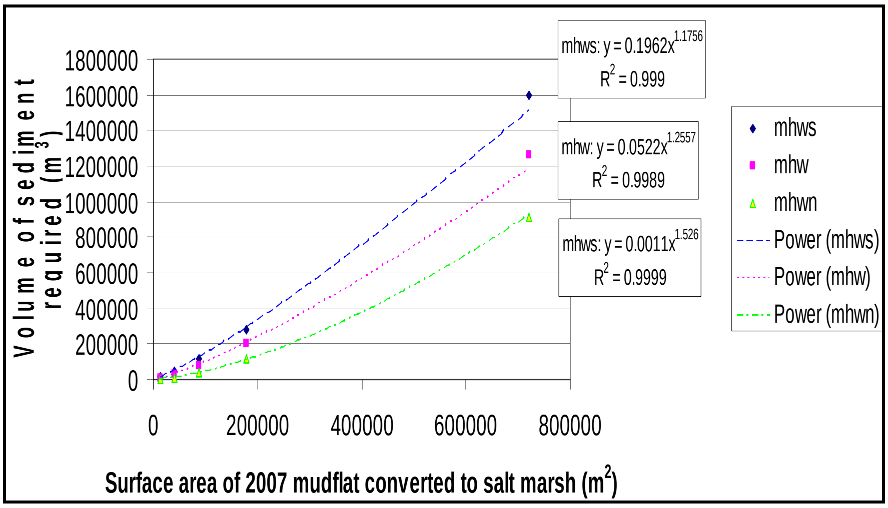


**Figure 5.58 Volume of sediment to convert mudflat to saltmarsh – West Hayling**

Compared to the 2007 LTEI saltmarsh extent, both the saltmarsh areas in 1946 and 1963 were greater (Figs. 5.53 and 5.54). To increase the saltmarsh area to that found in 1946 would require a minimum of 6,489m$^3$ of sediment (Table 5.23).

TABLE 5.23 SEDIMENT VOLUME TO RE-ESTABLISH SALTMARSH - WEST HAYLING

| Year | Surface Area m$^2$ | Volume of sediment required m$^3$ | | |
|---|---|---|---|---|
| | | mhws | mhw | mhwn |
| 1946 | 27,350 | 32,269 | 19,461 | 6,489 |
| 1963 | 3,006 | 2,407 | 1,216 | 223 |

5.4.32 West Hayling: Multi Criteria Analysis

The West Hayling site may currently be accreting, therefore it is recommended that further investigation into this site be done before introducing dredged material into the system.

**Presence of existing natural saltmarshes** – indicates the existence of favourable conditions for saltmarsh creation – there are existing saltmarshes opposite the site, but separated by a deeper water channel: AMBER.
**Elevation** – most successful marshes have been approximately 2.1 m OD – majority of site varies between -2.7 and 0.7 m relative to OD, with only small amounts of the site between 0.7 and 2.1m relative to OD (Fig 5.55): AMBER.
**Drainage –** an extensive creek system is required – no existing creek system: RED.
**Surface gradient –** optimum is approximately 1-2% (<1:50) – calculated mean slope for West Hayling saltmarsh is 5.66% (Fig 5.59): RED.

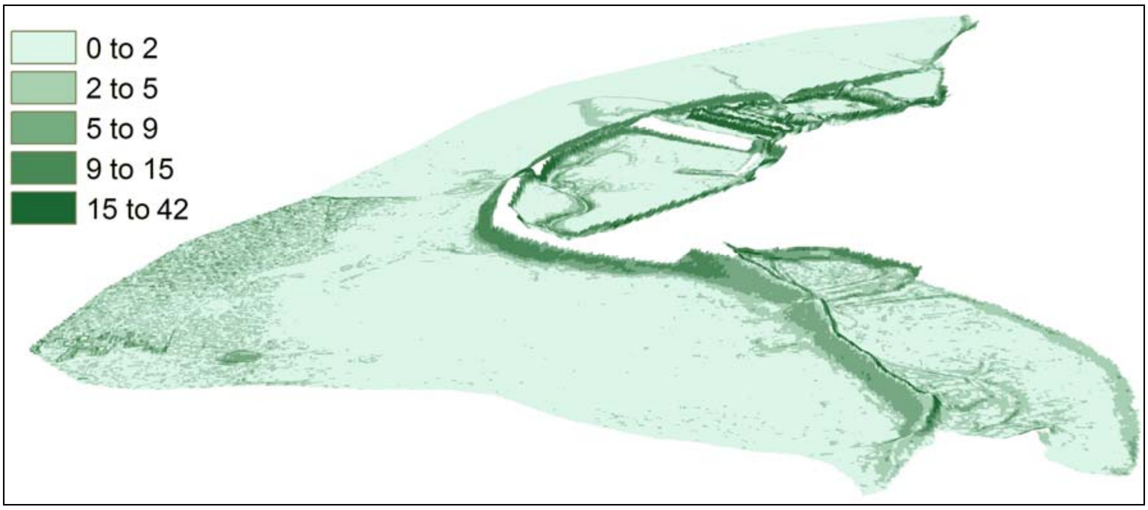

**Figure 5.59 Mean slope (%) for West Hayling saltmarsh site**

**Soil grain size –** sediment grain size, composition and porosity of the dredge sediments used will affect drainage characteristics and organic content – composition of dredged sediment to be used for recharge is unknown: AMBER.
**Sediment Supply –** presence of healthy marshes close to a proposed site would indicate a suitable location in terms of sediment supply – marshes nearby and potential accretion indicates a suitable sediment supply: GREEN.
**Contamination –** areas away from major pollutant sources are preferable – limited local sources of pollution: GREEN.
**Land Conservation Value -** sites selected for saltmarsh creation should not have a high conservation value (such as SSSIs, Ramsar sites etc.) – West Hayling site designated SSSI, SAC, Ramsar, SPA: RED.
**Local Economic/Recreational Activities –** all current activities should be checked that they are not likely to be adversely affected by the creation of the recharge site – moderate recreational value, unlikely to be negatively affected by impacts of recharge scheme: GREEN.
**Accessibility -** when selecting areas for recharge, consideration of the accessibility and costs for appropriate vessels/plants/machinery to handle the material must be considered – accessibility good for both vessels and machinery and plant: GREEN.

5.4.33 Gutner Point: Introduction

Gutner Point (SU 735 015) lies on the eastern shore of Hayling Island and was purchased by Hampshire County Council in 1989. The area consists of a small grazing paddock, saltmarsh, intertidal mudflats and tidal creeks through to the Emsworth Channel. It is a relatively remote area, but is used by the local community and has a medium recreational value. The site is a designated under SSSI, SAC and SPA. There are occasional residential properties in the area with the nearest. 300 m from the middle of Gutner Point.

5.4.34 Gutner Point: Historic Saltmarsh Change

Gutner Point has experienced significant edge erosion between 1946 and 2007 with a 66% loss in area in this period (Table 5.24, Fig 5.60). The increase in area in 1971 (Fig. 5.61) appears to be due to a decrease in the detail of digitising the saltmarsh edge and creeks and so has been excluded from recharge requirement calculations. The majority of the decline in saltmarsh area occurred between 1971 and 1991 (Fig 5.60) after which there has been some relative regain in area in the south of the site (Fig. 5.61 (2007).

TABLE 5.24 HISTORIC SALTMARSH CHANGE – GUTNER POINT
(Based on HPI)

| Year | Surface area $m^2$ | Source | Period | Total Loss $m^2$ | %loss | % loss pa |
|---|---|---|---|---|---|---|
| **1946** | 577,196 | CCO | 1946-2007 | 380,790 | 65.97 | 1.08 |
| **1965** | 583,558 | CCO | 1965-2007 | 387,152 | 66.34 | 1.58 |
| **1971** | 649,737 | CCO | 1971-2007 | 453,331 | 69.77 | 1.14 |
| **1991** | 157,100 | CCO | 1991-2007 | -39,306 | -25.02 | -1.56 |
| **2002** | 219,032 | CCO | 2002-2007 | 22,626 | 10.33 | 2.07 |
| **2007** | 196,406 | LTEI | | | | |

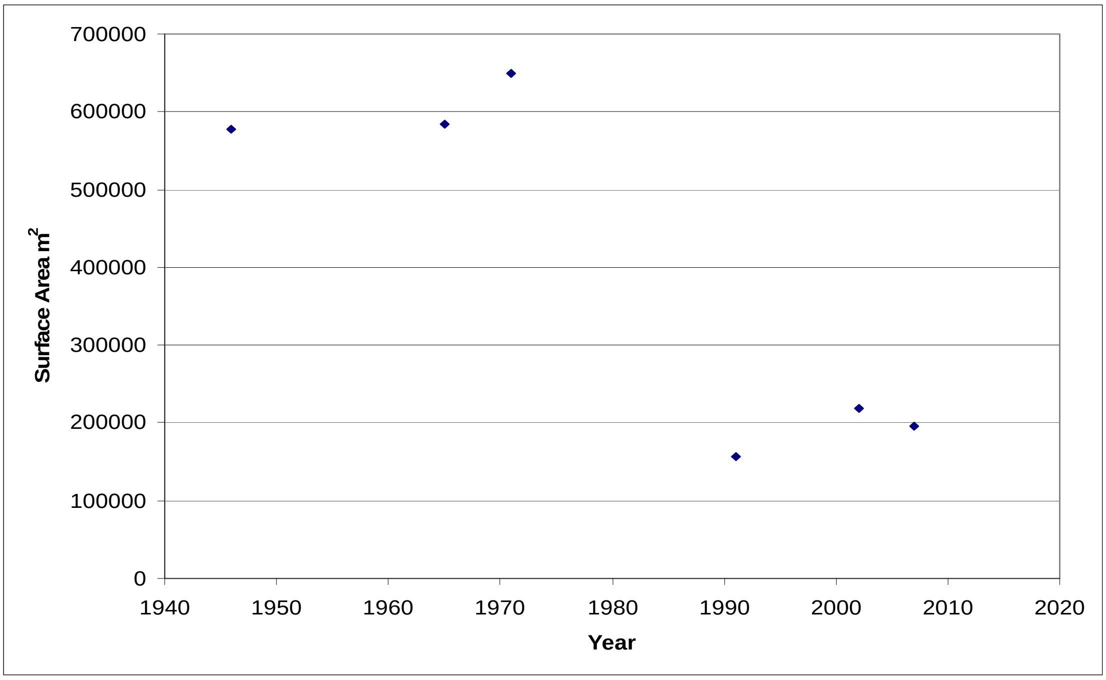


**Figure 5.60 Historic saltmarsh change – Gutner Point**

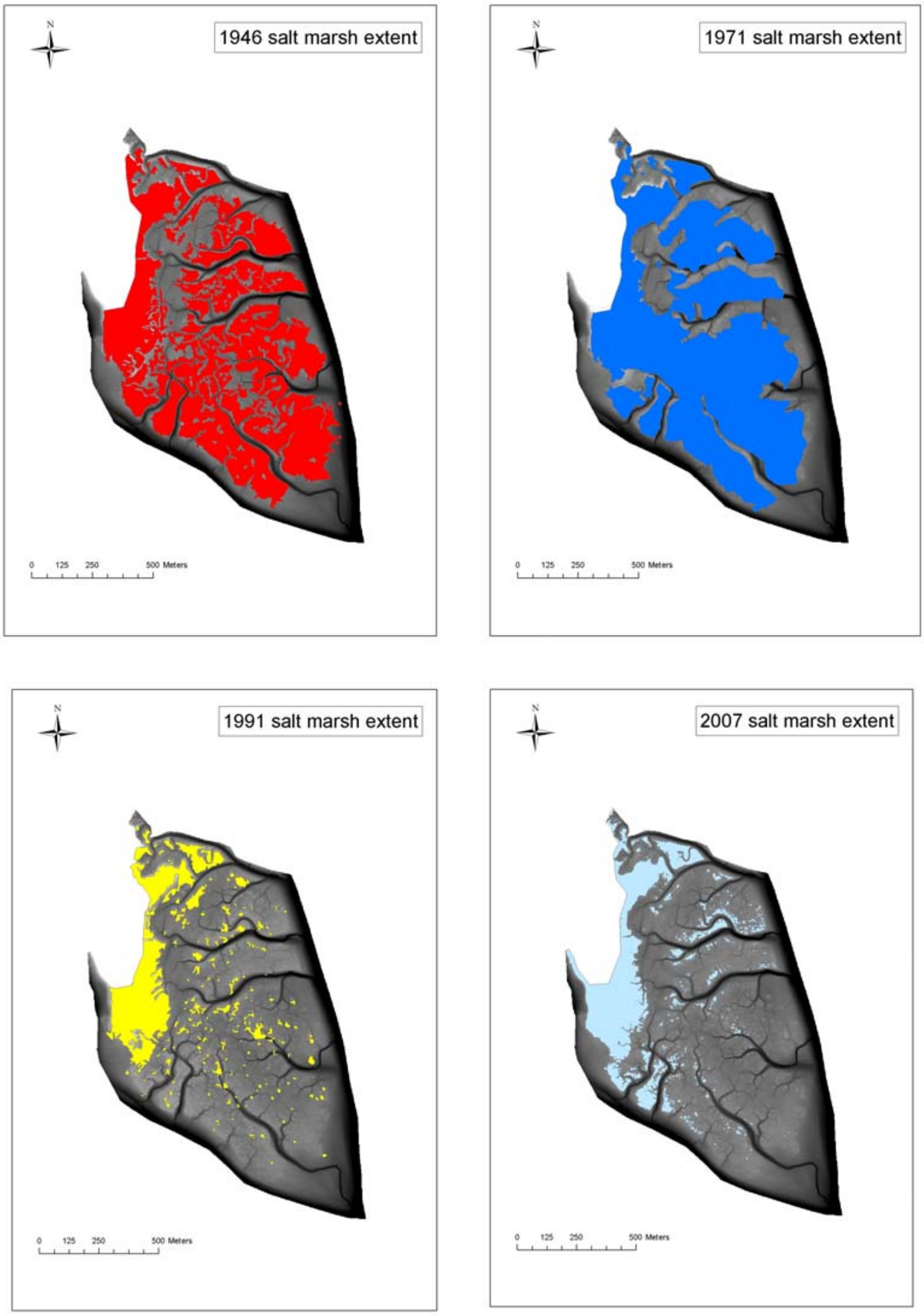


**Figure 5.61 Saltmarsh extents 1946-2007 – Gutner Point**

The majority of the Gutner Point lies between 0 and 2.1m relative to OD (Fig. 5.62).

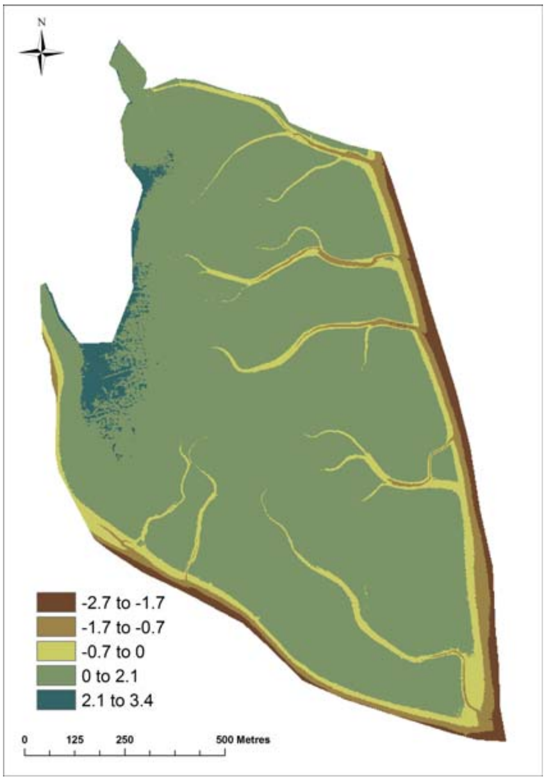


**Figure 5.62 Height of the Gutner Point site relative to OD**

5.4.35 Volume Requirements for Mudflat Recharge

Figs 5.63 and 5.64 show the area of saltmarsh present at Gutner Point in 2007 and the potential area for mudflat recharge. As shown in Table 5.25 the total volume of sediment to increase the mudflat area to MHWN level is 598,964 $m^3$.

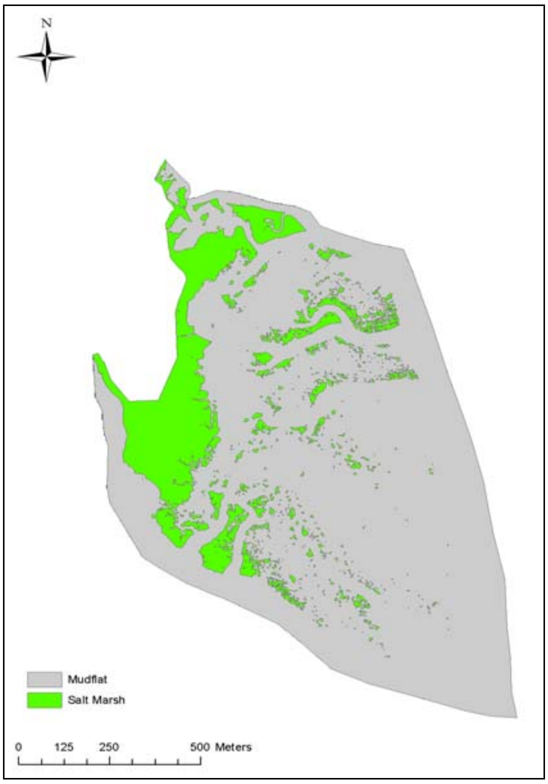


**Figure 5.63 Area selected for potential mudflat recharge- Gutner Point**

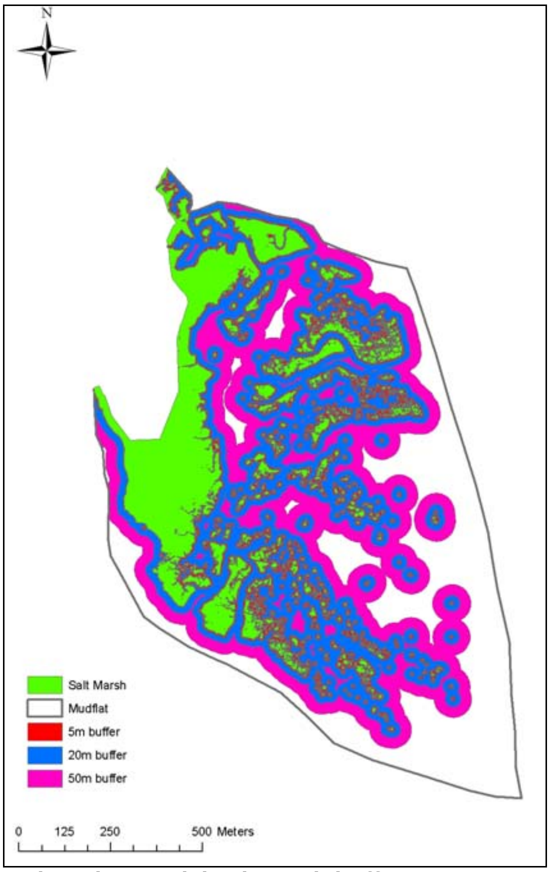


**Figure 5.64 Existing saltmarsh and potential saltmarsh buffers – Gutner Point**

TABLE 5.25 SEDIMENT VOLUME TO CONVERT MUDFLAT TO SALTMARSH – GUTNER POINT

| | Surface area m$^2$ | % mudflat surface area | Volume of sediment required m$^3$ | | |
|---|---|---|---|---|---|
| | | | **mhws** | **Mhw** | **mhwn** |
| **5m** | 148,807 | 15 | 158,486 | 88,547 | 17,119 |
| **20m** | 452,474 | 45 | 514,267 | 301,605 | 84,417 |
| **50m** | 716,738 | 72 | 813,507 | 476,640 | 132,606 |
| **Mudflat** | 998,272 | 100 | 1,547,321 | 1,078,134 | 598,964 |

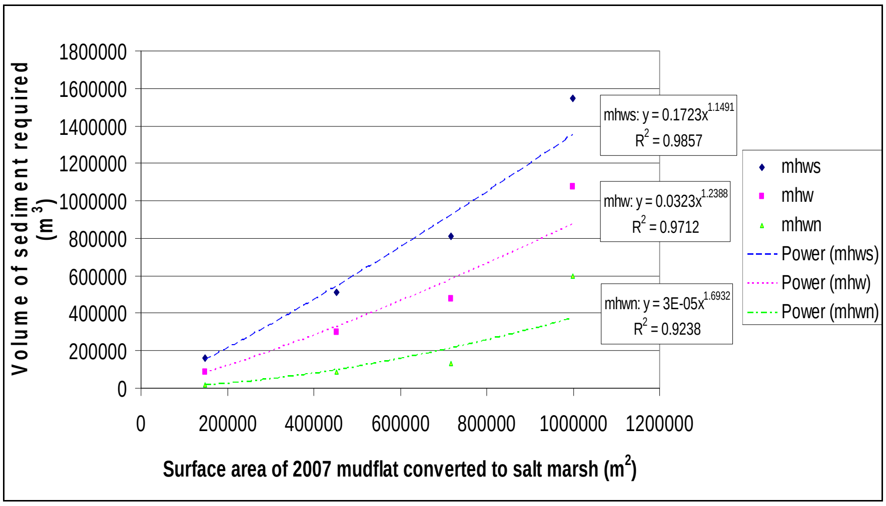


**Figure 5.65 Volumes of sediment to convert mudflat to saltmarsh – Gutner Point**

By interpolating the trend between surface area gain and volume of sediment required (Fig 5.65) it was found that to raise the saltmarsh height to regain the saltmarsh area in 1946 a minimum of 84,399 m$^3$ would be required (Table 5.26).

TABLE 5.26 SEDIMENT VOLUMES TO RE-ESTABLISH SALTMARSH - GUTNER POINT

| Year | Total Loss $m^2$ | Volume of sediment required $m^3$ | | |
|---|---|---|---|---|
| | | mhws | mhw | mhwn |
| **1946** | 380,790 | 447,519 | 264,579 | 84,399 |
| **1965** | 387,152 | 456,122 | 270,066 | 86,800 |
| **2002** | 22,626 | 17,455 | 8,011 | 709 |

5.4.36 Gutner Point: Multi Criteria Analysis

**Presence of existing natural saltmarshes** – indicates the existence of favourable conditions for saltmarsh creation – there are extensive existing saltmarshes close to the site: GREEN.
**Elevation –** most successful marshes have been approximately 2.1m OD – majority of lies between 0 and 2.1m relative to OD (Fig 5.62): GREEN.
**Drainage –** an extensive creek system is required – extensive existing creek system: GREEN.
**Surface gradient –** optimum is approximately 1-2% (<1:50) – calculated mean slope for Gutner Point saltmarsh is 3.26% (Fig 5.66): AMBER.

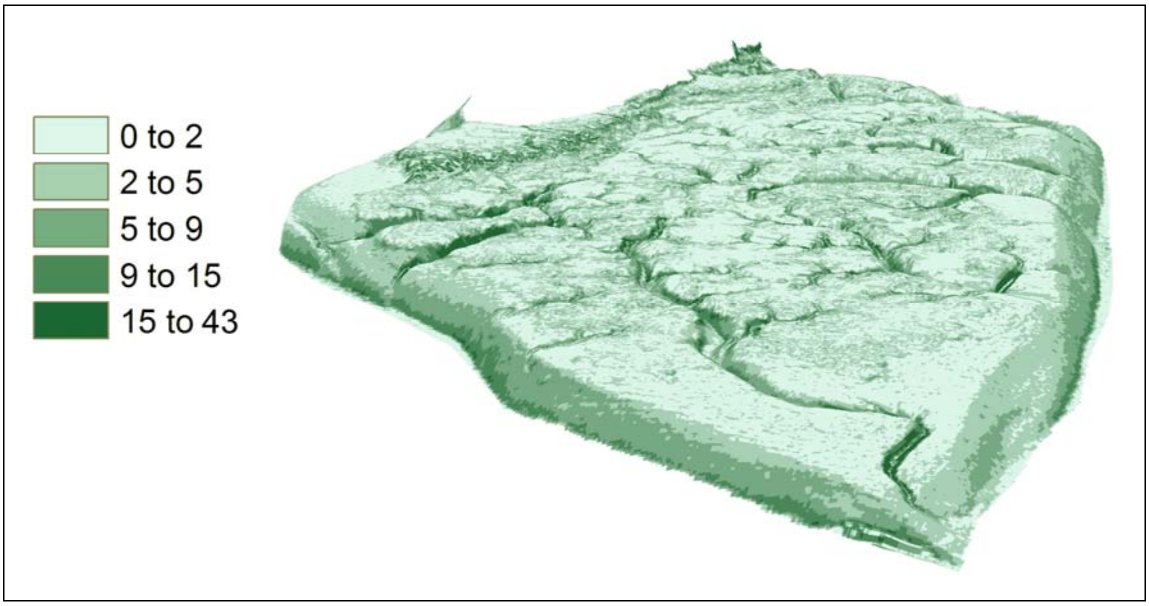


**Figure 5.66 Mean slope (%) for Gutner Point site**

**Soil grain size –** sediment grain size, composition and porosity of the dredge sediments used will affect drainage characteristics and organic content – composition of dredged sediment to be used for recharge is unknown: AMBER.
**Sediment Supply –** presence of healthy marshes close to a proposed site would indicate a suitable location in terms of sediment supply – extensive marshes and mudflats nearby indicate a good fine sediment supply: GREEN.
**Contamination –** areas away from major pollutant sources are preferable – no known local sources of pollution: GREEN.
**Land Conservation Value -** sites selected for saltmarsh creation should not have a high conservation value (such as SSSIs, Ramsar sites etc.) – Gutner Point site designated SSSI, SAC, SPA: RED.
**Local Economic/Recreational Activities –** all current activities should be checked that they are not likely to be adversely affected by the creation of the recharge site – moderate recreational value, unlikely to be negatively affected by impacts of recharge scheme: GREEN.
**Accessibility -** when selecting areas for recharge, consideration of the accessibility and costs for appropriate vessels/plants/machinery to handle the material must be considered – accessibility will be difficult for plant / machinery and vessels: RED.

5.4.37 Conclusions for Hampshire County Council Sites

Priority sites for recharge based on historic erosion rates are Gutner Point which experienced 66% loss in area between 1946 and 2007; Keyhaven which experienced a 45% loss in area between 1971 and 2007 and; Calshot which experienced a 70% loss in area between 1946 and 2007. Calshot is managed by ESSO Oil Refinery, however despite initially reducing the rate of erosion of saltmarsh area decline between 1971 and 1984 the saltmarsh is continuing to erode with a 20% loss in area since 1984. Bunny Meadows is accreting at a high rate so would perhaps best be left to increase in area naturally. The rate of saltmarsh decline at Hacketts Marsh is also minimal compared to other locations thus this site should not be a high restoration priority.

For each saltmarsh location a trend line was applied to best fit the relationship between saltmarsh area and volume of sediment required to increase the mudflat to a level suitable for saltmarsh development. The gradients of these were compared to provide an indication of which site would require the minimum sediment input to increase the saltmarsh area by $10{,}000m^2$/1 ha (Tables 5.27 to 5.29).

TABLE 5.27 TOTAL MUDFLAT AREA – SEDIMENT VOLUME TO INCREASE MUDFLAT HEIGHT TO MHWS

| HCC site | Volume required per 10,000 metre$^2$ (1ha) of surface area to raise mudflat to mhws m$^3$ |
|---|---|
| **Hook** | 24,559 |
| **Pennington** | 16,107 |
| **West Hayling** | 9,888 |
| **Bunny Meadows** | 8,417 |
| **Hacketts** | 7,556 |
| **Gutner Point** | 6,803 |
| **Calshot** | 6,246 |
| **Keyhaven** | 4,484 |
| **Mercury** | 454 |

TABLE 5.28 TOTAL MUDFLAT AREA – SEDIMENT VOLUME TO INCREASE MUDFLAT HEIGHT TO MHW

| HCC site | Volume required per 10,000 metre$^2$ (1ha) of surface area to raise mudflat to mhw m$^3$ |
|---|---|
| **Hook** | 21,059 |
| **Pennington** | 13,707 |
| **West Hayling** | 5,501 |
| **Bunny Meadows** | 4,965 |
| **Hacketts** | 4,273 |
| **Calshot** | 3,109 |
| **Gutner Point** | 2,913 |
| **Keyhaven** | 2,598 |
| **Mercury** | 365 |

TABLE 5.29 TOTAL MUDFLAT AREA – SEDIMENT VOLUME TO INCREASE MUDFLAT HEIGHT TO MHWN

| HCC site | Volume required per 10,000 metre$^2$ (1ha) of surface area to raise mudflat to mhwn |
|---|---|
| **Hook** | 14,059 |
| **Pennington** | 11,407 |
| **Bunny Meadows** | 1,531 |
| **Hacketts** | 1,491 |
| **West Hayling** | 1,398 |
| **Keyhaven** | 1,070 |
| **Calshot** | 966 |
| **Mercury** | 263 |
| **Gutner Point** | 178 |

From the analysis of sediment volume requirements for MHWN (Table 5.29), Hook would take the largest input of sediment to increase to a height promoting saltmarsh growth. However, despite a small but growing spit, Hook is a relatively n exposed site on the entrance to Southampton Water, thus may not provide a suitably sheltered location to encourage saltmarsh. Pennington marsh would require the second greatest volume of sediment input to increase mudflat height to promote saltmarsh growth. Pennington experienced a 99% loss in area between 1971 and 2001 suggesting that wave pressure may render the site unsuitable for saltmarsh growth. However, its rapid decline also indicates the need for saltmarsh restoration in this location if at all feasible. This juxtaposition may require further consideration of wave climate and the influence of nearby factors (e.g. shore defences).

Keyhaven, Gutner Point and Mercury marsh would require the least volume of sediment input to increase the area of saltmarsh, therefore, based on physical factors, appear suitable for intertidal recharge trials.

The results of the MCA for the HCC sites are summarised in Table 30 below. The MCA allows comparison of both qualitative analysis and quantitative data (where available). This allows data to be compared and gives a framework for decision makers to identify potentially suitable sites.

A "traffic light" system has been chosen to allow the criteria to be compared. It must be noted that green does not mean "*definitely go*", nor red mean "*definitely stop*", these colours simply allow comparison of the various criteria against one another. The qualitative assessments are therefore highly simplified, and the judgements of the research team should be tested by a stakeholder group before decisions are made. It should also be noted that the criteria are unweighted, thus at this stage they are all deemed to be of equal importance. The stakeholder group may decide that certain criteria should be weighted relative to others and this may alter the conclusions of the MCA.

TABLE 5.30 MCA SUMMARY FOR HAMPSHIRE COUNTY COUNCIL SITES

| | Presence of existing marsh | Elevation | Drainage | Gradient | Grain Size | Sediment Supply | Contamination | Conservation Value | Economic/ Recreation | Accessibility |
|---|---|---|---|---|---|---|---|---|---|---|
| **Keyhaven** | Green | Green | Green | Green | Amber | Amber | Amber | Red | Amber | Amber |
| **Pennington** | Red | Amber | Amber | Amber | Amber | Red | Amber | Red | Red | Green |
| **Calshot** | Green | Green | Green | Amber | Amber | Green | Red | Red | Red | Green |
| **Mercury** | Amber | Green | Red | Red | Amber | Green | Red | Red | Red | Amber |
| **Hacketts** | Green | Green | Green | Red | Amber | Green | Red | Red | Red | Amber |
| **Bunny** | Amber | Green | Red | Red | Amber | Amber | Red | Red | Red | Amber |
| **Hook** | Amber | Amber | Amber | Red | Amber | Amber | Red | Red | Amber | Amber |
| **West Hayling** | Amber | Amber | Red | Red | Amber | Green | Green | Red | Green | Green |
| **Gutner Point** | Green | Green | Green | Amber | Amber | Green | Green | Red | Green | Red |

No data are available for the grain size of the dredged sediment to be deposited on the potential sites so all of these fields are given an "amber light"

Bunny Meadows and Hook Marsh are accreting, while West Hayling and Hacketts may be accreting. It is therefore recommended that no introduction of dredge sediment be made into these systems at the present time. Of the remaining sites the MCA suggests that Gutner Point, Keyhaven and Calshot show a positive balance of criteria for trial recharge using dredge spoil.

### 5.5 Results: SDCP Sites

5.5.1 Introduction

Through the SDCP (Cope *et al*., 2007) 11 sites were recommended for realignment across the north Solent. The advantages of these sites were that:

- The land use is either unused or low grade agricultural;
- There is no or little cultural heritage;
- There are no, or few, licensed abstraction sites;
- There is low recreational usage;
- There are no rights of way;
- The land is owned by one statutory body rather than a number of individual private landowners;
- The site is greater than 10 ha in area

In total from these sites a total area of 5,980,424 $m^2$ (598ha) of saltmarsh and 1,894,973 $m^2$ (189 ha) of mudflat could be potentially created through managed realignment. Sediment volumes required to increase mudflat areas to levels where saltmarsh can develop were calculated. The benefit of converting mudflat from realigned sites to saltmarsh is that the mudflat is not designated and therefore legal constraints are not a limiting factor unlike on the Hampshire County Council sites. The limiting factor in terms of designation is whether the managed realignment site is designated for another habitat such as reed beds; however this would limit the whole creation of realignment sites. The sites and sediment requirements are outlined in the following sections.

5.5.2 Saltgrass Lane

Saltgrass Lane (SZ 305 912) site consists of intertidal mudflats and Atlantic salt meadows. It is owned by NFDC and HCC and numerous private owners. The area currently has a medium recreational use (Cope *et al*., 2007) with the area being used for walking, bird watching, fishing and bait digging. Numerous rights of way run through the site and NFDC is investigating enhanced access. The site contains no designated archaeological remains and is designated under SSSI (part), Ramsar and SPA.

Defences are maintained by the EA. Approximately half of the site is designated as grazing marsh SPA, thus requiring replacement habitat. The cost of compensation for replacement freshwater habitat creation could result in site being unfavourable for managed realignment. Realignment would result in the creation of 74,924 $m^2$ of saltmarsh, a volume of 182,755 $m^3$. A potential 35,690 $m^2$ of mudflat would also be created and require 1,353 $m^3$ of sediment to convert to saltmarsh (Fig 5.67).

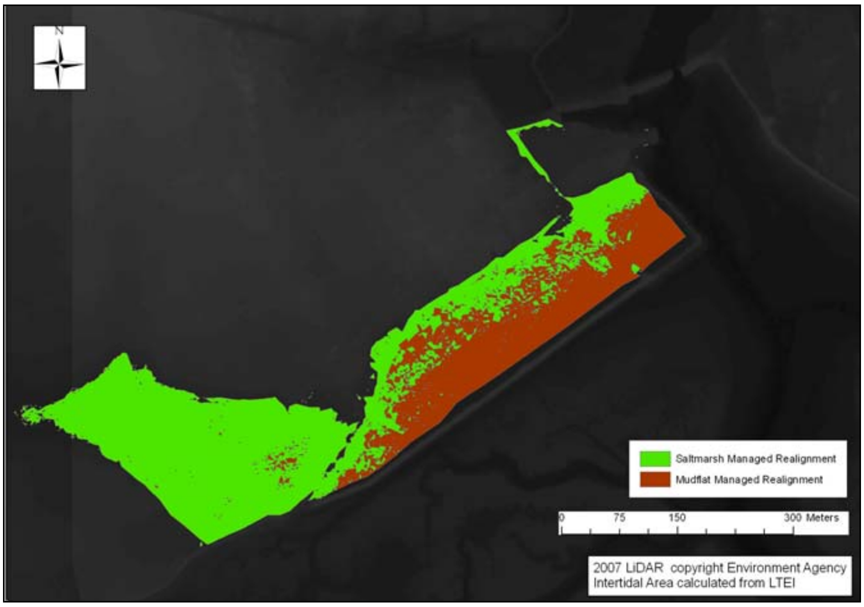


**Figure 5.67 Managed realignment site Salt Grass Lane**

The majority height of Salt Grass Lane is between -0.1 and 0.9m relative to OD (Fig 5.68).

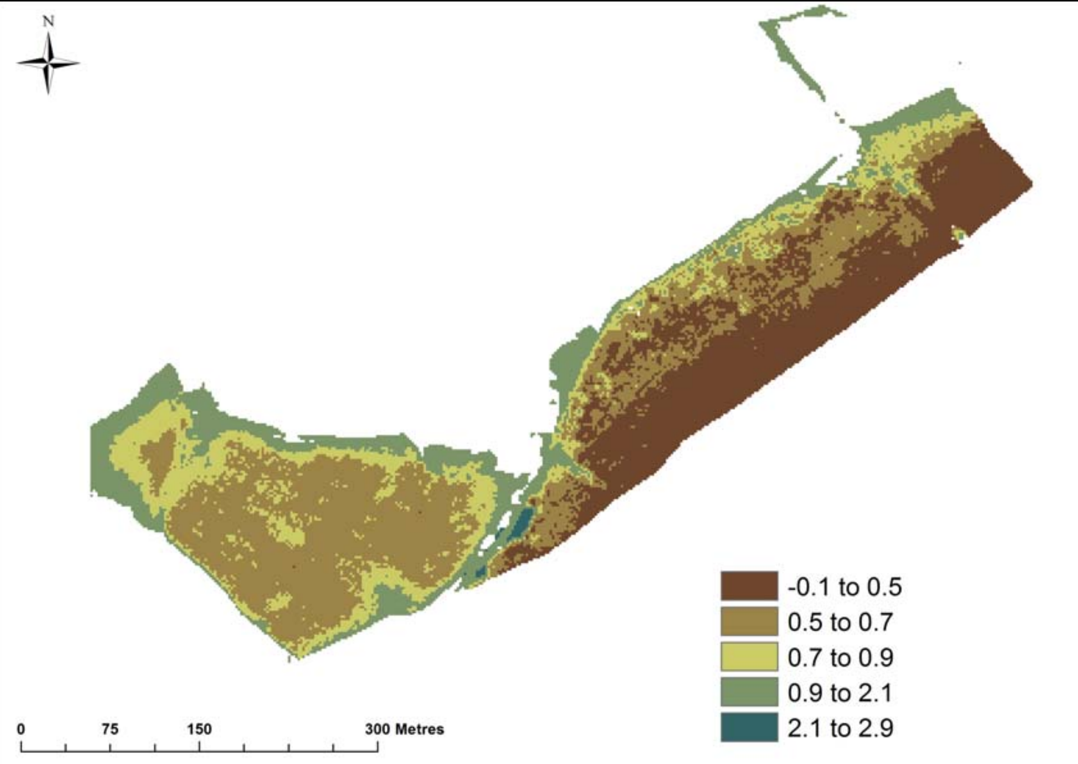


**Figure 5.68 Height of the Salt Grass Lane site relative to OD**

5.5.2 Salt Grass Lane: Multi Criteria Analysis

**Presence of existing natural saltmarshes** – indicates the existence of favourable conditions for saltmarsh creation – there are extensive existing saltmarshes adjacent to the site: GREEN.
**Elevation –** most successful marshes have been approximately 2.1m OD – majority of site between -0.1 to 0.9m above O.D. (Fig. 5.68): GREEN.
**Drainage –** an extensive creek system is required – limited existing creek system: AMBER.
**Surface gradient –** optimum is approximately 1-2% (<1:50) – calculated mean slope for Salt Grass Lane mudflat is 1.87% (Fig. 5.69): GREEN.

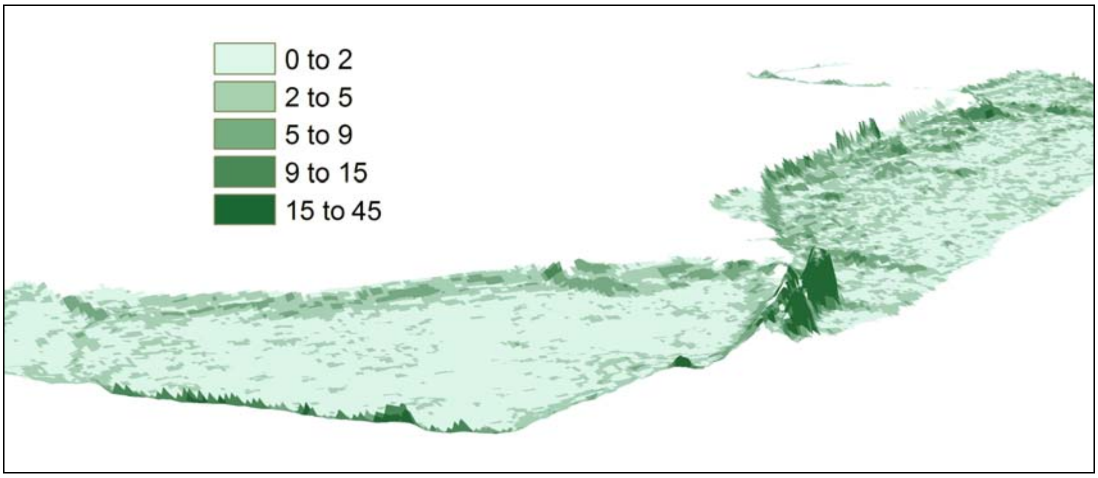


**Figure 5.69 Mean slope (%) for Salt Grass Lane site**

**Soil grain size –** sediment grain size, composition and porosity of the dredge sediments used will affect drainage characteristics and organic content – composition of dredged sediment to be used for recharge is unknown: AMBER.
**Sediment Supply –** presence of healthy marshes close to a proposed site would indicate a suitable location in terms of sediment supply – extensive saltmarshes adjacent to site: GREEN.

**Contamination –** areas away from major pollutant sources are preferable – moderate boating use and a potential for antifouling / hydrocarbons: AMBER.
**Land Conservation Value -** sites selected for saltmarsh creation should not have a high conservation value (such as SSSIs, Ramsar sites etc.) – Salt Grass Lane site designated (part) SSSI, Ramsar, SPA: RED.
**Local Economic/Recreational Activities –** all current activities should be checked that they are not likely to be adversely affected by the creation of the recharge site – potential shellfishery (Ostrea edulis), which may be impacted through sediment drift and high volumes of recreational boating: AMBER.
**Accessibility** – when selecting areas for recharge, consideration of the accessibility and costs for appropriate vessels/plants/machinery to handle the material must be considered – reasonable accessibility for vessels, but poor accessibility for plant / machinery from land side: AMBER.

5.5.3 Lymington Reed Beds

Lymington Reed Beds (SZ 324 964) consist of river valley marshes and are jointly owned by Hampshire Wildlife Trust and numerous private owners. They currently have a medium recreational use with the area being used for bird watching and fishing. Only permissive rights of way exist over the site (Cope *et al*., 2007). The marshes contain no designated archaeological remains and are designated sites under Ramsar and SPA designations. The western side of the site lies close (less than 100m) from residential areas

The defence is maintained by the Environment Agency. The existing reedbed SPA would benefit from saline intrusion which is currently in poor condition. Although the SPA would not require replacement habitat but the saltmarsh and mudflat created would be unable to count towards offsetting coastal squeeze. A volume of 76,418m$^3$ of saltmarsh would be created. There is a great potential for mudflat creation at this realignment site, an area of 212,242m$^2$ which would require 149,598m$^3$ of sediment to convert to a tidal height suitable for pioneer marsh to grow (MHWN) (Fig 5.54).

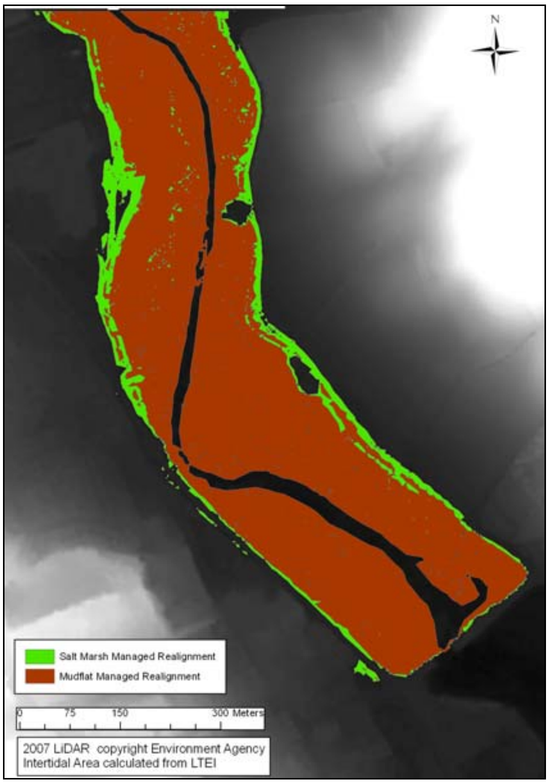


**Figure 5.70 Managed realignment site Lymington Reed Beds**

The majority height of Lymington Reed Beds is between -0.27 and 0.4m relative to OD (Fig 5.71).

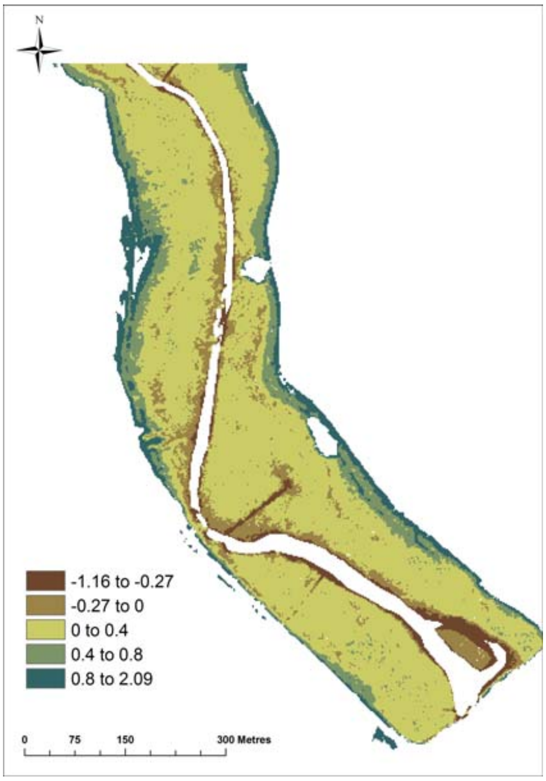


**Figure 5.71 Height of the Lymington Reed Beds site relative to OD**

5.5.4 Lymington Reed Beds: Multi Criteria Analysis

**Presence of existing natural saltmarshes** – indicates the existence of favourable conditions for saltmarsh creation – there are limited existing saltmarshes close to the site: AMBER.

**Elevation –** most successful marshes have been approximately 2.1m OD – majority of site between -0.27 to 0.4m relative to OD (Fig. 5.71): GREEN.

**Drainage –** an extensive creek system is required – limited creek system visible: AMBER.

**Surface gradient –** optimum is approximately 1-2% (<1:50) – calculated mean slope for Lymington Reed Beds mudflat is 2.91% (Fig 5.72): AMBER.

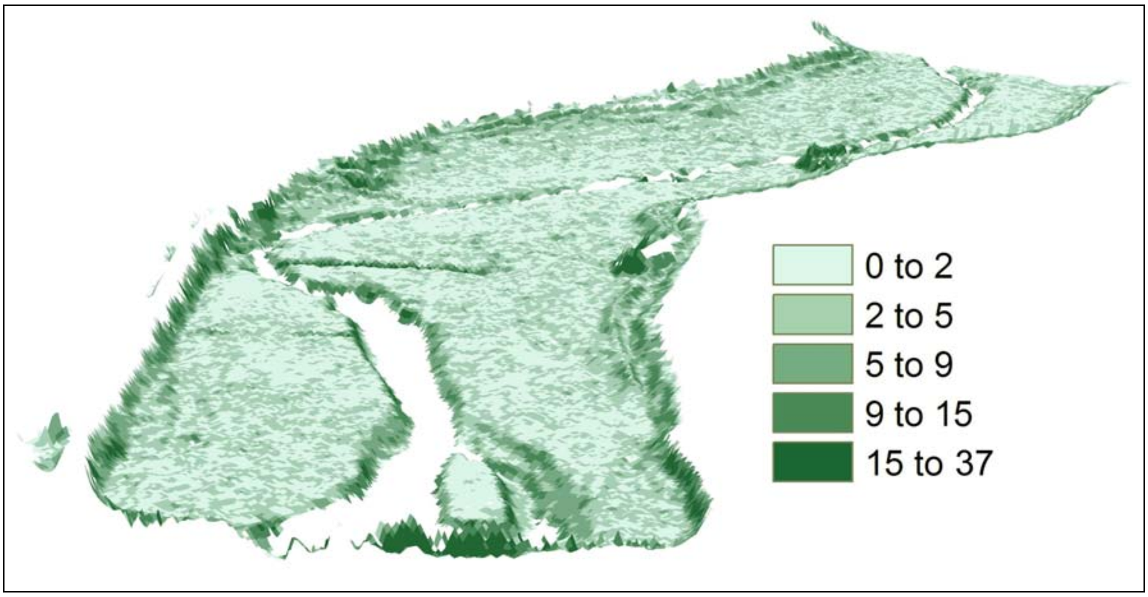


**Figure 5.72 Mean slope (%) for Lymington Reed Beds site**

**Soil grain size –** sediment grain size, composition and porosity of the dredge sediments used will affect drainage characteristics and organic content – composition of dredged sediment to be used for recharge is unknown: AMBER.
**Sediment Supply –** presence of healthy marshes close to a proposed site would indicate a suitable location in terms of sediment supply – limited saltmarshes nearby: AMBER.
**Contamination –** areas away from major pollutant sources are preferable – high historical antifouling pollution in the Lymington River: AMBER.
**Land Conservation Value -** sites selected for saltmarsh creation should not have a high conservation value (such as SSSIs, Ramsar sites etc.) – Lymington site designated Ramsar and SPA: RED.
**Local Economic/Recreational Activities –** all current activities should be checked that they are not likely to be adversely affected by the creation of the recharge site – site has a medium amenity value being used for fishing and bird watching. No substantial boating: AMBER.
**Accessibility -** when selecting areas for recharge, consideration of the accessibility and costs for appropriate vessels/plants/machinery to handle the material must be considered – good road access allowing plant and machinery access to the site, however vessel access is extremely difficult: AMBER.

5.5.5 Gillies

Gillies (SU 574 058) is an old river valley and has no site designations. The site currently has a high recreational use (Cope *et al*., 2007) because of the presence of a sports ground and the general recreational use of the area. A number of rights of way run around the site, which is owned by HCC and is surrounded by a high-density residential area.

The potential saltmarsh volume from realignment is 67,567 $m^3$. The potential mudflat area is 471 $m^2$ which would require 1,368 $m^3$ to increase the height to MHWN (Fig 5.73).

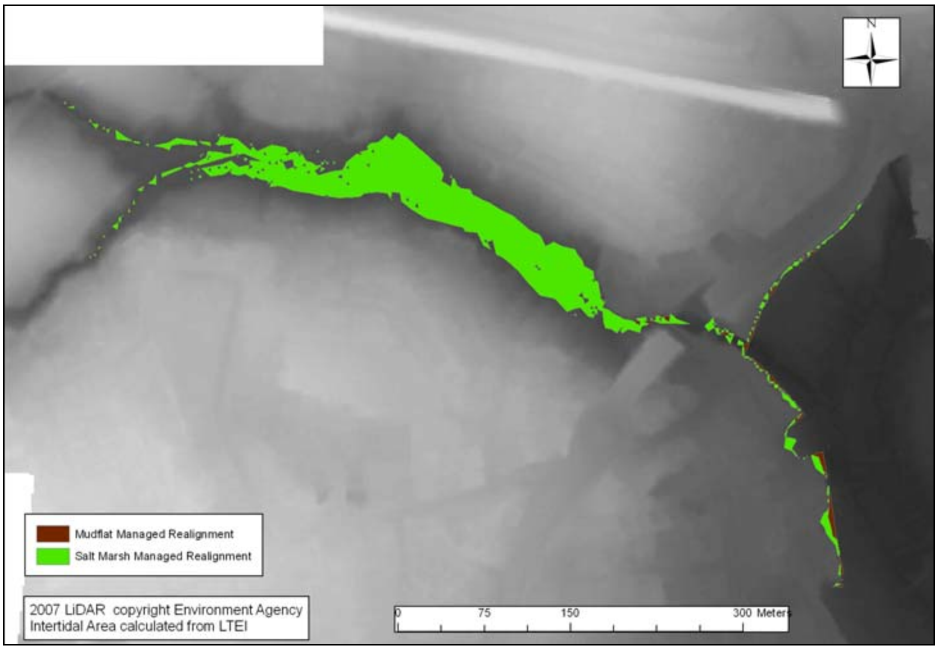


**Figure 5.73 Managed realignment site Gillies**

The height of the majority of the Gillies site is between 0.9 and 2.1m relative to OD (Fig 5.73).

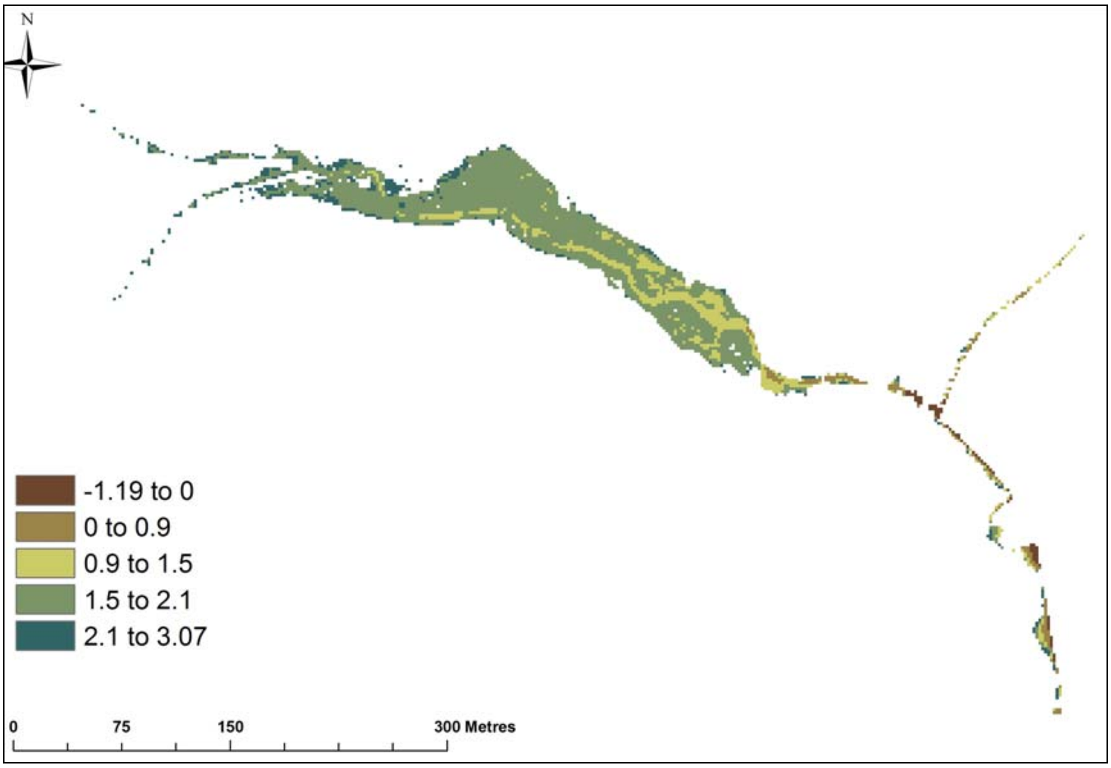


**Figure 5.74 Height of the Gillies site relative to OD**

5.5.6 Gillies: Multi Criteria Analysis

**Presence of existing natural saltmarshes** – indicates the existence of favourable conditions for saltmarsh creation – there are no existing saltmarshes close to the site: RED.

**Elevation –** most successful marshes have been approximately 2.1m OD – majority of site between 0.9 to 2.1m relative to OD (Fig. 5.74): GREEN.

**Drainage –** an extensive creek system is required – extensive former creek system visible: GREEN.

**Surface gradient –** optimum is approximately 1-2% (<1:50) – calculated mean slope for Gillies site is 8.93% (Fig. 5.75): RED.

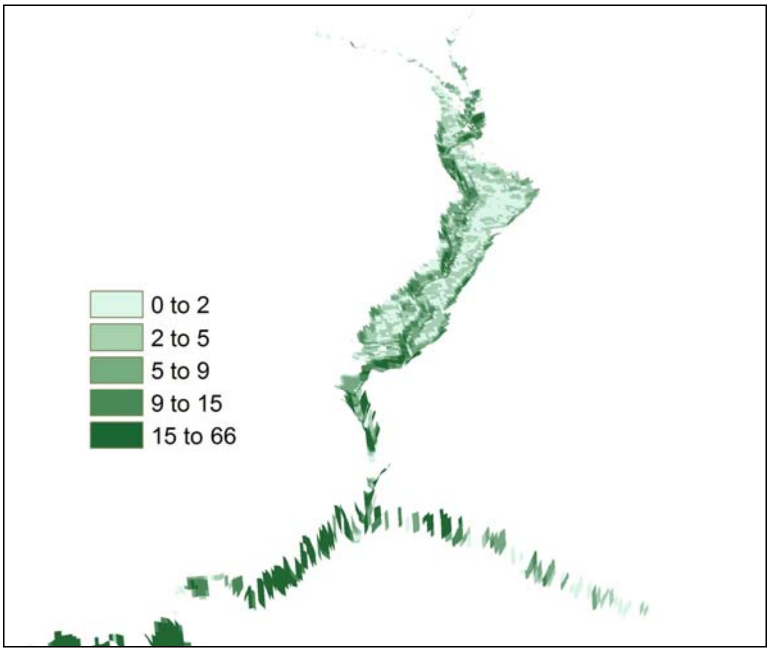


**Figure 5.75 Mean slope (%) for Gillies saltmarsh site**

**Soil grain size –** sediment grain size, composition and porosity of the dredge sediments used will affect drainage characteristics and organic content – composition of dredged sediment to be used for recharge is unknown: AMBER.
**Sediment Supply –** presence of healthy marshes close to a proposed site would indicate a suitable location in terms of sediment supply – no saltmarshes nearby, some fine sediment transported within Fareham Creek: AMBER.
**Contamination –** areas away from major pollutant sources are preferable – likely to be very high local pollution: RED.
**Land Conservation Value -** sites selected for saltmarsh creation should not have a high conservation value (such as SSSIs, Ramsar sites etc.) – No designations: GREEN.
**Local Economic/Recreational Activities –** all current activities should be checked that they are not likely to be adversely affected by the creation of the recharge site – high recreational value: RED.
**Accessibility -** when selecting areas for recharge, consideration of the accessibility and costs for appropriate vessels/plants/machinery to handle the material must be considered – good road access allowing plant and machinery access to the site, however no vessel access: AMBER.

5.5.7 Farlington

Farlington Marshes (SU 685 042) consist of freshwater grazing marshes and freshwater and saline lagoons. They are owned by Portsmouth City Council and managed by the Wildlife Trust. They currently have a medium recreational use (Cope *et al*., 2007) being popular for general recreational use, bird watching and walking; the Solent Way runs along the perimeter of the site. The marshes contain designated archaeological features and are designated sites under SSSI, Ramsar and SPA designations. There are occasional residential dwelling within the site.

The LiDAR coverage of the Farlington site was restricted and it is suggested that future LiDAR scans are taken of the whole site to enable more accurate prediction of the habitat creation from this site. From the scanned area there is the potential for the creation of 6,738,773$m^3$ of saltmarsh. The surface area of potential mudflat from the realigned site is 659,6012$m^2$ and to increase this area to MHWN would require 1,841,779 $m^3$ of sediment (Fig 5.76).

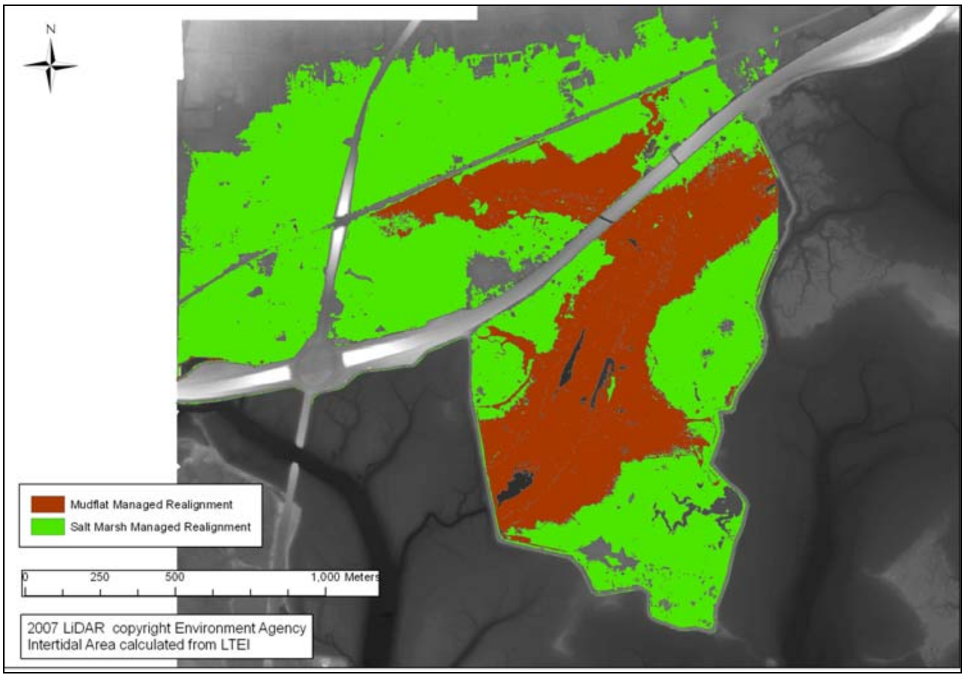


**Figure 5.76 Managed realignment site Farlington**

The majority height of Farlington is between -1.9 and 2.1 m relative to OD (Fig. 5.77).

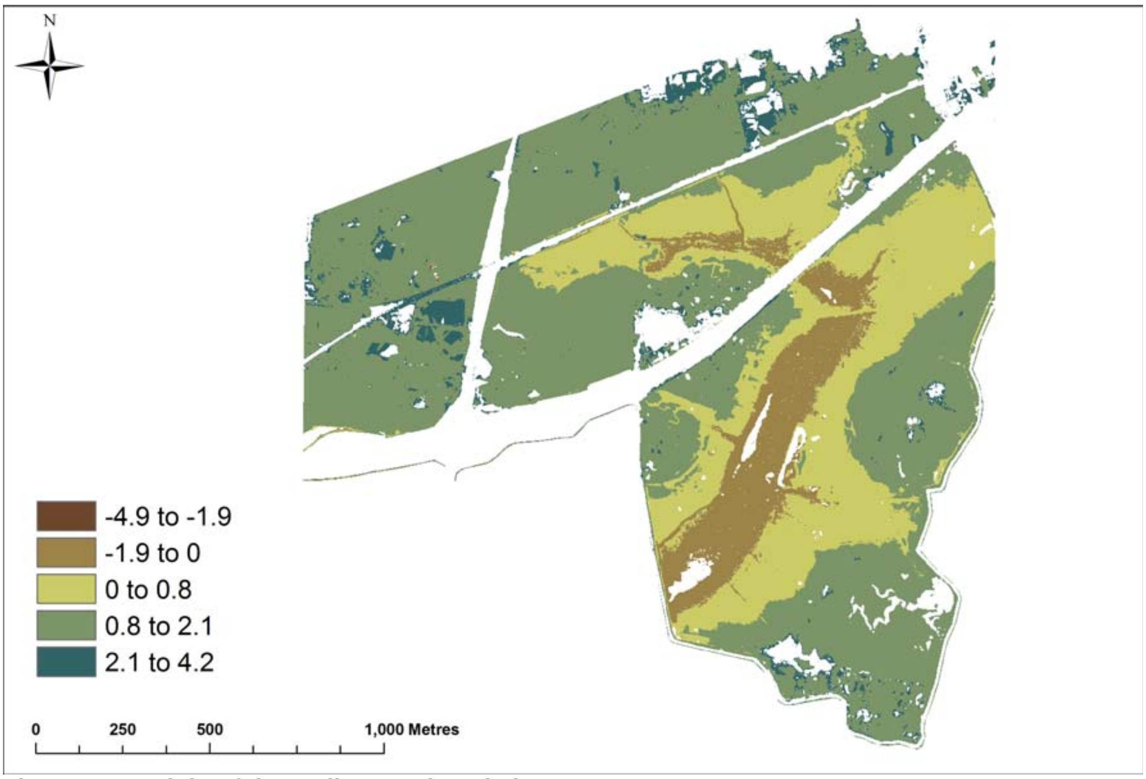


**Figure 5.77 Height of the Farlington site relative to OD**

5.5.8 Farlington: Multi Criteria Analysis

**Presence of existing natural saltmarshes** – indicates the existence of favourable conditions for saltmarsh creation – there are extensive existing saltmarshes adjacent to the site: GREEN.

**Elevation –** most successful marshes have been approximately 2.1m OD – majority of site between -1.9 to 2.1m relative to OD (Fig 5.77): GREEN.

**Drainage –** an extensive creek system is required – extensive former creek system visible: GREEN.

**Surface gradient –** optimum is approximately 1-2% (<1:50) – calculated mean slope for Farlington mudflat is 2.15% (Fig. 5.78): GREEN.

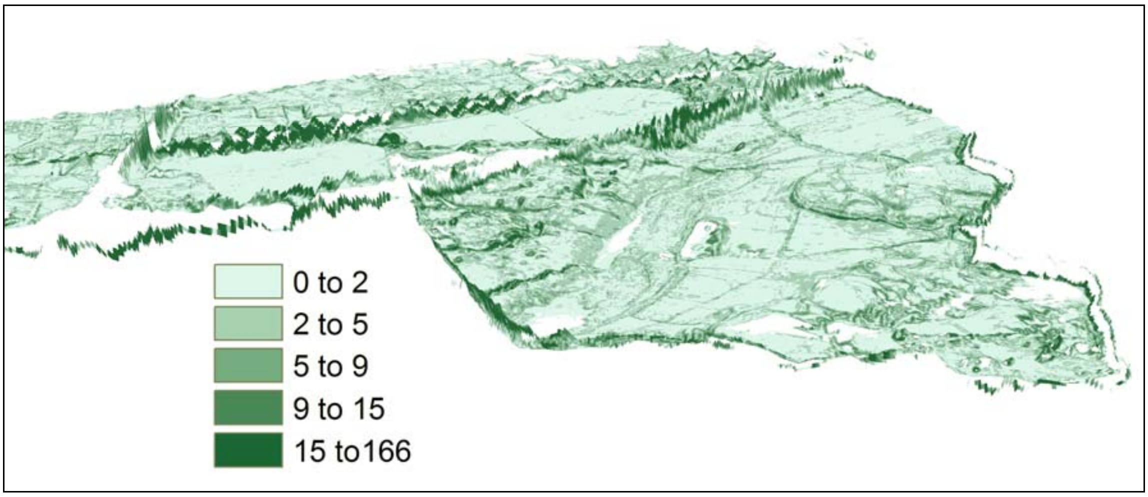


**Figure 5.78 Mean slope (%) for Farlington site**

**Soil grain size –** sediment grain size, composition and porosity of the dredge sediments used will affect drainage characteristics and organic content – composition of dredged sediment to be used for recharge is unknown: AMBER.

**Sediment Supply –** presence of healthy marshes close to a proposed site would indicate a suitable location in terms of sediment supply – extensive saltmarshes adjacent: GREEN.
**Contamination –** areas away from major pollutant sources are preferable – potential historical antifouling and road runoff: AMBER.
**Land Conservation Value -** sites selected for saltmarsh creation should not have a high conservation value (such as SSSIs, Ramsar sites etc.) – Farlington site designated SSSI, Ramsar, SPA: RED.
**Local Economic/Recreational Activities –** all current activities should be checked that they are not likely to be adversely affected by the creation of the recharge site – medium recreational value with the Solent Way running along the perimeter of the site: AMBER.
**Accessibility -** when selecting areas for recharge, consideration of the accessibility and costs for appropriate vessels/plants/machinery to handle the material must be considered – there is good accessibility to the site both for vessels and for machinery and plant: GREEN.

5.5.9 Stoke
Stoke (SU 717 028) consists of pasture land and is owned by Hampshire County Council. The site is maintained by the EA and is non-designated. It has low recreational value although a footpath runs through it and it contains an archaeological site of interest. Stoke is close to residential dwellings (less than 100 m) and the main N-S Hayling Island road (A3023).

Managed realignment would result in a volume of 495,497 $m^3$ of saltmarsh. Only 4 $m^3$ of mudflat would be created and would not be financially suitable for sediment recharge (Fig 5.79).

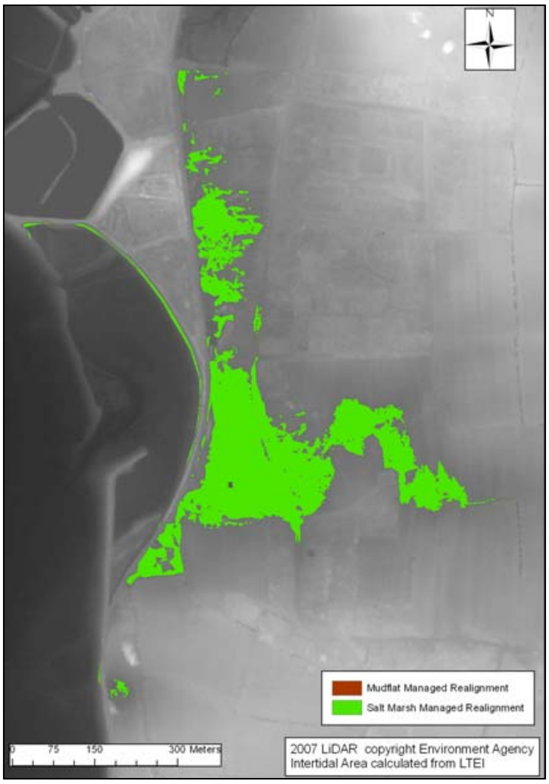


**Figure 5.79 Managed realignment site Stoke**

The majority height of Stoke is between 0.9 and 2.7 m relative to OD (Fig. 5.80).

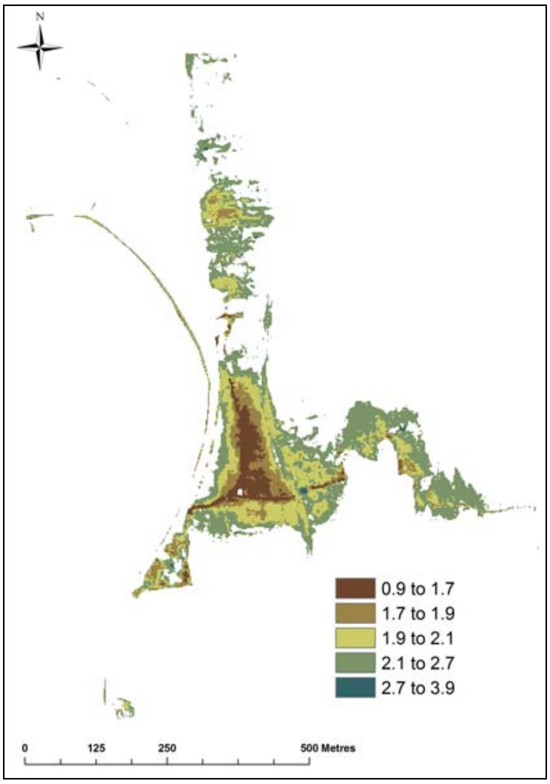


**Figure 5.80 Height of Stoke site relative to OD**

5.5.10 Stoke: Multi Criteria Analysis

**Presence of existing natural saltmarshes** – indicates the existence of favourable conditions for saltmarsh creation – there are limited saltmarshes close to the site: AMBER.

**Elevation –** most successful marshes have been approximately 2.1m OD – majority of site between 0.9 to 2.7m above OD (Fig. 5.80): AMBER.

**Drainage –** an extensive creek system is required – no drainage system evident: RED.

**Surface gradient –** optimum is approximately 1-2% (<1:50) – calculated mean slope for Stoke mudflat is 9.04% (Fig. 5.81): RED.

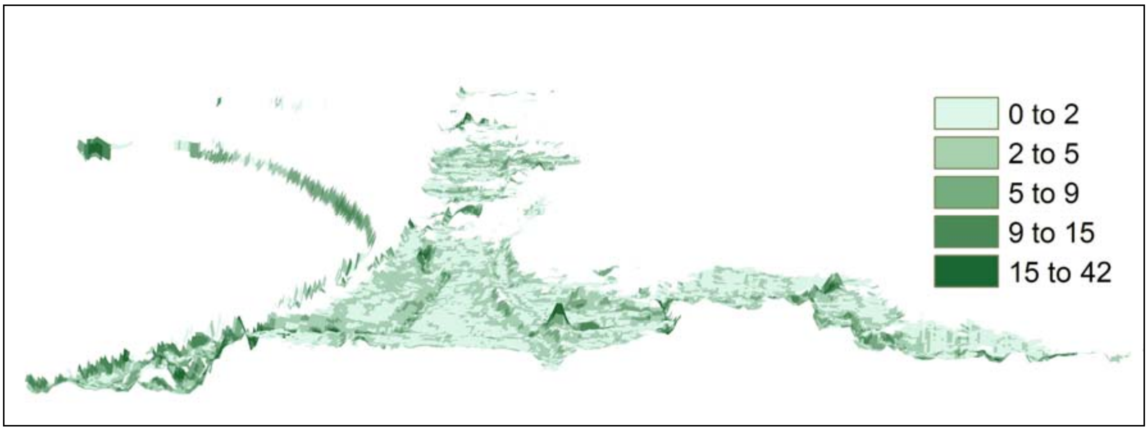


**Figure 5.81 Mean slope (%) for Stoke site**

**Soil grain size –** sediment grain size, composition and porosity of the dredge sediments used will affect drainage characteristics and organic content – composition of dredged sediment to be used for recharge is unknown: AMBER.

**Sediment Supply –** presence of healthy marshes close to a proposed site would indicate a suitable location in terms of sediment supply – limited saltmarshes nearby: AMBER.

**Contamination –** areas away from major pollutant sources are preferable – limited local sources of pollution: GREEN.
**Land Conservation Value -** sites selected for saltmarsh creation should not have a high conservation value (such as SSSIs, Ramsar sites etc.) – undesignated for conservation, some archaeological sites of interest: AMBER.
**Local Economic/Recreational Activities –** all current activities should be checked that they are not likely to be adversely affected by the creation of the recharge site – pasture land with low economic and moderate recreational value, unlikely to be negatively affected by impacts of recharge scheme: GREEN.
**Accessibility -** when selecting areas for recharge, consideration of the accessibility and costs for appropriate vessels/plants/machinery to handle the material must be considered – accessibility good for both vessels and machinery and plant: GREEN.

5.5.11 West Northney

West Northney (SU 717 037) consists of unused pasture land and is owned by Hampshire County Council. Being mainly pasture the land itself has a low recreational value although a popular footpath borders the site and this would be disturbed and need to be relocated should realignment occur. The site contains archaeological sites of interest designated by Hampshire County Council and West Sussex County Council. The site is adjacent to the main Hayling Island north-south route (A3023) and close to a boatyard (less than 200 m) and a residential area (approximately 250 m).

This site is non-designated and has potential to create 209,749 m$^3$ saltmarsh volume and 34,686 m$^3$ through managed realignment. If mudflat were converted to saltmarsh this would create an additional 9,099m$^2$ in area achievable through recharging with a minimum of 256 m$^3$ sediment to MHWS to encourage pioneer species (Fig 5. 82).

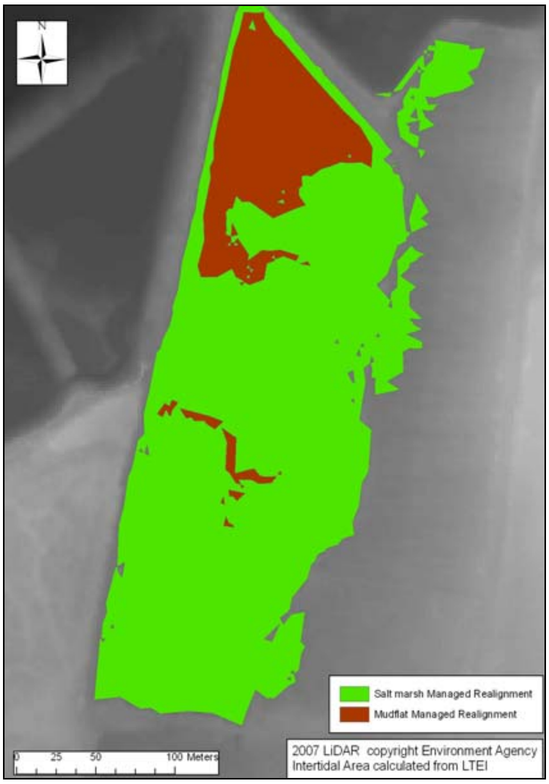


**Figure 5.82 Managed realignment site West Northney**

The majority height of West Northney is between 0.6 and 2.1 m relative to OD (Fig 5.83).

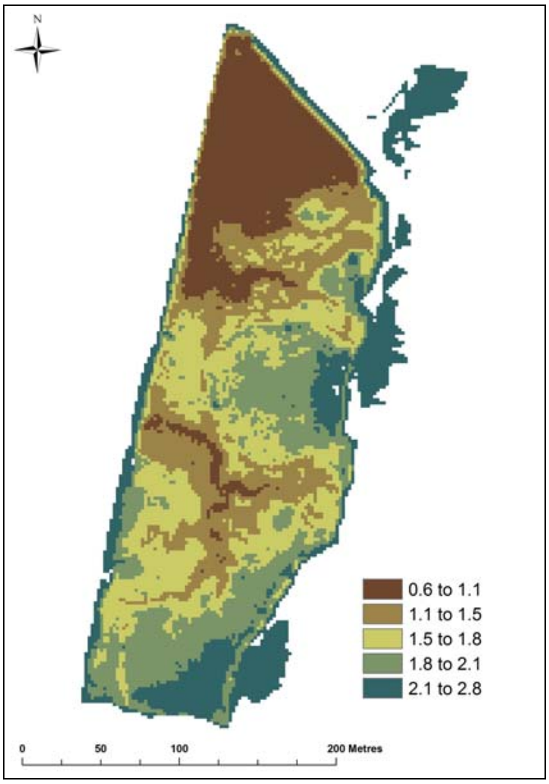


**Figure 5.83 Height of West Northney site relative to OD**

5.5.12 West Northney: Multi Criteria Analysis

**Presence of existing natural saltmarshes** – indicates the existence of favourable conditions for saltmarsh creation – Cope *et al*., (2007) report that there are extensive existing saltmarshes adjacent to the site, however much of this is fragmented and separated from the site by the Hayling Island bridge: GREEN.

**Elevation –** most successful marshes have been approximately 2.1m OD – majority of site between 0.6 and 2.1m relative to OD (Fig. 5.83): GREEN.

**Drainage –** an extensive creek system is required – extensive former creek system: GREEN.

**Surface gradient –** optimum is approximately 1-2% (<1:50) – calculated mean slope for West Northney site is 1.5% (Fig. 5.84): GREEN.

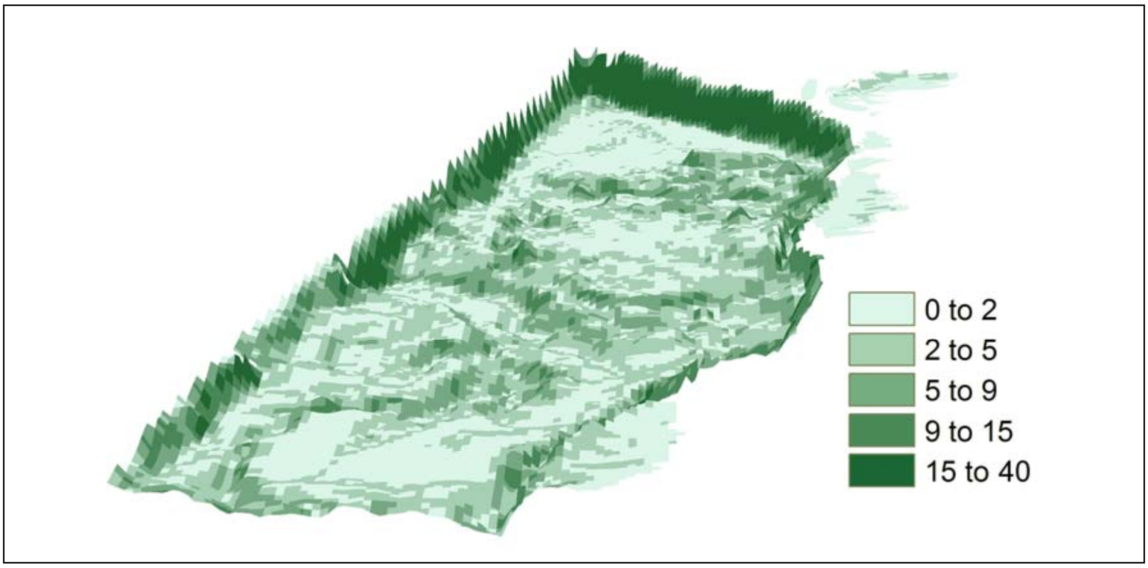


**Figure 5.84 Mean slope (%) for West Northney site**

***Soil grain size –*** *sediment grain size, composition and porosity of the dredge sediments used will affect drainage characteristics and organic content* – composition of dredged sediment to be used for recharge is unknown. AMBER

***Sediment Supply –*** *presence of healthy marshes close to a proposed site would indicate a suitable location in terms of sediment supply* – saltmarshes adjacent: GREEN

***Contamination –*** *areas away from major pollutant sources are preferable* – limited local sources of pollution: GREEN

***Land Conservation Value -*** *sites selected for saltmarsh creation should not have a high conservation value (such as SSSIs, Ramsar sites etc.)* – undesignated for conservation, some sites of archaeological interest: AMBER

***Local Economic/Recreational Activities –*** *all current activities should be checked that they are not likely to be adversely affected by the creation of the recharge* site – the site itself has low amenity value however a popular local path would have to be rerouted should a scheme be undertaken: AMBER

***Accessibility -*** *when selecting areas for recharge, consideration of the accessibility and costs for appropriate vessels/plants/machinery to handle the material must be considered* – highly accessible by road for plants and machinery while vessel accessibility is also good: GREEN

5.5.13 North Common

North Common (SU 726 039) consists partly of unused land and a recreation ground. The recreation ground is privately owned, however HCC own the potential saltmarsh section. Due to the proximity of the recreation field the site has a high amenity value. There is a footpath adjacent to the site, but no right of way runs through the site (Cope et al., 2007). The site backs onto residential housing and is close to commercial property and a major marina. Access to the site from the water would involve passing a large marine immediately North.

The site is non-designated and is maintained by the EA. There is a potential to develop a volume of 381,789$m^3$ of saltmarsh through managed realignment. The initial flooding of North Common, through managed realignment, would result in saltmarsh only (Fig 5.85).

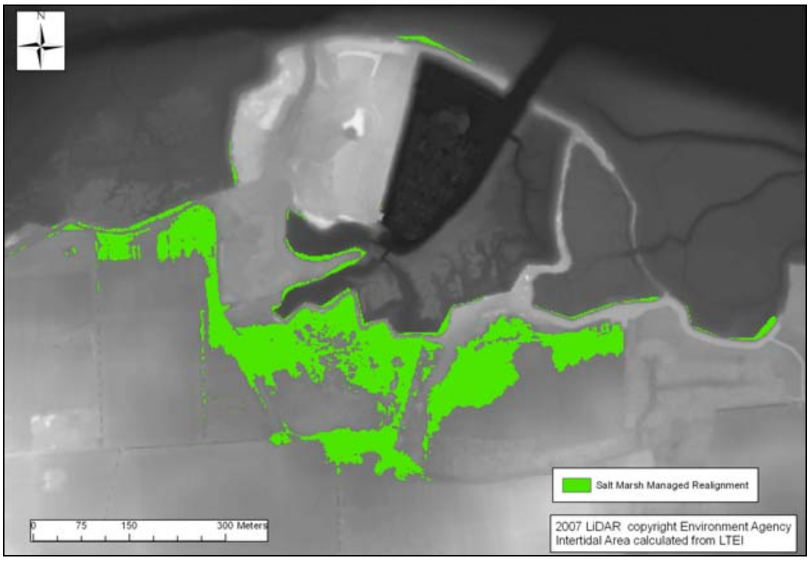


**Figure 5.85 Managed realignment site North Common**

The majority height of North Common lies between 1.5 and 3.2m relative to OD (Fig 5.86)

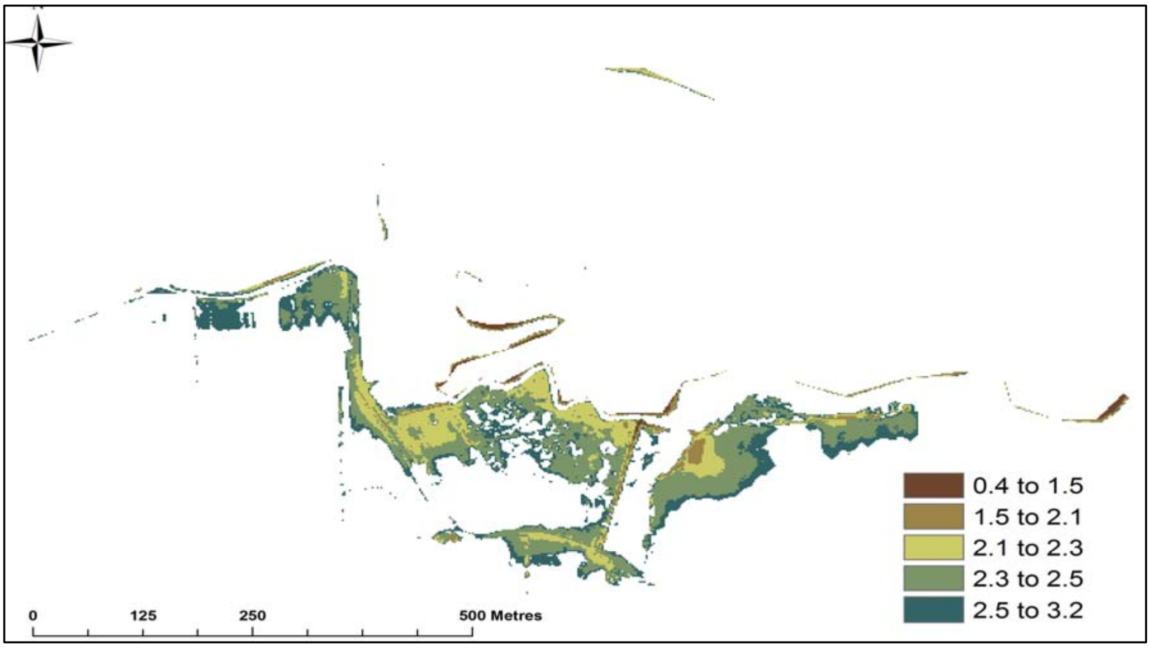


**Figure 5.86 Height of North Common site relative to OD**

5.5.14 North Common: Multi Criteria Analysis

**Presence of existing natural saltmarshes** – indicates the existence of favourable conditions for saltmarsh creation – there are existing saltmarshes adjacent to the site: GREEN.

**Elevation –** most successful marshes have been approximately 2.1 m OD – majority of site between 1.5 to 3.2 m above OD (Fig 5.86): AMBER.

**Drainage –** an extensive creek system is required – limited existing creek system: AMBER.

**Surface gradient –** optimum is approximately 1-2% (<1:50) – calculated mean slope for North Common mudflat is 0% (Fig 5.87): AMBER.

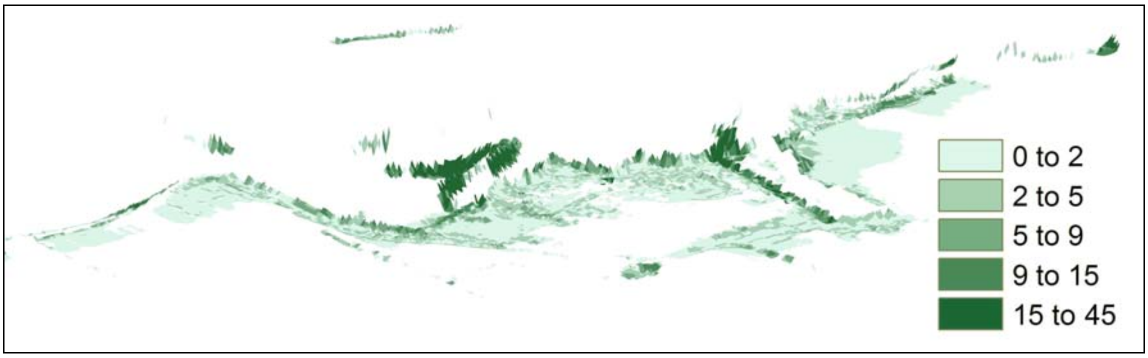


**Figure 5.87 Mean slope (%) for North Common site**

**Soil grain size –** sediment grain size, composition and porosity of the dredge sediments used will affect drainage characteristics and organic content – composition of dredged sediment to be used for recharge is unknown: AMBER.

**Sediment Supply –** presence of healthy marshes close to a proposed site would indicate a suitable location in terms of sediment supply – saltmarshes nearby: GREEN.

**Contamination –** areas away from major pollutant sources are preferable – potential localised antifouling pollution from recreational boating using nearby marina: RED.

**Land Conservation Value -** sites selected for saltmarsh creation should not have a high conservation value (such as SSSIs, Ramsar sites etc.) – no conservation designations, some archaeological sites of interest: AMBER.

**Local Economic/Recreational Activities –** all current activities to be checked that they are not likely to be adversely affected by recharge site creation, – part of the site lies on a well used recreation field so amenity value is high. In addition the site is close to a major marina: RED.

**Accessibility -** when selecting areas for recharge, consideration of the accessibility and costs for appropriate vessels/plants/machinery to handle the material must be considered – access for vessels is reasonable, although water depths may be shallow. There is good road access for plant and machinery: AMBER.

5.5.15 Nutbourne

The majority of the Nutbourne (SU 774 048) site is arable land with a small area designated. Being mainly arable land it has a low to medium amenity value and is used by bird watchers. The site contains archaeological sites of interest and two footpaths run through the site.

The existing defence is maintained by the Environment Agency. Natural England will allow change to the existing SPA, therefore replacement habitat would not be required. An area of 6,358 $m^2$ of potential mudflat could be raised to MHWN level with 808 $m^3$ of sediment (Fig 5.88).

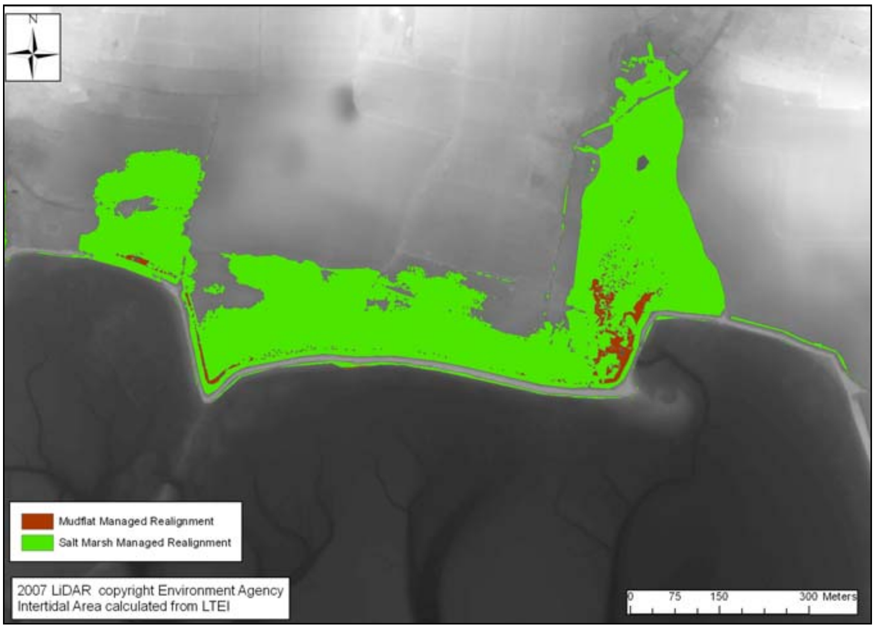


**Figure 5.88 Managed realignment site Nutbourne**

The majority height of Nutbourne lies between 0.5 and 2.1 m relative to OD (Fig 5.89).

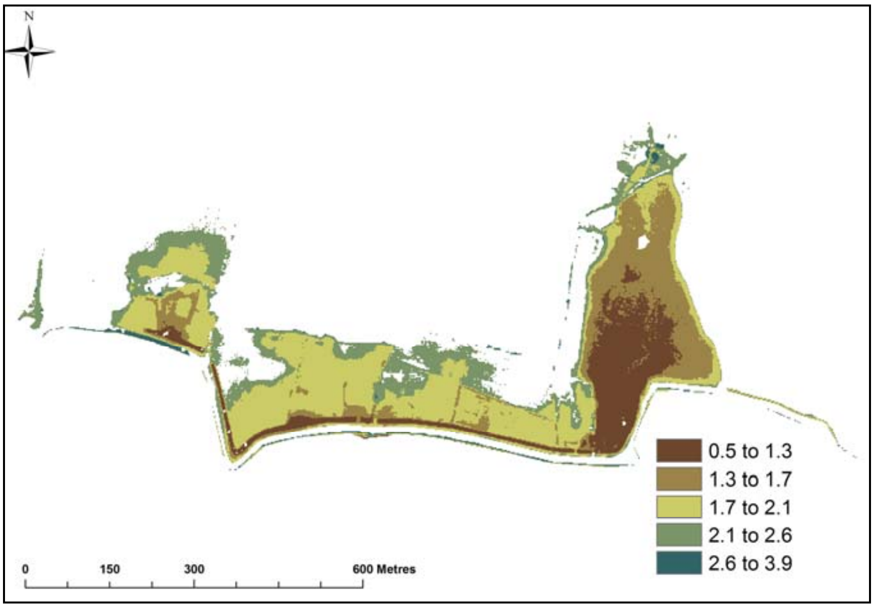


**Figure 5.89 Height of the Nutbourne site relative to OD**

5.5.16 Nutbourne: Multi Criteria Analysis

**Presence of existing natural saltmarshes** – indicates the existence of favourable conditions for saltmarsh creation – there are limited saltmarshes close to the site: AMBER.
**Elevation –** most successful marshes have been approximately 2.1 m OD – majority of site between 0.5 to 2.1 m above OD (Fig 5.89): GREEN.
**Drainage –** an extensive creek system is required – little existing creek system on majority of site, some remnants to linear N-S feature to eastern end: AMBER.
**Surface gradient –** optimum is approximately 1-2% (<1:50) – calculated mean slope for Nutbourne mudflat is 1.64% (Fig 5.90): GREEN.

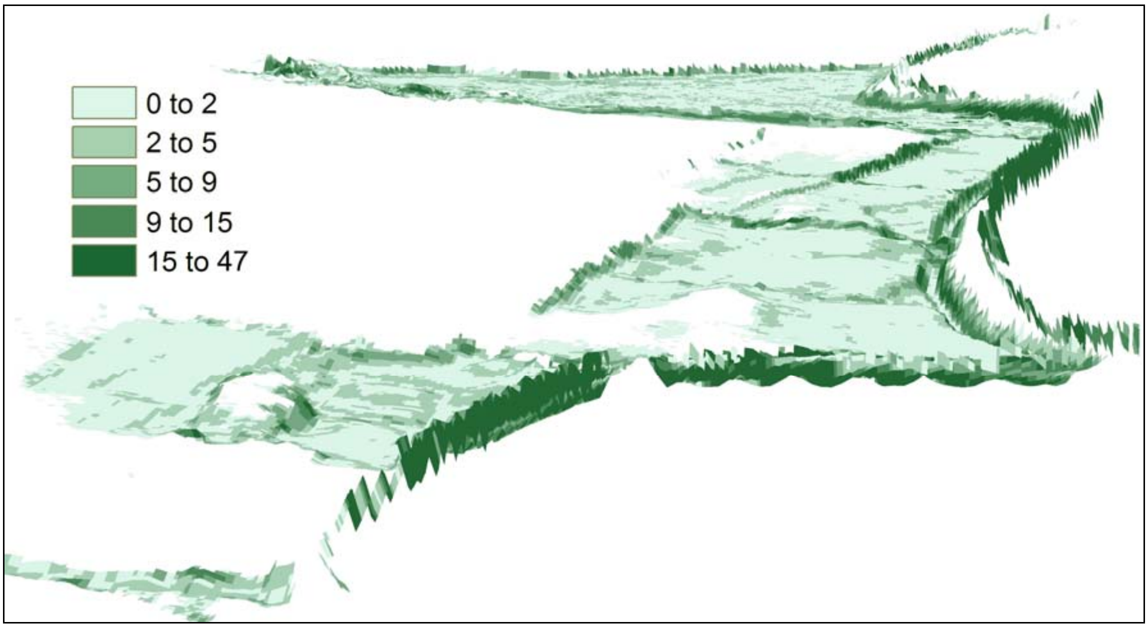


**Figure 5.90 Mean slope (%) for Nutbourne site**

**Soil grain size –** sediment grain size, composition and porosity of the dredge sediments used will affect drainage characteristics and organic content – composition of dredged sediment to be used for recharge is unknown: AMBER.
**Sediment Supply –** presence of healthy marshes close to a proposed site would indicate a suitable location in terms of sediment supply – limited saltmarshes nearby, but extensive mudflats: GREEN.
**Contamination –** areas away from major pollutant sources are preferable – potential localised high nutrient pollution from agricultural run off: AMBER.
**Land Conservation Value -** sites selected for saltmarsh creation should not have a high conservation value (such as SSSIs, Ramsar sites etc.) – small area of site designated, with some archaeological sites of interest: AMBER.
**Local Economic Activities –** all current activities should be checked that they are not likely to be adversely affected by the creation of the recharge site – area is almost completely arable so low economic and amenity value: GREEN.
**Accessibility -** when selecting areas for recharge, consideration of the accessibility and costs for appropriate vessels/plants/machinery to handle the material must be considered – good accessibility for machinery and plant, however vessel access is poor: AMBER.

5.5.17 West Wittering

West Wittering (SZ 771 983) consists mainly of agricultural land and is owned by the West Wittering Estate Company. The area has a high recreational value with many tourists attracted to the beach and other recreational pursuits. The site contains archaeological sites of interest and listed buildings and a footpath runs through the site. The site is designated under SSSI, SPA, SAC and Ramsar designations. Parts of the site lie within 100 m of residential properties.

The existing defence is maintained by Chichester District Council. Natural England will allow change to the existing SPA, therefore replacement habitat is not required however the site cannot be used to offset coastal squeeze. A total potential volume of 235,872 $m^2$ of saltmarsh would be created by the realignment at West Wittering. The 50,769 $m^2$ of potential mudflat would need a minimum of 16,033 $m^3$ of sediment to raise the surface level to MHWN (Fig 5.91).

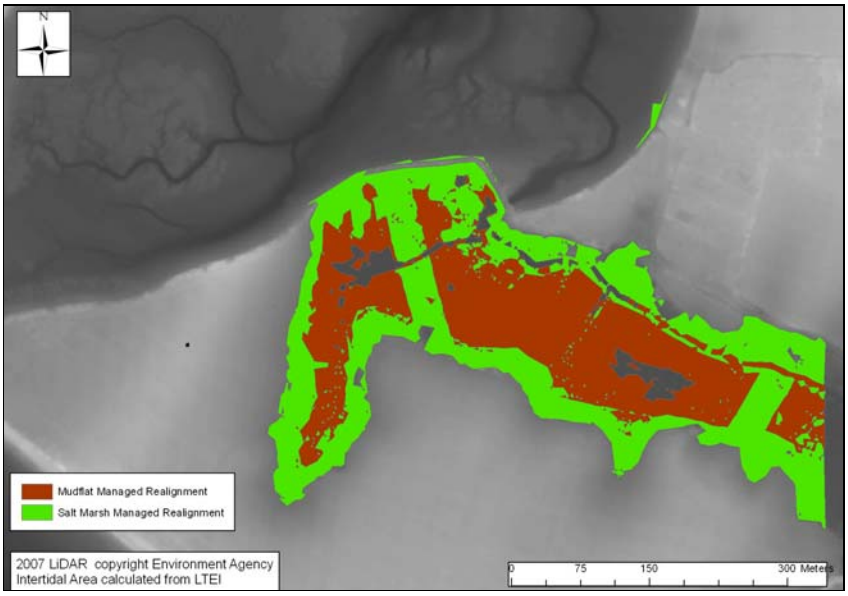


**Figure 5.91 Managed realignment site West Wittering**

The majority height of West Wittering is between 0.5 and 1.8 m relative to OD (Fig 5.92).

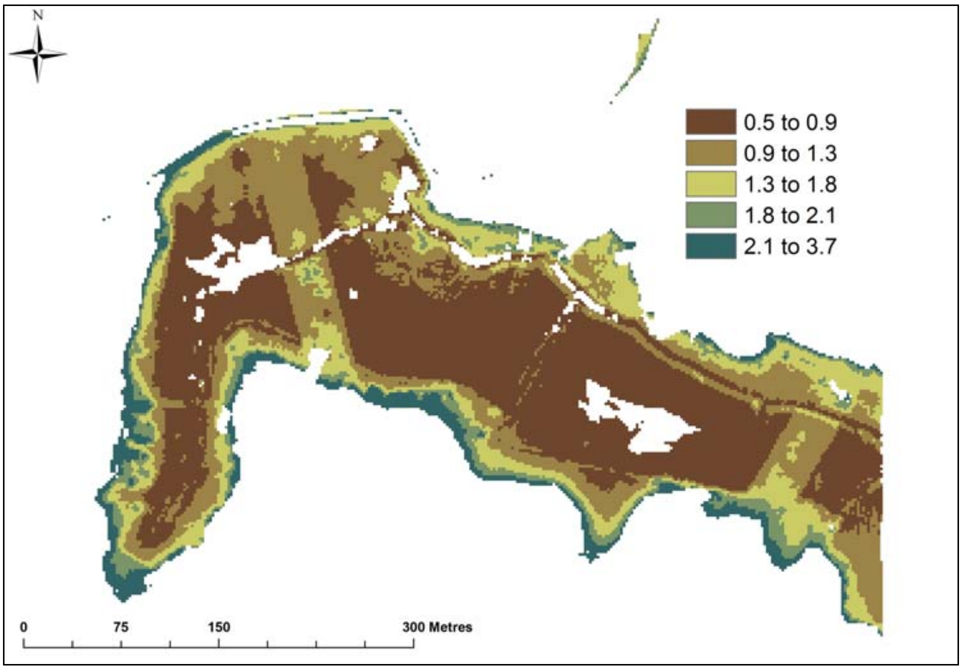


**Figure 5.92 Height of West Wittering site relative to OD**

5.5.18 West Wittering: Multi Criteria Analysis

**Presence of existing natural saltmarshes** – indicates the existence of favourable conditions for saltmarsh creation – there are extensive existing saltmarshes adjacent to the site: GREEN.

**Elevation –** most successful marshes have been approximately 2.1 m OD – majority of site between 0.5 to 1.8 m above OD (Fig 5.92): GREEN.

**Drainage –** an extensive creek system is required – extensive former creek system: GREEN.

**Surface gradient –** optimum is approximately 1-2% (<1:50) – calculated mean slope for West Wittering mudflat is 1.45% (Fig 5.93 below): GREEN.

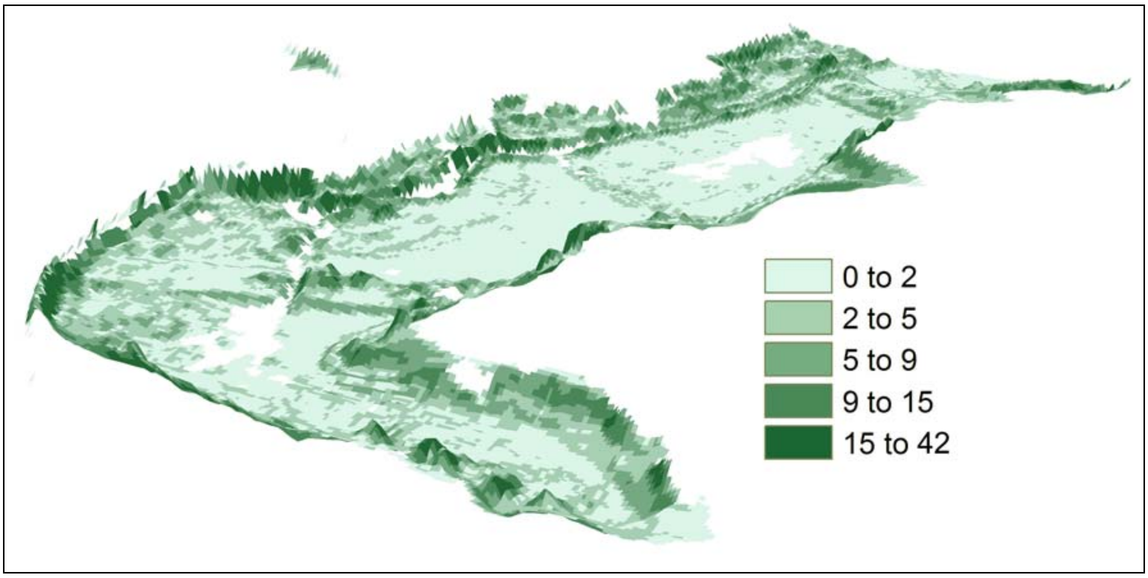


**Figure 5.93 Mean slope (%) for West Wittering site**

**Soil grain size –** sediment grain size, composition and porosity of the dredge sediments used will affect drainage characteristics and organic content – composition of dredged sediment to be used for recharge is unknown: AMBER.
**Sediment Supply –** presence of healthy marshes close to a proposed site would indicate a suitable location in terms of sediment supply – saltmarshes and extensive mudflats adjacent to the site: GREEN.
**Contamination –** areas away from major pollutant sources are preferable – no known local sources of pollution: some potential runoff from local arable fields: AMBER.
**Land Conservation Value -** sites selected for saltmarsh creation should not have a high conservation value (such as SSSIs, Ramsar sites etc.) – West Wittering site designated SSSI, Ramsar, SPA, SAC. RED.
**Local Economic/Recreational Activities –** all current activities should be checked that they are not likely to be adversely affected by the creation of the recharge site – area has a high amenity value with many tourists attracted by the beach and numerous recreational activities: RED.
**Accessibility -** when selecting areas for recharge, consideration of the accessibility and costs for appropriate vessels/plants/machinery to handle the material must be considered – good road access. Vessel access adjacent to the site is difficult but could anchor offshore and pump sediments: AMBER.

5.5.19 Medmerry

The Medmerry (SZ 835 945) site consists of marsh and arable land. The area is agricultural land so currently has a low amenity and recreational value. There are no archaeological sites of interest within the site although there are listed buildings in the vicinity. A footpath runs through the site and small parts of the site are designated under SSSI, SPA and Ramsar designations. A large caravan park lies within the site, while a water treatment works lies adjacent. Some agricultural properties lies within the proposed site.

The existing defence is maintained by the Environment Agency. Natural England will allow a small change to the small area of SSSI. Managed realignment would result in the creation of 2,203,617 $m^3$ of saltmarsh. The 828,555 $m^2$ of mudflat could be increased to MHWN with 3,449,016 $m^3$ of sediment and allows for the greatest potential of saltmarsh creation from sediment recharge (Fig 5.94).

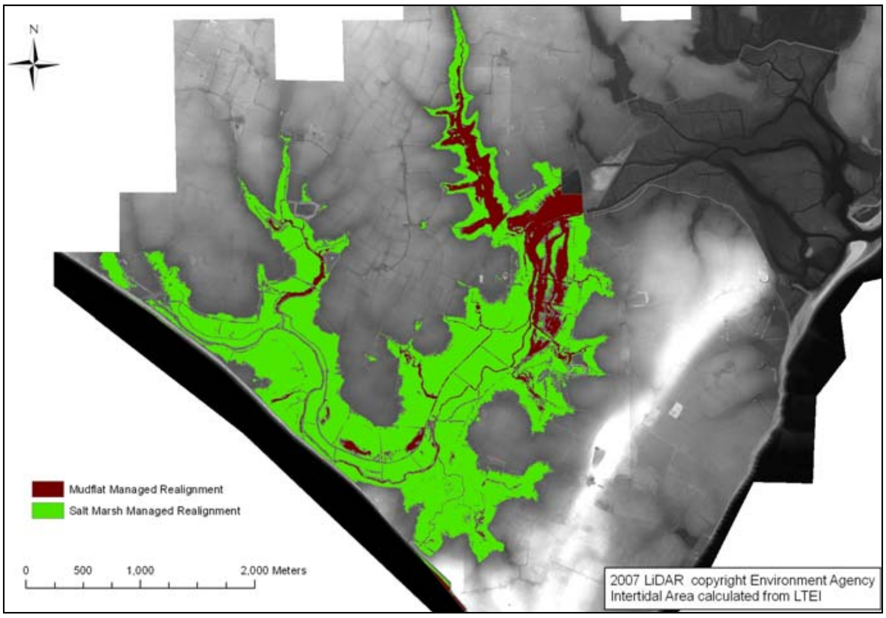


**Figure 5.94 Managed realignment site Medmerry**

The majority height of Medmerry lies between 0.6 and 2.1 m relative to OD (Fig 5.95).

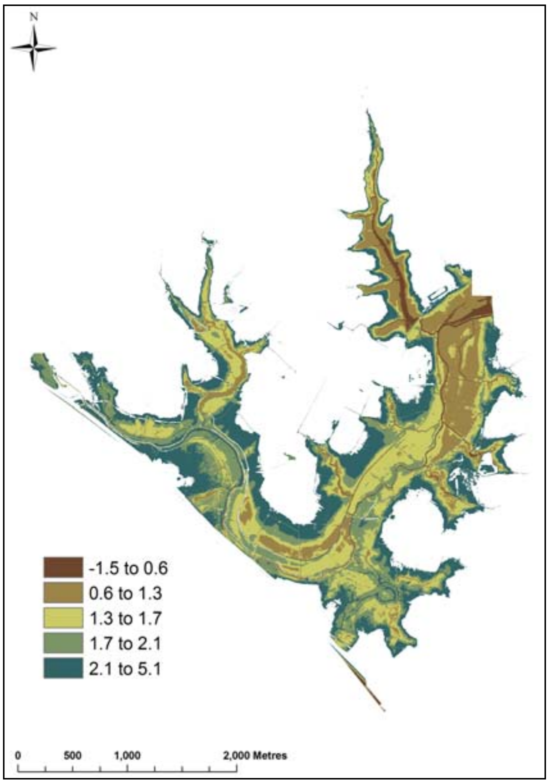


**Figure 5.95 Height of Medmerry relative to OD**

5.5.20 Medmerry: Multi Criteria Analysis

**Presence of existing natural saltmarshes** – indicates the existence of favourable conditions for saltmarsh creation highly limited saltmarshes close to the site: RED.

**Elevation –** most successful marshes have been approximately 2.1m OD – majority of site between 0.6 to 2.1 m above OD (Fig 5.95): GREEN.

**Drainage –** an extensive creek system is required – extensive existing creek system: GREEN.

**Surface gradient –** optimum is approximately 1-2% (<1:50) – calculated mean slope for Medmerry mudflat is 4.3%, but it is such an extensive site that mean slope may not be an appropriate measure for the entire area (Fig. 5.96): AMBER.

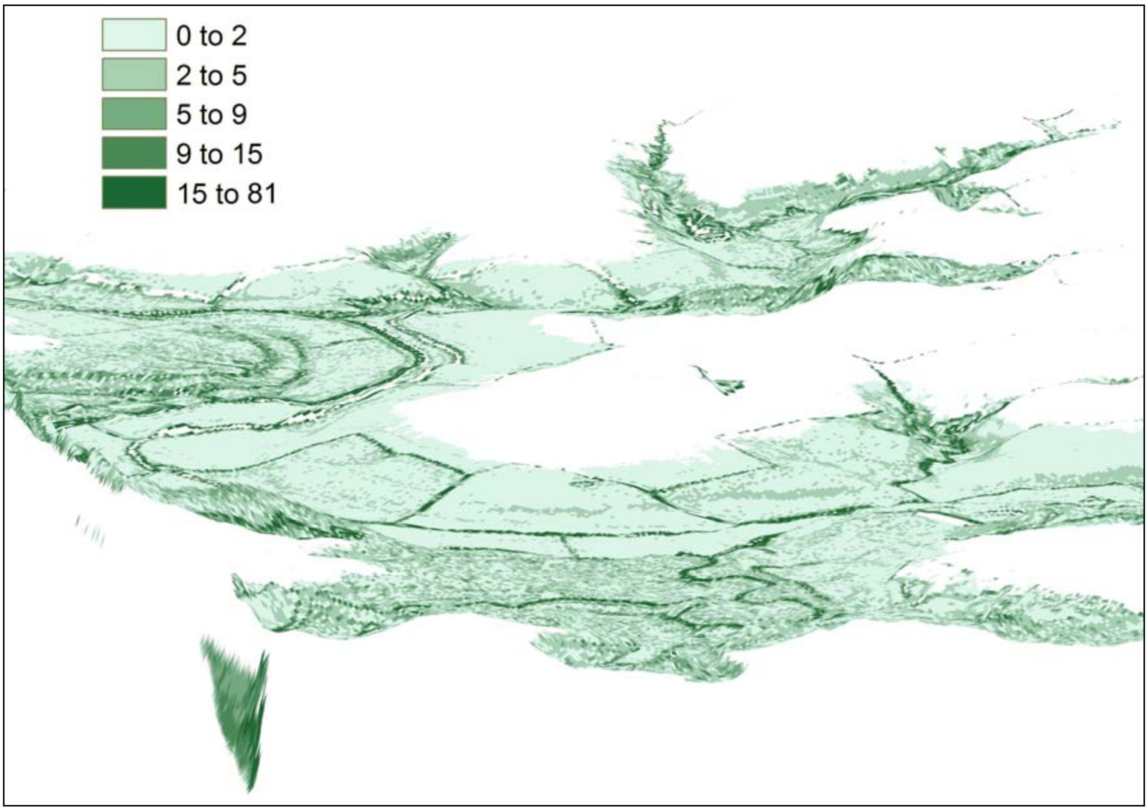


**Figure 5.96 Mean slope (%) for Medmerry site**

**Soil grain size –** sediment grain size, composition and porosity of the dredge sediments used will affect drainage characteristics and organic content – composition of dredged sediment to be used for recharge is unknown: AMBER.
**Sediment Supply –** presence of healthy marshes close to a proposed site would indicate a suitable location in terms of sediment supply – potential limited natural sediment supply: RED.
**Contamination –** areas away from major pollutant sources are preferable – potential localised nutrient pollution due to run off from agricultural land: AMBER.
**Land Conservation Value -** sites selected for saltmarsh creation should not have a high conservation value (such as SSSIs, Ramsar sites etc.) – Parts of the site designated SSSI, Ramsar, SPA: RED.
**Local Economic/Recreational Activities –** all current activities should be checked that they are not likely to be adversely affected by the creation of the recharge site – the site is mainly agricultural land with a low economic and amenity value, however the major caravan park will have significant economic value: RED.
**Accessibility -** when selecting areas for recharge, consideration of the accessibility and costs for appropriate vessels/plants/machinery to handle the material must be considered – good accessibility for vessels, although the site would be exposed. Good road access for plant and machinery: GREEN.

5.5.21 Pagham South

Pagham South (SZ 873 959) consists mainly of arable land and is part owned privately, however there is uncertainty about the ownership of the remainder of the site. The area has a low recreational value because of the agricultural use of the land. The area is undesignated with no archaeological sites of interest or nature conservation designations. A footpath crosses the site although it is relatively isolated from commercial and major residential properties.

The existing defence is maintained by the EA. Natural England will allow change to the 3 ha of designated SSSI, SPA and RAMSAR. A volume of 13,195 $m^3$ of mudflat could be converted to saltmarsh with 4,428 $m^3$ of sediment to raise the height to MHWN (Fig 5.97).

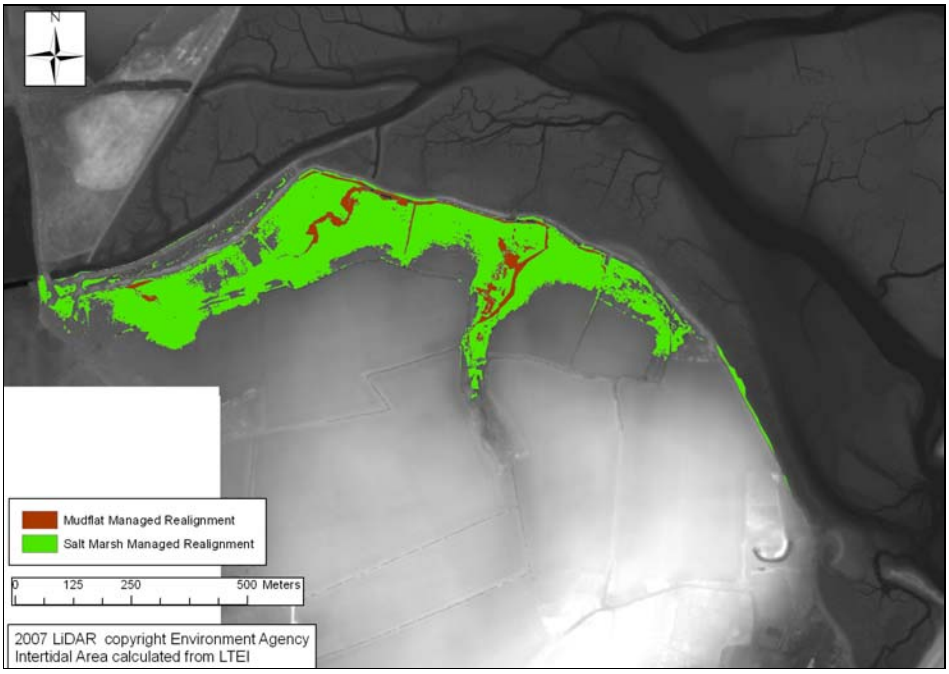


**Figure 5.97 Managed realignment site Pagham**

The majority height of Pagham South is between -0.03 and 2.4m relative to OD (Fig 5.98)

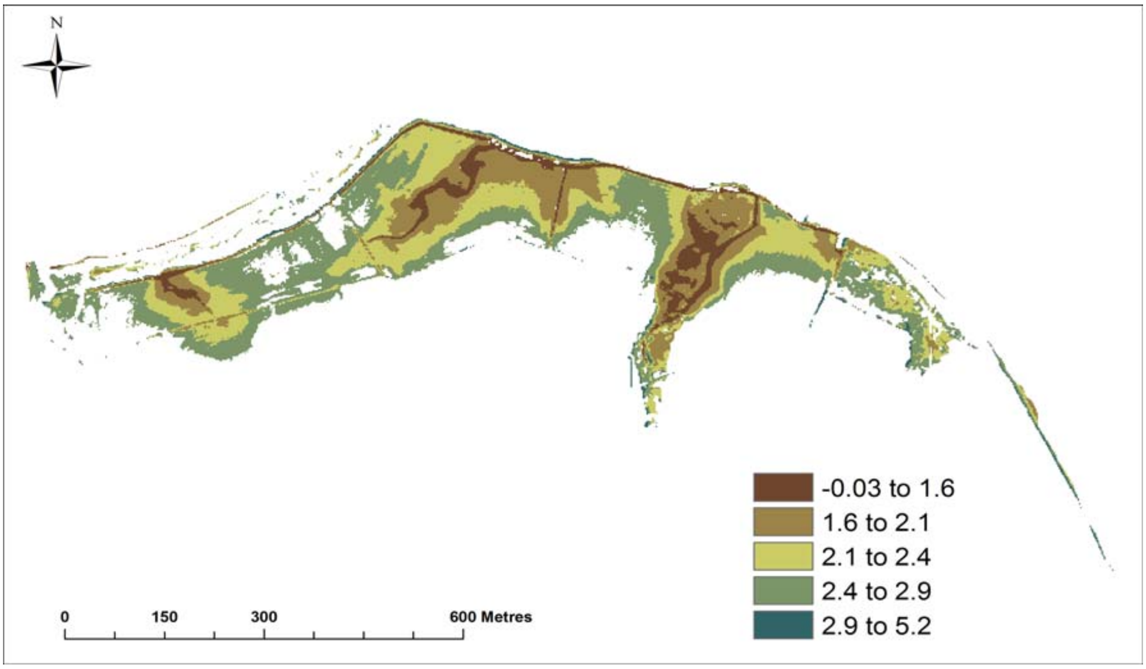


**Figure 5.98 Height of Pagham South relative to OD**

5.5.22 Pagham South: Multi Criteria Analysis

**Presence of existing natural saltmarshes** – indicates the existence of favourable conditions for saltmarsh creation – there are existing saltmarshes close to the site: GREEN.

**Elevation –** most successful marshes have been approximately 2.1m OD – majority of site between -0.03 to 2.4m relative to OD (Fig. 5.98): GREEN.

**Drainage –** an extensive creek system is required – limited former creek system visible: AMBER.

**Surface gradient –** optimum is approximately 1-2% (<1:50) – calculated mean slope for Pagham South mudflat is 5.4% (Fig. 5.99): RED.

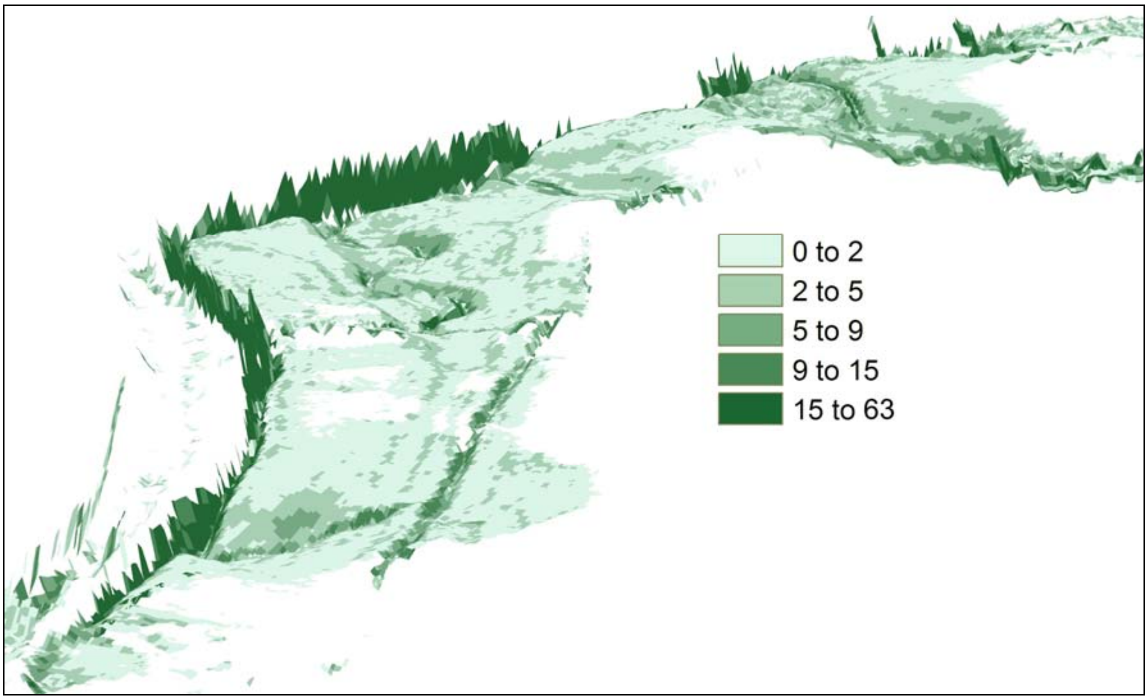


**Figure 5.99 Mean slope (%) for Pagham South site**

**Soil grain size –** sediment grain size, composition and porosity of the dredge sediments used will affect drainage characteristics and organic content – composition of dredged sediment to be used for recharge is unknown. AMBER

**Sediment Supply –** presence of healthy marshes close to a proposed site would indicate a suitable location in terms of sediment supply – extensive saltmarshes and mudflats nearby indicate a fine sediment supply: GREEN

**Contamination –** areas away from major pollutant sources are preferable – potential run-off from arable fields may cause nutrient pollution: AMBER

**Land Conservation Value -** sites selected for saltmarsh creation should not have a high conservation value (such as SSSIs, Ramsar sites etc.) – No designations. GREEN

**Local Economic Activities –** all current activities should be checked that they are not likely to be adversely affected by the creation of the recharge site – land is agricultural so has low economic and amenity value: GREEN

**Accessibility -** when selecting areas for recharge, consideration of the accessibility and costs for appropriate vessels/plants/machinery to handle the material must be considered – vessel access is difficult due to the shallow water depths, while there is reasonable road access for plant and machinery: AMBER

### 5.5.23 Conclusions for SDCP Sites

The surface area of mudflats which could be converted to saltmarsh for each of the managed realignment sites is indicated in Table 5.31.

TABLE 5.31 SURFACE AREA OF MANAGED REALIGNED MUDFLAT REQUIRING SEDIMENT INPUT

| SDCP site | Surface Area $m^2$ |
|---|---|
| **Medmerry** | 828,555 |
| **Farlington** | 659,612 |
| **Lymington** | 212,242 |
| **West Wittering** | 50,769 |
| **Saltgrass Lane** | 35,690 |
| **Pagham South** | 13,195 |
| **West Northney** | 9,099 |
| **Nutbourne** | 6,358 |
| **Gillies** | 471 |
| **Stoke** | 4 |
| **North Common** | 0 |

North Common and Stoke can be excluded due to their mudflat surface areas being minimal. As can be seen in Table 5.31 Medmerry and Farlington would provide the greatest area of mudflat for conversion. Smaller schemes would be Gillies and Nutbourne.

By comparing the volume requirement for dredge material against the surface area of mudflat to increase the height of the mudflat to a level suitable for saltmarsh growth it can be seen that Salt West Northney and Salt Grass Lane would require the least amount of sediment to increase their surface area of saltmarsh (Tables 5.32-5.334.

TABLE 5.32 TOTAL MUDFLAT AREA – SEDIMENT VOLUME TO INCREASE MUDFLAT HEIGHT TO MHWS

| SDCP Site | Ratio Surface Area/ Volume mhws |
|---|---|
| **Farlington** | 1.78 |
| **Gillies** | 1.66 |
| **Pagham South** | 1.30 |
| **Lymington** | 1.23 |
| **West Wittering** | 1.21 |
| **Medmerry** | 1.16 |
| **Nutbourne** | 1.13 |
| **West Northney** | 0.98 |
| **Saltgrass Lane** | 0.44 |

TABLE 5.33 TOTAL MUDFLAT AREA – SEDIMENT VOLUME TO INCREASE MUDFLAT HEIGHT TO MHW

| SDCP Site | Ratio Surface Area/ Volume mhw |
|---|---|
| **Farlington** | 1.35 |
| **Gillies** | 1.23 |
| **Lymington** | 0.97 |
| **West Wittering** | 0.77 |
| **Pagham South** | 0.65 |
| **Nutbourne** | 0.63 |
| **Medmerry** | 0.61 |
| **West Northney** | 0.51 |
| **Saltgrass Lane** | 0.24 |

TABLE 5.34 TOTAL MUDFLAT AREA – SEDIMENT VOLUME TO INCREASE MUDFLAT HEIGHT TO MHWN

| SDCP Site | Ratio Surface Area/ Volume mhwn |
|---|---|
| **Farlington** | 0.92 |
| **Gillies** | 0.80 |
| **Lymington** | 0.70 |
| **Pagham South** | 0.34 |
| **West Wittering** | 0.32 |
| **Nutbourne** | 0.13 |
| **Medmerry** | 0.11 |
| **Saltgrass Lane** | 0.04 |
| **West Northney** | 0.03 |

MCA results for the SDCP sites are summarized in Table 5.35. The MCA allows comparison of both qualitative analysis and quantitative data where they are available. This allows data to be compared and gives a framework for decision makers to identify potentially suitable sites.

TABLE 5.35 MCA FOR SDCP SITES.

| | Presence of existing marsh | Elevation | Drainage | Gradient | Grain Size | Sediment Supply | Contamination | Conservation Value | Economic/ Recreational | Accessibility |
|---|---|---|---|---|---|---|---|---|---|---|
| **Salt Grass** | Green | Green | Amber | Green | Amber | Green | Amber | Red | Amber | Amber |
| **Lymington** | Amber | Green | Amber | Amber | Amber | Amber | Amber | Red | Amber | Amber |
| **Gillies** | Red | Green | Green | Red | Amber | Amber | Red | Green | Red | Amber |
| **Farlington** | Green | Green | Green | Green | Amber | Green | Amber | Red | Amber | Green |
| **Stoke** | Amber | Amber | Red | Red | Amber | Amber | Green | Amber | Green | Green |
| **W. Northney** | Green | Green | Green | Green | Amber | Green | Green | Amber | Amber | Green |
| **N. Common** | Green | Amber | Amber | Amber | Amber | Green | Red | Amber | Red | Amber |
| **Nutbourne** | Amber | Green | Amber | Green | Amber | Green | Amber | Amber | Green | Amber |
| **W. Wittering** | Green | Green | Green | Green | Amber | Green | Amber | Red | Red | Amber |
| **Medmerry** | Red | Green | Green | Amber | Amber | Red | Amber | Red | Amber | Green |
| **Pagham** | Green | Green | Amber | Red | Amber | Green | Amber | Green | Green | Amber |

A "traffic light" system has been chosen to allow the criteria to be compared. It must be noted that green does not mean "definitely go", nor red mean "definitely stop" – these colours simply allow comparison of the various criteria against one another. The qualitative assessments are therefore highly simplified, and the judgements of the research team should be tested by a stakeholder group before decisions are made. In addition none of the criteria have any weighting at this stage. The stakeholder group should judge whether some of the criteria should be given more importance than others.

No data are available for the grain size of the dredged sediment to be deposited on the potential sites so all of these fields are given an "amber light"

Stoke and North Common have minimal mudflat area so are not considered further. Of the remaining sites the unweighted MCA suggests that West Northney, Farlington and Pagham South show the most positive balance of criteria. Of these three sites West Northney would require the least sediment to be introduced to the system.

## 5.6 Conclusions

### 5.6.1 Site Recommendations

Based on the analysis of volume requirements the overall choice of site is dependant on the location of the availability of dredge spoil which will restrict the size of site chosen. The largest areas of potential saltmarsh are at Keyhaven for the Hampshire County Council Sites and Medmerry and Farlington for the SDCP sites. The locations which would provide the greatest increase in surface area for the minimum volume of dredge material input are Keyhaven and Mercury marshes from the list of HCC sites and Salt Grass Lane from the SDCP sites. The unweighted MCA suggests that of the HCC sites Keyhaven and Gutner Point should be considered, while of the SDCP sites West Northney, West Wittering and Pagham show the most suitable potential.

### 5.6.2 Monitoring Requirements for Chosen Sites

- To improve the accuracy of volume requirements for each location, full LiDAR coverage would be recommended, for example at Farlington and Calshot. Site visits would indicate the reliability of LTEI outcomes;
- Detailed monitoring of present saltmarsh and mudflats heights is required to increase the accuracy of data and the success of saltmarsh creation at the correct height;
- Detailed monitoring of the tidal levels at sites is required, rather than interpolating tide heights from the nearest port to determine tide levels for saltmarsh species growth;
- Understanding of the causes for previous saltmarsh change for HCC sites are required to ensure the successful development of future saltmarsh species, including soil sampling and vegetation surveys, for example if dieback of *Spartina* is a problem on a specific site this may be detrimental to the success of future growth;
- The creek network is vital for drainage of the saltmarsh and research regarding the optimal position for such is necessary, including the measurement of existing channels and mapping of the location of historic creek networks.

## 5.7 Potential Locations of Dredged Material

As has been discussed, one potential method of recharging saltmarsh is the reuse of sediments that have been dredged from a system. Analysis of CEFAS dredging and disposal data for the years 2002-2007 inclusive has been done as part of this study. No earlier data were available from CEFAS for analysis.

These analyses show that sediment from 47 separate source areas was disposed of at licensed dumping sites in and around the study area during the period 2002 – 2007 inclusive. Fig. 5.60 shows the annual tonnages disposed of at licensed dumping sites over this period.

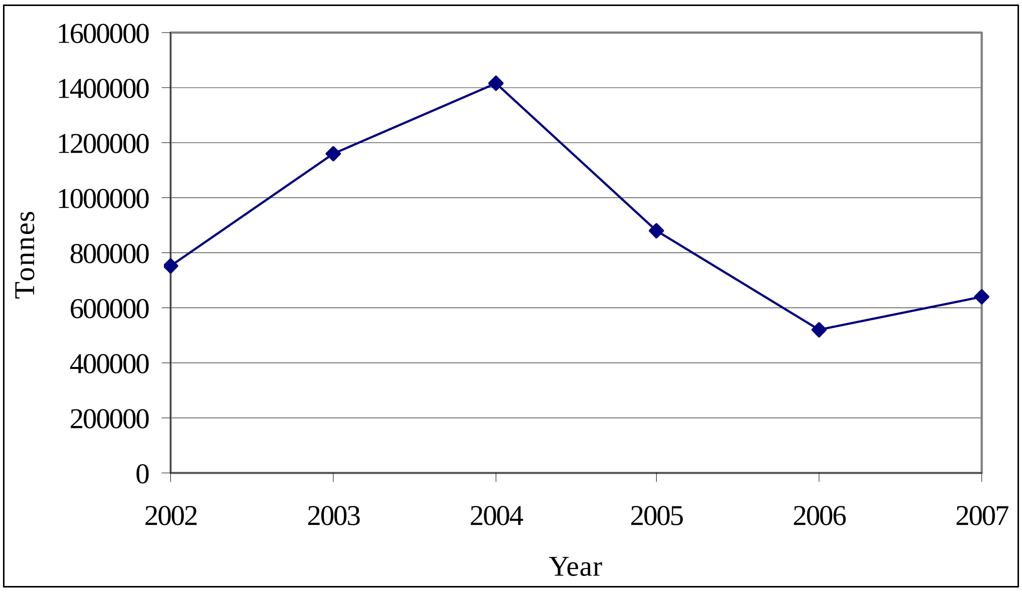


**Figure 5.60 Annual Tonnage Sediment Disposal for Solent Area (2002-2007)**

The annual tonnage deposited varies between approximately 520,000 and 1,400,000 tonnes of sediment, depending on the nature and scale of dredging carried out e.g. the peak tonnage of 1.4 million tonnes in 2004 corresponds to a major maintenance dredging of Southampton Water where in excess of 600,000 tonnes of sediment was dredged from this scheme alone. In total 5,364,199 tonnes of sediment, which potentially would be available for recharge schemes, was dumped during the years 2002-2007 inclusive. However, the sediment volumes dumped are not evenly distributed throughout a year. CEFAS figures for 2006 and 2007 are broken down into monthly disposals and Fig. 5.61 shows the variability over this period.

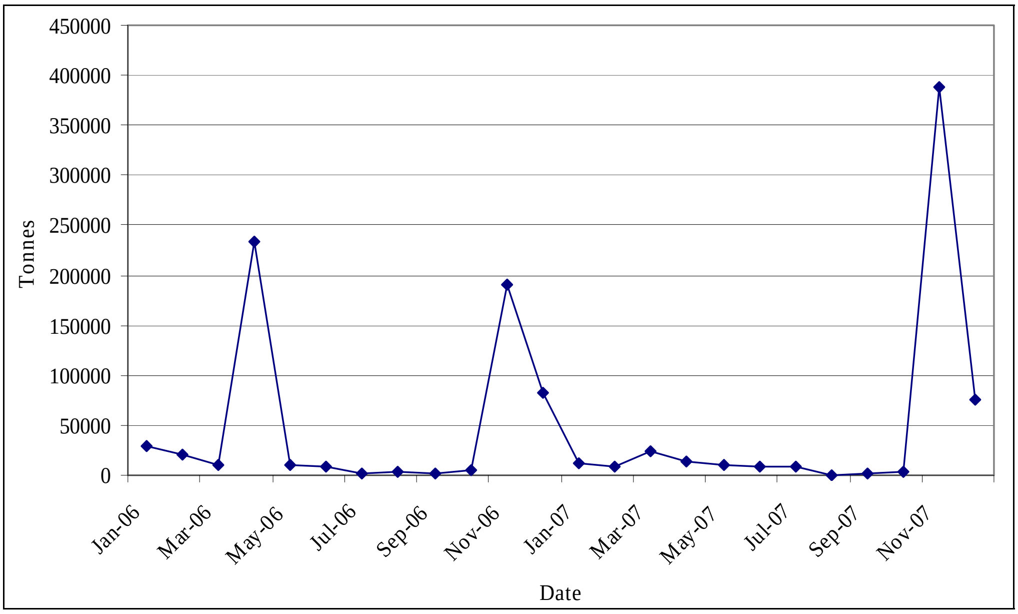


**Figure 5.61 Monthly Tonnage Sediment Disposal for Solent Area (2006-2007)**

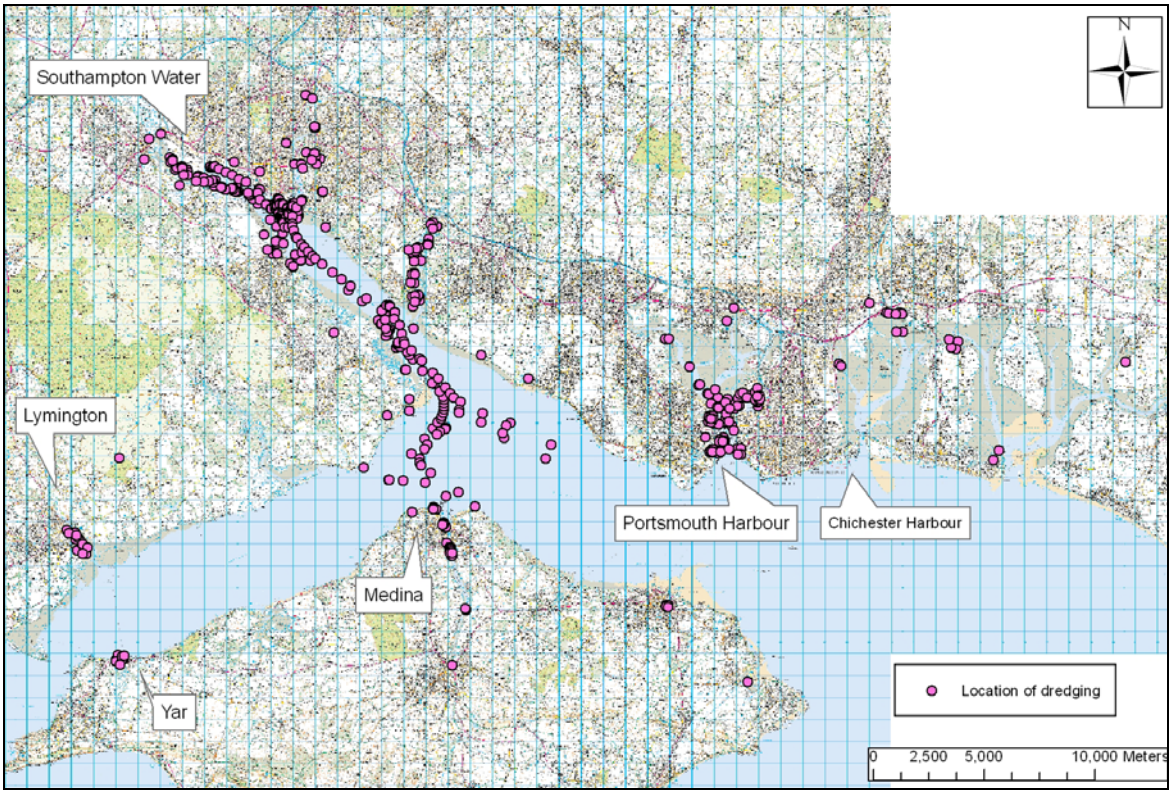


**Figure 5.62 Dredge Locations within the Solent**
(Basemap Ordnance Survey, 2007)

There was at least one disposal of sediment for each month of 2006/2007, however it can be seen that the monthly tonnages disposed of varied widely. A minimum value of 536 tonnes was disposed of during August 2007, while a maximum of 387,549 tonnes was dumped during November 2007. This clearly illustrates one problem associated with using dredge material in recharge schemes – namely volumes of sediment available tend to be variable, and may not be available at the most appropriate time for a recharge scheme.

In addition, those disposals that occur regularly tend to be for relatively low tonnages of sediment while those that generate large sediment volumes occur infrequently. This then may also be an issue where regular sediment inputs to a recharge scheme are required. For instance, in 2006 and 2007 there were 24 disposals from Bedhampton Quay i.e. occurring every month; however, of these the maximum dumped was 1,072 tonnes. By contrast there were only two dredging spoil disposals at Yarmouth (Isle of Wight), however one was in excess of 380,000.

When assessing dredged material suitability for recharge schemes, a further consideration is the sediment chemical composition i.e. whether it is contaminated by heavy metals, hydrocarbons etc; more likely for dredge locations close to industrial activity (Fig. 5.62). For this project CEFAS supplied dredging data were analysed for contaminants in sediment dredged from the 26 areas with 'Action Levels' for contaminants used by CEFAS.

Action Levels are used by CEFAS as part of a 'weight of evidence' approach to assessing dredged material and its suitability for disposal at sea, and hence by extension within this project, its suitability for use in recharge projects. For CEFAS' decision making process these values are used in conjunction with a range of other assessment methods. These may be bioassays and Historic data and knowledge regarding the dredging site and the material's physical characteristics, the disposal site characteristics and other relevant data. These data are then employed to aid management decisions regarding the fate of dredged material. These further methods are beyond the scope of this review, however some of these may be appropriate if this scoping study was to lead to a full-scale trial project.

TABLE 5.36 ACTION LEVELS FOR DREDGED SEDIMENT AS DEFINED BY CEFAS

| Contaminant / Compound | ACTION LEVELS | |
|---|---|---|
| | Action Level 1 | Action Level 2 |
| | mg/kg Dry Weight (ppm) | |
| As (Arsenic) | 20 | 100 |
| Hg (Mercury) | 0.3 | 3 |
| Cd (Cadmium) | 0.4 | 5 |
| Cr (Chromium) | 40 | 400 |
| Cu (Copper) | 40 | 400 |
| Ni (Nickel) | 20 | 200 |
| Pb (Lead) | 50 | 500 |
| Zn (Zinc) | 130 | 800 |
| | | |
| Organotins; TBT DBT MBT | 0.1 | 1 |
| PCB's, sum of ICES 7 | 0.01 | none |
| PCB's, sum of 25 congeners | 0.02 | 0.2 |
| | | |
| *DDT | *0.001 (set in 1994) | |
| *Dieldrin | *0.005 (set in 1994) | |

Table 5.36 shows a range of contaminants, linked to a series of Action Levels. In general, contaminant levels in dredged material below Action Level 1 (in Green) are of no concern to CEFAS and are unlikely to influence the licensing decision. Dredged material with contaminant levels above Action Level 2 is generally considered unsuitable for sea disposal. However it must also be remembered that all these data come from sediments disposed of at sea and CEFAS guidelines state that dredged material with contaminant levels between Action Levels 1 and 2 requires further consideration and testing before a decision can be made. It is therefore not explicitly prohibited that sediment exceeding Action Level 1 for contaminants are unsuitable for further use. Accordingly contaminant data for Solent dredge sites were compared with these levels and are summarised in Table 5.37.

It can be seen that no dredged sediment contains contaminants that exceed Action Level 2, as defined by CEFAS. All green cells show contaminant levels below Action Level 1, while orange cells show contaminant levels in excess of Action Level 1 but below Action Level 2. Any dredged sediment from these sources would require further consideration before any decision on its use could be made.

By combining these contaminant data with previous data of number and volume of disposals some conclusions about potential sources of sediment can be drawn. The dredge sites where disposals were frequent in 2006-2007 are:

- Bedhampton Quay (24 disposals in 2 years);
- Burnley Wharf, Southampton (14 disposals in 2 years);
- Hall Aggregates Area 137 and 313 (10 disposals in 2 years);
- Kendall's Wharf, Portsmouth (18 disposals in 2 years);
- Lymington Yacht Haven (11 disposals in 2 years).

Data show that sediment from Hall Aggregates Area 137 and 313, Kendall's Wharf, Burnley Wharf and Lymington Yacht Haven all show contaminant levels below Action Level 1 (Table 5.37). Sediments from Bedhampton Quay exceed Action Level 1 for Arsenic. It should be noted that this does not mean that sediments from Bedhampton Quay are unsuitable for beneficial re-use but that further consideration is required before their potential use.

The dredge sites where large tonnages of sediment are potentially available include:

- Southampton Maintenance Dredging (1,245,000 tonnes during 2002-2007)
- Esso Terminal Coastal Berths and Approaches (470,000 tonnes during 2002-2007);
- Harbour Entrance Yarmouth, Isle of Wight (388,000 tonnes during 2002-2007);
- River Itchen Berths and Channels (978,000 tonnes during 2002-2007).

TABLE 5.37 DREDGE SITE CONTAMINANT DATA COMPARED WITH CEFAS ACTION VALUES

| Source Site | Arsenic | Cadmium | Chromium | Copper | Lead | Mercury | Nickel | Zinc | Tetrabutyl tin | Dibutyl tin |
|---|---|---|---|---|---|---|---|---|---|---|
| BEDHAMPTON CHANNEL, LANGSTONE HARBOUR | 5.76 | 0.24 | 22.50 | 18.33 | 21.17 | 0.075 | 9.52 | 60.33 | 0.011 | 0.019 |
| BEDHAMPTON QUAY | 28 | 0.06 | 19 | 10 | 17 | 0.23 | 19 | 39 | 0.002 | 0.002 |
| BEMBRIDGE HARBOUR | 13 | 0.097 | 28 | 13 | 17.3 | 0.077 | 13.3 | 51.7 | 0.052 | 0.012 |
| BOSHAM QUAY (TIDAL CHANNEL) | 6.51 | 0.08 | 14.9 | 26.6 | 14.2 | 0.03 | 7.69 | 42.6 | 0.09 | 0.009 |
| BURNLEY WHARF, SOUTHAMPTON | 17 | 0.06 | 18 | 5 | 7.4 | 0.02 | 10.1 | 27 | 0.003 | 0.002 |
| CLARENCE WHARF, PORTSMOUTH | 8.725 | 0.148 | 24.25 | 63.25 | 32.75 | 0.49 | 10.8 | 114 | 0.739 | 0.071 |
| ESSO TERMINAL COASTAL BERTHS & APPROACHES | 8.19 | 0.1 | 22 | 22.8 | 13.8 | 0.1 | 9.77 | 48.4 | 0.06 | 0.009 |
| FOUNTAIN LAKE PORTSMOUTH HARBOUR | 13 | 0.09 | 43 | 26 | 35 | 0.15 | 29.5 | 91 | 0.06 | 0.008 |
| HALL AGGREGATES LTD AREA A 137& 313 | 17.702 | 0.067 | 20.166 | 5.422 | 9.187 | 0.027 | 13.444 | 32.266 | 0 | 0 |
| HAMBLE POINT MARINA (RIVER HAMBLE) | 5.3 | 0.02 | 10.2 | 16.9 | 13.8 | 0.1 | 5.6 | 40.2 | 0 | 0 |
| HAMBLE RIVER (B.P. OIL LTD HAMBLE) | 11 | 0.05 | 14 | 14 | 14 | 0.07 | 10 | 36 | 0.016 | 0.002 |
| HAMBLE RIVER (HAMBLE POINT MARINA) | 16 | 0.07 | 24.5 | 57.5 | 33.5 | 0.19 | 16.5 | 127 | 0.094 | 0.02 |
| HAMBLE RIVER (MERCURY YACHT HARBOUR) | 7.6 | 0.09 | 24.67 | 27 | 23.33 | 0.097 | 11.67 | 60 | 0.015 | 0.005 |
| HARBOUR ENTRANCE, YARMOUTH, IOW | 9.675 | 0.17 | 14.75 | 16.75 | 17 | 0.17 | 11.175 | 44 | 0.319 | 0.019 |
| HARBOUR MASTERS JETTY, WARSASH | 10 | 0.06 | 9 | 20 | 15 | 0.014 | 8 | 57 | 0.098 | 0.02 |
| HMS DOLPHIN, HASLAR LAKE, GOSPORT | 20 | 0.15 | 53 | 70 | 56 | 0.35 | 25 | 128 | 0.071 | 0.022 |
| HMS WARRIOR BERTH, PORTSMOUTH | 7.3 | 0.048 | 20 | 10.9 | 18.5 | 0.053 | 8.22 | 44 | 0.004 | 0.015 |
| HORN REACH | 9.05 | 0.078 | 24.75 | 9.5 | 11.175 | 0.093 | 11.5 | 48 | 0.01 | 0.044 |
| HYTHE MARINA | 12.87 | 0.15 | 20.67 | 34.33 | 27 | 0.207 | 10.6 | 58.333 | 0.057 | 0.015 |
| ISLAND HARBOUR MARINA, RIVER MEDINA | 5.8 | 0 | 12 | 8.3 | 14 | 0.04 | 15 | 35 | 0.009 | 0.02 |
| ISLE OF WIGHT COAST (YARMOUTH HARBOUR) | 9.675 | 0.17 | 32 | 16.75 | 20.2 | 0.17 | 15.4 | 56.6 | 0.319 | 0.019 |
| ITCHEN RIVER (FRP 01 & 02) | 6 | 0.09 | 26 | 22 | 21 | 0.09 | 11 | 53 | 0.07 | 0.02 |
| ITCHEN RIVER (PORTSWOOD STW WHARF) | 7.6 | 0.05 | 20 | 20 | 18 | 0.07 | 9.8 | 47 | 0.059 | 0.021 |
| KENDALL'S WHARF PORTSMOUTH | 8.3 | 0.1 | 27.66 | 10.7 | 16.01 | 0.063 | 11.1 | 42.33 | 0.013 | 0.001 |
| KINGSTON LIFT DOCK, COWES HARBOUR | 7.97 | 0.046 | 16.64 | 14.69 | 20.18 | 0.08 | 9.7 | 44.73 | 0.159 | 0.023 |
| LYMINGTON HARBOUR | 8.4 | 0.075 | 19.5 | 13.75 | 14.75 | 0.04 | 8.45 | 47 | 0.033 | 0.007 |
| LYMINGTON YACHT HAVEN | 18 | 0.16 | 38 | 35 | 32 | 0.14 | 19 | 111 | 0.026 | 0.007 |
| MEDINA RIVER, EAST COWES MARINA 'A' | 9.8 | 0.073 | 20 | 10.33 | 11.333 | 0.053 | 15 | 40.667 | 0.025 | 0.006 |
| MERCURY YACHT HARBOUR RIVER HAMBLE | 20.5 | 0 | 30.5 | 91 | 41 | 0.28 | 19.5 | 178 | 0.065 | 0.033 |
| NEWPORT HARBOUR | 14.8 | 0.155 | 24.66 | 25.83 | 64.5 | 0.145 | 14.5 | 92.166 | 0.121 | 0.036 |
| NORTHNEY MARINA | 7 | 0.17 | 29 | 13 | 11 | 0.05 | 9 | 25 | 0.003 | 0.002 |
| PORT HAMBLE MARINA (RIVER HAMBLE) | 5.9 | 0.07 | 24.5 | 57.5 | 33.5 | 0.19 | 16.5 | 127 | 0.033 | 0.011 |
| PORTSMOUTH HARBOUR (PORT SOLENT MARINA) | 5.533 | 0.08 | 23.667 | 14 | 18.333 | 0.057 | 9.9 | 52.333 | 0.092 | 0.023 |
| PORTSMOUTH NAVAL BASE MAIN HARBOUR | 3.246 | 0.013 | 4.772 | 4.845 | 6.924 | 0.036 | 3.584 | 16.532 | 0.038 | 0.012 |
| RAF HYTHE (DARSA) | 17 | 0.18 | 27 | 81 | 46 | 0.39 | 25 | 108 | 0.059 | 0.022 |
| RIVER ITCHEN BERTHS AND CHANNELS | 8.22 | 0.04 | 16.66 | 16.34 | 12.09 | 0.03 | 9.11 | 39.77 | 0.112 | 0.018 |
| ROYAL CLARENCE YARD | 8.167 | 0.065 | 26.333 | 12.333 | 17 | 0.073 | 11.667 | 42 | 0.025 | 0.004 |
| RYDE HARBOUR, ISLE OF WIGHT | 8.77 | 0.065 | 16.33 | 12.1 | 12.67 | 0.04 | 7.8 | 37.33 | 0.07 | 0.023 |
| SAXON WHARF, RIVER ITCHEN, SOUTHAMPTON | 6 | 0.13 | 19 | 30 | 27 | 0.21 | 9 | 84 | 0.15 | 0.07 |
| SHAMROCK QUAY, RIVER ITCHEN, SOUTHAMPTON | 6.1 | 0.265 | 20.75 | 28 | 32 | 0.18 | 9.65 | 73 | 0.108 | 0.052 |
| SOUTHAMPTON (SOLENT, ITCHEN, TEST) | 7.6 | 0.069 | 29.778 | 15.267 | 16.044 | 0.064 | 11.156 | 52 | 0.116 | 0.02 |
| SPARKES MARINA BASIN | 6.77 | 0.055 | 19.62 | 13.6 | 10.06 | 0.06 | 7.95 | 36 | 0.016 | 0.001 |
| SQUADRON YACHT HAVEN AND APPROACHES | 4.3 | 0.12 | 19 | 20 | 11 | 0.02 | 26 | 48 | 0.035 | 0.011 |
| SWANWICK MARINA | 6.07 | 0.07 | 25 | 40 | 19.3 | 0.1 | 12 | 80 | 0.06 | 0.02 |
| UK SAILING ACADEMY MARINA | 7.3 | 0.07 | 27 | 16 | 32 | 0.12 | 13 | 59 | 0.075 | 0.027 |
| UNIVERSAL & CRABLECK MARINA | 7 | 0.09 | 22.67 | 33.33 | 23 | 0.4 | 8 | 63.33 | 0.156 | 0.037 |
| WEEVIL LAKE A, GOSPORT | 7.3 | 0.08 | 27.5 | 75 | 27.5 | 0.12 | 13.5 | 57.5 | 0.04 | 0.019 |

Sediments from all four sites are problematical for re-use. While Table 5.37 shows that sediments from the Esso Terminal and River Itchen are below Action Level 1 for the contaminants shown, these sediments also contain a significant proportion of hydrocarbons. Applying the Precautionary Principle leads to this material being unsuitable for beneficial re-use.

Hydrocarbons are not thought to be a significant issue in sediments from Yarmouth, Isle of Wight and no testing data for these compounds were contained within the contaminant data set. Sediments from Yarmouth do, however, exceed Action Level 1 for TBT so further consideration would potentially be required before their re-use. Sediments from the general maintenance dredging of Southampton Water also exceed Action Level 1 for TBT, and depending on their location within the system may also contain hydrocarbons.

The data on sediment availability indicate the large volumes of sediment that are derived from the periodic maintenance dredging of the harbours and ports around the Solent region. It may therefore be sensible to organise a trial restoration in conjunction with a programme of planned dredging to ensure a supply of dredged material.

Two possible upcoming projects that may supply significant volumes of dredged sediment are the Associated British Ports (ABP) plans of (i) channel deepening to improve the tidal access window of the main navigational channel for commercial shipping to the Port of Southampton; and (ii) the reconfiguration of an existing berth at the container terminal to accommodate deeper draughted vessels. (Details of both of the schemes are available at www.southamptonvts.co.uk).

Under the terms of the Environmental Impact Assessment associated with these plans there is a requirement, under Part II of the Food and Environmental Protection Act (FEPA) 1985, to “have regard to the practical availability of any alternative methods of disposal” of dredged material, in addition to considering the disposal of material at sea. A trial of the use of dredge sediment to recharge saltmarshes would be a beneficial alternative use of the sediments generated by these schemes.

The contaminant levels in previously dredged sediment from Southampton have been shown to be low (Table 5.37) and are also expected to be “low” for sediments generated during the upcoming projects (Simmonites, pers. com., 2008). One potential problem may be the grade of the sediment generated. A recharge scheme would require fine grained sediment, while Table 5.38 shows that much of the sediment expected to be dredged would be sand and gravel.

TABLE 5.38 APPROXIMATE SEDIMENT QUANTITIES FROM PROPOSED SOUTHAMPTON WATER DREDGE
(Source: Simmonites, pers. Com., 2008)

| Material | Approximate Quantity (Million $m^3$) | Likely Method of Dredging |
|---|---|---|
| Stiff Clay / Dense Sand | 0.5 | Backhoe |
| Stiff Clay / Silt | 2.6 | Backhoe |
| Dense Sand / Silt | 0.3 | Backhoe |
| Glacial Gravel | 2.1 | Trailer Suction |
| Peat / Organic Clay | 0.3 | Trailer Suction |
| Alluvium | 2.5 | Trailer Suction |
| Sands and gravels (Solent Marine Shingle) | 1.2 | Trailer Suction |

To enable access this dredged sediment there are a number of criteria that would have to be met:

1. The proposing organisation will be responsible for the cost of and securing all planning, environmental and other consents required for the beneficial use scheme, as well as commissioning the necessary environmental assessments;
2. The timing of the beneficial use scheme must be compatible with the timeframe of the Capital Dredge which is currently proposed between January and December 2010;
3. The costs of the scheme, encompassing matters such as engineering and methodology will be the responsibility of the proposing organisation.

The timing of the dredging plans is subject to ABP itself securing the necessary consents for the capital dredge, and therefore subject to approval of the applications by the regulators.

### 5.8 Restoration Methods

Restoration models have been discussed in relation to specific projects (§ 2) and to specific methods (§ 3). The MCA analysis undertaken in this study is subject to final agreement with site owners, stakeholders and interested parties. To that end, whilst methods have been identified, it has been considered inappropriate to stipulate final methods at this stage without more detail of local site conditions and consultation with dredging experts, site visits and local knowledge.

# 6 Possible Environmental Issues for Solent Saltmarsh Restoration

As discussed, due to the significant sensitivity of existing saltmarsh and potential sites for their creation, any application for consents and licences will need to be considered for an EIA and potentially AA (Collins *et al.,* 2000). When undertaking an EIA, sufficient information must be obtained through scoping, baseline data review and new data collection. This allows consideration of individual and cumulative scheme impacts and may include studies on:

- Hydrodynamics (tidal and current influences);
- Hydrogeology (sediment pathways and budgets);
- Geomorphology (processes affecting or influence erosion, deposition etc (a combination of the above);
- Flood defence (long term sustainability etc.);
- Navigation (impacts on channel changes and navigation both during construction and after restoration);
- Water quality / Pollution (particularly related to bioaccumulation issues from contaminants associated with disturbed sediment);
- Noise and air quality (associated with construction phase);
- Ecology and nature conservation (of paramount importance and likely to be a decisive factor);
- Recreation (impacts on recreational craft, bird watching, walking etc);
- Socio-economics (impacts on businesses (e.g. aquaculture, agriculture, marinas, small scale livelihoods etc.));
- Landscapes (significant loss/change to local vista);
- Cultural Heritage (site in context with surrounding heritage, or loss/potential loss of any significant archaeological assets);
- Sustainability (projected development lifetime, materials used, resources employed).

The discussion will focus on the generic process for an assessment instead and it should be borne in mind that each site will have its own specific issues that will require consideration.

Following a desk based scoping study and consultation with appropriate statutory bodies and interested parties to raise possible environmental impact issues, a scoping opinion will be requested from the local council or county council responsible for the management of the site. Following the scoping out of impacts considered immaterial to the development and once significant issues have been clarified, an Environmental Statement (ES) will be prepared, which will assess the likely impacts of the project. This provides:

- A description of the proposed scheme, including consideration of alternatives and reasons for the final choice of site;
- A full outline of the existing site conditions to create a comprehensive detailed baseline;
- A systematic assessment of the potential effects of all activities involved with the scheme including, where possible, quantitative supporting data and predictions including direct and indirect impacts on a variety of scales;
- Recommendations for mitigation measures to reduce any associated impact;
- Recommendations for monitoring environmental impact and continuing management procedures.

Following this process, results should be reviewed to ensure full inclusion of all possible environmental impacts (Nottage and Robertson, 2005). The possible impacts of schemes will differ based on the scale of the project and must be considered on a site by site basis (§ 4.5).

It is not possible in this report to explicitly identify all the relevant issues that will need to be considered within an EIA. However, Table 6.1 indicates the possible impacts of intertidal recharge scheme.

TABLE 6.1 SALTMARSH RESTORATION SCHEMES POTENTIAL ENVIRONMENTAL ISSUES SUMMARY

| Activity | Target | Possible Environmental Impact |
|---|---|---|
| **Short Term-Placement of dredge material on the intertidal area** | Flora and fauna/biodiversity | Short term loss of existing mudflat habitat could lead to reduction in meiofauna.<br>Possible impact to associated SPAs, SACs and Ramsar sites due to sediment dispersal. |
| | Social | Short term increases in noise due to plant accessing site.<br>Increases in traffic congestion of plant accessing site.<br>Reduction in site accessibility e.g. for dog walkers.<br>Health and safety considerations to public of dredge placement activities and road traffic.<br>Possible impact to adjacent shellfisheries. |
| | Water Quality | Reduction in water quality due to the displacement of sediment. |
| | Cultural Heritage Archaeology | Resources situated in areas proposed for saltmarsh creation may be lost. |
| **Long Term-Saltmarsh Habitat Creation** | Flora and fauna | Increase in salt marsh species and supporting bird populations. |
| | Social | Increase in natural coastal defence, which can increase land and property prices. Reduction in the cost of required hard defences.<br>Increase in amenity for activities such as dog walking.<br>Increase in shelter for boat moorings.<br>May create new shell fisheries and fisheries. |
| | Coastal Morphodynamics | Possible reduction in sediment availability further along the coastline.<br>Change in tidal regime and hydrodynamics of the site. |
| | Navigation | Improved/reduced navigability due to alterations in channel morphology. |

# 7 Conclusions

The loss of wetlands has been acknowledged as a global problem and has become more pressing as weather and global climate patterns change. This has come combined with the increasing knowledge that wetlands offer important ecosystem services, not least coastal protection to human infrastructure, and supply habitat and nutrients to a wide variety of species thus enhancing biodiversity. Worldwide efforts have been made to restore wetlands using a variety of passive approaches which have seen varying degrees of success. Subsequently a more active method has been trialled which utilises dredge spoil. This keeps fine sediments within coastal geomorphological systems, reduces the impact of dredge spoil dumping on offshore benthic communities and aims to restore the wetland habitat to provide greater coastal protection and, in the longer run, to enhance habitat.

In the UK, trials to beneficially utilise dredge spoil were first undertaken in Essex and since that time further efforts have proceeded cautiously but with some success. The Solent region, however, has seen little attempts to trial this practice despite the presence of significant areas of eroding saltmarsh within its boundary. As inertest in Solent saltmarshes has increased, the Environment Agency and Hampshire County Council have sought to clarify the status of the Solent's wetlands and to establish whether restoration trials using dredge spoil may be viable. A team from the University of Southampton were subsequently tasked to review saltmarsh restoration methods and to analyse a substantial GIS and LiDAR dataset of saltmarsh erosion trends. This was coupled with consideration dredge site locations and sediment contaminant status for sites in the Solent as potential sources of soil for beneficial use.

Concurrently to this work, a review of applicable methods to retain sediment was undertaken as well as a review of legislation barriers to beneficial use trails within the Solent. The latter has often been considered to be problematic due to the significant conservation, coast protection and harbour/navigation legislation that may be applicable. Through this work it is hoped that summaries and clarification, including discussions with regulatory agencies, may have smoothed this path. Furthermore, an overview of aspects that may arise through application of legislation requirements (such as EIA and AA) was also considered. This cannot be exhaustive, as both processes are iterative, but is intended to provide background to ensure that those planning this route are aware of what may require consideration.

Recommendations highlight that of the sites put forward for enquiry, the more suitable for saltmarsh beneficial use trials are Keyhaven Calshot and Gutner Point. For managed realignment the MCA trialled in this report indicates that West Northney, Farlington and Pagham South show the most positive balance of criteria and that of these West Northney would require the least sediment introduced to the system.

Based on these recommendations and subject to final agreement on a trial suitable site, restoration approach and formation of a stakeholder team, the University would seek to submit a full proposal. This would require input from key consultees and collation of information from which a targeted approach can be made to secure funding adequate to run a full trial restoration and monitoring scheme which has been subject to robust environmental assessment and overall agreement.

## References

ABP Research & Consultancy LTD (1998) R.909 Review of Coastal Habitat Creation, Restoration and Recharge Schemes.

Andresen, H., Bakker, J.P., Brongers, M., Heydemann, B., and Irmler, U. (1990). Long-term Changes of Salt-Marsh Communities by Cattle Grazing. *Vegetatio*. Vol. 89, 137-148.

Anisfield S.C., Tobin, M.J. and Benoit, G. (1999). Sedimentation Rates in Flow Restricted and Restored Saltmarshes in Long Island Sound. *Estuaries*. Vol. 22, 231-244.

Atkinson. P.W., Crooks, S., Grant, A. and Rehfisch, M.M. (2001) *The success of creation and restoration schemes in producing intertidal habitat suitable for waterbirds*. English Nature Research Reports. No. 425. English Nature, Northminster House, Peterborough PE1 1UA. ISSN 0967-876X.

Baily, B. and Pearson, A. (2007) Change detection mapping and analysis of saltmarsh areas of central Southern England from Hurst Castle Spit to Pagham Harbour. *Journal of Coastal Research*. **23**, No. 6, 1549-1564.

Bakker, J.P. (1985). The Impact of Grazing on Plant Communities, Plant Populations and Soil Conditions on Saltmarshes. *Vegetatio*. **62**, 391-398.

Bennett, E.L. and Reynolds, C.J. (2004) The value of a mangrove area in Sarawak. *Biodiversity and Conservation*. **2**, No. 4, 359-375.

Bertness M., Silliman B.R., Jefferies R. (2004) Saltmarshes under siege. *American. Scientist*. **92**, No. 1, 54-61.

Birks, C. J. (1993). Managed Retreat : Putting the Theory into Practice : The NRA Perspective. *Proceedings of seminar on Managed retreat*, 17 March 1993. London Zoo, London, UK.

Blankenship, K. (1996). From Shipping Lanes to Shorelines : ‘Beneficial Use' Projects give new life to Dredged Materials. *Bay Journal* **6**, No. 7 October 1996 Alliance for the Chesapeake Bay. www.gma.edu/bios/Bay/journal/96-10/benefici.htm.

Bird, E.C.F. (1987) Man 's Response to Changes in the Australian Coastal Zone. *Resource Management and Optimization RMOPDH*. 4**,** Nos. 3-4, 215-232.

Bloomfield, L. and Gillanders, B.M. (2007) Fish and invertebrate assemblages in seagrass, mangrove, saltmarsh, and nonvegetated habitats. *Estuaries and Coasts*. **28**, No. 1, 63-77.

Bolam, S. G., Rees, H. L., Murray, L. and Waldock, R. (2002) *Intertidal Placement of Dredged Material: A Biological Perspective.* In Smith, J. (Ed.) Proceedings of the 28th International Conference of Coastal Engineers 2002. Cardiff, Wales, ASCE American Society of Civil Engineers.

Bolam, S.G. and Whomersley, P. (2003) Invertebrate recolonisation of fine-grained beneficial-use schemes: An example from the southeast coast of England. *Journal of Coastal Conservation*. **9**, 159-169.

Bolam, S. G. and Rees, H. L. (2003) Minimising impacts of maintenance dredged material disposal in the coastal environment: A habitat approach. E*nvironmental Management*. **32**, 171-188.

Bolam, S. G. and Whomersley, P. (2005) Development of macrofaunal communities on dredged material used for mudflat enhancement: a comparison of three beneficial use schemes after one year. *Marine Pollution Bulletin*. **50**, 40-47.

Bolam, S. G., Rees, H. L., Somerfield, P. J., Smith, R., Clarke, K. R., Warwick, R. M., Atkins, M. and Garnacho, E. (2006) Ecological consequences of dredged material disposal in the marine environment: A holistic assessment of activities around the England and Wales coastline. *Marine Pollution Bulletin*. **52**, 415-426.

Boorman, L., Hazelden, J. and Boorman, M. (2002) *New saltmarshes for old – saltmarsh creation and management*. Littoral, 2002, The Changing Coast. EUROCOAST, EUCC, Porto, Portugal.

Bozek, C.M. and Burdick, D.M. (2005) Impacts of seawalls on saltmarsh plant communities in the Great Bay Estuary, New Hampshire USA. *Wetlands Ecology and Management*.**13**, 553–568.

BRANCH partnership (2007) *Planning for biodiversity in a changing climate – BRANCH project Final Report*. Natural England, UK. http://www.naturalengland.org.uk/press/docs/branch-report.pdf. Accessed 5th June 2008.

Bray, M. J., Carter, D. J. and Hooke, J. (1992). *Sea-level Rise and Global Warming : Scenarios, Physical Impacts and Policies*. SCOPAC.

Bray, M.J., Hooke, J.M., Carter, D.J. and Clifton, J. (2000) *Littoral sediment transport pathways, cells and budgets within the Solent.* In: Solent Science – A Review. Proceedings in Marine Science, 1. (Collins, M. and Ansell, K. Eds). Elsevier Science, Amsterdam, Netherlands. ISBN: 0-444-50465-6. pp 103-106.

Bray, S. (2005) *The Long Term Recovery of the Bioindicator Species* Nucella lapillus *from Tributyltin Pollution*. Unpublished PhD thesis, Centre for Environmental Sciences, School of Civil Engineering and the Environment, University of Southampton

Brooke, J. S. (1993). Marine Update. No. 10. *World Wildlife Fund for Nature*.

Broome, S.W., Seneca, E.D. and Woodhouse, W.W. (1988). Tidal Salt-Marsh Restoration. *Aquatic Botany*. **32**, 1-22.

Burchett, M.D., Pulkownik, A. Grantà, C. and Macfarlane, G. (1998) Rehabilitation of Saline Wetlands, Olympics 2000 Site, Sydney (Australia) - I: Management Strategies Based on Ecological Needs Assessment. *Marine Pollution Bulletin*. **37**, Nos. 8-12, 515-525.

Burd, F. (1995) *Managed Retreat: A Practical Guide*. Institute of Estuarine and Coastal Studies, Hull, English Nature.

Carpenter, K.E. and Pye, K (1996) *Saltmarsh change in England and Wales – Its history and causes.* Environment Agency, South West Region, RandD Technical Report W12. Prepared by H.R. Wallingford.

CEFAS (2003) Monitoring the quality of the marine environment 1999-2000. In Sci.Ser.Aqua.Environ.Monit.Report (Ed.), CEFAS, Lowestoft, **54**, 98pp.

CERC (1992). *Saltmarsh Erosion and Accretion Processes*. Coastal Defence, Research News from Flood Defence Division, MAFF. **1**, 2-3.

Channel Coastal Observatory (2008) Mean monthly wave heights, Lymington. http://www.channelcoast.org/data_management/real_time_data/charts/?chart=87&tab=stats&disp_option=&data_type=Hs&year=All%20years&data_plot=1 . Accessed 10th October, 2008.

Chesworth, J. C., King, D. G. and Swales, V., 2008. *Inventory of eelgrass Beds in Hampshire and the Isle of Wight*. Hampshire and Isle of Wight Wildlife Trust, Hampshire. http://www.hwt.org.uk/data/files/Marine/inventory_of_eelgrass_beds_in_hampshire_and_the_isle_of_wight_report_v1.pdf. Accessed 19th December 2008.

Chmura, G.L. and Hung, G. (2004). *Controls on Saltmarsh Accretion: a Test in Saltmarshes of Eastern Canada*. Estuaries. **27**, 70-81.

Civco, D., Kennard, W. & Lefor, M. (1986) Changes in Connecticut saltmarsh vegetation as revealed by historical aerial photographs and computer assisted cartographics. *Environmental Management,* 10**,** 229-239.

Colenutt, A.J. (1999). *Beneficial Use of Dredged Material for Inter-tidal Recharge: Management Options for the Lymington Saltmarshes*. Unpublished M.Sc Dissertation, University of Portsmouth.

Colenutt, A. (2001) *Saltmarsh Management Techniques: A Review*. New Forest District Council, Coast Protection Group, October 2001. http://www.newforestdc.gov.uk/media/adobe/reviewofsaltmarshmanagementtechniques2001.pdf . Accessed 25th July 2007.

Colenett, A. (2008) Personal communication. *The wave climate and shoreline defence status of the Solent.* Channel Coastal Observatory (Email. 8th Sept 2008).

Collins, M. and Ansell, K. (2000) *Solent Science – A Review*. Proceedings in Marine Science, 1. (Collins, M and Ansell, K Eds). Elsevier Science, Amsterdam, Netherlands. ISBN: 0-444-50465-6. pp 225-335.

Collins, D., Richardson, D., Noble, D., Collins., T, Burney, J. Reed, S., Horrocks, R., Frew, P., Pepper, A. (2000) *FCDPAG5 Flood and Coastal Defence Project Appraisal Guidance Environmental Appraisal*, Ministry of Agriculture, Fisheries and Food

Construction Industry Research and Information Association. (1995). *Beach Management Manual*. Funders Report/IP/18. CIRIA.

Cope, S.N., Bradbury, A.P. and Gorcynska, M. (2007) *Solent Dynamic Coast: A tool for SMP2*. Main Report. In: New Forest District Council/ Channel Coastal Observatory (Eds).

Csiti, A. and Burt, T. N. (1999) *Re-use, Recycle or Relocate. Environmental Aspects of Dredging Guide 5*. International Association of Dredging Companies and Central Dredging Association, The Hague.

Cundy, A.B. and Croudace, I.W. (1996) Sediment accretion and recent sea-level rise in the Solent, southern England: Inferences from radiometric and geochemical studies. *Estuarine, Coastal and Shelf Science*. **43**, 449–467.

Dausse, A., Merot, P., Bouzille, J.-B., Bonis, A., and Lefeuvre, J.-C. (2005). Variability of Nutrient and Particulate Matter Fluxes Between the Sea and a Polder After Partial Tidal Restoration, Northwestern France. Estuarine, Coastal and Shelf Science. **64**, 295–306.

Davis, J. E. and Landin, M. C. (1998). *Geotextile Tube Structures for Wetlands Restoration and Protection*. WRP Technical Note. http://el.erdc.usace.army.mil/elpubs/pdf/hsrs3-2.pdf.

Dearnaley, M, Fletcher, C., Bolam, S., Kenny, A. and Schratzberger, M (2007) *Large Scale use of Muddy Dredged Material for Sustainable Flood Defences and Habitat Management*. Paper 03-2, Defra Flood and Coastal Management Conference, 3rd July, 2007. http://www.defra.gov.uk/environ/fcd/conference/2007/03-2.pdf. Accessed 26th July, 2007.

Defra and Environment Agency (2005) Saltmarsh Management Manual. In Environment Agency (Ed.). www.saltmarshmanagement.co.uk. Accessed 29th June, 2008.

English Nature (1997). Habitats Regulations Guidance Note 1 – The Appropriate Assessment. 6pp.

English Nature (2003) *Coastal Habitat Restoration – Towards Good Practice*. http://www.english-nature.org.uk/livingwiththesea/project_details/good_practice_guide/HabitatCRR/ENRestore/Habitats/Saltmarsh/Restorationmethods/RecreatingVegetation.htm. Accessed 12th April 2007.

Environment Agency (1998). *Foreshore Recharge Strategy 1998-2002. Beneficial Use of Dredgings: Environmental Appraisal*. Environment Agency.

*Environment Agency (*2000) *Environment 2000 and Beyond.* (ISBN 1857054783)

EA (2000) *Dibden terminal project – Proposed port of Southampton (Dibden terminal) harbour Revision order (DETR ref: p89/24/59): Proposed Fawley branch line improvements order (DETR Ref: p89/24/59) Proposed Dibden stopping-up order (DETR ref: Gose/029/001/hamp/046). Initial response and objections by the Environment Agency*. http://74.125.47.132/search?q=cache:0JsZ9mlsX3sJ:www.environment-agency.gov.uk/commondata/acrobat/initial_response__objection.pdf+southampton+water+sea+trout&hl=en&ct=clnk&cd=10&gl=uk. Accessed 23rd December 2008.

Fletcher, C.A., Stevenson, J.R. and Dearnaley, M.P. (2001) *The beneficial use of muddy dredged material.* Report SR570, H.R. Wallingford, Oxfordshire.

Fletcher, C. I. (1992) Sea-level trends and physical consequences: applications to the U.S. shore. *Earth Science Review*. **33**, 73-109.

Fonseca, M.S., and Cahalan, J.A. (1992). *A Preliminary Evaluation of Wave Attenuation by Four Species of Seagrass. Estuarine, Coastal and Shelf Science*. **35**, 565-576.

Ford, M. A., Calhoon, D.R., and Lynch, J.C. (1999). Restoring Marsh Elevation in a Rapidly Subsiding Saltmarsh by Thin-layer Deposition of Dredged Material. *Ecological Engineering*. **12**, 189-205.

Fowler, J. And Sprague, C. J. (1993). Dredged Material Filled Geotextile Containers. In: *Symposium on Coastal and Ocean Management*. Ed by Orville, T. Magoon *et al.,* New York, N. Y. ASCE.

Fowler, S.L. (2000) Coastal habitats of the Solent. In: *Solent Sciences - A Review*. Collins, M. and Ansell, K. (eds). Elsevrer Science. ISBN. 0 444 50465 6.

French, P. W. (1997). *Coastal and Estuarine Management*. Routledge, London.

French, P.W. (1999) Managed retreat: a natural analogue from the Medway estuary, UK. *Ocean and Coastal Management*. **42**, No. 1, 49-62.

French, J. R. And Watson, C. (1999). *Foreshore Recharge for Restoration of Eroded Inter-tidal Profiles : Shotley Point Mud Placement. Year 1, Monitoring and Evaluation (November 1997 to January 1999)*. Report for EA, Anglian Region and Harwich Haven Authority. Coastal and Estuarine Research Unit, University College London.

French, J.R., Watson, C.J., Moller, I. , Spencer, T., Dixon, M. and Allen, R. (2001). Beneficial use of cohesive dredgings for foreshore recharge. *Proceedings 35th MAFF Conference of River and Coastal Engineers*. 5 th-7th July 2000, Keele.

French, P.W (2001) *Coastal Defences. Processes, Problems and Solutions*. Routledge, London.

French, P.W. (2006). Managed Realignment – the Developing Story of a Comparatively New Approach to Soft Engineering. *Estuarine, Coastal and Shelf Science*. **67**, 409–423.
Frey, R. W. and Basan, P. B. (1985). *Coastal Saltmarshes*. In Davis (Ed) Coastal Sedimentary Environments. Springer-Verlag, New York.

Friel, I. (2007) Henry V's *Grace Dieu* and the wreck in the R. Hamble near Bursledon, Hampshire *International Journal of Nautical Archaeology*. **22**, No. 1, 3-19.

Goodman, P.J., Braybrooks, E.M. and Lambert, J.M. (1959) *Investigations into `Die-Back' in Spartina Townsendii AGG*. In The Present Status of *Spartina Townsendii* in Britain. British Ecological Society.

Gray, A. J. (1992) *Saltmarsh Plant Ecology: Zonation and Succession Revisited*. In Allen, J. and Pye, K. (Eds.) Saltmarshes- Morphodynamics, Conservation and Engineering Significance.

HAM (1994). *The Advantages of Dredging by Water Injection*. HAM, Rotterdam.

Hansson, L.A., Brönmark, C., Anders-Nilsson, P. and Åbjörnsson, K. (2005) Conflicting demands on wetland ecosystem services: nutrient retention, biodiversity or both? *Freshwater Biology.* **50**, No. 4, 705-714.

Hawley, S. (2008) Personal communication. Beneficial use of dredged sediments in the Medina Estuary, Isle of Wight. Email 17th November 2008.

Hofstede, J. L. A. (1995). Saltmarsh Management in the Federal State of Schleswig-Holstein, Germany. In *Saltmarsh Management for Flood Defence: Research Seminar Proceedings*. November 1995 (Ed) Sir William Halcrows and Partners Ltd.

Haslett, S.K., Strawbridge, F., Martin, N.A. and Davies C.F.C. (2001) Vertical Saltmarsh Accretion and its Relationship to Sea-level in the Severn Estuary, U.K.: An Investigation using Foraminifera as Tidal Indicators . *Estuarine, Coastal and Shelf Science*. **52**, No. 1, 143-153.

Haslett, S.K., Cundy, A.B., Davies, C.F.C., Powell, E.S. and Croudace, I.W. (2003) Saltmarsh Sedimentation over the Past c. 120 years Along the West Cotentin Coast of Normandy (France): Relationship to Sea-level Rise and Sediment Supply. *Journal of Coastal Research*. **19**, No. 3, 609-620.

Hawkins, S.J., Allen, J.R. and Bray, S. (1999). Restoration of temperate marine and coastal ecosystems: nudging nature. *Aquatic Conservation*, *Marine and Freshwater Ecosystems*. **9**, 23-46.

HCC (2000) *Hampshire County Council Community Development and Conservation Sub-Committee Item 5 18 February 2000 The Saltmarsh Project (Solent Action Link for the Management and Restoration of Saltmarsh Habitats) Report of the County Planning Officer*. http://www.hants.gov.uk/scrmxn/c28960.html. Accessed 10th December 2008.

Holder, C.L. and Burd, F. (1990) *Overview of Saltmarsh Restoration Sites in Essex: an Interim Report*. Nature Conservancy Council.

Holzer, T. (2009) Personal Communication. Environment Agency comments on beneficial use of dredge spoil with respect to legislation. Email, 9th January 2009.

Houwing, E.J., van Duin, W.E, Dijkema K.S., and Terwindt J.H.J. (1999). Biological and Abiotic Factors Influencing the Settlement and Survival of *Salicornia dolichostachya* in the Intertidal Pioneer Zone. *Mangroves and Saltmarshes*. **3**, 197-206.

HR Wallingford (1999). Beneficial Use of Dredged Material in Chichester Harbour. *Discussion Document Prepared on Behalf of Chichester Harbour Conservancy*. Report EX4044.

HR Ltd. (1987). *The Effectiveness of Saltings*. Report SR 109. Wallingford.

Hubbard, M. and MacGuire, F. (1997). *Going Under? UK Coastal Habitats Threatened by Sea Level Rise*. Friends of the Earth. http://www.foe.co.uk/wildplaces/squeeze.html

Hubbard, J.C.E. (1970). Effects of Cutting and Seed Production in *Spartina anglica*. *Journal of Ecology*. **58**, 329-334.

Hughes, R.G. and Paramor, O.A.L. (2004) On the loss of saltmarshes in south-east England and methods for restoration. *Journal of Applied Ecology*. **41**, 440-448.

Jensen, A. (1985). The Effects of Cattle and Sheep Grazing on Saltmarsh Vegetation at Skallingen, Denmark. *Vegetatio*. **60**, 37-48.

Jensen, A. and Mogensen, B. (2000) *Environmental Aspects of Dredging*. IADC/CEDA. Effects, ecology and economy. Environmental aspects of dredging - Guide No. 6. International Association of Dredging Companies (IADC) and Central Dredging Association (CEDA), 119 pp.

Jensen, A. (2000) *Fisheries of Southampton Water and the Solent*. In: Solent Science – A Review, Proceedings in Marine Science, 1. (Collins, M. and Ansell, K. Eds). Elsevier Science, Amsterdam, Netherlands. ISBN: 0-444-50465-6. pp 271-279.

JNCC (2004) Common Standards Monitoring Guidance for Saltmarsh Habitats. Joint Nature Conservation Committee.

JNCC (2006) *Revised Biodiversity Action Plan*. Joint Nature Conservation Committee.

Jordaan, J.M. (1970) Study of Durban harbour silting and beach erosion. In: *Proceedings of the twelfth coastal engineering conference*, September 13-18, 1970, Washington, D.C. Volume **2**, American Society of Civil Engineers, New York, N.Y., p 1097-1116, 1970.

Johnson, D.E. (2000) Ecological restoration options for the Lymington and Keyhaven saltmarshes. *Journal of the Chartered Institute of Water and Environmental Managers*. **14**, 111-116.

Johnson, D.E., Bartlett, J. and Nash, L.A. (2007) Coastal lagoon habitat re-creation potential in Hampshire, England. *Marine Policy*. **5,** No. 31, 599-606.

King S. E. and J. N. Lester. (1995). The Value of Saltmarsh as a Sea Defence. *Marine Pollution Bulletin*. **30**. No. 3. 180-189.

Kirby, R. (1995). *Tidal Flat Regeneration: A Beneficial Use of Muddy Dredged Material*. World Dredging Congress, Amsterdam, November 1995.

Kusler, J. and Kentula, M. E. (1990). *Wetland Creation and Restoration*: The Status of the Science. Island Press, Washington.

Konisky, R.A., Burdick, D.M., Dionne, M. and Neckles, H.A. (2006) A Regional Assessment of Saltmarsh Restoration and Monitoring in the Gulf of Maine. *Restoration Ecology*. **14**, No. 4, 516–525.

Laegdsgaard, P. (2006) Ecology, disturbance and restoration of coastal saltmarsh in Australia: a review. *Wetlands Ecology and Management*. **14**, 379-399.

Langis, R., Zalejko, M. and Zedler, J.B. (1991) Ecological Nitrogen Assessments in a Constructed and a Natural Saltmarsh of San Diego Bay Society of America. *Ecological Applications*. **1**, No.1, 40-51.

Lee, M. (2002) Coastal defence and the Habitats Directive: predictions of habitat change in England and Wales. *Geographical Journal*. **67**, 39-56.

Leggett, D. J. and Dixon, M. Management of the Essex Saltmarshes for Flood Defence. In ICE (1994). Wetland Management. Falconer, R. A. and Goodwin, P. (Eds). Thomas Telford, London.

LRDC International Ltd. (1993) *Saving the Saltings: A Strategy*. Report for Lymington Harbour Commissioners.

MacLeod, C.L., Scrimshaw, M.D., Emmerson, R.H.C., Chang, Y.-H., and Lester, J.N. (1999). Geochemical Changes in Metal and Nutrient Loading at Orplands Farm Managed Retreat Site, Essex, UK (April 1995-1997). *Marine Pollution Bulletin*. **38**, 1115–1125.

McCaffery R.J. and Thompson, J. (1980). A Record of the Accumulation of Sediment and Trace Metals in a Connecticut Saltmarsh. In: *Estuarine Physics and Chemistry-Studies in Long Island Sound*. Saltzman, B. (Ed). Academic Press, New York, NY.

MCEU (2008) *Beneficial and Mitigating Use of Dredged Materials*. Marine Consents and Environmental Unit. http://www.mceu.gov.uk/mceu_local/FEPA/FEPA-beneficial.htm. Accessed 29th June, 2008.

Mendelssohn, I.A. and Kuhn, N.L. (2003) Sediment subsidy: effects on soil-plant responses in a rapidly submerging coastal saltmarsh. *Ecological Engineering*. **21**, 115-128.

Ministry of Agriculture, Fisheries and Food. (1993) *Coastal defence and the environment: A guide to good practice.* MAFF PB 1191.

Ministry of Agriculture, Fisheries and Food (1996). *Flood and Coastal Defence Strategy*. http://www.maff.gov.uk/environ/fcd/strategy.htm. Accessed 29th June, 2008.

Moore, A., Ives, S., Mead, T.A. and Talks, L. (1998) The migratory behaviour of wild Atlantic salmon (*Salmo salar* L.) smolts in the River Test and Southampton Water, southern England. *Hydrobiologia*. **371/372**, 295-304.

Morris, R. (2007) A nature conservation perspective of port-related dredging. *Proceedings of the Institute of Civil Engineers: Maritime Engineering*. **160**, 19-23.

New Forest District Council. (1997). *Coastal Management Plan*. NFDC.

Norris, K., Brindley, E., Cook, T., Babbs, S., Brown, C.F. and Yaxley, R. (1998) Is the density of redshank *Tringa totanus* nesting on saltmarshes in Great Britain declining due to changes in grazing management? *Journal of Applied Ecology*. **35**, No. 5, 621-634.

North Solent SMP (In preparation) **DRAFT** North *Solent Shoreline Management Plan 2, Appendix C* (*Baseline Process Understanding*). Channel Coastal Observatory.

Nottage, A.S. and Robertson, P.A. (2005) *The saltmarsh creation handbook: a project managers guide to the creation of saltmarsh and intertidal mudflat*. The RSPB, Sandy and CIWEM, London. ISBN: 1 901930 54 8.

Nyman, J.A., Walters, R.J., DeLaune, R.D., and Patrick, Jr., W.H. (2006). Marsh Vertical Accretion via Vegetative Growth. *Estuarine Coastal and Shelf Science*. **69**, 370-380.

Office of the Deputy Prime Minister (ODPM) (2005) *Government Circular: Biodiversity And Geological Conservation – Statutory Obligations And Their Impact Within The Planning System.* ODPM Circular 06/2005. http://www.communities.gov.uk/documents/planningandbuilding/pdf/147570.pdf. Accessed 29th August 2008.

Packham, J.R. and Willis, A.J. 1997. *Ecology of Dunes, Saltmarsh and Shingle*. Chapman and Hall, London.

Pethick, J.S. (1992). Saltmarsh Geomorphology. In: *Saltmarshes – Morphodynamics, Conservation and Engineering Significance*. Allen, J.R.L. and Pye, K. (Eds). Cambridge University Press, Cambridge.

Pontee, N. I. (2003) Designing sustainable estuarine habitats. *Engineering Sustainability*. **156**, 157-167.

Pontee, N.I. (2004) Saltmarsh loss and maintenance dredging in estuaries. *Maritime Engineering*. **157**, 71-81.

Posey, M. H., Alphin, T. D. and Powell, C. M. (1997) Plant and infaunal communities associated with a created marsh. *Estuaries*. **20**, 42-47.

Proffitt, C.W., Chiasson, R.L., Owens, A.B., Edwards, K.R. and Travis, S.E. (2005) *Spartina alterniflora* genotype influences facilitation and suppression of high marsh species colonizing an early successional saltmarsh. *Journal of Ecology*. **93**, No. 2, 404–416.

Pye, K. And French, P. W. (1993). Targets for Coastal Habitat Re-creation. English Nature Science 13. English Nature, Peterborough.

RACER (2004) *Sediment Transport Study. Standing Conference on Problems Associated with the Coastline*. River and Coastal Environments Research University of Portsmouth.

Radley, G. P. (1993). The Environmental Objectives of Managed Retreat. In: *Managed Retreat : Putting the Theory into Practice. Proceedings of Seminar on Managed Retreat*. 17 March 1993. London Zoo, London, UK.

Ray, G.L. (2000) Infaunal Assemblages on Constructed Intertidal Mudflats at Jonesport, Maine (USA). *Marine Pollution Bulletin*. **40**, No. 12, 1186-1200.

Reed, D. J. (1990). The Impact of Sea-level Rise on Coastal Saltmarshes. *Progress in Physical Geography*. **14**, 465-482.

Reise, K. (2001). *Ecological Comparisons of Sedimentary Shores*. Springer Verlag. 384pp.

River and Coastal Environments Research (RACER) (2004) Sediment Transport Study. *Standing Conference on Problems Associated with the Coastline.* University of Portsmouth.

Robinson, J.E., Newell, R.C., Seiderer, L.J. and Simpson, N.M. (2005) Impacts of aggregate dredging on sediment composition and associated benthic fauna at an offshore dredge site in the southern North Sea. *Marine Environmental Research*. **60**, 51-68.

Rogers, H.R. (2002) Assessment of PAH contamination in estuarine sediments using the equilibrium partitioning–toxic unit approach. *The Science of the Total Environment*. **290**, 139–155.

Rooth, J.E., Stevenson, J.C., and Cornwall, J.C. (2003). Increased Sediment Accretion Rates Following Invasion by *Phragmites australis*: the Role of Litter. *Estuaries*. **26**, 475-483.

Rowe, M (2008) Shifting sands. *Geographical*. **80**, No. 3, 39-42.

Rupp, S. and Nicholls, R.J. (2002). *Managed Realignment of Coastal Flood Defences: A Comparison Between England and Germany*. In: Proceedings of Dealing with Flood Risk - An Interdisciplinary Seminar of the Regional Implications of Modern Flood Management. van Kappel, B. (Ed.). Delft Hydraulics.

RYA (2003) Personal communication. On the levels of recreational vessel use in the UK. Bayliss, P. Marketing Officer, Royal Yachting Association, Romsey, Hampshire.

Rybczyk, J.M., Callaway, J.C., and Day J.W. (1998). A Relative Elevation Model for a Subsiding Coastal Forested Wetland Receiving Wastewater Effluent. *Ecological Modeling*. **112**, 23-44.

Santos, M.M., Viera, N. Reis-Henriques, M.A., Santos, A.M., Gomez-Ariza, J.L., Giraldaez, I. and ten Hallers-Tjabbes, C.C (2004) Imposex and butyltin contaminants off the Oporto Coast (NW Portugal): a possible effect of the discharge of dredged material. *Environment International*. **30**, 793-798.

Schrift, A.M. (2006) *Saltmarsh Restoration With Sediment-Slurry Amendments Following A Drought-Induced, Large-Scale Disturbance*. Unpublished Masters Thesis, University of West Florida (Louisiana State University and Agriculture and Mechanical College). http://etd.lsu.edu/docs/available/etd-06012006-154808/unrestricted/Schrift_thesis.pdf. Accessed 25th June, 2008.

Seneca, E.D. (1974). Stabilization of Coastal Dredge Spoil with *Spartina alterniflora*. In: *Ecology of Halophytes*. Reimold, R.J. and Queen, W.H. (Eds).

Seneca, E.D., Woodhouse, W.W., and Broome, S.W. (1975). Saltmarsh Creation. In: *Estuarine Research*. Cronin, L.E. (Ed.). Academic Press.

Shennan, I. and Horton, B. (2002) Holocene land- and sea level changes in Great Britain. *Journal of Quaternary Science*. **17**, 511-526.

Simmonites, S. (2008) ABP Southampton. On sources and disposal of potential dredge spoil arising from proposed capital dredge of Southampton Water. Email, 20th October 2008.

Slocum, M. G., I. A. Mendelssohn, N. L. Kuhn (2005). Effects of sediment slurry enrichment on saltmarsh rehabilitation: Plant and soil responses over seven years. *Estuaries*. **28,** No. 4, 519-528.

Smith, D., Firee, T., Mitchell, C., Whitt, M.( 1975) Feasibility of using dredge spoil to generate a wildlife reserve and saltmarsh in San Diego Bay, California. *OCEANS*. **7**, 180-187. http://ieeexplore.ieee.org/iel6/8271/25909/01154065.pdf?arnumber=1154065. Accessed 25th June, 2008.

Smith, H.K. (1978). Habitat Creation with Dredged Material. *Dredging and Marine Construction*. **14**, 14-20.

Solent Forum (2006) *Marine Consents Guide*. http://www.solentforum.hants.org.uk/pdf/MCG2006.pdf. Accessed 29th June, 2008.

Solent forum (2008) *Solent forum meeting. 18 march 2008 – Minutes*. http://www.solentforum.org/resources/pdf/meetings/sfmin0308.doc. Accessed 13th November 2008.

Spencer, K.L., Dewhurst, R.F. and Penna, P. (2006) Potential impacts of water injection dredging on water quality and ecotoxicity in Limehouse Basin, River Thames, SE England, UK. *Chemosphere*. **63**, 509-521.

Spurgeon, J. (1999) The Socio-Economic Costs and Benefits of Coastal Habitat Rehabilitation and Creation. *Marine Pollution Bulletin*. **37**, Nos. 8-12, 373-382.

Steetzel, H. (1996). Environmental Consequences. Alkyon Hydraulic Consultancy and Research. http://www.abag.ca.gov/govnet/clearinghouse/ltms/chapters/6-impact.htm.

Streever, W. J. (2000) *Spartina alterniflora* marshes on dredged material: a critical review of the ongoing debate over success. *Wetlands Ecology and Management*. **8**, 295-316.

Suntornvongsagul, K., Burke, D.J., Hamerlynck, E.P. and Hahn, D. (2007) Fate and effects of heavy metals in salt marsh sediments. *Environmental Pollution*. **149**, 79-91.

Svavarsson, J., Granmo, A., Ekelund, R. and Szpunars, J. (2001) Occurrence and effects of organotins on adult common whelk (*Buccinum undatum*) (Mollusca, Gastropoda) in harbours and in a simulated dredging situation. *Marine Pollution Bulletin*. **42**, No. 5, 370-376.

Tay, K., Teh, S.J., Doe, K., Lee, K. and Jackman, P. (2003) Histopathologic and Histochemical Biomarker Responses of Baltic Clam, *Macoma balthica*, to Contaminated Sydney Harbour Sediment, Nova Scotia, Canada. *Environmental Health Perspectives*. **111**, No. 3, 273-280.

Thomsen, D., Marsden, I.D. and Sparrow, A.D. (2005) A field experiment to assess the transplant success of saltmarsh plants into tidal wetlands. *Wetlands Ecology and Management*. **13**, 489-497.

Toft, A. R. and R. J. Maddrell. (1995). A Guide to the Understanding and Management of Saltmarshes. RandD Note 324. Sir William Halcrow and Partners.

Tsuzaki, T., (2006) Spartina ecology" *Evidence for morphological variation in* Spartina anglica *C.E. Hubbard* MRes Report, University of Southampton pp 81.

UK Biodiversity Action Plan (UKBAP) (1999) *Habitat Action Plan: Coastal Saltmarsh*. http://www.ukbap.org.uk/UKPlans.aspx?ID=33. Accessed 14th August, 2008.

Van Der Wal, D. and Pye, K. (2004 ) Patterns, rates and possible causes of saltmarsh erosion in the Greater Thames area (UK). *Geomorphology* **61**, Nos. 3-4, 373-391.

Van Proosdij, D., Ollerhead, J. and Davidson-Arnott, R.G.D. (2006) Seasonal and annual variations in the volumetric sediment balance of a macro-tidal saltmarsh. *Marine Geology*. **225**, Nos. 1-4, 103-127.

Van Wesenbeeck, B.K., van de Koppel, J., Herman, P.M.J. and Bouma T.J. (2008) Does scale-dependent feedback explain spatial complexity in salt-marsh ecosystems? *Oikos*. **117**, No. 1, 152–159.

Velegrakis, A. (2000) *Geology, geomorphology and sediments of the Solent system*. In: Solent Science – A Review, Proceedings in Marine Science, 1. (Collins, M. and Ansell, K. Eds). Elsevier Science, Amsterdam, Netherlands. ISBN: 0-444-50465-6. pp 21-43.

Warren, R. S., Fell, P. E., Rozsa, R., Brawley, A. H., Orsted, A., C., Olson, E. T. Swamy, V. and Niering, W.A. (2002) Saltmarsh Restoration in Connecticut: 20 Years of Science and Management. *Restoration Ecology*. **10**, No. 3, 497-513.

Weichsel, T., Cameron, P., Fick, A. and Watermann, B. (1998) *Remobilisation of Organotin Compounds from Sediments of the North Sea and the Baltic and the Relevance for Biological Effects*. Oslo and Paris Conventions for the Prevention of Marine Pollution. Working Group on Sea-Based Activities (Seba). Copenhagen, 16-20 February 1998. Submitted by the World Wide Fund For Nature (WWF). Agenda Item 9. SEBA 98/9/NGO.2-E. http://www.ngo.grida.no/wwfneap/Publication/Submissions/OSPAR98/WWF_OSPAR98TBT.doc. Accessed 3rd March 2007.

Weis, J.S. and Weis, P. (2004) Metal uptake, transport and release by wetland plants: implications for phytoremediation and restoration, *Environmental International.* **30**, 685–700.

Wilber, P. (1992). Thin-layer Dredged Material Disposal in Coastal Marshes – Case Studies. In: *Ports '92. Proceedings of the Conference*. July 20-22 1992, Seattle, WA. Washington, DC: Permanent International Association of Navigation Congresses.

Wilber, P. (1993). *Environmental Effects of Dredging Technical Notes: Managing of Dredged Material via Thin-layer Disposal in Coastal Marshes*. U.S. Army Corps of Engineers. Technical Note EEDP-01-32.

Williams, E.C.R. (2006) *A Study of the Change in Levels and Distribution of Saltmarsh and Mudflats on Southampton Water 1889-2003*. MRes Thesis, Unpublished School of Civil Engineering and the Environment. University of Southampton.

Williams, E.C.R. (In preparation) Impact of changing sediment budget on the intertidal zone around an active port: A case study of Southampton water, UK. PhD thesis, Centre for Environmental Sciences, School of Civil Engineering and the Environment, University of Southampton.

Williams, J. and Lester, J. (1994) Metal Accumulation Within Saltmarsh Environments: A Review. *Marine Pollution Bulletin*. **28**, 277-290.

Windham, L. and R. G. Lathrop. (1999) Effects of *Phragmites australis* (Common Reed) invasion on aboveground biomass and soil properties in brackish tidal marsh of the Mullica River, New Jersey. *Estuaries*. **22**, 927-935.

Winn, P. J. S., Young, R. M. and. Edwards, A. M. C. (2003) Planning for the rising tides: the Humber Estuary Shoreline Management Plan. *The Science of The Total Environment*. **314**, 13-30.

Wolaver, T.G., Dame, R.F., Spurrier, J.D., and Miller, A.B. (1988). Sediment Exchange Between A Euhaline Saltmarsh in South Carolina and the Adjacent Tidal Creek. *Journal of Coastal Research*. **4**, 17-26.

Wolters, M., Garbutt, A. and Bakker, J.P. (2004) Salt-marsh restoration: evaluating the success of de-embankments in north-west Europe. *Biological Conservation*. **123**, 249-268.

Wolters, M., Bakker, J.P., Bertness, M.D., Jefferies, R.L. And Möller, I. (2005[a]) Saltmarsh erosion and restoration in south-east England: squeezing the evidence requires realignment. *Journal of Applied Ecology*. **42**, 844-851.

Wolters, M., Garbutt, A. and Bakker, J.P. (2005[b]) Salt-marsh restoration: evaluating the success of de-embankments in north-west Europe. *Biological Conservation*. **123**, No. 2, 249-268

Yang, S.L. (1998). The Role of Scirpus Marsh in Attenuation of Hydrodynamics and Retention of Fine Sediment in the Yangtze Estuary. *Estuarine, Coastal and Shelf Science*. **47**, 227-233.

Younger, A. and Kershaw, S. (2004) Sewage discharge improvements in the solent and their Effect on the shellfishery. *Shellfish News*. CEFAS. Laing, I. and Glassock, D. (eds). http://www.cefas.co.uk/publications/shellfishnews/shellnews17.pdf#page=18. Accessed 20th October 2008.

Yozzo. D.J., Pace Wilber, P. and Will, R.J. (2004) Beneficial use of dredged material for habitat creation, enhancement, and restoration in New York–New Jersey Harbor. *Journal of Environmental Management*. **73**, No. 1, 39-52.