Part D

CONCEPTUAL SEDIMENT PROCESS MODELS

The shoreline presents a mobile environment and regardless of whether it is accreting or eroding, an understanding of how littoral material is moving is essential to effective future management. Consequently, a series of Conceptual Sediment Process Models have been created to assist in the preparation of sustainable coastal defence policy options for Poole and Christchurch Bays.

These models provide a unified synthesis of the results of detailed coastal processes, evolution and geological classification studies underpinned by earlier reports set out within this Volume.

Attempts have been made to provide qualitative and quantitative information about sediment processes within Poole and Christchurch Bays in addition to setting longer term assessments of how the coast is likely to be impacted upon.

CONCEPTUAL SEDIMENT PROCESS MODELS

CONTENTS

1 CONCEPTUAL SEDIMENT PROCESS MODELS

1.1 Introduction

It was recommended during Stage 1 of this SMP, that a series of conceptual sediment process models should be produced to describe the ongoing littoral regime that occurs within Poole and Christchurch Bays, based upon existing work, the modelling of coastal conditions described in an earlier section. This facilitates explanation of the larger scale and longer term behaviour of the coastal landforms and examines the relationships between potential long term sediment movements, sources and sinks. Separate conceptual models are therefore prepared for each Process Unit identified, with sufficient detail to determine the impacts of any coastal defence strategies upon these processes and landforms over short (1 – 5 years) and medium term timescales (5 – 50 years).

Details on the concept of the Process Unit framework adopted has already been presented in the front (yellow) pages of this volume. The reader should be fully conversant with this approach at this point.

1.2 Overview of Littoral Processes

The boundaries of Sub-cell 5F are located at Hurst Spit and Durlston Head. Both boundaries represent Partial Fixed drift barriers. To the east, the Sub-cell is bound by Sub-cell 5C (Hurst Spit to Southampton Water) and to the west by Sub-cell 5G (Durlston Head to Portland Bill) (Brampton & Motkya, 1993). It must be recognised that Hurst Spit is "fixed" only by continuing beach management techniques currently being operated at this location.

Sub-cells were originally categorised on the direction and movement (littoral drift) of sand and gravel along beaches. Two main types of boundary between cells were recognised, firstly at littoral drift divides and secondly at sediment sinks (Motyka and Brampton, 1993). In the former, littoral drift moves in opposite directions from the divide e.g. at a headland such as Selsey Bill. Sediment sinks are points at which littoral drift pathways meet, and where beach sediment tends to accumulate. These generally occur in deep bays, tidal inlets and estuaries. It should also be recognised that some sub-cell boundaries within the SMP comprise physical barriers to a unidirectional net transport, producing partial interception of transport, such as the Hengistbury Long Groyne. Motyka & Brampton (1993) stress that the division into coastal cells is strictly applicable to the purpose of coastal defence management on non-cohesive beaches. The direction and movement of sediment further offshore is unlikely to mirror littoral drift directions and boundary conditions in all cells.

Both Christchurch and Poole Bay are similar in plan shape (i.e. log spiral curves), characteristic of an eroding coastline contained between hard points. Both Bays are anchored at Hengistbury Head, the long term integrity of which has been preserved by locally resistant beds within the Barton Clay (Ironstone Nodules). Christchurch Harbour is located immediately to the east of Hengistbury Head. The entrance to the Harbour is almost closed by two spits and is characterised by a fast flowing tidal exchange and freshwater discharge.

The bathymetry of Christchurch Bay is characterised by offshore banks and sedimentary deposits, including Christchurch Ledge, Dolphin Sand, Dolphin Bank and Shingles Bank. Poole Bay in comparison is relatively simple, though it is complicated by sand banks at the entrance to Poole Harbour which are characterised by north and south facing spit formations. Immediately to the south of the entrance, the remainder of Poole Bay of Handfast Point is characterised by Studland Bay the shoreline of which is composed of sandy beaches. Details on the geology and geomorphology of the subcell has already been covered in an earlier Section of this Volume, though in summary, the main sediment budget elements are classified as follows :

- Cliff erosion – in the past this was both Poole and Christchurch Bays with lesser erosion in south Studland Bay and Swanage Bay
- Main Sinks – Shingles bank, Dolphin Sand , Hook Sand, South Haven Peninsula and Poole Harbour (cohesive sediments)..

1.3 Division and Explanation of Process Units

For the purposes of creating meaningful conceptual sediment process models, and subsequently to set accurate areas for future management based on prevailing coastal conditions and historic shoreline evolution, the subcell has been divided into Coastal Process Units based on the sub-cell system derived from the "Mapping of Littoral Cells" report commissioned by MAFF in 1993 (Motyka and Brampton).

The Process Unit is a critical concept in the preparation of an SMP and is a great advance over earlier methods based upon decision making exclusively at the level of management units. By relating decision making to the Process Unit it encourages a more strategic approach that should better accommodate measures to facilitate the operation of "natural" processes and the freedom to adjust of coastal landforms. As such it is likely to become a key element in approaches involving identification, delivery and testing of sustainable long-term management options for the future.

The Process Unit should provide the basis for evaluating the spatial interdependence of management units, thus allowing selection of management options that should not adversely affect neighbouring areas and collectively should promote the long term sustainable management of the Process Unit. A better understanding of the purposes of a process units within an SMP should help to clarify the necessary levels of knowledge required and assist in defining requirements for future research. A useful goal would be to promote standard procedures for identifying and applying Process Units - this could help to achieve a better conformity of approach for SMPs when they are next revised and enable improved regional comparisons of SMP results.

An important clarification to make is that the demarcation of these Process Units is not made on the geographic limits of certain physical features. Different coastal characteristics (such as dune, storm ridge or marsh) should not be separately divided based purely on the fact that they are very different in their morphological appearance. On the contrary, their formation is likely to be attributed to linked coastal processes that have occurred over a range of temporal scales. In addition to this, their integrity is dependent upon sedimentary budget regimes that act over a far wider scale than the geographic limits of a certain coastal feature. With reference to Poole and Christchurch Bays, there is a physical relationship between areas of open coast and sediment sink areas (such as Poole and Christchurch Harbours). The following definition has been created to explain a Process Unit. It is described as:

"an area of coastline reflecting the complexity or simplicity of a particular coastal area, not merely representing lengths of coherent physical characteristics, but

considers aspects of related littoral interdependencies that impact upon both ecological and geomorphological evolutionary trends over a range of spatial and temporal scales"

The areas, from east to west around the coast, are

5F-1	Hurst Spit to Hengistbury Head Long Groyne (overlap with 5F-2 at Harbour entrance)
5F-2	Christchurch Harbour (overlap with 5F-1 at Harbour entrance)
5F-3	Hengistbury Head Long Groyne to Sandbanks Ferry Slipway (overlap with 5F-4 at Harbour entrance)
5F-4	Poole Harbour (overlap with 5F-3 at Harbour entrance)
5F-5	South Haven Point to Handfast Point
5F-6	Handfast Point to Peveril Point
5F-7	Peveril Point to Durlston Head

1.4 Evaluation of Conceptual Sediment Process Models (CSPMs)

The detailed text provided within this Volume has been evaluated here in order to synthesise the results of the coastal process analysis. It should be noted that whilst the CSPMs seek to provide an overview of sediment budgets and likely future impacts, they have been prepared in advance of some very valuable information being compiled for the CIRIA Sea Bed Mobility Study. Some information has been made available here though there is inevitably some very useful information coming out of this exercise that could be used in future revisions of the Poole and Christchurch Bays SMP.

One of the key aims of the Conceptual Sedimen Process Model is to clearly identify sediment sources (input), sediment transport pathways, temporary stores and sediment destination paths (losses) which contribute to the littoral system. This enables scientists and engineers to form an assessment of their relative significance in sustaining existing and/or future defences within the study area. It must be stressed here that all elements of the sediment budget are important and any one of these elements may be critical. The important aspect to develop is an understanding of the function of each Process Unit, identifying key landforms and sustaining present day processes.

A useful definition provided as part of a Research Project for SCOPAC on Cliff Sediment Inputs (1997) has been assessed for this SMP and is deemed relevant to include within the compilation of CSPMs for this subcell. Here, the definition of key sediment sources is noted as being a *'source of natural sediment input into the littoral system, which provides a critical sediment contribution to ensure the integrity of immediate and/or other frontages, ie: a curtailment of supply from a key source might be expected to compromise existing coastal defences or other unprotected frontages which currently rely on a natural supply of beach material'*. For clarity, sediment inputs have been divided into component sediment size fractions, notably coarse sediments (gravels, shingle and sand) and fine sediments (silts and muds).

In addition to sediment inputs, an attempt has been made to establish sediment outputs. These can either be recognised as output or loss from the littoral system to various sediment stores or sinks within, for example, Poole and Christchurch Harbours or alternatively more permanent output from the offshore circulatory system. Secondly, outputs can be further distinguished according to the dominant transport mechanism. Estuarine (or harbour) output is possible by rapid tidal currents generated at estuary entrances whereas offshore transport may also occur by currents generated by wave action.

Attempts have also been made to assess source significance (length of frontage for which it provides a source of sediment) which combines the two main sub-headings 'Sediment Budget' and 'Sediment Transport Regime' set up for each CSPM. In addition, it is important to include the likely impacts of natural and artificial change and so a section entitled 'Implications of Change on Shoreline Evolution' is also included. Whilst information here cannot be exact due to the nature of the science involved, it intends to illuminate the general sensitivity and likely problems associated with natural (eg: sea level rise) and anthropogenic (eg: coastal defence schemes) interference along the coast.

Although cliff toe erosion rates provide an indication of the volume of material released from the cliff as a result of marine erosion, the analysis does not reflect the true long term sediment yield from the entire cliff system. This scenario is particularly relevant at cliff sites, where cliff top erosion rates exceed cliff toe erosion rates and failures are episodic. For these reasons, calculations of sediment input and subsequent transport regimes have attempted to combine these results where known and where possible.

2 SUBCELL SYNOPSIS OF SEDIMENT TRANSPORT

2.1 Movement of Seabed Sediments

Information for this section has relied heavily on the work prepared for the CIRIA Sea Bed Mobility Study (1998). Information presented for that project has been reviewed and where relevant to this Conceptual Process Model section, has been summarised as follows.

Figure 2.1 shows the main bed load sediment transport pathways which exist inshore of the 20m depth contour in the study area. This has been deduced from the presence of major bed-forms which can confidently be expected to show a consistent rather than an ephemeral or time-varying transport. It can be seen that the major feature is the transport 'path' running south-westward from the western arm of the Solent, from Hurst Spit Narrows along the eastern face of the Shingles Bank (mainly sand and shingle transport) and continuing across Dolphin Bank and Dolphin Sands (mainly sand transport), into the central part of Poole Bay. There is evidence of 'opposite' pathways on the northern flanks of some of these features, indicating the likelihood of sediment circulation cells, especially around the Shingles Bank and Dolphin Bank. To the west of Dolphin Sands, however, there is no evidence of such a circulatory sediment system, and the possibility of the 'inshore' south-westward transport path merging with the 'offshore' westward transport path deduced by Stride cannot be ruled out.

By applying the concept of a sediment 'budget', this work concludes that there appears to be evidence of a relatively 'closed' system ie. with limited bed sediment being added or removed to these inshore bank systems (except for periodic additions and winnowing away of fine sediments). Further offshore, however, the evidence is less clear. Figure 2.1 also shows the presence of pronounced sediment transport pathways in the western part of Poole Bay, whose disposition indicates a sediment 'store' or 'sink' in the area. However the sediment transport regime here is particularly complex with both tidal flows and waves helping to create the transport pathways. Sediment, principally sand, is transported not only as bed load but also in suspension, making the interpretation of the total sediment transport in this area exceptionally difficult.

2.2 Sediment Transport on Beaches

The sediment dynamics of the shoreline in Poole and Christchurch Bays, has been the subject of many studies. In Poole Bay much work has been carried out in connection with the various beach recharge operations along the Bournemouth seafront, which started in the early 1970s. An early investigation by Henderson (1979) based on a wave refraction analysis calibrated by wave measurements made off Southbourne, indicated a littoral drift divergence point at Durley Chine, with beach sediment moving westwards towards Sandbanks and eastward toward Hengistbury Head. A later study by Lacey (1985), using similar methods, also predicted a strong westward transport in the western part of Poole Bay. Although the potential drift rates calculated were very high (because these were "energy based" model studies), the overall pattern of drift inferred by both studies was in agreement with the conventional view of the drift regime along the frontage of Poole Bay at that time. It should be noted that these studies calculated potential drift and didn't allow for the effects of groynes.

A more recent study by HR Wallingford (1994) however, predicted an eastward net transport over much more of the frontage. It also indicated the potential importance of the flood-dominated tidal flows close inshore along the Sandbanks frontage, which contribute to the complex drift regime in this area. Even more recent observations by staff from both Poole and Bournemouth Borough Councils (see Harlow, 1995) now suggest an easterly drift along the whole frontage from Sandbanks to Hengistbury Head. It remains to be seen whether this changing view point is a result of better understanding of the coastal processes, or a genuine change in the drift rates in recent years.

Within Christchurch Bay, problems of eroding cliffs and the repeated breaching of Hurst Spit have also encouraged considerable research into longshore transport rates. The studies by Henderson (1979) and Lacey (1985) both predicted an easterly drift along most of the Bay, in accordance with observations, but had difficulty in modelling drift rates along Hurst Spit, especially at its eastern end, where the wave transformation over Shingle Bank is particularly difficult to predict.

Most of these studies have been well documented and Portsmouth University (Bray *et al* 1991) has produced a synthesis for SCOPAC. To date, the present knowledge of drift rates indicates that;

- Long term net longshore drift is predominantly eastward in both Poole and Christchurch Bay. Beach material in the Bays varies spatially, with material generally being coarser in the eastern parts of both. This variability adds to the difficulties of computing drift rates as does the extent of coastal defence structures which alter conditions that makes validation of potential drift rates difficult.

- the calculation of drift rates are particularly difficult at Sandbanks and along Hurst Spit. At both sites, the presence of large banks in shallow water (Hook Sand and Shingles Bank respectively) and the diffraction of waves entering from the English Channel around major headlands (the Isle of Purbeck and the Needles respectively) make the character of waves, and their prediction, very complex.

- Except for the work of Velegrakis (1994) very little research has been done on the onshore-offshore transport of beach material. Such inferred seaward or landwards movements of beach material are often very dubious and should be treated with caution. The new work carried out by CIRIA (1998) has attempted to bridge this gap in our knowledge.

2.3 Present Understanding of Littoral Processes

The sedimentary regime of the seabed over the whole study area is very dynamic. The sediment within the Bays moves along transport pathways that are controlled by three key driving factors;

- Tidal flow through the mouths of the coastal inlets

- Wave induced currents

- The tidal currents of the English Channel

The variables controlling sedimentary processes in Poole and Christchurch Bays are reflected in the distribution pattern of the sedimentary environments. The topography of the embayment controls the location of modern erosional and depositional environments. Erosion is taking place along the cliffed coastlines and head lands, and accretion is associated with buried palaeovalleys and submarine bed-rock ridges (compare Figures 2.2 and 2.3)

The nature of the available sediments is demonstrated by the fact that all the depositional environments within the embayment are characterised by medium and coarse grained sediments. Fine grained sediments only accumulate in Poole and Christchurch Harbours, even though large quantities have been generated by the erosion of the clay-rich Tertiary formations. Such sediments types appear not to be in equilibrium with the hydrodynamic regime of the present system (ie: cannot be deposited in the medium to high energy environment of the open coast) and therefore are either lost offshore or are trapped within the sheltered environments of the tidal inlets (ie: Christchurch Harbour, Poole Harbour etc) (Gao, 1992).

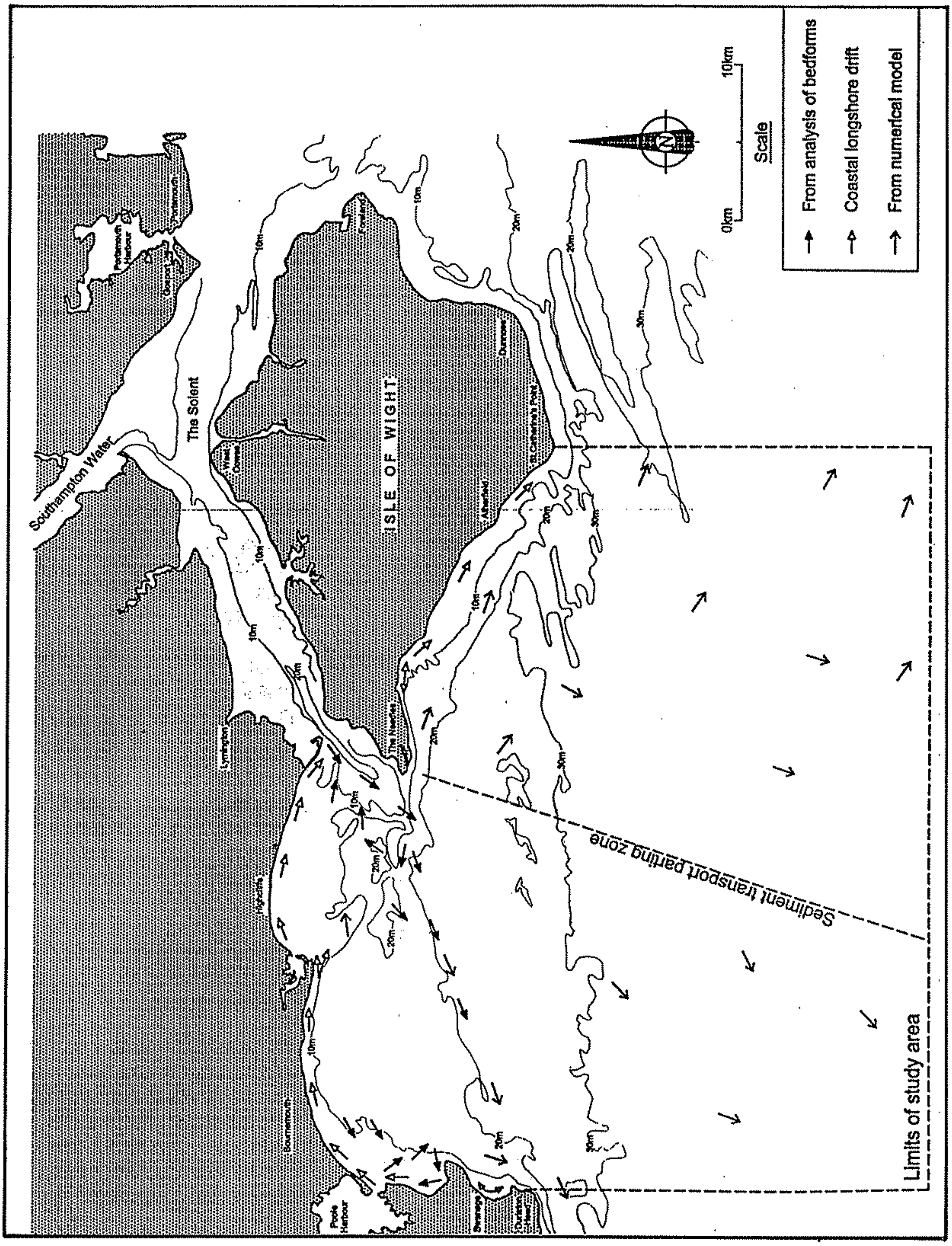
The sediment transport pathways based upon all the available information are summarised in Figure 2.4. This shows that sediment moves eastward within the littoral zone along the coast from a disputed point at Durley Chine to Hurst Spit, interrupted by some change in coastal configuration at Hengistbury Head and the entrance to Christchurch Harbour. To the west of the chine, littoral sediment processes are complex and variable, though sand transport is believed to occur both westward over the inshore seabed but apparently eastward along the beach. South West of the Harbour entrance, drift rates are variable and modest within Swanage and Studland Bays, although there is probably a net north-westward transport in the latter. Towards the east of the study area, sediment drift at Hurst Spit is caught up in the West Solent tidal current and flows predominantly south-westwards along the edge of Shingles Bank and then on towards Dolphin Bank and Dolphin Sand. Some sediment circulates around the banks but the dominant net direction is to the west-south-west.

In the west of the study area, both the modelling carried out for this study and from that published previously, agreed on the likelihood of sediment leaving the area around Handfast Point and Durlston Head in a south-westerly direction. There would appear to be, as a result, a net loss of sandy sediments from the coast and nearshore seabed since the coast further west has little in the way of beaches. There also appears to be a 'parting zone' running roughly SSW from The Needles, ie a line away from which sediment moves (see Figure 2.1).

Along the southern edge of the study area, the Draft Seabed Sediment Mobility Study (CIRIA, 1998) suggest a southerly component to the sediment transport pathways near the parting zone, a feature not so strongly suggested by previous, albeit coarser scale, modelling by Grochowski (1993).

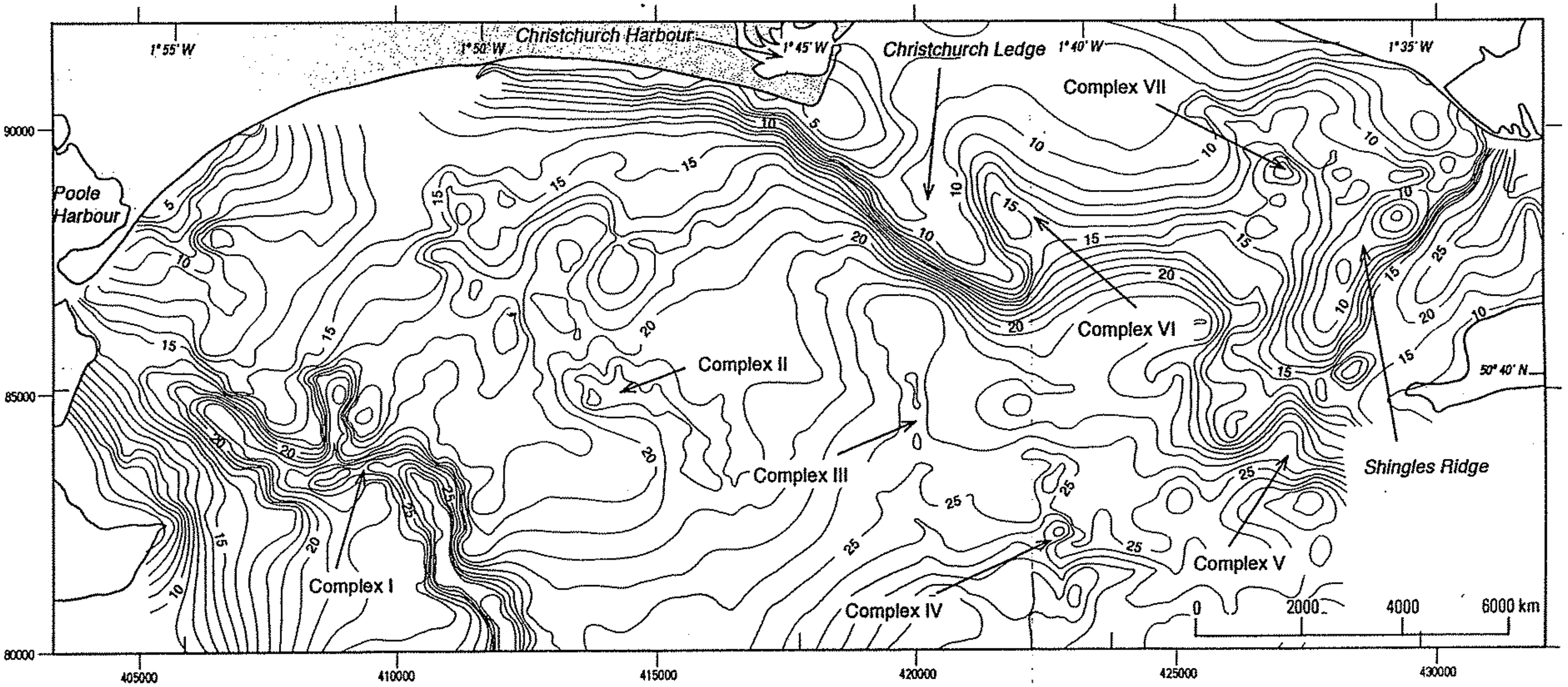
Overall it appears that the main sources of sediment in the study area are the coastline (beaches and cliffs) and perhaps the nearshore seabed (ie. the shore platform). At the seaward limits of the study area, the sediment transport is always predicted to be offshore, so that the net result is a loss of sediment into deeper water, or perhaps to the coastlines further east and west. There is evidence from the bedforms in the western part of Poole Bay that some sediment is likely to settle in the sheltered waters of Studland Bay, and this accords with the history of beach accretion in this area.

Elsewhere in the study area there is no clear evidence of sediment accumulating, although transport into the tidal inlets/ estuaries has not been specifically considered. This undoubtedly occurs but has not been well documented by previous research. The sediment accumulations of the Shingles Bank and the



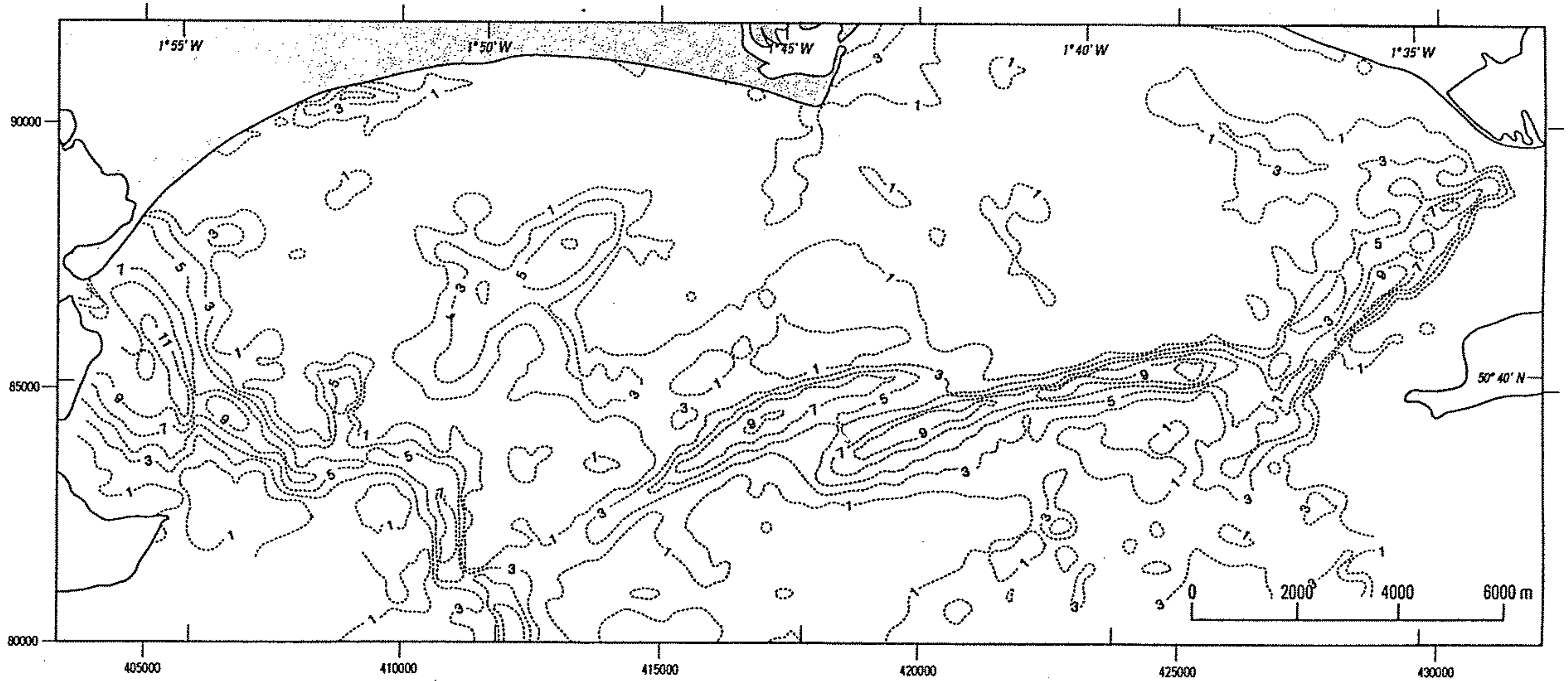
SIMPLIFIED "EXPLANATORY MODEL" OF SEDIMENT TRANSPORT IN THE STUDY AREA

Figure 2.2



STRUCTURE CONTOUR MAP OF THE BEDROCK EROSIONAL SURFACE, CONTOURS IN METRES BELOW O.D. (AFTER VELEGRAKIS, 1994). THE LOCATIONS OF THE PALEOVALLEY COMPLEXES ARE ALSO SHOWN

Figure 2.3



THICKNESS OF UNCOLIDATED (CHANNEL-INFILLING + SUPERFICIAL) SEDIMENTS IN POOLE-CHRISTCHURCH EMBAYMENT (AFTER VELEGRAKIS, 1994) Contours in metres

Dolphin sandbank system may be gradually increasing in volume. It is believed, however, that the Dolphin sandbanks are more likely to be a 'transit camp', only storing sediment arriving from the north-east temporarily before it resumes its journey seaward.

3 PROCESS UNIT 5F-1: HURST SPIT TO HENGISTBURY HEAD LONG GROYNE (CBY)

3.1 Overview of the Process Unit

Christchurch Bay is subject to wave action from both south-westerly and south-easterly directions. Incoming offshore waves are transformed and dissipated by refraction and shoaling effects resulting from the complex bathymetry of the outer reaches of the Bay, including Christchurch Ledge, Dolphin Bank, Dolphin Sands and Shingles Bank.

Littoral drift along the Christchurch Bay frontage occurs predominantly in an easterly direction towards Hurst Spit and due to cyclical paths of sediment transport operating within it, Bray, Carter and Hooke (1991) have regarded Christchurch Bay as a relatively closed sediment system for shingle. This is because the Long Groyne at Hengistbury Head provides a sufficient barrier to prevent coarse material entering Christchurch Bay whilst it is considered that only fine sediments and sand can negotiate the outer reaches of the groyne.

The main sediment input within this Process Unit has historically been from cliff erosion. However, magnitudes of eroded material are believed to have reduced over recent centuries. Overall cliff input into Christchurch Bay has declined from 63,000 m^3pa (>0.08mm diameter) for 1887-1932 to 44,000 m^3pa for 1932-68 (Lacey 1985). Although this may partly reflect early stabilisation measures involving drainage interceptors, groynes and sea walls at Highcliffe, Barton and Milford, effective cliff stabilisation was not achieved until the 1960s and 1970s. Reduction of supply may therefore be related to improved beach conditions within Christchurch Bay.

An important factor as part of this CSPM is the general shortage of beach material in Christchurch Bay (Lacey 1985). Contributory factors causing this are the interception of littoral input from Poole Bay by the Hengistbury Long Groyne and a legacy of reduced cliff input over the period 1932-68. Cliff stabilisation has therefore contributed towards concentration of erosion on remaining unprotected frontages which must recede at increasingly rapid rates to maintain steady cliff sediment input. Application of crenulate bay concepts to Christchurch Bay have revealed that between 250 and 400m further recession was required for a stable plan shape to develop, assuming no defences(Webber 1980, Halcrow 1980).

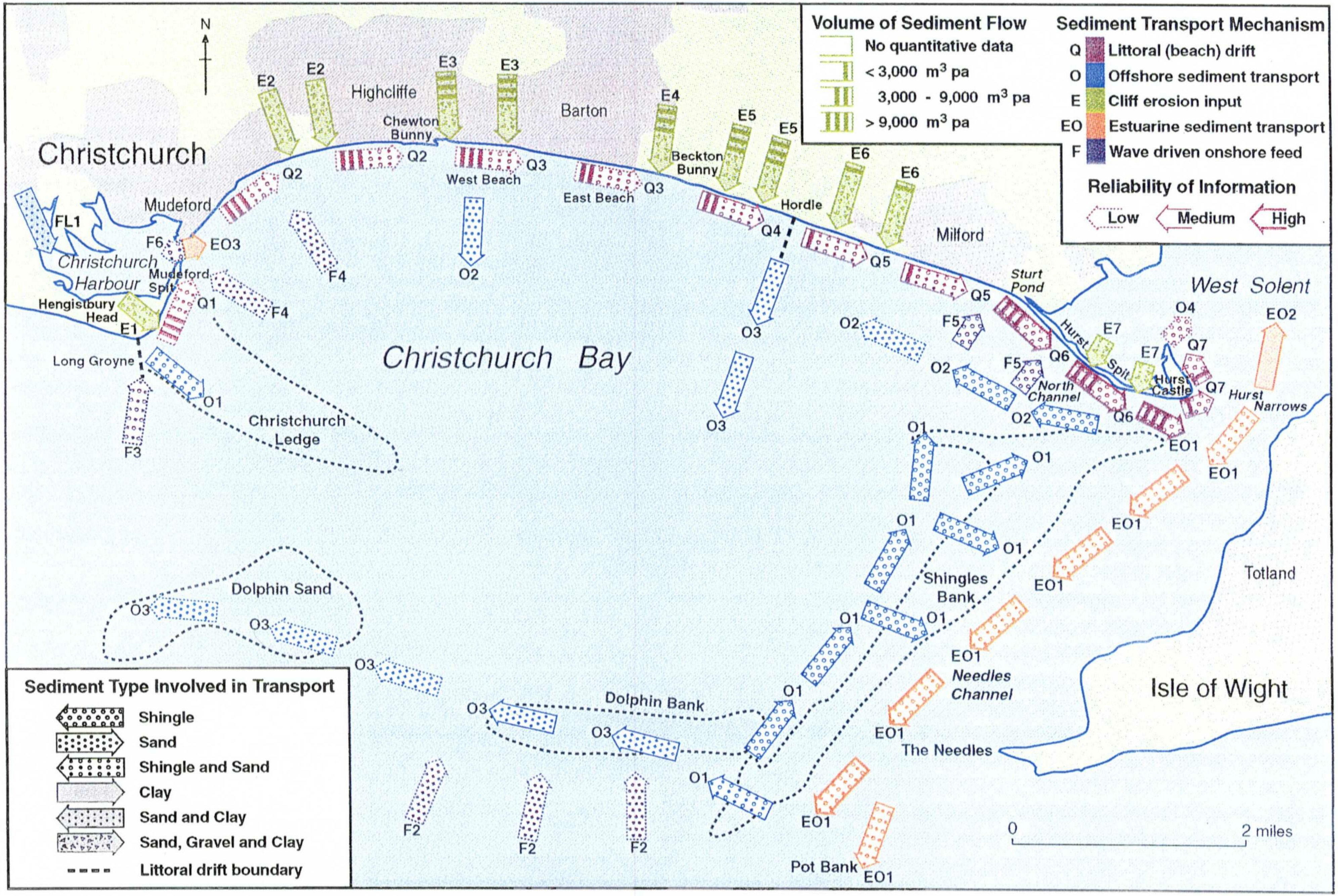
3.2 Sediment Budget

3.2.1 Sediment Inputs (General)

Christchurch Bay is widely regarded as a relatively self-contained coarse sediment circulation system (Nicholls 1985), thus it is difficult to envisage significant marine input. Regardless of this, there are two categories of potential marine input, first, input of fresh sediment to the Christchurch Bay system (cliff erosion) and second, sediment feed to beaches from offshore (either natural or artificially introduced), within the Christchurch Bay circulation system.

<u>Cliff Erosion</u> (See labels E1 to E7 on Figure 3.1)

Much of Christchurch Bay is backed by rapidly eroding cliffs of up to 30m height which provide a major sediment input. The rate of erosion is determined by geology, the longshore distribution of wave energy, the degree of protection afforded by the natural beach or coast protection structures and cliff stabilisation



CONCEPTUAL SEDIMENT PROCESS MODEL
FOR CHRISTCHURCH BAY

measures. There are two key sources of cliff derived sediment released into the littoral system within this process Unit

The length of coast between **East Barton-on-Sea and Milford-on-Sea** provides a key source of fresh beach building material to the immediate frontage and the frontage at Milford-on-Sea. The source is therefore significant in terms of it being a provider of beach material to ensure the integrity of adjacent downdrift defences (towards Hurst Spit). Bray *et al* (1998), suggest that the mean sediment supply rate from the cliffs here is of the order of 58,000 m^3pa (this includes 33,000 m^3 sand, 23,000 m^3 clay and up to 2,000 m^3 gravel).

Between **Chewton Bunny and Barton-on-Sea,** an approximate mean sediment supply rate has been calculated in the order of 50,000 m^3pa (assuming constant erosion rate and cliff geology etc). Research by Lacey suggests a total supply of sediments with a mean diameter of >0.08mm (i.e. sands and gravels) in the order of 9,000 m^3pa. Further research by the University of Portsmouth provides an estimated gravel yield rate of 2,500 m^3pa (Bray *et al*, 1998).

Material released from Naish Cliffs primarily contributes to the immediate foreshore zone (West Beach) and the defended coastline between Barton-on-Sea and Becton Bunny (East Beach). Although the relationship between West and East Beach is unclear, West Beach is the only provider of a natural source of beach building material to supplement the immediate foreshore and any offshore losses from East Beach. This source provides material to adjacent frontages whose integrity is dependent upon their supply.

<u>Onshore transport</u> (See labels 01 to 03 in Figure 3.1)

Coarse sediments are highly mobile offshore of Milford-Hurst and an onshore transport pathway to North Channel has been recognised. Feed to adjacent beaches is only supported by sea bed drifter studies that are not necessarily representative of the actual transport of sediment (Clark and Small 1967) from Shingles Bank. Sand input from offshore is believed to be significant, especially from The Shingles Bank though establishing quantifiable amounts is difficult. The key issue here is that offshore sand resources are believed to play a key role in providing sediment transport "bridges" within Christchurch Bay to allow a continual circulation of sediment to occur in a clockwise direction.

<u>Beach Nourishment</u>

Artificial beach nourishment constitutes a significant sediment input and this has been practised at several locations including a major scheme at Highcliffe and frequent topping up/beach restoration at Hurst Spit.

Coarse Sediments

There are significant key sources of coarse sediment input within this CPM area, particularly where rocks show evidence of continual rotational failure, sliding or toppling such as at Naish Farm.

The relative composition of sediments contained within the cliff faces mentioned above has not been studied in detail, however estimates by Bray suggest an estimated input of 50,000 split between 58% sand, 40% clay and 2% gravel. Research by Lacey (1985) suggests a total supply of sand and gravel sediment is in the order of 9,000 m^3pa. Further research by the University of Portsmouth incorporates work by Indoe and Barton and Cole and provides an estimated gravel yield rate of 2,400 m^3pa (*Bray et al*, 1991). The probable reason for these different estimates is the changes in retreat rate, with the past two decades being more rapid than the long term mean.

Fine Sediments

The fine grained material is commonly input in the littoral system through flows and / or rotational failures from the Naish / Barton cliffs. Fine materials derived from cliff rotational failures are transported ("winnowed") offshore in suspension while coarser clastic deposits are deposited in upper beach sediment sinks or transported alongshore towards Hurst Spit. Further east at Highcliffe, the cliffs contributing fine sediment to the foreshore through largescale debris sliding processes. These are very significant in sedimentary budget terms, though it is also important to stress the contribution of foreshore wave cut platform erosion in the littoral budget regime as well as considering sediment exchanges with the offshore zone for this CSP model area.

There is negligible fluvially derived material being added to the shoreline, nor from the erosion of saltmarshes in Christchurch Harbour.

3.2.2 Sediment Losses (General)

Two types of output can be recognised. These are (i) output from the beach system to various sediment stores or sinks in Christchurch Bay and (ii) permanent output from the Christchurch Bay circulation system.

Outputs can be further distinguished according to the dominant transport mechanism (see Figure 3.1). Estuarine output is possible by rapid tidal currents generated at estuary entrances at Hurst Narrows (EO1), suspended sediment loss to the West Solent (EO2) and Christchurch Harbour (EO3). Offshore transport may also occur by currents generated by wave action, though often with a superimposed tidal current at Hengistbury (WO1), Barton (WO2), Hordle (WO3) and Hurst Castle (WO4) (see Section 3.3).

Sediment eroded from beaches in Christchurch Bay does not balance with inputs by littoral drift and cliff erosion, so there is net loss of beach sediment offshore (Lacey 1985). A major component of this loss is progressively offshore transport of sand eastward towards Hordle and Milford (Nicholls 1985). This process is confirmed by bedform characteristics (Velegrakis 1991) and the high glaucanite content of seabed sediments which are characteristic of the eroding Tertiary cliffs in Christchurch Bay (Dyer 1970).

Coarse Sediments

The majority of sea bed sediments in Christchurch Bay are derived from local cliff erosion. Sand is transported offshore and deposited in the Bay (Dyer 1970, Nicholls 1985, Velegrakis 1991) whereas shingle is retained on the beach, but transported offshore by rapid tidal currents at Hurst Narrows and in the Needles Channel. Chart comparisons of the whole of Christchurch Bay revealed net loss of 505,000 m^3pa over the period 1868-1968 (Lacey 1985). If this is accurate, Christchurch Bay is subject to net output and continuing tendency for offshore loss of beach sediment. This may require checking due to the high potential for error when calculating volume change using comparisons of large areas on hydrographic charts.

No licensed dredging take place within this Model Area, though recycling of aggregate material has taken place in the area of the Shingles Bank for the Hurst Spit Stabilisation Scheme. Clasts derived from the eroding cliffs along the frontage move along the shoreline in an easterly direction though remain within the overall sediment budget due to the general offshore movement of coarse sediment in the vicinity of the Shingles Bank.

Fine Sediments

Clays eroded from the cliffs are transported out of Christchurch Bay in suspension (Lacey 1985). It has been calculated (Lacey 1985) that between 48 and 54% of all cliff input comprises sediments too fine to remain on the beach and thus are transported offshore in suspension. Christchurch Bay therefore represents a major source of suspended (fine) sediments.

3.2.3 Sediment Stores

Foreshore Stores

Coarse material (gravels and coarse sand) is predominantly retained at the shoreline forming beach deposits. Material released from Naish Cliffs primarily contributes to the immediate foreshore zone (West Beach) and the defended coastline between Barton-on-Sea and Becton Bunny (East Beach). Although the precise relationship between West and East Beach is unclear due to intervening rock coastal defence structures, West Beach is the only provider of a natural source of beach building material to supplement the immediate foreshore and any offshore losses from East Beach. This source provides material to adjacent frontages whose integrity is dependent upon their supply.

The majority of coarse material released from cliff falls between eastern Barton and Rook Cliff at Milford is likely to remain within the immediate foreshore zone. These materials are deposited in a wide shingle beach at Hordle estimated to contain 0.5 – 1.5 million cubic metres of sediment. Coast protection works at Milford, comprising a series of groynes, trap the remainder of residual drift. Consequently the supply of fresh material to Hurst Beach is limited. Further west towards Highcliffe, experiments carried out during the 1970 (Tyhurst 1976) clearly revealed that Mudeford-Highcliffe was a major receptive area for drifters injected in both Poole and Christchurch Bays. It has therefore been postulated that these studies indicate a potential for onshore transport to this coastal segment, though there are difficulties relating results to the actual transport of sediments using this experimental technique.

Hurst Spit may be classified as a sediment store (approximately 0 - 5 million cubic metres of sediment) whilst Mudeford Spit is a minor store in addition to the nearshore banks seaward of Christchurch harbour Inlet (volumes unknown)

Offshore Stores

Shingles Bank (volume estimated as 42 million cubic metres – Velegrakis Ph.D Thesis) and Dolphin Bank (volume unknown) are key offshore sediment stores of strategic importance within this Process Unit. Offshore surveys using echo-sounding, side-scan and sediment sampling revealed sand megaripples to the south of Dolphin Bank indicating northward transport onto and across the bank (Velegrakis 1991). Southward sand transport was indicated by bedforms several kilometres to the north which suggested that a sediment sink is likely to exist in the central /east part of Christchurch Bay.

3.3 Sediment Transport Regime

3.3.1 General

Net sediment drift is eastward along the entire bay. A number of littoral drift "compartments" are present, though these do not represent self-contained sediment circulation systems because transport is possible between adjoining compartments. New "compartments" have been created by the creation of rock strongpoints or the insertion of groynes or other structures which intercept littoral drift and often result in downdrift scour. Compartments of this type have been created at Highcliffe, Barton, Milford and at Beckton Bunny when an outfall was reinforced in 1971 a rock and sheet pile strongpoint was constructed (Nicholls 1985). Consequently, residual shingle drift between defended and undefended areas, such as between Barton and Becton Bunny is therefore likely to be small, even though the potential drift may be large.

3.3.2 Wave Induced Transport (See labels Q1 to Q7 on Figure 3.1)

Wave transformation modelling carried out for this study clearly shows a south westerly wave approach in Christchurch Bay, creating an energy flux that is eastwards. This conforms to drift directions reported according to observations by Robinson (1955), Toswell (1978) and Tyhurst (1987). Analysis also suggests that wave induced littoral drift is more significant in the vicinity of Hengistbury-Mudeford Spit, with annual alongshore wave energy levels reducing further east towards Hurst Spit (function of coastal orientation with respect to predominant wave direction). Wave induced residual drift to the east of the Process Unit between the Barton defences and Becton Bunny is therefore likely to be much reduced.

Estimates of wave induced littoral drift have previously been obtained using refraction analysis to generate longshore wave energy flux to determine drift. Analysis using sediment transport equations indicated drift of 96,000m^3pa to the Long Groyne and 575,000m^3pa northward to Mudeford Spit (Lacey 1985). A further improved longshore wave energy flux technique suggested drift of 45,000m^3pa towards the Long Groyne (Hydraulics Research 1986). Mathematical model studies indicated eastward drift of 45,000m^3pa (Hydraulic Research 1986) and sand bypassing the Long Groyne may be a similar order of magnitude.

At West Barton, an indicated drift volume of 167,000m^3pa (Henderson 1979) and 308,000m^3pa (Lacey 1985) were calculated. The drift rates quoted are applicable from just west of Chewton Bunny to the approximate boundary between Barton West and East Beaches. Much lower drift rates of 2,000 m^3pa (Henderson 1979) and 21,000 m^3pa (Lacey 1985) were determined for the length covering East Barton beach. This was attributed to diminished longshore wave energy flux caused by local refraction effects and lower "drift efficiency" due to increased shingle on the beach.

Between Hordle and Milford, longshore wave energy flux analysis indicated drift of 7,000 m^3pa in the west reducing to 2,000 m^3pa at Milford (Henderson 1979) and 71,000 m^3pa reducing eastward to 21,000 m^3pa (Lacey 1985). The magnitude and transient behaviour of the boundary at Hordle means that some material from Hordle Cliff can migrate in an easterly direction towards Milford-on-Sea. It is important to note that littoral drift between Hordle and Milford has decreased threefold between the dates 1939-68 and 1969-82 (Bray, Carter & Hooke, 1991) and at Hurst Castle, littoral drift, calculated from longshore wave energy flows, yielded a significantly reduced net eastward drift volume of 15,000 m^3pa.

These high values relate to the potential transport of "sand" in the Process unit. Values for shingle are much lower (20 to 30 times lower) which is due primarily to the interception of shingle by structures and the shortage of available material.

3.3.3 Potential Bedload Transport Direction

As well as alongshore sediment drift, sand is also believed to be mobile in an onshore-offshore direction causing development of distinctive storm (offshore transport) and swell profiles (onshore transport). These transfers frequently have a net longshore component allowing sand to bypass coast protection structures that are ultimately designed to intercept such beach drift.

In terms of the complicated hydrodynamics of the Process Unit, ebb currents appear to be shorter lived, but more rapid at Hurst Narrows (Webber 1980). Therefore, a dominant south westerly sediment transport pathway extends to the Needles Channel (Dyer 1970, Nicholls 1985, Velegrakis 1991). It is therefore postulated that tidal sediment output of finer material is possible from Christchurch Bay, feeding the established transport stream at its extreme eastern margin.

Sub-bottom profiling revealed only thin sediment cover and much bedrock occurs in this area and so it is concluded that sand is highly mobile in Christchurch Bay and bedload transport pathways may vary seasonally (Velegrakis 1991). Transport out of the area cannot be discounted.

3.3.4 Potential Suspended Material Transport Direction

Research by Lacey (1985) suggests that the volume of suspended sediments circulating within Christchurch Bay is seasonal. This statement would seem plausible since the majority of fine sediments released into the littoral system from cliff erosion (which peaks in winter and spring) do not remain stable within the foreshore zone.

Muds derived from local sources (cliffs or eroded wave cut platform) potentially of key significance within the overall sediment budget are believed to settle out at low water and high water slack. The potential for deposition in high velocity areas is obviously low, though a large percentage of fine grained material in suspension is moved offshore. Results from the recent CIRIA Seabed Sediment Mobility Study (1998) suggests that despite the residual discharges in Christchurch Bay, there is negligible suspended sand transport because the tidal current speeds remain below the threshold of motion for fine sand throughout the tidal cycle. Therefore, fine sand transported very far offshore is unlikely to be returned naturally to the intertidal sediment budget regime.

3.3.5 Aeolian Transport Direction

Prevailing wind directions are from the south west. Any potential movement of beach sand by wind here is nevertheless likely to be localised occurring in a west to east direction, though this cannot be substantiated over longer timescales. This transport method is not, however, significant in overall sediment budget terms within Christchurch Bay.

3.3.6 Temporal Variations in Transport Direction

No evidence has been found to suggest that potential sediment transport significantly alters from the residual littoral drift rates shown previously. Very little information exists relating to the variability of net drift around the values given here. Significant variability has been recorded elsewhere on the south coast of England (HR Wallingford 1993) although the impacts of such changes maybe reduced by the high degree of compartmentalisation of the area

3.4 Implications of Change on Shoreline Evolution

3.4.1 Sea Level Rise

Key strategic issues related to sea level rise include an increased risk of flooding behind Hurst Spit, potential increase in cliff instability at Naish Farm and a possible increased financial burden to areas of already defended coastline. It is believed that, for this Process Unit, noticeable change to beach levels may occur as they potentially become more exposed to higher energy wave attack. An increasing frequency of severe gales is estimated by recent climatic research (Hulme and Jenkins 1998) and could result in additional beach and cliff erosion. Also increasing winter rainfall may cause greater cliff instability and perhaps result in difficulties in maintaining defences at Barton

3.4.2 Anthropogenically Induced Change

Littoral drift at Hengistbury Head has varied over the past 150 years due to human activity (see Shoreline Evolution section in this Volume). The key issues in summary are the stability of Hurst Spit, the Highcliffe, Barton and Milford Cliffs are artificially stabilised and that cliff erosion is accelerating downdrift of the various strong points in the Process Unit (terminal scour).

The feed of material to Hurst Spit has been reduced by the construction of the coastal defences to the west of Chewton Bunny limiting the eastward feed of material. Artificial recycling of material within Christchurch Bay does take place (Hurst Spit), however, this is utilising natural littoral drift regimes and so is unlikely to impact upon adjacent areas within the subcell so long as consideration is given to the possible effect of introducing different clast sizes to the west. Shingle is seen as the most suitable nourishment material for Christchurch Bay because it is transported less rapidly on an open beach (Webber 1980, Halcrow 1980, Nicholls 1985, Lacey 1985) and it is less subject to onshore-offshore exchange, meaning that it is more effectively retained by groynes.

3.4.3 Impact on Adjacent Conceptual Process Model Areas

There has historically been an interrelation between the littoral sediment regimes of Poole and Christchurch Bays, with the key strategic link being Hengistbury Head. Some fine and coarse sediment movements occur around and over Hengistbury Long Groyne, with shingle settling in the trough which occurs to the south (Christchurch Ledge). This natural landform feature plays an important role in the integrity and configuration of both Bays. As a result, it is important to fully recognise the status and position of it within integrated process systems (Bray and Hooke 1998) and thus the future management of Process Units 5F-1, 5F-2 and 5F-3.

4 PROCESS UNIT 5F-2: CHRISTCHURCH HARBOUR (CHB)

4.1 Overview of the Process Unit

Christchurch Harbour comprises the lower portions of the flood plains of the Rivers Avon and Stour flooded immediately north of Hengistbury Head by rising sea-levels in the late Holocene. Littoral drift on the open coast has resulted in the development of two spits which enclose a narrow entrance channel subject to rapid tidal flows. Flood and ebb tidal deltas composed primarily of sandy sediments are present close to the inlet which itself is lined by gravels. The Harbour margins are mostly low-lying and a significant grazing marsh has developed in the NE.

Sediment transport is governed by the currents generated by tidal exchange, freshwater discharge and also by wave action from the open coast although this does not penetrate very far into the Harbour. Wave action is weak due to limited fetch. Both the ebb tidal delta and the southern spit are dynamic and have undergone periods of growth and erosion thought to be related to variations in quantities of material drifting around Hengistbury Head. The Harbour is subject to significant seasonal freshwater discharges from its two rivers producing notable variations in salinity and is a low energy accretionary environment but contains only relatively thin recent sediment sequences of 1m to 2m thickness suggesting a low rate of sediment input since its formation.

Bedload and suspended load sediment transport are calculated to operate in a net seaward direction (Gao, 1993) resulting in theoretical loss of sediments from the harbour and possibly explaining the limited accretion. Surface sediments within the harbour are predominantly sands and muddy sands which are transported towards the east within the southerly area of the river channel (ebb dominant) and to the NE along the northern margin of the harbour (flood dominant). Within this area of local flood dominance there may be significant net inputs of sediment from the open coast to areas where it cannot be returned seaward by ebb currents. On balance, the harbour is probably a net sediment sink receiving very small quantities of suspended fluvial sediments (and some bedload sands, possibly during flood events) and limited inputs of marine derived sand within the northern flood dominated portion.

4.2 Sediment Budget

4.2.1 Sediment Inputs

Coarse Sediments

Sediment input is possible at Christchurch Harbour. This is proven by the presence of a significant delta of well sorted sands and sandy gravels located immediately inside the entrance (Murray 1966, Tosswell 1978, Gao 1990). This feature is attributed to transport and deposition on the flood tide (Murray 1966, Gao 1990), but detailed current metering at the entrance revealed that ebb flow (peak surface velocity $1.9ms^{-1}$) was significantly stronger than the corresponding flood ($1.15ms^{-1}$). However, the ebb and flood currents occupy different parts of the Harbour so it is likely that flood current inputs will not immediately be removed by the ebb such that accretion can occur in some areas.

The supply of coarse material from Hengistbury Spit passed the "Run" and into Christchurch Harbour is believed to be negligible due to the strong longshore currents that are apparent in the immediate area.

Quantities of suspended sediment are supplied to the Harbour by erosion of saltmarsh, the harbour margins and from fluvial input. However, the Harbour sediments are predominantly sandy.

Fine Sediments

The only significant rivers in Christchurch Bay are the Stour and the Avon which discharge into Christchurch Harbour. The combined fluvial discharge to Christchurch Harbour averages $41m^3s^{-1}$ with a minimum flow of $7.5m^3s^{-1}$ and a maximum of $220m^3sec^{-1}$ (Tosswell 1978, Gao 1990). From this, it can be deduced that suspended sediment load to the Harbour is low due to the nature of the catchment (chalk) and from interruptions to flow, eg. weirs (Murray 1966, Tosswell 1978 - Also see Gao (1993 - PhD thesis).

4.2.2 Sediment Losses

Coarse Sediments

Net seaward transport is predicted due to dominance of ebb tidal currents at the entrance (Gao, 1993). This is probably sufficient to remove those materials (mostly sands) entering the Harbour, but which do not reach the flood tide delta.

Fine Sediments

The transport of fine material, whilst low in magnitude, is expected to be predominantly out of Christchurch Harbour (ebb dominated movement). Sediments of a certain size may be readily re-suspended by wave action in the Harbour and are effectively output by ebb tidal flow. Incoming flood flow from Christchurch Bay is significantly less turbid (Bray *et al* 1991) therefore it may be deduced that there is a net loss of fine material from this Process Unit.

4.2.3 Sediment Stores

Sediment inputs to the Harbour are deposited in sub-tidal features such as sand and gravel bars that form inside the harbour entrance and contribute to the flood tide delta. Other potential sediment stores are the saltmarsh areas and associated sandy mudflats that front them. These figures are difficult to quantify but are strategically significant issues to address in the light of new information on sea level rise acceleration and its role in marsh erosion.

4.3 Sediment Transport Regime

4.3.1 Wave Induced Transport

Wave induced transport predominates at the mouth, though it is not deemed to be significant within the Harbour due to the protection afforded by both Mudeford and Hengistbury Spits. There is some wave energy present within the Harbour as this is believed to assist in re-suspending fine material to be later transported out of the Harbour on ebb currents.

4.3.2 Potential Bedload Transport Direction

Bedload transport is expected to be predominantly out of Christchurch Harbour. This may vary as ebb and flood flow follow different paths or flood flow coincides with storm waves to create intermittent sediment pulses into the Harbour (Tosswell 1978).

4.3.3 Potential Suspended Material Transport Direction

As mentioned above, suspended sediment load is believed to be low due to the nature of the fluvial watershed that supplies Christchurch Harbour (chalk aquifers and interruptions to flow, eg. weirs). Detailed sediment analysis carried out in the Harbour indicates that mud content is low indicating that suspended sediments tend to be output from the Harbour (Gao1990).

4.3.4 Aeolian Transport Direction

Prevailing wind directions are from the south west. The saltmarsh deposits at Stanpit Marsh do not appear to have wind blown deposits on them. Consequently, this transport method is not, therefore, seen to be significant in overall sediment budget terms.

4.3.5 Temporal Variations in Transport Direction

No evidence has been found to suggest that potential sediment transport significantly alters from the residual littoral drift rates shown for this area on the accompanying map. Undoubtedly, north easterly storms impacting upon the shoreline are likely to generate a change in wave approach and thus sediment movement at the mouth of the Harbour and on the magnitude of the sand and gravel bars found at the mouth.

4.4 Implications Of Change On Shoreline Evolution

4.4.1 Sea Level Rise

In addition to the predicted 5-6mm per annum rate of sea level rise increase (to 2050), one implication of changes to global climate may be an increase in the frequency of storm events. This may lead to increased erosion rates of Mudeford and Hengistbury Spits and increase the threat of flooding and terminal breaching close to Double Dykes. Whilst the potential magnitude of such material released into the active littoral zone is likely to be limited, the strategic implications of this for the human and natural environment could be immense. Therefore, although limited impact is likely to be seen on sediment budget regimes, there may be a major impact upon landforms and habitat extents in particular (ie: saltmarshes).

4.4.2 Anthropogenically Induced Change

Undoubtedly, land claims have led to a "squeezing" of the intertidal area over time and this is likely to be exacerbated with the onset of sea level rise. New works at Mudeford (Tyhurst 1998) have been designed to be environmentally acceptable, acting with and not against natural coastal processes, however, human intervention within fragile areas such as Christchurch Harbour need to be carefully planned and managed if they are to be successful over the long term.

4.4.3 Impact on Adjacent Conceptual Process Model Areas

Changes in tidal prism due to any future reclamation (or Harbour enlargement following sea-level rise) would affect tidal currents at the Harbour entrance and thus the configuration of the ebb tidal delta (and flood delta) which could affect conditions on the open coast. The possibility of a breach at Double Dykes could affect the regime of the open coast (and the Harbour) if a permanent tidal channel and ebb tidal delta were to become established.

5 PROCESS UNIT 5F-3: HENGISTBURY HEAD LONG GROYNE TO SANDBANKS FERRY SLIPWAY (PBY)

5.1 Overview Of The Process Unit

Within this Process Unit, longshore drift is predominantly eastward in Poole Bay, however, in the general vicinity of Durley Chine near Bournemouth, a drift reversal appears to occur towards Poole Harbour (Bray, Carter & Hooke, 1991). The magnitude and frequency of this reversal is variable in time and the continued monitoring of change is required to assess the net trend. Beach material in the Bay varies spatially, with material generally being coarser to the east.

Whilst a good understanding of longshore littoral drift has been attained from research over the past twenty years, very little has been done on the on-shore offshore transport of beach material. Any inferred seaward or landwards net movements of beach material are therefore often very dubious and should be treated with caution. Hook Sands is a good example of a submerged geomorphological feature that is of strategic importance within this and adjacent process units. However, a clear understanding of its future evolution is currently subject to debate.

Tidal currents within the Bay are generally low except at the outer end of Long Groyne and the entrance to Poole Harbour.

To the east of the Process Unit, the integrity of the beaches between Double Dykes and the Long Groyne at Hengistbury Head are partially dependent on the supply of beach material released from local cliff falls. A supply of material may be available from residual losses after periodic beach replenishment at Solent Beach and within Poole Bay (main 1988-89 replenishment). In general terms, recent additions of sediment by beach replenishment have far outweighed typical annual gains from cliff erosion. However, as the replenishment material has dispersed so the cliff inputs will begin to assume a proportionately more important role. Although a substantial shingle beach has accumulated against the Long Groyne, the cliffs have continued to erode suggesting that the beach does not provide full protection of the cliff and may be insufficient to maintain the long term integrity of Hengistbury Head.

5.2 Sediment Budget

5.2.1 Sediment Inputs

Westward Transport in Offshore Zone from Christchurch Bay

A variety of evidence is available, both supporting and opposing feed from Christchurch Bay. Comparison of Admiralty charts covering the period 1849-1977 revealed net accretion of 727,000 m^3pa, mostly in the central part of Poole Bay (Lacey 1985). Comprehensive analysis of available documents revealed no other possible sediment input which could account for this accretion. Cliff erosion input was greatly reduced by coast protection along much of the Bournemouth frontage in the early 1900s (Lacey 1985). Input from the English Channel is unlikely because detailed offshore transport studies reveal net south or south westerly sediment transport (Hydraulics Research 1986, 1988, 1991b. Fitzpatrick 1987). Furthermore, chart comparisons revealed net erosion of the seabed in Christchurch Bay by 505,000 m^3pa for the period 1849-1977 (Lacey 1985). Westward transport to Poole Bay is a logical explanation for the observed features.

Nearshore/offshore sediment stores

Along the Bournemouth to Southbourne frontage, there is a potential for onshore transport, though this is dependent on sediment availability offshore. No permanent onshore feed is likely for the Bournemouth and Sandbanks beaches because any such feed would not appear to be maintained by a corresponding feed from further offshore (Lacey 1985, Hodder 1986). Onshore transport at Bournemouth Beach is likely to be a seasonal effect associated with relatively calm swell conditions and simply constitutes a redistribution of existing beach material. (classic "cut" and "fill" profile adjustments and exchange with a temporary nearshore bar according to variations in wave energy).

Examination of the pattern of sediment accretion against stone groynes constructed at Sandbanks between 1896 and 1898 revealed net eastward drift (Robinson 1955). It was suggested that the accreting sand comprised an onshore feed from Hook Sand. Historic maps show a tendency for offshore bars to form between and Sandbanks and Bournemouth and it is envisaged that onshore migration of the features could supply sand to the beach (Robinson 1955). Numerous academic reports have suggested that this is the situation, though the majority of published reports are not backed up by site investigation findings. Clarification of sediment movements for this frontage can be attained from Bournemouth Borough Council, Borough of Poole and HR Wallingford (1995).

Coast Erosion

The coast between Poole Head and Hengistbury was previously subject to continuous erosion throughout the Late Holocene period resulting in development of steep retreating cliffs 20m-35m in height and supply of much sand and gravel to the beach. This situation was altered in the 1890s by construction of coast protection structures west of Canford Cliffs Chine. Further schemes involving protection by seawalls and groynes following in 1907-11 (Bournemouth-Boscombe), 1927-35 (Boscombe-Southbourne) and 1955-75 (Southbourne). By 1975, virtually the whole frontage from Poole Head to Solent Road was protected (Lacey 1985, Lelliot 1989). These measures progressively reduced the supply of sediment to the beach as protection and cliff stabilisation spread eastward along the frontage from Poole Head to Solent Road. Erosion rates were combined with details of cliff height and sedimentology to determine past rates of cliff sediment supply taking into account the progressive extension of stabilisation. The analysis for 1867-1933 map data yielded a total supply of 115,000 m^3pa of which 91,000 m^3pa was sufficiently coarse to remain on the beach. Similar analysis for 1933-1967, correcting for protected frontages revealed supply of 77,000 m^3pa and 66,000 m^3pa respectively (Lacey 1985). Contemporary supply is restricted to the eroding cliffs between Solent Road and Hengistbury and was estimated at 4,000 m^3pa in 1985 (Lacey 1985).

One potential key source of sediment released into the littoral drift system from cliff erosion is identified between **Hengistbury Head and Solent Beach**. This stretch of coastline is confined between coastal defence structures at Solent Beach (rock groynes and beach replenishment) and Hengistbury Head (the Long Groyne). Cliff elevation varies along the frontage (4-35 metres). The cliffs are afforded a degree of protection by the immediate foreshore zone which is characterised by a wide sand and shingle beach. Groundwater seepage appears to facilitate surface softening and gully erosion resulting in localised small scale slippages, intermittent along the frontage and therefore, marine erosion of the cliff face is considered a secondary process of erosion in comparison to mud and debris slides resulting from inadequate land drainage.

Estimates by Bray, 1993 indicate total supply of 12,000 m3pa comprising 1,000 m3pa gravel, 5,500 m3pa sand and 5,500 m3pa clay. These values are higher than those of Lacey (1985) as they are based on the full Southbourne to Hengistbury frontage and also reflect recent increases in retreat at Hengistbury.

Beach Nourishment

Significant beach nourishment has been placed on the beach along three main lengths; Sandbanks, Bournemouth and Solent Beach. Further details of these schemes has been included in the Coastal Defences Section in Volume 3. In addition, during the 1980's Bournemouth Borough Council regraded the backing cliffs along part of their frontage and the spoil from this operation was recycled back onto the active foreshore.

Coarse Sediments

In summary, coarse material is ultimately derived from cliff inputs, offshore sources and regular beach nourishment schemes. To the east of the Process Unit, it should be noted, however, that there is lateral variance in the exposures of river gravel deposits within the cliffs between Hengistbury Head and Double Dykes. This variance makes quantification of coarse material contribution difficult, however, Bray (1993) estimates inputs of 1,000 m3pa of gravel and 5,500 m3pa sand.

There is no significant fluvial inputs of coarse material to the shoreline, nor fine materials from the erosion of saltmarshes as, in this Process Unit, the only marshes present are found within Poole Harbour.

Fine Sediments

Research by Bray (1993) suggests that the sediment supply rate for Hengistbury based on erosion rates between 0.2 and 1.0mpa (apparent within this Process Unit) is of the order of 8,000 m^3pa (250 m^3pa gravel, 3,500 m^3pa sand, 250 m^3pa ironstone nodules and 4,000 m^3pa clay). Interestingly, 50% of sediment input is classified as being fine material and so it may be deduced that cliffs are the key source of fine sediment input in the sediment budget here. A further 4000 m3pa total input is estimated from the Southbourne-Double Dykes frontage comprising 750 m3pa 2000 m3pa sand and 1250 m3pa. These figures should be considered as approximate only, since it is difficult to determine a representative long term erosion rate, on which to base a calculation due to effects of periodic beach replenishment and other management interventions.

No rivers of any significance empty directly into Poole Bay although the Frome and Piddle flow into the Bay via Poole Harbour. These are the only possible sources of fine sediment input and are analysed in more detail within the CSPM for Process Unit 5F-4.

5.2.2 Sediment Losses

Two types of output are recognised. Firstly, sediment output from the beach/littoral system to various sediments sinks or stores in Poole Bay. This may comprise estuarine output by rapid tidal currents at estuary entrances or predominantly wave powered offshore transport. Secondly, permanent output from the Poole

Bay circulation system. This generally comprises transport in the offshore zone by tidal currents alone, or in combination with stirring action of waves.

Output from the beach/littoral system

Coarse Sediments

Between Solent Beach and Double Dykes, offshore transport of 25,000m^3pa was estimated from the residual between predicted and observed change (HR Wallingford 1986[22]). Sea-bed drifter experiments (Watson 1975, Tyhurst 1976, Turner 1990) also noted a major offshore tendency between Solent Beach and Hengistbury. This sediment "loss" pathway is more reliable for the sand friction.

Between Bournemouth and Southbourne, two phases of offshore transport from the 1974/75 nourished beach were recognised. Rapid initial offshore loss from the nourished intertidal zone involved the much finer material than was indigenous to the area (Lacey 1985). Volumetric analysis revealed that offshore transport was not permanent for the nearshore zone which accreted substantially during the first three years after nourishment (Hodder 1986). Losses are reanalysed and brought up to date by Harlow and Cooper, (1995) and (Cooper 1998). A loss of 0.4 million cubic metres was recorded between 1990 and 1993, thereafter losses reduced and only a further 350,000 m3of loss is anticipated by 2003 when it is estimated that the next phase of replenishment should be required.

Much slower, but persistent losses were recorded from the entire beach (0-300m offshore) after 1978. Integration of littoral drift and beach volume change revealed offshore losses averaging 95,000 m^3pa for 1979-81, but declined thereafter (Hodder 1986). Interestingly, the switch from onshore transport to offshore transport in 1978/79 was attributed to exhaustion of offshore dump-sites (Hodder 1986).

Sediment loss from Poole Bay to Christchurch Bay via Dolphin Sand is unlikely though losses directly southward are likely. Typical Tertiary derived heavy minerals are present in Christchurch Bay, eg epidote, glauconite, appatite and also in smaller quantities south of the eroded Purbeck-Needles chalk ridge despite relative absence from the *in situ* seabed geology. This indicates southward supply from Poole Bay. No evidence of corresponding northward return feed was available, so it is concluded that this pathway comprises a net output from the Poole Bay system. Much material may have been supplied from Christchurch Bay via Dolphin Sand and possibly only passes through Poole Bay en route to a sediment sink in the Channel.

Details on offshore movement at Poole Harbour Entrance and the Swash Channel are described under the Sediment Transport Regime heading.

Fine Sediments

Fine material including silts, clays and sands are more susceptible to longshore and cross shore transport. Of particular relevance to this Process Unit, it is perceived by HR Wallingford (1986) and Bray et. al. 1991 that the Long Groyne to the east, whilst an effective barrier to coarse material, provides only a partial barrier to sandy material which can pass over it in suspension during storms and also outflank it. Although reliable transport pathways have not been established, research strongly suggest that fine material released from Poole Bay via the outer reaches of Long Groyne is likely to contribute to the Christchurch Bay sediment budget (Bray *et al*, 1991).

5.2.3 Sediment Stores

Chart comparisons indicate that the even after capital dredging schemes, the Swash Channel, Hook Sand and Poole Bar are in a relative state of equilibrium. The model studies indicated significant sediment transport in this area so strong throughput is indicated with sediments travelling onward to sediment sinks further afield indicating that, long term, littoral sediments are transported out of the Bay. Hook Sand and Studland Bay/ South Haven Peninsula are believed to be strategic sediment stores and sinks which may receive sediments from the western portion of the Bay and possibly Poole Harbour.

5.3 Sediment Transport Regime

The following text has been divided up into geographic lengths to more easily describe the complex littoral drift patterns that appear to occur in this Process Unit. The text is presented under the Wave Induced Transport section as this is perceived as being the dominant littoral driving mechanism within this Process Unit (See Figure 5.1)

5.3.1 Wave Induced Transport

Durley Chine to Branksome Chine

Calculations by Hodder (1986) showed that westward drift of 51,000m^3pa was estimated. These calculations are probably only accurate on groyned beaches and likely to be site specific to Poole Bay. For these reasons the volumetric information is of medium reliability and confidence limits of $\pm$ 12,000 m^3pa were quoted by Henderson (1979).

Branksome Chine to Sandbanks

The Borough of Poole Shoreline Strategy Study (HR Wallingford 1995) provides the definitive work relating to this problematic area. Net drift is south-westward and found to increase from 20,000 m^3pa at Branksome Chine to 34,000 m^3pa at Flag Head Chine and 70,000 m^3pa just west of Poole Head. Net drift at Sandbanks car park was reversed and amounted to 5,000 m^3pa to the north-east. A zone of convergence was therefore recognised between the car park and Poole Head which comprised 7,500 m^3pa beach accretion or offshore transport. Accelerating south-west drift from Branksome Chine (20,000 m^3pa) to Poole Head (70,000 m^3pa) must be fed either by beach erosion or onshore feed of approximately 50,000 m^3pa. It should be noted that drift directions are variable along this frontage and in recent years there has been a higher frequency of eastward drift intervals contrary to the estimated long term net direction. This suggests that in addition to wave induced movement, tidal induced currents play a more important role in transporting sediment along certain sections of this length.

Sandbanks Car Park

Littoral drift modelling has indicated north-east drift of 5,000 m^3pa (Hydraulics Research 1991b). Calculations of drift rates are particularly difficult at Sandbanks. The presence of a large bank in shallow water (Hook Sand), and the diffraction of waves entering from the English Channel around a major headland such as the Isle of Purbeck make the character of waves, and their prediction, very complex.

Sandbanks to the Haven Hotel

Littoral drift modelling revealed drift reversal west of Sandbanks car park with net westward drift continuing at 20,000 m^3pa towards the Haven Hotel (Hydraulics Research 1991b). A drift divergence was therefore recognised west of Sandbanks car park and was characterised by beach erosion/onshore transport of 25,000 m^3pa. Drift from this pathway fails to accumulate at the Haven Hotel therefore the majority must be entrained by tidal currents in Poole Harbour Entrance. Modelling showed that littoral drift was greatest below MSL where tidal currents are higher (Hydraulics Research 1991b). It is also unlikely that any significant amounts of sand are moved onshore from Hook Sands.

Hook Sand

A large proportion of the crest of Hook Sand lies above –1m OD causing waves to break resulting in littoral drift of predominantly sandy sediments. It is suggested that the Q2 pathway feeds sediment offshore in the shallows of Poole Head and then southwards along the east side of the bank (Hydraulic Research 1986). Refraction and shoaling models based on a 10 year hindcast offshore wave climate indicated potential for net southward drift of 25,000 m^3pa. Sand from this pathway may periodically settle within parts of the Swash Channel or be transported further south towards Handfast Point. It is uncertain whether any significant material is moved onshore by wave action.

Bournemouth to Southbourne

Loss of 65,000m^3pa was calculated by Newman (1978), 91,000 m^3pa by Lacey (1985) and 40,000 m^3pa over 9 years by Hodder (1986). The estimates of Hodder (1986) are regarded as the most reliable, although they are only applicable to a recently nourished groyned beach. All authors agreed that drift was eastward and increased from Bournemouth Pier to Southbourne which was attributed to increasing wave energy in the direction (Henderson 1979). This observation can be roughly confirmed by recent wave modelling results carried out. A couple of anomalies do exist though the general trend is increased wave energies from Sandbanks to Hengistbury Head.

Southbourne to Hengistbury Head

An eastward drift of 45,000 m^3pa has been calculated, based on a sediment transport calibration for which no source was given and was also based on the assumption that the Long Groyne was not present (Hydraulics Research 1986). The littoral drift estimate of 45,000 m^3pa may be more representative of conditions at Double Dykes where the Long Groyne has no effect. The model showed that drift on the upper beach (shingle) was small compared to that further offshore (sand). The groynes therefore intercepted only a small proportion of overall drift, mostly the shingle fraction. By analogy this situation may also exist at the Long Groyne. Seabed drifter studies, beach profiling and aluminium tracer experiments all indicate offshore, rather than onshore transport on Solent Beach one kilometre to the west (Watson 1975, Tyhurst 1976, Wright 1976, Webber 1980, Halcrow 1980, Wright 1982, Hydraulics Research 1986).

Hengistbury Long Groyne

Accretion at groynes recently constructed on Mudeford Spit indicated substantial northward transport (Tyhurst 1987). In the absence of any obvious source, it was generally held (but unproven) that drift originated from bypassing of the Long

Groyne. Although subject to scaling effects, physical modelling results corroborate findings of earlier drifter research which indicated strong trend for eastward transport around the groyne (Watson 1975, Tyhurst 1976, Turner 1990). Most transport occurs in the nearshore zone on Solent Beach and is not intercepted by groynes (Hydraulics Research 1990). If an analogous situation exists at the Long Groyne, much of the predicted drift from may outflank the Long Groyne. Evidence of this was provided by rapid accretion against rock groynes recently constructed immediately north of the Long Groyne. Sand accreted initially and progressively filled embayments from south to north, shingle accretion was much slower and probably dependent on overtopping of the Long Groyne. These observations corroborate the physical modelling and clearly indicate bypassing of the Long Groyne.

5.3.2 Potential Bedload Transport Direction

Analysis of bedform asymmetry indicated transport from Dolphin Sand to the south-west with transport veering more directly southward further offshore (Fitzpatrick, 1987). Currents were locally intensified by irregular bathymetry in the vicinity of the eroded Needles-Purbeck chalk ridge and significant gravel transport is indicated in this area.

5.3.3 Potential Suspended Material Transport Direction

Movement of fine suspended material at Hengistbury Head was tested by physical modelling of the groyne and adjacent area (Hydraulics Research 1986). Tests revealed that sediment could overtop the groyne during storms and fine sand could outflank the groyne in suspension.

At Poole Harbour entrance, where tidal currents are important in terms of influencing littoral drift, ebb tidal currents are shorter-lived, but more rapid (up to $2.5ms^{-1}$) than corresponding flood currents (BP 1991), thus potential exists for net seaward transport along the Swash Channel. Tidal modelling was used to determine sand transport using empirical calculations (Hydraulics Research 1986). The study showed increasing transport potential southward down the Swash Channel and thereafter towards Handfast Point. The analysis showed that the localised ebb tidal jet from Poole Harbour entrance was deflected southward by interaction with dominant SW circulation within Poole Bay although this would depend upon prevailing wave conditions. The zone of maximum interaction was at Poole Bar, where transport of 20,000 m^3pa across the bar was predicted. Transport from the harbour entrance was supported by limited sediment sampling (15 grab samples) which showed fining down the pathway from coarse gravel (harbour entrance) to fine sand (Poole Bar) (Hydraulics Research 1986).

5.3.4 Aeolian Transport Direction

Prevailing wind directions are from the south west, however, due to the limited stored intertidal sands, this transport method is not significant in overall sediment budget terms. Minor dunes have developed beneath Hengistbury Head and on the Sandbanks peninsular indicating the potential for dune formation should an increased supply of sand be available.

5.3.5 Temporal Variations in Transport Direction

There are uncertainties relating the directional stability of drift in the western portion of the Bay. Reversals are frequent making the net trend difficult to discern, indeed in 1994 eastward drift predominated throughout the Bay (Harlow 1995).

Additional complexities are introduced by the interaction of nearshore tidal currents with incident waves along the Sandbanks Peninsular and have resulted in some unpredictable coastal responses and a new coastal defence scheme at Sandbanks (Hall et al, 1995).

5.4 Implications Of Change On Shoreline Evolution

5.4.1 Sea Level Rise

The most critical issue in this Process Unit is related to the impacts of sea level rise on strategically important sites such as Sandbanks peninsula. Increased erosion here may lead to undercutting of the sea defences. If the narrow neck was breached, the viability of Poole Harbour would be threatened as areas within the Harbour became exposed to greater wave energy and altered tidal currents.

Along the open coast away from Sandbanks, it would appear that natural evolution of Poole Bay is constrained by sea walls and other protective structures. The future evolution of the shoreline is thus unlikely to be able to adapt naturally to events such as sea level rise and therefore be unable to provide significant amounts of material to the sediment budget due to the percentage of coast defended (e.g. for landward and upward profile adaptation as envisaged by the Bruun model (Bruun, 1988). Consequently, future acceleration of sea level rise may, result in beach lowering and narrowing in front of defences unless further replenishment schemes can continue to provide inputs of fresh sediments.

5.4.2 Anthropogenically Induced Change

Coast protection along this process unit frontage has had a progressive effect in reducing sediment supply from coast erosion and this is widely cited as a major cause of the marked reduction in beach levels recorded over the past 80 years (Lelliott 1989). Continued beach replenishment schemes are seen as integral to the future management of this Process Unit.

5.4.3 Impact on Adjacent Conceptual Process Model Areas

There is believed to be a littoral link between Poole and Christchurch Bays with some material being transported round Long Groyne. Although estimates have been put forward quantifying the amount, HR Wallingford (1986) suggest that only limited quantities of material are likely to overtop the Long Groyne during periods of intense wave activity coincident with high tides. Furthermore, the extent of outflanking is also highly uncertain making it difficult to determine its effect on the sediment budget of Christchurch Harbour and Christchurch Bay as a whole. The variations in the configuration of Mudeford spit and delta before (accreting) and after (eroding) the construction of the Long Groyne suggest strongly that in their natural state the two process units west and east of Hengistbury would be quite closely linked

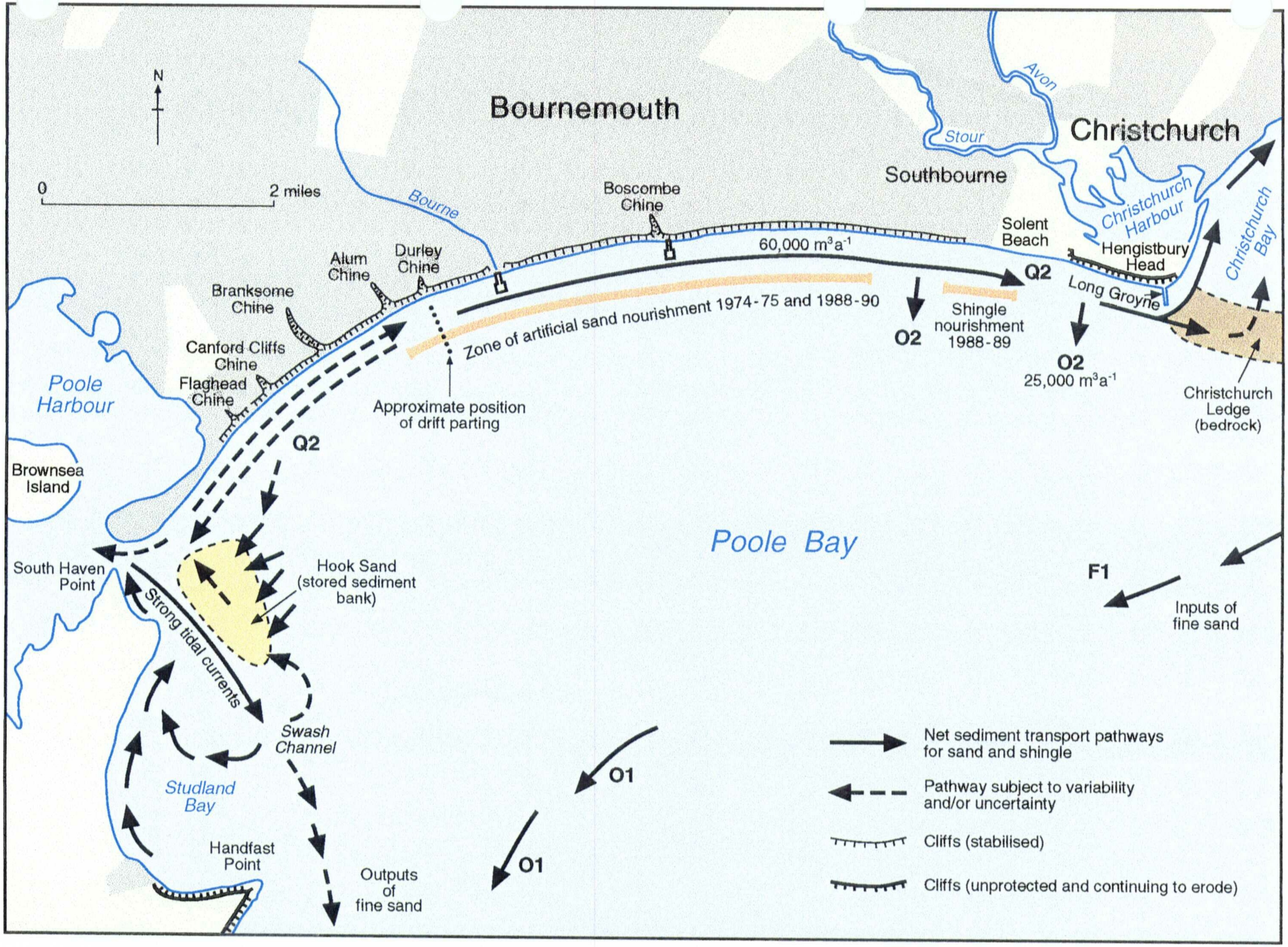


Figure 5.1 **Morphology and Conceptual Sediment Dynamics in Poole Bay**

6 PROCESS UNIT 5F-4: POOLE HARBOUR (PHB)

6.1 Overview of the Process Unit

Poole Harbour is a shallow estuary, with an irregular, indented coastline of just over 100kms. It is a product of postglacial sea-level rise, but its shape and plan form reflect both the original topography of the inundated basins of the Frome and Piddle rivers together with subsequent modifications by marginal erosion and accretion. Physical and biotic characteristics show distinct west to east environmental gradients reflecting the increasing marine influence and energy levels in that direction. Artificial reclamation and shoreline protection have modified much of the north-eastern sector of the harbour, but elsewhere, natural processes and habitats have been preserved.

Tidal amplitudes are modest, but long periods of rising and standing water result from a double high tide effect, which create a lagoon-like character. Extensive mudflats reflect a long-term imbalance in the sedimentary system in favour of deposition, although at the present time there may be a condition approaching dynamic balance between input and output. Input of sediment derives from suspended load discharging by rivers draining into the harbour and from cliff/marsh bluff erosion. Introduction of sandy sediments from marine sources, via the harbour mouth, is possible but has not yet been satisfactorily demonstrated.

Transport pathways are complex, and are not understood in detail although littoral drift is generally from west to east along the more exposed shorelines. Both wave and tidal processes initiate and sustain sediment transport, with tidal scour being the dominant influence. There is believed to be loss of material from the harbour on ebb tides though the net sediment transport at the entrance remains very uncertain. A detailed study of littoral drift within part of Poole Harbour is that of May (1976), who has carefully examined the association of cliffs, beaches and spits in the vicinity of Shipstal Point. He observes that the southern spit is migrating southwards, whilst the net direction of longshore transfer of sediment along the northern spit is south to north. The southern spit is in an equilibrium condition, adjusted to prevailing local wave climate, whilst the northern spit is currently adjusting to alterations in the longshore transport sediment budget.

Taking into account evidence of input, circulation and output near the Harbour mouth, it may be tentatively stated that the inner and outer sectors of Poole Harbour have a negative sediment balance whilst the central area is in positive balance. There is not sufficient transport evidence to support the contention in the Master Plan Study (1985) that sediment in the Harbour as a whole serves to balance input from fluvial sources with output at the mouth.

6.2 Sediment Budget

6.2.1 Sediment Inputs

Coarse Sediments

There are two key sources of coarse sediment input within Poole Harbour.

<u>Marine Inputs</u>

During the coincidence of typical or storm waves and spring tides, clear potential exists for significant sediment input into the Harbour. During calm conditions sediment is removed seaward by dominant ebb currents. The balance between these processes is uncertain because long-term aspects of sediment flux have yet to be studied. Presence of sand and gravel banks immediately inside the Harbour suggest a small net input and visual inspections by officers of the Borough of Poole suggests these features are increasing in magnitude. The possibility of sediment input by flood tidal streams may produce a "dynamic balance" (Poole Harbour Master Plan Study, Part II, 1985).

Coast Erosion

There is believed to be little exchange between beaches and channel deposits, and the contribution of beach material to the general sediment budget of the harbour is small, but not necessarily insignificant. Erosion may be caused by tidal currents, or a combination of wave disturbance and tidal flows. Nevertheless, available evidence suggests that erosion of cliffs or marsh scarps is a significant source of material into Poole Harbour, particularly at Rockley Cliff, Brownsea Island, Furzey Island, Brands Bay and on the Arne Peninsula.

Fine Sediments

Fluvial input

River-transported sediment is delivered to the Harbour by four rivers and a number of small streams that drain catchments that are underlain by erodable sands and clays. Over the long-term, however, much fluvial sediment that might have been discharged into Poole Harbour has been trapped as alluvium within flood plains.

The quantitative understanding of the contribution of fluvial material to the sediment budget of the harbour is very poor, although Hydraulics Research (1990) report on clay materials obtained from the north-east sector which could be of fluvial origin. Intuitively, it may be argued that much of the suspended load is added to mudflat and channel margins in the vicinity of the Upper Wareham.

May (1969) pointed out that there have been significant land use changes in the catchments of the rivers discharging into Poole Harbour since at least the early 1930s and, on balance, they may have resulted in a slight decrease in the volume of sediment load. Further changes in the subsequent 20 years may have reversed this effect.

Biotic Input

On the basis of data available at present it is difficult to draw any conclusions on the significance of the biotic component. Instead, the most important biotic factor operating within Poole Harbour is salt marsh creation, which has trapped – and in more recent years has begun to release – large quantities of clay and silt into Poole Harbour (ie: possible sediment output).

6.2.2 Sediment Losses

For this Process Unit, no distinction between the loss of coarse or fine littoral material has been made. There are, however, four key causes of sediment loss from the Harbour.

Tidal Outputs

As the ebb tidal stream has a higher velocity than the flood at the harbour mouth and in most (but not all) of the main channels, on theoretical grounds, an output of bedload sediment into Poole Bay might be expected. The longer duration flood tide may result in net input of suspended sediments, but this has yet to be confirmed. These arguments have been advanced by several authors (Green 1938, Poole Harbour Master Plan Study, Part II, 1985, Howard and Moore 1988), though others, eg. Gray (1985) have contended that tidally transported sediment loss is prevented or inhibited by the construction of the harbour mouth.

Saltmarsh Erosion

The available evidence for lateral and vertical accretion rates and spatial change in the extent of *Spartina* could be used to estimate approximate volumes of silt and clay initially trapped and subsequently released from mudflats. The greatest quantities of sediment taken out of temporary store must be derived from areas either of extensive natural "dieback" or subject to active wave and tidal abrasion. It might be expected that a significant increase in suspended sediment in Poole Harbour has occurred as a result, possibly indicating an increase in sediment output from the Harbour. Furthermore, the loss of saltmarsh has in many places increased the exposure of the shoreline and cliffs to wave action.

Reclamation

The major source of natural reclamation has been the expansion of mudflats as a result of the spread of *Spartina* in the present century, though the longer-term contribution of salt marsh species such as Zostera should not be underestimated.

The loss of sediment contribution, as a result of artificial reclamation, has not been quantified for all parts of the harbour margins. Reductions in area have occurred due to agriculture, urban development, port extension, marina construction (between Parkstone and Lychett Bays). This may have reduced sediment output from the Harbour due to a change in tidal prism and thus currents generated at the Harbour entrance, although some of this loss is countered by saltmarsh erosion that is occurring as die back of *Spartina* marsh continues.

Dredging

Dredging of the main navigation channels has been maintained for over a century, and in terms of the sediment budget for the Harbour, contributes to the net loss of material. Access to the Port of Poole by shipping requires regular maintenance of navigational channels, particularly in the Main (or 'North') and Middle (or 'Middle Ship') Channels. Dredging figures available (which includes dredging within the Swash Channel that was partly used for beach replenishment along the Bournemouth frontage) substantially reflects the programme of capital dredging over the time periods reviewed. For example, between 1969 to 1975 (inclusive) the figure was 138,618m^3; 1975 to 1984, 349,800m^3; 1985-1990, 2,017,000m^3 and 1990 to 1997 1,531,336m^3. In places, the removal of non-cohesive material also includes the extraction of previously stable sediment and underlying substrate. Some sand is removed from the Swash Channel has been used as beach recycling material within Poole Bay. Other material is removed to an approved, licensed dredge spoil dumping site outside of the confines of Poole Harbour, which contributes a sediment input (potential store) into Poole Bay. An important issue is related to the release of material (previously bound) as Spartina die back accelerates. As this material is likely to be deposited within navigable channels, their subsequent removal by maintenance dredging would constitute an output from the system.

6.2.3 Sediment Stores

Fine Sediments

The colonisation of mudflats by saltmarsh vegetation has been decisive in accelerating rates of deposition. Extensive accumulation of clay and silt ("mud") exist around the southern, western and north-western margins of Poole Harbour. In the north-eastern sector mudflats form eroded foreshores of limited horizontal development. Large volumes of fine-grained sediments have been immobilised by the consolidation and stabilisation of mudflats by salt marsh vegetation. The dominant plant has been *Spartina,* which vigorously invaded nearly all parts of the harbour in the early decades of this century and greatly accelerated accretion rates. Since the mid-1920s in some areas, and later in others, it has degenerated and been subject to widespread "die-back". In the absence of colonisation of mudflats by other species, the absolute decline in the area of *Spartina* sward has released large quantities of silt and clay. Some of this has been incorporated into areas of contemporaneous growth and some has been deposited on banks and shoals (albeit temporary).

Extensive mudflats act as sediment stores. The lower Frome, for example, is characterised by a wide alluvial flood plain that represents a sediment store. These are also characterised along other sections of Poole Harbour, particularly along the south coast and either side of the Upper Wareham Channel where wave and tidal energy are significantly reduced. The sources of the clay and fine silt particles that have provided the raw material for mudflat construction include river suspended load, marginal erosion and (more debatable) reworking of deposits on the harbour bed.

Hubbard and Stebbing (1968) calculated that *Spartina* growth has stimulated approximately 1,000,000 tonnes of mud and silt accretion in the upper part of the Poole Harbour since 1900. On this basis, it could be argued that volumes in the middle and lower parts of the harbour would be between 2 to 3 of this total. Siltation resulting from the breakdown of these upper harbour mud stores may account for some shallowing of the main channels which was experienced during the 1940s and 1950s.

Unless or until data is available to indicate significant output of fine-grained sediment via the harbour mouth, the only conclusion that can be drawn is that mudflats represent an accumulating store trapped in a slowly-subsiding basin.

Coarse Sediments

<u>Beaches</u>

There are several sites around the Harbour margins where distinctive sandy, shingle or mixed sand and shingle beaches have developed. Whilst some beaches are clearly associated with recent or contemporary erosion of cliffs, and are affected by littoral drift, others appear to be non-active. The major cause of abandonment has been the growth of *Spartina* saltmarsh and mudflats in former foreshore zones. In some cases, beaches have developed spit or cuspate elongation's, eg. the eastern shoreline of Brownsea Island; at the eastern side of the channel draining Lychett Bay and around the Arne Peninsula.

Within the central and eastern parts of the Harbour there are well-defined banks, or shoals, that appear to be composed predominantly of fine to medium sand (although thin and patchy superficial mud deposits may be present). All of the banks are separated by channels, some of which have been dredged over a long period of time for navigation purposes.

6.3 Sediment Transport Regime

General

There are a number of papers and reports that either directly or indirectly discuss transport of sandy and muddy sediments at or close to the bed of Poole Harbour without specifically identifying the mechanism(s) of transportation. There is also some difficulty in distinguishing between suspended and bed-load transport in general. Regardless of this, a general eastward sediment transport direction is postulated for shoreline sediments within Poole Harbour. This is confirmed by Bird and Ranwell (1964), who describe shingle spit structures along the north-east of the Arne Peninsula and near the jetty on Furzey Island that appear to have extended eastwards. Gray (1985) also notes the presence of a sandy spit projecting eastwards along the north-west shoreline of Brownsea Island. Patterns of spit projection along the eastern coastline of Brownsea, whilst somewhat modified by development, appear to indicate a drift junction.

6.3.1 Wave Induced Transport

Although the surface area of Poole Harbour at high water, is large, its irregular and indented shape, together with the presence of one large and several small islands, restricts fetch distances available for wave generation. Waves of modest height break along most sectors of the shoreline and are affected by localised refraction. This is reflected in the process of littoral drift of beach sediments. Sediments ranging in size from clay through to very close clastic grades may be entrained by breaking waves along exposed parts of the Harbour margins.

6.3.2 Potential Bedload Transport Direction

Green (1940) noted that the ebb current is stronger than the flood in the lower, south-eastern parts of the Harbour, with the reverse case in Upper Wareham Channel. It has more recently been noted that whilst the spring ebb is stronger in the Main and Wych channels, the flood stream has greater velocity, though shorter duration, compared to the ebb in the Middle Channel. This raises the possibility that net bedload transport is in different directions in different channels.

Hydraulics Research (1990) conducted field, numerical modelling and other approaches to investigate potential sediment transport in and close to the Middle Channel. It was found that maximum accretion will occur where net transport vectors converge, and an attempt was made to map the pattern of sediment pathways. The conclusion that the Middle Channel has a positive sediment balance concurs with earlier studies, demonstrating quantitatively that "siltation" rates up to 18,000m^3/year may accumulate in the mid-section of the channel, with scour on the main bend reducing this to under half of this amount. These values appear to refer to sandy-silty sediment though it is uncertain what influence maintenance dredging has had on these results.

6.3.3 Potential Suspended Material Transport Direction

Examination of the tidal curve for Poole Harbour Entrance revealed flood tides of longer duration, but lower velocity compared to the ebb (BP 1991). The implication of this is that by analogy to other harbours with similar flow regimes (Chichester, Langstone, Portsmouth) a net input of fine grained suspended sediments is indicated (Harlow 1980, Wallace 1988). Some authors, however, consider that suspended sediment, derived from erosion of mudflats, shoals and marginal cliffs, are discharged via the harbour mouth at low tide.

Howard and Moore (1988) observe that because of greater exposure to waves in certain sections of the Harbour, fines may be selectively removed by suspension transport. Disturbance of fine-grained sediments in a shallow area (less than 1.4m) east of Little Channel by waves may be sufficient to prevent deposition of material there.

The marked stand or double high water feature would allow deposition of suspended sediments on mudflats and up creeks within Harbour saltmarshes. It is possible, indeed probable, that much remobilised clay and silt-sized sediment has either been deposited on banks and shoals or re-incorporated into advancing/accreting mudflats elsewhere. The evidence for deposition on the harbour floor is ambiguous, though the sediment samples recovered by Green (1940) gives some support to this mechanism. One is left with the concept of an essentially closed system of clay/silt transport, subject to re-working and recycled between sites (Ranwell 1964).

6.3.4 Aeolian Transport Direction

Dunes are present in a few locations in the Harbour, in particular to the north of Hydes Quay and southwest of Arne Peninsula. A series of dune ridges run south to Studland bay which are vegetated with major dune building grasses, *Ammophilia arenaria* and *Elymus arenarius*. The large eastern dune section of the Studland Dune system has formed by sand accretion caused by aeolian processes which have lead to the enclosure of a freshwater lagoon. Prevailing wind directions are westerly here, though sustained easterly winds may transport sediments inland. Further inland within the South Haven Peninsular, the sands are well stabilised by vegetation so it is likely that aeolian transport is confined within a relatively narrow zone extending inland of the shoreline.

6.3.5 Temporal Variations in Transport Direction

The enclosed nature of the Harbour consequently reduces the possibility of changes in littoral transport direction that are caused by waves. Minor changes to airflows during the summer (easterly) may have an impact on wave climate though this is uncertain. However, a higher frequency of easterly winds may well have the affect of enhancing locally generated wave approach from the east and so effect the low energy western shores. Any increase in erosion rates of the north and east shoreline may release more sediment into the harbour sediment system.

6.4 Implications of Change on Shoreline Evolution

6.4.1 Sea Level Rise

With a potential sea level rise of 1.7 – 2.2mm / yr based on the present trends observed from Newlyn tide gauge, the impacts on the landform assemblage would be varied. However, an acceleration in this rate of change is likely and a total relative sea level rise of 34cm (including land movements) is estimated to occur by 2050 (Hulme and Jenkins, 1998). Key strategic issues related to sea level rise include impacts on both the developed and natural environments of Poole Harbour. The protected coast (north coast) cannot now naturally adjust to sea level rise as it is constrained by development and coastal defences. This is likely to be subject to "squeeze" resulting in the lowering and erosion of the foreshore.

Further loss of sandy beaches, seawall overtopping and structural damage may subsequently be likely.

Wetlands and salt marshes will be vulnerable to increasing sea levels, particularly if marshes are unable to accrete vertically to keep pace. Generally, marshes to the north and east of the Harbour are backed by sea walls and embankments (except Holes Bay) and thus less able to retreat inland. Depending upon the ability of natural sand and shingle features to adapt to rising sea levels, the erosion of intertidal mud and sand banks at the outer edge of the Harbour may reduce the area of habitat for intertidal species and thus impact upon habitat extent and ultimately biodiversity levels. Alternatively, policies such as managed retreat which lead to regeneration of saltmarsh should encourage natural sedimentation within the marshes such that sediments are less likely to migrate to navigable channels.

Finally, inundation and saline intrusion of increased sea levels is likely to significantly modify plant communities around the Harbour margins, unless they are able to migrate inland.

6.4.2 Anthropogenically Induced Change

Currently, dredge spoil is dumped well offshore from Poole Harbour, supplying material to the beaches of Bournemouth and Poole Bay in general. The actual amount of material finding its way onto the foreshore of Poole Bay from this source has not been quantified and has not specifically been used for beach replenishment as it is too muddy. Future efforts need to be made to assess the benefit / impact of using this fine grained material within the upper reaches of tidal inlets within the Harbour as part of long term habitat regeneration scheme which caters for sea level rise. With the onset of sea level rise and the likely biodiversity and engineering impacts of marsh depletion, it may be beneficial to consider recharging mudflats. This may involve placement of some spoil back within the upper reaches of the Harbour and so encourage sand, mudflat and saltmarsh development over time.

In terms of maintenance dredging, the continued viability of the commercial port requires a minimum of maintenance as essential. To date, maintenance dredging has not caused any noted environmental impacts on the Harbour as a whole. Should sediment supply decrease in the future, proposed capital dredging in the Harbour should be carefully considered in terms of the environmental and coastal dynamic influences this may cause.

One of the main potential impacts affecting Poole Harbour is that of the current nature and presence of "static" defences which may result in coastal squeeze of the foreshore, preventing the natural readjustment of, and subsequent reduction in, intertidal habitats. This issue is inextricably linked to sea level rise and is consequently discussed in section 6.4.1 above.

Changes to the tidal prism within the Harbour, be it by anthropogenic intervention or by natural die back may result in a minor reduction in tidal currents. In theory this could reduce the supply of sediments to ebb and flood tidal deltas. There are implications of managed retreat within Poole Harbour associated with increased sediments released into the Harbour thus impacting upon navigation channels and thus increased financial commitment towards dredging. Actual amounts have not been quantified as yet, though it is likely that changes to the sediment budget will occur over the long term, bringing with it potential long term financial implications for those authorities with responsibilities in Poole Harbour.

6.4.3 Impact on Adjacent Conceptual Process Model Areas

It is unlikely that activities within Poole Harbour are likely to affect adjacent process units. It is more likely that activities within the adjoining Swash Channel or along the shoreline immediately outside of the Harbour entrance will have a higher probability of changing the sediment budget regime, altering tidal currents, sediment transport directions and sandbank morphology outside of the Harbour entrance.

7 PROCESS UNIT 5F-5: SOUTH HAVEN POINT TO HANDFAST POINT (STU)

7.1 Overview of the Process Unit

The wave regime within Poole Bay varies spatially due to a sheltering effect of Handfast Point and waves generated from a south-westerly direction are diffracted around this headland. The degree of protection afforded increases westwards towards Handfast Point consequently wave activity within Studland Bay is low and governed primarily by waves generated from the south and south-east. Northern parts are subject to currents generated by the tidal exchange at Poole Harbour entrance. This area has been characterised by the accumulation of sandy sediments within the nearshore zone and at the shoreline forming the South Haven Peninsular dune complex which has grown since 1700. By contrast, southern parts have suffered erosion producing cliffs in Tertiary sands and clays as well as the Chalk at Handfast Point. The Training Bank and the Swash Channel are two man induced features that have had an influence on littoral transport in this process unit.

7.2 Sediment Budget

7.2.1 Sediment Inputs

Coarse Sediments

In recent times, the north-eastern and central areas fronting Studland Bay have accreted most rapidly with maximum rates of 1.4mpa for 1880-1930 (Diver 1933) and 3.0-4.0mpa for 1933-70 (Carr 1971a). Recent accretion has built a new dune ridge over the period 1933-70 (Carr 1971a) and visual inspections suggest that growth of the northern and central parts is an ongoing process with new embryo dunes continuing to be formed. The source of sand is generally regarded as onshore feed from the shallow sandy Studland Bay (Carr 1971a).

Examination of hydrographic charts covering the period 1785-1849 revealed narrowing of the foreshore and deepening of Studland Bay in association with a major phase of dune building. This is regarded as evidence of onshore sediment feed (Robinson 1955). A question remains as to the source of sandy sediments which become deposited in Studland Bar - a possible explanation is that they comprise materials transported into the Swash Channel from Hook Sand and then flushed seaward to accumulate and be driven shoreward by waves in Studland Bay.

Fine Sediments

Erosion of the Chalk headland at Handfast Point is characterised by rock falls, the size and frequency of which are governed by joint and bedding plane discontinuities. Blocks that remain at the base of the cliff dissipate wave energy and temporarily suppress toe erosion though most Chalk material degrades rapidly and is removed in suspension leaving only a few flints. Some sands and clays (unquantified) are also supplied by erosion of Tertiary strata in the vicinity of Studland Village.

7.2.2 Sediment Losses

Coarse Sediments

For the area between Poole Bar and Handfast Point, tide and wave modelling validated by OSCR data indicated strong potential for sediment transport from Poole Bar south to Handfast where strong tidal currents rapidly flush sandy and fine gravels into Swanage Bay (Hydraulics Research 1986, 1988, 1991b). Modelling studies indicate a strong trend for bed erosion which is offset by coarse resistant gravel armoured beds and bedrock floors so it is likely that sediment transported along this pathway is output from the Poole Bay system. A combination of information derived from, tide/wave modelling, sea-bed sampling, and bedforms all indicated a southward trending pathway of high reliability although quantitative information was not available.

No reclamation or dredging are believed to take place within this Model Area and so artificial coarse sediment output is believed to be negligible. Navigation dredging of the Swash Channel may be significant as it could intercept sediments destined for Studland Bay, or for eventual transport further south towards Handfast Point and Swanage Bay.

Fine Sediments

A zone of flint gravel and exposed bedrock extends several km east of Handfast Point and indicates the strong winnowing effect of rapid tidal currents (>1ms^{-1}). Consequently, fine grained material is likely to be lost from this CPM area and transported by tidal currents further offshore.

7.2.3 Sediment Stores

Modelling work has suggested that strong wave action, during the spring tide cycle, tends to push sediment westward off Poole Bar to accrete in Studland Bay. This feed and subsequent accumulation probably supply considerable quantities of material that are transported onshore. Thus, Studland Bay and the South Haven Peninsula are sinks for much of the sediment which converges upon Poole Bar from the Swash Channel and Hook Sand.

Tidal and wave model studies of the Swash Channel indicate a large potential zone of accretion within Studland Bay and suggest that this area may be a major sediment sink for the western part of Poole Bay (Hydraulics Research 1986, 1988).

7.3 Sediment Transport Regime

Due to shelter afforded by Handfast Point and the Isle of Purbeck, littoral drift is not rapid in Studland Bay and dominant sediment transport is possibly normal to the beach (Robinson 1955). In spite of this, net northward drift is recognised along the bay from a trend for accretion on the southern side of the training bank (Robinson 1955, Lacey 1985). This pattern is supported by the results of sediment sampling along the bay which revealed northward increase of sand size (Lacey 1985). On Bournemouth, Southbourne and Hengistbury beaches sediment size is shown to increase downdrift so the grading on Studland Bay suggests northward drift (Lacey 1985). Sand flux studies based on tidal flow revealed marked potential for net south-east offshore transport (Hydraulics Research 1986, 1988, 1991) and a prediction point at Shell Bay is almost certainly influenced by strong tidal currents.

7.3.1 Wave Induced Transport

Wave studies in the area, and general observations, show that Studland Bay is virtually unaffected by westerly or south westerly waves propagating up the English Channel. Some residual wave activity, differacting around Durlston Head and Handfast Point and then propagating inshore, gives a small northward component of wave energy flux which is generally balanced by the shorter period wave action approaching from the east and north-east. This balance may be disturbed when seasonal wave conditions vary from the mean, which has occurred in Studland Bay over the past few years.

7.3.2 Potential Bedload Transport Direction

Bedload littoral drift within Studland Bay is in a net northerly direction, although rates are probably low due to the relatively low energy levels and the balance between northward and southward drift.

7.3.3 Potential Suspended Material Transport Direction

The Process Unit, is subjected to low energy tidal flows, where figures of 0.3m/s have been published (CIRIA 1998) and hence are barely capable of initiating sand movement without the aid of wave action.

7.3.4 Aeolian Transport Direction

The Studland environmental complex consists of sands deposited under wave generated currents on the foreshore, though also by aeolian transport in the backshore and the dunes. Sediment transport and deposition here is clearly controlled by wind direction with the dominant winds with respect to sand carrying capacity being virtually perpendicular to the shoreline (ie: easterly). Texturally, the wind laid sediments differ little from those deposited by waves, indicating that the source of sand for dune building is the beach foreshore exposed between tides. It should be stressed that aeolian transport mechanisms are perhaps more important in this Model Area than in any other and therefore this should not be overlooked in terms of the overall sediment budget.

The amount of such material that is lost from the immediate area is not quantifiable though is unlikely to be significant in overall sediment budget terms as much of the accreting land surface rapidly becomes stabilised by vegetation. More likely is the constant redistribution of fine sand within the Studland Dune complex as a whole.

7.3.5 Temporal Variations in Transport Direction

When seasonal wave conditions vary from the norm, which has occurred in Studland Bay over the past few years, they may result in an increase in wave attack on the southern beaches of Studland Bay. Persistent drift reversals are likely to result in local zones of erosion as sediments are transported away from regular accretion zones.

7.4 Implications of Change on Shoreline Evolution

7.4.1 Sea Level Rise

The estimated future global warming induced acceleration in sea-level rise is likely to result in beach erosion due to upward and landward adjustments of the profile to maintain equilibrium with sea-level rise. It involves loss of upper beach sediments to build the nearshore profile at a rate corresponding to the rate of sea-level rise. This process has been studied by Bray *et al.* (1992) using an application of the Bruun model (Bruun, 1988). Results suggested that the northern part of Studland Bay could in future accrete slightly less rapidly, whilst erosion in southern parts could accelerate significantly (possible doubling of present rates). Shell Bay was estimated to continue to erode, but at a slightly more rapid rate. Another potential climate change impact relates to estimates of increasing future storm activity (Hulme and Jenkins, 1998). In particular, an increase in the frequency of winter storm wave activity from a north easterly direction may result in an increase in the rate of landward migration of parts of the Studland Dunes due to storm overtopping and profile readjustments. The southern end of the Studland Peninsula is most likely to be at risk. Whilst limited impact will be seen on regional sediment budget regimes, there is likely to be a major impact upon landforms (eg: dune fronts) and habitat extents. For example, increased dune face erosion, presently occurring at Studland, may possibly increase. Fahy et al (1993) state that on the Studland Peninsula, heightened sea level will increase the "swivel" effect of the outer coast, as at present, the coast is changing orientation with the southern half eroding and the northern end accreting.

7.4.2 Anthropogenically Induced Change

Limited Man induced change is likely within this Process Unit, and so consideration should be given for managed retreat or "do nothing" . These options appear viable along many stretches of the Studland Peninsula as development is limited and conservation values are high.

7.4.3 Impact on Adjacent Conceptual Process Model Areas

Studland Bay is a sediment sink so that it is more likely to be affected itself by changes in adjoining process units e.g. Poole Bay & Poole Harbour. Interference with incoming sediment supplies could for example result in dune erosion. The only manner in which internal changes could impact upon adjoining process units would be if rapid recession of Shell Bay were to affect the configuration of the Poole Harbour inlet (an unlikely event at present erosion rates).

8 PROCESS UNIT 5F-6 : HANDFAST POINT TO PEVERIL POINT (SWA)

8.1 Overview of the Process Unit

The Isle of Wight provides Swanage Bay with a degree of shelter from easterly storms. The Bay is therefore susceptible only to a relatively narrow corridor of waves generated from the south-east. Tidal streams are weak but gather strength significantly towards Peveril Point. The wave climate, apart from the occasional easterly storm, is mild and the coastline exhibits a remarkable degree of stability and the amount of sediment in movement is evidently small.

The geology of the northern end of Swanage Bay is complex and affects the cliff processes and distribution of mass movements. Basically, the Bay is formed in less resistant Wealden Beds, comprising sandstones, grits, marls and clays lying between harder Chalk and limestone (Jurassic) formations which the form headlands that define the Bay. Mass movements occur, particularly just north of the groynes, in the weak sand and clays so high slope angles cannot be maintained in these materials. Instability is enhanced by seepage in the material and mudflows and fans form on the beach after heavy rain. This material is soon removed by higher tides.

Littoral drift is in a northerly direction evidenced by patterns of sediment accumulation with groyne compartments. It is suggested that little to no sediment is fed to Swanage Bay via Peveril Point (Bray, Carter and Hooke, 1991).

In Swanage Bay the beach material gradually becomes finer, with a decrease in shingle from the start of the sea wall southwards. The beach levels apparently varied prior to groyning, which first took place in 1925, and the beach is now gently sloping. The main beach of Swanage (just north of Mowlem) is composed predominantly of medium sand. The beach at the southern end of the Bay is exclusively composed of sand due to the low energy and sheltered environment.

8.2 Sediment Budget

8.2.1 Sediment Inputs

Coarse Sediments

There is one key sources of coarse sediment input within this CPM area, coastal erosion.

May (1969) has shown that the erosion is controlled by the joints and structure of the chalk. Waves are refracted around Handfast Point but erosion is negligible on the NW side. Scouring takes place between the stacks and the mainland on a falling tide. Chalk blocks are easily broken down so it is only the flint which makes a net contribution to beach material and the marine sediment system.

At Ballard Point waves are reflected at High Water and do not break but a narrow beach is exposed at Low Water. On the south side of Ballard Point erosion is limited because of wave refraction, the dip of the rocks and a change in chalk lithology. 2m^3 is calculated to be added annually by small falls.

Erosion of the chalk headland between Handfast Point and Ballard Point provides little notable sediment of the littoral system. Chalk blocks are broken down by wave action and transported offshore. Flint nodules predominantly form pocket beaches adjacent to the cliff toe. Between Handfast Point and Purfield Cove, a total, potential, sediment supply rate of the order of 30,000m^{3}pa is arrived at (10,000m^{3}pa chalk, <500m^{3}pa flint and 20,000m^{3}pa sand and clay).

Instability and mass movements are also still active further south where there is a promenade and sea wall at the base of the cliffs. Falls and slips are reported and material falls annually onto the promenade. Some may be removed by waves though erosion is obviously reduced.

Fine Sediments

Fine material derived from cliff erosion are believed to be transported ("winnowed") offshore while coarser clastic deposits are deposited in upper beach sediment. These are not very significant in sedimentary budget terms. Consideration should also be given to sediment exchanges with the offshore zone for this Process Unit. There is no fluvially derived material being added to the shoreline.

8.2.2 Sediment Losses

Coarse Sediments

No reclamation or dredging is believed to take place within this Process Unit and so artificial coarse sediment output is believed to be negligible

Fine Sediments

Fine material appears to be removed from the littoral zone, presumably offshore. Sand and finer material occurs in the deeper offshore zone, where it is not subject to high stresses but there is no indication that this is a net accumulation zone. However, it appears that removal of finer material from the base of the cliffs outwards takes place without significant lateral movement. May (1979) estimates that chalk pebbles from the cliffs can be moved 1.5km before destruction.

Sediment Stores

The beaches derived from erosion of the solid geology outcrops of the coast are relatively small and mainly composed of coarse clastic materials. This is because the finer material is commonly broken down and moved offshore, as opposed to alongshore.

8.3 Sediment Transport Regime

Material released from cliff falls within Swanage Bay is transported longshore by moderate wave action. The overall evidence based on composition of shingle and the pattern of accumulations, eg against groynes at different times suggests a generally northward movement of littoral drift under the influence of the prevailing SW winds. However, chalk and flints are found south of the chalk cliffs in Swanage Bay so reversals of the normal direction must occur.

Sediment transport may take place westwards from Peveril Point but this is ultimately determined by sediment availability. Only sand, no shingle, is present at the southern end of the Bay because of the low energy and sheltered environment. Sediment transport could take place westwards from Peveril Point but is limited by sediment availability. Peveril Point, composed of Lower Cretaceous Upper Purbeck Beds, provides virtually no material and no exchange appears to take place around Peveril Point from the south. It is uncertain whether sands and fine gravels that are transported southwards out of Studland and Poole Bays actually enter Swanage Bay and contribute to the shoreline.

8.3.1 Wave Induced Transport

Studies carried out for this SMP confirm that the dominant wave action within the Bay is from the east. General observations, show that Swanage Bay is virtually unaffected by westerly or south westerly waves propagating up the English Channel. Some residual wave activity, turning around Durlston Head to the south and Handfast Point to the north (and then propagating inshore), gives a small northward component of wave energy flux which is generally balanced by the shorter period wave action approaching from the east and north-east. This balance may be disturbed when seasonal wave conditions vary from the norm, which has occurred in Swanage Bay over the past few years.

Recent work carried out by Halcrow for this SMP show that potential wave longshore energies are higher in the southern half of Swanage Bay reducing in magnitude towards Ballard Point.

8.3.2 Potential Bedload Transport Direction

The tidal circulation in Swanage Bay has a net anti-clockwise flow, circulation in that direction being much longer sustained than the clockwise flow in each tidal cycle. Strong tidal currents occur around Handfast Point and the coast is shallow there because of a chalk platform, which has a marked outer edge. Gravels occur on this platform and are poorly sorted though generally the tidal currents have a winnowing action through sand transport. Tidal currents are also quite strong towards Peveril Point but within Swanage Bay are low, attaining maximum velocities of 0.2-0.3ms^{-1}. Gravels also occur in Swanage Bay in the whole area above the 18m contour, but further south they are better sorted and clean washed. The sorting occurs asymmetrically from the chalk ridge. There is also a high content of shell material in Swanage Bay.

The direction of movement off Swanage Bay is southwards and Fitzpatrick (1987) states that the Tertiary heavy mineral assemblage indicates a general provenance from Poole Bay. No indication of volumes of transport is given. In deeper water, the offshore sediments become progressively finer eastwards, with an area of rippled sand about 4km east of Swanage Bay. Movement there is in a SW direction (Fitzpatrick 1987).

It appears that some material may move from onshore to offshore, particularly in the vicinity of steep cliffs and especially off Handfast Point. Simulation of removal of effluent from an outfall in Swanage Bay also shows removal straight out to sea (Hydraulics Research 1987).

8.3.3 Potential Suspended Material Transport Direction

The Process Unit is subject to low energy tidal flows, where figures of 0.3m/s have been published (CIRIA 1998) and hence are barely capable of initiating sand movement without the aid of wave action. Consequently, tidal currents within the Bay are insignificant in terms of sediment budget analysis.

8.3.4 Aeolian Transport Direction

Unlike further north in Studland Bay, this transport method is not seen to be significant in overall sediment budget terms.

8.3.5 Temporal Variations in Transport Direction

As stated above, littoral transport is in a net northerly direction but reversals occur occasionally. It is conjectured, that localised southerly movement of sand takes place in the southern part of Swanage Bay under the influence of north-easterly and easterly generated waves (Bray *et al.* 1991). These reversals are, however, only temporary, witnessed primarily in the winter months.

8.4 Implications of Change on Shoreline Evolution

8.4.1 Sea Level Rise

The implications of sea level rise within Swanage Bay are likely to reflect the nature of the bay as it stands today. The southern half is protected and controlled by artificial structures which cannot adjust naturally to sea level rise or changing patterns of storminess. These sections will not supply sufficient sediments in response to changing patterns of erosion and accretion and so beach loss and scour are anticipated to increase resulting in more seawall overtopping, an increasing probability of structural damage and loss of beach amenity values. To the north of Swanage Bay, where artificial structures do not occur and cliffs predominate, erosion rates are likely to increase, triggering fresh landslides in the Wealden clay cliffs and rockfalls in the Chalk. This may lead to the threat of outflanking of existing coastal defences within Swanage Bay.

8.4.2 Anthropogenically Induced Change

The recently prepared draft Swanage Bay Beach Management Study (Halcrow 1998) outlines future intervention and management within the Bay. This should be used as a key reference to assess anthropogenically induced change. The cliffs in the northern part of the Bay are likely to become increasingly unstable in the future due to accelerating sea-level rise and climate change involving increased storminess and precipitation such that there are likely to be increasing needs to control future development in these areas.

8.4.3 Impact on Adjacent Conceptual Process Model Areas

Swanage Bay is a relatively self-contained, low flux sediment system so that internal changes are unlikely to affect adjoining units - nor are those units likely to affect Swanage Bay.

9 PROCESS UNIT 5F-7 : PEVERIL POINT TO DURLSTON HEAD (DUR)

9.1 Overview Of The Process Unit

Durlston Bay has many similar characteristics to those described for Swanage Bay to the north. It is separated from it by Peveril Point, which acts as a barrier, preventing beach building materials from being transported from one bay to another. Bray et al (1991) suggest that coastal processes themselves are similar to those acting within Swanage Bay, since both bays are of similar plan shape and orientation, however wave energy is greater in Durlston Bay as it is more exposed to the S and SE. Rapid tidal currents operate at each end of the Bay where the headlands interfere with tidal flows.

Rapid cliff recession at Durlston Bay is well documented, mainly because of its impact on coastal properties and the problems of coastal management caused by the mass movements. The cliffs are composed mainly of closely interbedded and jointed limestones and marls of the Purbeck Beds but the situation is complicated by compound faults and thrust planes. These faults are an important component of the potential instability and the site of an active slide which, at times, becomes a mudflow. Major falls are attributed to the combination of wave action at the toe, weathering of the marl and water seepage from above the marl.

The foreshore comprises a mass of limestone blocks and boulders in varying states of degradation, having become detached from the cliffs in rock fall events. These provide some protection to the cliff toes against wave attack.

9.2 Sediment Budget

9.2.1 Sediment Inputs

Coarse Sediments

Material released during cliff erosion within Durlston Bay generally comprises fragments, slabs and boulders derived from limestone and marls. The retreat process is sporadic since cliff falls are characterised by large block failures followed by little to no subsequent erosion. Coarse material remains on the beach until it becomes broken down into sufficiently small pebbles to be transported. Research by Crocker suggest that approximately 8,000m^3 of material had fallen between 1976-1986 (Bray *et al*, 1991), *i.e.* of the order of 1,000m^3/annum.

Fine Sediments

Fine sediments are input to the system through erosion of marls within Durlston Bay. It is uncertain exactly what percentage of the total sediment input from cliff erosion is fine material. The cliff geology suggests that this could be considerable. Wave attack occurs directly at the base of the active cliffs and is believed to quickly remove all fine material offshore in suspension.

9.2.2 Sediment Losses

Coarse Sediments

It is likely that coarse materials are retained within the Bay until reduced by abrasion and attrition to sizes sufficiently small to be transported offshore.

Fine Sediments

Fine material, derived from cliff erosion, are believed to be transported ("winnowed") offshore while coarser clastic deposits are deposited in upper beach sediment. Fine material is not seen to be very significant in overall sedimentary budget terms.

9.2.3 Sediment Stores

Landslide debris accumulating at the cliff toe forms the main sediment store and performs a valuable role in protecting the cliff toes from wave attack. Large quantities of material enter this store following major cliff falls, but are rapidly removed by wave action during intervening periods of low cliff activity.

9.3 Sediment Transport Regime

9.3.1 Wave Induced Transport

Details regarding coastal processes and transport pathways within Durlston Bay are limited. There is little documented evidence on littoral drift though it is assumed that any occurring would follow the same pattern as Swanage Bay since both have a similar orientation (ie: south to north). Wave modelling carried out for this SMP, however, does suggest that potential mean annual alongshore wave energies in Durlston Bay are much higher than Swanage, Studland and Poole Bays. Explanation of this is described in more detail within Section 2 of this Volume. Irrespective of drift potential, the boulder strewn foreshore would tend to restrict freedom of coarse sediment movement and reduce drift. The distribution of sediments on the foreshore would therefore tend to reflect the distribution of delivery from cliff processes rather than the net direction of drift.

9.3.2 Potential Bedload Transport Direction

On the basis of existing knowledge for Swanage Bay, similar bedload characteristics are believed to occur and be relevant for Durlston Bay. Any material that is broken down from the foreshore area is most likely to be broken down and transported offshore though quantifying this amount is difficult to establish.

9.3.3 Potential Suspended Material Transport Direction

The Process Unit is subjected to low energy tidal flows, where figures of 0.3m/s have been published (CIRIA 1998) and hence are barely capable of initiating sand movement without the aid of wave action. Consequently, tidal currents within the Bay are insignificant in terms of sediment budget analysis. By contrast, currents are rapid at each of the headlands defining the Bay such that material reaching these points would be removed rapidly.

9.3.4 Aeolian Transport Direction

Due to the sheltered nature of the Bay and lack of aeolian derived sediment or dune systems, this transport method is not seen to be significant in overall sediment budget terms.

9.3.5 Temporal Variations in Transport Direction

Irrespective of the likelihood of reversals in drift potential, the boulder strewn foreshore would tend to restrict freedom of coarse sediment movement and minimise the effects of any such variations.

9.4 Implications Of Change On Shoreline Evolution

9.4.1 Sea Level Rise

The impacts of sea level rise are uncertain, though effects may be felt in terms of increased cliff erosion as wave attack at the base increases with storm frequency. As sediment supply to these beaches is of local derivation (*in situ* sources), the sediments providing natural cliff toe protection within Durlston Bay are more likely to diminish if engineering methods to reduce cliff instability are promoted.

9.4.2 Anthropogenically Induced Change

Future coast protection schemes are likely to be considered for control of cliff erosion in Durlston Bay due to the geological composition in the cliffs area and the needs to protect existing property. The problem is complex and involves balancing the needs to protect the flats built at the cliff top as opposed to the requirements of geological conservation and the maintenance of sediment processes within the Bay.

9.4.3 Impact on Adjacent Conceptual Process Model Areas

It is reasonable to suggest that material released from the cliff falls within Durlston Bay do not influence or benefit adjacent Process Units, therefore the level of significance of the sources is related to the immediate frontages within the Bay.