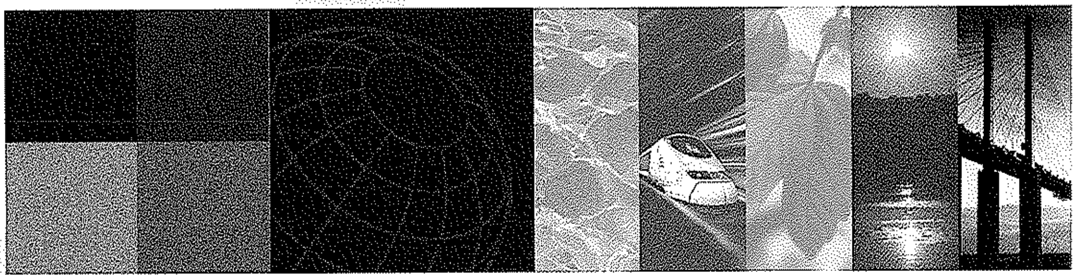
**Halcrow Maritime**

# Poole and Christchurch Bays Shoreline Management Plan
## Volume 2 - Physical Environment

March 1999



Halcrow

# Halcrow Maritime

Poole and Christchurch Bays
Shoreline Management Plan
Volume 2 - Physical Environment
March 1999

**Halcrow Maritime**
Burderop Park Swindon Wiltshire SN4 0QD
Tel +44 (0)1793 812479 Fax +44 (0)1793 812089
www.halcrow.com

# PREFACE

This is the Consultation Draft of the Poole and Christchurch Bays Shoreline Management Plan. It sets out the strategy for management of coastal defences between Durlston Head in Dorset and Hurst Spit in Hampshire, including Poole and Christchurch Harbours (Subcell 5F). The SMP has been prepared by Halcrow Maritime on behalf of the Poole and Christchurch Bays Coastal Group.

The SMP is divided into the following 4 volumes:

## VOLUME 1 – STRATEGY DOCUMENT

PART A : INTRODUCTION
Sets out the background to, and role of, the SMP, along with its aims and objectives.

PART B : HOW TO USE THE PLAN
Describes the key elements of strategy presentation, in the Process and Management Unit sections.

PART C : PROCESS UNIT DESCRIPTIONS
Present a synopsis of the main characteristics of each Process Unit, summarised from Volumes 2 and 3.

PART D : MANAGEMENT UNIT STATEMENTS
Divided into two sections, Part D1 presents the 'Management Unit Characteristics' and Part D2 the 'Appraisal of Strategic Options' which identifies the preferred option along with implementation and monitoring guidance.

PART E : FUTURE DEVELOPMENT
Describes where/how current understanding needs to be improved and gives a suggested time frame for both the review of the strategies and, further into the future, for a more comprehensive reappraisal of the Plan as a whole.

## VOLUME 2 – PHYSICAL ENVIRONMENT

PART A : GEOLOGY AND GEOMORPHOLOGY
Presents the physical characteristics of the shoreline along with its the formative geomorphological history, and describes the subdivision of the coast into Process Units.

PART B : COASTAL CONDITIONS
Describes the wind, wave, tide and current regimes driving contemporary coastal processes.

PART C : SHORELINE EVOLUTION
Identifies and reviews historical evolution of the shoreline, both 'natural' and due to Mans intervention.

PART D : CONCEPTUAL SEDIMENT PROCESS MODELS
Provides 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.

ANNEX A : ISSUES ANALYSIS AND STATEMENT OF OBJECTIVES
Presents shoreline management issues and associated objectives, relevant to the Physical Environment of the coast, identified during public consultation on the SMP.

## VOLUME 3 – DEVELOPED AND NATURAL ENVIRONMENT

PART A : COASTAL DEFENCES
Examines the current state of knowledge of coastal defences, and where possible reviews the nature and standard of defence provided, and their suitability to provide the standards required in the future.

PART B : DEVELOPED ENVIRONMENT
Human use of the shoreline is assessed through descriptions of land use, coastal activities, offshore use and archaeological interest, and requirements for coastal defence planning.

PART C : NATURAL ENVIRONMENT
Reviews landscape, habitat and earth science conservation value of the shoreline, and the key issues relating to coastal defence provision.

PART D : PLANNING
Detail present planning procedures and sets out existing policies and objectives, of both statutory and non-statutory plans, of relevance to coastal defence.

PART E : LIST OF RELEVANT DOCUMENTS
A bibliographical listing of those documents/sources used during the production of the SMP.

ANNEX A : ISSUES ANALYSIS AND STATEMENT OF OBJECTIVES
Presents shoreline management issues and associated objectives, relevant to the Developed and Natural Environment of the coast, identified during public consultation on the SMP.

## VOLUME 4 – MAPS AND SUPPORTING INFORMATION

*Maps presented in Parts A to D are at 1:25,000 scale.*

PART A : DEVELOPED ENVIRONMENT MAPS
These base maps illustrate the land use of the area, categorised into ten classifications.

PART B : CONSERVATION MAPS
Includes details of all international, national and local conservation designations, whether statutory or non-statutory. Archaeological and historical features of a terrestrial and maritime nature are also depicted.

PART C : COASTAL DEFENCES
The extent and nature of all forms of coastal defence have been mapped.

PART D : PHOTOGRAPHS
A series of photographs representative of each Process Unit.

A consistent **page numbering** style has been used throughout Volumes 1 to 3, as follows:
**Volume – Part Page.**
For example, 1-A4 is Volume 1 Part A Page 4.

# INTRODUCTION TO THIS VOLUME

During their development of SMPs around the country, Halcrow have been able to witness, at first hand, the "evolution" of the SMP process and have subsequently been involved in many useful discussions and exchanges of ideas. One important outcome of this has been the proposal of adopting wider remit "Process Units" which Halcrow advocated and used in 1996 (Suffolk Shoreline Management Plan).

The structure of this Volume has been set out in the same vein, purposely to assist in the preparation of the Volume 1 Strategy Document. Therefore, the following text has been produced to clarify why and how the study area has been divided up the way it has and also to provide an indication of how this breakdown will be used effectively during Phase 2.

## WHY SET UP PROCESS UNITS ?

The key to achieving effective and sustainable management of the shoreline is linked to a sound knowledge of coastal processes and their interaction along the coast. All management decisions ought therefore to be linked primarily to the processes and their implications. Management strategies need to address these implications on a broader scale than land use alone and the defence options for individual management units must be appraised against the overall processes within a larger area. The structure of the management for Poole and Christchurch Bays is therefore one where conformity with the requirements of the Process Unit is paramount. Therefore, it is for these reasons that the Process Unit framework has been set up for this SMP.

The basic building block for the development of policies within an SMP is the "Management Unit". In the MAFF Guidelines (1993), a management unit is defined as "a length of shoreline with coherent characteristics in terms of both natural coastal processes and land use". The Guide goes on to say that "these are likely to constitute discreet benefit areas at the economic appraisal stage". For this SMP, a broader more strategic approach is to be adopted that takes into consideration wider issues and impacts that should, over the long term, provide a more useful framework from which to manage the shoreline.

The groundwork for using this approach has been set within this Volume and, where possible, the final strategy Document (Volume 1) of the SMP will utilise this to its fullest effect.

## HOW ARE PROCESS UNITS IDENTIFIED ?

The sub-cell system derived from the "Mapping of Littoral Cells" report commissioned by MAFF in 1993 (Motyka and Brampton) originally categorised sub-cells 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). It was stressed in this report that the division into coastal cells is strictly applicable to the purpose of coastal defence management on non-cohesive beaches (such as Poole and Christchurch Bays). The direction and movement of sediment further offshore is unlikely to mirror littoral drift directions and boundary conditions in all cells.

Based upon the Terms of Reference set out for this SMP, the shoreline of the sub-cells shall be divided into discrete "Process" and associated "Management Units". A Process Unit is defined in the Consultants Brief as being "a length of shoreline with coherent characteristics in terms of processes and based upon an understanding of the geology and geomorphology, the prevailing sea conditions and natural shoreline evolution". This is seen as a necessary development of the present MAFF Guidelines and one that is required to ensure sustainable management techniques are followed on the coast.

An important clarification to make is that the demarcation of these Process Units is not merely made on the geographic limits of certain physical features or landforms. 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 strong physical relationship between areas of open coast and sediment sink areas (such as Poole and Christchurch Harbours). Consequently, interlinkages will and do occur especially between areas, such as harbour mouths and the open coast. There are also key strategic landforms (terrestrial or subtidal, such as Hook Sand or Double Dykes) where actions in one Process Unit may well be influential on the natural evolution of another. Therefore, the concept of introducing Process Units that emphasise links with adjacent units is ultimately required. This shall be assisted through the use of Process Unit Statements. The wordings used for these shall be presented in more detail during the development of Volume 1 ("The Strategy Document") and shall be subject to review and general acceptance from the Coastal Group.

## HOW ARE PROCESS UNITS DEFINED ?

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

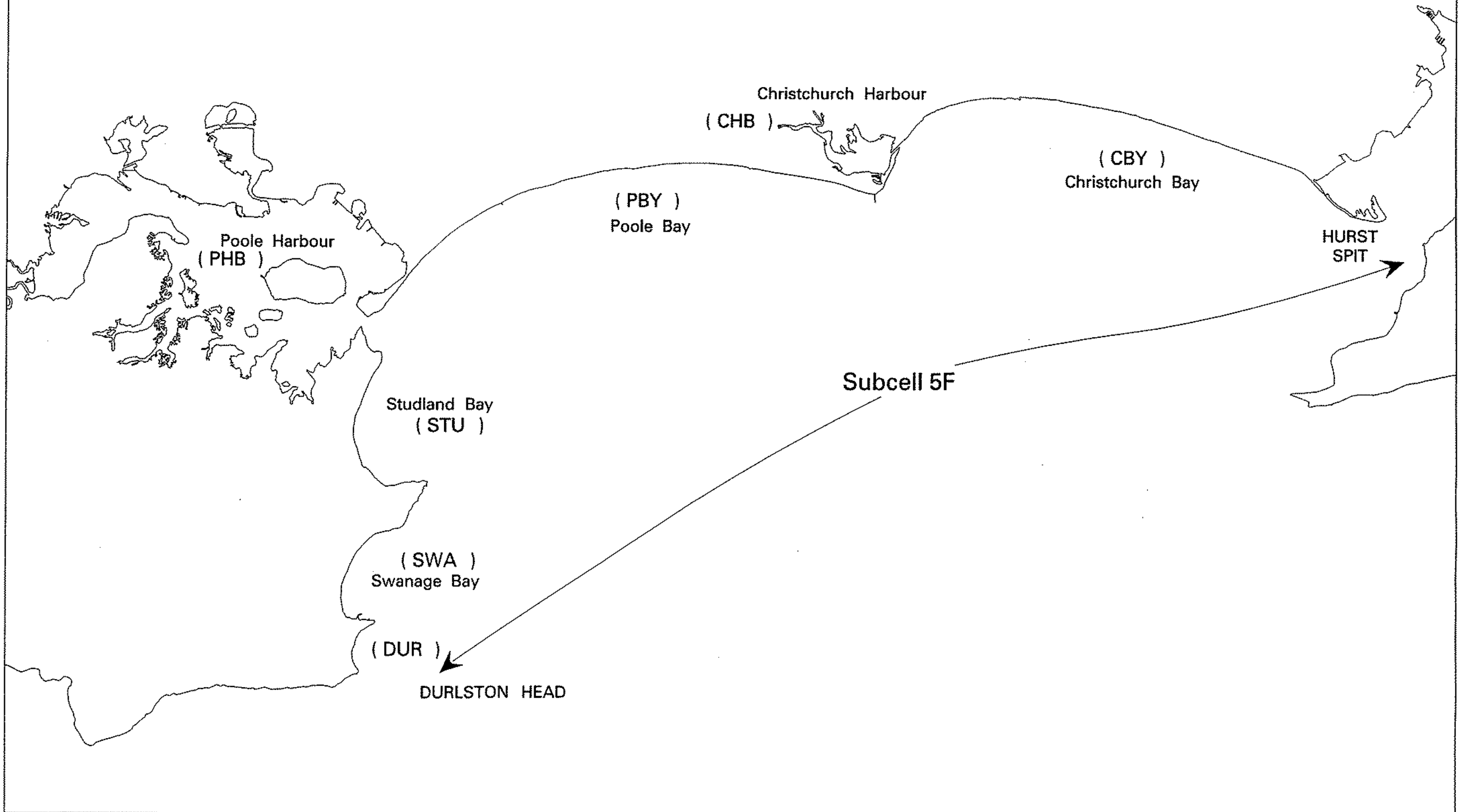
## WHERE ARE THESE PROCESS UNITS ?

There are seven Process Units established for this SMP, based primarily on the identification of landforms, critical coastal processes (waves, currents), their interlinkages and variability giving special attention to their position and function within the overall sub-cell.

The Process Units, from east to west around the sub-cell (see opposite), are as follows:

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

| Poole and Christchurch Bays Coastal Group | SHORELINE MANAGEMENT PLAN<br>POOLE AND CHRISTCHURCH BAYS<br>DURLSTON HEAD TO HURST SPIT (Subcell 5F)<br>Process Units | Halcrow 1999 |
| --- | --- | --- |



## HOW THE PROCESS UNIT FRAMEWORK INTENDS TO OPERATE ?

The Process Unit framework, in very simple terms, has enabled the various topic areas to be conveniently divided up into manageable areas. This has been followed for the contents of Volumes 2 and 3 of the SMP as shown below :

***Volume 2***

- Geology / Geomorphology
- Coastal Conditions
- Shoreline Evolution
- Conceptual Sediment Process Models

***Volume 3***

- Coastal Defences
- Developed Environment
- Natural Environment
- Planning

In addition to this and from a more strategic view, the two tier "Process " and "Management Unit" approach will also prove most useful on two accounts. Firstly, it shall enable long term options (ie: long term sustainability) to be developed that will permit free operation of key process components (ie:geomorphological evolution). Secondly, shorter term measures may be set out for individual shorter management units *so long* as management decisions comply to the longer term objective of an area and thus are not detrimental to processes over a broader timescale.

## WHAT COMES NEXT ?

The results of the Phase 1 studies (Volumes 2,3 and 4) represent a detailed understanding of the processes and issues relating to Poole and Christchurch Bays. At this point, the division into Process Units and Management Units can be confirmed and the detailed objectives for each Unit established. These will be forwarded under separate cover to a draft level.

The next step (Phase 2) will be to determine the appropriate policy for each of these Units taking into account the various pressures and conflicts of interests that exist, and establish the preferred strategic coastal defence options to achieve these policy requirements. This needs to take into account all of the issues and objectives identified. Additional information to be established will be the standards of service required by any future defence policy and the economic justification for providing protection. The MAFF guide to coastal defence authorities on Shoreline Management Plans describes four generic strategic options for defence. The SMP will adopt these as a baseline but not be restricted by them, ie: elaboration on these options will be put forward particularly in terms of time frame strategies (long and short term actions).

Presentation of the strategies will be in the form of individual Management Unit Statements which summarise the main information and issues, and show the rationale behind the strategic decisions that have been proposed. Recommendations will also be made on how the strategic coastal defence options should be implemented, to justify their suitability as a sustainable solution. The Statements will include descriptive maps indicating the key aspects for each unit.

# Part A

# GEOLOGY/GEOMORPHOLOGY

*It is important to stress the geology and geomorphological history of the coast as this has a direct impact upon the shaping of the shoreline both in the long term and short term.*

*Changes in coastal orientation, cliff structure and surface deposits are all important to understanding material sources, sediment sinks and general behaviour of the shoreline, including appreciation of those areas at risk. Existing published information has been used to assist in this task.*

## GEOLOGY & GEOMORPHOLOGY

CONTENTS

# 1 INTRODUCTION

The physical environment of Poole and Christchurch Bays should be understood in terms of its formative geomorphological history, the operation of its contemporary natural process systems and its management history. This is seen as essential if sustainable management of the shoreline is to be achieved. Therefore, the underlying geological and morphological issues and processes are outlined in this report so that the framework of scientific understanding can be set out prior to examination of the modifications and impacts that have resulted from coastal defence activities.

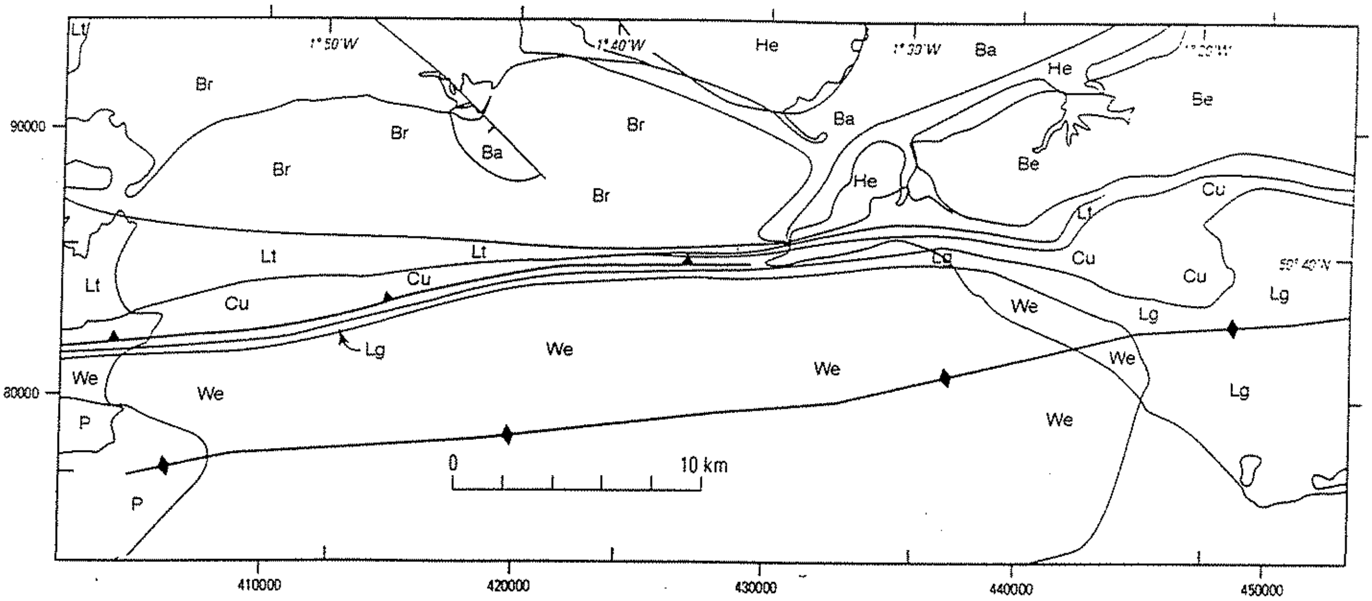
The description of the geology and geomorphology covers the coast from Hurst Spit westwards around Christchurch and Poole Bays to Durlston Head and offshore to the 20 m depth contour which equates approximately to a line drawn between The Needles and Durlston Head. The eastern limit of the offshore area is the Needles Channel.

## 1.1 Geology

In terms of solid geology the coast and sea bed of the Poole and Christchurch embayment is formed principally of sediment and rock of Tertiary (Palaeogene) age (Figure 1.1) with some relatively thin cover of Quaternary sediment (Figure 1.2). It is only at the southern end of Studland Bay that older Cretaceous strata, the Chalk which forms Handfast Point and Ballard Down, encroaches into the area.

The geological structures within the Cretaceous and Jurassic strata are aligned east - west and the steeply dipping Chalk at Handfast Point lies on the Purbeck - Wight Disturbance, a major monoclinal structure which runs across the outer part of the Poole and Christchurch embayment from Handfast Point to The Needles (Figure 1.1). To the south of the Disturbance, Cretaceous Wealden Group rocks cover most of the sea bed and come inshore at Swanage Bay. The headland at Peveril Point at the southern end of Swanage Bay marks the northern limit of the Lower Cretaceous strata in the area with Upper Purbeck Group rocks at the Point. In Durlston Bay to the south, the strata includes Lower Cretaceous Durlston Beds and Upper Jurassic Lulworth Beds (ie: Jurassic – Cretaceous boundary). These beds only extend eastward offshore for about 4 km.

North of the Purbeck - Wight Disturbance the Tertiary strata within the Poole and Christchurch embayment lie on the south-western flank of the Hampshire Basin. The Hampshire Basin is a structural basin, defined by tectonic movement that created the gentle downwarp in which the Tertiary sediments are laid. The regional dip of the Tertiary is generally less than 1° eastwards towards the centre of the basin in the Isle of Wight. Superimposed on this regional dip are small, commonly asymmetrical, folds or flexures which generally trend E - W or NW - SE. These flexures in Tertiary strata commonly lie above folds affecting Cretaceous and older rocks. It is probable that many changes in thickness within the Tertiary are controlled by movement of older deeper faults during deposition of the Tertiary sediments (Bristow, Freshney and Penn, 1991). The Hampshire Basin originally formed part of a single basin of deposition, the Anglo-Paris-Belgian Basin (Melville & Freshney, 1982) which, during Tertiary times, 65 million to approximately 2 million years ago, evolved tectonically into a number of subsidiary basins including the Hampshire Basin and the London Basin to the north.




Key

Be Bouldnor and Bembridge Formations
He Headon Hill Formation
Ba Barton Group
Br Bracklesham Group
Lt Lambeth and Thames Group
Cu Chalk Group
Lg Lower Greensand Group
We Wealden Group
P Portland and Purbeck Group

Age (million years)

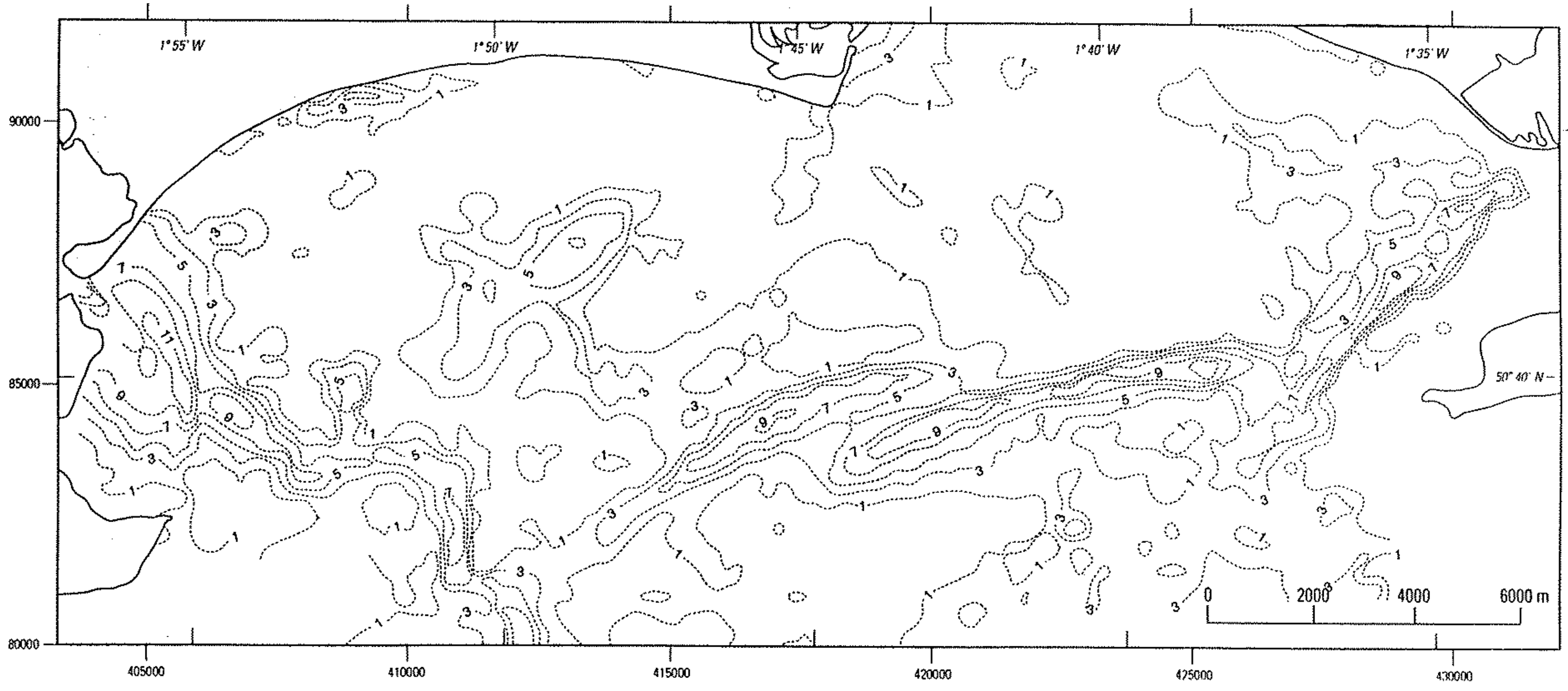
| Age (million years) | Epoch | Period |
|---|---|---|
| | Oligocene | Paleogene |
| 36 | Eocene | Paleogene |
| 53 | Palaeocene | Paleogene |
| 65 | Upper Cretaceous | |
| 95 | Lower Cretaceous | |
| 135 | Jurassic | |

Anticlinal axis

Monocline axis - locally omitted for clarity

**BEDROCK (PRE-QUATERNARY) SOLID GEOLOGY**
**(After BGS map, Andrews and Balson, 1995)**

Figure 1.2




THICKNESS OF UNCONSOLIDATED SEDIMENT (PALAEOVALLEY AND SUPERFICIAL) IN THE POOLE - CHRISTCHURCH EMBAYMENT (AFTER VELEGRAKIS, 1994) CONTOURS IN METRES

The stratigraphy and geology of the Dorset and Hampshire coast has been of great interest to geologists from the 19th Century to the present day. Although the basic framework of the stratigraphy has remained unchanged advances in knowledge and interpretation has led to changes in the way some strata have been named and sub-divided. This is especially true of the Tertiary sediments. Figure 1.3 is taken from the British Geological Survey Bournemouth Memoir (Bristow, Freshney & Penn, 1991) and shows the development of Tertiary stratigraphy to the current form used in the memoir and adopted for this report.

## 1.2 Geomorphological History

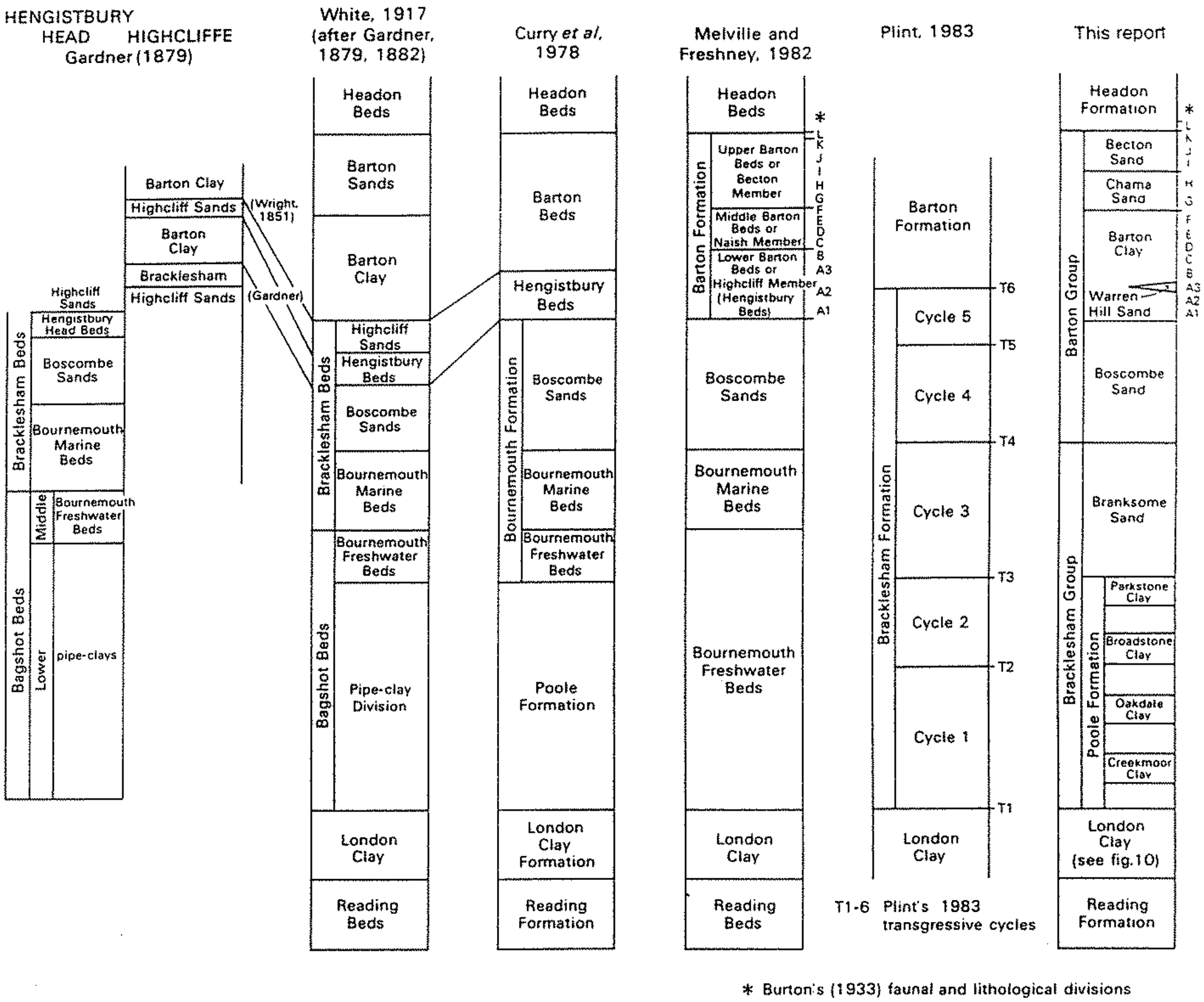
Whilst this geological description is important, a fundamental relationship that needs addressing is that of relating geological structure and lithology to the geomorphological history of Christchurch, Poole, Studland, Swanage and Durlston Bays. This study area is a classic in terms of showing distinct relationships between the coastal configuration and the outcrops of soft or resistant rocks. A summary of the geomorphological history is provided below to set the scene for a clearer understanding of how form and process have interacted within the study area over the past 15,000 years.

During the low sea-level Devensian (late Pleistocene) cold stage (sea-level at up to 120m below present), an ancient Solent River (Figure 1.4) flowed previously across south east Dorset and southern Hampshire and into a major 'English Channel' river either directly southward (Velegrakis *et al.*, 1998), or through what is now the Solent (Allen and Gibbard, 1993). An elevated Chalk ridge was previously continuous between the Foreland of the Isle of Purbeck and the Needles (Isle of Wight) and would have formed the southern limit of this ancestral drainage basin. Poole and Christchurch Bays were opened up by rapid marine erosion of the soft Tertiary strata following the breaching of this Chalk ridge. The initial breach is thought to have been associated with a southward re-orientation of the Frome/Upper Solent River ancestral drainage (Wright, 1982), commencing in the early Devensian (West, 1980) however, the age and development of this palaeo drainage system is a matter of debate. Rapid sea-level recovery and marine erosion during the Holocene transgression, 15,000-5,000 years BP (Devoy, 1982) would have completed removal of the ridge and facilitated excavation of the bays (Nichols and Webber, 1987). The plan shape of the Poole Bay coastline is approximately zetaform, fixed by the "anchoring" presence of Hengistbury Head. The headland was previously much larger, but was substantially eroded during the late-Holocene and only remains as the submerged shoal of Christchurch Ledge extending several kilometres further southeast. Removal of this point of resistance triggered the erosion of Christchurch Bay, which is therefore younger than Poole Bay (Nichols and Webber, 1987). The remaining headland is critical to the stable configuration of both embayments.

Inundation and erosion of Christchurch Bay eventually led to the connection of a tidal channel through the western Solent to isolate the Isle of Wight at between 7,000 to 7,500 years BP (Nichols and Webber, 1987; Velegrakis *et al.*, 1998). River terrace gravels released by the eroding cliffs in Poole and Christchurch Bays drifted eastward to form a spit extending across part of the west Solent entrance (the ancestral Hurst Castle spit). Fine sediments were deposited and saltmarshes formed to the north east within the shelter afforded by the spit. Subsequent 'rollover' of the spit has occurred to shift its position to the north-east.

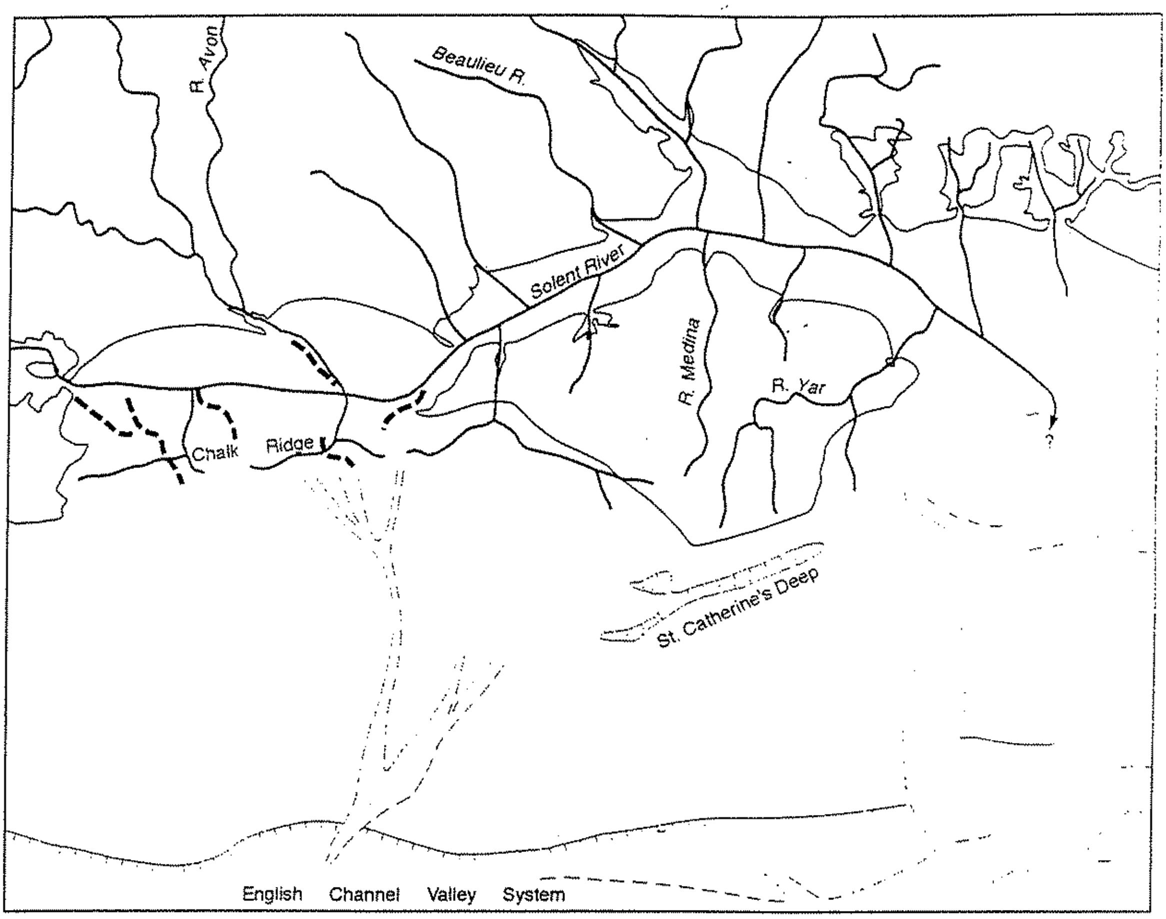
Within Studland, Swanage and Durlston Bays, less detailed study has taken place. The Studland Peninsula has been studied by (Diver 1933) and more

Figure 1.3




**STAGES IN THE STRATIGRAPHIC EVOLUTION AND NAMING OF THE PALAEOGENE (TERTIARY)**

From Bristow, Freshney, and Penn (1991)




Drainage system of the Solent River during the Pleistocene (from Nicholls. 1986)

Submarine cliff line

Infilled palaeovalley
From Harrison and Hamblin (1989). Note that seismic profiles examined for this project from southwest of the Isle of Wight show that the paleovalley system draining south from the Poole-Christchurch embayment is more complex than shown here

Palaeovalley systems in the Poole-Christchurch embayment. from Velegrakis (1994)

## QUATERNARY PALEO-GEOMORPHOLOGY AND THE PROTO-SOLENT RIVER SYSTEM

detailed assessment of Studland is available from this source. Contemporary observations suggest that 300 years ago, the Peninsula covered approximately one quarter of the area it does at present.

## 1.3 Establishing Coastal Process Units

In order to describe the SMP study area in detail, it is 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). Hurst Spit to Durlston Head (this SMP area) falls within Sub-cell 5f.

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. 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.

Based upon the Terms of Reference set out for this SMP, the shoreline of the sub-cells shall be divided into discrete "Process" and associated "Management Units". A Process Unit is defined in the Consultants Brief as being "a length of shoreline with coherent characteristics in terms of processes and based upon an understanding of the geology and geomorphology, the prevailing sea conditions and natural shoreline evolution". This is seen as a necessary development of the present MAFF Guidelines and one that is required to ensure sustainable management techniques are followed on the coast.

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 (Christchurch Bay) |
| 5F-2 | Christchurch Harbour |
| 5F-3 | Hengistbury Head Long Groyne to Sandbanks Ferry Slipway (Poole Bay) |
| 5F-4 | Poole Harbour |
| 5F-5 | South Haven Point to Handfast Point (Studland Bay) |
| 5F-6 | Handfast Point to Peveril Point (Swanage Bay and Ballard Down) |
| 5F-7 | Peveril Point to Durlston Head (Durlston Bay) |

The offshore section of the Poole and Christchurch embayment will be described separately from that prepared for the areas set out above.

# 2 HURST SPIT TO HENGISTBURY HEAD LONG GROYNE (5F-1)

## 2.1 Geology and Geomorphology

Hurst Spit lies at the eastern end of the SMP study area. It guards and lies across the western entrance to the Solent. It is about 2 km long and forms a ridge 2 to 6 m above mean sea level which protects the extensive Keyhaven marshes behind it. It is believed that Hurst Spit began to form following breaching of the Western Solent around 7000-7500 years ago as erosion and a rapidly rising sea level (caused by climatic warming) separated the mainland from the Isle of Wight. This episode joined up Christchurch Bay and the Western Solent and created the conditions for the present wave and tidal regimes. A combination of sediment transport along the Spit and the effects of strong tidal currents passing between the Solent and Christchurch Bay led to deposition of shingle and sand on the seabed close to the Isle of Wight. The resulting shoal, known as Shingles Bank, now provides the Spit with significant shelter from wave activity generated by south westerly storms (Wright 1996).

The spit is a mobile feature. In the period 1870 - 1970 the neck of the spit moved progressively north-eastwards into the Solent (Hooke & Riley, 1987). There has also been a progressive narrowing of the spit in a number of areas west of the head (Hooke & Riley, op cit.), for example, from 70 m to 17 m in width between 1867 and 1968, although some parts of the mid-section widened during this interval. Nicholls (1985) indicated that recession of the spit increased during the period 1968 - 1982 to 3.5 m $yr^{-1}$ from a previous average of 1.5 m $yr^{-1}$. He attributed the increase to the development of sea defences protecting the cliffs to the west which cut off the supply of sediment to the spit from cliff sourced gravel. The increasing risk of a breach in the spit due to narrowing was confirmed in 1989 when a breach did occur. This risk has now been minimised by recent engineering work and replenishment of gravel on Hurst Spit and Beach from Shingles Bank in 1996. The natural gravel within the spit is predominantly flint gravel derived from the erosion of River Terrace Gravel (Plateau Gravel) which form a blanket of Quaternary age sediment on top of the cliffs to the west of Hurst Spit.

Cliffs are the prominent geomorphological feature along the coast west of the White House at Milford grid reference (SZ288 914). They increase in height over a distance of 9 km to Highcliffe, where they are about 30 m high, before lowering to 20m between Hordle and Highcliffe and finally descending back down to the sea at Mudeford Quay. Where the cliffs are open to wave attack, their morphology is controlled strongly by the nature of their ground forming materials. The predominantly sandy sediments of Hengistbury Head, Becton and Hordle degrade to result in steep, relatively simple morphological forms that maintain good geological exposures so long as there is periodic erosion of basal debris (Bray 1993). The Barton Cliffs are complex, being composed of interbedded sands and clays of the Barton Group and susceptible to a variety of landslide mechanisms including rotational failures of a steep upper scarp and mudsliding of debris over several mid slope benches (Bray 1996).

The geology of these cliffs is of international significance and the cliffs at Highcliffe, Barton, Becton and Hordle have been designated Sites of Special Scientific Interest (SSSI). They include sediments of the Palaeogene, Barton Group and contain the global stratotype for sediments of this age. The Barton Group comprises four formations (Figure 1.3) which are, in ascending order (thickness in brackets), Boscombe Sand (20 - 25 m), Barton Clay (c. 30 m), Chama Sand (6 - 10 m) and Becton Sand (24 m). These sediments dip eastward at a low angle and the dipping structure brings the younger Palaeogene, Headon Formation, which lies on the Barton Group, to outcrop at the top of the cliff near Becton Bunny. The formations within the Barton Group progressively disappear eastward as they dip beneath the base of the cliff and at Hordle, east of Taddiford Gap, the Palaeogene sediments in the cliff are composed entirely of Headon Formation sediments and these continue eastward to Milford.

The Headon Formation consists of pale greenish grey, relatively sand-free, locally shelly clays and poorly laminated, very fine grained sand, silt and clay. There is usually carbonaceous silt, commonly associated with lignite at the base of the formation. It lies on a palaeosol with rootlets at the top of the Becton Sand. The lower and upper members of the Headon Formation are believed to have been deposited in freshwater lagoons behind beach-barrier sands and there is also evidence for fluvial and marine derived sand within the formation (Bristow, Freshney & Penn, 1991).

The Becton Sand comprises yellow to pale grey, well sorted, fine- to very fine-grained quartz sand. In the cliffs at Barton on Sea a greyish brown shelly clay has been recognised and this has been named the Becton Bunny Member although it appears to be impersistent in its occurrence (Bristow, Freshney & Penn, 1991).

The Chama Sand is about 8 m thick at Barton on Sea and consists of greenish grey to grey, slightly glauconitic, clayey, silty, very fine-grained sand, silt and sandy clay. It is highly bioturbated with many burrows and where unweathered, it is commonly shelly (Bristow, Freshney & Penn 1991.).

The Barton Clay consists mainly of yellow-weathering, greenish grey to olive-grey, commonly glauconitic clay with some disseminated and bedded very fine-grained sand. At Highcliffe the base of the Barton Clay sits at a bed of well rounded flint pebbles in a matrix of sandy glauconitic clay (Prestwich, 1849). The type section of the Barton Clay at Barton on Sea (grid ref. SZ235 929) contains an abundant marine fauna, dominated by gastropods and bivalves, with corals, serpulids, scaphopods, echinoids and fish vertebrae (Bristow, Freshney & Penn, op cit.).

The Boscombe Sand is the oldest formation within the Barton Group. It forms the cliff east of Mudeford Quay and gradually dips eastward beneath the Barton Clay at Highcliffe and disappears below the base of the cliff before reaching Chewton Bunny. It is 15 to 18 m thick at Steamer Point (SZ 197 928) and consists of three units of intensely bioturbated, dark brown, sandy and silty clay, rich in plant debris, with silty sand and sand and some layers of mud pellets (Bristow, Freshney & Penn, op cit.).

The formations within the Barton Group were deposited during a series of marine transgressions and regressions as the sea advanced and retreated across the area (Plint, 1983, Hooker, 1986). These created a variety of environments including offshore marine, shoreface, beach, estuarine and tidal channels and lagoons. Aeolian sediment and soil formation (palaeosol) have also been noted indicating sub-aerial exposure during some marine regressions.

The Tertiary (Palaeogene) formations within the cliffs from Mudeford Quay to Milford on Sea are covered by a veneer of Quaternary sediment which is variable in thickness along the cliffed sections, generally <2 - 3 m, but noted to 7.6 m (Barton, 1973). These sediments are River Terrace Deposits, some of which are thought to have been deposited by the River Avon, but the higher deposits east of Chewton Bunny may be associated with rivers of the proto-Solent drainage system (Figure 1.4). On some geological maps these River Terrace Deposits are shown as 'Valley Gravels' or 'Plateau Gravels' (Bristow, Freshney & Penn, op cit.), these were the previous commonly used terms in the geological literature for these gravels.

The River Terrace Deposits consist mainly of flint gravel, which is commonly very sandy. Chert, 'sarsen' stone, which is a form of silicified gravel, and limestone are present as minor components; the limestone is likely to be of Jurassic age. The gravels were frozen during glacial periods, although not covered by ice, they exhibit cryoturbation structures associated with frozen ground such as involutions, frost wedges and flame structures. These gravels, when eroded from the cliffs and transported eastward by longshore drift, are a source of gravel for Hurst Spit.

The amount of gravel available in Christchurch Bay from cliff erosion for littoral drift and beach development has decreased during the last twenty to thirty years with the development of coastal protection measures. This has occurred not only along this section of coast but also further west in Poole Bay over a longer period, diminishing the sediment available from eastward littoral drift. Details of this are given by Lacey (1985) and are summarised in Bray *et al* (1991). Nevertheless, beach nourishment inputs during the mid 1970's (sand) and late 1980's (sand and shingle) may have compensated, to some degree, the natural loss of sediment supply to the littoral system.

Mudeford Spit is believed to have undergone accretion as a consequence of ironstone mining from the beach and shoreface at Hengistbury Head during the years of 1847 to 1865. The ironstone boulders originally protected Hengistbury Head from erosion and probably arrested the drift of sediment eastward along Poole Bay. The removal of the protective boulders accelerated erosion at Hengistbury Head and increased the supply and drift of sediment into Christchurch Bay and allowed accumulation at Mudeford Spit. By 1880 the spit extended east almost to Cliff End, a kilometre beyond its present position (Burton, 1931). Details on the historical change of the coast in this vicinity is covered in more detail in the Shoreline Evolution Section, presented within this Volume.

Mudeford Spit was still a substantial feature on the coast between Highcliffe and Milford on Sea as late as 1950 (Clasby, 1970). However, the subsequent loss of beach material and lack of replenishment from the south increased the susceptibility of cliffs at Highcliffe to toe erosion by wave attack, with subsequent steepening of cliff slopes and cliff top failure and retreat. Cliff protection measures have been undertaken at Highcliffe, immediately west of Chewton Bunny, also at Barton on Sea and further east at Milford on Sea to Hurst Spit. Currently between Mudeford Quay and Hurst Spit there are three areas of cliff which are unprotected; a stretch of coast between Highcliffe Castle and Friars Cliff, a 1.4 km stretch at Naish Farm between Barton on Sea and Chewton Bunny, and at Hordle Cliff between Beckton Bunny and Milford on Sea.

The cliff at Naish Farm is formed of Barton Clay and is being actively eroded and forming a re-entrant in the coastline at Chewton Bunny east of the groynes and coastal protection at Highcliffe. Prior to the construction of groynes the average cliff recession rate at Naish Farm was about 1 m $yr^{-1}$, however, since 1959 and the initiation of coastal protection measures at Highcliffe this rate has doubled. The re-entrant will continue to recede inland but it has been suggested that a stable bay will eventually form between the groynes at Highcliffe and the groynes at Barton on Sea. It is believed this will occur after further recession of the low water mark by 60 - 120 m in the centre of the bay and 120 - 240 m at Chewton Bunny (Oranjewoud, 1990).

The asymmetrical plan of the re-entrant, which is evident from the current form of the high water mark is likely to become even more pronounced in the future. The problem is that the clay cliffs are unlikely to form a stable slope whilst material continues to be removed by the sea at the cliff toe.

The erosion and degradation processes of the cliff at Naish Farm have created a characteristic stepped bench and scarp cliff profile. The presence of three preferred bedding plane shear surfaces within the Barton Clay controls the form of benching (Barton, 1973, 1984). These benches may also dip gently eastward at angles of <1° following the regional dip of the formation. The major degradation process within the cliff is the sliding of material over *in situ* Barton Clay with the base of the shear conforming to preferred bedding planes within the formation. Barton (1984) called this process bench sliding and estimated it accounted for the movement of 93% of the material within the cliff erosion system. Other complementary processes associated with the mass movement of material within the cliff include block slumping and scarp development, common in the River Terrace Deposits at the top of the cliff. Debris and mud slides and flows are seen at the foot of bench toes and flow out on to bench tops. Some of these tops are ponded and marshy. Spring lines and small water flows are evident within the cliff. A scattered veneer of eroded River Terrace Deposit gravel moving down the cliff towards the beach is apparent in many areas.

At Hordle a wide beach and shallow shoreface prior to 1959, plus the relatively massive form of the Headon Formation has allowed the 20 - 25 m high cliffs to become covered in vegetation and retain relatively steep slopes of about 25° - 45°. The decrease in littoral drift from the west, primarily associated with the coastal protection measures adopted in the adjacent cliffs at Barton, has led to a tripling of the cliff erosion rate since 1959 at Beckton which now averages about 2 m $yr^{-1}$ (Orangewoud, 1990). This rate of erosion is not experienced at Hordle Cliff though this zone of 'reactivation' appears to be migrating slowly towards Hordle. The low water mark is also receding at a similar rate and although an offshore bar is often developed beneath the low water mark, there is the danger of a steepening shoreface leading to greater wave energy at the beach and base of the cliff.

# 3 CHRISTCHURCH HARBOUR (5F-2)

## 3.1 Geology and Geomorphology

The solid geology of the area is essentially composed of Recent and Pleistocene valley gravels and alluvium that contrast with the more resistant rocks (Barton Group) at Hengistbury Head. The morphological characteristics of Christchurch Harbour are ultimately governed by the protection from wave attack that is provided by Hengistbury Head and so it has over evolutionary timescales been and remains an important feature. It is apparent that Hengistbury Head performs an important role in "anchoring" the planform of both Poole and Christchurch Bays, emphasising the importance of key geological controls in this area.

Structurally, a major fault runs through the harbour which possibly controls the form of Christchurch Ledge off Hengistbury Head. The rocks beneath the harbour appear to dip gently eastward. The lowland areas that occur consist mainly of river gravels and old alluvium deposits and silt laid down over the last 3000 years forming the present day salt marshes. A gravel embankment occurs towards Stanpit Marsh and Grimbury Marsh on the western side is formed from river deposits that may have been added to at a later date by dredged materials.

Details on the habitats that occur within the Harbour are presented in more detail within the Natural Environment section of the SMP.

The key aspects of note for the SMP relate to sediments inputs and outputs in Christchurch Harbour and how this may influence sediment dynamics along the open coast. Bray *et al* (1991) state that sediment input is possible at Christchurch Harbour and a significant delta of sands and sandy gravels is located immediately inside the entrance. This feature is believed to be attributed to transport and deposition on both the flood and ebb tides (Gao 1990). Fluvially derived sediments into Christchurch Harbour are believed to be low due to supply from chalk aquifers and interruptions to flow (from weirs etc).

More specific details on sediment transport within Christchurch Harbour are presented in the Conceptual Sediment Process Model Section of this Volume.

# 4 HENGISTBURY HEAD LONG GROYNE TO SANDBANKS FERRY SLIPWAY (5F-3)

## 4.1 Geology and Geomorphology

Warren Hill, which forms the high ground at Hengistbury Head, has a maximum elevation of over 36 m O.D. The headland has been designated a Site of Special Scientific Interest (SSSI) and has a national status for the geology and morphology of the eroded cliff.

The cliff has excellent exposures of Palaeogene, Barton Group sediments that comprise Boscombe Sand at the base overlain by Barton Clay. Hengistbury Head is an outlier of Barton Clay and its only exposure in the cliffs of Poole Bay.

The upper part of the Barton Clay at Hengistbury Head includes very fine-grained, buff and yellow, unfossiliferous, cross-bedded sands up to a maximum thickness of 10 m. These sands have been termed the Warren Hill Sand (Bristow, Freshney & Penn, op cit.) (Figure 1.3). Beneath the Warren Hill Sand the Barton Clay is a glauconitic, very clayey, fine-grained sand, or very sandy clay up to 16 m thick. It is sparsely fossiliferous, but the fauna is diverse and includes plants, foraminifera, molluscs, crustaceans, echinoids and fish, indicative of deposition in a shallow marine environment.

A distinctive feature of the Barton Clay at Hengistbury are the ironstone nodules, up to 1 m in diameter, which occur as impersistent layers at four levels within the Clay. These nodules were actively quarried between 1847 and 1865, their removal from the beach and foreshore, where they formed natural protection for the cliff, resulted in rapid erosion. A retreat of 32 m was noted between 1870 and 1907 and about half the headland is thought to have been lost between 1852 and 1932 (Turner, 1996).

The Boscombe Sand sits beneath the Barton Clay, and at Hengistbury comprises carbonaceous, silty sand with some bituminous sand overlying sand with flint pebble and cobble beds.

The cliff at Hengistbury Head from the rock groyne at Double Dykes to the Long Groyne is unprotected. The highest part of the cliff, which exceeds 30 m in height, is virtually a single face, with a slope of about 75° in its upper half and 45° to 55° in its lower half. Mass movement forms include minor run off gullying in the sandy units and small mud flows on to the beach. Some modest rockfall failures of the upper slope occur, though large scale failure of the upper cliff appears to be rare. An example that is available is a gully failure with an arcuate scar cut back into the gravel at the cliff top and a large toe of slumped debris, including ironstone nodules, protruding on to the storm beach. Further east towards the Long Groyne where the Boscombe Sand dips under the beach and the cliff is composed entirely of Barton Clay slumping and sliding has led to a shallower angled - 25° - lower cliff.

West of Hengistbury Head the Boscombe Sand continues around the cliffs of Poole Bay and underlies much of Bournemouth until it thins out east of Durley Chine. The pebble and cobble beds of rounded flint within the Boscombe Sand are well developed in the cliffs between Boscombe and Southbourne (Bristow, Freshney & Penn, 1991).

The Branksome Sand underlies the Boscombe Sand, which is a formation within the Palaeogene Bracklesham Group, a group that includes all the strata between the top of the London Clay and the base of the Barton Group. The Branksome Sand includes the sediments that were formerly termed the Bournemouth Freshwater Beds and the Bournemouth Marine Beds (Bristow, Freshney & Penn, op cit.) (Figure 1.3). It is well exposed in cliff sections from Bournemouth Pier west to Canford Cliffs. It consists of eight fining upward units, in other words, each with very coarse-grained sand at the base passing upward into coarse and medium sand and capped by interbedded fine-grained sand and silty clay. Some of the clays give rise to perched water tables and spring lines in the cliffs. A laminated carbonaceous brown clay and associated palaeosol commonly occurs at the top of the Branksome Sand and a spring line is often associated with this horizon.

The Branksome Sand is interpreted as a fluvial deposit with clays infilling channels although there is some minor evidence for a marine influence and connection to the sea (Plint, 1983).

The cliffs in Poole Bay from Poole Head to Southbourne are approximately 30 m high with a relatively smooth cliff top profile incised by a number of chines or valleys along its length. Many areas of the cliff at Bournemouth have been regraded to a slope angle of 35° and drainage, planting and engineering works have been undertaken to mitigate the problems of spring flow and slumping in the cliffs. The whole of this coast is now promenaded with the base of the cliff protected from wave attack. There still remain some good geological exposures in the cliffs west of Branksome Chine, east of Branksome Dene Chine and east of Bournemouth Pier.

The Poole Formation lies beneath the Branksome Sand at the base of the Bracklesham Group. Its only exposure in the cliffs is at Poole Head at the western end of Poole Bay. The Poole Formation consists of an alternating sequence of fine- to very coarse-grained, locally pebbly sands, and pale grey to dark brown, carbonaceous and lignitic, commonly laminated clays. The sands are generally thicker than the clays. Within the Poole Formation the clays are the product of marine transgressions and incursions associated with sands deposited in back-barrier lagoons (Bristow, Freshney & Penn, op cit.).

As with the cliffs of Christchurch Bay the Tertiary (Palaeogene) formations within the cliffs of Poole Bay are covered by a veneer of Quaternary sediment generally <2 - 3 m thick. These are River Terrace Deposits. On some geological maps these are shown as 'Valley Gravels' or 'Plateau Gravels' (Bristow, Freshney & Penn, op cit.) which are the previously used terms in the geological literature for these gravels.

The River Terrace Deposits consist mainly of flint gravel, which can be very sandy. Chert, 'sarsen' stone - a form of silicified gravel, and limestone are present as minor components; the limestone is likely to be of Jurassic age. East of Bournemouth Pier to Southbourne Blown Sand up to 7 m thick commonly covers these gravels. Blown Sand also covers the spit at Sandbanks at the entrance to Poole Harbour. The Sandbanks peninsula is simple in form with a single ridge of sand dunes up to a height of 50 feet (Robinson 1955). There are clear configuration differences between this area and that of South Haven Peninsula suggesting that the two are morphologically distinct. Whilst the shoreline of South Haven Peninsula is advancing, that at Sandbanks has retreated which is intimately linked to the erosion trend within Poole Bay as a whole.

Hook Sands is a significant feature within this Process Unit that is believed to be of strategic importance. One key impact that the feature has is to reduce wave energy and drive sediment movement onshore. The reduction in wave height introduces shoals that act to move fine material. The feature also plays a role in refracting storm waves from the south east so as to approach Sandbanks from the south contributing to an easterly drift of material in the Process Unit. This issue is discussed more fully in the Conceptual Sediment Process Model Section within this Volume.

This latter point is important in terms of future shoreline management within Poole Bay. It is without question that both Poole and Christchurch Bays, as crenulate bay shapes, have not established their equilibrium shape. Poole Bay does have a greater indentation than Christchurch Bay and as opposed to the more resistant Handfast Point headland further south, erosion at Hengistbury Head may possibly induce major instability and potentially rapid coastal retreat and readjustment within Poole Bay (HR Wallingford 1995).

# 5 POOLE HARBOUR (5F-4)

## 5.1 Geology and Geomorphology

Poole Harbour has a branched configuration of a valley system partly drowned by submergence. It rests on a portion of the Hampshire basin laid down in the Eocene, 60 million years ago, when this area was part of the bed of the Solent River (Fahy *et al* 1993). The basin thus contains a series of soft and unconsolidated sands, gravels and clays of fluvial origin (Poole Formation). Bedrock is almost absent within the harbour with the exception of a sandstone outcrop in the Haven Channel (Fahy *et al* 1993).

Poole Harbour owes its main outline to submergence (from about 8500 years before present) converting what was formerly a low moorland area with sandy knolls into a broad lagoon or estuary. The former knolls are now islands (Green, Furzey and Brownsea Islands). Submergence is most likely due to a combination of Holocene sea level rise, sinking land mass due to isostatic readjustment and slow local subsidence (HR Wallingford 1995). The maximum extent of the marine transgression, reached about 6000 years ago, is marked by a low bluff or by cliffs surrounding much of the Harbour above the present shoreline. Local sedimentary processes and reclamation have now extended the shoreline somewhat seaward seaward of the cliffs in sheltered areas with low lying beaches or mudflats (HR Wallingford 1995).

Recent deposits comprise layers of alluvium laid down by existing streams and in marshy areas of Poole Harbour, for example at Lytchett Bay. Sedimentation of these fine materials has kept pace with rising water levels to form the deep sediment column that now covers much of the Harbour.

The exact formation process for the sand spits at the mouth of the harbour is uncertain, particularly for the northern one. They have probably developed towards each other by different periods of longshore drift direction with material being supplied both from erosion of Bournemouth cliffs to the north and the bed of Studland Bay to the south (at different periods). Details on sediment transport pathways and the role of tidal currents in maintaining the Harbour mouth are described in full detail within the Conceptual Sediment Process Model Section.

The major human influence on the geomorphology of the shoreline here has been the large areas of land claim that have been undertaken primarily in association with agricultural land reclaim and to a lesser extent, port development and urbanisaton of the north-eastern shore. It has been estimated that the net result of these combined natural and human induced processes has been to reduce the harbour area at HWST by 20% (1000ha) over the last 6000 years (Gray 1985) to its present area of approximately 4000ha.

# 6 SOUTH HAVEN POINT TO HANDFAST POINT (5F-5)

## 6.1 Geology and Geomorphology

The geology of the coast has had an important influence in shaping the morphology of Studland Bay. Handfast Point is a major headland and is geomorphologically significant in that it represents a barrier to the transport of littoral sediments and thus cannot be ignored in terms of shoreline management. It is important as the headland separates a predominantly accretional bay (Studland) from an erosional one (Swanage Bay).

Studland Bay is cut back into sand and clay of the Bracklesham Group, Poole Formation (previously termed Bagshot Beds, Figure 1.3). An extensive dune system covers the peninsula south of South Haven Point and this extends to Studland village. The geomorphological history of this site is significant to mention as accretion is believed to have began here at approximately 400 years ago. Details of the physiographical evolution of the South Haven Peninsula are presented in detail in Diver's (1933) account. More detailed work has been carried out by the University of Bournemouth (1996). The north-eastern and central part of these dunes continue to be accreting with maximum rates of 3 - 4 m $yr^{-1}$ noted for the period 1933 - 1970 (Carr, 1971). However, during the last three years over 3m of the beach at Studland has been eroded and the National Trust are planning to move 60 beach huts inland as a precaution against their loss to the sea. A narrow outcrop of London Clay and Reading Formation sediments occurs in the southern corner of Studland Bay.

At Redend Point, a resistant iron rich sandstone forms low steep cliffs. Erosion along this segment supplies small amounts of clays and sands (Bray *et al* 1991).

# 7 HANDFAST POINT TO PEVERIL POINT (5F-6)

## 7.1 Geology and Geomorphology

The geological structures of the Palaeogene, Cretaceous and Jurassic rocks which crop out along the coast to the south of Poole Harbour are aligned east – west, forming east-west trending ridges and valleys behind the headlands and bays such as Swanage Bay and Durlston Bay further south. The link between geology and geomorphology is important to make here. Swanage Bay is formed by the erosion of soft rock cliffs. These are fronted by a sand shingle beach. By contrast, Durlston Bay is formed within rocks of modest resistance and is fronted by a rocky boulder strewn shore.

The narrow outcrop of London Clay and Reading Formation sediments that occurs to the north (southern corner of Studland Bay) rest unconformably on the steeply dipping Cretaceous Chalk of Ballard Down which forms the cliffed headland between Handfast Point and Ballard Point. These attain a height of 117m at Ballard Cliff. The headland itself lies on the Purbeck - Wight Disturbance, a major monoclinal structure that runs across the outer part of Poole and Christchurch Bay to The Needles (Figure 1.1). May and Heeps (1985) have provided a review of sediment inputs derived from Chalk cliffed coastlines, concentrating on specific sites within Dorset including Ballard Down. It is concluded that where Upper Chalk (which is the most jointed and generally weakest) outcrops, there is a higher rate of retreat, though the height of the cliffs and the local dip of the chalk are all considerations on cliff top retreat rates for the area. The north facing chalk cliffs at Handfast Point (20-30m in height) are less exposed to direct wave attack and are characterised by a less steep profile with a central truncated debris slope. Consequently, erosion is probably less than recorded for the exposed coast (May and Heeps 1985). Nevertheless, chalk debris is reported at the foot of the cliff indicating periodic supply by rockfall and weathering. This debris tends to be eroded rapidly on the foreshore, but flints contained therein are released and can contribute to beaches.

On the south side of Ballard Down a narrow outcrop of Greensand and Gault Clay, also dipping steeply north, forms the northern margin of Swanage Bay. Red and grey Wealden clay and sand form the cliffs behind Swanage Bay. The Wealden sediments are relatively soft compared to their flanking headlands, and the bay, which is 2.5 km wide, is cut back over a kilometre between Ballard Point and Peveril Point.

At New Swanage the cliffs reach over 20m high and gradually increase in height to the northern end of the bay. The Wealden sediments dip north at angles of 16° to 28°; the apparent dips are shallower. There are at least three beds of competent sands which form high (8 - 10 m) steep features on the cliff top and these are interbedded with red and grey clay. There is prominent red clay which is about 8 - 10 m high between two of these sands with a good spring line at its top. The red clay is disturbed by slumps and slides which has pushed debris over the promenade. The multi-storey concrete chalets on the promenade are, in some cases, protecting the cliff from further collapse but the apparent lack of drainage behind the chalets and adjacent mass movement means the structures are likely to be in jeopardy. There is also some faulting in the cliff which downthrows sediment to the south.

The cliff is being eroded north of the sea wall promenade and the groynes on the beach. It is extensively disturbed by slumps and slides with small scale gullying and seeps. The sediments are poorly lithified. Towards the northern end of the bay the storm beach becomes wider because of the northern littoral drift in the bay. This gives better protection to the toe of the cliff and enabled vegetation to become well established.

Folded Lower Cretaceous Durlston Beds form the headland at Peveril Point (Arkell, 1947, House, 1989). The small syncline extends offshore to form the Peveril Ledges. As well as providing important geological exposures for conservation, Peveril Point headland plays a significant geomorphological role as it functions as an effective barrier to the transport of littoral sediments around it.

# 8 PEVERIL POINT TO DURLSTON HEAD (5F-7)

## 8.1 Geology and Geomorphology

Durlston Bay is formed within rocks of modest resistance and is fronted by a rocky boulder strewn shore. South of the Peveril Point headland, the Purbeck Beds comprise cliffs of interbedded limestone and mudstone dipping at about 8° - 12° north. The limestones are well jointed and the erosion of the mudstones produces large blocks of tabular limestone on the beach. There are some faults in the central part of the cliff, an area which includes some slumps and falls which have necessitated slope protection. In the southern half of Durlston Bay the cliffs are shallower and generally well vegetated, although there is evidence for on-going mass movement in this area. The junction of the Purbeck Beds and the Portland Bed limestone which forms Durlston Head is disturbed by faulting.

# 9 OFFSHORE GEOLOGY AND GEOMORPHOLOGY

The description of the offshore geology includes the embayment of Poole Bay and Christchurch Bay out to the 20 m depth contour which equates approximately to a line drawn between The Needles and Durlston Head. The eastern limit of the offshore area is the Needles Channel.

## 9.1 Morphological Description

Christchurch Bay has a generally shallower shoreface than Poole Bay. The implication of this is a potentially greater refraction and shoaling of incident waves within the Bay. The 10 m contour lies at 3 to 5 km offshore in Christchurch Bay and joins two shoals at either end of the Bay. The western shoal is a south-east trending narrow platform of rock known as Christchurch Ledge which forms a submerged, 5 km long promontory, generally <5m deep, offshore from Hengistbury Head. The eastern shoal is the gravel bank of The Shingles. This trends south-westwards for about 7 km off Hurst Spit and much of it is at or just below zero water depth (Chart Datum). Sand banks at Dolphin Bank and Dolphin Sand form an outer barrier across Christchurch Bay at depths of 6 to 14 m outside a line from the end of The Shingles to Christchurch Ledge.

In Poole Bay the shoreface down to 10 m is steeper, the contour forms the south-western margin of Christchurch Ledge and at Hengistbury Head it is only 500 m offshore. West across Poole Bay the 10 m contour continues close to the shore only reaching a kilometre width off Bournemouth Pier. In front of Poole Harbour and across Studland Bay it widens to 3 km before returning to within a kilometre at Handfast Point and Durlston Head. Sand shoals associated with ebb tidal sedimentation lie on either side of the entrance to Poole Harbour.

The sea bed of the embayment is formed of three principal sedimentary deposits

- Solid geological outcrops of Jurassic, Cretaceous and Tertiary rocks
- Quaternary Palaeovalley infill deposits
- Mobile superficial sediments

## 9.2 Solid Geology

The solid geology of the Poole - Christchurch Embayment is formed principally of sediment and rock of Tertiary (Palaeogene) age. The most extensive deposits are Bracklesham Group sediments. Barton Group sediments are confined to a narrow shore parallel corridor off the coast of Christchurch Bay from Highcliffe to Hurst Spit, and as a faulted block forming Christchurch Ledge off Hengistbury Head.

The southern limit of the embayment is closely aligned with the Purbeck - Wight Disturbance, a major monoclinal structure which runs from Handfast Point to The Needles (Figure 1.1). The core of the monocline is formed of Cretaceous Chalk with a thin occurrence of London Clay on its northern limb and thin Greensand to the south. Cretaceous Wealden Group strata extend offshore from Swanage Bay and continue to the south of the Disturbance. The Purbeck Group limestone and mudstone at Peveril Point and in Durlston Bay only continue offshore for about 4 km (Andrews and Balson, 1995).

Knowledge of the offshore solid geology is limited. The information available is based on individual grab sampling and coring, and some seismic profiling. This does not allow detailed mapping of the geology to formation level as is possible onshore. Hence the offshore solid geology can only be mapped to the more simplified group level (Figure 1.1).

Solid bedrock outcrops and areas of very thin sediment cover occur extensively at the sea bed within the embayment. These include the eastern part of Christchurch Bay adjacent to the Needles Channel, around the Chalk headland at Handfast Point, Christchurch Ledge off Hengistbury Head, Peveril Ledge in the Purbeck Beds at Swanage and around Durlston Head. Numerous small bedrock exposures occur within the central part of the embayment, where they form elongated ridges trending predominantly NW-SE, parallel to the strike of the Tertiary strata (Velegrakis, 1994).

Exposed bedrock is common close to the coast and in these exposures gully erosion has been observed perpendicular to the coastline. These gullies occur in Chalk and Tertiary strata, although they are deeper and more closely spaced in the Chalk.

## 9.3 Quaternary deposits

Velegrakis (1994) identified seven palaeovalleys or palaeovalley complexes in the embayment. Only the western palaeovalleys in Poole Bay have thick infills of sediment. Elsewhere infill sediments are absent, or are thin and of limited extent. Fluvial sediments are present in the majority of palaeovalley complexes but form only thin basal deposits of coarse sediment. The thickness of unconsolidated sediment in the Poole-Christchurch embayment, including palaeovalley infill sediment is shown in Figure 1.2.

## 9.4 Mobile superficial sediments

The mobile sediments are controlled, totally or partially, by the contemporary hydrodynamic regime within the embayment. Where present, they form very thin sheets of sediment spread over the sea bed or relatively thick accumulations associated with sand banks, gravel banks and ebb-tidal deltas.

Gravels form localised deposits over the Shingles Bank, adjacent to the Needles Channel, and east of Handfast Point in south-west Poole Bay. Sandy sediments with some extensive areas of sandy bedforms occur inshore in Poole and Christchurch Bays, in the ebb-tidal delta of Poole Harbour, Hook Sands and Dolphin Sands. Muddy sands, possibly associated with Tertiary mud bedrock, lie within central Poole Bay. Coarser deposits of sandy gravel form extensive deposits on the sea bed in western Poole Bay and south of the Dolphin sand banks (Velegrakis, 1994).

The thickest deposits of superficial sediments are associated with the Poole Harbour and West Solent tidal inlets and the Shingles and Dolphin Banks with over 9 m of sediment and a maximum recorded of 11 m. Some of the thickest accumulations include palaeovalley infill sediments (Figure 1.2).

Sediment movement follows transport pathways which are controlled by three processes (Brampton & Evans, 1997)

- Tidal flow through coastal inlets
- Wave-induced currents

- Tidal currents of the English Channel

Medium- and coarse-grained sediment are the dominant grade of sediment which accumulates within the embayment. Fine-grained sediments are not stored, even though the erosion of Tertiary sediment in the embayment generates large quantities of mud. Fine sediment is either lost offshore beyond the embayment or deposited locally within the marshes and creeks of tidal inlets (Gao, 1992).

Henderson's (1979) work theoretically indicated a potential for littoral drift divergence in the vicinity of Durley Chine, with sediments moving east from Bournemouth past Hengistbury Head and along Christchurch Bay to Hurst Spit. This finding was supported by work carried out by Hydraulics Research (1991) though the levels of accuracy in terms of drift rates, volumes and the actual location of the drift divide are still open to debate. Robinson (1955) and anecdotal evidence from recent schemes indicate an easterly drift.

Sediment drift at Hurst Spit is caught in the West Solent tidal system but generally flows south-west along the south eastern edge of the Shingles Bank where the main tidal flow occurs. It then flows west-south-west over Dolphin Bank and Dolphin Sand. Sediment drift is variable as far as Poole Sandbanks where littoral drift modelling (HR Wallingford 1991) revealed (from computational work) a drift reversal west of Sandbanks car park with net westwards drift continuing towards the Haven Hotel (Bray *et al* 1991). Anecdotal evidence, however, based on beach response to recent coastal defence works indicates an easterly drift, possibly episodic. Overall, the drift in this area is clearly variable. It appears that drift fails to accumulate at the Haven Hotel vicinity and instead material is entrained by tidal currents in Poole Harbour Entrance.

There is anecdotal evidence based on recent beach response to coastal defence schemes of an episodic onshore sediment supply from Hook Sands to Poole Sandbanks. This is also reported for the first stone groynes built in 1896/1898 (Robinson 1955) although interaction of Hook Sands with the coastline does undoubtedly change over time and in response to conditions at particular times.

The banks and ebb-tidal deltas of the embayment are areas of sediment accumulation which act as "stores" of sediment rather than permanent "sinks" because exchanges of sediment, both positive and negative, can be associated with these features (Velegrakis, 1994).

## References

Allen, L.G. And Gibbard, P.L., 1993. Pleistocene Evolution Of The Solent River Of Southern England. *Quaternary Science Reviews*, 12, 503-528

Andrews, I.J. And Balson, P.S. (1995): Wight. Solid Geology, 2nd Edition. *British Geological Survey. Map 50°N-02°W.* Scale 1:250,000.

Arkell, W.J. 1947. The Geology Of The Country Around Weymouth, Swanage, Corfe And Lulworth. *Memoir Of The Geological Survey Of Great Britain.* Sheets 341, 342, 343 And Portions Of Sheets 327, 328, 329 (England And Wales).

Barton, M E.1973. The Degradation Of The Barton Clay Cliffs Of Hampshire. *Quarterly Journal Of Engineering Geology,* Vol.6 , P.423-440.

Barton, M E, And Coles, B J.1984. The Characteristics And Rates Of The Various Slope Degradation Processes In The Barton Cliffs Of Hampshire. *Quarterly Journal Of Engineering Geology,* Vol.17, P.117-136.

Brampton, A.H. And Evans, C.D.R. 1997. Seabed Sediment Mobility Study. *CIRIA Interim Report* Rp549/9

Bray, M.J., Carter, D.J. And Hooke, J.M., 1995. Littoral Cell Definition And Budgets For Central Southern England. *Journal Of Coastal Research*, 11, (2), 381-400.

Bray, M.J., 1993 Hengistbury Head Coast Protection Works : Impacts and Impiciations. Report to Bournemouth Borough Council, prepared by Univ. of Portsmouth

Bray, M.J.; Carter, D.J. And Hooke, J.M., 1991. *Coastal Sediment Transport Study* (5 Vols). Report To SCOPAC, Department Of Geography, Portsmouth Polytechnic. 498p. Plus 32 Maps.

Bristow, C.R., Freshney, E.C. And Penn, I.E. 1991. Geology Of The Country Around Bournemouth. *Memoir Of The British Geological Survey.* Sheet 329

Burton, E, St John. 1931. Periodic Changes In The Position Of The Run At Mudeford Near Christchurch, Hants. *Proceedings Of The Geologists' Association.* Vol.42, P.157-174.

Carr, A.P. 1971. South Haven Peninsula: Physiographic Changes In The Twentieth Century. P. 32-37 *In* Merret, P (Ed). *Cyril Diver: A Memoir.* (Furzebrook; Nature Conservancy Council)

Clasby, P.S. 1971. The Coast Protection Works At Barton-On-Sea. *Tertiary Times.* Vol.1, No.3, P.77-83.

Devoy, R.J.N., 1982. Analysis Of The Geological Evidence For Holocene Sea-Level Movements In Southeast England. *Proceedings Of The Geologists' Association*, 93 (1), 65-90.

Dyer, K.R. 1975. The Buried Channels Of The 'Solent River', Southern England. *Proceedings Of The Geologists' Association,* Vol.86, No.2, P.239-245.

Everard, C.E. 1954. The Solent River: A Geomorphological Study. *Transactions Of The Institute Of British Geographers.* Vol.20, P.41-58

Fahy, F.M, Hansom.J.D and Comber.D.P.M. *1993 "Estuaries Management Plans – Coastal Processes and Conservation in Poole Harbour".* Coastal Research Group, Dept. of Geography and Topographic Science, University of Glasgow.

Gao, S. 1990. *Sediment Dynamics of Tidal Inlet Systems with special reference to Christchurch harbour.* Unpublished Ph.D upgrading Report., Department of Oceanography, Southampton University, 44pp.

Gao, S. 1992. *Sediment Dynamics And Stability Of Tidal Inlets.* Unpublished Ph.D., Department of Oceanography, Southampton University.

Gray.A.J 1985 Poole Harbour : Ecological Sensitivity Analysis of the Shoreline. Report prepared for BP Petroleum Development Ltd. Pub. Institute of Terrestrial Ecology.

Hamblin, R.J.O. And Harrison, D.J. 1989. The Marine Sand And Gravel Resources Off The Isle Of Wight And Beachy Head. *British Geological Survey Technical Report,* No.Wb/89/41c.

Hooke, J.M. And Riley, R.C. 1987. *Historical Changes On The Hampshire Coast, 1870 - 1965.* Department Of Geography, Portsmouth Polytechnic, Report To Hampshire County Council

Hooker, J.J. 1986. Mammals From The Bartonian (Middle/Late Eocene) Of The Hampshire Basin, Southern England. *Bulletin Of The British Museum (Natural History) Geology,* Vol. 39, P191-478.

House, M.R. 1989. *Geology Of The Dorset Coast.* Geologists' Association Guide

HR Wallingford, 1995. *Poole Bay Strategy Study.* Report Ex 2881 To Poole Borough Council. 112p.

HR Wallingford, 1991. *Poole Bay Sediment Study.* Report Ex 2153

Lacey, S., 1985. *Coastal Sediment Processes In Poole And Christchurch Bays, And The Effects Of Coast Protection Works*, Unpublished Phd Thesis, Department Of Civil Engineering, University Of Southampton, 372p.

May V and Heeps C, (1985), 'The Nature and Rates of Change on Chalk Coastlines', *Zeit. Geomorph. N F Suppl. Band*, 57, 81-94

Melville, R.V. And Freshney, E.C. 1982. *British Regional Geology: The Hampshire Basin* (London: Hmso For The Institute Of Geological Sciences)

Motyka, J.M. And Brampton, A.H. 1993. Coastal Management: Mapping Of Littoral Cells. *Hr Wallingford Report,* No.Sr328.

Nicholls, R J.1985. *The Stability Of Shingle Beaches In The Eastern Half Of Christchurch Bay.* Unpublished Ph.D. Thesis, Department Of Civil Engineering University Of Southampton. 468p.

Nicholls, R J.1986. The Evolution Of The Upper Reaches Of The Solent River And The Formation Of Poole And Christchurch Bays. P99-114 *In* Barber, K.E. (Ed) Wessex And The Isle Of Wight: *Quaternary Research Association Field Guide*

Nicholls, R.J. And Webber, N.B., 1987. The Past, Present And Future Evolution Of Hurst Castle Spit. *Progress In Oceanography,* 18, 119-137.

Oranjewoud International B.V. 1990. *Hampshire's Coast: Christchurch Bay - West Solent, Framework For Coastal Defence.* Report To Hampshire County Council. (Heerenveen, The Netherlands) Code:28241

Plint, A.G. 1983. Facies, Environments And Sedimentary Cycles In The Middle Eocene, Bracklesham Formation Of The Hampshire Basin: Evidence For Global Sea Level Changes. *Sedimentology*, Vol. 30, P625-653.

Prestwich, J. 1849. On The Position And General Characters Of The Strata Exhibited In The Coast Section From Christchurch Harbour To Poole Harbour. *Quarterly Journal Of The Geological Society Of London*. Vol. 5, P43-49.

Reid, C. 1905. The Island Of Ictis. *Archaeologica*. Vol. 59, P.281-288.

Turner, N. 1996. Poole Bay And Hengistbury Head. P23-31 *In* Bray, M J. *Excursion Guidebook: Poole And Christchurch Bay: Geomorphology And Shoreline Management*. Littoral '96: Post Conference Study Tour, University Of Portsmouth.

Velegrakis, A.L., Dix, J. & Collins, M.B. In Press - To Appear In Marine Geology.

Velegrakis, A.F. 1994. *Aspects Of The Morphology And Sedimentology Of A Transgressional Embayment System: Poole And Christchurch Bays, Southern England*. Unpublished Ph.D., Department Of Oceanography, Southampton University. 319pp.

West, I.M. 1980. Geology Of The Solent Estuarine System. P.6-19 *In* The Solent Estuarine System. *N.E.R.C. Publications, Series C*. No.22.

Wright, P. 1982. *Aspects Of Coastal Dynamics Of Poole And Christchurch Bays*, Unpublished Phd Thesis, Department Of Civil Engineering, University Of Southampton, 201p.