Christchurch Bay and Harbour Flood and Coastal Erosion Risk Management Study

Technical Annex 2: Option Appraisal and Economic Assessment for Christchurch Bay

Prepared by

New Forest District Council

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2	1	Revised Draft	2008	S Cook
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Contents

1 Background

1.1 General

This report presents the work undertaken in the economic appraisal of coastal defence options for the coastline between Hengistbury Head and Hurst Spit. The appraisal seeks to determine the best value for money option for Christchurch Bay. In the first instance this involved definition and evaluation of the do nothing scenario for coastal erosion for the majority of the frontage along with tidal flooding at Christchurch Harbour and Hurst Spit. The do nothing scenario provides the baseline for the assessment of all defence options.

The majority of this frontage is primarily at risk from coastal erosion, with some low-lying land at risk from tidal flooding. The benefit cost analysis for the bay has been divided into the management units defined in the first round Poole and Christchurch Bays SMP (1999), as shown in Table 1.

Unit	Start Unit	End Unit
CHB1	Harbour Side Of Mudeford Spit	Harbour Side Of Mudeford Spit
CHB2	South Side Of Christchurch Harbour	South Side Of Christchurch Harbour
CHB3	Stanpit	Grimbury Marshes
CHB4	Mudeford Town Frontage	Mudeford Town Frontage
CHB5	Mudeford Quay	Mudeford Quay
CBY1	Hengistbury Long Groyne	Tip Of Mudeford Sandbank
CBY2	Mudeford Sandbank	Chewton Bunny
CBY3	Chewton Bunny	Start Of Defence At Barton-on-Sea
CBY4	Start Of Defence At Barton-on-Sea	Barton Golf Course
CBY5	Barton Golf Course	Hordle Cliff
CBY6	Hordle Cliff	Hurst Beach
CBY7	Hurst Beach	Tip of Hurst Spit

Table 1. SMP1 Management Units

The economic benefits of various intervention options have been calculated following the procedures recommended in MAFF's (now Defra) Flood and Coastal Defence Project Appraisal Guidance 3 (FCDPAG3). The supplementary note issued to Operating Authorities in March 2003, "Revisions to Economic Appraisal Procedures Arising From The New HM Treasury Green Book" and guidance notes issued by Risk and Policy Analysts Ltd on the new multicoloured manual have been incorporated into this benefit cost analysis. The benefit of erosion and flood protection measures has been calculated as the value of damages that would be averted by implementing a Option. Thus, an assessment of the damage caused under the do-nothing option has been carried out.

2 Sources of Economic Data

2.1 Property Values

Damage to property upon defence failure could either be through complete loss as a result of erosion of the coastline, or alternatively water damage from flood inundation. If the property is lost, the capital value of the property is taken as the value of that loss, whereas if the property is flooded, a cost including damage to both the building fabric and contents is used.

Properties within the management units deemed to be 'at risk' were identified using O.S. mapping and ortho-rectified photography. Capital valuations for properties located within the 'at risk' areas were obtained from local Estate Agents and internet property sites by obtaining valuations for properties on the housing market and actual as sold values. Valuations for properties that could not be identified by these means were estimated by using valuations from similar properties within the same area. Property values have been updated to 2004 valuations (quarter 4) using the Nationwide house price index for the Southwest region.

Damage to property due to flooding is dependent on the flood depth and the generic type of property. Residential properties were classified by the nature of the property (flat, semi-detached, etc.) whilst damage to commercial properties was indicated by the service it provided (shop, garage, etc). Standard monetary values from "The Benefits of Flood and Coastal Defence: Techniques and Data for 2003" ('Multicoloured Manual', Penning-Rowsell et al, 2003) were used to calculate flood damage values. These flood damage values were adjusted to December 2004 values according to the appropriate Retail Price Index.

2.2 Amenity Values

The approximate capital values of various permanent amenities contained within the 'at risk' areas are included in the analysis. Such amenities include, for example, car parks, beach huts and public conveniences. Whilst this provides a monetary basis for the analysis, the true value of such amenities to the community is difficult to gauge, and therefore it should be noted that a low capital value assigned to an amenity may not properly justify its continued protection. This is particularly true for the undeveloped open space on the frontage in unit CBY7, between Marine Drive and the clifftop, which has been given an approximate capital value of £100,000/ha in the analysis. This value is based on an assessment provided by the District Council's Estates and Valuations team. It should also be noted that due to the prime seafront location of this open space, such a valuation is not considered excessive.

3 CBY1 Hengistbury Long Groyne to tip of Mudeford Sandbank

3.1 CBY1 – Extent of Frontage

The unit can be broadly split into two distinct frontages, the cliff section of Hengistbury Head and the low lying Mudeford Spit. The whole of the unit lies within the boundary of Christchurch Borough Council. The unit is defended along much of its length by rock groynes and a rock revetment.

There are 344 beach huts on the sandbank, for which overnight sleeping is allowed. This increases the summer resident population by more than 2000. There are also numerous other assets, including; five toilet blocks, a beach office and a cafe.

3.1.1 Do Nothing

An extensive study undertaken by HR Wallingford (Mudeford Sandbank, Coastal Defence Strategy – Preliminary Studies, Report EX 3970, January 1999) details the various failure scenarios behind the do-nothing option. Reference should be made to this study for a full explanation behind the do-nothing and subsequent failure scenarios. The do-nothing option would lead to the eventual failure of the existing defences, along with the erosion of the sandbank, resulting in beaching and increased flooding.

Three possible breach scenarios are identified and considered within the study, as detailed below.

Breach Scenario 1: A breach at the root of the Sandbank

This assumes a breach at the root of the Sandbank, exposing Christchurch Harbour to increased wave activity and, due to the increased restriction in flow, an increased tidal range.

Breach Scenario 2: A breach at the root of the Sandbank

Again this assumes a breach at the root of the Sandbank, but at the southern end of the seawall and promenade. The consequences would be as mentioned above.

Breach Scenario 3: A breach at the distal end of the Sandbank

This assumes that a breach would form downdrift of the last groyne, resulting in the flows through the Mudeford Quay navigational channel (locally termed the Run) being significantly altered. Mudeford Quay and the Christchurch Harbour defences would be exposed to increased wave activity.

3.1.2 Evaluation of Do Nothing Damages

Table 2 details the assets that are on Mudeford Sandbank.

Item	Number	Market Value (£M)	Annual Income (£m)
The Black House	1	0.29	
Beach huts @ £90,000	344	30,96	0.73
Fisherman huts @ £23,000	5	0.115	
Beach Office	1	0.005	
Workshop	1	0.01	
Beach House café	1	0.165	
Toilet blocks	5	0.35	
Land train terminus	1	0.005	
Ferry pontoon	1	0.056	

Table 2. Mudeford Sandbank Assets

Breach Scenario 1: A breach at the root of the Sandbank
Under this scenario losses will occur due to increased flooding of properties around Christchurch Harbour with losses to the assets on the sandbank. Including:-

- 27 beach huts lost
- 12 beach huts untenable due to increased water levels
- 1 toilet block lost
- Water service disrupted to beach huts
- Access road severed
- Access to Sandbank disrupted
- Land train access lost
- Amenity value reduced

Breach Scenario 2: A breach at the root of the Sandbank
Under this scenario losses will occur due to increased flooding of properties around Christchurch Harbour with losses to the assets on the sandbank. Including:-

- 13 beach huts lost
- 1 toilet block lost
- Water service disrupted to beach huts
- Access road severed
- Access to Sandbank disrupted
- Land train access lost
- Amenity value reduced

Breach Scenario 3: A breach at the distal of the Sandbank
Under this scenario losses will occur due to increased flooding of properties around Christchurch Harbour with losses to the assets on the sandbank. Including:-

- 20 beach huts lost
- 32 beach huts untenable due to increased water levels
- 1 toilet block lost
- Black House lost
- fisherman huts lost

3.2 Intervention Options – CBY1

3.2.1 Introduction

The options for CBY1 have been considered within CHB1

3.3 Benefit Cost Assessment – CBY1

3.3.1 Introduction

The options for CBY1 have been considered within CHB1

4 CBY2 Mudeford Sandbank to Chewton Bunny

4.1 CBY2 – Extent of Frontage

The extent of this unit includes the low lying area at Mudeford Quay through to Chewton Bunny; the whole of this unit lies within the boundary of Christchurch Borough Council. To the west the unit is defended with varying concrete seawalls, along with timber groynes and strongpoints. While the central section between the Coastguard Station and Highcliffe Castle is undefended. The eastern end of the unit from Highcliffe Castle through to Chewton Bunny is defended by a rock armour revetment and a number of strongpoints.

The full extent of this unit includes a high proportion of apartment developments along with large detached houses. There are also five public car parks and approximately 259 beach huts. The Maritime & Coastguard Agency training centre is located at Steamer Point.

4.1.1 Clifftop Recession

Under the “do-nothing” option, following the failure of the existing defences the coastline is assumed to erode at a constant rate of 0.68m/year (Poole & Christchurch Bay SMP 1999) until year 2044. Future coastal recession from year 2044 has been assessed on forecast erosion rates, which will occur within the Naish boundary of 1.48m/year. This rate has been calculated as the average of the upper and lower rates assessed for Naish. Asset condition assessments of the existing defences have been undertaken to determine when failure is likely to occur (Technical Annex Assessment of Standards of Service) and therefore when coastal erosion will commence. This information is summarised in Table .

Section	Start of Recession	Length (m)
Start of CBY2 to eastern end of Avon Run CP	2024	620
Eastern end Avon Run CP to 22 Avon Run Road	2034	220
22 Avon Run Road to Southcliffe Road	2024	140
Southcliffe Road to Seaway Avenue	2014	380
Seaway Avenue to eastern end MCA	2024	325
Highcliffe Castle	2021	700
Highcliffe Castle east to Chewton Bunny	2019	1350

Table 3. Commencement of Cliff Recession

The specified erosion lines were plotted on OS maps in 10 year time bands, allowing assets to be classified with a predicted year of loss, these projected recession lines have also been plotted on the 2001 ortho-rectified aerial photographs.

4.1.2 Evaluation of Do Nothing Damages

The assets at risk from erosion consist mainly of residential properties, with a small number of commercial premises and beach huts.

For the eastern section of the frontage (Highcliffe Castle to Chewton Bunny) there is a “buffering” zone between the clifftop and the first line of properties. This zone generally comprises of amenity land, a public car park along with a section of large rear gardens for 27 to 35 Wharncliffe Road, meaning that the majority of properties are set back a distance of approximately 35 to 105 metres from the cliff edge and would only become vulnerable after some considerable time (47 plus years) under a do-nothing strategy. The approximate area of amenity land that would be lost through erosion is shown in Table 4. The section between Warncliffe Road and Highcliffe Castle consists mainly of apartment buildings with a small number of large detached properties. These apartments (Palma Court through to Hambledon Court) will not be affected until years 42 to 50, when erosion of the clifftop will have reached the properties. The large detached properties (accessed via Rothesay Drive) are located much closer to the cliff edge. These properties will become vulnerable from year 20 through to year 52. Highcliffe Castle itself will not be at risk within the 100 year period, although the car park and an area of the grounds will be lost. It is anticipated that the 100 year erosion line will be located approximately 20 metres from the Castle.

Year	Area (Ha)	Value (£)
0 - 20	0.7	70,000
20 - 30	1.4	140,000
30 - 40	1.4	140,000
40 - 50	2.6	260,000
50 - 60	2.3	230,000
60 - 70	2.3	230,000
70 - 80	2.2	220,000
80 - 90	1.7	170,000
90 - 100	1.5	150,000

Table 4. Amenity Land Erosion

The Maritime & Coastguard Agency training centre located at Steamer Point will start to become vulnerable to erosion from year 40. The properties on Freshwater Road, Medina Way, Vecta Close are located some 85 metres from the front and will not be affected until year 78. At Cliff Drive the southern properties will be come vulnerable from approximately year 46, with the northern properties being affected from year 72 when the access will be lost. The section from Southcliffe Road, through Avon Run Road to Sandhills Caravan Park consists mainly of high value detached properties. These properties are located close to the front and will become vulnerable when the access is lost, approximately year 40 to 50. The first row of caravans at the park are located directly behind the seawall and will become vulnerable once failure occurs, this will be in approximately year 20.

Within the western frontage there are a number of assets that will become vulnerable as failure occurs of the various defences. These are generally recreational assets, such as; beach huts, a café, public conveniences and car parks. There are five public car parks within the erosion risk area, along with one private car park. Table 5 identifies these along with the forecast year of erosion risk and annual income.

Car Park	Erosion Year	Annual Income (£)
Highcliffe	60	80,400
Highcliffe	55	44,500
Steamer Point	60	38,000
Avon Run Road	50	47,000
Avon Run	20	25,000

Table 5. Public Car Parks at Risk

There are a significant number of beach huts within this unit, at Friar's Cliff there are 139 beach huts, which fall under the jurisdiction of Christchurch Borough Council. The annual income from each hut is £617 in the form of an annual licence fee. At Avon Beach there are approximately 150 huts, managed by a private company. These huts are rented on a daily (£15), weekly (£79) or seasonal (£622) basis. The market value of each beach hut is approximately £20,000. Table 6 details values and incomes generated from the beach huts.

Beach Hut Site	Erosion Year	Number of Huts	Market Value (£m)	Annual Income (£)
Friars Cliff	10	139	2.78	85,763
Avon Beach	20	150	3	241,433

Table 6. Beach Huts at Risk

Annual recreational losses have been determined using the data provide in the Multi-Coloured Handbook and the Multi-Coloured Manual (MCM). The frontage is an important recreational asset, attracting both day and staying visitors to the area. Figures from Christchurch Borough Council suggest that some 195,000 staying visitors and 720,000 day visitors are attracted to the area each year. The loss of visitors as a result of erosion of the frontage is considered to result in an economic loss, as the seafront is a major recreational asset.

The proportion of the total visitors that would be lost because of the lack of seafront amenities is extremely difficult to gauge due to the alternative attractions of a visit to the area, such as the New Forest, Bournemouth and Poole. However it is considered reasonable to assume that half of the total would not visit the area under a do-nothing strategy.

Under the do-nothing option there are a number of scenarios that will have an adverse impact on the recreational use of the frontage, these are:-

- Changes in beach composition: e.g. from sand to coarse material such as pebbles affecting the suitability of the beach for sitting, walking and children's play.

- Changes in beach profile: as a beach steepens its value for walking, sitting and lying will be reduced.

- As the beach is lowered by erosion, the seawall will become undermined or damaged.

- Where the beach is lowered by erosion, there may be a steep drop or steep steps from the seawall to the beach making access inconvenient or unsafe.

- Damage to the seawall may make the seafront appear dilapidated and visually unattractive.

- With undermining, slumping and collapse, promenades and seawalls may become dangerous and access may in extreme cases be restricted or closed altogether.

- Damaged groynes may initially appear unattractive and may thus reduce enjoyment. Eventually the dilapidation of the groynes may present a hazard to beach visitors.

- Lowering of beaches may make access over groynes difficult or hazardous. With long shore drift, different levels of beach material may build up on either side of groynes creating a further potential hazard.

- Increasing cliff top erosion may make the cliff edge unstable and dangerous. This may result in access to the cliff edge and views being restricted.

- Erosion or flooding may damage or destroy access steps or ramps from cliff top to beach or seawall resulting in restrictions on or closure of access.

Data from Table 8.6 of the MCM has been used to determine annual recreational losses. From the table average costs for "Yellow Manual Standard data: 4 sites", "Lee-on-Solent" and "Herne Bay" have been used. The monetary value of losing staying visitors was evaluated at £785,000 and for day/local visitors at £1,050,000.

The PV damage for the do-nothing scenario is shown in Table 7 (see Annex A for detailed FCDPAG3 project summary sheets).

Scenario	PV Damages (£)
Do Nothing	40,340,000

Table 7. Do Nothing PV Damages

A summary of those assets identified as being within the 100 year period is shown in Table 8.

Year	Number	Value (£M)
1 to 10	Beach huts & caravans	3,28
11 to 20	9 + beach huts	5,833
21 to 30	38	10,498
31 to 40	10	7,263
41 to 50	90	29,575
51 to 60	47	12,688
61 to 70	36	9,554
71 to 80	34	20,483
81 to 90	36	12,291
91 to 100	54	22,270
Total	354	130,455

Table 8. Summary of Erosion Damages (not discounted)

5 Intervention Options – CBY2

5.1 Introduction

The following sections identify and cost those defence intervention options that have been considered in the benefit cost analysis. These options include such works as, removing existing defences, reconstruction of the seawalls and beach recharge. Maintenance of the existing defences has also been considered.

5.2 Optimism Bias

As part of the FDCPAG3 Economic Appraisal the quantification of project risk is dealt with by utilising a factor known as "Optimism Bias" and is used to provide a suitable uplift to early best estimates of project costs, thereby reducing the effect of under estimating project costs.

The guidance provide by Defra suggests that for a strategy study a starting value of 60% should be used for the Optimism Bias factor. This value is built up from a number of key components of risk, each with its own value derived from the "Average % for Flood and Coast Defence (FCD) projects", the sum of which equals 100. If justifiable these risk components may be reduced, increased or unaltered to suit the particular circumstances of the study. The resulting total is multiplied by 60 to determine the "Optimism Bias" factor to be used in the benefit cost analysis. Table 9 details both the "Average % for FCD projects" (for comparison) and the adjusted percentage for each risk component. Justification for each risk component is provided in the text following the table.

Risk Components			Average % for FCD projects	% risk Option A	% risk Option B	% risk Option C	% risk Option D	% risk Option E
(a)	Procurement	Late contractor involvement in	1	1	1	0	1	1
		Dispute and claims occurred	11	11	11	6	6	6
		Other	1	1	1	1	1	1
(b)	Project-specific	Design complexity	4	3	3	1	3	3
		Degree of innovation	4	2	2	1	2	2
		Environmental impact	13	6	6	4	6	7
		Other	9	9	9	9	9	9
(c)	Client Specific	Inadequacy of the business case	23	18	18	18	18	18
		Funding availability	2	2	2	2	2	2
		Project Management Team	1	1	1	0	0	1
		Poor project intelligence	8	4	4	4	4	4
(d)	Environment	Public relations	5	7	7	1	1	1
		Site characteristics	4	2	2	2	2	2
(e)	External influences	Economic	5	5	5	5	5	5
		Legislation / regulations	4	2	2	2	2	2
		Technology	4	1	1	1	1	1
		Other	1	1	1	1	1	1
Totals			**100**	**76**	**76**	**58**	**64**	**66**
Optimism Bias			**60**	**46**	**46**	**35**	**38**	**40**

Table 9. Risk Components & Associated Factors

(a) Procurement

Late contractor involvement in design: "Late involvement of the contractor in the design leads to redesign or problems during construction". For Option C this has been reduced to 0%, as this is standard maintenance work that has been undertaken by the Authority for a number of years. Options A, B, D & E are currently at strategy stage and contractors have not been involved with the preliminary Options. Therefore the risk component remains unchanged for these Options.

Disputes and claims occurred: "Disputes and claims occur where no mechanisms exist to manage effectively adversarial relationships between project stakeholders". The risk component for Options C, D & E have been reduced to 6% as these are fairly standard work options and would be unlikely to cause disputes between the stakeholders. For Options A & B the risk component remains unchanged.

Other: "Other factors that relate to procurement which affect the final project cost". This risk component remains unchanged.

(b) Project-specific

Design complexity: "The complexity of design (including requirements, specifications and detailed design) requires significant management, impacting on final project costs". As discussed previously Option C is standard maintenance work, therefore the risk component under Option C has been reduced to 1%. The other Option designs not considered to be overly complex. The risk component for these Options has therefore been reduced to 3%.

Degree of innovation: "The degree of innovation required due to the nature of the project requires unproven methods to be used". Option C uses standard maintenance techniques, therefore the risk component under Option C has been reduced to 1%. The other Options use standard construction methods, the risk component has therefore been reduced to 2%.

Environmental impact: "The project has a major impact on its adjacent area leading to objection from neighbours and the general public". English Nature is a member of the strategy steering group and has closely been involved throughout the development of the proposals. The recommended Options have been developed to ensure that the impact will be minimal on adjacent sites. The risk component has therefore been adjusted accordingly to take account of the varying options.

Other: "Other project specific factors, which affect the final project cost". This risk component remains unchanged.

(c) Client-specific

Inadequacy of the business case: "The project scope changes as a result of the poor quality of requirement specifications and inadequate project scope definition". The requirements of the strategy have been clearly defined in the study. The risk component has therefore been reduced to 18%.

Funding availability: "Project delays or changes in scope occur as a result of the availability of funding (e.g. departmental budget spend or insufficient contingency funds)". This component has been left unchanged.

Project management team; "The project management team's capabilities and/or experience impact on final project costs". The experience of the project management team is sufficient to ensure minimal impact on final costs. This component has been reduced to 0% for Option C & D and left unchanged for Options A, B and E.

Poor project intelligence: "The quality of initial project intelligence (e.g. preliminary site investigation, user requirements surveys etc) impacts on the occurrence of unforeseen problems and costs". The necessity of carrying out a strategy study requires that sufficient investigation / information be gathered to complete the study. This component has therefore been reduced to 4%.

(d) Environment

Public relations: "A high level of effort is required to address public concern about the project, which impacts on the final project cost". The recommended options will be brought to the public's attention through public exhibitions and consultation leaflets, to be distributed locally. The risk component for Options C, D & E have been reduced to 1% as this involves no real change to the existing frontage. Options A & B involve the removal or shortening of some defences and are therefore likely to have some impact on public concerns. The risk component has therefore been increased to 7%.

Site characteristics: "The characteristics of the proposed environment for the project are highly sensitive to the project's environmental impact (e.g. Greenfield site with badger setts, or contaminated brownfield site)". The environmental issues have been addressed through the Strategic Environmental Assessment and full consultation with English Nature. Therefore this component has been reduced to 2%.

(e) External influences

Economic: "The project costs are sensitive to economic influences such as higher than expected construction cost, inflation, oil price shocks etc". This component has remained unchanged at 5%.

Legislation / regulations: "The project costs are sensitive to legislation and regulation changes e.g. health and safety and building regulations". The construction processes are considered to be relatively simple and unlikely to be affected by changes to legislation / regulations, which would affect the cost of the works. This component has therefore been reduced to 2% for all Options.

Technology: “”The project costs are sensitive to technological advancements, e.g. the effects of obsolescence”. It is anticipated that construction techniques may improve, but that the methods of providing coastal defence will not become obsolete. The risk component has been reduced to 1%.

Other: “Other external influencing factors which affect the final project cost”. This component has been left unaltered.

5.3 Options Considered

5.3.1 Option A

The beach plan assessment (see Technical Annex: Beach Plan Modelling) has identified a minimal sediment transport rate through to Naish beach and the management units to the east. This Option allows for the removal of the existing cross-shore defences from Mudeford Quay to Steamer Point and at Highcliffe. Allowance has also been made for a beach recharge to be undertaken at the western end of the frontage. Beach management works have also been included for the 100 year assessment period. These allow for interim recharges at 15 year intervals along with recycling works every year.

5.3.2 Option B

This option is a variation on Option A. Allowance is made for shortening the existing cross-shore defences by either 20m (Option B1) or 40m (Option B2), this will result in a slight improvement in sediment movement to the east. Allowance is also made for a beach recharge.

5.3.3 Option C

This option allows for the replacement of the timber groynes at the western end of the frontage with rock structures. Maintenance of the defences at Highcliffe would continue. This option still leaves the seawall open to failure as beach levels lower.

5.3.4 Option D

This option allows for the work to be undertaken as in Option C, but also for a beach recharge to be carried out. This will widen the beach and increase the level of protection to the existing seawalls, therefore increasing the residual life and reducing the requirement for the seawalls to be rebuilt. Beach management works have also been included for the 100 year assessment period. These allow for interim recharges at 15 year intervals along with recycling works every year. This Option also has the added benefit of increasing the recreational benefits of the unit due to the increased beach width.

5.3.5 Option E

This option allows for the replacement of the seawall along with the continued maintenance of the existing cross-shore defences. Due to the projected decline in beach volumes if no intervention occurs then extensive capital works will be required to replace the seawalls. The unit has been divided into 5 sections, depending on when failure is predicted to occur. This is detailed in Table 10.

Section	Length (m)	Replacement (years)
Mudeford Quay to Avon Run Road Car Park	600	20 & 70
Avon Run Road Car Park to 22 Avon Run Road	180	30 & 80
22 Avon Run Road to Southcliffe Road	150	20 & 70
Southcliffe Road to Seaway Avenue	350	10 & 60
Seaway Avenue to Steamer Point	300	20 & 70

Table 10. Seawall Replacement

Replacement of each section of seawall would be undertaken twice within the 100 year assessment period, this being based on a 50 year design life of the structure.

5.4 Option Costs

5.4.1 Unit Costs

The costs (see Annex A for detailed FCDPAG3 project summary sheets) have been based on benchmarking against similar projects currently being undertaken around the UK, while Table 11 summaries the rates used for the cost estimates.

Work	Rate (Excluding mobilisation /demobilisation)
Shingle Recharge	£15/m^3
Rock Groyne Maintenance	£73,000/year
Increased rock groyne maintenance	£100,000/year
Rock Groyne Construction	£10,000/groyne
Seawall Construction	£4,000/m
Seawall Maintenance	£80,000/10 year
Recycling	£7/ m^3
Remove / reduce timber groyne	£130/ m
Remove / reduce rock groyne	£25/tonne

Table 11. Construction Rates

5.4.2 Option A

Costs for this Option are shown in Table 12. Table 13 provides details on the phasing of the works along with cash costs and present value costs.

Description	Quantity	Value (£) (Including mobilisation / demobilisation)	Frequency
Remove timber groynes	1281m	167,000	
Remove rock groynes	186,120 t	4,690,000	
Beach recharge	70,000m^3	1,110,000	
Interim recharge	17,500m^3	322,500	15 years
Annual recycling	3,500m^3	22,750	Annually
Seawall maintenance		80,000	10 years
Cliff drain maintenance		5,000	Annually

Table 12. Option A (Present day capital and maintenance cash costs)

Year	Description	Cash Cost (£)	PV Cost (£)
0-2	Cliff drain maintenance	15,000	15,000
3	Remove groynes & recharge	5,967,000	5,336,000
4-9	Drain maintenance & recycling	168,000	135,000
10	Drain, seawall maintenance & recycling	108,000	77,000
11-17	Drain maintenance & recycling	168,000	121,000
18	Interim recharge	323,000	177,000
19	Drain maintenance & recycling	28,000	15,000
20	Drain, seawall maintenance & recycling	108,000	54,000
21-29	Drain maintenance & recycling	252,000	107,000
30	Drain, seawall maintenance & recycling	108,000	38,000
31-32	Drain maintenance & recycling	56,000	19,000
33	Interim recharge	323,000	107,000
34-39	Drain maintenance & recycling	168,000	49,000
40	Drain, seawall maintenance & recycling	108,000	29,000
41-47	Drain maintenance & recycling	196,000	46,000
48	Interim recharge	323,000	69,000
49	Drain maintenance & recycling	28,000	6,000
50	Drain, seawall maintenance & recycling	108,000	21,000
51-59	Drain maintenance & recycling	252,000	43,000
60	Drain, seawall maintenance & recycling	108,000	16,000
61-62	Drain maintenance & recycling	56,000	8,000
63	Interim recharge	323,000	44,000
64-69	Drain maintenance & recycling	168,000	20,000
70	Drain, seawall maintenance & recycling	108,000	12,000
71- 77	Drain maintenance & recycling	196,000	19,000
78	Interim recharge	323,000	29,000
79	Drain maintenance & recycling	28,000	2,000
80	Drain, seawall maintenance & recycling	108,000	9,000
81- 89	Drain maintenance & recycling	252,000	19,000

90	Drain, seawall maintenance & recycling	108,000	7,000
91- 92	Drain maintenance & recycling	56,000	4,000
93	Interim recharge	323,000	20,000
94- 99	Drain maintenance & recycling	168,000	9,000
	Totals	**11.195M**	**6.731M**
	PV cost inc. optimism bias	**9.83M**	

Table 13. Option A – Option Implementation

5.4.3 Option B

Costs for this Option are shown in Table 14. Table 15 provides details on the phasing of the works along with cash costs and present value costs. Maintenance and recycling costs are also allowed for.

Description	Quantity	Value (£)	Frequency
Shorten timber groynes		22,000	
Shorten rock groynes (20m)	21,600 t	544,000	
Shorten rock groynes (40m)	43,200 t	1,089,000	
Beach recharge	70,000m^3	1,110,000	
Interim recharge	17,500m^3	322,500	15 years
Annual recycling	3,500m^3	22,750	Annually
Seawall maintenance		80,000	10 years
Cliff drain maintenance		5,000	Annually

Table 14. Option B (Present day capital and maintenance cash costs)

Year	Description	Cash Cost (£)	PV Cost (£)
0 - 2	Cliff drain & rock groyne maintenance	234,000	226,000
3	Shorten groynes & recharge (20m)	1,750,000	1,580,000
3	Shorten groynes & recharge (40m)	2,300,000	2,070,000
4 - 9	Drain, rock maintenance & recycling	606,000	485,000
10	Drain, rock, seawall maintenance & recycling	179,000	127,000
11 - 17	Drain, rock maintenance & recycling	707,000	438,000
18	Interim recharge & maintenance	401,000	216,000
19	Drain, rock maintenance & recycling	101,000	53,000
20	Drain, rock, seawall maintenance & recycling	179,000	90,000
21 - 29	Drain, rock maintenance & recycling	909,000	386,000
30	Drain, rock, seawall maintenance & recycling	179,000	64,000
31 - 32	Drain, rock maintenance & recycling	202,000	69,000
33	Interim recharge & maintenance	401,000	131,000
34 - 39	Drain, rock maintenance & recycling	606,000	178,000
40	Drain, rock, seawall maintenance & recycling	179,000	47,000
41 - 47	Drain, rock maintenance & recycling	707,000	167,000
48	Interim recharge & maintenance	401,000	84,000

49	Drain, rock maintenance & recycling	101,000	21,000
50	Drain, rock, seawall maintenance & recycling	179,000	35,000
51 - 59	Drain, rock maintenance & recycling	909,000	155,000
60	Drain, rock, seawall maintenance & recycling	179,000	26,000
61 - 62	Drain, rock maintenance & recycling	202,000	28,000
63	Interim recharge & maintenance	401,000	54,000
64 - 69	Drain, rock maintenance & recycling	606,000	73,000
70	Drain, rock, seawall maintenance & recycling	179,000	20,000
71 - 77	Drain, rock maintenance & recycling	707,000	69,000
78	Interim recharge & maintenance	401,000	35,000
79	Drain, rock maintenance & recycling	101,000	9,000
80	Drain, rock, seawall maintenance & recycling	179,000	15,000
81 - 89	Drain, rock maintenance & recycling	909,000	67,000
90	Drain, rock, seawall maintenance & recycling	179,000	12,000
91 - 92	Drain, rock maintenance & recycling	202,000	12,000
93	Interim recharge & maintenance	401,000	24,000
94 - 99	Drain, rock maintenance & recycling	606,000	34,000
	Totals (20m)	**14.19M**	**5.03M**
	PV cost inc. optimism bias	**7.35M**	
	Totals (40m)	**14.73M**	**5.52M**
	PV cost inc. optimism bias	**8.06M**	

Table 15. Option B – Option Implementation

5.4.4 Option C

Costs for this Option are shown in Table 16. Table 17 provides details on the phasing of the works along with cash costs and present value costs. Maintenance costs are also allowed for.

Description	**Quantity**	**Value (£)**	**Frequency**
Construct rock groynes	21	210,000	
Seawall maintenance		80,000	10 years
Cliff drain maintenance		5,000	Annually
Rock groyne maintenance		100,000	Annually

Table 16. Option C (Present day capital and maintenance cash costs)

Year	Description	Cash Cost (£)	PV Cost (£)
0 - 4	Cliff drain & rock groyne maintenance	390,000	365,000
5	Replace timber groynes	218,000	184,000
6 - 9	Cliff drain & rock groyne maintenance	312,000	241,000
10	Replace timber groynes. Drain, rock & seawall maintenance	228,000	162,000
11 - 15	Cliff drain & rock groyne maintenance	390,000	250,000
16 - 19	Cliff drain & rock groyne maintenance	420,000	230,000
20	Drain, rock & seawall maintenance	185,000	93,000
21 - 29	Cliff drain & rock groyne maintenance	945,000	401,000
30	Drain, rock & seawall maintenance	185,000	66,000
31 - 39	Cliff drain & rock groyne maintenance	945,000	291,000
40	Drain, rock & seawall maintenance	185,000	49,000
41 - 49	Cliff drain & rock groyne maintenance	945,000	217,000
50	Drain, rock & seawall maintenance	185,000	36,000
51 - 59	Cliff drain & rock groyne maintenance	945,000	161,000
60	Drain, rock & seawall maintenance	185,000	27,000
61 - 69	Cliff drain & rock groyne maintenance	945,000	120,000
70	Drain, rock & seawall maintenance	185,000	20,000
71 - 79	Cliff drain & rock groyne maintenance	945,000	90,000
80	Drain, rock & seawall maintenance	185,000	15,000
81 - 89	Cliff drain & rock groyne maintenance	945,000	70,000
90	Drain, rock & seawall maintenance	185,000	12,000
91 - 99	Cliff drain & rock groyne maintenance	945,000	54,000
	Totals	**10.998M**	**3.155M**
		PV cost inc. optimism bias	**4.26M**

Table 17. Option C – Option Implementation

5.4.5 Option D

Costs for this Option are shown in Table 18 below. Table 19 provides details on the phasing of the works along with cash costs and present value costs.

Description	Quantity	Value (£)	Frequency
Construct rock groynes	21	210,000	
Beach recharge	70,000m^3	1,110,000	
Interim recharge	17,500m^3	322,500	15 years
Annual recycling	3,500m^3	23,000	Annually
Seawall maintenance		80,000	10 years
Rock groyne maintenance		100,000	Annually
Cliff drain maintenance		5,000	Annually

Table 18. Option D (Present day capital and maintenance cash costs)

Year	Description	Cash Cost (£)	PV Cost (£)
0- 4	Cliff drain & rock groyne maintenance	390,000	365,000
5	Replace timber groynes	218,000	184,000
6- 9	Cliff drain & rock groyne maintenance	312,000	241,000
10	Replace timber groynes, recharge, seawall yr 10	1,338,000	949,000
11-24	Drain, rock maintenance & recycling, seawall yr 20	1,629,000	886,000
25	Recharge	478,000	202,000
26-39	Drain, rock maintenance & recycling, seawall yr 30	1,872,000	628,000
40	Interim recharge & maintenance	508,000	135,000
41- 54	Drain, rock maintenance & recycling, seawall yr 50	1,872,000	399,000
55	Interim recharge & maintenance	428,000	73,000
56- 69	Drain, rock maintenance & recycling, seawall yr 60	1,872,000	258,000
70	Interim recharge & maintenance	531,000	58,000
71- 84	Drain, rock maintenance & recycling seawall yr 70	1,872,000	167,000
85	Interim recharge & maintenance	428,000	32,000
86- 99	Drain, rock maintenance & recycling, seawall yr 90	1,872,000	115,000
	Totals	**15.62M**	**4.69M**
	PV cost inc. optimism bias		**6.47M**

Table 19. Option D – Option Implementation

5.4.6 Option E

This Option consists of the works shown in Table 20. Table 21 provides details on the phasing of the options along with cash costs and present value costs.

Description	Quantity	Value (£)	Frequency
Seawall	1580	6,320,000	50 years
Cliff drain maintenance		5,000	Annually
Rock revetment maintenance		73,000	Annually

Table 20. Option E (Present day capital and maintenance cash costs)

Year	Description	Cash Cost (£)	PV Cost (£)
0 to 9	Cliff drain & rock groyne maintenance	780,000	657,000
10	Seawall reconstruction	1,478,000	1,048,000
11 to 19	Cliff drain & rock groyne maintenance	702,000	421,000
20	Seawall reconstruction	4,278,000	2,150,000
21 to 29	Cliff drain & rock groyne maintenance	702,000	298,000
30	Seawall reconstruction	798,000	284,000
31 to 59	Cliff drain & rock groyne maintenance	2,262,000	506,000
60	Seawall reconstruction	1,478,000	217,000
61 to 69	Cliff drain & rock groyne maintenance	702,000	89,000
70	Seawall reconstruction	4,278,000	467,000
71 to 79	Cliff drain & rock groyne maintenance	702,000	67,000
80	Seawall reconstruction	798,000	66,000
81 to 99	Cliff drain & rock groyne maintenance	1,482,000	97,000
	Totals	**20.44M**	**6.409M**
		PV cost inc. optimism bias	**8.970M**

Table 21. Option E – Option Implementation

6 Benefit Cost Assessment – CBY2

6.1 Introduction

Tables 22 show the PV benefit cost ratios for each Option for CBY2.

	Costs and Benefits (£M) for Options						
	Do-Nothing	**A**	**B1 (20m)**	**B2 (40m)**	**C**	**D**	**E**
PV costs	0-	6.73	5.03	5.52	3.15	4.69	6.41
Optimism bias		3.1	2.31	2.54	1.1	1.78	1.78
Total PV costs		9.83	7.34	8.06	4.26	6.47	6.47
PV assets PVa	40.34	1.29					
Total PV benefits		39.04					
NPV		29.22	31.07	30.98	34.79	32.57	30.07
Benefit/cost ratio		3.97	5.31	4.84	9.17	6.03	4.35

Table 22. PV benefit cost ratios for Options in CBY2

The results indicate that to adopt the do nothing option would result in significant damages to local assets. Option C is shown to be the most beneficial option with a benefit cost ratio of 9.17. However, this option leaves the seawall at risk of failure as the beach volumes reduce. Option D has the second best benefit cost ratio of 6.03. This Option would also have the added benefit of increasing the recreational benefits due to the increased beach volumes.

7 CBY3 Chewton Bunny to Barton-on-Sea

7.1 CBY3 – Extent of Frontage

The extent of this unit has been reduced at the eastern end to remove the residential properties that are situated in Marine Drive West. The unit extends from Chewton Bunny in the west to the start of Marine Drive West (eastern boundary of Hoburne Naish Holiday Park). The whole of the unit frontage consists of eroding, undefended cliffs, fronting the Naish Holiday Park.

The holiday village comprises of a variety of holiday homes, including chalets, lodges and static caravans. There is also a club house, swimming pool and electricity sub-stations within the site.

7.1.1 Clifftop Recession

Future clifftop recession rates have been assessed through the soft cliff recession model developed by Halcrow for this strategy study, (Cliff Behaviour Assessment: A Quantitative Approach Using Digital Photogrammetry and GIS, 2003). Using this model future clifftop positions have been forecast for the first 50 years of the strategy study by separating management units CBY3 and CBY4 into 6 cliff behaviour units (CBU) and assessing recession rates within each unit. Table 23 shows the CBU's and the profile numbers for each CBU.

CBU Frontage	Profiles
Naish Farm	12 to 16
Cliff House Hotel	17
Marine Drive West	18 to 21
Barton Court	22 to 24
Marine Drive East	26 to 31
Becton Bunny	32 to 34

Table 23. Barton-on-Sea Cliff Behaviour Units

To enable future projections to be made for the period from year 50 to year 100 it was considered that the cliff recession model would be subject to a high level of uncertainty. Therefore projections for this period have been evaluated using a probabilistic method.

Under the 'do nothing' option, the coastline is assumed to be subject to the rates of erosion detailed in Tables 24 and 25. Both tables also show the projections for the upper and lower bound recession rates using both the cliff recession model and the probabilistic recession model.

	Cumulative Cliff Retreat (m)				
CBU	**Year 10**	**Year 20**	**Year 30**	**Year 40**	**Year 50**
Naish Farm					
Lower Bound	10.6	21.3	31.9	42.5	53.2
Annual Erosion Rate (m/yr)	*1.06*	*1.07*	*1.06*	*1.06*	*1.07*
Upper Bound	18.9	37.9	56.8	75.7	94.7
Annual Erosion Rate (m/yr)	*1.89*	*1.9*	*1.89*	*1.89*	*1.9*

Table 24. Projected Cliff Recession Year 0 to Year 50

	Cumulative Probability Distance (m)	
CBU	**Upper Bound**	**Lower Bound**
Naish Farm	425	275
Annual Erosion Rate (m/yr)	*6.61*	*4.44*

Table 25. Projected Cliff Recession Year 100 Using Probabilistic Model

The specified cliff recession lines, for both the upper and lower bound projections were plotted on OS maps in 10 year time bands, allowing assets to be classified with a predicted year of loss, these projected recession lines have also been plotted on the 2005 ortho-rectified aerial photographs.

Evaluation of Do Nothing Damages

At Naish the assets at risk from erosion consist of the holiday properties within the Naish Holiday Park. Table 26 details these assets along with the values (2004 prices) that have been assigned to each asset.

Asset	Value (£)
Lodge	95,000
Chalet	20,000
Caravan	39,000
Caravan relocation	7,000
Club house	6,000,000

Table 26. Asset Type and Value

Along with the asset values shown in the table above there will also be a loss of income due to the site / pitch of each asset being lost to erosion. Typical annual income figures for each asset are given in Table 27.

Asset	Value (£)
Lodge	17,600
Chalet	11,000
Caravan	2,600

Table 27. Asset Type and Annual Income

Erosion of the cliff top through the holiday park would continue as identified in the cliff recession model and a summary of those assets identified as being at risk within the 100 year period for the upper and lower bound projections are shown in Table 28. The holiday park management have a policy of relocating caravans as they become vulnerable. However, in a study undertaken in 1996 it was identified that the park would be faced with a significant problem within five years, as they would run out of space for relocating caravans and chalets. The BCA assumes that the caravans within the 100 year zone can be relocated to other sites either within the ownership of Hoburne Holiday Parks or by private sale. It is assumed that chalets and lodges will be lost to erosion as they cannot easily be relocated of site.

	Year	Number	Value (£M)
Lower Bound	1 - 10	0	0
	11 - 20	10	0.174
	21 - 30	24	0.363
	31 - 40	23	0.343
	41 - 50	24	0.35
	51 - 60	101	1.5
	61 - 70	124	1,809
	71 - 80	101	2.986
	81 - 90	88	7.524
	91 - 100	82	1.802
	Total	577	
Upper Bound	1 - 10	0	0
	11 - 20	45	0.679
	21 - 30	41	0.651
	31 - 40	46	0.66
	41 - 50	49	0.681
	51 - 60	174	2.492
	61 - 70	126	7.724
	71 - 80	104	2.536
	81 - 90	99	3.929
	91 - 100	102	3.269
	Total	786	

Table 28. Summary of Erosion Damages (not discounted)

The damage to Barton-on-Sea for the do-nothing scenario is shown in Table 29 (see Annex A for detailed FCDPAG3 project summary sheets).

Scenario	PV Damages (£M)
Lower bound	29.58
Upper bound	51.4

Table 29. Do Nothing PV Damages

8 Intervention Options – CBY3

8.1 Introduction

The following sections identify and cost those defence intervention options that have been considered in the benefit cost analysis. The options include three main areas of work, beach recharge, installation of siphon drains and the construction of hard defences.

8.2 Optimism Bias

As part of the FDCPAG3 Economic Appraisal the quantification of project risk is dealt with by utilising a factor known as "Optimism Bias" and is used to provide a suitable uplift to early best estimates of project costs, thereby reducing the effect of under estimating project costs.

The guidance provide by Defra suggests that for a strategy study a starting value of 60% should be used for the Optimism Bias factor. This value is built up from a number of key components of risk, each with its own value derived from the "Average % for Flood and Coast Defence (FCD) projects", the sum of which equals 100. If justifiable these risk components may be reduced, increased or unaltered to suit the particular circumstances of the study. The resulting total is multiplied by 60 to determine the "Optimism Bias" factor to be used in the benefit cost analysis. Table 30 details both the "Average % for FCD projects" (for comparison) and the adjusted percentage for each risk component. Justification for each risk component is provided in the text following the table.

Risk Components			Average % for FCD projects	% risk Recharge Option A	% risk Drainage Option B	% risk Revetment Option C	% risk Seawall Option D
(a)	Procurement	Late contractor involvement in	1	1	1	1	1
		Dispute and claims occurred	11	11	11	11	11
		Other	1	1	1	1	1
(b)	Project-specific	Design complexity	4	2	4	4	4
		Degree of innovation	4	3	4	3	3
		Environmental impact	13	13	3	13	13
		Other	9	9	9	9	9
(c)	Client Specific	Inadequacy of the business case	23	18	18	18	18
		Funding availability	2	2	2	2	2
		Project Management Team	1	0	0	0	0
		Poor project intelligence	8	6	6	6	6
(d)	Environment	Public relations	5	4	3	5	5
		Site characteristics	4	2	2	4	4
(e)	External influences	Economic	5	5	5	5	5
		Legislation / regulations	4	3	3	3	3
		Technology	4	1	1	1	1
		Other	1	1	1	1	1
Totals			**100**	**82**	**74**	**87**	**87**
Optimism Bias			**60**	**49**	**44**	**52**	**52**

Table 30. Risk Components & Associated Factors

(a) Procurement

Late contractor involvement in design: "Late involvement of the contractor in the design leads to redesign or problems during construction". The project is currently at strategy stage and contractors have not been involved with the preliminary Options. Therefore this risk component remains unchanged.

Disputes and claims occurred: "Disputes and claims occur where no mechanisms exist to manage effectively adversarial relationships between project stakeholders". This risk component remains unchanged.

Other: "Other factors that relate to procurement which affect the final project cost". This risk component remains unchanged.

(b) Project-specific

Design complexity: "The complexity of design (including requirements, specifications and detailed design) requires significant management, impacting on final project costs". The Option design for Option A is considered to be relatively simple and not overly complex; the risk component has therefore been reduced to 2%. For Option B the works will consist of installing siphon drains, which is a relatively new technique, the risk component therefore remains unchanged. The risk component has also been left unchanged for Options C and D.

Degree of innovation: "The degree of innovation required due to the nature of the project requires unproven methods to be used". Option B proposes the use of siphon drains. This is a relatively new technique, used only once in the UK. With this consideration the risk component remains unchanged at 4%. The other three Options are based on standard construction techniques, the risk component has therefore been reduced to 3%.

Environmental impact: "The project has a major impact on its adjacent area leading to objection from neighbours and the general public". English Nature is a member of the strategy steering group and has closely been involved throughout the development of the proposals. The recommended Options have been developed to ensure that the impact will be minimal on adjacent sites. The risk component has therefore been adjusted accordingly to take account of the varying options.

Other: "Other project specific factors, which affect the final project cost". This component has been left unchanged.

(c) Client-specific

Inadequacy of the business case: "The project scope changes as a result of the poor quality of requirement specifications and inadequate project scope definition". The requirements of the strategy have been clearly defined in the study. The risk component has therefore been reduced to 18%.

Funding availability: "Project delays or changes in scope occur as a result of the availability of funding (e.g. departmental budget spend or insufficient contingency funds)". This component has been left unchanged.

Project management team: "The project management team's capabilities and/or experience impact on final project costs". The experience of the project management team is sufficient to ensure minimal impact on final costs. This component has been reduced to 0%.

Poor project intelligence: "The quality of initial project intelligence (e.g. preliminary site investigation, user requirements surveys etc) impacts on the occurrence of unforeseen problems and costs". The necessity of carrying out a strategy study requires that sufficient investigation / information be gathered to complete the study. This component has therefore been reduced to 6%.

(d) Environment

Public relations: "A high level of effort is required to address public concern about the project, which impacts on the final project cost". The recommended options will be brought to the public's attention through public exhibitions and consultation leaflets, to be distributed locally. The risk components have therefore been adjusted accordingly to suit the individual Options.

Site characteristics: "The characteristics of the proposed environment for the project are highly sensitive to the project's environmental impact (e.g. Greenfield site with badger setts, or contaminated brownfield site)". The environmental issues have been addressed through the Strategic Environmental Assessment and full consultation with English Nature. The risk component for Options A and B has therefore been reduced to 2%. Options C and D involve the construction of "hard defences", which would result in a significant negative impact on the designated site. Therefore this component has remained unchanged.

(e) External influences

Economic: "The project costs are sensitive to economic influences such as higher than expected construction cost, inflation, oil price shocks etc". This component has remained unchanged at 5%.

Legislation / regulations: "The project costs are sensitive to legislation and regulation changes, e.g. health and safety and building regulations". The construction processes are considered to be relatively simple and unlikely to be affected by changes to legislation / regulations, which would affect the cost of the works. This component has therefore been reduced to 3%.

Technology: "The project costs are sensitive to technological advancements, e.g. the effects of obsolescence". It is anticipated that construction techniques may improve, but that the methods of providing coastal defence will not become obsolete. The risk component has been reduced to 1%.

Other: "Other external influencing factors which affect the final project cost". This component has been left unchanged.

8.3 Option Costs

8.3.1 Unit Costs

The costs (see Annex A for detailed FCDPAG3 project summary sheets) have been based on benchmarking against similar projects currently being undertaken around the UK, while Table 31 shown below summaries the rates that have been used for the cost estimates.

Work	Rate
Shingle recharge	£15/m^3
Seawall Construction	£4,000/m
Siphon Drainage	£3,000/m
Revetment	£6,000/m

Table 31. Construction Rates

8.3.2 Main Options

Four main Options have been developed to be taken forward to the benefit cost analysis, additional supplementary Options have also been developed using a combination of the main Options. The indicated costs are current capital costs with no allowance for maintenance. A sensitivity analysis has been undertaken for each Option by varying the timing of the implementation of the works.

8.3.3 Option A

This Option consists of a beach recharge, which would have the effect of reducing toe erosion but still allowing exposures of the geological aspects of the SSSI. A secondary Option (A1) has also been considered, this includes siphon drains to the clifftop, which would reduce the rate of clifftop erosion. Table 32 details the Options and costs that have been evaluated.

Allowance has been made for interim beach recharges to be made at 15 year intervals. Maintenance costs allow for recycling shingle every 2 years, while Option A1 also allows for maintenance of the siphon drains to be undertaken at 5 yearly intervals. Table 33 provides details on the phasing of the options along with cash costs and present value costs.

Description	Capital Works (£M)		Maintenance	
	Option A	Option A1	Value (£m)	Frequency
Beach Recharge	1.74 (112,000m^3)	1.74 (112,000m^3)		
Drainage		2.52 (840m)		
Recycling			0.0364 (5.600m^3)	24 months
Interim Recharge	0.48 (28,000m^3)	0.48 (28,000m^3)		15 years
Drainage			0.042 (840m)	5 years

Table 32. Option A & A1 (Present day capital cash costs)

Option	Description	Option A		Option A1	
		Cash Cost (£M)	PV Cost (£M)	Cash Cost (£M)	PV Cost (£M)
3	Beach recharge	1.74	1.57		
3	Beach recharge & siphon drains			4.26	3.84
18	Interim beach recharge	0.48	0.26	0.48	0.28
33	Interim beach recharge	0.48	0.16	0.48	0.17
48	Interim beach recharge	0.48	0.1	0.48	0.11
63	Interim beach recharge	0.48	0.06	0.48	0.07
78	Interim beach recharge	0.48	0.04	0.48	0.05
93	Interim beach recharge	0.48	0.3	0.48	0.03
Totals		**6.24**	**2.66**	**9.56**	**5.13**

Table 33. Option A – Option Implementation
Note: Total cash and PV costs include maintenance costs

8.3.4 Option B

Principally the Option consists of siphon drains. Table 34 provides details on the phasing of the options along with cash costs and present value costs.

Option	Description	Option B	
		Cash Cost (£M)	PV Cost (£M)
3	Siphon drains	2.52	2.27
Totals		**3.32**	**2.48**

Table 34. Option B – Option Implementation (Upper Bound).
Note: Total cash and PV costs include maintenance costs

8.3.5 Option C

The proposed Option involves construction of a rock revetment (Option C). The benefit cost analysis has also been undertaken to assess the option with additional siphon drainage (Option C1). Maintenance costs have been included for the siphon drains. Table 35 provides details on the phasing of the options along with cash costs and present value costs.

Option	Description	Option C		Option C1	
		Cash Cost (£m)	PV Cost (£m)	Cash Cost (£m)	PV Cost (£m)
3	Construction of revetment	5.04	4.55		
3	Construction of revetment and installation of siphon drains			7.56	6.82
53	Construction of revetment	5.04	0.091		
53	Construction of revetment with siphon drains			5.08	0.092
	Totals	**10.08**	**5.46**	**13.4**	**7.93**

Table 35. Option C – Option Implementation (Upper Bound)
Note: Total cash and PV costs include maintenance costs

8.3.6 Option D

The proposed Option involves construction of a seawall (Option D). The benefit cost analysis has also been undertaken to assess the option with additional siphon drainage (Option D1). Maintenance costs have been included for the siphon drains. Table 36 provides details on the phasing of the options along with cash costs and present value costs.

Option	Description	Option D		Option D1	
		Cash Cost (£m)	**PV Cost (£m)**	**Cash Cost (£m)**	**PV Cost (£m)**
3	Construction of seawall	3.36	3.03		
3	Construction of seawall and installation of siphon drains			5.88	5.3
53	Construction of seawall	3.36	0.061		
53	Construction of seawall and installation of siphon drains			3.4	0.061
Totals		**6.72**	**3.640**	**10.04**	**6.11**

Table 36 Option D – Option Implementation (Upper Bound)
Note: Total cash and PV costs include maintenance costs

9 Benefit Cost Assessment – CBY3

9.1 Introduction

Tables 37 show the PV benefit cost ratios for each Option (for the lower bound recession rates).

	Costs and benefits £M for Options							
	Do-Nothing	**A**	**A1**	**B**	**C**	**C1**	**D**	**D1**
PV costs		2.66	5.13	2.48	5.46	7.93	3.64	6.11
Optimism bias		1.32	2.52	1.09	2.84	4.13	1.89	3.18
Total PV costs		3.96	7.65	3.57	8.29	12.06	5.53	9.29
PV damage	35.94	1.15	1.15	1.15	1.15	1.15	1.15	1.15
Total PV		34.79	34.79	34.79	34.79	34.79	34.79	34.79
NPV		30.83	27.14	31.22	26.5	22.73	29.26	25.5
Benefit/cost		8.79	4.55	9.75	4.2	2.89	6.29	3.74

Table 37. Option D benefits/costs

The results shown in the tables above indicate that to adopt the do nothing option would result in significant damages to local assets. Option B is shown to be the most beneficial option with benefit cost ratio of 9.75. (See Annex A for detailed FCDPAG3 project summary sheets).

10 CBY4 Barton-on-Sea

10.1 CBY4 – Extent of Frontage

The extent of this unit has been extended to the west to include all properties that are situated in Marine Drive. The majority of the unit frontage consists of an “engineered” cliff with a rock armour revetment, drainage and a steel sheet piled wall. The western end of the frontage that has been included is a 470m length from the Naish boundary to the start of the defences by the Cliff House Hotel.

The full extent of this unit includes a high proportion of highly desirable detached properties along with a number of “up market” apartment developments. The number of commercial premises within the unit is minimal, with the significant premises being the Cliff House Hotel to the west of the unit and the Barton Court area which consists of 7 different commercial premises. The unit also includes high value amenity land and recreational benefits.

10.1.1 Clifftop Recession

Future clifftop recession rates have been assessed through the soft cliff recession model developed by Halcrow for this strategy study. See Annex B Cliff Behaviour Assessment: A Quantitative Approach Using Digital Photogrammetry and GIS, 2003 for full description of methodology. Using this model future clifftop positions have been forecast for the first 50 years of the strategy study by separating the management unit into 6 cliff behaviour units (CBU) and assessing recession rates within each unit. Table 38 shows the CBU’s and the profile numbers for each CBU.

CBU Frontage	Profiles
Naish Farm	12 to 16
Cliff House Hotel	17
Marine Drive West	18 to 21
Barton Court	22 to 24
Marine Drive East	26 to 31
Becton Bunny	32 to 34

Table 38 Barton-on-Sea Cliff Behaviour Units

To enable future projections to be made for the period from year 50 to year 100 it was considered that the cliff recession model would be subject to a high level of uncertainty. Therefore projections for this period have been evaluated using a probabilistic method.

The cliff recession model makes allowance for the reducing effectiveness of the existing toe and cliff stabilisation defences over the assessment period. Without maintenance work, the effectiveness of the defences will reduce over time, within the cliff recession model this is shown as a decreasing percentage in effectiveness. The effectiveness of the defences has been based on assessments from the Engineers responsible for the frontage and from previous experience of how similar structures have behaved. Under the 'do nothing' option, the coastline is assumed to be subject to the rates of erosion detailed in Table 39.

CBU	Cumulative Cliff Retreat (m)				
	2012	**2022**	**2032**	**2042**	**2052**
Naish Farm					
Lower Bound	10.6	21.3	31.9	42.5	53.2
Annual Erosion Rate (m/yr)	*1.06*	*1.07*	*1.06*	*1.06*	*1.07*
Upper Bound	18.9	37.9	56.8	75.7	94.7
Annual Erosion Rate (m/yr)	*1.89*	*1.9*	*1.89*	*1.89*	*1.9*
Cliff House Hotel					
Lower Bound	9.8	27.2	44.6	62.2	79.8
Annual Erosion Rate (m/yr)	*0.98*	*1.74*	*1.74*	*1.76*	*1.76*
Upper Bound	15.3	42.7	70.9	99.6	129.1
Annual Erosion Rate (m/yr)	*1.53*	*2.74*	*2.82*	*2.87*	*2.95*
Marine Drive West					
Lower Bound	7.9	16.4	25.7	42.1	58.7
Annual Erosion Rate (m/yr)	*0.79*	*0.85*	*1.3*	*1.64*	*1.66*
Upper Bound	11.0	23.0	36.3	59.9	84.6
Annual Erosion Rate (m/yr)	*1.1*	*1.2*	*1.33*	*2.36*	*2.47*
Barton Court					
Lower Bound	8.3	17.2	26.5	36.0	52.6
Annual Erosion Rate (m/yr)	*0.83*	*0.89*	*1.3*	*1.06*	*1.66*
Upper Bound	11.6	24.0	37.1	50.6	74.1
Annual Erosion Rate (m/yr)	*1.16*	*1.24*	*1.31*	*1.35*	*2.35*
Marine Drive East					
Lower Bound	7.3	15.3	23.8	33.0	42.5
Annual Erosion Rate (m/yr)	*0.73*	*0.8*	*0.85*	*0.92*	*0.95*
Upper Bound	10.2	21.4	33.7	47.1	61.1
Annual Erosion Rate (m/yr)	*1.02*	*1.12*	*1.23*	*1.34*	*1.4*
Becton Bunny					

Lower Bound	10.5	21.0	31.5	42.0	52.5
Annual Erosion Rate (m/yr)	*1.06*	*1.05*	*1.05*	*1.05*	*1.05*
Upper Bound	19.1	38.1	57.2	76.3	95.4
Annual Erosion Rate (m/yr)	*1.91*	*1.9*	*1.91*	*1.91*	*1.91*

Table 39 Projected Cliff Recession Year 0 to Year 50

Table 40 show the projections for the upper and lower bound recession rates using both the cliff recession model and the probabilistic recession model.

	Cumulative Probability Distance (m)	
CBU	**Upper Bound**	**Lower Bound**
Naish Farm	425	275
Annual Erosion Rate (m/yr)	*6.61*	*4.44*
Cliff House Hotel	275	175
Annual Erosion Rate (m/yr)	*2.92*	*1.9*
Marine Drive West	225	125
Annual Erosion Rate (m/yr)	*2.8*	*1.34*
Barton Court	225	125
Annual Erosion Rate (m/yr)	*3.02*	*1.45*
Marine Drive East	225	175
Annual Erosion Rate (m/yr)	*3.28*	*2.65*
Becton Bunny	275	225
Annual Erosion Rate (m/yr)	*3.60*	*3.45*

Table 40 Projected Cliff Recession Year 100 Using Probabilistic Model

The specified cliff recession lines, for both the upper and lower bound projections were plotted on OS maps in 10 year time bands, allowing assets to be classified with a predicted year of loss, these projected recession lines have also been plotted on the 2001 ortho-rectified aerial photographs**.**

10.1.2 Evaluation of Do Nothing Damages

At Barton – on - Sea the assets at risk from erosion consist mainly of residential properties, with a small number of commercial premises. The majority of these properties are quite large detached houses with large gardens, particularly in Marine Drive, which runs parallel with the cliff. The study area also contains a significant number of apartment developments containing a high number of “up market” apartments. There are also 3 public car parks and 114 timber beach huts within the at risk area.

Between the clifftop and Marine Drive there is a significant area of amenity land, meaning that the majority of properties are set back some 50 to 80 metres from the cliff edge and would only become vulnerable after some considerable time (30 plus years) under a do-nothing strategy. The area of amenity land that would be lost through erosion is shown in Table 41. After year 40 for the upper bound and year 60 for the lower bound the clifftop will have receded back to Marine Drive and further erosion will then begin to affect the properties on the north side of the road. The Cliff House Hotel and Barton Court properties have been identified as being at particular risk from erosion at an early stage under a do-nothing strategy, due to their proximity to the cliff edge.

	Year	Area (Ha)	Value (£)
Upper Bound	10	2.4	240,000
	20	2.5	250,000
	30	2.4	240,000
	40	1.6	160,000
Lower Bound	10	1.6	160,000
	20	1.6	160,000
	30	1.7	170,000
	40	1.8	180,000
	50	1.7	170,000
	60	1.1	110,000

Table 41. Amenity Land Erosion

Table 42 below identifies the public car parks at risk, along with the forecast year of erosion risk and the annual income.

Car Park	Erosion Year Upper Bound	Erosion Year Lower Bound	Annual Income (£)
Marine Drive	20	30	4,000
Marine Drive	15	20	6,000
Golf Course	20	30	1,500

Table 42. Public Car Parks at Risk

There are 114 beach huts within this unit, all are located on the undercliff area. The market value of each beach hut is approximately £10,000 based on previous sales. Table 43 details values and incomes generated from the beach huts.

Beach Hut Site	Erosion Year	Number of Huts	Market Value (£)	Annual Income (£)
Barton-on-Sea	20	114	1,140,000	28,000

Table 43. Beach Huts at Risk

Erosion of the clifftop back to Marine Drive would continue as identified in the cliff recession model, with the efficiency of the existing defences continuing to decline with an adverse effect on the recession rates. Marine Drive West is undefended and recession rates on this frontage would continue in line with those of the Naish frontage, with both the cliff edge and toe being eroded.

The damage to Barton-on-Sea for the do-nothing scenario is shown in Table 44 (see Annex A for detailed FCDPAG3 project summary sheets).

Scenario	**PV Damages (£M)**
Lower bound	29.58
Upper bound	51.4

Table 44. Do Nothing PV Damages

A summary of those assets identified as being within the 100 year period is shown in Table 45, along with the asset value and the projected year of loss for both the upper and lower bound projections.

Year	**Number**	**Value (£)**	**Number**	**Value (£)**
	Lower Bound		Upper Bound	
1 to 10	6	2,226,000	6	2,226,000
11 to 20	3	2,235,000	3	2,235,000
21 to 30	0	0	38	14,593,000
31 to 40	18	7,230,000	173	60,361,000
41 to 50	170	46,520,000	68	26,308,000
51 to 60	92	38,366,000	58	18,765,000
61 to 70	28	11,795,000	68	37,037,000
71 to 80	83	29,340,000	94	41,668,000
81 to 90	36	29,929,000	103	42,048,000
91 to 100	29	16,987,000	58	25,726,000
Total	465	184,628,000	669	270,967,000

Table 45. Summary of Erosion Damages (not discounted)

11 Intervention Options CBY4

11.1 Introduction

The following sections identify and cost those defence intervention options that have been considered in the benefit cost analysis. The options include two main areas of work, cliff stabilisation measures and the installation of siphon drains. Maintenance of the existing defences has not considered as this would have no impact on reducing the rates of clifftop erosion.

11.2 Optimism Bias

As part of the FDCPAG3 Economic Appraisal the quantification of project risk is dealt with by utilising a factor known as “Optimism Bias” and is used to provide a suitable uplift to early best estimates of project costs, thereby reducing the effect of under estimating project costs.

The guidance provide by Defra suggests that for a strategy study a starting value of 60% should be used for the Optimism Bias factor. This value is built up from a number of key components of risk, each with its own value derived from the “Average % for Flood and Coast Defence (FCD) projects”, the sum of which equals 100. If justifiable these risk components may be reduced, increased or unaltered to suit the particular circumstances of the study. The resulting total is multiplied by 60 to determine the “Optimism Bias” factor to be used in the benefit cost analysis. Table details both the “Average % for FCD projects” (for comparison) and the adjusted percentage for each risk component. Justification for each risk component is provided in the text following the table.

Risk Components			Average % for FCD projects	% risk Option A	% risk Option B	% risk Option C	% risk Option D
(a)	Procurement	Late contractor involvement in	1	1	1	1	1
		Dispute and claims occurred	11	11	11	11	11
		Other	1	1	1	1	1
(b)	Project-specific	Design complexity	4	3	3	4	4
		Degree of innovation	4	4	4	4	4
		Environmental impact	13	7	8	3	6
		Other	9	9	9	9	9
(c)	Client Specific	Inadequacy of the business case	23	18	18	18	18
		Funding availability	2	2	2	2	2
		Project Management Team	1	0	0	0	0
		Poor project intelligence	8	6	6	6	6
(d)	Environment	Public relations	5	5	5	3	3
		Site characteristics	4	2	2	2	2
(e)	External influences	Economic	5	5	5	5	5
		Legislation / regulations	4	3	3	3	3
		Technology	4	1	1	1	1
		Other	1	1	1	1	1
Totals			**100**	**79**	**80**	**74**	**77**
Optimism Bias			**60**	**47**	**48**	**44**	**46**

Table 46. Risk Components & Associated Factors

(a) Procurement

Late contractor involvement in design: "Late involvement of the contractor in the design leads to redesign or problems during construction". The project is currently at strategy stage and contractors have not been involved with the preliminary Options. Therefore this risk component remains unchanged.

Disputes and claims occurred: "Disputes and claims occur where no mechanisms exist to manage effectively adversarial relationships between project stakeholders". This risk component remains unchanged.

Other: "Other factors that relate to procurement which affect the final project cost". This risk component remains unchanged.

(b) Project-specific

Design complexity: "The complexity of design (including requirements, specifications and detailed design) requires significant management, impacting on final project costs". The Option designs for Options A and B are not considered to be overly complex. Initial Option design for stabilisation works have been undertaken through specialist geo-technical consultant's who have a good understanding of the frontage. The risk component for Options A and B has therefore been reduced to 3%. For Options C and D the majority of the works will consist of installing siphon drains, which is a relatively new technique, the risk component therefore remains unchanged.

Degree of innovation: "The degree of innovation required due to the nature of the project requires unproven methods to be used". To some degree all four Options propose the use of siphon drains. This is a relatively new technique, used only once in the UK. With this consideration the risk component remains unchanged at 4%.

Environmental impact: "The project has a major impact on its adjacent area leading to objection from neighbours and the general public". English Nature is a member of the strategy steering group and has closely been involved throughout the development of the proposals. The recommended Options have been developed to ensure that the impact will be minimal on adjacent sites. The risk component has therefore been adjusted accordingly to take account of the varying options.

Other: "Other project specific factors, which affect the final project cost". This component has been left unchanged.

(c) Client-specific

Inadequacy of the business case: "The project scope changes as a result of the poor quality of requirement specifications and inadequate project scope definition". The requirements of the strategy have been clearly defined in the study. The risk component has therefore been reduced to 18%.

Funding availability: "Project delays or changes in scope occur as a result of the availability of funding (e.g. departmental budget spend or insufficient contingency funds)". This component has been left unchanged.

Project management team: "The project management team's capabilities and/or experience impact on final project costs". The experience of the project management team is sufficient to ensure minimal impact on final costs. This component has been reduced to 0%.

Poor project intelligence: "The quality of initial project intelligence (e.g. preliminary site investigation, user requirements surveys etc) impacts on the occurrence of unforeseen problems and costs". The necessity of carrying out a strategy study requires that sufficient investigation / information be gathered to complete the study. This component has therefore been reduced to 6%.

(d) Environment

Public relations: "A high level of effort is required to address public concern about the project, which impacts on the final project cost". The recommended options will be brought to the public's attention through public exhibitions and consultation leaflets, to be distributed locally. The risk component for Options A and B have been left unchanged, due to the proposed regrading of the cliff top, which may promote some public uncertainty. The component for Option C and D has been reduced to 3%, as there will be little physical change to the site, better suiting the public view.

Site characteristics: "The characteristics of the proposed environment for the project are highly sensitive to the project's environmental impact (e.g. Greenfield site with badger setts, or contaminated brownfield site)". The environmental issues have been addressed through the Strategic Environmental Assessment and full consultation with English Nature. Therefore this component has been reduced to 2%.

(e) External influences

Economic: "The project costs are sensitive to economic influences such as higher than expected construction cost, inflation, oil price shocks etc". This component has remained unchanged at 5%.

Legislation / regulations: "The project costs are sensitive to legislation and regulation changes e.g. health and safety and building regulations". The construction processes are considered to be relatively simple and unlikely to be affected by changes to legislation / regulations, which would affect the cost of the works. This component has therefore been reduced to 3%.

Technology: "The project costs are sensitive to technological advancements, e.g. the effects of obsolescence". It is anticipated that construction techniques may improve, but that the methods of providing coastal defence will not become obsolete. The risk component has been reduced to 1%.

Other: "Other external influencing factors which affect the final project cost". This component has been left unaltered.

11.3 Secondary Options Considered

11.3.1 CBY4

This management unit has been sub-divided into a number of cliff behaviour units, as previously described and detailed in Table 47.

Cliff Behaviour Unit	Length (metres)	Area Number
Naish Frontage (part)	500	2
Cliff House Hotel	165	3
Marine Drive West	345	4
Barton Court	215	4a
Marine Drive East	600	5

Table 47. CBY4 Cliff Behaviour Units

A number of options have been considered for each CBU and where appropriate, if the options are considered to be technically and environmentally suitable they have been included in the Options taken forward to the benefit cost analysis.

The suitable options available for each CBU have been combined to develop four main Options for the Barton-on-Sea frontage.

11.3.2 Naish Frontage (part)

This CBU includes the frontage from the western end of Marine Drive to 5 Marine Drive West, with the majority of the CBU being undefended. The secondary defence options considered with benefit cost analysis are described below.

- **Rock Revetment -** The continuation of the existing defence to the east by constructing a rock armour revetment fronting the cliff toe. However, environmentally this option would not be acceptable to English Nature due to the change in status this option would inflict on the SSSI. In addition, given the depth of slip planes in the area and a design life of 50 years, which would require the revetment to be built twice in 100 years it would not be technically the best solution. This secondary option has therefore not been taken forward to the main Option development.

- **Dynamic Toe –** the construction of a dynamic toe by beach recharge would have the effect of slowing down toe erosion rates, while still allowing exposures of the geological aspects of the SSSI to be maintained. This secondary option is technically and environmentally sound and would suit the requirements of English Nature. This secondary option has therefore been taken forward to the main Option development.

- **Sea Wall –** The construction of a concrete sea wall along the base of the cliff would not be acceptable to English Nature due to the environmental damage that would be inflicted on the SSSI. In addition, given the depth of slip planes in the area it would not technically be the best solution. Also a design life of 50 years would require the wall to be built twice within the 100 year period.

- **Cliff Stabilisation –** This would involve regrading the cliff to a point where it would be stable. The Option would also include associated drainage and landscaping works. This could be left until year 10 at the earliest. There would be considerable Environmental impacts on the SSSI and it is unlikely that this option would be favourable to English Nature. However, this option has been taken forward to the main Option development.

- **Siphon Drains** – These would be installed along the southern edge of Marine Drive, to reduce the rate of erosion due to ground water effects. A combination of siphon and electro pneumatic drains would be used. The installation would also include a collector drain with a discharge point into the sea, as well as a pumping station. This option presents the most environmentally sound solution as there would be no adverse impact on the SSSI.

11.3.3 Cliff House Hotel

This CBU includes the frontage from 5 Marine Drive West to the Sea Road access. The toe of the cliff is defended by a rock revetment and strongpoints, cliff stabilisation defences have effectively failed due to ongoing slope failures. The secondary defence options considered with benefit cost analysis are described below.

- **Dynamic Toe –** this frontage is already protected by a rock revetment, however, the construction of a dynamic toe by beach recharge would have the effect of increasing the protection to this defence and by adding tow weighting to the slip zone. This secondary option is technically and environmentally sound and would suit the requirements of English Nature. This secondary option has therefore been taken forward to the main Option development.

- **Cliff Stabilisation –** This would involve regrading the cliff to a point where it would be stable. The Option would also include associated drainage and landscaping works. However, due to the proximity of the Cliff House Hotel to the cliff edge this is not a technically viable option. There would also be considerable Environmental impacts on the SSSI and it is unlikely that this option would be favourable to English Nature.

- **Siphon Drains** – due to the proximity of the Cliff House Hotel to the cliff edge works in this CBU would be carried out as a priority. The drains within this frontage would be used as a trial site to develop the technique and measure their effectiveness. A "ring" of drains would be installed around the Cliff House Hotel to reduce the rate of erosion due to ground water effects. Again, a combination of siphon and electro pneumatic drains would be used. The installation would also include a collector drain with a discharge point into the sea, as well as a pumping station. This option presents the most environmentally sound solution as there would be no adverse impact on the SSSI.

11.3.4 Marine Drive West

This CBU includes the frontage from the Sea Road access to Hoskin's Gap. The toe of the cliff is defended by a rock revetment and strongpoints, while the cliff has been stabilised through regarding and drainage measures. However, there is considerable ground movement within this frontage with the slope stabilisation measures having effectively failed.

Due to the significant failures that have occurred within this unit there is a requirement to undertake works to reinstate suitable access tracks to enable access for plant to undertake future maintenance works. These works will also have the added benefit of increasing the recreational benefits, by allowing access from Barton through to Naish and Christchurch. The works would consist of the following elements: -

- **Lower Roadway –** a large amount of slip material has covered the roadway preventing plant and pedestrian access to the west. This element of the work would involve clearing the slip material from the roadway. Estimated cost - **£20,000**.

- **Slope Regarding –** between MH17 and MH20 there has been significant failure of the slope. This failure has resulted in material covering the lower roadway and the destabilisation of the upper roadway and sheet piled cut-off wall. Estimated cost **-** £**60,000.**

- **Drainage Repairs –** the slope stabilisation failures have resulted in the surface water pipe between MH18 and MH21 slumping and therefore reducing the effectiveness of the pipe. Surface water is "ponding" and contributing to slope failure mechanisms. It is estimated that 225m of pipe requires replacement along with two manholes. Additional drainage works are also required within the failure area to improve the groundwater drainage and existing outfall pipe. Estimated cost **- £100,000**.

- **Upper Roadway –** failure of the sheet piled cut-off wall has resulted in the upper roadway becoming unusable to both maintenance plant and pedestrians. The estimated cost of undertaking repairs to the roadway is **- £20,000**.

- **Sheet Piled Cut-Off Wall –** the wall in the section has effectively failed, resulting in it moving out of alignment. A 100m section of the wall requires replacement. Estimated cost **- £200,000**.

The secondary defence options considered with benefit cost analysis are described below.

- **Dynamic Toe –** this frontage is already protected by a rock revetment, however, the construction of a dynamic toe by beach recharge would have the effect of increasing the protection to this defence and by adding tow weighting to the slip zone. This secondary option is technically and environmentally sound and would suit the requirements of English Nature. This secondary option has therefore been taken forward to the main Option development.

- **Cliff Stabilisation –** This would involve regrading the cliff to a point where it would be stable. The Option would also include associated drainage and landscaping works. This could be left until year 10 at the earliest. There would be considerable Environmental impacts on the SSSI and it is unlikely that this option would be favourable to English Nature. However, this option has been taken forward to the main Option development.

- **Siphon Drains** – These would be installed along the southern edge of Marine Drive, to reduce the rate of erosion due to ground water effects. A combination of siphon and electro pneumatic drains would be used. The installation would also include a collector drain with a discharge point into the sea, as well as a pumping station. This option presents the most environmentally sound solution as there would be no adverse impact on the SSSI.

11.3.5 Barton Court

This CBU includes the frontage from the Hoskin's Gap access to Fisherman's Walk. The toe of the cliff is defended by a rock revetment and strongpoints, while the cliff has been stabilised through regarding and drainage measures. However, there is considerable ground movement within this frontage with the slope stabilisation measures having effectively failed. The secondary defence options considered with benefit cost analysis are described below.

- **Dynamic Toe –** this frontage is already protected by a rock revetment, however, the construction of a dynamic toe by beach recharge would have the effect of increasing the protection to this defence and by adding tow weighting to the slip zone. This secondary option is technically and environmentally sound and would suit the requirements of English Nature. This secondary option has therefore been taken forward to the main Option development.

- **Cliff Stabilisation –** This would involve regrading the cliff to a point where it would be stable. The Option would also include associated drainage and landscaping works. However, due to the proximity of Barton Court to the cliff edge this is not a technically viable option. There would also be considerable Environmental impacts on the SSSI and it is unlikely that this option would be favourable to English Nature.

- **Siphon Drains** – These would be installed along the southern edge of Marine Drive, to reduce the rate of erosion due to ground water effects. A combination of siphon and electro pneumatic drains would be used. The installation would also include a collector drain with a discharge point into the sea, as well as a pumping station. This option presents the most environmentally sound solution as there would be no adverse impact on the SSSI.

11.3.6 Marine Drive East

This CBU includes the frontage from Fisherman's Walk to the end of the defences at the eastern end of Barton. The toe of the cliff is defended by a rock revetment and strongpoints, while the cliff has been stabilised through regarding and drainage measures. The secondary defence options considered with benefit cost analysis are described below.

- **Dynamic Toe –** this frontage is already protected by a rock revetment, however, the construction of a dynamic toe by beach recharge would have the effect of increasing the protection to this defence and by adding tow weighting to the slip zone. This secondary option is technically and environmentally sound and would suit the requirements of English Nature. This secondary option has therefore been taken forward to the main Option development.

- **Cliff Stabilisation –** This would involve regrading the cliff to a point where it would be stable. The Option would also include associated drainage and landscaping works. This could be left until year 10 at the earliest. There would be considerable Environmental impacts on the SSSI and it is unlikely that this option would be favourable to English Nature. However, this option has been taken forward to the main Option development.

- **Siphon Drains** – These would be installed along the southern edge of Marine Drive, to reduce the rate of erosion due to ground water effects. A combination of siphon and electro pneumatic drains would be used. The installation would also include a collector drain with a discharge point into the sea, as well as a pumping station. This option presents the most environmentally sound solution as there would be no adverse impact on the SSSI. This secondary option has therefore not been taken forward to the main Option development.

11.4 Option Costs

11.4.1 Unit Costs

The costs (see Annex A for detailed FCDPAG3 project summary sheets) have been based on benchmarking against similar projects currently being undertaken around the UK, while Table 48 shown below summaries the rates that have been used for the cost estimates.

Work	**Rate £**
Shingle recharge	23.50/m^3
Groyne Construction (timber)	125,000
Groyne Maintenance	100/m
Seawall Construction	4,000/m
Seawall Maintenance	1000/m
Siphon Drainage	3,000/m
Revetment	6,000/m
Cliff stabilisation with revetment (no existing defences)	9,900/m
Cliff stabilisation (no existing defences)	6,500/m
Cliff stabilisation with revetment (existing defences)	8,000/m
Cliff stabilisation (existing defences)	5,000/m

Table 48. Construction Rates

11.4.2 Main Options

Four main Options have been developed to be taken forward to the benefit cost analysis. The indicated costs are current capital costs with no allowance for maintenance. A sensitivity analysis has been undertaken for each Option by varying the timing of the implementation of each secondary option within the CBUs.

11.4.3 Option A

This Option consists of the secondary options as shown in Table 49. Principally the Option consists of cliff stabilisation works within three of the CBU’s along with enhancements to the existing rock toe. Where it is not possible to undertake stabilisation works due to the proximity of existing properties to the cliff edge the proposed option is to install siphon drains and beach recharge to form a dynamic toe.

Description	Cliff Behaviour Unit				
	Naish Frontage (part)	Cliff House Hotel	Marine Drive West	Barton Court	Marine Drive East
	Area 2	Area 3	Area 4	Area 4A	Area 5
Dynamic toe/ recharge (m^3)		1.3M (60,000)			
Siphon Drains		495,000 (165m)		645,000 (215m)	
Cliff Stabilisation with Rock Toe (no existing defence)	4.95M (500m)				
Cliff Stabilisation with Rock Toe (existing defence)			2.76M (345m)		4.8M (600m)

Table 49 Option A (Present day capital cash costs)

The benefit cost analysis has been undertaken twice to assess the implications of implementing the Option over two time periods. The first (Option A1) of these shows the works being constructed in the early years of the assessment period, with capital beach recharges being undertaken at 15-year intervals. The stabilisation works have been designed on a 50-year life and so will need to be constructed twice within the assessment period.

The second analysis (Option A2) has been undertaken with the works for each CBU being phased in over a longer period. As in the first analysis the same allowance has been made for beach recharges and a 50 year design life.

Maintenance costs for recycling shingle every 2 years have been included as well as 5 yearly maintenance costs for the siphon drains. Table 50 provides details on the phasing of the options along with cash costs and present value costs.

Year	Description	Option A		Option A1	
		Cash Cost (£)	PV Cost (£)	Cash Cost (£)	PV Cost (£)
1	Siphon drains & dynamic toe (area 3)	1,300,000	1,260,000	1,300,000	1,260,000
3	Cliff stabilisation (area 2, 4, 5). Siphon drains (area 4a)	13,155,000	11,870,000		
3	Cliff stabilisation (area 5) Siphon drains (area 4a)			5,445,000	4,910,000
12	Cliff stabilisation (area 2)			4,950,000	3,280,000

16	Dynamic toe recharge	285,000	360,000	285,000	360,000
21	Cliff stabilisation (area 4)			2,760,000	1,340,000
31	Dynamic toe recharge	285,000	220,000	285,000	220,000
46	Dynamic toe recharge	285,000	140,000	285,000	140,000
53	Cliff stabilisation (area 2, 4, 5)	12,510,000	2,260,000		
53	Cliff stabilisation (area 5)			4,800,000	870,000
61	Dynamic toe recharge	285,000	90,000	285,000	90,000
62	Cliff stabilisation (area 2)			4,950,000	680,000
71	Cliff stabilisation (area 4)			2,760,000	290,000
76	Dynamic toe recharge	285,000	60,000	285,000	60,000
91	Dynamic toe recharge	285,000	40,000	285,000	40,000
Totals		**31,110,000**	**16,360,000**	**31,110,000**	**13,610,000**

Table 50. Option A – Option Implementation (Upper Bound)
Note: Total cash and PV costs include maintenance costs

11.4.4 Option B

This Option consists of the secondary options as shown in Table 51. Principally the Option consists of cliff stabilisation works within three of the CBU's (Option B). Where it is not possible to undertake stabilisation works due to the proximity of existing properties to the cliff edge the proposed option is to install siphon drains. Instead of increasing the existing rock revetment along the frontage beach recharge will be undertaken to form a dynamic toe.

Description	**Cliff Behaviour Unit**				
	Naish Frontage (part)	**Cliff House Hotel**	**Marine Drive West**	**Barton Court**	**Marine Drive East**
	Area 2	**Area 3**	**Area 4**	**Area 4A**	**Area 5**
Dynamic toe/ recharge (m^3)	1.5M (100,000)	900,000 (60,000)	1.2M (80,000)	0.6M (40,000)	1.5M (100,000)
Siphon Drains		495,000 (165m)		645,000 (215m)	
Cliff Stabilisation (no existing defence)	3.25M (500m)				
Cliff Stabilisation (existing defence)			1.725M (345m)		3M (600m)

Table 51. Option B (Present day capital cash costs)

The benefit cost analysis has also been undertaken to assess the implications of implementing the Option over an alternative time periods (Option B1), with works being constructed in the early years of the assessment period, with capital beach recharges being undertaken at 15-year intervals. The stabilisation works have been designed on a 50-year life and so will need to be constructed twice within the assessment period. Maintenance costs for recycling shingle every 2 years have been included as well as 5 yearly maintenance costs for the siphon drains. Table 52 provides details on the phasing of the options along with cash costs and present value costs.

Year	Description	Option B1		Option B2	
		Cash Cost (£)	PV Cost (£)	Cash Cost (£)	PV Cost (£)
1	Siphon drains (area 3)	495,000	480,000	495,000	480,000
3	Cliff stabilisation (area 2, 4, 5); Dynamic toe (area 2, 3, 4, 4a, 5); Siphon drains (area 4a)	14,320,000	12,920,000		
3	Cliff stabilisation (area 5) Siphon drains (area 4a) Dynamic toe (area 3, 4a, 5)			7,045,000	6,350,000
12	Cliff stabilisation (area 2) Dynamic toe (area 2)			5,150,000	3,410,000
16	Dynamic toe recharge (area 2, 3, 4, 4a, 5)	1,825,000	1,050,000		
18	Dynamic toe recharge (area 3, 4a, 5)			810,000	460,000
21	Cliff stabilisation (area 4) Dynamic toe (area 4)			3,325,000	1,610,000
27	Dynamic toe recharge (area 2)			435,000	190,000
31	Dynamic toe recharge (area 2, 3, 4, 4a, 5)	1,825,000	630,000		
33	Dynamic toe recharge (area 3, 4a, 5)			810,000	280,000
36	Dynamic toe recharge (area 4)			360,000	110,000
42	Dynamic toe recharge (area 2)			435,000	110,000
46	Dynamic toe recharge (area 2, 3, 4, 4a, 5)	1,825,000	410,000		
48	Dynamic toe recharge (area 3, 4a, 5)			810,000	180,000
51	Dynamic toe recharge (area 4)			360,000	70,000

53	Cliff stabilisation (area 2, 4, 5)	7,975,000	1,440,000		
53	Cliff stabilisation (area 5)			3,000,000	550,000
57	Dynamic toe recharge (area 2)			435,000	70,000
61	Dynamic toe recharge (area 2, 3, 4, 4a, 5)	1,825,000	260,000		
62	Cliff stabilisation (area 2)			3,250,000	460,000
63	Dynamic toe recharge (area 3, 4a, 5)			810,000	120,000
66	Dynamic toe recharge (area 4)			360,000	40,000
71	Cliff stabilisation (area 4)			1,725,000	190,000
72	Dynamic toe recharge (area 2)			435,000	50,000
76	Dynamic toe recharge (area 2, 3, 4, 4a, 5)	1,825,000	170,000		
78	Dynamic toe recharge (area 3, 4a, 5)			810,000	80,000
81	Dynamic toe recharge (area 4)			360,000	30,000
87	Dynamic toe recharge (area 2)			435,000	30,000
91	Dynamic toe recharge (area 2, 3, 4, 4a, 5)	1,825,000	120,000		
93	Dynamic toe recharge (area 3, 4a, 5)			810,000	50,000
96	Dynamic toe recharge (area 4)			360,000	20,000
Totals		**39,520,000**	**19,010,000**	**38,140,000**	**16,150,000**

Table 52. Option B – Option Implementation (Upper Bound)
Note: Total cash and PV costs include maintenance costs

11.4.5 Option C

This Option consists of the secondary options as shown in Table 53. The proposed Option C involves installing siphon drains within all 5 CBUs on the Barton frontage.

Description	Cliff Behaviour Unit				
	Naish Frontage (part)	Cliff House Hotel	Marine Drive West	Barton Court	Marine Drive East
	Area 2	**Area 3**	**Area 4**	**Area 4A**	**Area 5**
Siphon Drains	1,500,000 (500m)	495,000 (165m)	1,035,000 (345m)	645,000 (215m)	1,800,000 (600m)

Table 53. Option C (Present day capital cash costs)

The benefit cost analysis has also been undertaken to assess the implications of implementing the Option over alternative time periods. Option C1 shows the works being constructed in the early years of the assessment period; Option C2 with the works being phased over a longer period. Maintenance costs have been included for the siphon drains. Table 54 provides details on the phasing of the options along with cash costs and present value costs.

Year	Description	Option C		Option C1		Option C2	
		Cash Cost (£)	PV Cost (£)	Cash Cost (£)	PV Cost (£)	Cash Cost (£)	PV Cost (£)
	Design	438,000	420,000	91,000	90,000	40,000	40,000
2	Siphon drains (area 2,3,4, 4a, 5)	5.437M	5.08M				
2	Siphon drains (area 3, 4a)			1.449M	1.35M		
2	Siphon drains (area 3)					855,000	800,000
7	Siphon drains (area 4a)					593,000	470,000
30	Siphon drains (area 2, 5)			3.036M	1.08M	3.036M	1.75M
35	Siphon drains (area 4)			952,000	310,000	952,000	490,000
Totals		**7.74M**	**5.96M**	**7.16M**	**3.17M**	**7.16M**	**3.07M**

Table 54. Option C – Option Implementation (Upper Bound)
Note: Total cash and PV costs include maintenance costs

11.4.6 Option D

This Option consists of the secondary options as shown in Table 55. The proposed Option D involves installing siphon drains within all 5 CBUs on the Barton frontage, with a dynamic on the Naish and Cliff House frontages.

Description	Cliff Behaviour Unit				
	Naish Frontage (part)	Cliff House Hotel	Marine Drive West	Barton Court	Marine Drive East
	Area 2	Area 3	Area 4	Area 4A	Area 5
Siphon Drains	1.5M (500m)	495,000 (165m)	1.035M (345m)	645,000 (215m)	1.8M (600m)
Dynamic toe/ recharge (m^3)	1.,5M (100,000)	900,000 (60,000)			

Table 55. Option D (Present day capital cash costs)

The benefit cost analysis has also been undertaken to assess the implications of implementing the Option over alternative time periods. Option D1 shows the works being constructed in the early years of the assessment period; Option D2 with works being phased over a longer period. Maintenance costs have been included for the siphon drains, at 5 yearly intervals. Maintenance costs for the dynamic toe have been included as recycling every other year with interim beach recharges being undertaken at 15 year intervals. Table 56 provides details on the phasing of the options along with cash costs and present value costs.

Year	Description	Option D		Option D1		Option D2	
		Cash Cost (£)	PV Cost (£)	Cash Cost (£)	PV Cost (£)	Cash Cost (£)	PV Cost (£)
1		630,000	610,000	163,000	160,000	112,000	110,000
2	Siphon drains (area 2,3 4, 4a, 5) Dynamic toe (area 2 & 3)	7.65M	7.14M				
2	Siphon drains (area 3, 4a) Dynamic toe (area 3)			2.28M	2.13M		
2	Siphon drains and dynamic toe					1,683M	1,57M

	(area 3)						
7	Siphon drains (area 4a)					593,000	470,000
17	Dynamic toe recharge (area 2, 3)	660,000	420,000				
17	Dynamic toe recharge (area 3)			285,000	170,000	285,000	190,000
30	Siphon drains (areas 2, 5)			4.42M	1.57M	4.42M	1.57M
32	Dynamic toe recharge (area 2, 3)	750,000	250,000				
32	Dynamic toe recharge (area 3)			285,000	110,000	285,000	110,000
35	Siphon drain (area 4)			0.95M	310,000	0.95M	310,000
45	Dynamic toe recharge (area 2)			435,000	120,000	435,000	120,000
47	Dynamic toe recharge (area 2, 3)	750,000	160,000				
47	Dynamic toe recharge (area 3)			285,000	70,000	285,000	70,000
60	Dynamic toe recharge (area 2)			435,000	70,000	435,000	70,000
62	Dynamic toe recharge (area 2, 3)	750,000	100,000				
62	Dynamic toe recharge (area 3)			285,000	50,000	285,000	50,000
75	Dynamic toe recharge (area 2)			435,000	50,000	435,000	50,000

76	Dynamic toe recharge (area 2, 3)	660,000	60,000				
77	Dynamic toe recharge (area 3)			285,000	30,000	285,000	30,000
90	Dynamic toe recharge (area 2)			435,000	30,000	435,000	30,000
92	Dynamic toe recharge (area 2, 3)	750,000	5,000				
92	Dynamic toe recharge (area 3)			285,000	20,000	285,000	20,000
Totals		**16.6M**	**9.87M**	**15.32M**	**5.7M**	**15.33M**	**5.61M**

Table 56. Option D – Option Implementation (Upper Bound)
Note: Total cash and PV costs include maintenance costs

12 Benefit Cost Assessment CBY4

12.1 Introduction

Table 57 shows the PV benefit cost ratios for Option A and Table 58 shows the PV benefit cost ratios for the other Options (for the lower bound recession rates).

	Costs and benefits £M		
	Do-Nothing	**Option A**	**Option A1**
PV costs		16.36	13.61
Optimism bias		7.69	6.4
Total PV costs		24.05	20.01
PV damage	29.90	0.96	0.96
Total PV benefits		28.94	28.94
NPV		4.89	8.93
Benefit/cost ratio		1.2	1.45

Table 57. Option A benefits/costs

	Costs and benefits £M for Options								
	Do-Nothing	**B**	**B1**	**C**	**C1**	**C2**	**D**	**D1**	**D2**
PV costs		19.01	16.15	5.96	3.17	3.07	9.87	5.7	5.61
Optimism		9.13	7.75	2.62	1.39	1.35	4.54	2.62	2.58
Total PV		28.14	23.89	8.59	4.56	4.42	14.42	8.32	8.19
PV damage	29.58	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Total PV		28.66	28.66	28.66	28.66	28.66	28.66	28.66	28.66
NPV		0.52	4.77	20.07	24.10	24.24	14.25	20.34	20.47
Benefit/cost		1.02	1.2	3.34	6.28	6.48	1.99	3.45	3.5

Table 58. Option D benefits/costs

The results shown in the tables above indicate that to adopt the do nothing option would result in significant damages to local assets. Option C is shown to be the most beneficial option with benefit cost ratios ranging from 3.34 to 6.48. (See Annex A for detailed FCDPAG3 project summary sheets).

13 CBY5 Barton Golf Course to Hordle Cliff

13.1 CBY5 – Extent of Frontage

The extent of this unit is from the eastern end of the defences at Barton through to the western end of Hordle Cliff. The unit consists of unprotected cliffs for the whole of the frontage.

Aside from the Hordle House School development and Hordle Point House the frontage is undeveloped. There is Barton Golf Course to the west with the remaining frontage consisting of agricultural land. A coastal footpath runs along the cliff top from Milford through to Barton.

13.1.1 Clifftop Recession

Assessment of the erosion rates under the "do-nothing" option have been based on information from the SMP and the erosion rates used for CBY4 and CBY6. The frontage has been divided into two sections, from the start of the unit with CBY4 to a point 1,366m to the east and then from this point to the eastern end of the unit.

Erosion rates for this first section have been estimated at 1.46m/year and are assumed to happen from now, as it is known that this coastline is eroding. For the second section the rate has been assessed as 0.4m/year from now until year 35. From year 35 it has been assessed that the reducing beach volume will have reached the toe of the cliff and that erosion will then increase to the rate of 1.46m/year.

The specified erosion lines were plotted on OS maps in 10 year time bands, allowing assets to be classified with a predicted year of loss, these projected recession lines have also been plotted on the 2005 ortho-rectified aerial photographs**.**

13.1.2 Evaluation of Do Nothing Damages

The assets at risk from erosion are minimal, consisting of one property, agricultural land and part of the golf course. The one property affected (Hordle Point House) is some 85m from the cliff edge and is not likely to become vulnerable until year 88. The area of land that would be lost through erosion is shown in Table 59. Agricultural land has been assessed to have a value of £10,000/ha, under PAG3 guidance this is then multiplied by a factor of 0.45 to remove the cost of UK agricultural support.

Year	Agricultural Land (Ha)	Value (£)	Amenity Land (Ha)	Value (£)
10	1.2	5,400	1.8	180,000
20	1.2	5,400	1.8	180,000
30	1.2	5,400	1.8	180,000
40	1.9	8,550	1.8	180,000
50	2.4	10,800	1.8	180,000
60	2.4	10,800	1.8	180,000
70	2.4	10,800	1.8	180,000
80	2.4	10,800	1.8	180,000
90	2.4	10,800	1.8	180,000
100	2.4	10,800	1.8	180,000

Table 59. Land Erosion

The PV damage for the do-nothing scenario is shown in Table 60 (see Annex A for detailed FCDPAG3 project summary sheets).

Scenario	PV Damages (£)
Do Nothing	1,070,000

Table 60. Do Nothing PV Damages

A summary of those assets identified as being within the 100 year period is shown in Table 61.

Year	Number	Value (£)
1 to 10	0	0
11 to 20	0	0
21 to 30	0	0
31 to 40	0	0
41 to 50	0	0
51 to 60	0	0
61 to 70	0	0
71 to 80	0	0
81 to 90	1	1,000,000
91 to 100	0	0

Table 61. Summary of Erosion Damages (not discounted)

14 Intervention Options CBY5

14.1 Introduction

Due to the low value of assets at risk, intervention options for this unit have not been considered. The PV damages of £1,070,000 are insufficient to justify expenditure on any defence options.

15 Benefit Cost Assessment CBY5

15.1 Introduction

Due to the low value of assets at risk, an economic assessment of intervention options has not been considered.

16 CBY6 Hordle Cliff to Hurst Beach

16.1 CBY6 – Extent of Frontage

The extent of this unit includes Hordle Cliff to the west, where the developed area starts, through Milford-on-Sea to the start of Hurst Spit. The unit consists of the unprotected Hordle Cliff, with varying defences covering the frontage from Hordle Cliff House through to the eastern end of Hurst Road. The existing defences include concrete seawalls of varying forms, timber groynes, rock armour revetment and strongpoints. The full extent of this unit includes a high proportion of apartment developments along with large detached houses. There are also four public car parks and approximately 550 concrete and timber beach huts. The number of commercial premises within the unit is minimal, consisting of a hotel, café and restaurant.

16.1.1 Clifftop Recession

Under the "do-nothing" option, following the failure of the existing defences the coastline is assumed to erode at a constant rate. The future coastal recession rate has been assessed on the basis of historical erosion rates of 1.69m / year, which occurred prior to the coastal defences being in place. Asset condition assessments of the existing defences were undertaken to determine when failure is likely to occur and when erosion will commence (see Technical annexes: condition assessment & beach profile analysis). This information is summarised in Table 61 below.

Section	Start of Recession (year)	Length (m)
Start of CBY6 to start of seawall	2014	524
Start of seawall to Paddy's Gap	2024	210
Paddy's Gap	2034	120
Paddy's Gap car park	2024	60
Paddy's Gap car park to groyne 27	2034	310
Groyne 27 to strongpoint 5	2024	880
Strongpoint 5 to strongpoint 1	2014	230

Table 61. Commencement of Cliff Recession

The specified erosion lines were plotted on OS maps in 10 year time bands, allowing assets to be classified with a predicted year of loss, these projected recession lines have also been plotted on the 2001 ortho-rectified aerial photographs.

16.1.2 Evaluation of Do Nothing Damages

At Milford–on-Sea and Hordle Cliff the assets at risk from erosion consist mainly of residential properties, with a small number of commercial premises. The majority of these properties consist of apartment blocks. The main coastal road between Milford–on–Sea and Barton–on–Sea, Cliff Road would become subject to erosion by year 28. This would result in a relatively minor alternative route being used until year

60, at which point a significant length of the road would have been eroded to prevent traffic entering Milford–on–Sea from the west.

For the majority of the frontage there is a “buffering” zone between the clifftop and the properties to the north of Cliff Road and Hurst Road. This zone comprises of amenity land and four public car parks, meaning that the majority of properties are set back some 50 to 75 metres from the cliff edge and would only become vulnerable after some considerable time (30 plus years) under a do-nothing strategy. The area of amenity land that would be lost through erosion is shown in Table 62. The properties to the west of Whitby Road will not be affected until years 38 to 50, when erosion of the clifftop will have reached Cliff Road. Properties between Whitby Road and De La Warr Road will start to become vulnerable from erosion between years 40 and 60. Between De La Warr Road and Sea Road there are three groups of properties that will be affected by erosion at different periods, at the junction with De La Warr Road, Cliff Road is at its closest point to the cliff edge, Richmond Court will become vulnerable from approximately year 62. Moving to the east Shingles Bank Drive, Needles Point and Ravenhurst will start to be affected by erosion from year 48 and the properties to the north of Hurst Road will start to become affected from year 50. The properties at the eastern end of Hurst Road, from Sea Road will be affected from year 32 to 42. The Whitehouse, Needles Eye Café and Marine Café are the closest properties to the coast but will still not be affected for some considerable time under the do-nothing option, some 20 to 30 years.

Year	Area (Ha)	Value (£)
20	1.5	150,000
30	2.0	200,000
40	2.2	220,000
50	1.6	160,000
60	0.8	80,000
70	0.7	70,000

Table 62. Amenity Land Erosion

As discussed previously there are four public car parks within the erosion risk area Table 63 identifies these along with the forecast year of erosion risk and annual income.

Car Park	Erosion	Annual Income (£)
Hordle Cliff West	20	23,800
Paddy’s Gap	25	8,275
Hurst Road West	25	5,655
Hurst Road East	18	40,230

Table 63. Public Car Parks at Risk

There are a significant number of beach huts within this unit, divided between Milford-on-Sea and Hordle Cliff. At Hordle Cliff there are 470 beach huts, all are privately owned with 418 being on located on New Forest District Council land. At Milford-on-Sea there are approximately 133 beach huts, with all being located on District Council land. The market value of the timber beach huts is between £10,000 and £12,000, while the concrete huts at Milford-on-Sea are valued at £15,000, these values are based on previous sales. The average value of £11,000 has been used for the timber beach huts. Table 64 details values and incomes generated from the beach huts.

Beach Hut Site	Erosion Year	Number of Huts	Market Value (£)	Annual Income (£)
Hordle Cliff	10	53	583,000	0
Hordle Cliff	10	418	4,598,000	99,760
Milford (timber)	20	19	209,000	4,985
Milford-on-Sea	20	114	1,710,000	29,915

Table 64. Beach Huts at Risk

The PV damage for the do-nothing scenario is shown in Table 65 (see Annex A for detailed FCDPAG3 project summary sheets).

Scenario	PV Damages (£)
Do Nothing	38,990,000

Table 65. Do Nothing PV Damages

A summary of those assets identified as being within the 100 year period is shown in Table 66.

Year	Number	Value (£)
1 to 10	Beach huts	5,181,000
11 to 20	2 + beach huts	2,789,000
21 to 30	18	6,180,000
31 to 40	38	13,658,000
41 to 50	138	39,408,000
51 to 60	46	16,304,000
61 to 70	116	33,572,000
71 to 80	43	13,519,000
81 to 90	81	14,924,000
91 to 100	53	18,584,000

Table 66. Summary of Erosion Damages (not discounted)

17 Intervention Options CBY6

17.1 Introduction

The following sections identify and cost those defence intervention options that have been considered in the benefit cost analysis. The options include two main areas of work, reconstruction of the seawalls and beach recharge. Maintenance of the existing defences has also been considered.

17.2 Optimism Bias

As part of the FDCPAG3 Economic Appraisal the quantification of project risk is dealt with by utilising a factor known as “Optimism Bias” and is used to provide a suitable uplift to early best estimates of project costs, thereby, reducing the effect of under estimating project costs.

The guidance provide by Defra suggests that for a strategy study a starting value of 60% should be used for the Optimism Bias factor. This value is built up from a number of key components of risk, each with its own value derived from the “Average % for Flood and Coast Defence (FCD) projects”, the sum of which equals 100. If justifiable these risk components may be reduced, increased or unaltered to suit the particular circumstances of the study. The resulting total is multiplied by 60 to determine the “Optimism Bias” factor to be used in the benefit cost analysis. Table 67 details both the “Average % for FCD projects” (for comparison) and the adjusted percentage for each risk component. Justification for each risk component is provided in the text following the table.

Risk Components			Average % for FCD projects	% risk Option B	% risk Option C
(a)	Procurement	Late contractor involvement in	1	0	1
		Dispute and claims occurred	11	5	11
		Other	1	1	1
(b)	Project-specific	Design complexity	4	1	3
		Degree of innovation	4	1	2
		Environmental impact	13	2	5
		Other	9	5	9
(c)	Client Specific	Inadequacy of the business case	23	5	18
		Funding availability	2	2	2
		Project Management Team	1	0	1
		Poor project intelligence	8	4	4
(d)	Environment	Public relations	5	1	4
		Site characteristics	4	2	2
(e)	External influences	Economic	5	5	5
		Legislation / regulations	4	2	3
		Technology	4	1	1
		Other	1	1	1
Totals			**100**	**38**	**73**
Optimism Bias			**60**	**23**	**44**

Table 67. Risk Components & Associated Factors

(a) Procurement

Late contractor involvement in design: "Late involvement of the contractor in the design leads to redesign or problems during construction". For Option A this has been reduced to 0%, as this is standard maintenance work that has been undertaken by the Authority for a number of years and for which a contractor has already been appointed through the coastal maintenance contract. Options B & C are currently at strategy stage and contractors have not been involved with the preliminary Options. Therefore the risk component remains unchanged for these Options.

Disputes and claims occurred: "Disputes and claims occur where no mechanisms exist to manage effectively adversarial relationships between project stakeholders". Maintenance works are run through a partnership contract, which greatly reduces the risk of disputes and claims. The risk component has therefore been reduced to 5%. This risk component remains unchanged for Options b & C.

Other: "Other factors that relate to procurement which affect the final project cost". This risk component remains unchanged.

(b) Project-specific

Design complexity: "The complexity of design (including requirements, specifications and detailed design) requires significant management, impacting on final project costs". As discussed previously Option A is standard maintenance work, therefore the risk component under Option A has been reduced to 1%. The Option designs for Options B and C are not considered to be overly complex. The risk component for Options B and C has therefore been reduced to 3%.

Degree of innovation: "The degree of innovation required due to the nature of the project requires unproven methods to be used". Option A uses standard maintenance techniques, therefore the risk component under Option A has been reduced to 1%. Options B and C use standard construction methods, the risk component has therefore been reduced to 2%.

Environmental impact: "The project has a major impact on its adjacent area leading to objection from neighbours and the general public". English Nature is a member of the strategy steering group and has closely been involved throughout the development of the proposals. The recommended Options have been developed to ensure that the impact will be minimal on adjacent sites. The risk component has therefore been adjusted accordingly to take account of the varying options.

Other: "Other project specific factors, which affect the final project cost". For Option A this component has been reduced to 5%. This component has been left unchanged for Options B and C.

(c) Client-specific

Inadequacy of the business case: "The project scope changes as a result of the poor quality of requirement specifications and inadequate project scope definition". The requirements of the strategy have been clearly defined in the study. The risk component has therefore been reduced to 5% for Option A and 18% for Options B and C.

Funding availability: "Project delays or changes in scope occur as a result of the availability of funding (e.g. departmental budget spend or insufficient contingency funds)". This component has been left unchanged.

Project management team: "The project management team's capabilities and/or experience impact on final project costs". The experience of the project management team is sufficient to ensure minimal impact on final costs. This component has been reduced to 0% for Option A and left unchanged for Options B and C.

Poor project intelligence: "The quality of initial project intelligence (e.g. preliminary site investigation, user requirements surveys etc) impacts on the occurrence of unforeseen problems and costs". The necessity of carrying out a strategy study requires that sufficient investigation / information be gathered to complete the study. This component has therefore been reduced to 4%.

(d) Environment

Public relations: "A high level of effort is required to address public concern about the project, which impacts on the final project cost". The recommended options will be brought to the public's attention through public exhibitions and consultation leaflets, to be distributed locally. The risk component for Option A has been reduced to 1% as this involves work that is currently undertaken, with the public being fully aware. Options B and C have been reduced accordingly to 4% and 3%.

Site characteristics: "The characteristics of the proposed environment for the project are highly sensitive to the project's environmental impact (e.g. Greenfield site with badger setts, or contaminated brownfield site)". The environmental issues have been addressed through the Strategic Environmental Assessment and full consultation with English Nature. Therefore this component has been reduced to 2%.

(e) External influences

Economic: "The project costs are sensitive to economic influences such as higher than expected construction cost, inflation, oil price shocks etc". This component has remained unchanged at 5%.

Legislation / regulations: "The project costs are sensitive to legislation and regulation changes e.g. health and safety and building regulations". The construction processes are considered to be relatively simple and unlikely to be affected by changes to legislation / regulations, which would affect the cost of the works. This component has therefore been reduced to 2% for Option A and 3% for Options B and C.

Technology: "The project costs are sensitive to technological advancements, e.g. the effects of obsolescence". It is anticipated that construction techniques may improve, but that the methods of providing coastal defence will not become obsolete. The risk component has been reduced to 1%.

Other: "Other external influencing factors which affect the final project cost". This component has been left unaltered.

17.3 Options Considered

17.3.1 Option A – Do nothing, abandon the defences

This option seeks to undertake no further capital or maintenance works, allowing the frontage to develop naturally as the existing defences fail. As the defences reach the end of their residual life structure failure will occur and erosion will commence. With the resultant loss of recreational land, beach huts, car parks and property.

17.3.2 Option B – Maintain existing defences

This option seeks to develop the minimum expenditure required whereby the current defences can be maintained. No capital expenditure is proposed, with the works being undertaken through revenue maintenance budgets. Maintenance works would be undertaken on the timber groynes on an annual basis, this would include replacing piles, boards and pile protection units. In addition to this there would be a requirement to undertake repairs to the existing concrete seawalls, it is estimated that these will be required every 10 years. The existing rock structures within the frontage will also require maintenance and it is anticipated that this will be undertaken every 10 years. However, due to reducing beach volumes (Technical Annex: beachplan modelling) it is estimated that by year 20 the concrete seawalls will have reached their residual life and failed. This failure will be due to the low level of protection afforded by the reduced beach volumes, causing failure of the structures by undermining and no toe protection.

17.3.3 Option C – Maintain existing defence and replace seawalls

This option includes the maintenance works undertaken in option B, as described above. However, due to the projected decline in beach volumes if no intervention occurs then extensive capital works will be required for a phased replacement of the concrete seawalls. The unit has been divided into 5 sections, depending on when failure is predicted to occur. This is detailed in Table 68 below.

Section	Length (m)	Replacement (years)
End of unit to start of seawall	520	10 &60
Start of seawall to Paddy's Gap	210	18 & 68
Paddy's Gap	120	28 & 78
Paddy's Gap car park	60	28 & 78
Paddy's Gap car park to groyne 27	310	28 & 78
Groyne 27 to strongpoint 5	880	18 & 68
Strongpoint 5 to strongpoint 1	230	10 & 60

Table 68. Seawall Replacement

Replacement of each section of seawall would be undertaken twice within the 100 year assessment period, this being based on a 50 year design life of the structure. Within the western section of the unit there is currently no existing defence in place. It is estimated that with the declining beach volumes that a new seawall would require constructing in year 10 in order to prevent the on-set on cliff erosion.

17.4 Option Costs

17.4.1 Unit Costs

The costs (see Annex A for detailed FCDPAG3 project summary sheets) have been based on benchmarking against similar projects currently being undertaken around the UK and costs incurred by the District Council in undertaking maintenance works, while Table 69 summaries the rates that have been used for the cost estimates.

Work	Rate
Shingle Recharge - lower	£15/m^3
Shingle Recharge - middle	£23.50/m^3
Shingle Recharge - upper	£32/m^3
Delivery - rainbow	£60,000
Delivery - pipeline	£400,000
Seawall Construction	£4,000/m
Groyne Maintenance	
Pile protection units	£165 each
Replace boards	£450 each
Replace piles	£800 each
Replace bolts	£45 each
Seawall maintenance	£80,000
Recycling	£7/ m^3

Table 69.Construction Rates

17.4.2 Option B

Maintenance costs for this Option are shown in Table 70 below. Table 71 provides details on the phasing of the works along with cash costs and present value costs.

Description	Value (£)	Frequency
Groyne Maintenance	28,000	Annually
Rock Maintenance	30,000	5 years
Seawall Maintenance	80,000	10 years

Table 70. Option B (Present day capital cash costs)

		Option B	
Year	Description	Cash Cost (£)	PV Cost (£)
0	Groyne & rock maintenance	58,000	58,000
1	Groyne & seawall maintenance	108,000	104,000
2-4	Groyne maintenance	84,000	76,000
5	Groyne & rock maintenance	58,000	49,000
6-9	Groyne maintenance	112,000	87,000
10	Groyne & rock maintenance	58,000	41,000
11	Groyne & seawall maintenance	108,000	74,000
12-14	Groyne maintenance	84,000	54,000

15	Groyne & rock maintenance	58,000	35,000
16-19	Groyne maintenance	112,000	61,000
20	Groyne & rock maintenance	58,000	29,000
Totals		**900,000**	**670,000**

Table 71. Option B – Option Implementation

17.4.3 Option C

This option includes maintenance of the existing defences along with the replacement of the concrete seawall. The cost of replacing each section of seawall is shown in Table 72 below.

Section	Cost (£)
Groyne1 to groyne 5	920,000
Groyne 5 to groyne 27	3,520,000
Groyne 27 to Paddy's Gap	1,960,000
Paddy's Gap to end of wall	840,000
End of wall to end of unit	2,080,000

Table 72. Seawall Replacement

It is estimated that the seawall will have a design life of 50-years and so will need to be constructed twice within the assessment period. The costs shown above are present value costs of constructing the wall once. Table 73 provides details on the phasing of the options along with cash costs and present value costs.

		Option C	
Year	**Description**	**Cash Cost (£)**	**PV Cost (£)**
0	Groyne & rock maintenance	58,000	58,000
1	Groyne & seawall maintenance	108,000	104,000
2-4	Groyne maintenance	84,000	76,000
5	Groyne & rock maintenance	58,000	49,000
6-9	Groyne maintenance	112,000	87,000
10	Replace seawall groyne 1 to 5 and end of wall. Maintenance	3,058,000	2,168,000
11	Groyne & seawall maintenance	108,000	74,000
12-14	Groyne maintenance	84,000	54,000
15	Groyne & rock maintenance	58,000	35,000
16-17	Groyne maintenance	56,000	32,000
18	Replace seawall groyne 5 to 27 and Paddy's Gap to end of wall. Maintenance	4,388,000	2,362,000
19	Groyne maintenance	28,000	29,000
20	Groyne & rock maintenance	58,000	35,000
21	Groyne & seawall maintenance	108,000	50,000
22-24	Groyne maintenance	84,000	40,000
25	Groyne & rock maintenance	58,000	20,000
26-27	Groyne maintenance	56,000	20,000
28	Replace seawall groyne 27-Paddy's Gap.	1,990,000	760,000

29	Groyne maintenance	28,000	10,000
30	Groyne & rock maintenance	58,000	21,000
31	Groyne & seawall maintenance	108,000	37,000
32-34	Groyne maintenance	84,000	27,000
35	Groyne & rock maintenance	58,000	18,000
36-39	Groyne maintenance	112,000	32,000
40	Groyne & rock maintenance	58,000	15,000
41	Groyne & seawall maintenance	108,000	28,000
42-44	Groyne maintenance	84,000	20,000
45	Groyne & rock maintenance	58,000	13,000
46-49	Groyne maintenance	112,000	24,000
50	Groyne & rock maintenance	58,000	11,000
51	Groyne & seawall maintenance	108,000	21,000
52-54	Groyne maintenance	84,000	15,000
55	Groyne & rock maintenance	58,000	10,000
56-59	Groyne maintenance	112,000	18,000
60	Replace seawall groyne 1 to 5 and end of wall. Maintenance	3,058,000	449,000
61	Groyne & seawall maintenance	108,000	15,000
62-64	Groyne maintenance	84,000	11,000
65	Groyne & rock maintenance	58,000	7,000
66-67	Groyne maintenance	56,000	7,000
68	Replace seawall groyne 5 to 27 and Paddy's Gap to end of wall. Maintenance	4,388,000	508,000
69	Groyne maintenance	28,000	3,000
70	Groyne & rock maintenance	58,000	6,000
71	Groyne & seawall maintenance	108,000	11,000
72-74	Groyne maintenance	84,000	8,000
75	Groyne & rock maintenance	58,000	5,000
76-77	Groyne maintenance	56.000	5,000
78	Replace seawall groyne 27 to Paddy's Gap. Maintenance	1,988,000	174,000
79	Groyne maintenance	28,000	2,000
80	Groyne & rock maintenance	58,000	5,000
81	Groyne & seawall maintenance	108,000	9,000
82-84	Groyne maintenance	84,000	6,000
85	Groyne & rock maintenance	58,000	4,000
86-89	Groyne maintenance	112,000	8,000
90	Groyne & rock maintenance	58,000	4,000
91	Groyne & seawall maintenance	108,000	7,000
92-94	Groyne maintenance	84,000	5,000
95	Groyne & rock maintenance	58,000	3,000
96-99	Groyne maintenance	112,000	6,000
Totals		**22,840,000**	**7,630,000**

Table 73. Option C – Option Implementation

18 Benefit Cost Assessment CBY6

18.1 Introduction

Table 74 shows the PV benefit cost ratios for each Option for CBY6. The results indicate that to adopt the do nothing option would result in significant damages to local assets. (See Annex A for detailed FCDPAG3 project summary sheets).

	Costs and benefits £M		
	Do-Nothing	**Option B**	**Option C**
PV costs		0.67	7.63
Optimism bias		0.15	3.36
Total PV costs		0.82	10.99
PV assets PVa	38.99	19.6	19.6
Total PV benefits		19.4	19.4
NPV		18.58	8.41
Benefit/cost ratio		23.62	1.77

Table 74. Option Benefits / Costs

Annex A: FCDPAG3 Project Summary Sheets

	Project Summary Sheet				
Client/Authority				Prepared	
New Forest District Council				Printed	09/05/2012
Project name				Prepared by	SJC
Christchurch Bay CSP - CBY2a and CBY2b Highcliffe				Checked by	
Project reference		2124		Checked	
Base date for estimates (year 0)		Jan-2003			
Scaling factor (e.g. £m, £k, £)		£m	(used for all costs, losses and benefits)		
Principle land use band		A	(A to E)		
Initial discount rate		3.5%			
Optimism bias factor		46.0%			
Costs and benefits of options					
	Costs and benefits £m				
	No Project	Option A	Option B20	Option B40	
PV costs from estimates	0.00	6.73	5.03	5.52	
Optimism bias adjustment		3.10	2.31	2.54	
Total PV Costs for appraisal PVc		9.83	7.35	8.06	
PV damage PVd	40.34	1.29	1.29	1.29	
PV damage avoided		39.04	39.04	39.04	
PV assets Pva					
PV asset protection benefits		0.00	0.00	0.00	
Total PV benefits PVb		39.04	39.04	39.04	
Net Present Value NPV		29.22	31.70	30.98	
Average benefit/cost ratio		3.97	5.31	4.84	
Incremental benefit/cost ratio			0.00	0.00	
		-	Highest b/c	-	
Brief description of options:					
Option A	removal of defences from Mudeford Quay to Steamer Point and Highcliffe yr3; beach recharge from yr3 with recycling every 15yrs				
Option B20	shorten defences (by 20m) from Mudeford Quay to Steamer Point, and Highcliffe yr3, beach recharge from yr3 with recycling every 15yrs				
Option B40	shorten defences (by 40m) from Mudeford Quay to Steamer Point, and Highcliffe yr3, beach recharge from yr3 with recycling every 15yrs				

	Project Summary Sheet				
Client/Authority				Prepared	
New Forest District Council				Printed	09/05/2012
Project name				Prepared by	SJC
Christchurch Bay CSP - CBY2c				Checked by	
Project reference		2124		Checked	
Base date for estimates (year 0)		Jan-2003			
Scaling factor (e.g. £m, £k, £)		£m	(used for all costs, losses and benefits)		
Principle land use band		A	(A to E)		
Initial discount rate		3.5%			
Optimism bias factor		35.0%			
Costs and benefits of options					
	Costs and benefits £m				
	No Project	Option C			
PV costs from estimates	0.00	3.15			
Optimism bias adjustment		1.10			
Total PV Costs for appraisal PVc		4.26			
PV damage PVd	40.34	1.29			
PV damage avoided		39.04			
PV assets Pva					
PV asset protection benefits		0.00			
Total PV benefits PVb		39.04			
Net Present Value NPV		34.79			
Average benefit/cost ratio		9.17			
Incremental benefit/cost ratio					
		Highest b/c			
Brief description of options:					
Option C	replace timber groynes with rock groynes, maintenance of existing at Highcliffe				

	Project Summary Sheet				
Client/Authority				Prepared	
New Forest District Council				Printed	09/05/2012
Project name				Prepared by	SJC
Christchurch Bay CSP - CBY2d				Checked by	
Project reference		2124		Checked	
Base date for estimates (year 0)		Jan-2003			
Scaling factor (e.g. £m, £k, £)		£m	(used for all costs, losses and benefits)		
Principle land use band		A	(A to E)		
Initial discount rate		3.5%			
Optimism bias factor		38.0%			
Costs and benefits of options					
	Costs and benefits £m				
	No Project	Option D			
PV costs from estimates	0.00	4.69			
Optimism bias adjustment		1.78			
Total PV Costs for appraisal PVc		6.47			
PV damage PVd	40.34	1.29			
PV damage avoided		39.04			
PV assets Pva					
PV asset protection benefits		0.00			
Total PV benefits PVb		39.04			
Net Present Value NPV		32.57			
Average benefit/cost ratio		6.03			
Incremental benefit/cost ratio					
		Highest b/c			
Brief description of options:					
Option D	replace timber groynes with rock groynes, maintenance of existing at Highcliffe, and beach recharge from yr10 with recycling every 15yrs				

	Project Summary Sheet				
Client/Authority				Prepared	
New Forest District Council				Printed	09/05/2012
Project name				Prepared by	SJC
Christchurch Bay CSP - CBY2a and CBY2b Highcliffe				Checked by	
Project reference		2124		Checked	
Base date for estimates (year 0)		Jan-2003			
Scaling factor (e.g. £m, £k, £)		£m	(used for all costs, losses and benefits)		
Principle land use band		A	(A to E)		
Initial discount rate		3.5%			
Optimism bias factor		40.0%			
Costs and benefits of options					
	Costs and benefits £m				
	No Project	Option E			
PV costs from estimates	0.00	6.41			
Optimism bias adjustment		2.56			
Total PV Costs for appraisal PVc		8.97			
PV damage PVd	40.34	1.29			
PV damage avoided		39.04			
PV assets Pva					
PV asset protection benefits		0.00			
Total PV benefits PVb		39.04			
Net Present Value NPV		30.07			
Average benefit/cost ratio		4.35			
Incremental benefit/cost ratio					
		Highest b/c			
Brief description of options:					
Option E	replacement of seawall and maintenance of existing groynes				

Project Summary Sheet					
Client/Authority				Prepared	11/03/2003
New Forest District Council				Printed	09/05/2012
Project name				Prepared by	SJC
Christchurch Bay CSP - CBY3 lower bound Option A and A1				Checked by	
Project reference		2124		Checked	11/03/2003
Base date for estimates (year 0)		Jan-2003			
Scaling factor (e.g. £m, £k, £)		£m	(used for all costs, losses and benefits)		
Principle land use band		A	(A to E)		
Initial discount rate		3.5%			
Optimism bias factor		49.0%			
Costs and benefits of options					
	Costs and benefits £m				
	No Project	Option A	Option A1		
PV costs from estimates	0.00	2.66	5.13		
Optimism bias adjustment		1.30	2.52		
Total PV Costs for appraisal PVc		3.96	7.65		
PV damage PVd	35.94	1.15	1.15		
PV damage avoided		34.79	34.79		
PV assets Pva					
PV asset protection benefits		0.00	0.00		
Total PV benefits PVb		34.79	34.79		
Net Present Value NPV		30.83	27.14		
Average benefit/cost ratio		8.79	4.55		
Incremental benefit/cost ratio			0.00		
		Highest b/c	-		
Brief description of options:					
Option A	Beach recharge from yr3 with interim recharges every 15yrs and recycling every 2yrs				
Option A1	Beach recharge from yr3 with interim recharges every 15yrs and recycling every 2yrs, siphon drains yr3 maintenance of siphon drains every 5yrs,				

	Project Summary Sheet				
Client/Authority				Prepared	11/03/2003
New Forest District Council				Printed	09/05/2012
Project name				Prepared by	SJC
Christchurch Bay CSP - CBY3 lower bound Option B				Checked by	
Project reference		2124		Checked	11/03/2003
Base date for estimates (year 0)		Jan-2003			
Scaling factor (e.g. £m, £k, £)		£m	(used for all costs, losses and benefits)		
Principle land use band		A	(A to E)		
Initial discount rate		3.5%			
Optimism bias factor		44.0%			
Costs and benefits of options					
	Costs and benefits £m				
	No Project		Option B		
PV costs from estimates	0.00		2.48		
Optimism bias adjustment			1.09		
Total PV Costs for appraisal PVc			3.57		
PV damage PVd	35.94		1.15		
PV damage avoided			34.79		
PV assets Pva					
PV asset protection benefits			0.00		
Total PV benefits PVb			34.79		
Net Present Value NPV			31.22		
Average benefit/cost ratio			9.75		
Incremental benefit/cost ratio			9.75		
			Highest b/c		
Brief description of options:					
Option B	cliff stabilisation siphon drains yr3 and maintenance every 5yrs				

	Project Summary Sheet				
Client/Authority				Prepared	11/03/2003
New Forest District Council				Printed	09/05/2012
Project name				Prepared by	SJC
Christchurch Bay CSP - CBY3 lower bound Option C				Checked by	
Project reference		2124		Checked	11/03/2003
Base date for estimates (year 0)		Jan-2003			
Scaling factor (e.g. £m, £k, £)		£m	(used for all costs, losses and benefits)		
Principle land use band		A	(A to E)		
Initial discount rate		3.5%			
Optimism bias factor		52.0%			
Costs and benefits of options					
	Costs and benefits £m				
	No Project			Option C	Option C1
PV costs from estimates	0.00			5.46	7.93
Optimism bias adjustment				2.84	4.13
Total PV Costs for appraisal PVc				8.29	12.06
PV damage PVd	35.94			1.15	1.15
PV damage avoided				34.79	34.79
PV assets Pva					
PV asset protection benefits				0.00	0.00
Total PV benefits PVb				34.79	34.79
Net Present Value NPV				26.50	22.73
Average benefit/cost ratio				4.20	2.89
Incremental benefit/cost ratio				4.20	0.00
				Highest b/c	-
Brief description of options:					
Option C	construct revetment yr3 and replace yr53				
Option C1	construct revetment and siphon drains yr3 and replace yr53, with maintenance every 5yrs				

	Project Summary Sheet				
Client/Authority				Prepared	11/03/2003
New Forest District Council				Printed	09/05/2012
Project name				Prepared by	SJC
Christchurch Bay CSP - CBY3 lower bound Option D				Checked by	
Project reference		2124		Checked	11/03/2003
Base date for estimates (year 0)		Jan-2003			
Scaling factor (e.g. £m, £k, £)		£m	(used for all costs, losses and benefits)		
Principle land use band		A	(A to E)		
Initial discount rate		3.5%			
Optimism bias factor		52.0%			
Costs and benefits of options					
	Costs and benefits £m				
	No Project			Option D	Option D1
PV costs from estimates	0.00			3.64	6.11
Optimism bias adjustment				1.89	3.18
Total PV Costs for appraisal PVc				5.53	9.29
PV damage PVd	35.94			1.15	1.15
PV damage avoided				34.79	34.79
PV assets Pva					
PV asset protection benefits				0.00	0.00
Total PV benefits PVb				34.79	34.79
Net Present Value NPV				29.26	25.50
Average benefit/cost ratio				6.29	3.74
Incremental benefit/cost ratio				6.29	0.00
				Highest b/c	-
Brief description of options:					
Option D	construct seawall yr3 and replace yr53				
Option D1	construct seawall and siphon drains yr3 and replace yr53, with maintenance every 5yrs				

Project Summary Sheet					
Client/Authority				Prepared	11/03/2003
New Forest District Council				Printed	09/05/2012
Project name				Prepared by	SJC
Christchurch Bay CSP - CBY4 Option A - lower bound				Checked by	
Project reference		2124		Checked	11/03/2003
Base date for estimates (year 0)		Jan-2003			
Scaling factor (e.g. £m, £k, £)		£m	(used for all costs, losses and benefits)		
Principle land use band		A	(A to E)		
Initial discount rate		3.5%			
Optimism bias factor		47.0%			
Costs and benefits of options					
	Costs and benefits £m				
	No Project	Option A	Option A1		
PV costs from estimates	0.00	16.36	13.61		
Optimism bias adjustment		7.69	6.40		
Total PV Costs for appraisal PVc		24.05	20.01		
PV damage PVd	29.90	0.96	0.96		
PV damage avoided		28.94	28.94		
PV assets Pva					
PV asset protection benefits		0.00	0.00		
Total PV benefits PVb		28.94	28.94		
Net Present Value NPV		4.89	8.93		
Average benefit/cost ratio		1.20	1.45		
Incremental benefit/cost ratio			0.00		
		-	Highest b/c		
Brief description of options:					
Option A	beach recharge (Cliff House Hotel) from yr1 and every 15yrs; cliff stabilisation and siphon drains (Cliff House Hotel and Barton Court) and 500m extension rock toe (Naish) yrs1-3 and 53				
Option A1	beach recharge (Cliff House Hotel) yr1 and every 15yrs; cliff stabilisation and siphon drains (Cliff House Hotel and Barton Court) yrs1, 3, 12, 21, 53, 62, 71 and 54 and 500m extension rock toe (Naish) yrs 12 and 62				

Project Summary Sheet						
Client/Authority					Prepared	11/03/2003
New Forest District Council					Printed	09/05/2012
Project name					Prepared by	SJC
Christchurch Bay CSP - CBY4 Option B - lower bound					Checked by	
Project reference		2124			Checked	11/03/2003
Base date for estimates (year 0)		Jan-2003				
Scaling factor (e.g. £m, £k, £)		£m	(used for all costs, losses and benefits)			
Principle land use band		A	(A to E)			
Initial discount rate		3.5%				
Optimism bias factor		48.0%				
Costs and benefits of options						
	Costs and benefits £m					
	No Project	Option B	Option B1			
PV costs from estimates	0.00	19.01	16.15			
Optimism bias adjustment		9.13	7.75			
Total PV Costs for appraisal PVc		28.14	23.89			
PV damage PVd	29.58	0.92	0.92			
PV damage avoided		28.66	28.66			
PV assets Pva						
PV asset protection benefits		0.00	0.00			
Total PV benefits PVb		28.66	28.66			
Net Present Value NPV		0.52	4.77			
Average benefit/cost ratio		1.02	1.20			
Incremental benefit/cost ratio			0.00			
		-	Highest b/c			
Brief description of options:						
Option B	Siphon drains at Cliff House Hotel yr1 and Barton Court yr3; beach recharge (all areas) from yr3; cliff stabilisation and 500m extension rock toe (Naish) yr3 and 53					
Option B1	Siphon drains Cliff House Hotel yr1 and Barton Court yr3; beach recharge (all areas yrs3 and Naish yr12) and recycling; cliff stabilisation yrs3, 12, 21, 53, 62, 71 and 500m extension rock toe (Naish) yr 62					

	Project Summary Sheet				
Client/Authority				Prepared	11/03/2003
New Forest District Council				Printed	09/05/2012
Project name				Prepared by	SJC
Christchurch Bay CSP - CBY4 Option C - lower bound				Checked by	
Project reference		2124		Checked	11/03/2003
Base date for estimates (year 0)		Jan-2003			
Scaling factor (e.g. £m, £k, £)		£m	(used for all costs, losses and benefits)		
Principle land use band		A	(A to E)		
Initial discount rate		3.5%			
Optimism bias factor		44.0%			
Costs and benefits of options					
	Costs and benefits £m				
	No Project	Option C	Option C1	Option C2	
PV costs from estimates	0.00	5.96	3.17	3.07	
Optimism bias adjustment		2.62	1.39	1.35	
Total PV Costs for appraisal PVc		8.59	4.56	4.42	
PV damage PVd	29.58	0.92	0.92	0.92	
PV damage avoided		28.66	28.66	28.66	
PV assets Pva					
PV asset protection benefits		0.00	0.00	0.00	
Total PV benefits PVb		28.66	28.66	28.66	
Net Present Value NPV		20.07	24.10	24.24	
Average benefit/cost ratio		3.34	6.28	6.48	
Incremental benefit/cost ratio			0.00	0.00	
		-	-	Highest b/c	
Brief description of options:					
Option C	Siphon drains (all areas) yr2				
Option C1	siphon drains yr2 Cliff House Hotel and Barton Court; yr16 Naish and Marine Drive East; yr21 Marine Drive West				
Option C2	siphon drains yr2 Cliff House Hotel; yr7 Barton Court; yr16 Naish and Marine Drive East; yr21 Marine Drive West				

	Project Summary Sheet				
Client/Authority				Prepared	11/03/2003
New Forest District Council				Printed	09/05/2012
Project name				Prepared by	SJC
Christchurch Bay CSP - CBY4 Option D - lower bound				Checked by	
Project reference		2124		Checked	11/03/2003
Base date for estimates (year 0)		Jan-2003			
Scaling factor (e.g. £m, £k, £)		£m	(used for all costs, losses and benefits)		
Principle land use band		A	(A to E)		
Initial discount rate		3.5%			
Optimism bias factor		46.0%			
Costs and benefits of options					
	Costs and benefits £m				
	No Project	Option D	Option D1	Option D2	
PV costs from estimates	0.00	9.87	5.70	5.61	
Optimism bias adjustment		4.54	2.62	2.58	
Total PV Costs for appraisal PVc		14.42	8.32	8.19	
PV damage PVd	29.58	0.92	0.92	0.92	
PV damage avoided		28.66	28.66	28.66	
PV assets Pva					
PV asset protection benefits		0.00	0.00	0.00	
Total PV benefits PVb		28.66	28.66	28.66	
Net Present Value NPV		14.25	20.34	20.47	
Average benefit/cost ratio		1.99	3.45	3.50	
Incremental benefit/cost ratio			0.00	0.00	
		-	-	Highest b/c	
Brief description of options:					
Option D	siphon drains (all areas) and beach recharge (Naish and Cliff House Hotel) yr2 with recharges every 15yrs				
Option D1	siphon drains yr2 Cliff House Hotel and Barton Court; yr16 Marine Drive East and recharge Naish every 15yrs; yr17 recharge Cliff House Hotel and every 15yrs; yr21 siphon drains Marine Drive West				
Option D2	yr2 siphon drains and recharge yr2 Cliff House Hotel; yr7 siphon drains Barton Court; yr16 Marine Drive East and recharge Naish every 15yrs; yr17 recharge Cliff House Hotel and every 15yrs; yr21 siphon drains Marine Drive West				

	Project Summary Sheet				
Client/Authority				Prepared	
New Forest District Council				Printed	09/05/2012
Project name				Prepared by	SJC
Christchurch Bay CSP - CBY6 Milford-on-Sea Option B				Checked by	
Project reference		2124		Checked	
Base date for estimates (year 0)		Nov-2004			
Scaling factor (e.g. £m, £k, £)		£m	(used for all costs, losses and benefits)		
Principle land use band		A	(A to E)		
Initial discount rate		3.5%			
Optimism bias factor		23.0%			
Costs and benefits of options					
	Costs and benefits £m				
	No Project	Option B			
PV costs from estimates	0.00	0.67			
Optimism bias adjustment		0.15			
Total PV Costs for appraisal PVc		0.82			
PV damage PVd					
PV damage avoided		0.00			
PV assets Pva	38.99	19.60			
PV asset protection benefits		19.40			
Total PV benefits PVb		19.40			
Net Present Value NPV		18.58			
Average benefit/cost ratio		23.62			
Incremental benefit/cost ratio					
		Highest b/c			
Brief description of options:					
Option B	groyne and rock maintenance				

	Project Summary Sheet				
Client/Authority				Prepared	
New Forest District Council				Printed	09/05/2012
Project name				Prepared by	SJC
Christchurch Bay CSP - CBY6 Milford-on-Sea Option C				Checked by	
Project reference		2124		Checked	
Base date for estimates (year 0)		Nov-2004			
Scaling factor (e.g. £m, £k, £)		£m	(used for all costs, losses and benefits)		
Principle land use band		A	(A to E)		
Initial discount rate		3.5%			
Optimism bias factor		44.0%			
Costs and benefits of options					
	Costs and benefits £m				
	No Project	Option C			
PV costs from estimates	0.00	7.63			
Optimism bias adjustment		3.36			
Total PV Costs for appraisal PVc		10.99			
PV damage PVd					
PV damage avoided		0.00			
PV assets Pva	38.99	19.60			
PV asset protection benefits		19.40			
Total PV benefits PVb		19.40			
Net Present Value NPV		8.41			
Average benefit/cost ratio		1.77			
Incremental benefit/cost ratio					
		Highest b/c			
Brief description of options:					
Option C	groyne, seawall and rock maintenance; yrs10 and 60 replace seawall and groynes 1-5 and end of wall; yrs18and 68 replace seawall groyne 5-27 and Paddy's Gap to end of wall; yrs28 and 78 replace seawall groyne 27 to Paddy's Gap				

Annex B: CLIFF BEHAVIOUR ASSESSMENT: A QUANTITATIVE APPROACH USING DIGITAL PHOTOGRAMMETRY AND GIS

CLIFF BEHAVIOUR ASSESSMENT: A QUANTITATIVE APPROACH USING DIGITAL PHOTOGRAMMETRY AND GIS

Roger Moore, PhD CGeol, Paul Fish, PhD and Mark Glennerster, Halcrow Group Ltd, Andrew Bradbury, PhD, New Forest District Council

ABSTRACT
Further to DEFRA's *FutureCoast* study and the recently published *Investigation and Management of Soft Rock Cliffs*, there is a need to make robust projections of coastal change over the next 50 to 100 years to support coastal management strategies and decision-making. Projection of coastal change is not new, but until recently, the historical and baseline data on which they were based were largely qualitative and incorporated unknown errors. Probabilistic methods have been advocated in such cases to account for the errors with data and the wider uncertainties associated with the prediction of coastal change.

A quantitative approach for evaluating historical and future cliff behaviour is desirable given the nature of coastal geohazards and risk and the consequences of making decisions on high levels of uncertainty. With recent advances in technology and computer software, it is now possible to make use of spatially referenced (i.e. map-accurate) historical aerial photographs and compare these with digital historical mapping using desktop and laptop computers.

The UK archive of aerial photography dates back to the late 1930s, which provides a 60 year historical record of change of value to coastal studies. When used in a geomorphological context, quantification of the spatial and temporal pattern of coastal change provides a fundamental basis for making projections of coastal change for at least a comparable future period, all factors considered. The quantitative approach is primarily focused on establishing the errors with data so that account can be made of these in the projections. The approach is ideally suited for relatively simple coastal cliffs that have maintained an equilibrium form and behaviour in historical times that is set to continue during the life of the strategy.

The paper demonstrates the benefits of digital photogrammetry and the use of geographic information systems (GIS) by illustration of a quantitative cliff behaviour assessment of the Barton-on-Sea frontage carried out to inform the Christchurch Bay Coastal Defence Strategy.

INTRODUCTION

Reliable projection of cliff recession is fundamental to coastal planning and shoreline management. Indication of the likely position of the cliff line at various time steps in the future is needed to underpin land use policies and to avoid locating new development in areas at risk of cliff recession. Such projections might also be used by coastal authorities to adopt a more proactive approach to evaluating the risks to existing development, to provide warnings of the risks and to mitigate the potential impacts of cliff instability and recession events.

Projections of cliff recession are also needed to decide on the preferred strategic coastal defence option for specific management units identified by the shoreline mangement plan. Where coast protection works or improvements may be required, accurate projections of cliff recession rates are needed to evaluate scheme options and to test their economic viability and cost-effectiveness (Hall *et al*., 2000). Such decision-making is not only dependent on the accuracy of historical recession rates but also the reliability of cliff behaviour assessments.

The Christchurch Bay coastal strategy study incorporates management unit CBY4, Barton-on-Sea. One of the main challenges presented by this stretch of coastline is to accurately predict future cliff behaviour and recession, under various scenarios, to underpin coastal planning policies and the viability of cliff stabilisation and protection works. A further complication is the need to evaluate the effects of existing cliff stabilisation and protection works (Plate 1) on historical cliff behaviour and recession, and how these measures and any future improvements will influence cliff behaviour and recession over the lifetime of the strategy. The brief for this study was to develop an approach which would take into account all relevant factors that might influence future cliff instability and recession along the frontage.

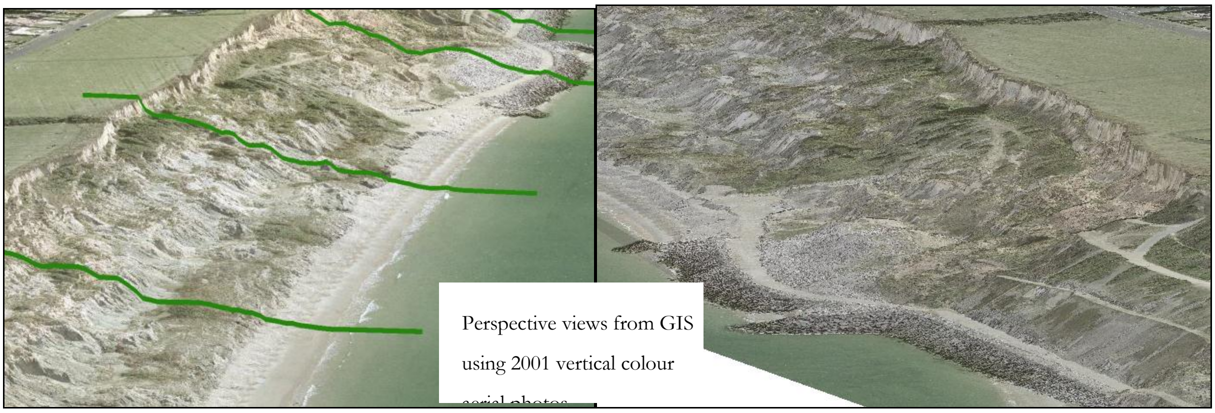

Plate 1. Barton cliffs: showing sections for analysis and cliff stabilisation measures

CLIFF BEHAVIOUR ASSESSMENT

The concept of a cliff behaviour unit (CBU) provides an important framework for the investigation and management of cliffs (Lee 1997, Moore *et al*. 1998, Lee and Clark 2002). Cliff behaviour units include the foreshore and the cliff top as these component landforms, and the processes that act upon them, can have a significant influence on cliff instability and recession behaviour. They are cascading systems or open sediment transport systems characterised by inputs, throughputs and outputs. DEFRA's '*Investigation and management of soft rock cliffs*' (Lee and Clark 2002) provides further background to the concept and classifies diagnostic cliff types according to their relative complexity, which include:

- Simple cliff systems;
- Composite cliff systems;
- Complex systems, and
- Relict cliff systems.

A key objective of cliff behaviour assessment is not only to understand the materials, forms and processes of cliff systems but also their sensitivity to change and evolution through time. The timescale over which these factors are considered has a significant bearing on how the cliff instability and recession process appears to have operated in historical times. The significance of past events and recession rates need to be evaluated in this context. Lee and Clark (2002) identify three important timescales for cliff management purposes:

1. short-term, where recession can be a highly variable process;
2. medium-term, where fluctuations are smoothed out and there is an apparent balance between form and process; and
3. long-term, where the nature and rates of cliff behaviour may change in response to internal and external influences, such as variations in lithology and sea level.

Cliff behaviour assessments generally comprise measurement of historical and contemporary rates of cliff recession, consideration of the geological, geomorphological, geotechnical and hydrogeological controls, and the influence of coastal processes. At some sites, specific monitoring of cliff behaviour is carried out and there is now an increased awareness and commitment to carrying out strategic monitoring of the coastline for scientific and management purposes (Bradbury 2001).

In the past, most cliff recession studies have been qualitative due to the lack of spatial and temporal data, with heavy reliance given to expert judgement and the use of historical records where the errors in data and interpretation are neither quantified or made explicit. Technology now exists to make better use of historical mapping and aerial photographs where the errors of data and interpretation of features can be quantified to a high degree of accuracy. In the context of a wider cliff behaviour assessment, use of a quantitative approach can significantly improve confidence with future projections of cliff recession. This is illustrated by the Barton-on-Sea example presented in Section 4, following a description of the digital photogrammetry and GIS approach.

DIGITAL PHOTOGRAMMETRY AND GIS

Photogrammetry is a method of obtaining accurate measurements, maps and digital elevation models from photographs. The method allows quantification of terrain features in terms of their location, extent and surface topography. Digital photogrammetry makes use of scanned images or digital aerial photography captured ‘on-the-fly’, and references these to digital maps and other survey data to produce map-accurate orthophotographs or photomaps (Graham and Koh 2002). The method requires the selection of appropriate aerial photographs and digital maps for specific applications. The following sections consider the various sources of aerial photography and digital mapping data and provide some guidance on the choice of products for cliff behaviour assessment. The processing and data management of orthophotographs is then described along with the added value these data can provide.

Aerial photography sources

Aerial photography of UK built up areas and coastal sites was systemically captured by the RAF (and Luftwaffe) between the late 1930s and 1945. Since 1945, aerial photography has been captured regularly, with the Ordnance Survey (OS) being the main agent.

Combining these data for coastal studies provides a real-time record of landform change and coastal development over the historical period.

For coastal change analysis, a number of aerial photograph epochs are needed to ensure that the correct pattern and rates of geomorphological change are recognised. This is particularly important when projecting historical rates of change. If budgets allow, it is recommended that an aerial photograph epoch is obtained for each decade in the photographic archive.

Lawrence *et al*. (1993) and Lee and Clark (2002) provide information about aerial photograph sources in the UK, which include national archives, commercial suppliers, private collections and specially commissioned aerial surveys. National archives are generally more extensive collections and are most likely to hold repeat surveys of coastal sites. Commercial suppliers and private collections can be limited and held under copyright. Many commercial suppliers host websites offering a variety of photographic survey products and services, including the commission of new aerial surveys. Capturing new aerial photography is not necessarily uneconomic, as digital aerial photography can be captured and geocoded ‘on-the-fly’, saving post-survey scanning and processing time. New Forest District Council (NFDC) commissioned an aerial survey of the Barton frontage in 2001 including the production of a digital elevation model that has proved valuable to this work.

For this study, historical aerial photography was procured from English Heritage (Table 1) who maintains a large archive of aerial photography for England at their National Monument Records Centre (NMRC) in Swindon. This collection brings together a variety of material, including aerial surveys undertaken by the RAF, MoD and OS. They offer a free search for small areas (up to 9 km^2) with larger areas charged by the hour. Photographs can be viewed at the NMRC and are available at a variety of scales, print sizes and image qualities; all copyrights are held by the NMRC. Purchase costs depend on the number, size and colour of reprints and whether the order is made a priority request, with delivery of prints normally within several weeks.

Table 1. Details of aerial photography procured for this study

Date	Source	Scale (1:x)	Format	Sortie/Camera
12 Aug 1940	MoD	6000	B/W	225K/BR270
18 Sept 1957	OS	6350	B/W	OS/57R4
17 May 1966	OS	4000	B/W	OS/66067
5 May 1989	OS	5100	B/W	OS/89131
5 May 1989	OS	7600	B/W	OS/89132
19 September 2001	CSL*	2500	Colour	010910Ac
13 October 2001	CSL*	2500	Colour	011013Ac

*Cartographical Surveys Ltd

Digital mapping and heighting data sources

In order to view and make measurements from aerial photographs in a GIS, the images need to be geocoded. This is achieved through the process of orthorectification, whereby an image is fitted to a digital elevation model and mapping grid to generate an orthophoto model. In simple terms, this process warps the photograph to the landsurface by applying coordinates and heighting data of features on maps to the same features seen in the aerial photograph.

Spot heights or contour heighting data are available from OS digital map products and their co-ordinates are derived at an appropriate scale. For most photogrammetry, this will be OS Land-Line™ (recently relaunched as MasterMap™) mapping at 1:2,500 scale. An issue to bear in mind with these products is that they are sold as 'current' data and may show active features, such as clifflines, out of position as they will invariably be based on survey data several years out-of-date. The timeless nature of Land-Line and MasterMap products is a major setback for geomorphological studies as periodic updates of mapped features of interest are neither identified nor dated separately. This renders them of little value in the analysis of coastal change, emphasising the need for photogrammetric studies.

Probably the best source of digital survey data for photogrammetry is LiDAR, which is an aerial laser scanning technique capable of capturing a dense grid of accurate heighting data. The Environment Agency captures and sells LiDAR data on a 1 km^2 map tile basis. At present, coverage of LiDAR is restricted to coastal lowland and river catchments and, therefore, data is not generally available for coastal cliffs, which includes the Barton cliffs.

Choosing appropriate scales and quality of data, relative accuracies and cost
Considerations of scale are critical in digital photogrammetry and determine:

- the number of photographs to be purchased and ortho-rectified;
- the amount of detail that can be seen in the image; and
- the accuracy of data extracted from the photograph.

Together, these factors determine the cost and appropriateness of aerial photography and mapping for specific applications (Lawrence *et al*. 1993). At large scales (1:5,000 to 1:10,000), a wealth of detail can be seen and confidently interpreted, whilst at smaller scales only larger features will be visible and important detail may be lost. Coastal features that can be observed in aerial photography at various scales are indicated in Table 2.

Table 2. Coastal features observed in commonly found scales of aerial photography

Scale	**Features recognised**	**Approximate area of image (km^2)**
1: 60,000	Coastlines, rivers, towns and hinterland geomorphology	180
1: 20,000	Coastlines, large landslide systems, streams, road network and villages	25
1: 10,000	Coastlines, cliffs and shorelines. Discrete landslide units, sand bars and houses	5
1: 5,000	Detail of coastal landslides, including scarps and benches, tension cracks, debris tracks, toe erosion, etc.	2.5

The number of photographs required to cover a given area is determined by their scale. Choosing an appropriate scale is therefore essential to ensure both accurate recognition of features whilst avoiding too much detail and high costs. It is worth noting that doubling the photograph scale will quadruple the number of photographs needed, which has a significant impact on purchasing and processing costs.

When working with paper maps, it is important to ensure that they are digitised using a specialist photogrammetric scanner at an appropriate resolution. Digital historical mapping can be purchased through the Landmark Information Group, under licence from the OS. The advantage of using historical maps is to gain very early data on the positions of coastal features. The first County Series of OS mapping dates from the mid-1800s and was updated regularly until 1945 when the British National Grid system was introduced and a new series of maps published. Historical mapping should be used with caution, however, as cliff lines were not always clearly marked making accurate digitising of feature positions difficult. There are also uncertainties with the accuracy and depiction of features in the early surveys.

Scanning and orthorectification of aerial photography

Aerial photography is scanned to produce digital images. To achieve nominal ground sampled distances of 25cm by 25cm for all epochs, specialist photogrammetric scanners are needed so that the scan resolution can be adjusted to compensate for the different scales of photography:

- 63 microns for 1:4,000 scale photography;
- 50 microns for 1:5,000 scale photography;
- 42 microns for 1:6,000 scale photography; and
- 36 microns for 1:7,000 scale photography.

As the true scale of the historical aerial photography used in this study was not known, it was calculated directly from the photographs by extracting the camera parameters (principle distance, principle point, fiducial marks) and the scan resolution adjusted accordingly. Significant defects in photography, e.g. from scratches, colour excursions, noise and dust, were digitally repaired.

The scanned images were then processed to derive usable coverage for each photo model. A dataset of ground control points of known height associated with each photo model was constructed from the 2001 digital elevation model commissioned by NFDC. The models were processed for interior, relative and absolute orientations. The orthorectified photographs were then processed to image match the photo models and produce a seamless orthophoto mosaic. For data management reasons the mosaic was split into OS 1 km^2 grid tiles and index catalogues prepared. An accuracy assessment for all photomap tiles was carried out.

Production of orthophoto maps requires specialist software. Typical products are Virtuoso or ERDAS Imagine, which enable stereo viewing and warping of imagery over a digital elevation model to generate ‘map-accurate’ orthophotographs. These applications can also extract height data from orthophotographs and allow digitising of features, such as cliff edges, using 3D visualisation.

The orthophotomap files can be saved as TIFFs with separate World files (.tfw) that contain the geocode data, or less preferably as geoTIFFs, which include the reference data within the image file that cannot be easily viewed or edited. In both these examples, the resultant file sizes can be very large (typically over 10 megabytes), posing difficulties with data storage, retrieval and analysis. This can be overcome by exporting the data to ER Mapper raster format (.ecw). These files are typically ten times smaller than the equivalent TIFFs and can be viewed in GIS packages using a free plug-in, or viewed using the free ER Viewer software. Both MapInfo Professional 6 and ArcView 8 GIS systems have been used to view and analyse the orthophotomaps for this study. The ArcView ‘3D Analyst’ plug-in was used to visualise the photography in 3D.

Analysis and value of orthophoto maps

The orthophotomaps are viewed in a GIS system, at any desired scale, facilitating the identification and measurement of features. Typically, feature positions are digitised as vector lines which are compared with the same feature vector lines from other epochs. Accurate planimetric measurements can then be made between the feature vector lines and offsets derived. Data is recorded in a database where it can be used to calculate cumulative, mean and maximum rates of change between epochs. When applied in the context of a 'coastal behaviour assessment', the spatial and temporal patterns of historical change can be accounted for and fully quantified. The influence of coast protection and stabilisation measures on cliff behaviour and recession in the past can also be evaluated in this way.

Use of historical aerial photographs has several key advantages over historical mapping. Orthophotomaps combine the advantages of a ground coordinate system (the same as a map) with the detail provided by the photograph. Features of relevance to coastal change studies are not always shown on historical maps, and those that are shown may be in part 'interpreted' by surveyors, introducing uncertainty into the analysis. Superimposition of mapping with aerial photography provides an historical space-time dataset of known accuracy from which quantitative analysis can be conducted with a high degree of confidence.

With an historical series of orthophotomaps and GIS software tools, a wide range of analysis and applications become possible. For example, slope angle and aspect can be calculated, 2D section lines can be drawn anywhere across the image, data can be visualised in 3D from any direction, and other map-based datasets can be overlain, integrated and compared. Use of 3D data enables volumes to be calculated and comparison of digital elevation surfaces to determine areas of erosion, deposition or no change. Such datasets are invaluable in retrospective analysis of landslides, for example, enabling very accurate detailing of the dimensions, volume and 3D displacement characteristics.

BARTON-ON-SEA QUANTITATIVE CLIFF BEHAVIOUR ASSESSMENT

The 2km cliff section between Barton-on-Sea and Naish Farm (Figure 1) is characterised by an 'undercliff' of steep slopes and terraces up to 33m high and 120m wide from crest to toe. The cliffs are formed of overconsolidated Eocene clays, sands and sandy clays that are overlain by Quaternary sands and gravels (Barton and Coles 1984; Allen and Gibbard 1994). The strata are strongly bedded and dip 1° ENE. The sequence of interbedded clays and sands makes the Barton cliffs very susceptible to erosion and mass movement processes that have resulted in some of the highest rates of coastal cliff recession on the south coast (Table 3).

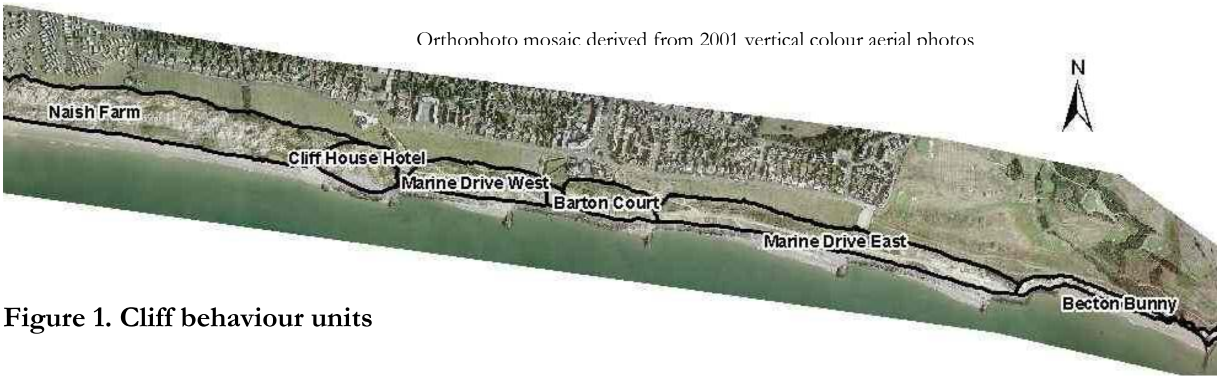

Figure 1. Cliff behaviour units

Naish Farm, to the west of Barton, is a Site of Special Scientific Interest (SSSI) as the type locality of the Bartonian sequence and for its geomorphology. The cliffs at Naish Farm, and those to the east of Barton at Becton Bunny, have remained unprotected and free to evolve 'naturally' over the historical period. This has led to the loss of cliff-top bungalows at Naish Farm with unsightly exposure of building debris in the cliffs and on the coastal slope.

Cliff-top assets are present along the Barton frontage, which have been used in the past to justify works. The first defences were in evidence during the late 1950s in the form of timber groynes. During the 1960s, the cliffs were stabilised with deep drainage, piling and slope profiling (Clark *et al*. 1976). Further works were undertaken in the early 1990s comprising the construction of rock armour groynes and revetment along the entire frontage and the installation of cut-off drains.

Table 3. Reported cliff recession data

Mean annual cliff recession rate (m)	**Period**	*Cliff Section*	**Data Source**	**Reference**
5.1	1984	Barton-on-Sea	Site survey	Barton and Coles 1984
1.2	1869-1898	Barton-on-Sea	OS maps	Woodrow 1991
1	1869-1959	Barton-on-Sea	OS maps	May 1966, Nicholls 1985
0.96	1909-1931	Barton-on-Sea	OS maps	Woodrow 1991
0.7	1898-1909	Barton-on-Sea	OS maps	Woodrow 1991
0.55	1931-1975	Barton-on-Sea	OS maps	Woodrow 1991
1.9	1950-1980	Naish Farm	OS maps, aerial photographs	Barton and Coles 1984

Despite these measures, major slope failures occurred in 1974 and 1987/88 at Barton Court, and in 1993 and 1996 at the Cliff House Hotel. Mass movement and cliff recession has continued at the western and eastern limits of the protected cliff section, causing outflanking and failure of defences. Currently there is concern over the stability of the cliff behaviour units west of Barton Court, which have been affected by significant ground movements in recent years, with large tension cracks evident in the adjacent roadway, distortion of the steel sheet piled wall, and failure of the cliff top (Plates 2 and 3).

Plate 2. Marine Drive West CBU

Plate 3. Cliff House Hotel CBU

Previous geomorphological and geotechnical investigations

The Barton cliffs have been extensively investigated and are subject to ongoing monitoring. Detailed geomorphological mapping of the cliffs was carried out in 1991, 1992 and 1998. The mapping provides a framework for identifying CBUs that reflect variations in failure mechanisms, activity and cliff recession potential along the frontage (Figure 1). The original mapping was used to prioritise further investigations and engineering works.

Geotechnical investigations carried out during the 1990s broadly confirmed the zonation of the Barton Clays proposed by Barton (1973), which was based on lithological rather than palaeontological features. The stratigraphy visible in the cliffs comprises two formations of the Barton Group. The Barton Clay (Beds A-F) comprises dark sandy clay whilst the Becton or Barton Sand (Beds G-L) comprises light grey sands with occasional clay-rich horizons. The Barton Clay and Becton Sand are separated by a distinctive limestone bed (Bed G) and the Chama Bed (Bed H), a shelly bluish-grey clayey sand. Fort *et al*. (2000) emphasise the importance of the Chama Bed and the presence of hard bands of calcareous mudstone and nodule beds, which may induce strain concentration during swelling and shearing and possibly control the basal geometry of the landslides.

The mechanisms of landsliding along the protected CBUs are different from those along the unprotected cliffs and comprise, respectively:

- Deep-seated translational failures along shallow dipping beds within the Barton Clay. Failure involves near horizontal block displacement and formation of graben structures. A major failure surfaces lies at the contact between the Barton Clay and Becton Sand. Deeper-seated translational surfaces also occur within the Barton Clay at the F1/F2 lithological contact at Marine Drive West, and at the C/D contact at the Cliff House Hotel.
- Shallow translational mudslides, mainly within the Barton Clay, but also in previously failed material. These features comprise slow-moving clay-rich debris sliding on translational shear surfaces, often controlled by lithological boundaries.

At Naish Farm, active mass movement processes (shallow mudslides) are sustained by seepage erosion and the removal of debris by waves at the toe of the cliffs. The high rates of recession and unloading result in depressed groundwater pressures in the Barton Clays, which tend not to promote deep-seated failure of the cliffs. This natural process has been intervened along the protected cliff section and despite the presence of drainage measures, groundwater pressures have been slowly recovering which has caused deep-seated failure of the cliffs.

Measurement of historical cliff recession

Using the orthophoto maps, historical recession of each CBU was measured. Each orthophoto map was examined in the GIS at a scale of 1:300 and the cliff line digitised on screen to produce a vector line. As each of the lines is saved separately, they can be presented individually or together in the GIS. The distances between the cliff lines can then be compared to derive cumulative cliff recession and retreat rates for each CBU. As some CBUs are laterally extensive, a number of regular-spaced cliff profiles (Plate 1) were adopted and data for these entered into a database. Populating each CBU with a number of measured profiles enables a statistical dataset to be derived from which the mean and maximum recession can be calculated and plotted (Figure 2).

All measurements have an associated error, which can be quantified using orthophoto maps. For this study, the orthophoto maps represent state-of the-art accuracy with low

RMS errors (Table 4) due to the high quality of the 2001 digital elevation model. These figures represent the possible variance in feature positions shown on each photomap.

Figure 2. Cumulative recession of CBUs 1940-2001

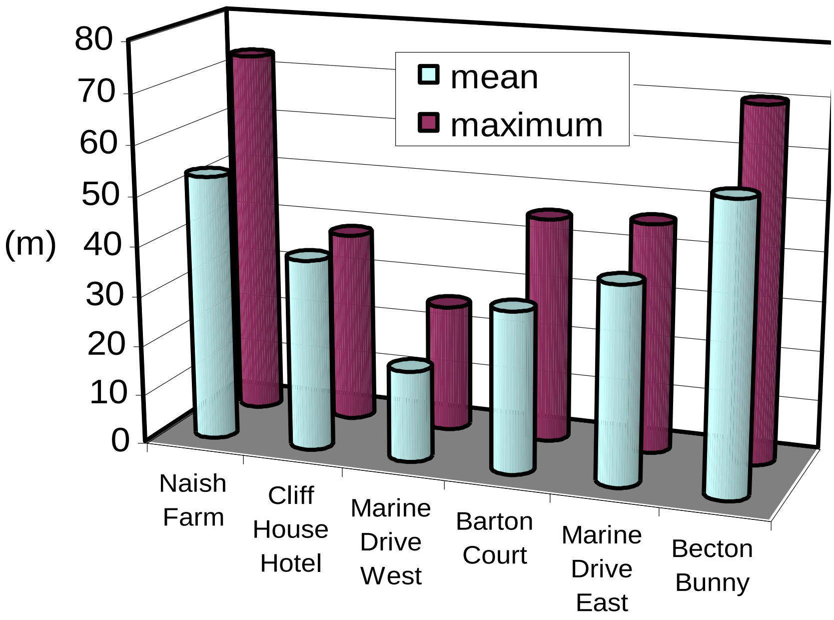

Table 4. Errors

Epoch	RMS (± m)
1940	0.9
1957	1.4
1966 east	1.2
1966 west	0.6
1989	1.2
2001	0.3

The historical cliff recession results reveal a number of interesting points:

- Between 1940-2001, the mean and maximum annual recession of unprotected cliffs at Becton Bunny and Naish Farm were 1.13m and 1.63m ±0.08m /yr; respectively;
- Between 1940-2001, the mean and maximum annual recession of the protected cliffs were 0.4m and 0.7m ±0.08m /yr; respectively;
- The 65% difference between the mean annual recession of the unprotected and protected cliffs can be attributed to the effects of cliff stabilisation and coast protection works which, notably, have not entirely prevented cliff recession; and
- The results are broadly consistent with those reported by others (Table 3) although there are important differences in the pattern and rates of change that are not readily apparent or explainable by the published data.

Projection of cliff behaviour scenarios

The quantitative cliff behaviour assessment can be used to make projections of future change given knowledge of the cliff geology, landslide mechanisms, historical recession of CBUs and the sensitivity to external influences such as sea level and climate change. Projections of future change over the next 50 years are needed to inform the coastal strategy. For this purpose, a cliff behaviour projection model was developed for each CBU. The key model parameters include:

- The mean and maximum annual cliff recession rate for unprotected CBUs, including the errors of measurement, which represent ‘natural’ recession rates for the Barton Cliffs;
- A cliff resistance factor, measured as a percentage increase or decrease in the natural recession rates, based on calculated factors of safety, to account for changes in geology and the resistance to erosion and landsliding as the cliff retreats;
- A climate change factor, measured as a percentage increase in natural recession rates to account for potential increases in sea level, winter rainfall and groundwater levels;

- A coastal defence factor, measured as a percentage reduction in natural recession rates, to account for the residual effects of existing protection and stabilisation measures, assuming no maintenance or improvement works are carried out during the strategy lifetime; and
- A cliff recession accelerator, measured as a percentage increase in natural recession rates to account for the likely reactivation of landsliding and rapid increase in cliff recession following total failure of the coast protection and stabilisation works.

The long-term mean and maximum annual recession of the unprotected cliffs at Becton Bunny and Naish Farm are used as the benchmark for the entire cliff section assuming no protection measures are in place. This is a reasonable assumption given that the Barton Cliffs are reported to have experienced recession rates in excess of 1m/year prior to their stabilisation in the 1960s. The mean recession rate less the RMS error is used to define a lower bound recession potential while the maximum rate plus the RMS error defines an upper bound recession potential.

The geology of the Barton Cliffs is reasonably well defined with a slight 1° dip of bedding to the ENE. The cliff top is also characterised by a level plateaux and, therefore, it is assumed there will be no significant change in geology and resistance to erosion and landsliding during the strategy lifetime. Therefore, the cliff resistance change factor is not used in the model.

The possible impacts of increases in sea level, winter rainfall and groundwater levels on future cliff recession cannot be quantified with any certainty given current climate change predictions. It is assumed, therefore, that a 10mm rise in sea level and a 10% increase in rainfall will result in a 10% increase in cliff recession (Figure 3). The effects of a 20mm rise in sea level and 20% increase in rainfall on cliff recession potential are also modelled.

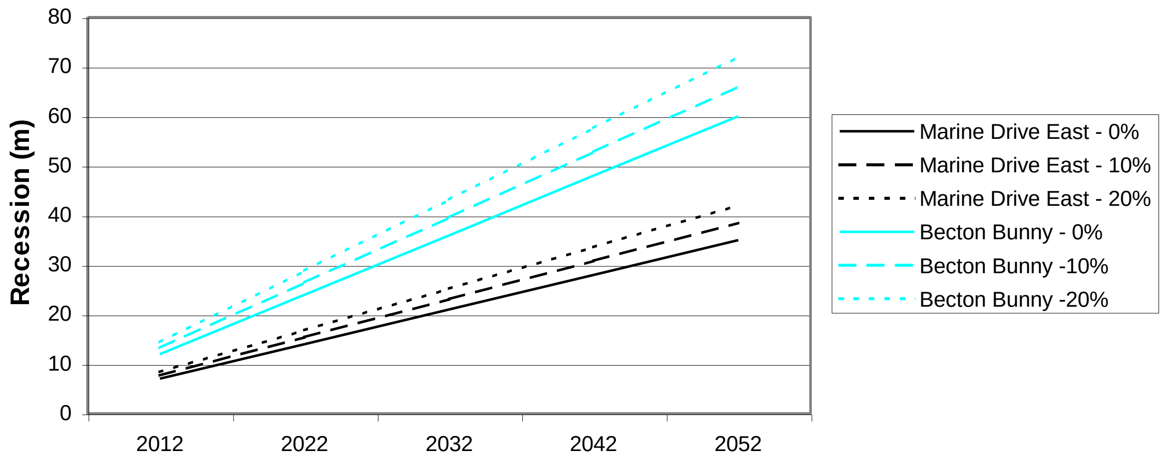

Figure 3. Sensitivity of CBUs to the effects of climate change

The existing coast protection and slope stabilisation measures along the Barton frontage have reduced cliff recession by 65%. This fact has been used to model the future residual effects of the measures in place assuming no further maintenance or improvement works. Under this scenario it is assumed that the stabilisation measures will have failed within 20 years from now and that the rock toe revetment will have failed within 30 years.

The cliff recession accelerator allows a higher rate of recession than the long-term 'natural' mean and maximum rates, to account for the likely rapid breakdown of previously protected cliffs, including the removal of artificially formed headlands and the re-orientation of the coastline. It is assumed that recession rates could be 65% higher than the natural rates after defence failure. This response will in part be due to a change in failure mechanism from deep-seated translational failure to relatively shallow mass movements comprising mudslides and seepage erosion. The response will be delayed and it is assumed will continue for a period equivalent to the time the cliffs were stabilised, i.e. 70 years in this scenario, which will extend beyond the lifetime of the current strategy.

The combination of a decline in the effectiveness of existing coast protection and stabilisation measures and the possible rapid response and acceleration of cliff instability and recession is illustrated in Figure 4.

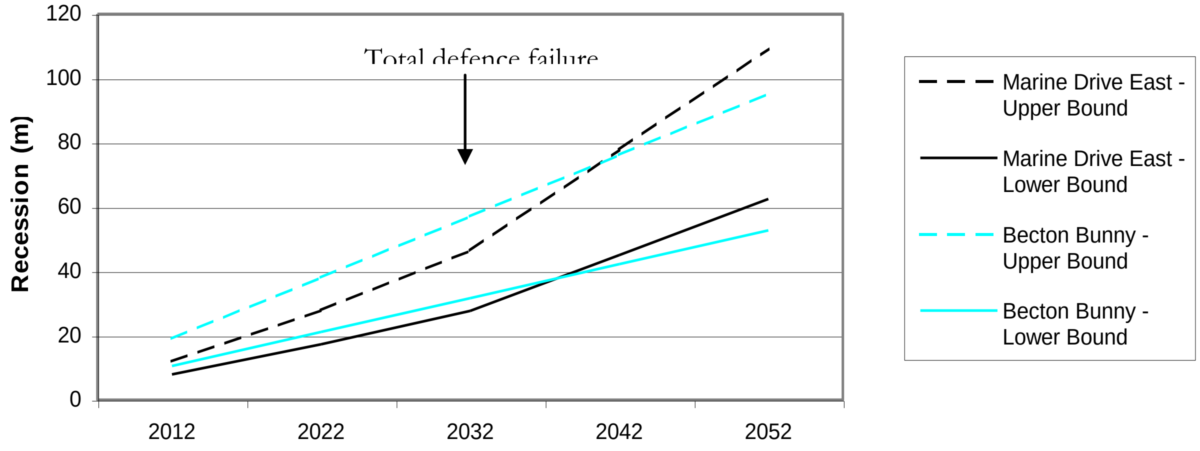

Figure 4. Model of the effects of defence failure on projected cliff recession

CONCLUSIONS

The study has demonstrated the value of a quantitative cliff behaviour assessment to determine accurate rates of cliff recession and the effects of past coast protection and stabilisation measures on a geomorphologically sensitive coastline. The approach enables projection of 'natural' and 'managed' cliff behaviour scenarios to predict future cliff positions with a high degree of confidence, which NFDC can use to make informed decisions on the long-term sustainability of coastal development and infrastructure. The cliff behaviour projection model provides:

- Coastal managers with a tool that allows various scenarios and parameters of defence condition, climate change and cliff behaviour to be modelled;
- An adaptable 'real-time' model that can be improved with ongoing monitoring and understanding, which in turn can be used to update previous projections; and
- A tool by which option selection for future coast protection and stabilisation Options can be assessed.

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