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# Blyth Estuary FRM Strategy Cost Appraisal Report - Final Draft

November 2007

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## Contents

<b>1</b>	<b>Introduction .....</b>	<b>1</b>
<b>2</b>	<b>Methodology.....</b>	<b>3</b>
2.1	Compartmentalisation.....	3
2.2	Uncertainty allowance .....	4
2.3	Sea Level Rise .....	4
2.4	Flood defence options .....	5
2.4.1	Option 1 – No Active Intervention throughout the Blyth Estuary.....	5
2.4.2	Option 2 – Do Minimum throughout the Blyth Estuary .....	5
2.4.3	Option 3 – Hold the Line throughout the Blyth Estuary .....	5
2.4.4	Option 4 – Manage the man made structures at the mouth of the Blyth Estuary with No Active Intervention Elsewhere.....	6
2.4.5	Option 5 – No Active Intervention at Robinson’s Marsh and Hold the Line Elsewhere ...	6
2.4.6	Option 6 – Advance the Line of the flood defence by making the Blyth Estuary shallower or narrower close to the Bailey Bridge and Hold the Line elsewhere.....	6
2.4.7	Option 7 – Advance the Line by making the Blyth Estuary shallower or narrower close to the Bailey Bridge and No Active Intervention at Tinker’s Marsh. ....	7
2.4.8	Option 8 – Hold the Northern Line of defence and No Active Intervention elsewhere in the estuary.....	7
2.5	1st Replacement Cycle.....	7
2.6	Components of the Total Cost.....	8
2.6.1	Replacement Works .....	8
2.6.2	Raising Works .....	10
2.6.3	Maintenance.....	10
2.6.4	Present Value Costs (PVC) .....	11
2.6.5	Optimism Bias Cost.....	12
2.7	Water Levels .....	12
<b>3</b>	<b>Derivation of Costs for Works to Flood Defences .....</b>	<b>13</b>
3.1	Basic Assumptions .....	13
3.2	Construction Types .....	13
3.2.1	Earth Embankments.....	13
3.2.2	Concrete Defences.....	14
3.2.3	Sheet Pile Defences.....	14
3.2.4	Mini Piles.....	14
3.2.5	undefended Sections .....	14
3.2.6	Flow Restriction Structure.....	14

3.3	Costing Sequence .....	15
3.4	Rates Used.....	15
3.4.1	Materials, Plant and Labour.....	15
3.4.2	General and Preliminaries Items.....	16
3.4.3	Access.....	16
3.4.4	Land Purchase .....	16
3.4.5	Habitat Replacement.....	16
3.4.6	Public Water Supply Costs .....	17
3.4.7	Site Investigations .....	17
3.4.8	Engineering Cost.....	17
3.4.9	Environment Agency Cost .....	17
<b>4</b>	<b>Summary of Base Case Costs .....</b>	<b>18</b>
4.1	Option 2 –Do Minimum throughout the Blyth Estuary.....	18
4.2	Option 3 - Hold the Line throughout the Blyth Estuary .....	19
4.3	Option 4 – Manage the man made structures at the mouth of the Blyth Estuary with No Active Intervention elsewhere.....	19
4.4	Option 5 - No Active Intervention at Robinson’s Marsh and Hold the Line elsewhere .....	20
4.5	Option 6 - Advance the Line of the flood defence by making the Blyth Estuary shallower or narrower close to the Bailey Bridge and Hold the Line elsewhere. .....	21
4.6	Option 7 - Advance the Line of the flood defence by making the Blyth Estuary shallower or narrower close to the Bailey Bridge and No Active Intervention at Tinker’s Marsh .....	22
4.7	Option 8 - Hold the Northern Line of defence and No Active Intervention elsewhere in the estuary.....	23
<b>5</b>	<b>Draft Strategy .....</b>	<b>24</b>
<b>6</b>	<b>Cost Sources.....</b>	<b>27</b>
6.1	Previous B&V Estimates.....	27
6.2	Contractors and Others .....	27
6.3	Literature .....	27
	<b>References .....</b>	<b>28</b>
	<b>ANNEX A – RATES .....</b>	<b>29</b>

## Tables

Table 1 - Summary of existing defence residual life and standard of protection .....	2
Table 2 – Distribution of costs for assets that benefit the whole estuary between flood compartments .....	4
Table 3 - 1st replacement cycle .....	7
Table 4 - Replacement Schedule .....	9
Table 5 – Summary of Maintenance Costs.....	11
Table 6 – Flow Restriction Structure Costs .....	15
Table 7 - Cost Calculation Sequence .....	15
Table 8 – Summary of Replacement Habitat Costs.....	16
Table 9 - Summary Cost of Option 2 .....	18
Table 10 - Summary costs for Option 3 .....	19
Table 11 - Summary Costs for Option 5.....	20
Table 12 - Summary of Costs for Option 6 .....	21
Table 13 - Summary of Costs for Option 7 .....	22
Table 14 - Summary of Costs for Option 8 .....	23
Table 15 – Withdrawal of Maintenance Timescale .....	24
Table 16 – Summary of Costs for the Draft Strategy.....	26

## Figures

# 1 Introduction

The River Blyth is a short river, which rises near Laxfield in Suffolk and meanders eastwards out to the sea between the coastal towns of Southwold and Walberswick on the Suffolk coastline. The Blyth Estuary is approximately 11km long. Below Blythburgh, it consists of a large mudflat (250ha), which is connected to the North Sea via a narrow straight canalised section (3.1km).

The existing flood defences in the Blyth Estuary, approximately 17km, are the result of navigational improvements, reclamations and local bank failures. At one stage the River Blyth below Blyford was almost entirely canalised following the meandering route between the flood defences to the coast. However, defences at Angel and Bulcamp marshes just downstream of Blythburgh were abandoned in the 1950/60s following breaches during storm events.

The uncontrolled inundation of Angel and Bulcamp Marshes allowed a large intertidal area to fill on every high tide. The resultant increase in tidal volume caused the velocity of the water flowing in and out of the estuary to increase, thereby causing increased erosion to existing flood defences along the canalised portion of the estuary.

The Environment Agency has permissive powers regarding flood defence within this estuary and they commissioned Black and Veatch (BV) to undertake a Flood Risk Management Strategy for the Blyth Estuary. The Strategy is a long-term plan (in this case 100 years) for the efficient management of the whole defence system.

As part of this study, BV undertook a condition assessment of all the flood defences in the Blyth Estuary and assessed the current standard of protection provided. The condition assessment found that many defences would require renewal within the next five years, though the standard of protection provided was generally appropriate for the type of asset being protected. These results are set out in Table 1 for each flood compartment.

**Table 1 - Summary of existing defence residual life and standard of protection**

FC	Name	Length (m)	Residual Life of defence in 2007 (years)	Erosion protection	Minimum standard of protection in 2004 ( 1 in n years)
FC1	Havenbeach Marsh	548	2 – 20	Poor/good	5
FC2	Town Marsh	813	10 – 20	Fair	20
FC3	Woodsend	302	5 – 20	Fair	5
FC4	Botany Marsh	222	2 – 10	Good/poor	5
FC5	Reydon Marsh	2693	0 – 10	Poor	1
FC6	Wang Valley	No flood defences within this compartment			
FC7	Bulcamp House Marsh	428	10 – 20	None	20
FC8	Union Farm	1873	Failed	Poor	1
FC9	Blyford	1584	Failed	None	1
FC10	Robinson's Marsh	1906	10 – 20	Fair/poor	5
FC11	Tinker's Marsh	2910	0 – 5	Poor	1
FC12	Blythburgh East	537	0 – 10	None	1
FC13	Blowers Farm	3493	Failed	Poor	1
FC14	Blackheath	No flood defences within this compartment			

The aim of this report is to provide implementation costs for a range of flood defence options in the Blyth Estuary. The costs derived in this exercise have been used in the economic analysis, which will provide benefit-cost ratios for each option, in accordance with Defra's Project Appraisal Guidance, see Economics Report, (November 2007).

The following are included in this report:

- A methodology of the work undertaken and the assumptions made;
- A description of the options to be considered;
- A summary of the costs for the various options investigated;
- Derivation of the rates used in the cost calculation;
- Sources of Information.

## 2 Methodology

### 2.1 Compartmentalisation

The land at risk from flooding on the Blyth Estuary is split up into 14 flood compartments of varying size and land use. The compartments are arranged, so that flood compartments 1 to 9 are on the northerly side and 10 to 14 are on the southerly side. Two of the flood compartments (FC 7 and 12) are hydraulically independent with definite boundaries formed by high ground. The rest are separated by less prominent topographic features that would overtop during certain flood conditions allowing the conveyance of flood water from one flood compartments to the next and hence linking these compartments together. These 'partial' boundaries exist between compartments 1, 2, 3, 4, 5 and 6, 8 and 9, 10 and 11, and, 13 and 14.

The flood defence for compartment 6, with the exception of Wolsey Sluice, is provided by compartment 5. In this costing report, compartments 5 and 6 are assumed to act as one with the relatively small costs associated with Wolsey Sluice added to the costs of the remainder of the flood defences for compartment 5.

The economic appraisal of flood defence options for the Blyth Estuary is undertaken for the whole of the floodplain, as well as for individual compartments. This approach provides a preferred option for the whole of the study area and also for each individual compartment.

The costs for maintaining and replacing the Harbour arms at the mouth of the estuary have been included for some strategy options. However these costs are not assigned to a single flood compartment but distributed between the flood compartments assumed to benefit from their presence as indicated on Table 1.

Where a replacement groyne at Gunhill forms part of an option to protect the Southwold frontage, its costs are not included within the option costs as it has already been included within the costs of the Southwold Coastal Defence Scheme.

For those options that include construction of a flow controlling structure, its cost has also been divided between the flood compartments upstream that benefit. The proportion of the cost that is borne by each of these compartments is set out in Table 2.

The cost of creating replacement habitat, where areas of designated habitats have been lost due to the implementation of various options, has also been included. These costs are assigned to the compartment containing the designated habitat.

**Table 2 – Distribution of costs for assets that benefit the whole estuary between flood compartments**

Flood Compartment	Distribution of costs (%) between compartments	
	Harbour arm	Flow Restriction Structure
1	10	0
2	25	0
3	10	0
4	5	0
5	50	40
6	0	0
7	0	20
10	0	0
11	0	20
12	0	20
8, 9, 13, 14	0	0

## 2.2 Uncertainty allowance

All new or replacement defences in the Blyth Estuary are assumed to be built higher than required to meet the design standard at the end of their design life to cover design and construction tolerances and settlement of earth embankments. In this cost calculation, an uncertainty allowance of 300mm has been added to the crest level of all new defences. This allowance was not included in the assessment of existing standard of protection described in the technical report.

## 2.3 Sea Level Rise

In 2004 when most of the costs were derived, the sea level along the Suffolk Coast was generally expected to rise by approximately 600mm over the next 100 years and fluvial events were expected to increase in magnitude by 20%. To account for the anticipated sea level rise, any works to the existing flood defences either to raise or replace the flood defences included a sea level rise allowance to the crest level to protect against the specified event in the future.

In October 2006, Defra updated their guidance on sea level rise allowances. The new sea level rise allowance result in a further 417mm rise over the next 100 years. This means that over the short-term (0 – 20 years) the new sea level rise guidance shows no significant change. Over the medium term (20 – 50 years), the new guidance predicts that sea level rise will become a little bit higher towards the end of this period. As the difference is relatively small (approximately 70mm), this is assumed not to significantly increase the costs of any works that come to the end of their design life during this period, which more or less coincides with the first replacement cycle described in Section 2.5 below.

In the long-term (50 – 100 years), sea level rise will be significantly higher and this will significantly increase the costs of all works proposed in this timeframe above those estimated in this report. These capital and maintenance costs have not been updated to incorporate the long term increase in sea level rise as it is clear that the additional costs would only weaken the existing argument further especially as there are no new assets at risk. Hence the costs discussed in this report relate to the old Defra sea level rise guidance and have not been updated to incorporate the new sea level rise allowances.

## 2.4 Flood defence options

The following section describes the options considered in the technical, economic and environmental assessment.

### 2.4.1 Option 1 – No Active Intervention throughout the Blyth Estuary

No costs incurred. No maintenance, repair or renewal work is carried out on the defences including the harbour. To prevent erosion of the Southwold coastline in front of the town to the north a new rock groyne will need to be constructed to the south of Southwold in the region of Gunhill when the existing harbour arms have failed. This new groyne is assumed to be required in year 2 and its cost (plus optimism bias) has been distributed between the estuary flood compartments as indicated on Table 2.

### 2.4.2 Option 2 – Do Minimum throughout the Blyth Estuary

Under this option, the existing defences are maintained by undertaking works to the existing crest level to maintain the crest level at current levels until the defence begin to fail. Once the defence begin to fail the Environment Agency would implement its policy on withdrawal of maintenance. Under this policy, there would normally be a period of between six months and two years of continued maintenance before the Environment Agency walk away from the defences. Under this option, the standard of protection will decrease over time due to the effect of sea level rise.

From a costing perspective, maintenance on the flood defences in each compartment is assumed to cease when the upper limit on the residual life shown in Table 1 is reached. When the Environment Agency ceases maintenance on a defence in a flood compartment it is assumed to fail.

### 2.4.3 Option 3 – Hold the Line throughout the Blyth Estuary

Under the Hold the Line scenario, the current line of flood defence throughout the Blyth Estuary with the exception of flood compartments 8, 9, 13 and 14 where the defences have already failed are maintained. Although there may be some local realignment as a result of poor ground conditions over the full 100 year life of the strategy, this option will typically entail the raising and/or replacement of defences in their existing positions. The implementation costs have been calculated for the provision of defences to protect against a 1 in 5 extreme fluvial and tidal flood event throughout the Blyth Estuary accounting for sea level rise.

This option has also been costed assuming the defences are maintained and replaced until the last defence has been replaced at least once. This is referred to as “the end of the 1<sup>st</sup> replacement cycle”, discussed in Section 2.5. After the 1<sup>st</sup> replacement cycle the defences are then maintained until they come to the end of their asset life, assumed to be 50 years. Towards the end of this period, the Environment Agency would need to decide if these defences should be replaced again at the 1 in 5 year standard of protection or a No Active Intervention policy implemented. Both these options have been costed and referenced as Options 3a and 3b

#### 2.4.4 Option 4 – Manage the man made structures at the mouth of the Blyth Estuary with No Active Intervention Elsewhere

This option involves maintaining the line of the existing northern harbour arm that forms the mouth of the estuary. Costs have been generated for maintaining the existing harbour arm structure for 50 years and then replacing it with a rock groyne structure on the same alignment as the existing. Elsewhere in the estuary, no active intervention would be applied as per Option 1. The costs of this arm are divided between the flood compartments as indicated in Table 2.

A sub option has been costed, which consists of maintaining the mouth until year 50 and then replace the harbour arm with a new rock groyne to the south of Southwold in the region of Gunhill to minimise the erosion of the Southwold coastal frontage.

#### 2.4.5 Option 5 – No Active Intervention at Robinson’s Marsh and Hold the Line Elsewhere

This option would involve No Active Intervention along the stretch of defence that protects Robinson’s Marsh (FC10). All the other defences in the estuary including the mouth would be maintained.

This option has also be costed for the case where all the defences that are previously held in this option are maintained for the 1<sup>st</sup> replacement cycle and then have No Active Intervention following the 1<sup>st</sup> replacement cycle. Under this sub option the northern harbour arm will be maintained until year 50 and then allowed to fail. In year 50, a new rock groyne to the south of Southwold in the region of Gunhill will be constructed to minimise the erosion of the Southwold coastal frontage.

#### 2.4.6 Option 6 – Advance the Line of the flood defence by making the Blyth Estuary shallower or narrower close to the Bailey Bridge and Hold the Line elsewhere

The most viable ‘advance the line’ option considered as part of this study concerned the construction of a flow restriction structure (FRS) in the River Blyth at a site in the vicinity of the existing Bailey Bridge adjacent to Woodsend Marsh (FC3) and Robinson’s Marsh (FC10). This location was chosen to allow the option to be costed. The actual location will need further study in order to determine the precise location for the flow restriction structure.

The flow restriction structure is a structure that reduces the width of the estuary to 42m by the use of sheet piling along a 30m length of the river bank. The structure also has a raised river bed level that includes a rock weir type wall that will restrict the flow of water into and out of the estuary. Both options are designed to restrict the tidal flow into the estuary upstream of the structure to a volume below that which currently occurs. As a result the water levels in the estuary upstream of the flow restriction structure will be reduced and the erosion of the defences will be slowed as a result of the lower flow rates. With this option the assumption is made that the residual life of the existing defences upstream of the flow restriction structure are increased by 10 years. This applies to flood compartments 5, 6, 7, 11 and 12. The costs of the structure are divided between the flood compartments that benefit as indicated in Table 2.

Under this option, all the defences are maintained including the mouth.

This option has also be costed for the case where all the defences that are previously held in this option are maintained for the 1<sup>st</sup> replacement cycle and then have No Active Intervention following the 1<sup>st</sup> replacement cycle. Under this sub option, the northern harbour arm will be maintained until year 50 and then allowed to fail. In year 50, a new

rock groyne to the south of Southwold in the region of Gunhill will be constructed to minimise the erosion of the Southwold coastal frontage.

#### 2.4.7 Option 7 – Advance the Line by making the Blyth Estuary shallower or narrower close to the Bailey Bridge and No Active Intervention at Tinker’s Marsh.

This option is similar to Option 6, however in this option there is No Active Intervention at Tinker’s Marsh (FC10). Tinker’s Marsh receives maintenance until it fails, assumed to occur in year 12.

This option has also been costed for the case where all the defences that are previously held in this option are maintained for the 1<sup>st</sup> replacement cycle and then have No Active Intervention following the 1<sup>st</sup> replacement cycle. Under this sub option the northern harbour arm will be maintained until year 50 and then allowed to fail. In year 50, a new rock groyne to the south of Southwold in the region of Gunhill will be constructed to minimise the erosion of the Southwold coastal frontage.

#### 2.4.8 Option 8 – Hold the Northern Line of defence and No Active Intervention elsewhere in the estuary.

This option involves holding the Northern side of the Blyth Estuary (i.e. FC1, 2, 3 4 and 5) and No Active Intervention throughout the rest of the estuary. Under this option the defences along the Northern side of the estuary would be maintained at a 1 in 5 year standard of protection until they reach the end of their useful life. At which point they will be replaced by either rebuilding along the existing line of defence, again to a 1 in 5 year standard of protection or by building along a set back line to avoid possible poor ground conditions (for example at Reydon Marsh).

The existing harbour mouth will be maintained for 50 years and then allowed to fail. In year 50, a new rock groyne to the south of Southwold in the region of Gunhill will be constructed to minimise the erosion of the Southwold coastal frontage. The failure of the harbour mouth in year 50 increases the flows into the estuary and increases the pressure on the defences and reduces the time to failure.

### 2.5 1st Replacement Cycle

The replacement cycle for the sub options for options 3, 5, 6, 7 and 8 where the hold the line defences are only maintained for the first replacement cycle are called 3b, 5b, 6b, 7b, and 8b. The timing of these replacement cycles are shown in Table 3 after which time the maintenance ceases, and the standard of protection provided by hold the line is 1 in 5.

**Table 3 - 1st replacement cycle**

Option	Timing of 1 <sup>st</sup> Replacement Cycle
3b	50
5b	50
6b	50
7b	50
8b	50

## 2.6 Components of the Total Cost

For the purposes of this cost calculation, the total cost of providing flood defences to the required standard of protection is the sum of the cost of raising the existing defences to that standard plus the cost of replacing the defences to that standard when they reach the end of their residual life. In addition to this, annual maintenance over the whole strategy period and the cost refurbishment works to the existing control structures has been included. For the flow restriction structure option, the cost of construction of the flow restriction structure has been considered only, no maintenance of this structure has been included.

Where hard defence currently exists, in some cases the defence has been replaced at the end of its residual life by a different type of defence deemed more suitable.

Some parts of the estuary have no defences as the estuary is adjacent to higher ground. These lengths which were classified 'undefended' during the condition assessment have not been assigned either a raising or replacement cost in this assessment.

### 2.6.1 Replacement Works

As mentioned above, each of the flood defences in the Blyth has been assigned a residual life value based on their relative condition. This value is a band of a number of years during which the defence is expected to fail. These residual life bands range between 0 to 2 years and 15 to 20 years.

It is assumed that the first replacement works to each defence will take place at the end of its residual life bracket.

It has been assumed that the required standard of protection should be achieved for all the defences within the first 10 years of the strategy. For a defence with a residual life longer than the required strategy implementation year, if the crest level at the first replacement is lower than the required crest level for a given standard of defence, the defence must be either replaced or raised early (within the first 10 years). The order in which defences are replaced within the first 10 years has been assumed to depend on its compartment, as shown below in Table 4.

For the advance the line options (Options 6, and 7) it has been assumed that the required standard of protection should be achieved for all the defences within the first 20 years.

The replacement year for the defences has been decided on a flood compartment basis. The flood compartments are prioritised so that the flood compartments with the largest benefits are replaced first.

For example, a defence in flood compartment 7, with a residual life of 10 to 15 years will undergo replacement works in year 15 of the strategy. However, if the predicted crest level of the defence in year 15 when it would normally be replacement is lower than the required crest level for that defence frontage then the defence will be replaced in the first 10 years of the strategy (i.e. in year 9). Future replacement works are assumed to take place over a regular cycle depending on the assumed design life of the new defence type (as described below).

**Table 4 - Replacement Schedule**

Flood Compartment	Replacement Year in Strategy Implementation Period	
	Options 3, 4, 5, 8	Options 6, 7 (with FRS)
1	10	10
2	15	15
3	10	10
4	5	5
5	5	15
6	5	15
7	15	25
10	15	15
11	2	12
12	5	15
8, 9, 13, 14	-	-

The existing defences have been assumed to be replaced on a like for like basis for the purposes of costing. Exceptions to this are masonry walls, which are assumed to be replaced by concrete walls and concrete walls that run along quay sides which are assumed to be replaced by steel sheet piled walls. The types of defence considered are concrete walls, steel sheet pile walls and earth embankments. The design life of new structures has been assumed as:

- Concrete walls – 100 years after replacement;
- Steel sheet pile walls – 50 years after replacement;
- Earth embankments – 50 years after replacement.

Most defences therefore need to be replaced more than once throughout the 100 year strategy.

A replacement cost has been identified for each defence and for each option identified. The replacement cost for each defence has been generated individually and is dependant on the required crest levels for the defences. These levels are determined by comparing the predicted river water level (for each defence standard) at the next planned replacement year with the ground level at each defence location. If the water level is greater than the ground level, a replacement cost is incurred equal to the cost of works to insert a new defence along the same line, to the required crest level (including an allowance for freeboard).

Where a defence also includes erosion protection a cost for the erosion protection has been included at the replacement year of the hard defence.

## 2.6.2 Raising Works

It has been assumed that within the first 10 years for options without a flow restriction structure and in the first 20 years for options with a flow restriction structure of the strategy raising works will be undertaken to the hard defences in order to ensure that the Strategy standard of defence is implemented within this timescale. All hard defences will be raised (if required), unless they are to be replaced in years 0 - 10 or years 0 - 20 for non flow restriction structure options or flow restriction structure options respectively.

All earth embankments have been assumed to be replaced and not raised as the costs for both activities have in practice shown to be very similar.

The timing of raising hard defence works has been assumed to depend on which compartment the defences defend. The timing of the works is shown in Table 4 above.

A defence is raised when the current standard of protection is lower than the required standard of protection for that flood compartment. The predicted water level is determined by interpolating linearly between the present day water levels (2004) and future water levels with 0.6m sea level rise.

The cost of raising a defence has been determined by the comparison of the required water level to the effective crest level of that defence (with freeboard removed). If the water level is not in excess of the effective crest level of a defence, no raising cost is incurred.

It has been assumed for the purposes of this cost calculation that all defences in the Blyth Estuary have the capacity to be physically raised by up to 600mm, subject to a site investigation of some kind. Where defences would require raising in excess of 600mm it has been assumed that the defences would need to be replaced as opposed to being raised, as the existing foundations of the defences may not be sufficient. In these instances it has been assumed that replacement would be undertaken within the first 10 years of the Strategy to the same timetable as that used for the raising works.

## 2.6.3 Maintenance

The annual maintenance cost has been assumed to be approximately £5.43 per metre of defence for all the defences (updated to Q2 2007 values using the Output Price Index for Public Works – non roads). This figure is based on information provided by the Environment Agency operation staff and covers the following items:

- Grass and weed cutting;
- Control structure maintenance;
- Grounds maintenance.

This sum has been assumed for every year of the strategy, but has been discounted to year 0. The total sum has been proportioned amongst the flood compartments that are to be defended, according to the length of the defences protecting them. The total length of the defences in each compartment to be defended is shown below in Table 5.

**Table 5 – Summary of Maintenance Costs**

Flood Compartment	Length (m)	Cost (£/m)	Maintenance Costs (£/Yr)	Total Maintenance Costs over 100 Years (£)
1	575	5.43	3,122	93,067
2	795	5.43	4,317	128,690
3	280	5.43	1,520	45,311
4	222	5.43	1,205	35,921
5	2298	5.43	12,478	371,969
5*	230	5.43	1,249	37,233
7	428	5.43	2,324	69,278
(8)	1583	5.43	8,596	256,247
8*	530	5.43	2,878	85,793
(9)	1786	5.43	9,698	289,097
10	1553	5.43	8,433	251,388
11	2910	5.43	15,801	471,028
12	437	5.43	2,373	70,739
(13)	3289	5.43	17,859	532,377
(14)	210	5.43	1,140	33,983

Notes: \* Indicates embankments required to protect both the A12 and the A1095  
 ( ) Indicates flood compartments that have already breached and no longer require maintenance

Maintenance costs associated with the flow restriction structure and other control structures (i.e. sluices) are discussed below.

#### 2.6.4 Present Value Costs (PVC)

The PVC for each option has been determined using a variable discount rate as recommended in Defra's Flood and Coastal Defence Project Appraisal Guidance.

The variable discount rate can be summarised as:

- 3.5% for years 0 to 30;
- 3.0% for years 31 to 75;
- 2.5% for years 76 to 100.

This discount rate has been applied to all raising and replacement works, flow restriction structure costs, maintenance costs and control structure costs (i.e. sluices).

### 2.6.5 Optimism Bias Cost

Recent changes to Defra PAG require strategy costs to be increased by up to 60% to account for the appraiser's initial optimism in the production of cost estimates.

Optimism bias has been applied to the total present value costs for each option.

## 2.7 Water Levels

Present day river levels (2004) and future water levels including 0.6m sea level rise have been determined using a sophisticated calibrated numerical model of the Blyth Estuary. Further details can be found in the final Blyth Estuary Modelling Report, (January 2006).

## 3 Derivation of Costs for Works to Flood Defences

### 3.1 Basic Assumptions

For the purposes of this cost estimate calculation, the following assumptions have been made:

- All earthworks are solid measure (in-situ volume);
- All prices are exclusive of VAT;
- Work is awarded to a single contractor and not tendered separately as smaller packages;
- Resident/landowner approval is obtained prior to works;
- Defence replacement is on a 'like for like' bases. Masonry walls will be replaced by reinforced concrete walls, and concrete quays have been replaced by steel sheet piled walls.

### 3.2 Construction Types

The flood defences in the Blyth Estuary are of varying construction. Generally, the defences can be categorised as earth embankments, concrete walls or sheet pile defences.

#### 3.2.1 Earth Embankments

The Environment Agency recommends that new earth embankments have a minimum crest width of 4m with slopes of approximately 1 in 3, however, following liaison with the Environment Agency's Operations Team the crest width for each of the embankments within this estuary have been relaxed to 3m. The replacement costs for embankments in this cost calculation assume these dimensions. When replacing an embankment it is assumed that 70% of the material in the embankment being replaced is reused. This is to allow for material loss due to:

- Erosion of the embankment during its asset life;
- Inappropriate material for reuse;
- Material losses during the construction process.

Given the nature of the weak underlying strata and soft peaty top soil within Reydon Marsh (FC5) it is believed that the construction of any earth embankments in this area will result in high levels of settlement, such that an approximate 30% of additional material and additional geotextile have been included in the cost to account for this poor ground conditions. It has also been assumed that under a 'hold the line' scenario the reconstruction of the Reydon defence will be set back from the original line of defence and will be made up of 100% new material.

Whilst the majority of the defences have been costed to a 1 in 5 standard of protection the embankments and erosion protection costed to defend the A12 (FC8) and A1095 (FC5) have been costed to a higher standard of protection of 1 in 100 and 1 in 20 respectively.

### 3.2.2 Concrete Defences

The raising of concrete flood defences has been assumed to be the works required to provide additional concrete to the crest of the existing defence.

An 'L' shaped reinforced concrete wall structure has been assumed for all concrete wall replacements. Minimum reinforcement has been assumed as per BS8110.

### 3.2.3 Sheet Pile Defences

Where concrete capping is present, the cost of raising the sheet pile has been assumed to be the same as the cost of raising a concrete wall. Where no capping is present, the cost of raising the defence has been calculated assuming the addition of a new capping beam to the existing sheet pile.

Where new steel sheet piles are required, it has been assumed that piling will be up to the landward ground level. The flood defences is provided by reinforced concrete capping on top of the piles. Masonry facing for the concrete capping and for 1m below on the riverward face has been included in the costs as well as the cost of a coping stone along the crest of the wall.

The length of piling varies from 9m to 12m depending on retained height. Available cross sections through the river at numerous locations indicate that the average retained height of sheet pile river walls is approximately 3m to 4m. The assumption has been taken that the embedded depth of the piles is twice the retained height.

The cost of replacing piling in three locations has been calculated.

Normal river section upstream of the Harbour –LX8 section;

Quay wall through the Harbour – LX16 section assumed due to increased surcharged loading in Harbour;

In the estuary section upstream of the Harbour – LX12 section assumed as boat moorings are more common in this section of river.

### 3.2.4 Mini Piles

Where the existing hard defence consists of sheet piled walls with an exposed depth of approximately 0 to 1.5m the defence has been assumed to be mini piles. The length of the piling therefore varies from 4m to 5m depending on retained height. The assumption has been taken that the embedded depth of the piles is twice the retained height.

The cost of raising the defence has been calculated assuming the addition of a new capping beam to the existing sheet pile.

### 3.2.5 undefended Sections

During the Condition Assessment several sections of the floodplain were designated as undefended. This was because the crest level of the riverbank was lower than the level of the ground landward of it i.e. no flood defences are in place as high ground forms the flood defence. No costs have been included for works to these undefended sections.

### 3.2.6 Flow Restriction Structure

Both Options 6 and 7 include the construction of a flow restriction structure. This is a structure that reduces the width of the estuary to 42m by the use of sheet piling along a 30m length of the river bank. The structure also has a raised river bed level that includes a rock weir type wall that will restrict the flow of water into and out of the estuary.

The cost of constructing a flow restriction structure for both Options 6 and 7 are detailed in Table 6 below:

**Table 6 – Flow Restriction Structure Costs**

Option	Year of Construction	PV Cost (£)	PV Cost Including Optimism Bias (£)
6	0	1,836,087	2,937,739
7	0	1,836,087	2,937,739

### 3.3 Costing Sequence

Table 7 shows the sequence that has been used throughout the cost calculation in order to establish raising/replacement costs per linear metre of flood defence.

**Table 7 - Cost Calculation Sequence**

<b>MATERIAL COSTS</b>	
Local Land Purchase Costs	SUM
Site Investigation	SUM
Labour and Plant	SUM or 15%
<b>BASE COSTS</b>	
Access and Mobilisation	15%
Contractors Overheads	20%
Contractors Profit	5%
<b>CONSTRUCTION COSTS</b>	
Major Land Purchase	SUM
Compensation	SUM
Engineering Costs	15%
Agency Costs	5%
<b>REPLACEMENT DEFENCE COSTS</b>	

### 3.4 Rates Used

#### 3.4.1 Materials, Plant and Labour

A summary of the rates used for materials is attached in Annex A of this report. The rates are taken from various sources and indexed to 2006.

Where SPON's has been used to derive rates, the cost of labour and plant is generally included in the cost of materials. However, literature of this nature is designed for use on larger construction projects where large volumes are used. To account for this and due to the piecemeal nature of this type of construction work, the rates for labour and plant have been added to cover inefficient working. Since SPON's relies on purchasing materials in bulk, the prices quoted are generally cheaper than can be expected to be

experience. As a result an additional 15% of the material cost has been added to allow for increase in plant and labour costs.

### 3.4.2 General and Preliminaries Items

A percentage of between 25 and 30% (depending on construction type) of the total material cost has been assumed to cover all general and preliminary items. These items include the following:

- Contract administration;
- Contractors contract management;
- Site signage;
- Site safety costs;
- Provision of services to site;
- Testing of materials, where necessary.

### 3.4.3 Access

15% of the total material cost has been assumed to cover any access difficulties. In general, access to the flood defences is good. Access for larger plant however may be restricted to some degree leading to the necessity for works to be carried out from the river at an increased cost.

### 3.4.4 Land Purchase

The Environment Agency are assumed to purchase the land on which replacement works and raising works are constructed and also to purchase a 3 metre working area per linear metre of defence. A cost of £7,346 per hectare was assumed for this purchase of land. This cost was derived from the approximate cost of local grade 1 and 2 agricultural land and was used for all land purchases in this cost assessment and updated to a present value using the Output Price Index for Public Works – Non Roads.

### 3.4.5 Habitat Replacement

The cost of habitat replacement is very specific to each individual flood compartment and to which option that is being adopted. Habitat replacement costs to create replacement habitat have been added to the construction cost. Replacement habitats are required where designated habitats are lost due to the implementation of one of the considered options, i.e. through the withdrawal of maintenance of a defence. The costs of replacement habitat are shown below in Table 8.

**Table 8 – Summary of Replacement Habitat Costs**

Flood Compartment	Habitat	Area (Ha)	Land Cost (£/Ha)	Habitat Cost (£/Ha)	Total Cost (£)	Annual Maintenance Cost (£)	Do Nothing Write-Off PV Cost (£)
5	Reydon Marsh	17	6,975	9,281	394,931	4,303	523,218
5*	Hen Reed Beds	30	6,975	9,281	696,938	7,594	923,327
11	Tinker's Marsh	56	6,975	10,125	1,348,200	11,340	1,686,274

Notes: \* Indicates an area that was formerly flood compartment 6

Within the cost of the total replacement habitat above a value of £6,975 per hectare has been used for the purchase of suitable land. These values have been derived using figures provided by the Environment Agency based on experience gained from other projects and has been used for each of the different types of habitat being replaced. Whereas the cost of attributed to the replacement of the habitat has been assumed to be £9,281/ha for both Hen Reed Beds and Reydon Marsh, and £10,125/ha for Tinker's Marsh. (All values present to Q2 2007.)

The current annual maintenance cost of these habitats has been assumed to be £253/ha for fresh water reed beds in both Hen Reed Beds and Reydon Marsh and £203/ha for the wet grasslands of Tinker's Marsh (values present to Q2 2007). Although these maintenance costs are currently met by a third party, such as the existing land owner's, should these habitats need to be relocated then these maintenance costs would have to be met by the Environment Agency.

### 3.4.6 Public Water Supply Costs

Where the managed withdrawal of defence maintenance in Reydon Marsh (FC5) is required, a cost of £5,955,880 (value present to Q2 2007) has been assumed for the relocation of the public water supply managed by Essex and Suffolk Water Company. In the cost calculation this cost along with all others is subject to a 60% optimism bias.

### 3.4.7 Site Investigations

A lump sum of £22.5 per linear metre has been assumed for site investigations prior to replacement of each defence. This sum is assumed to cover investigation of river walls and existing flood defences, as well as ground conditions.

### 3.4.8 Engineering Cost

15% of the construction cost has been added for engineering design costs. This sum covers the following:

- Professional fees for the design and construction of the preferred option;
- Design consultants costs and expenses for detailed design;
- Preparation of tender documents.

### 3.4.9 Environment Agency Cost

5% of the construction costs has been assumed for the Environment Agency costs. This is to cover staff costs for project management of the preferred option.

However, it is also expected that some additional Environment Agency's costs will be incurred due to the following:

- Promotional costs, which include liaison the landowners and key stakeholders;
- Legal and estates;
- Operations; and
- NCPMS.

These have been included in the economic analysis for the first 20 years of the appraisal period at the following values:

- £20,000 for years 0 to 9
- £10,000 for years 10 to 19.

## 4 Summary of Base Case Costs

The total PV costs for the base case options considered in this report are presented in this section. As discussed in Section 3.1, the cost of raising/replacement works has been split up according to the work involved in each of the 14 flood compartments, though all costs associated with flood compartment 6 are included within flood compartment 5 on which its defences depend. The cost of maintenance works and control structures is included in the cost of works to each compartment having been proportioned as described earlier in this report. All of the costs presented in this section include 60% optimism bias.

No costs are incurred in flood compartments 9, 13 and 14 which have already failed. In flood compartment 8, which has also failed, the only cost is the cost of an embankment to protect the A12 from being flooded from this compartment. The same cost is applied in all options where appropriate.

### 4.1 Option 2 –Do Minimum throughout the Blyth Estuary

The PV costs for the Do Minimum option in each flood compartment are summarised in Table 9.

**Table 9 - Summary Cost of Option 2**

Flood Compartment	Option 2
	SoP = 1 in 5 (£)
1	161,229
2	331,191
3	139,152
4	79,211
5	12,611,206
6	-
7	44,357
8	2,090,131
9	-
10	160,948
11	2,604,357
12	17,754
13	-
14	-
<b>Total PV Cost</b>	<b>18,239,536</b>

## 4.2 Option 3 - Hold the Line throughout the Blyth Estuary

A 1 in 5 standards of protection has been considered for the Hold the Line scenario. The PV costs for each flood compartment are summarised in Table 10.

**Table 10 - Summary costs for Option 3**

Flood Compartment	Option 3	
	3a (£)	3b* (£)
1	7,717,934	6,294,067
2	1,104,185	1,005,814
3	713,899	508,866
4	366,818	316,094
5	15,063,115	14,942,076
6	-	-
7	353,051	265,944
8	2,090,131	2,090,131
9	-	-
10	2,533,468	2,177,682
11	9,172,641	8,283,849
12	471,465	359,787
13	-	-
14	-	-
<b>Total PV Cost</b>	<b>39,586,708</b>	<b>36,244,308</b>

## 4.3 Option 4 – Manage the man made structures at the mouth of the Blyth Estuary with No Active Intervention elsewhere

Under this option there is a 'Hold the Line' policy for within the harbour mouth with no active intervention further upstream. This involves maintaining the line of the existing northern harbour arms that forms the mouth of the estuary. The costs have been generated are for maintaining the existing harbour arms structure for 50 years and then replacing it with a rock groyne structure on the same alignment as the existing. Elsewhere in the estuary where there is a policy of No Active Intervention no further cost are included.

However, the holding of the mouth option has been considered and costed as a part of the Southwold Coastal Defence Scheme and as such it has not been necessary to consider its costs within this report. Therefore Option 4 would be applied as per Option 1 without any associated costs.

#### 4.4 Option 5 - No Active Intervention at Robinson's Marsh and Hold the Line elsewhere

For defences being held, a 1 in 5 standards of protection has been considered. The PV costs for each flood compartment are summarised in Table 11.

**Table 11 - Summary Costs for Option 5**

Flood Compartment	Option 5	
	5a (£)	5b* (£)
1	7,715,759	6,292,871
2	1,098,146	1,000,104
3	546,003	507,237
4	365,295	314,712
5	15,063,115	14,983,335
6	-	-
7	351,342	264,408
8	2,090,131	2,090,131
9	-	-
10	1,493,344	1,360,619
11	5,683,165	5,163,649
12	469,101	357,667
13	-	-
14	-	-
<b>Total PV Cost</b>	<b>34,875,401</b>	<b>32,334,735</b>

Under this option the defences in Robinson's Marsh (FC 10) are maintained for 15 years as in Option 2 and not replaced for the remainder of the strategy. The PV value for compartment 10 is for the replacement of the cross bank separating flood compartments 10 and 11, the land purchase price and a defensive wall around some properties in Walberswick.

#### 4.5 Option 6 - Advance the Line of the flood defence by making the Blyth Estuary shallower or narrower close to the Bailey Bridge and Hold the Line elsewhere.

It has been assumed that the introduction of a flow restriction structure to the estuary system increases the asset life of all of the flood compartments upstream of it by 10 years. The asset life of defences downstream of the flow restriction structure have not been increased, and it is assumed that the flow restriction structure is constructed in Year 0.

For defence being held a 1 in 5 standards of protection has been considered. The PV costs associated with this option is summarised for each flood compartment in Table 12.

**Table 12 - Summary of Costs for Option 6**

Flood Compartment	Option 6	
	6a (£)	6b* (£)
1	7,709,236	6,288,307
2	1,122,143	1,017,428
3	510,047	474,107
4	331,328	284,252
5	12,348,771	12,941,414
6	-	-
7	806,691	740,527
8	2,090,131	2,090,131
9	-	-
10	1,826,083	1,495,602
11	4,641,527	4,371,761
12	881,302	798,157
13	-	-
14	-	-
<b>Total PV Cost</b>	<b>35,204,996</b>	<b>33,439,422</b>

#### 4.6 Option 7 - Advance the Line of the flood defence by making the Blyth Estuary shallower or narrower close to the Bailey Bridge and No Active Intervention at Tinker's Marsh

A 1 in 5 standards of protection has been considered for the advance the line with No Active Intervention at Tinker's Marsh and Hold the Line elsewhere option. The PV costs for each option in each flood compartment are summarised in Table 13.

**Table 13 - Summary of Costs for Option 7**

Flood Compartment	Option 7	
	7a (£)	7b* (£)
1	7,709,236	6,288,307
2	1,121,963	1,017,247
3	510,047	474,107
4	331,328	284,252
5	12,348,771	12,941,414
6	-	-
7	806,691	740,527
8	2,090,131	2,090,131
9	-	-
10	1,826,083	1,477,458
11	3,209,692	3,116,846
12	881,302	798,157
13	-	-
14	-	-
<b>Total PV Cost</b>	<b>33,772,981</b>	<b>32,166,183</b>

#### 4.7 Option 8 - Hold the Northern Line of defence and No Active Intervention elsewhere in the estuary

A 1 in 5 standards of protections has been considered for the Hold the Line on the northern side of the Blyth estuary with No Active Intervention elsewhere. The PV costs for each option in each flood compartment are summarised in Table 14.

**Table 14 - Summary of Costs for Option 8**

Flood Compartment	Option 8	
	8a (£)	8b* (£)
1	5,371,515	4,341,678
2	1,026,043	894,000
3	481,494	439,261
4	301,130	247,165
5	15,063,115	14,983,335
6	-	-
7	63,475	44,357
8	2,090,131	2,090,131
9	-	-
10	160,948	160,948
11	2,604,357	2,604,357
12	45,289	17,754
13	-	-
14	-	-
<b>Total PV Cost</b>	<b>27,207,497</b>	<b>25,822,986</b>

## 5 Draft Strategy

While the preferred technical and environmental option is hold the Northern Line of defence with No Active Intervention elsewhere in the estuary (Option 8), this does not satisfy the economic criteria for investment nor the priority score to attract funding. The Do Minimum strategy (Option 2) is probably the least acceptable on environmental and technical grounds and although it satisfies the economic criteria for investment it does not have the priority score required for investment to take place in the current climate.

In this situation, a policy of No Active Intervention (Option 1) is likely to be the preferred policy for the Blyth Estuary. However, it has been necessary to consider each flood compartment within the estuary individually to understand the consequences of a No Active Intervention policy and establish a schedule for the withdrawal of maintenance. Table 15 below displays the time before the maintenance is withdrawn from each of the flood compartments.

**Table 15 – Withdrawal of Maintenance Timescale**

Flood Compartment	Draft Strategy
	Withdrawal of Maintenance timescale (Years)
1	20
2	20
3	20
4	5
5	5
6*	5
7	2
(8)	6 months
(9)	6 months
10	20
11	2
12	2
(13)	6 months
(14)	6 months

Notes: \* FC 6 is linked to the estuary through FC5 and as such they have the same timings  
 ( ) Indicates Flood Compartments where the defences have already failed, thus requiring no maintenance.

Under the draft strategy of No Active Intervention through a managed withdrawal of maintenance, in addition to the Environment Agency maintenance costs, there are a number of defence costs that would need to be met from other funding sources if the current level of protection is to be maintained. These are the costs associated with protecting both the A1095 and the A12 in flood compartments 5 and 8 respectively, through the construction and maintenance of erosion protected earth embankments. In addition, it is also necessary to replace and maintain Wolsey Sluice as apart of the embankment in flood compartment 5.

The withdrawal of maintenance from the defences in flood compartments 5, 6 and 11 will result in various habitat replacement costs associated with the relocation of the designated habitats at Hen Reed Beds and Tinker's Marsh, as well as the cost of relocating the public water supply managed by Essex and Suffolk Water Company in flood compartment 5.

A break down of the costs associated with a managed withdrawal of maintenance through out the estuary have been summarised by flood compartment in Table 16 below.

The estimated PV costs associated with the Draft Strategy amount to £11.7M without optimism bias and £18.8M with 60% optimism bias. These PV costs are substantial but much lower than those associated with all other options considered in Tables 10 to 15, which also include optimism bias.

The estimated cash costs of the Draft Strategy amount to £18.6M excluding optimism bias. Approximately £7.1M of these cash costs are expected to fall on the Environment Agency. The remaining costs are assumed to be divided between Suffolk County Council highways department who are expected to incur a cash cost of around £5M excluding 60% optimism bias for construction and maintenance of embankments to protect the A12 and A1095. Within this total, approximately £0.8M has been included for the refurbishment and continued maintenance of the Wolsey Creek sluice. The remainder of the cost (approximately £6M) are expected to be incurred by utility companies for the protection or relocation of the public utilities throughout the Blyth Estuary.

**Table 16 – Summary of Costs for the Draft Strategy**

Responsible Authority		Environment Agency						Third Party								Summary				
Flood Compartment	Year of Retreat	Initial Average Annual Maintenance (£)	Terminal Groyne (£)	Habitat Replacement (£)	Habitat Annual Maintenance (£)	Sub Total Capital Costs (£)	Sub Total Maintenance Cost (£)	Initial Sluice Capital Works (£)	Replacement Sluice Capital Works (£)	Sluice Maintenance (£)	Utility Re-location (£)	Total Road Embankment Capital Costs (£)	Annual Road Embankment Maintenance (£)	Sub Total Capital Costs	Sub Total Maintenance Cost (£)	Total Maintenance Cost (£)	Total Capital Cost (£)	Total Cost (£)	PV Cost (£)	Total (With 60% Optimism Bias) (£)
1	20	6,644	104,207	0	0	104,207	132,881	0	0	0	0	0	0	0	0	132,881	104,207	237,087	186,118	297,788
2	20	7,839	260,516	0	0	260,516	156,789	0	0	0	0	0	0	0	0	156,789	260,516	417,306	335,311	536,497
3	20	5,041	104,207	0	0	104,207	100,822	0	0	0	0	0	0	0	0	100,822	104,207	205,028	162,538	260,062
4	5	8,273	52,103	0	0	52,103	41,366	0	0	0	0	0	0	0	0	41,366	52,103	93,469	82,437	131,900
5	5	31,014	521,033	1,091,869	11,897	1,612,901	1,765,383	45,000	450,000	3,600	5,955,880	2,090,060	1,250	8,540,940	484,976	2,250,360	10,153,841	12,404,201	7,832,216	12,531,546
6	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	2	4,576	0	0	0	0	9,151	0	0	0	0	0	0	0	0	9,151	0	9,151	8,997	14,394
8	-	0	0	0	0	0	0	0	0	0	0	2,194,747	2,880	2,194,747	287,989	287,989	2,194,747	2,482,735	1,306,332	2,090,131
9	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	20	11,958	0	0	0	0	239,165	0	0	0	0	0	0	0	0	239,165	0	239,165	176,550	282,480
11	2	29,402	0	1,348,200	11,340	1,348,200	1,170,124	0	0	0	0	0	0	0	0	1,170,124	1,348,200	2,518,324	1,632,147	2,611,435
12	2	4,625	0	0	0	0	9,249	0	0	0	0	0	0	0	0	9,249	0	9,249	9,093	14,548
13	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<b>Sub - Total</b>		109,372	1,042,065	2,440,069	23,237	3,482,134	3,624,931	45,000	450,000	3,600	5,955,880	4,284,807	4,130	10,735,687	772,965	4,397,896	14,217,820	18,615,717	11,731,738	18,770,781

## 6 Cost Sources

### 6.1 Previous B&V Estimates

Ipswich Flood Defence Management Strategy.

Humber Estuary Flood Management Strategy

### 6.2 Contractors and Others

BV project team have had estimating advice from a range of contractors to make sure the costs derived are robust. The following companies have assisted the projects to date.

- Earthmoving Consultant - Cost information for earth embankments.
- Jackson Civil Engineering – Information regarding the rates used for the cost build ups.

### 6.3 Literature

Spon's, 2007. Spon's Civil Engineering and Highway Works Price Book. 21<sup>st</sup> Edition, Edited by Davis Langdon. Taylor and Francis Group, London.

RPI, 2007. Retail Price Index, Wolfbane Cybernetics Ltd. 2007.

Quarterly Building Price and Cost Indices, September 2007, Department for Business Enterprise and Regulatory Reform.

## References

1. Blyth Estuary Flood Defence Management Strategy, Flood Defence Condition Survey; Black and Veatch Consulting (June 2004).
2. Flood and Coastal Defence Project Appraisal Guidance - Economic Appraisal; Ministry for Agriculture, Food and Fisheries (December 1999).
3. Civil Engineering and Highway Works Price Book 2002; SPON's (2002).
4. Quarterly Building Price and Cost Indices; Department of Trade and Industry (December 2001).
5. Flood and Coastal Defence Project Appraisal Guide – FCDPAG 3 Economic Appraisal Supplementary Note to Operating Authorities; Defra (March 2003).
6. Guidance on Costing of Environmental Pollution from Construction: CIRIA (2002)
7. BS8110 – Structural Use of Concrete part 1: Code of Practice for Design and Construction; British Standards Institute (1997).
8. Spon's, 2007. Spon's Civil Engineering and Highway Works Price Book. 21<sup>st</sup> Edition, Edited by Davis Langdon. Taylor and Francis Group, London.
9. RPI, 2007. Retail Price Index, Wolfbane Cybernetics Ltd. 2007.
10. Quarterly Building Price and Cost Indices, September 2007, Department for Business Enterprise and Regulatory Reform.

## ANNEX A – RATES

Refer to digital version of spreadsheets for rates and cost build-ups used to generate the costs for each of the options considered noting that the option reference numbers differ to those used in this and subsequent reports:

Cost Summary.xls

Blyth - Do Minimum.xls

Blyth - Option 2 - Hold the Line.xls

Blyth - Option 3 – Maintain & New Groyne.xls

Blyth - Option 4 - Hold the Line Except @ Robinsons.xls

Blyth - Option 5 - Hold the Line + Throat.xls

Blyth - Option 6 - HTL + Throat + DN @ Tinkers.xls

Blyth - Option 7 -Throat+DN@Tinker+HTL@Reydon.xls

Blyth - Option 8 - Hold Northern Line.xls

Blyth – Do Minimum\_ New Strategy Option.xls

Terminal Groyne.xls

Compensatory Habitat.xls

SCDC FC8 Embankment Costs (210607)Yr2.xls

Wolsey Sluice Costs.xls



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