Angus Council

Angus Shoreline Management Plan SMP2

Appendix H – Economic Appraisal and Sensitivity Testing

Buddon Ness, 2012

Contents Amendment Record

This report has been issued and amended as follows:

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1	0	Draft for consultation	March 2015	J Young
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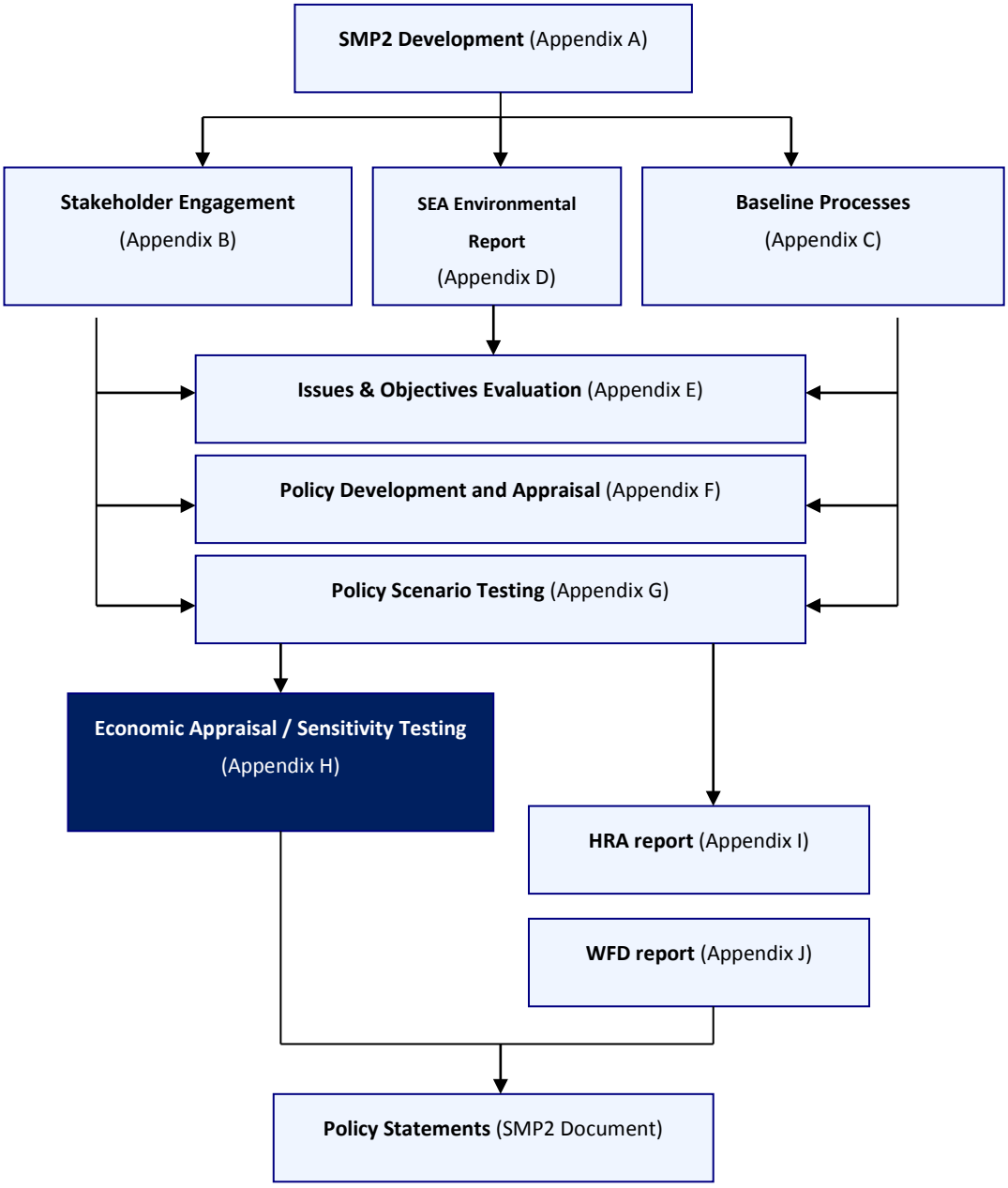
The Supporting Appendices

These appendices and the accompanying documents provide all of the information required to support the Shoreline Management Plan. This is to ensure that there is clarity in the decision-making process and that the rationale behind the policies being promoted is both transparent and auditable. The appendices are:

A: SMP2 Development	This reports the history of development of the SMP, describing more fully the plan and policy decision-making process.
B: Stakeholder Engagement	All communications from the stakeholder process are provided here, together with information arising from the consultation process.
C: Baseline Process Understanding	Includes baseline process report, defence assessment, NAI and WPM assessments and summarises data used in assessments.
D: Strategic Environmental Assessment (SEA) Environmental Report	This report identifies and evaluates the baseline environmental features (human, natural, historical and landscape) and presents an overview of the environmental assessment process, showing how the requirements of the EU Council Directive 2001/42/EC (the Strategic Environmental Assessment Directive) are met.
E: Issues & Objectives Evaluation	Provides information on the issues and objectives identified as part of the Plan development, including appraisal of their importance.
F: Policy Development and Appraisal	Presents the consideration of generic policy options for each frontage, identifying possible acceptable policies, and their combination into 'scenarios' for testing. Also presents the appraisal of impacts upon shoreline evolution and the appraisal of objective achievement.
G: Policy Scenario Testing	Presents the policy assessment and appraisal of objective achievement towards definition of the Preferred Plan (as presented in the Shoreline Management Plan document).
H: Economic Appraisal and Sensitivity Testing	Presents the economic analysis undertaken in support of the Preferred Plan.
I: Habitat Regulations Assessment	Presents an assessment of the effect the plan will have on European sites.
J: Water Framework Directive Assessment	Presents the Water Framework Directive assessment of the potential hydromorphological changes and consequent ecological impact of the preferred SMP2 policies.
K: Metadatabase and Bibliographic database	All supporting information used to develop the SMP2 is referenced for future examination and retrieval.

Within each appendix cross-referencing highlights the documents where related appraisals are presented. The broad relationships between the appendices are illustrated below.



Appendix H: Economic Appraisal and Sensitivity Testing

H.1 Introduction

A high level review of economic viability has been carried out for the Preferred Plan and its associated policies.

It should be noted that this review is not to establish the economic justification for a scheme as defined by the Flood and Coastal Erosion Management Appraisal Guidance (FCERM-AG, published by the Environment Agency, 2010). The review instead makes a broad assessment of the economic robustness of the preferred policies. The economic review therefore determines whether or not each policy is:

- Clearly economically viable;
- Clearly not economically viable; or,
- Potentially economically viable (and therefore may be in need of more detailed assessment at a later date, e.g. as part of a strategic plan, although some commentary on this is provided within this report).

It must be recognised that the justification for a particular policy is not necessarily dependant on economic viability based on the benefit-cost ratio alone; as impacts on other benefits may be considered more important (e.g. holding existing defences to sustain a designated habitat) and at the broad scale level of analysis undertaken at the SMP2 stage not all benefits are able to be evaluated in monetary terms. Although these other benefits have not been valued in monetary terms, they are taken into account during decision-making by considering whether they are likely to be sufficient to increase the benefits such that the benefit-cost ratio would be greater than one.

The following sections detail how the economic assessment has been undertaken. This is followed by a series of economic statements for each policy unit, and spreadsheets providing the numerical analysis performed as part of the SMP2.

H.2 Use of existing information

The following datasets were consulted to obtain information for the economic review:

- National Land and Property Gazetteer
- Registers of Scotland Quarterly House Price Statistical Report
- Scottish Assessors Association Valuation Role
- Miscellaneous GIS datasets including Scheduled Ancient Monuments, road and railways, coastal paths etc.

There were no strategy plans or scheme assessments available within the SMP area to supplement the analysis undertaken as part of this appraisal.

H.3 Generation of new data

As there is limited existing information that can be used directly to confirm robustness of the SMP2 policy, new economic data has been derived through application of a GIS (ESRI ArcView) and adapted FCREM-AG economic calculation sheets. This 'Broad-scale Economic Review', described below, uses nationally available information on property locations and values, and the risk maps developed through the assessment of coastal processes (**Appendix C**).

H3.1 Determining benefits and costs

The benefits are the damages avoided or delayed by the Preferred Plan, i.e. the difference in losses between implementing the Preferred Plan and the No Active Intervention (NAI) scenario. These have been calculated for each epoch.

Although policy appraisal has determined a 'zone' of likely future erosion, for the purposes of estimating possible benefits, only the most landward extent of the likely erosion (for each period: 0-20, 20-50 and 50-100 years) has been used in the present analysis. These lines have been mapped and overlain with the property location/value data to calculate potential economic losses and economic benefits for the NAI scenario and the Preferred Plan scenario. It should be noted that average erosion rates for each epoch are used in this analysis and as such, erosion losses calculated within the GIS are indicative and should be viewed accordingly.

In areas where there is a flooding risk, no attempt has been made to undertake detailed flood risk modelling. Instead, GIS analysis has been undertaken to translate design sea levels from the Coastal Flood Boundaries project (Environment Agency/SEPA/Defra, Project SC060064) into identified flood cells for each epoch (Year 0, 20, 50 and 100) in the NAI scenario. . The potential damages in these flood cells are simply taken as the summed value of all the 'at risk' assets. This is based on the assumption that under a NAI scenario flood defences would fail and all 'at risk' assets would be inundated and become uninhabitable. This is taken as an indicative figure for the assets potentially protected by defence structures. Flood damages have been calculated on a Policy Unit by Policy Unit basis, based on damages within Flood Cells. It should be noted that along a number of frontages, one or more Flood Cells cover multiple policy units, in these cases, damages may be shown to be the same in adjacent Policy Units which extend over the same flood cell, as failure of defences in either Unit will lead to inundation of the whole Flood Cell.

In calculating damages and benefits for the preferred scenario, no account has been taken of the potential for short-term accelerated or delayed losses compared to NAI, other than the total adjustment in shoreline position at the end of each epoch.

The SMP2 does not take account of standards of protection as it is only defence management policy that is being determined. Standards of protection relate to implementation of these policies, which is usually undertaken within more detailed strategy or scheme level studies.

H3.1.1 Benefit values

(a) Property values

For properties, losses and benefits have been calculated mainly on the basis of residential and commercial property values. In some instances, however, other assets, such as utilities, highways and railway lines have also had estimated values assigned to them based on the cost of reconstructing or re-routing the asset. Intangibles, such as recreation, and other impacts upon the local economy or environment, have not been valued, but the benefits that could be generated are taken into consideration when identifying if the preferred plan is likely to be economically viable (or not). Losses and benefits have been calculated using data from GIS. This was populated with data from the various datasets identified in Section H2.

Market values for households were identified for the three local authority areas in the SMP2 area (Angus, Dundee City and Aberdeenshire). Market values for commercials assets were derived by using the Rateable Value from the Assessors dataset, multiplied by a conversion factor of 10 (in accordance with the guidance in the Multi-Coloured Manual (FHRC, 2010)).

The National Property dataset is built from the Ordnance Survey Address Point dataset and the Valuation Office Focus database. Address Point identifies the location of all existing properties. The Focus database then

identifies which are non-residential (i.e. commercial/industrial) and provides a rateable value from which an approximate capital value is obtained, by applying a conversion factor. A conversion factor of 13 is used to convert rateable values to capital values, based on the types of commercial property affected and the typical yield they provide (around 7.6% to 7.7%). The remaining properties are assumed to be residential and property valuations included in the National Property Dataset were used in the analysis.

Using the 20, 50 and 100 year erosion contours, GIS has been used to identify assets at risk in each epoch, and this data has been used with FCERM-AG calculation sheets to calculate the Capital Value (CV) and discounted Present Value (PV).

For the flood risk areas, GIS has been used to simply sum the CV for all built assets within the predicted Year 100 1 in 200 year flood area (Annual Event Probability (AEP) of 0.5%), using the property database. It is not possible to derive an accurate PV flood damage value from this information; such a calculation require detailed flood modelling including event by event analysis outside the scope of the SMP2. However, the number and CV of the assets at risk can provide an indicator of likely economic viability.

(b) Agricultural land values

Following FCERM-AG guidance, the standard reference for the valuation of agricultural land is the RICS Rural Land Market (half yearly reports). This provides land values for agricultural data in two categories: arable and pasture. The latest RICS data available on the web is H2 2015, with arable land being valued at £4,750 / acre and pasture at £2,500 / acre. A further online source[1] indicated a spread across divisions of the two types of land, see Table H1.

Table H1 Average Scottish farmland prices 2015 H2 (£/acre)

Good arable	Average arable	Arable/ grass	Permanent pasture
£9,046	£5,612	£4,013	£2,783
1.61A	*A*	*0.71A*	*0.49A*

These two valuations have been combined to provide 2015 H2 values as presented in Table H2.

Table H2 Average Scottish farmland prices 2015 H2 (£/acre)

Good arable	Average arable	Arable/ grass	Permanent pasture
£7,650	£4,750	£3,375	£2,330

These land values have been allocated to the classifications from the Macauley Land Classification for Agriculture (LCA) at risk within the SMP area, as shown in Table H3.

[1] (http://content.knightfrank.com/research/443/documents/en/h1-2015-3007.pdf

Table H3 Land values used in SMP economics

Class	Description	Type	Value £/acre	Value £/ha	Economic value* £/ha
1	Land capable of producing a very wide range of crops	Good Arable	7,650	18,903	18,790
2	Land capable of producing a wide range of crops	Good Arable	7,650	18,903	18,790
3.1	Land capable of producing a moderate range of crops, capable of producing consistently high yields of a narrow range of crops (cereals/grass) and moderate yields of a wider range	Average Arable	4,750	11,737	11,625
3.2	Land capable of producing a moderate range of crops, capable of average production but high yields of grass, barley, oats often, Other crops limited to potato and forage	Average Arable	4,750	11,737	11,625
4.1	Land capable of producing a narrow range of crops, suited to crop rotations which are primarily based on long ley grassland include forage crops and cereals for stock feed	Arable / grass	3,375	8,340	8,227
4.2	Land capable of producing a narrow range of crops, land primarily grassland with some limited potential for other crops	Arable / grass	3,375	8,340	8,227
5.2	Land suited only to improved grassland and rough grazing, land moderately suited to reclamation and to use as improved grassland	Arable / grass	3,375	8,340	8,320
6.3	Land capable only of use as rough grazing, Low grazing value	Pasture	2,330	5,757	5,752
6.2	Land capable only of use as rough grazing, Moderate grazing value	Pasture	2,330	5,757	5,752

*In accordance with the guidance in Defra (2008), in the NAI Scenario (*land is abandoned or no longer fit for agricultural use for the foreseeable future*), the values of land were reduced to remove the cost of subsidies. The reductions are based on indicative values provided for the Basic Payment Scheme.[2]

H3.1.2 Generation of new defence cost information

Future coastal defence management approaches for each Policy Unit have been developed as part of the Preferred Plan. From this, the broad replacement and maintenance requirements for each epoch have been determined.

Where there is no existing information relating to future defence costs for an area, e.g. from a strategy plan or scheme design, costs have been generated using other nationally available information.

[2] https://www.ruralpayments.org/publicsite/futures/topics/all-schemes/basic-payment-scheme

(a) Cost Rates

Replacement costs for general defence types have been taken from Environment Agency's Unit Cost Database (Environment Agency, 2007). This suggests average replacement costs for linear structures (e.g. revetments, seawalls) beach management schemes, groynes and embankments based on costs incurred on recent Environment Agency projects. Additional costs included within recent strategies and completed works from within the SMP2 area were also included to help strengthen and validate the average cost rates used in the SMP.

Maintenance costs have been taken from the Defra 'National Appraisal of Defence Needs And Costs' (NADNAC) study (Defra 2004). Updated to current (2015 Q4) values using the Construction Price Index index, this suggested annual maintenance costs for linear structures and for groyne fields at £14,000/km, and for beach schemes £26,000/km.

(b) Cost Calculations

It has been assumed that the timing of full scheme reconstruction required (i.e. design life) is at least once every 100 years for linear defences, such as seawalls, revetments and embankments; every 50 years for beach schemes; and timber groynes. However, these periods may become more frequent for areas where erosion potential is high. Maintenance has been assumed to occur to the same level in every year throughout the life of the scheme. In reality, this will be less in the early years and will increase in later years of the scheme's life. However, for the broad brush appraisal undertaken for the SMP2 this will make negligible differences to decisions as the majority of costs are associated with capital works.

Allowance has also been made for the increase in costs due to climate change and sea level rise, based upon factors developed for the NADNAC study. This takes account of the need to make structures higher, deeper, and more resilient to increased exposure. The assumptions were: no cost increase for the 0-20 year epoch; costs factored up by 1.5 times present day rates for the 20-50 year epoch; and costs factored up by 2.0 times the present day rates for the 50-100 year epoch.

In accordance with the latest Defra and HM Treasury guidance, Optimism Bias (OB) was applied to all costs (at 60%) to reflect uncertainty in broad level analysis at the SMP2 scale.

As the SMP2 does not go into the detail of defining extents of potential managed realignment, cost allowances for set-back embankments make broad scale allowances for defence lengths required from map based assessments. In some locations it is assumed that the realignment would be to high ground and no defence would be required. No allowances have been made in the costs for land purchase or compensation as it is not clear at SMP development stage what approach to managed realignment would be taken, the existing defences may for example be handed over to the land owners and under withdrawal of maintenance policy and no compensation is due.

H3.2 Comparison of costs and benefits

As this review is not a full economic assessment, a formal benefit-cost assessment has not been conducted; however benefit-cost ratios (BCRs) for the scenario areas have been included to help clarify and review the 'robustness' of the preferred plan.

In comparing likely benefits and likely costs for the policies for an individual location, over the full 100 year period, it is however still useful to consider these in terms of Present Value (PV).

Present Value is the value of a stream of benefits or costs when discounted back to the present day. For this SMP, the discount factors used are the latest provided by Defra for assessment of schemes, i.e. 3.5% for years 0-30, 3.0% for years 31-75, and 2.5% for years 76-100.

For calculation of PV damages, the approximate timing of property losses has been taken as the mid point of the epoch in which the damage is expected to occur, and corresponding discount factors applied accordingly. There is a greater degree of certainty related to the analysis for erosion losses, as the predicted timing of losses is based on erosion rates. Assets at risk of flooding are identified via the 1 in 200 year predicted flood extent in each epoch and the full market value of the asset is used in the analysis. There is no guarantee that each property would incur damages up to the limit of its market value.

For the calculation of PV costs for defence replacement, both capital and year-on-year maintenance PV costs are calculated using the discount rate for the year in which intervention is predicted. A 60% Optimism Bias is added to the total PV cost over the 100 years to provide a risk allowance and therefore a robust cost estimate.

The figures generated for this SMP2 are presented only in PV in Section H.4, reflecting the 'broad-scale' nature of the assessments undertaken. However, for further information, the CV of these the No Active intervention damages are presented in Annex H.1 and Annex H.2 gives CV & PV costs.

H3.3 Coastal defence funding in Scotland

Capital Grant Funding for large flood defence projects (threshold set at £2m) is available via application from the Scottish Government, with grant funding currently available for 80% of eligible capital costs. The projects must have a benefit cost ratio greater than unity and demonstrate project value for money. The contribution level may change in the future.

Under the Coast Protection Act 1949, local authorities have discretionary powers to carry out coast protection work as may appear to them to be necessary of expedient for the protection of any land in their area against erosion and encroachment by the sea. The coast protection capital grant is now part of the General Capital Grant paid to Councils.

H3.4 Economic Uncertainties

The economic appraisal has estimated the damages for the no active intervention options and range of management options. Benefits were then calculated for each option (with NAI as the baseline) and compared with the costs of managing the 'at risk' assets in the particular cell. This results in a benefit-cost ratio which is reported in Economics Tables (**Section H.4**) and uncertainties addressed in the Uncertainties Tables (**Section H.5**). As discussed in **Section H.3.1**, the monetary damages primarily include residential and commercial property, critical infrastructure and agricultural land erosion / flood losses. The benefit-cost ratio therefore is not truly representative of the economic 'worth' of any particular option as it does not include those impacts that are more difficult to monetise (such as recreation, health effects, etc.). Some of these are described in the Preferred Policy Economic Tables (**Section H.4**) and addressed in more detail for the marginal units in the Uncertainties Tables (**Section H.5**). These are then brought together in the Preferred Policy Statements (**Section 5, Main SMP2 Document)**.

The SMP2 looks over a timescale of 100 years and predictions are therefore inherently uncertain. As such, there are a number of uncertainties associated with economic 'worth' of the preferred plan policies in the future. Key economic uncertainties are recognised here; however, many of these uncertainties should be addressed through regular updates of the SMP2 or when significant changes to input data become available:

Agricultural land

The area of land is measured from GIS and the value per acre is adjusted according to Defra guidance. Therefore, the uncertainty associated with damages to agricultural land should be LOW. Other uncertainties will be associated with GIS, erosion rates, flood risk maps, etc. used to determine when and which land will be written off, as well as changes in regional agricultural importance and associated land values in the future.

Residential properties

Data on properties at risk is based on GIS/property databases. Write-off values for properties from the National Property Database have been verified against average values. Therefore, uncertainty related to write-off damages for residential properties should be LOW. Other uncertainties will be associated with GIS, erosion rates, flood risk maps, etc. used to determine when and which residential properties will be written-off.

Commercial properties

Data on commercial properties has also been based on GIS/property datasets. It is known that the National Property Dataset (NPD) can introduce significant uncertainties for non-residential properties, with many properties not given a valuation and/or floor area. The economic appraisal does calculate valuations based on floor area where the NPD does not include specific valuations. This is based on a multiplier of 10 based on the yield of most properties. This helps to reduce the uncertainties although there are some 18% of commercial properties that still have no valuation (the majority of these have an X classification, which are often found to have low value). The overall level of uncertainty will vary by unit, but is likely to be LOW-MEDIUM. If there is a large number of X classified properties in any one unit, or other impacts that could not be valued in monetary terms then the uncertainty could be HIGH. Other uncertainties will be associated with GIS, erosion rates, flood risk maps, etc. used to determine when and which residential properties will be written-off.

Transport impacts

Costs of relocating/rebuilding roads and railways affected have been included in the economic damages where possible. There are uncertainties with the values used, with the impact on the economic damages likely to be MEDIUM-HIGH. Further investigation may be needed to more accurately estimate the costs, where these impacts are significant to the overall damages.

Environmental impacts

The economic analysis has not valued in monetary terms any impacts on environmental sites (designated or non-designated). The economic appraisal therefore excludes environmental issues such as impacts on habitats, water quality (or quantity, through loss of abstractions), historic environment (although impacts on buildings may be partly captured under properties), landscape impacts, etc. Environmental issues have been considered (in qualitative terms) as part of the approach to determining the preferred plan. Overall, therefore, the uncertainty should be LOW-MEDIUM (depending upon the extent of issues covered in the qualitative discussion).

Recreational/tourism impacts

Within some policy units there may be impacts on recreation and tourism, but these are not quantified and have not been included in the economic damages. The impact of exclusion of recreational / tourism damages will vary by policy unit but could be HIGH in areas of regional importance for recreation and tourism. Tourism impacts may relate to heritage features and sites, paths, tourist towns, and tourist accommodation (e.g. hotels, bed and breakfasts, and caravan parks).. Further investigation of the likely damages under NAI needs to be investigated at strategy/scheme level in those units with recreational and tourism assets that could

attract visitors/users from outside the immediate area (i.e. recreation assets that are used for more than short-cuts and/or dog walking).

Community/social impacts

Community impacts are likely to be greatest where there is write-off of residential and/or commercial properties. However, smaller settlements could have important social impacts reflecting the interactions between different community groups as well as between individuals. These cannot be valued in monetary terms but are taken into account during identification of the preferred plan. Some of the descriptions of the impacts refer to the integrity of settlements. The implications of lost integrity (including impacts on transport infrastructure as well as loss of properties and businesses) are included during assessment of whether the benefit-cost ratio of the preferred plan is likely to exceed one. In units where the integrity of the community could be affected, the uncertainty introduced in terms of the benefit-cost ratio could be MEDIUM-HIGH (depending on the actual impacts on the community and the proportion of the community affected). For erosion units, consideration needs to be given to blight affecting more than just those properties that are directly affected. Loss of other assets (e.g. the beach, access to the beach, recreational assets) could have significant effects on the whole community and could introduce MEDIUM-HIGH uncertainty.

H.4 Economic appraisal summary tables

The table below (Table H4) provides a summary of the economic review of the preferred plan for each Policy Unit. It outlines any information used in this review, including benefits and costs, together with a statement on economic viability. The table highlights where the preferred policy differs from the draft consultation policy. Indicative managed realignment costs are based on the capital value and maintenance costs of potential set back embankments, but are subject to uncertainty because detailed studies would be required to confirm precise alignments. Preferred plan damages relate to erosion losses avoided and property write off losses due to flooding, but not residual damages due to flood risk for a given standard of protection as this data is not available (refer also to **Annex H.1.2**). Note: An allowance should be made for errors of approximately +/- £1m in each epoch, due to an error allowance of +/- 250m in the measurement of defence lengths for each unit. It should be noted that where a benefit-Cost Ratio is not robust (e.g. <5), policy delivery may be compromised by funding prioritisation and therefore needs to be examined in more detail in a strategy and opportunities for co-funding will also need to be investigated.

Table H4: Economic summary table

		SMP2 Policy			Broad-scale SMP2 Review (PV, £k)		Benefits and Negative Impacts not Included in Benefit-Cost Ratio	Key Uncertainties	Benefit-Cost Ratio & Justification for SMP2 Policy
		Epoch 1	Epoch 2	Epoch 3	Benefits of Policy	Costs of Policy			
Policy Area: Montrose									
1/1	Montrose Bay (Milton Ness to Montrose Links)	NAI	NAI	NAI	18,493	16,140	• Cost of relocating assets landwards in third epoch; too uncertain to cost. • Recreational benefits.	• Relocation costs in third epoch.	BCR > 1. The cost of relocating assets in 1/3a and 1/3b has not been included due to uncertainty of costing. Relocation costs would have to exceed £2.3m PV cost in order to reduce the BCR to below unity (all other factors remaining unchanged). The indicative capital (undiscounted) equivalent cost is circa £15m.
1/2	Montrose Golf Links	MR	MR	MR					
1/3a	Splash (The Faulds)	HTL	HTL	MR					
1/3b	South Links Holiday Park	HTL	HTL	MR					
1/4	GlaxoSmithKline	HTL	HTL	HTL					

		SMP2 Policy			Broad-scale SMP2 Review (PV, £k)		Benefits and Negative Impacts not Included in Benefit-Cost Ratio	Key Uncertainties	Benefit-Cost Ratio & Justification for SMP2 Policy
		Epoch 1	Epoch 2	Epoch 3	Benefits of Policy	Costs of Policy			
Policy Area: Montrose Basin									
2/1a	Montrose Port (north bank – Glaxo to A92 bridge)	HTL	HTL	HTL	61,989	20,034	• Environmental benefits of habitat creation. • Land purchase costs for managed realignment. • Damages associated with disruption to the railway line due to flooding. • Recreational benefits.	• Land required for managed realignment in 2/4b.	BCR ~ 3. Taken as a policy area, the economics are considered healthy. It should be noted that the assets are not uniformly distributed throughout the component Management Units.
2/1b	Montrose Port (south bank – A92 bridge to Ferryden)	HTL	HTL	HTL					
2/2a	Montrose West (A92 Bridge to the end of the railway defences)	HTL	HTL	HTL					
2/2b	Montrose West (Railway defences to Tayock River)	HTL	HTL	HTL					
2/3a	Tayock (Tayock village)	HTL	HTL	HTL					
2/3b	Tayock (Sleepyhillock Cemetery)	HTL	HTL	HTL					
2/4a	West Montrose Basin (west of Tayock)	HTL	HTL	HTL					
2/4b	West Montrose Basin (Bridge of Dun)	MR	MR	MR					
2/4c	West Montrose Basin (Old Montrose)	HTL	HTL	HTL					

		SMP2 Policy			Broad-scale SMP2 Review (PV, £k)		Benefits and Negative Impacts not Included in Benefit-Cost Ratio	Key Uncertainties	Benefit-Cost Ratio & Justification for SMP2 Policy
		Epoch 1	Epoch 2	Epoch 3	Benefits of Policy	Costs of Policy			
2/5	Old Montrose to Railway Bridge	NAI	NAI	NAI					
2/6	Rossie Island to A92	HTL	HTL	HTL					
2/7	Ferryden	HTL	HTL	HTL					
2/8	Ferryden to Scurdie Ness	NAI	NAI	NAI					
Policy Area: Skurdie ness to Rickle Craig									
3/1	Scurdie Ness to Rickle Craig	NAI	NAI	NAI	0	0	• Cost of monitoring of railway line (undertaken by Network Rail). • Costs of redirecting/re-establishing access routes eroded. • Recreational benefits.	• None identified	NAI policy with no identified costs; no BCR calculated
Policy Area: Lunan Bay to Corbie Knowe									
4/1	Lunan Bay	NAI	NAI	NAI	22	299	• Recreational benefits.	• Cost of removing failed defences is probably conservative, so BCR would increase with accurate costing based on quantities and rates/method.	BCR < 1. Small cost associated with removal of failed defences.
4/2	Corbie Knowe	NAI	NAI	NAI					

		SMP2 Policy			Broad-scale SMP2 Review (PV, £k)		Benefits and Negative Impacts not Included in Benefit-Cost Ratio	Key Uncertainties	Benefit-Cost Ratio & Justification for SMP2 Policy
		Epoch 1	Epoch 2	Epoch 3	Benefits of Policy	Costs of Policy			
Policy Area: Lang Craig to Whiting Ness									
5/1	Lang Craig to Whiting Ness	NAI	NAI	NAI	0	0	• Costs of redirecting/re-establishing access routes eroded.	• None identified	NAI policy with no identified costs; no BCR calculated
Policy Area: Arbroath to West Haven									
6/1 (a)	Victoria Park	HTL	HTL	HTL	6,819	31,297	• Economic impacts associated with the loss of Arbroath Harbour. • Costs associated with dealing with contaminated land at Dowrie in NAI –likely to improve the BCR if considered in detail. • Recreational benefits.	• Costs associated with Arbroath Harbour structures. • The existing defences along this policy area are an interesting mosaic of old and new works, of varying types of works. The costs built up using the standard costs are most likely conservative and more efficient/ economic works could be considered at a scheme level.	BCR < 1. One third of the costs are associated with the structures at Arbroath Harbour, with little/no associated benefits. Consideration of individual frontages will results in more cost effective works being identified. BCR likely to improve as a result
6/1 (b)	Seagate	HTL	HTL	HTL					
6/2	Arbroath Harbour	HTL	HTL	HTL					
6/3	Inchcape Park to Westway Road	HTL	HTL	HTL					
6/4 (a)	West Links to East Haven	HTL	HTL	HTL					
6/4 (b)	East Haven	NAI	NAI	NAI					
6/4 (c)	East Haven to West Haven	NAI	NAI	NAI					
Policy Area: Carnoustie									
7/1	West Haven to Carnoustie Station	HTL	HTL	HTL	15,999	3,367	• Recreational benefits.	• None identified	BCR > 4. Indicatives robust policy at

		SMP2 Policy			Broad-scale SMP2 Review (PV, £k)		Benefits and Negative Impacts not Included in Benefit-Cost Ratio	Key Uncertainties	Benefit-Cost Ratio & Justification for SMP2 Policy
		Epoch 1	Epoch 2	Epoch 3	Benefits of Policy	Costs of Policy			
7/2	Carnoustie Station to Barry Burn	HTL	HTL	HTL					this broad level
Policy Area: Buddon Ness									
8/1	Barry Sands East	HTL	HTL	HTL	18	16,414	• MoD asset and associated infrastructure not represented in damages/benefits.	• None identified	BCR < 1.
8/2	Barry Buddon and Barry Sands West	NAI	NAI	NAI					
Policy Area: Monifieth to Broughty Ferry									
9/1	MoD Boundary to west Tayview Caravan Park	HTL	HTL	HTL	37,498	12,153	• Recreational benefits.	• None identified	BCR ~ 3. Taken as a policy area, the economics are considered healthy. It should be noted that the assets are not uniformly distributed throughout the component Management Units.
9/2	Monifieth West	HTL	HTL	HTL					
9/3	Barnhill to the Esplanade	HTL	HTL	HTL					
9/4	Broughty Ferry East	HTL	HTL	HTL					
9/5	Broughty Ferry	HTL	HTL	HTL					

H.5 Sensitivity Testing

Sensitivity testing was undertaken to highlight uncertainty or risks that may affect policy decisions and identifies the consequences for the preferred scenario. This information helps understand how robust the policy decision is, helps identify where changes in future circumstances may affect the policy, helps understand where further knowledge is needed to reduce uncertainty and importantly provides a link to policy and option development within subsequent flood and erosion risk management strategies. The conclusion of this assessment is described as part of presenting the concluding policy decisions in the **Main Document** (**Section 5**).

It is important to note that development of the Preferred Policies have recognised uncertainty is present and have therefore sought where needed to be adaptive and able to be refined through further understanding and evidence as gathered as part of the Action Plans going forward.

A staged approach has been applied involving the following:

- Understanding the ability for generic uncertainties to influence the policy decision (**Table H15**);
- Understanding the ability for specific uncertainties to influence the policy decision. Specific uncertainties were assessed during policy scenario assessment (**Appendix G**). Along the Morecambe Bay and Cumbria coast a number of different policy scenarios were assessed with and without the presence of the railway line to help inform the policy decision;
- Recording of those uncertainties potentially affecting the economic assessment (**Section H.3.3**);
- Concluding on the influence of uncertainties as part of the presentation of the policy decision and determining the robustness of the policy decision (**Table H15 and Main Document - Section 5**). Where the longer term policy choice is dependent on the outcome of further studies, for example in areas where MR is recommended, it is noted that due to the uncertainty regarding the outcome of these studies, the medium / long term preferred policy may change,; and,
- Detailing in the Action Plans for each Policy Statement (**Main Document – Section 5**) where further information is needed to help manage the policy going forwards to implementation stages.

SMP2 Procedural Guidance states that it is not appropriate to speculate regarding uncertainties in changes in social attitudes or socio-economic policy. As such, the following uncertainties are acknowledged here, but are not included in the main analysis:

- A change in social preferences in relation to an increased acceptance to flood and erosion and / or adaptive methods and changes in environmental legislation;
- A change in funding priorities leading to increased / decreased funding;
- Availability of compensation for those affected by flooding and / or erosion; and,
- An increasing prioritisation of agricultural land within flood and erosion risk management policy.

Supporting information regarding contemporary climate change predictions (**Appendix C**) and corresponding implications for the SMP2 area are found in **Annex H.3**.

Sensitivity to climate change impacts

Data on climatic variations and change is still extremely sparse with no quantitative predictions yet available. Hence it is difficult to make any firm recommendations as to the potential impacts of such changes on the Angus coast over the next 100 years. It is therefore extremely important from the planning viewpoint to carry out detailed monitoring so as to identify the onset of significant changes in, for example, erosion patterns. Without such long-term monitoring, assessments of change will remain qualitative and any predictions contain considerable uncertainties. Table H5 below provides a qualitative summary of the present evidence of climate change occurring:

OOO Generally accepted change occurring

OO Some present evidence of change occurring

O Little present evidence of change occurring

Table H5 Qualitative assessment of the evidence of climate change occurring.

Climate change	Evidence of change occurring
Changes in mean sea level	OOO
Changes in tide range	O (other than very localised effects)
Changes in extreme water levels	OO
Changes in mean and extreme wave heights	O
Changes in storm frequency	O
Changes in mean wave direction	OO
Changes in river flows	OO

With this in mind, the following tables attempt to provide a qualitative summary of the sensitivity of each Coastal Process Unit to climate change and variability using the following scale:

X Minor impact, other factors will dominate.

XX Moderate impact, will be responsible for some changes but other factors likely to be more important.

XXX Likely to be major factor causing change along the coastline.

However, it should be noted that actual changes experienced on the Angus coast would be as a result of a complex interaction of most or all of these processes.

Table H6 Sensitivity of CPU 1: Milton Ness to Montrose Harbour to climate change and variability.

Climate variability or change	Sensitivity of coastline to change or variability	Potential impacts
Changes in mean sea level	XX	• An increase would lead to long-term frontal erosion of dune line. However, not as significant as changes to extreme high water levels.
Changes in tide range	X	• Unlikely to be significant on open coast but possibly minor change in intertidal area. • Potential impact at southern end of bay and Annat Bank, which could indirectly impact on beach processes along the Splash and Glaxo frontage, if the volume of water entering and leaving Montrose Basin is altered.
Changes in extreme water levels	XXX	• An increase would lead to frontal erosion of the dune line and retreat of the MHWS. Impacts most evident along southern section of bay. • No significant increase in flood risk.
Changes in mean and extreme wave heights	XXX	• An increase would lead to frontal erosion of the dune line and retreat of the MHWS. Impacts most evident along southern section of bay but long-term impact of an increase in wave heights will depend on net longshore transport rates, which are linked to changes in mean wave direction (see below). • Increased risk of damage to rock structures at southern end of bay through reduced beach levels and armour stability. • Potential for increased overtopping of rock revetment. • Potential for increased frequency of beach renourishment within groyne bays at Glaxo corner.
Changes in storm frequency	XXX	• Potential to cause increase in short-term beach and dune erosion along entire frontage. The long-term impact of an increase in storm frequency will depend on net longshore transport rates, which are linked to changes in mean wave direction (see below). • Increased risk of damage to rock structures at southern end of bay through reduced beach levels and armour stability. • Potential for increased overtopping of rock revetment. • Potential for increased frequency for beach renourishment within groyne bays at Glaxo corner.
Changes in mean wave direction	XXX	• Potentially the most important factor controlling erosion rates and beach lowering along the southern section of Montrose Bay.
Changes in river flows	X	• Probably little impact from increased flows in River South Esk. • Potential for changes to river flows to alter dynamic

Climate variability or change	Sensitivity of coastline to change or variability	Potential impacts
		processes at the mouth of the River North Esk.
Overall likely impact	XXX	• Continued erosion along southern half of Montrose Bay but rate of 80m predicted by Halcrow (2000) likely to be reasonably conservative. • Potential increase in erosion rate along central section of the bay. • St Cyrus frontage to remain relatively stable unless substantial long term changes in wave climate.

Table H7 Sensitivity of CPU 2: Montrose Basin to climate change and variability.

Climate variability or change	Sensitivity of coastline to change or variability	Potential impacts
Changes in mean sea level	XX	• Potential to alter volume of water entering and leaving Montrose Basin. • Potential for increased wave activity if rate of accretion in basin is less than rate of change in extreme water levels. • Impacts on sediment processes within the basin not known.
Changes in tide range	XXX	• Potential to alter volume of water entering and leaving Montrose Basin. • Impacts on sediment processes within the basin not known.
Changes in extreme water levels	XX	• Potential to alter volume of water entering and leaving Montrose Basin. • Impacts on sediment processes within the basin not known. • Increased risk of breaching of flood embankments. • Increased risk of damage to ad hoc defences at Tayloan and Rossie Island. • Potential for increased wave activity if rate of accretion in basin is less than rate of change in extreme water levels. • Potential to increase minor erosion effects around edge of basin.
Changes in mean and extreme wave heights	X	• Increased risk of damage to ad hoc defences at Tayloan and Rossie Island. • Increased risk of breaching of flood embankments. • Potential to increase minor erosion effects around edge of basin.

Climate variability or change	Sensitivity of coastline to change or variability	Potential impacts
Changes in storm frequency	X	• Potential to increase minor erosion effects around edge of basin. • May lead to increased risk of breaching of embankments along western flank. • Increased risk of damage to ad hoc defences at Tayloan and Rossie Island. • Potential increase rate of saltmarsh erosion.
Changes in mean wave direction	X	• Unlikely to have a significant impact.
Changes in river flows	XX	• Potential to have local effects on channel position through the basin. • Increase in river flows may result in small increase in siltation of basin.
Overall likely impact	XX	• Present hydraulic and littoral processes within the basin are poorly understood. Hence any assessment of future changes is difficult. • Most significant change is likely to come from changing water levels, which will impact on the volume of water entering and leaving the basin. Whether this increases or reduces siltation is uncertain.

Table H8 Sensitivity of CPU 3: Scurdie Ness to Rickle Craig to climate change and variability.

Climate variability or change	Sensitivity of coastline to change or variability	Potential impacts
Changes in mean sea level	X	• Unlikely to have a significant effect.
Changes in tide range	X	• Unlikely to have a significant effect.
Changes in extreme water levels	X	• May result in loss of certain habitat, such as the perched saltmarsh but other than this, impacts likely to be minor.
Changes in mean and extreme wave heights	X	• May result in loss of certain habitat, such as the perched saltmarsh but other than this, impacts likely to be minor.
Changes in storm frequency	X	• May result in loss of certain habitat, such as the perched saltmarsh but other than this, impacts likely to be minor.

Climate variability or change	Sensitivity of coastline to change or variability	Potential impacts
Changes in mean wave direction	X	• Unlikely to have a significant effect.
Changes in river flows	-	• -
Overall likely impact	X	• Due to the hard nature of the coastline, climatic variability and change is unlikely to have any significant effect within the timescales of this SMP.

Table H9 Sensitivity of CPU 4: Lunan Bay to climate change and variability

Climate variability or change	Sensitivity of coastline to change or variability	Potential impacts
Changes in mean sea level	XX	• An increase would lead to long-term frontal erosion of dune line. However, not as significant as changes to extreme conditions.
Changes in tide range	X	• Unlikely to be significant on open coast but possibly minor change in intertidal area.
Changes in extreme water levels	XXX	• An increase would lead to frontal erosion of the dune line and retreat of the MHWS. • Increased risk of overtopping, damage to defences and holiday chalets. • Increased risk of dune breaching and flooding of hinterland to the north of the Lunan Water.
Changes in mean and extreme wave heights	XXX	• An increase would lead to frontal erosion of the dune line and retreat of the MHWS. • Increased risk of overtopping, damage to defences and holiday chalets. • Increased risk of dune breaching and flooding of hinterland to the north of the Lunan Water.
Changes in storm frequency	XXX	• An increase would lead to frontal erosion of the dune line and retreat of the MHWS. • Increased risk of overtopping, damage to defences and holiday chalets. • Increased risk of dune breaching and flooding of hinterland to the north of the Lunan Water.
Changes in mean	XX	• Less of a factor. Lunan Bay is less sensitive to changes in wave climate. However, such changes will impact most along

Climate variability or change	Sensitivity of coastline to change or variability	Potential impacts
wave direction		the southern section of the bay leading to varying beach levels and increased impacts at Corbie Knowe.
Changes in river flows	X	• Probably only localised impacts at the mouth of the Lunan Water from increased river flows.
Overall likely impact	XXX	• Continued dune erosion and retreat of MHWS along entire frontage but rate relatively low and relatively consistent along entire frontage. • Possibility of a dune breach to the north of the Lunan Water with increased risk of flooding behind the dunes at this location. • Increased risk of overtopping, and damage to coastal defences and property at Corbie Knowe.

Table H10 Sensitivity of CPU 5: Lang Craig to Whiting Ness to climate change and variability

Climate variability or change	Sensitivity of coastline to change or variability	Potential impacts
Changes in mean sea level	X	• Unlikely to have a significant effect.
Changes in tide range	X	• Unlikely to have a significant effect.
Changes in extreme water levels	X	• Unlikely to have a significant effect.
Changes in mean and extreme wave heights	X	• Possible increase in rate of cliff erosion / frequency of cliff slips but impacts likely to be minor.
Changes in storm frequency	X	• Possible increase in rate of cliff erosion / frequency of cliff slips but impacts likely to be minor.
Changes in mean wave direction	X	• Unlikely to have a significant effect.
Changes in river flows	-	• -
Overall likely impact	X	• Due to the hard nature of the coastline, climatic variability and change is unlikely to have any significant effect within the timescales of the SMP process.

Table H11 Sensitivity of CPU 6: Whiting Ness to West Haven to climate change and variability.

Climate variability or change	Sensitivity of coastline to change or variability	Potential impacts
Changes in mean sea level	XX	• Reduced protection from rock platform leading to increased erosion potential along entire frontage. However, unlikely to be as significant as changes to extreme conditions.
Changes in tide range	X	• Unlikely to be significant on open coast.
Changes in extreme water levels	XX	• Significant reduction in protection provided by rock platform leading to potential increased rate of landward retreat. • Increased risk of overtopping along entire protected frontage at Arbroath. • Increase risk of damage to defences through increased water depth at the toe of defences.
Changes in mean and extreme wave heights	XXX	• Increased rate of landward retreat along entire frontage. Rate of retreat is likely to be most evident at locations where accretion has been greatest over the last 100 or years, e.g. East Haven. • Increased risk of overtopping along entire protected frontage at Arbroath. • Increase risk of damage to defences through increased water depth at the toe of defences. • Increased risk to railway line at Hatton.
Changes in storm frequency	XX	• Increased rate of landward retreat along entire frontage. Rate of retreat is likely to be most evident at locations where accretion has been greatest over the last 100 or years, e.g. East Haven. • Increased risk of overtopping along entire protected frontage at Arbroath. • Increase risk of damage to defences through increased water depth at the toe of defences. • Increased risk to railway line at Hatton.
Changes in mean wave direction	XX	• Would lead to changing pattern of erosion and accretion along frontage, i.e. some areas would erode at a greater rate, other sections may accrete.
Changes in river flows	-	• -
Overall likely impact	XX	• Retreat of MHWS along entire frontage but rate relatively low and relatively consistent along entire frontage. However, longer-term rate is likely to be greater than experienced over the last 100 years, particularly along sections fronted by rock platform.

Climate variability or change	Sensitivity of coastline to change or variability	Potential impacts
		• Increased rate and frequency of overtopping and damage to coastal defences along all sections of protected frontage at Arbroath. • Likely to see a general change in beach character with the shingle storm beach which underlies the sand beach for much of this frontage becoming exposed.

Table H12 Sensitivity of CPU 7: West Haven to Buddon Ness to climate change and variability.

Climate variability or change	Sensitivity of coastline to change or variability	Potential impacts
Changes in mean sea level	XX	• Lead to continued erosion and changing patterns of erosion and accretion along much of the frontage, particularly as any increase in water depth over Gaa Sands would increase the amount of wave energy and the way waves are refracted into the bay. However, unlikely to be as significant as changes to extreme conditions.
Changes in tide range	XXX	• Potential impacts at Buddon Ness, Gaa Sands and the position of the main Tay Estuary channel, which indirectly may affect other coastal processes and patterns of erosion and accretion within Carnoustie Bay.
Changes in extreme water levels	XX	• Likely to lead to increased beach lowering along protected sections of frontage. • May result in direct or indirect changes to Gaa Sands, which in turn impacts on processes and patterns of erosion within Carnoustie Bay. • Potential for increase damage to revetment and gabion structures along entire frontage due to larger waves reaching the shoreline.
Changes in mean and extreme wave heights	XXX	• Likely to lead to increased beach lowering along protected sections of frontage. • May result in direct or indirect changes to Gaa Sands, which in turn impacts on processes and patterns of erosion within Carnoustie Bay. • Potential for increase damage to revetment and gabion structures along entire frontage due to larger waves reaching the shoreline.
Changes in storm frequency	XXX	• Likely to lead to increased beach lowering along protected sections of frontage.

Climate variability or change	Sensitivity of coastline to change or variability	Potential impacts
		• May result in direct or indirect changes to Gaa Sands, which in turn impacts on processes and patterns of erosion within Carnoustie Bay. • Potential for increase damage to revetment and gabion structures along entire frontage due to larger waves reaching the shoreline.
Changes in mean wave direction	XXX	• Difficult to assess the potential impact due to the influence of Gaa Sands on the way waves approach the shoreline, particularly from the south east. However, it is thought that erosion rates are quite sensitive to changing wave climate within Carnoustie Bay.
Changes in river flows	XX	• Potential impacts at Buddon Ness, Gaa Sands and the position of the main Tay Estuary channel which indirectly may affect other coastal processes and patterns of erosion and accretion within Carnoustie Bay.
Overall likely impact	XXX	• Due to the complexity of coastal processes within Carnoustie Bay and our lack of understanding of these processes it is difficult to even qualitatively assess how long-term climate variation and change may impact on the Carnoustie Bay coast. However, erosion is likely to continue over the foreseeable future at a rate similar to that presently experienced. • Increased risk of damage to coastal defences along the frontage due to low beach levels at the toe, crest damage due to overtopping and potential stability issues of rock armour.

Table H13 Sensitivity of CPU 8: Buddon Ness to Broughty Castle to climate change and variability.

Climate variability or change	Sensitivity of coastline to change or variability	Potential impacts
Changes in mean sea level	XX	• Lead to continued erosion and changing patterns of erosion and accretion along much of the frontage, particularly as any increase in water depth over the outer sand banks in the Tay Estuary would increase the amount of wave energy and the way waves are refracted into the bay.
Changes in tide range	XXX	• Potential impacts associated with changing river flows and alterations in the position and height of the sand banks at the mouth of the Tay Estuary.
Changes in extreme water levels	XXX	• Potential to lead to increased wave conditions, most critically along the Monifieth frontage. • Potential increase in longshore transport rate to west due to increased wave action during storm conditions, exacerbating

Climate variability or change	Sensitivity of coastline to change or variability	Potential impacts
		erosion / accretion tendencies. • Possibly lead to changing patterns of erosion/ accretion along the frontage as wave refraction patterns are changed. • May result in direct or indirect changes to the outer sand banks, which in turn impacts on processes and patterns of erosion within the Tay Estuary. • Potential for increase damage to revetment and groyne structures along entire frontage due to larger waves reaching the shoreline.
Changes in mean and extreme wave heights	XX	• Possibly not quite as significant an issue as elsewhere as frontage generally only exposed to the south easterly conditions. However: • Still likely to lead to increased erosion, particularly along Monifieth frontage. • Potentially increase in longshore transport rate to west due to increased wave action during storm conditions, exacerbating erosion / accretion tendencies. • Possibly lead to changing patterns of erosion/ accretion along the frontage as wave refraction patterns are changed. • May result in direct or indirect changes to the outer sand banks, which in turn impacts on processes and patterns of erosion within the Tay Estuary. • Potential for increase damage to revetment and groyne structures along entire frontage due to larger waves reaching the shoreline.
Changes in storm frequency	XX	• Possibly not quite as significant an issue as elsewhere as frontage generally only exposed to the south easterly conditions. However: • Still likely to lead to increased erosion, particularly along Monifieth frontage. • Potentially increase in longshore transport rate to west due to increased wave action during storm conditions, exacerbating erosion / accretion tendencies. • Possibly lead to changing patterns of erosion/ accretion along the frontage as wave refraction patterns change. • May result in direct or indirect changes to the outer sand banks, which in turn impacts on processes and patterns of erosion within the Tay Estuary. • Potential for increased damage to revetment and groyne structures along entire frontage due to larger waves reaching the shoreline.

Climate variability or change	Sensitivity of coastline to change or variability	Potential impacts
Changes in mean wave direction	XX	• Sensitive to any increase in conditions from the south easterly quadrant which would increase rate of longshore transport and exacerbate erosion / accretion patterns. • Increases in conditions from other directions may have a positive effect on the rate of erosion along the frontage.
Changes in river flows	XXX	• Potential impacts on lower sections of the intertidal beach resulting in increased transport of fine sediments along the lower beach to the east. • Potential impacts associated with changing river flows and alterations in the position and height of the sand banks at the mouth of the Tay Estuary.
Overall likely impact	XXX	• As at Carnoustie, due to the complexity of coastal processes within the outer Tay Estuary and our lack of understanding of these processes it is difficult to even qualitatively assess how long-term climate variation and change may impact on the coast. However, the present patterns of erosion are likely to continue over the foreseeable future but changes to the offshore banks could alter these patterns, for example eroding areas could start to accrete and vice versa. • The rates of erosion and accretion will be highly variable both spatially and temporally with no general patterns evident. • Increased risk of damage to coastal defences along the frontage due to low beach levels at the toe, crest damage due to overtopping and potential stability issues of rock armour. • Depending on changes to the outer banks and the way waves approach the shoreline, the existing groyne fields may become less effective in controlling longshore transport in the future.

A summary of the above tables linking the relative magnitude of change occurring with the relative sensitivity of the Angus coast to the change or variability for the eight Coastal Process Units is provided in table 2.17 below.

Table H14 Summary table for each CPU relating the evidence of change occurring with the sensitivity of the coastline to change or variability.

Climate variability or change	Evidence of change occurring	Sensitivity of coastline to change or variability		
		High	Moderate	Low
Changes in mean sea level	High		1, 2, 4, 6, 7, 8	3, 5
Changes in tidal range	Low	2, 7, 8		1, 3, 4, 5, 6

Climate variability or change	Evidence of change occurring	Sensitivity of coastline to change or variability		
		High	Moderate	Low
Changes in extreme water levels	Moderate	1, 4, 8	2, 6, 7	3, 5
Changes in mean and extreme wave heights	Low	1, 4, 6, 7	8	2, 3, 5
Changes in storm frequency	Low	1, 4, 7	6, 8	2, 3, 5
Changes in mean wave direction	Moderate	1, 7	4, 6, 8	2, 3, 5
Changes in river flows	Moderate	8	2, 7	1, 4
Overall likely impact		1, 4, 7, 8	2, 6	3, 5

Table H15 indicates those management policies that may be vulnerable to typical uncertainties.

Table H15 Uncertainty Identification Table

Uncertainty	Exposure to Uncertainty			
	HTL	ATL	MR	NAI
Increased development	Increased development will increase hinterland assets making Holding or Advancing the defence line more attractive.		An increase in development will reduce space for MR and increase hinterland assets thereby reducing the potential for MR and NAI. **MR and NAI policy exposed to this uncertainty**	
Decreased development	Holding or Advancing the line may not be economically justifiable if future development decreases or if policy choices have been made based on an assumption of increased future development. **HTL and ATL policy exposed to this uncertainty**		Reduced development will increase space for MR (enhancing the ability to retreat defences) and making a decision not to intervene more robust. Ultimately decreased development could bring forward any longer-term MR and NAI policies.	
Knowledge on climate change forecasts (sea level rise and storminess)	Enhanced rates of SLR and storminess may result in coastal squeeze and increased wave energy at defences making defences more expensive and technically difficult to maintain. This may reduce the potential for long-term Maintaining or Advancing the line and increase the attractiveness of other alternatives. **HTL and ATL policy exposed to this uncertainty**		Enhanced rates of SLR and storminess may be accommodated naturally by MR and NAI. However, in the longer term defended and undefended hinterland may be under threat resulting in additional investment or need to relocate and/or lose assets. Particularly relevant in areas of low lying hinterland. **MR and NAI policy exposed to this uncertainty**	
Reductions in sediment supply	A reduced sediment supply may increase the exposure of defences to wave energy, defences will become more expensive and technically difficult to maintain. This may reduce the potential for long-term Holding or Advancing the line and increase the attractiveness of other alternatives. **HTL and ATL policy exposed to this uncertainty**		Reduced sediment supplies will potentially limit the ability for MR sites to be self-maintaining but would not be a primary driver for selection of MR or NAI.	
Degree of land contaminated	The presence of contamination would increase the attractiveness of Holding or Advancing the line.		The presence of contaminated land would require expensive remediation to facilitate MR or NAI, making them less attractive as a policy. **MR and NAI policy exposed to this uncertainty**	
Accuracy of economic & defence data	The accuracy of economic information in terms of costs and benefits could potentially affect policy choice in cases where the decision is driven by economic viability and is marginal. This uncertainty arises from the level of detail within the economic analysis and the availability of supporting evidence (such as numerical modelling results and the condition of defences). **All policies are exposed to this uncertainty**			

Uncertainty	Exposure to Uncertainty			
	HTL	ATL	MR	NAI
Presence of protected habitats and species	The presence of protected habitats will increase the potential need for offsetting habitats, increasing cost and difficulty in deliverability. This is unlikely to result in a change in HTL policy but makes ATL less attractive. **ATL policy exposed to this uncertainty**		The presence of protected habitats (freshwater or saline) will result in the need to develop integrated solutions that maintain and improve existing habitats This is unlikely to result in a change to a MR policy but makes a NAI policy less attractive. **NAI policy exposed to this uncertainty**	

Angus Council

Angus Shoreline Management Plan SMP2

Appendix H – Economic and Sensitivity Testing

ANNEX 1 - Supporting Economic Appraisal Data – Damages / Benefits

Annex H.1 Supporting Economic Appraisal Data – Damages/Benefits

Summary of Predicted No Active Intervention Flooding and Erosion Losses

Table 1 No Active Intervention - Assets at Risk of Flooding and Erosion

Policy Area	Residential		Commercial		Agriculture		Key Infrastructure
	Properties	CV (£k)	Properties	CV (£k)	Land (ha)	CV (£k)	
Montrose MU: 1/1, 1/2, 1/3(a)-(b),1/4 *inc. 9 no commercial with no assigned value	195	31,172	47*	15,754	87	613	
Montrose Basin MU: 2/1(a)-(b), 2/2(a)-(b), 2/3(a)-(b), 2/4, 2/5, 2/6, 2/7, 2/8 *inc 27 no commercial with no assigned value	949	148,390	66*	23,355	677	7,695	Montrose Harbour Various outfalls in harbour area East coast mainline
Scurdie Ness to Rickle Craig MU: 3/1 *inc 3 no. commercial with no assigned value	2	362	5*	64	29	337	East coast mainline
Lunan Bay MU: 4/1, 4/2	2	406	1	8	29	264	
Lang Crag to Whiting Ness MU: 5/1 * 1 no. commercial with no assigned value	-	-	1*	-	34	454	
Arbroath to West Haven MU: 6/1(a)-(b), 6/2, 6/3, 6/4 (a)-(c) *inc 4 no. commercial with no assigned value	169	25,407	48*	2,991	10	84	Various outfalls, pumping station, WTW, rising main East coast mainline
Carnoustie MU: 7/1,7/2	233	36,992	28*	3,879	<1	3	Various outfalls, pumping stations, rising

Policy Area	Residential		Commercial		Agriculture		Key Infrastructure
	Properties	CV (£k)	Properties	CV (£k)	Land (ha)	CV (£k)	
*inc 6 no commercial with no assigned value							main East coast mainline
Buddon Ness MU: 8/1, 8/2	-	-	2	30	182	1,049	
Monifieth to Broughty Ferry MU: 9/1, 9/2, 9/3, 9/4, 9/5 *inc 2 no commercial with no assigned value	611	78,498	62*	5,233	8	47	Various outfalls, pumping stations, rising main East coast mainline
CV = Capital Value							

Summary of Predicted With Proposed Policies Flooding and Erosion Losses

Table 2 With Proposed Policies - Assets at Risk of Flooding and Erosion

Policy Area	Residential		Commercial		Agriculture	
	Properties	CV (£k)	Properties	CV (£k)	Land (ha)	CV (£k)
Montrose MU: 1/1, 1/2, 1/3(a)-(b),1/4 *inc. 6 no commercial with no value	6	1,176	17*	168	87	613
Montrose Bay MU: 2/1(a)-(b), 2/2(a)-(b), 2/3(a)-(b), 2/4, 2/5, 2/6, 2/7, 2/8 *inc 38 no commercial with no value	-	-	-	-	70	795
Scurdie Ness to Rickle Craig MU: 3/1 *inc 3 no. commercial with no value	2	426	5*	64	29	127
Lunan Bay MU: 4/1, 4/2	1	203	1	8	29	100
Lang Crag to Whiting Ness MU: 5/1	-	-		-	34	164
Arbroath to West Haven MU: 6/1(a)-(b), 6/2, 6/3, 6/4 (a)-(c) *inc 4 no. commercial with no value	1	159	-	-	10	33
Carnoustie MU: 7/1,7/2 *inc 6 no commercial with no value	-	-	-	-	-	-
Buddon Ness MU: 8/1, 8/2 *inc 1 no commercial with no value	-	-	-*	-	66	3,80
Monifieth to Broughty Ferry MU: 9/1, 9/2, 9/3, 9/4, 9/5 *inc 2 no commercial with no value	-	-	-	-	-	-

CV = Capital Value

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Angus Shoreline Management Plan SMP2

Appendix H – Economic and Sensitivity Testing

ANNEX 2 - Supporting Economic Appraisal Data - Costs

Annex H.2 – Supporting Economic Appraisal Data for SMP2 Costs

This annex presents the full preferred scenario costs developed for the SMP2. As outlined in the assumptions below, these are generated from national generic costs and do not reflect local conditions. These figures should not be considered out of context. The costs presented in section H4 have been taken from available strategy and/or scheme documents where available, as these represent a more accurate and site specific consideration of implementation costs. The figures presented in this Annex have only been used where other, more detailed, cost information is not available. As such the costs presented here differ from those in section H4 for frontages where more detailed costs are available.

Basis for cost assumptions:

- Replacement costs taken from the Unit Cost Database (Environment Agency, 2007). and costs included within recent strategies and completed works from within the SMP2 area;
- Maintenance costs taken from NADNAC study prepared for Defra (2004). This sets annual maintenance cost for linear structures and for groyne fields at £14k/km and for beach schemes £26k/km;
- Assumed design life (and thus full scheme reconstruction will be required) as 100 years for linear defences, 50 years for beach schemes and groynes;
- Allow for maintenance as a linear cost, although realistically less in early years and increasing in latter years of scheme life;
- Allowance for increase in costs due to climate change: Period 20-50 years - costs factored up by 1.5 x present day rates; Period 50-100 years - costs factored up by 2.0x present day rates;
- Optimism bias (at 60%) to be applied to all costs when examining BCR, to reflect uncertainty in broad level analysis at SMP2 scale.

Defence Type	Defence Type	Cost per m	
		Replacement	Maintenance
Standard piling	Urban/Rural Average	£4,384	£14
Earth Embankment	2.5m High	£915	£14
	3.5m High	£1,615	£14
Groynes		£1,133	£14
Revetment		£5,774	£14
Small scale rock armour		£1,797	£14
Beach Recharge		£1,801	£26
Sand Dune Works		£47	£0
Seawall	Shoreline (Stand alone structure)	£4,965	£14
	Shoreline (With Revetment)	£7,168	£14
	Setback (Stand alone structure)	£2,022	£14
	Setback (With Revetment)	£4,040	£14
Breakwater		£4,032	£14

Defence Costs for Preferred policies

The following tables presents the cost estimates only for those policy units where the preferred policies involve intervention during the 100 year time-frame of the SMP2 (i.e. managed realignment or hold the line are proposed), as those areas where no active intervention is proposed would not incur any cost of intervention.

Policy Unit	Whole Life Capital CV (£k)	Whole Life Maintenance CV (£k)	Total Whole Life PV (£k)	Total Whole Life Cost PV+60% Optimism Bias (£k)
MU 1/2 Montrose Golf Links MR/MR/MR	-	29	20	33
MU 1/3a Splash (The Faulds) (1) HTL/HTL/MR	6,772	759	2,234	3,575
MU 1/3b South Links Holiday Park (1) HTL/HTL/MR	4,289	651	1,2086	1,933
MU 1/4 GlaxoSmithKline HTL/HTL/HTL	11,894	2,340	2,592	4,147
MU 2/1 (a) Montrose Port (north bank – Glaxo to A92 bridge) HTL/HTL/HTL	2,606	329	624	998
MU 2/1 (b) Montrose Port (south bank –A92 bridge to Ferryden) HTL/HTL/HTL	-	75	22	36
MU 2/2 (a) Montrose West (A92 Bridge to the end of railway defences) HTL/HTL/HTL	6,027	1,795	2,052	3,284
MU 2/2 (b) Montrose West (Railway defences to Tayock River) HTL/HTL/HTL	-	75	22	36
MU 2/3 (a) Tayock (Tayock village) HTL/HTL/HTL	7,872	949	1,682	2,691
MU 2/3 (b) Tayock (Tayock Cemetery) HTL/HTL/HTL	1,840	591	512	819
MU 2/4 (a) West Montrose Basin (west of Tayock) HTL/HTL/HTL	2,323	8,381	2,750	4,400
MU 2/4 (b) West Montrose Basin (Bridge of Dun) MR/MR/MR	402	1,343	645	1,032
MU 2/4 (c) West Montrose Basin (Old Montrose) HTL/HTL/HTL	7,911	454	1,815	2,903
MU 2/6 Rossie Island to A92 HTL/HTL/HTL	1,977	454	583	933
MU 2/7 Ferryden HTL/HTL/HTL	7,819	1,023	1,814	2,902
MU 4/2 Corbie Knowe HTL/NAI/NAI	359	-	187	299
MU 6/1 (a) Victoria Park	14,838	3,136	3,602	5,764

Policy Unit	Whole Life Capital CV (£k)	Whole Life Maintenance CV (£k)	Total Whole Life PV (£k)	Total Whole Life Cost PV+60% Optimism Bias (£k)
HTL/HTL/HTL				
MU 6/1 (b) Seagate HTL/HTL/HTL	2,433	318	753	1,205
MU 6/2 Arbroath Harbour HTL/HTL/HTL	28,761	1,693	6,171	9,873
MU 6/3 Inchcape Park to Westway Road HTL/HTL/HTL	26,809	2,681	5,092	8,147
MU 6/4 (a) West Links to Easthaven HTL/HTL/HTL	17,814	1,806	3,943	6,308
MU 7/1 West Haven to Carnoustie Station HTL/HTL/HTL	2,021	227	320	511
MU 7/2 Carnoustie Station to Barry Burn HTL/HTL/HTL	11,215	1,307	1,785	2,855
MU 8/1 Barry Sands East HTL/HTL/HTL	51,935	5,089	10,259	16,414
MU 9/1 MoD Boundary to west Tayview Caravan Park HTL/HTL/HTL	4,621	3,022	1,196	1,914
MU 9/2 Monifieth West HTL/HTL/HTL	4,214	2,636	1,808	2,892
MU 9/3 Barnhill to the Esplanade HTL/HTL/HTL	9,145	1,716	2,616	4,185
MU 9/4 Broughty Ferry East HTL/HTL/HTL	5,312	1,045	1,301	2,082
MU 9/5 Broughty Ferry HTL/HTL/HTL	2,022	1,136	674	1,079

Angus Council

Angus Shoreline Management Plan SMP2

Appendix H – Economic and Sensitivity Testing

ANNEX 3 - Supporting information for Sensitivity Testing

Annex H.3 – Supporting information for Sensitivity Testing

Proposed climate change scenarios (UKCP09)[3]: the UKCP09 Relative Sea Level Rise predictions at the 95 percentile predicted from 1990 levels for Montrose, Arbroath and Dundee, for the UKCIP low, medium and high ranges refer to Appendix C for full details.

Actual Year	SMP2 Epoch	Year from 1990 in UKCIP09	Montrose		
			Low range	Medium range	High range
2015	**Present day**	25	**68mm** (0.068m)	**90mm** (0.090m)	**115mm** (0.115m)
2035	**Year 20**	45	**139mm** (0.139m)	**181mm** (0.181m)	**231mm** (0.231m)
2065	**Year 50**	75	**271mm** (0.271m)	**351mm** (0.351m)	**447mm** (0.447m)
2115	**Year 100**	Use 110	**463mm** (0.463m)	**599mm** (0.599m)	**760mm** (0.76m)

Actual Year	SMP2 Epoch	Year from 1990 in UKCIP09	Arbroath		
			Low range	Medium range	High range
2015	**Present day**	25	**68mm** (0.068m)	**89mm** (0.0789m)	**114mm** (0.114m)
2035	**Year 20**	45	**138mm** (0.138m)	**180mm** (0.1680m)	**230mm** (0.230m)
2065	**Year 50**	75	**269mm** (0.269m)	**349mm** (0.349m)	**445mm** (0.445m)
2115	**Year 100**	Use 110	**461mm** (0.461m)	**596mm** (0.596m)	**758mm** (0.758m)

[3] United Kingdom Climate Projections (UKCP09).

Actual Year	SMP2 Epoch	Year from 1990 in UKCIP09	Dundee		
			Low range	Medium range	High range
2015	**Present day**	25	**65mm** (0.065m)	**86mm** (0.865m)	**111mm** (0.111m)
2035	**Year 20**	45	**133mm** (0.133m)	**175mm** (0.175m)	**225mm** (0.225m)
2065	**Year 50**	75	**261mm** (0.261m)	**342mm** (0.342m)	**437mm** (0.437m)
2115	**Year 100**	Use 110	**449mm** (0.449m)	**585mm** (0.585m)	**746mm** (0.746m)

Angus Council

Angus Shoreline Management Plan SMP2

Appendix H – Economic and Sensitivity Testing

ANNEX 4 - Supporting information for economic assessment

Annex H.4 – Supporting information for economic assessment

Economic Summary Table

Policy Area	NAI PVd (£k)	WPP PVd (£k)	WPP PVb (£k)	WPP PV(OB)c (£k)	BCR
Montrose MU: 1/1, 1/2, 1/3(a)-(b),1/4	19,630	1,137	18,493	16,140	>1
Montrose Bay MU: 2/1(a)-(b), 2/2(a)-(b), 2/3(a)-(b), 2/4(a)-(c), 2/5, 2/6, 2/7, 2/8	62,784	795	61,989	20,034	3
Scurdie Ness to Rickle Craig MU: 3/1	514	514	-	-	-*
Lunan Bay MU: 4/1, 4/2	308	286	22	299	<1
Lang Crag to Whiting Ness MU: 5/1	454	454	-	-	-*
Arbroath to West Haven MU: 6/1(a)-(b), 6/2, 6/3, 6/4 (a)-(c)	6,951	132	6,819	31,297	<1
Carnoustie MU: 7/1,7/2	15,999	0	15,999	3,367	>4
Buddon Ness MU: 8/1, 8/2	1,067	18	1,050	16,414	<1
Monifieth to Broughty Ferry MU: 9/1, 9/2, 9/3, 9/4, 9/5	37,498	0	37,498	12,153	3

*NAI policy; no BCR calculated

KEY:

PVd	Present Value damages
PVb	Present Value benefits
PV(OB)c	Present Value (Optimism Bias) costs (OB rate is 60%)
BCR	Benefit Cost Ratio