FACET Modelling Documentation

Document: 1 Version: 3.1

Long Term Investment Strategy (LTIS) Improvements
– Part 1 Technical Documentation

Environment Agency

May 2012

Halcrow

FACET Modelling Documentation

Long Term Investment Strategy (LTIS) Improvements – Part 1 Technical Documentation

Environment Agency

May 2012

Halcrow Group Limited
Burderop Park, Swindon, Wiltshire SN4 0QD
tel 01793 812479 fax 01793 812089
halcrow.com

Halcrow

Document history

FACET Modelling Documentation – Part 1 Technical Documentation

Long Term Investment Strategy (LTIS) Improvements

Environment Agency

This document has been issued and amended as follows:

Version	Date	Description	Created by	Verified by	Approved by
2.1	March '11	Final technical report for FACET projects from 2008 - 2011			
3.0	18/04/2012	Draft	Petra Neve	Jon Wicks	Jon Wicks
3.1	11/05/2012	Final, following comments ICM New chapter 9	Petra Neve	Petra Neve	Jon Wicks

Contents

Appendix

Appendix E Data Sources

1 Introduction

1.1 Purpose of the document

This report provides the technical documentation on the Flood and Coastal Erosion Tool (FACET) analysis designed to support the Environment Agency's Long Term Investment Strategy (LTIS). It forms Part 1 of the FACET Modelling Documentation (Part 2 is the User Guide for the Policy Analysis Tool).

The intended readership for this report is Environment Agency technical specialists who have good knowledge of the wider LTIS analysis and of the supporting NaFRA and NCERM data sets. The report is a highly technical reference document – it is not intended to be read by those without extensive prior knowledge of the LTIS methods.

1.2 Brief development history

The development of the FACET toolset started in 2007/8 as part of the LTIS feasibility study. Further development of method, data and software tools was undertaken in 2008 and 2009 leading to the version of the FACET tools and data used to support the 2009/10 LTIS publications in England and Wales.

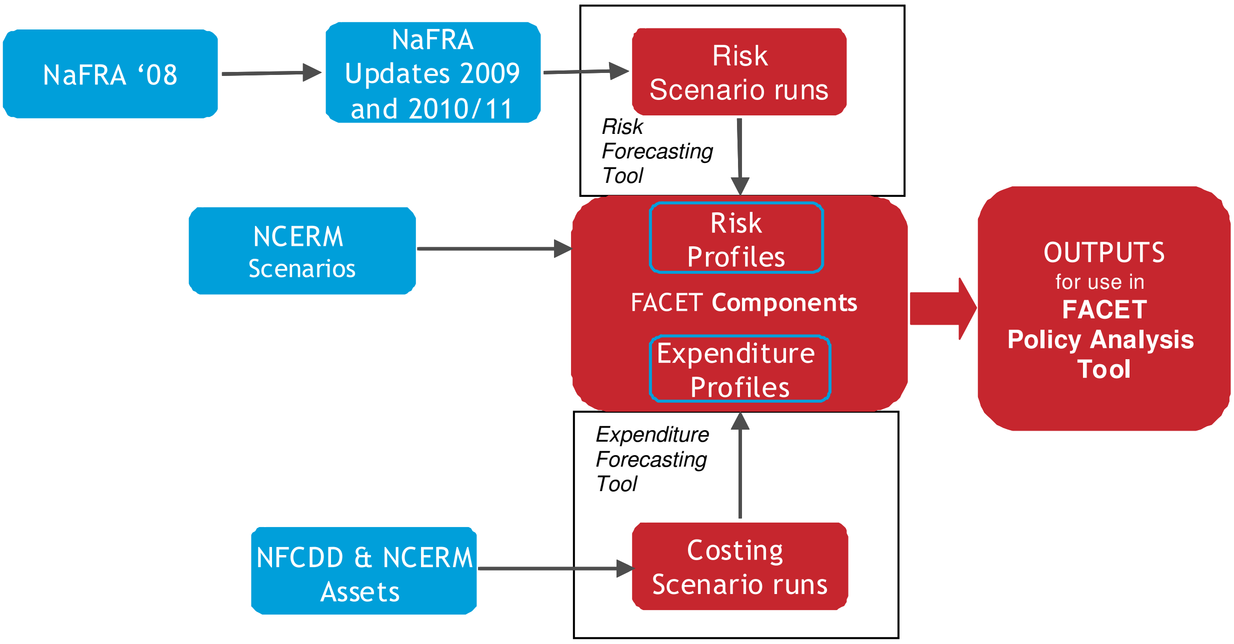
During spring 2011 the Policy Analysis Tool (PAT) functionality was updated and streamlined and a PAT User Guide developed.

Between November 2011 and April 2012, as part of the LTIS Improvements Project (Phase 1), work was undertaken to review and update the data sets and software tools to enable an updated and expanded LTIS evidence base.

This report describes the version of the FACET toolset as of April 2012.

2 FACET tool overview

The figure below provides an overview of the FACET tools which have been produced to inform the LTIS process. The blue boxes identify outputs from other projects that feed into the FACET analysis tool. .



Scenarios of future flood risk and expenditure requirements are forecast over a 100 year timeframe using the **Risk Forecast Tool** and the **Expenditure Forecast Tool** to produce a national dataset that can be analysed by the **Policy Analysis Tool**.

The underlying key assumptions and variables are discussed in section 3.

The **Risk Forecast Tool** adapts the NaFRA catchment models to indicate how policy choices would affect risk metrics (such as economic damages and property at risk) into the future. The Risk Forecast Tool is discussed in more detail in section 4.

The **Expenditure Forecast Tool** assesses the likely cost associated with the abandonment, maintenance, replacement or potential upgrade of flood defence assets. The Expenditure Forecast Tool is discussed in more detail in section 5.

The data from these two tools is aggregated to a flood risk management system (FRMS) level and forms a database of results that can then be accessed by the **Policy Analysis Tool**. The Policy Analysis Tool allows users to choose what level of asset intervention (policy) is implemented for each FRMS. The Policy Analysis Tool is discussed in more detail in section 6.

FACET provides a number of outputs including graphs and tabulated outputs. These need some post-processing to fully address LTIS questions including adjustments to economics metrics, and completing the necessary cost-benefit analysis to compare scenarios. The main post-processing steps are outlined Section 7

3 Key Variables

3.1 Overview

A number of key variables were identified at the feasibility stage of this project as important to understanding future investment and risk. The table below outlines the key variables and how they have been incorporated into the modelling.

Variable	Potential impact	Delivery
Change in desired standard of protection (SoP)	Expressed as change in policy and shown to be the most important variable for future investment requirement and residual flood risk	A range of policy options and decision rules included. The policy options are discussed in section 3.2 below
Impact of climate change	Affects overtopping rates and wave energy (in coastal locations) and river water levels, which affects the SoP provided and replacement cost of assets	A single climate change scenario based on the central change factor from UKCP09 as advised in the Adapting to Climate Change Guidance (*Environment Agency, 2011a*). The tools can assess different climate change scenarios if required
Population change in the floodplain	Affects the number of flood receptors therefore the number of people or properties and the estimate annual damage from flood events	Future development in flood plains can currently not be predicted beyond a 20-30 year time horizon. It is therefore assumed that building in the floodplain either does not occur and/or is a flood resilient development hence not included in risk quantification. This variable is therefore currently not included in the FACET models and tools
Inflation	Increases in construction costs, house price indices or damage costs could alter the assessment of investment or risks	Yearly variable inflation rates associated with construction and non construction spend can be included in the FACET policy analysis tool
Efficiency	An aim of the LTIS project is to improve efficiency in delivery of FCERM projects. These improvements will affect the investment requirements for providing assets	Variation in expenditure associated with efficiency is included as yearly variable efficiency rates associated with construction and non construction spend in the FACET policy analysis tool.

3.2 Policy options

The policy options are based on a broad range of possible policy responses. This gives the tool the flexibility to model a wide range of investments and risks. The policy options align closely with those used in Catchment Flood Management Plans. The table below outlines the LTIS policy options assessed.

Policy choice affects both the capital and maintenance spend allocated to an asset. It also affects the standard of service an asset provides to the floodplain it protects. These factors have been assessed and expressed by the risk and expenditure forecast tools described in sections 4 and 5. The table below gives a high-level overview of expected changes to expenditure and risk with each policy option.

Policy Option	Change to expenditure	Change to risk
1) Do Nothing (passive assets)	No expenditure on maintenance or replacement of passive assets	Passive assets degrade and fail over a short period of time. The level of flood risk will increase quickly over time as assets fail. *(Note: due to lack of suitable data, active assets such as barriers are generally considered to remain operational in the risk calculation for this policy option)*
2) Do Minimum	Maintain existing passive assets, do not replace when they fail.	The level of flood risk will increase slowly in the short term and then accelerate as assets begin to fail
3) Maintain crest level	Maintain and replace current assets to their existing crest levels	The level of flood risk will increase over time due to climate change.
4) Maintain current flood risk	Maintain current assets, replace with larger/longer/more robust structures. Build new assets	The level of flood risk will remain static as the size of defences keeps pace with climate change
5) Improve	Maintain and replace current assets. Assets to be replaced with larger/longer/more robust structures. Build new assets	The level of flood risk reduces as assets are replaced with ones that offer a better standard of protection
6) No maintenance, but replace	Do not maintain assets, but replace current assets to their existing crest levels.	Short term increases in flood risk as assets deteriorate faster, but then temporary reduction as assets are replaced sooner. Over longer term increase in risk due to climate change.

The impact in terms of risk and investment of each of these policy options on flood risk areas and defences has been assessed and provision for additional defences has been included where necessary. The FACET policy analysis tool is able to ‘pick and choose’ from these policies for different flood risk management systems according to user-specific decision rules. In this way the user is able to model a range of flood risk management scenarios with different national costs and outcomes.

Asset information is mainly taken from the National Flood and Coastal Defence Database (NFCDD). Other asset databases have also been used and are discussed in the appropriate section of the document.

In order to assess the impact of the policy options, a number of variables are identified that would be dependent on the policy option chosen. These are discussed qualitatively below with detailed, quantitative, discussion in the relevant sections.

3.3 Asset deterioration

Flood and coastal erosion assets deteriorate over time. Regular maintenance helps to maximise their life however there is a point at which continued maintenance is not economically viable at which point the asset is replaced.

Environment Agency assessment of assets is broken down into 5 condition grades.

Table 3.1 Asset Condition Grades

Condition grade	Description[1]
1	Very Good
2	Good
3	Fair
4	Poor
5	Very Poor

Based on previous research into performance and deterioration of assets, the FACET models reference the rate at which deterioration occurs for 60 different categories of assets. The asset categories are the RASP (Risk Assessment for Strategic Planning) assets, as also utilised for NaFRA risk assessment models.

Within the FACET risk and expenditure models, asset deterioration determines when an asset is to be replaced as well as the period of time over which the replacement cost is spread. The deterioration rate is assessed for two cases: with and without maintenance. Deterioration without maintenance is more rapid than with maintenance. The decision if an asset should be replaced is dependent on the policy; under ‘do nothing’ and ‘do minimum’ assets are never replaced: Assets subject to Policy 1 and 6 will be subject to the ‘without maintenance’ deterioration rates whilst

[1] See NFCDD Data Lists DOC0034

the Policies 2-5 utilise the 'with maintenance' rates. The deterioration tables are included in Appendix C.

It is recognised that deterioration can cover a range of rates and that maintenance activity can influence the deterioration rate. Maintenance costs are intrinsically linked to the extent of deterioration. These issues need to be considered when modelling asset deterioration and whole life costs.

Environment Agency R&D project SC060078 Phase 1 and Phase 2 'Asset deterioration and whole life costing' has been developing deterioration curves, maintenance regimes, costs and a whole life costing methodology (Environment Agency, 2012a). Where there is sound evidence and benefit to be gained, the deterioration curves as used for the LTIS in 2008/09 (see PAMS Guidance) have been updated with this latest available evidence as at December 2011, prior to final issue of the R&D report.

Though further evidence is available suggesting a complete detailed review of deterioration curves may be warranted, that is beyond the scope of the current LTIS Improvement project.

The review compared the existing deterioration curves against the early conclusions from the R&D project, this is summarised in the table below and the updated curves can be found in Appendix C.

Defence Class	Comments 'do nothing'	Comments 'normal maintenance'
Fluvial Vertical Wall (brick): 4, 5, 6 (narrow) 41, 42 (wide)	Phase 2 small extensions to estimated asset life (narrow and wide)	Narrow and wide: Increase best estimate life by 10 years to 90 and slow estimate life to 120 years (20%). No change fast estimate life
Fluvial Vertical Wall (gabion) (40)	Phase 2 small extensions to asset life generally	No real change
Coastal Vertical Walls (concrete): 26, 27(narrow) 55 (wide)	Narrow and Wide: Best estimate life and slow estimate life for Phase 2 curves show extended life by approx 50%	Narrow: Increase for best estimate life and slow estimate life (approx 33%). Fast estimate life is the same. Wide: best estimate life increased by approx 20% and slow by approx 40%.
Coastal Vertical Walls (brick): 29, 30 (narrow) 57 (wide)	Narrow and Wide: Best estimate and slow estimate lives for Phase 2 curves show extended life approx times 2 (i.e. 100% increase)	Narrow: Increase for best estimate and slow estimate lives of approx 33%. Fast estimate life is same. Wide: best estimate life increased by approx 20% and slow estimate life by approx 40%.
Fluvial Vertical Wall Steel Piles: 7, 8, 9 (narrow) 44 (wide)	Narrow and wide: slight increase in life for best estimate and slow. Slight fall in asset life for fast rate	Narrow and wide: Only small variations. Fast estimate life decreased and slow estimate life increased.

Defence Class	Comments 'do nothing'	Comments 'normal maintenance'
Fluvial Sloping Walls (turfed): 10 (narrow) 45 (wide)	Narrow: best and slow estimates show longer life values for Phase 2 curves. Fast estimate life much reduced from 19 years to 7 years (63%) Wide: As narrow but less reduction for fast estimate life 25 to 14 years (44%)	Narrow: best estimate and slow estimate lives doubled in Phase 2. However fast estimate life reduced to a third of original value. Wide: best estimate life raised 60% and slow estimate life raised 83% in Phase 2. However fast estimate life reduced to a half original value.
Coastal Sloping Walls: 31,34 (narrow) 58, 59, 60, 61 (wide)	Narrow: Main changes are for fast estimate life (23 years to 12 years (48% reduction)) and slow estimate life (38 years to 60 years (58% increase)). Wide: Phase 2 curves predict higher lives. Notable 80 years for slow estimate life (2 times original)	Narrow: best estimate life raised 50% and slow estimate life more than doubled in Phase 2. Fast estimate life reduced to half of original value. Wide: best estimate life raised up to 50% and slow estimate life raised between 83% and 130% in Phase 2. However fast estimate life roughly same.
Fluvial Sloping Walls: 11, 13, 14, 15, 16, 19 (narrow) 46, 48, 49, 50, 51 (wide)	Narrow: main change is for slow estimate for Phase 2 giving twice the life, but fast estimate giving half to third of life Wide: similar to narrow but changes not so great	Narrow: best estimate life raised between 50% and 80% and slow estimate between 100% and 125% increase. Fast estimate life reduced to less than half original value. Wide: best estimate life raised 50% and slow estimate life raised 75% in Phase 2. However fast estimate life slightly lower.
Culvert (21)	Main changes are for best estimate life and slow estimate life where there is major change (increase in asset life) (at least twice)	Variable materials. Phase 2 curves show improvement generally with between 25% to 50% on best estimate life, and 33% to 47% on slow estimate life. Original fast estimate life falls within revised range (at low end). *Note*: used the worst case across the distinct culvert materials for fastest, best and slowest in FACET models
Shingle Beach (38)	Main change is for slow estimate life with increase of approx 4 times	Best estimate life is 2x original, slow is 4x original but fast is 2/3rds original.
Dunes (37)	Main change is for slow estimate life with increase of approx 3 times	Best estimate life is increased by 87% on original, slow estimate life is 4x original but fast estimate life is 2/3 rds original

Table 3.2 Review of asset deterioration curves

3.3.1 Asset replacement

Once an asset has been calculated to have reached the end of its life it is replaced – this is set to be the point at which the asset reaches condition grade 5 (very poor). The scale of the replacement is dependent on the policy being assessed.

- Policies 1 and 2 assume there is no replacement of assets.
- Policy 3 and 6 assume assets are replaced with an asset of similar size
- Policy 4 assumes assets are replaced with an asset that is larger to keep up with increasing water levels due to climate change
- Policy 5 assumes assets are replaced with assets of a larger size to improve the standard of defence even with increasing water level due to climate change.

The replacement decision will affect the cost of replacement and the new level of protection afforded by the asset. The improvement to the condition grade will also reduce the likelihood of breach.

3.4 Climate Change

3.4.1 Introduction

Throughout the project climate change assumptions have been based on the latest Climate Change Guidance. The LTIS Improvement 2011 is based on the advice in the guidance from the *Environment Agency, 2011a*.

Due to time constraints and data limitations a single, 'change factor', climate change data set is used for FACET modelling. A limited number of different climate change factors have been implemented on a selection of catchments to inform statements on the sensitivity and uncertainty of the FACET models (Halcrow, 2012a).

The next sections provide a brief history of (3.4.2, 3.4.3) and the update to (3.4.4) the climate change assumptions and implementation in the various LTIS studies.

3.4.2 Feasibility study (2007/08)

Climate change assumptions were built into the initial model based on analysis carried out by Burgess and Townend, 2001 and Townend and Burgess, 2004. These papers outlined how the size and construction type of coastal defences were likely to change with increases in sea level and wave energy. The analysis was proxied to incorporate the impact of peak flow water level increases in rivers for fluvial defences.

3.4.3 Long Term Investment Strategy 2008-2010

This section describes the parameters used to represent Climate Change for the Long Term Investment Strategy as published in 2009 (England) and 2010 (Wales).

The Defra Guidance Note (2006) for Sea Level Change was applied for the Long Term Investment Strategy published in 2009/2010. Changes to in-river water levels were adjusted from this guidance and further reviewed on early knowledge from UKCP.

More detail on implementation is available in the LTIS Modelling Technical Documentation - Part 1 section 3.3 (Halcrow, 2011a). A summary of key variables for Sea Level Change and Peak River Flow are provided below.

Sea Level Change (LTIS 2008-2010)

The Defra Guidance Note (2006) for Sea Level Change has been applied. Following review of early outputs from UKCP, it was concluded that given that the FCDPAG allowances for climate change indicate a range of change to extreme coastal water levels of ~90cm in the next 100 years up to 2108, UKCP09 estimate derived here of 84cm up to 2100 suggests that the Defra guidance was applicable for use in the future projections for the LTIS published in 2009/10, see reproduced table below.

Administrative or Devolved Region	*Assumed Vertical Land Movement (mm/yr)*	*Net Sea-Level Rise (mm/yr)*				*Previous allowances*
		1990-2025	*2025-2055*	*2055-2085*	*2085-2115*	
East of England, East Midlands, London, SE England (south of Flamborough Head)	-0.8	4.0	8.5	12.0	15.0	6mm/yr* constant
South West and Wales	-0.5	3.5	8.0	11.5	14.5	5 mm/yr* constant
NW England, NE England, Scotland (north of Flamborough Head)	+0.8	2.5	7.0	10.0	13.0	4 mm/yr* constant

*Updated figures now reflect an exponential curve, and replaces the previous straight line graph representations.

Figure 3-1 taken from Defra Guidance (2006)

No changes are applied to the coastal overtopping rates.

Peak River Flow (LTIS 2008-2010)

The Defra 2006 climate change guidance sets out sensitivity ranges for peak river flows. These were assumed to represent the impact of climate change.

	1990-2025	**2025-2055**	**2055-2085**	**2085-2115**
Peak river flow	+10%	+20%		

Table taken from table 2 of Defra Guidance (2006)

These figures were used as the basis for the LTIS project to develop the change factors. Early outputs from UKCP were reviewed and used for the LTIS modelling to provide a regionalised change factor in peak river flow as presented in Table 3.3

Region	**Percentage change by 2080**
North East	16
Anglian	17
Thames	22
Southern	25

Region	Percentage change by 2080
South West	29
Midlands	28
North West	26

Table 3.3 Change from baseline period 1961-1990 following UKCP review

These increases in flows were translated into regionalised expected increases in peak water levels. The methodology used was taken from development work undertaken as part of the National Appraisal of Assets at Risk (NAAR, see Halcrow, 2001a). The study developed regionalised spreadsheets to estimate the effect of climate change on peak flows in each of the Agency regions. The NAAR study assessed the expected change in return period due to changes in river flow. These changes could then be related back to water level differences, required for the NaFRA models.

Region	Change factor for each epoch			
	2008	2033	2058	2108
North East	1.00	1.03	1.07	1.15
Anglian	1.00	1.04	1.08	1.16
Thames	1.00	1.04	1.10	1.20
Southern	1.00	1.05	1.11	1.23
South West	1.00	1.06	1.13	1.26
Midlands	1.00	1.06	1.12	1.25
North West	1.00	1.05	1.11	1.24
Wales	1.00	1.05	1.11	1.24

Table 3.4 Adjusted change factors from baseline year 2008

The procedure adopts the regional growth curves of the Flood Studies Report (1975), as up-dated in the Flood Studies Supplementary Report No.14 (August 1983), because the FSR regions align closely with the Agency's regional boundaries. The Flood Estimation Handbook (1999), which superseded the FSR and its supplementary reports, does not have an equivalent of the FSR regional growth curves therefore it was not possible to incorporate the updated FEH data into this analysis.

3.4.4 Long Term Investment Strategy (LTIS) Improvements 2011/12

Following new climate change scenarios in UKCP09 and research on regionalised flood flows under climate change[2], the Environment Agency produced new guidance

[2] FD2020 Regionalised Impacts of Climate Change on Flood Flows

in September 2011: Adapting to Climate Change: Advice for Flood and Coastal Erosion Risk Management Authorities and in November 2011: Adapting to Climate Change: Guidance for Flood and Coastal Erosion Risk Management Authorities in Wales (hereafter both are referred to as "the 2011 guidance"). The implementation of the climate change scenario for the 2011/12 review is therefore based on the advice in the guidance from the *Environment Agency, 2011a*.

Within the 2011 guidance there are estimates for three time horizons (2020s, 2050s and 2080s) and also upper, lower and central estimate changes. Based on the 2011 guidance, and the fact that the LTIS study is a national study requiring significant computational effort for each climate change scenario, we consider that the central estimate (referred to in the guidance as the change factor) is the most appropriate estimate of climate change allowance to use in this project. Use of the upper and lower estimates would be more appropriate on single site and high potential impact sites, for example a tidal barrier, rather than a nationwide study.

Relative Mean Sea Level Change

UKCP provided sea level change data grids around England and Wales. The medium emission scenario sea level change 5%ile, 50%ile and 95%ile values (metres) have been extracted.

The spatial coverage of the UKCP data grid does not fully coincide with the NaFRA coastline. Also, the current NaFRA model setup does not cater for an asset-specific implementation of sea level change. For these two reasons, the sea level change has been averaged to each Joint Probability Region to ensure full coverage.

The baseline year of the UKCP sea level change is 1990. Therefore, the values have been adjusted to the 2010/11 FACET baseline.

In the 2011 guidance the 95%ile is indicated as the central change factor to use for evaluating the impact of sea level rise (*Environment Agency, 2011a*). The NaFRA risk models have been run nationally for the medium emission scenario 50%ile and 95%ile. Mean sea level change is regarded as a factor with a large degree of uncertainty, and thus having a national model of the mid- and upper percentiles will assist to form the uncertainty statements.

Coastal Overtopping Rates

This section details the method used to calculate uplift factors for determining future overtopping discharge rates.

This NaFRA model variable was not changed for the LTIS published in 2009 (England) and 2010 (Wales).

Overtopping discharge uplift factors for 2075 have been extracted from the Coastal Defence Vulnerability 2075 report (HR Wallingford, 2002) (CDV2075). Factors are provided for three defence types; seawall, embankment and shingle beach, for five locations: Lincolnshire, Dungeness, Lyme Bay, Swansea Bay and Fylde, and for three probabilities 1:20, 1:50 and 1:200.

Uplift factors for overtopping rates

The uplift factors within CDV2075 are provided in both graphical form (Figure 17, pg 65) and tabular form (Table 3, pg 45). Relevant extracts are provided in Annex A. The report provides uplift factors for 1: 20, 1:50 and 1:200 AEP. Interpolation of these probabilities was not possible as no correlation exists between the uplift factors. The 1:50 uplift factors have been used.

The overtopping discharge uplift factors provided within CDV2075 have been interpolated to determine uplift factors for the years 2020, 2035, 2060 and 2110. The values for 2020 to 2060 have been calculated by linear interpolation from 2010 to 2075, with the factor for 2010 being 1. The uplift value for 2110 has been taken as the same value as 2075. Figure 1 graphically represents the uplift factors for an example location and defence type for the required years.

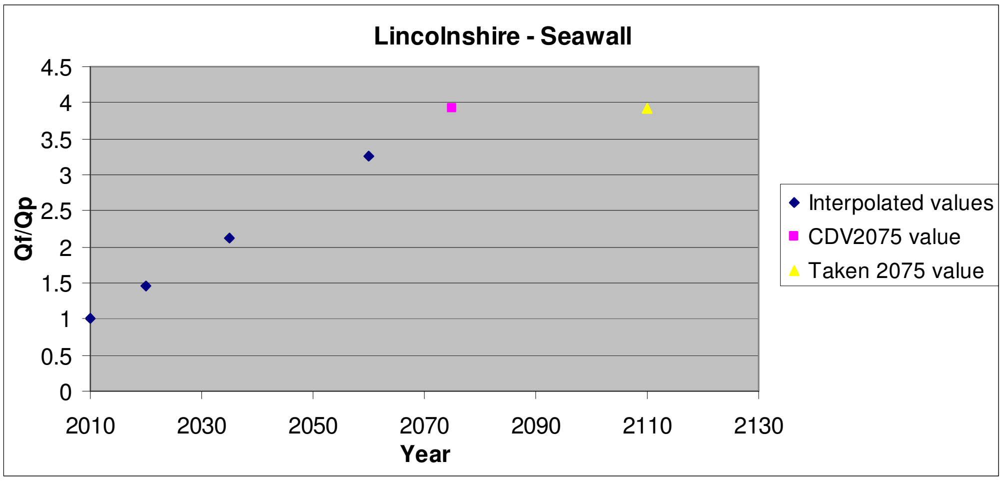


Figure 2: Uplift factors for example location and defence type

Table 3.5 details the uplift factors for all years, defence types and locations.

Location		Future overtopping discharge/Present overtopping discharge (Qf/Qp)				
Defence type	Year	Lincoln-shire	Dun-geness	Lyme Bay	Swansea Bay	Fylde
Seawall	2010	1	1	1	1	1
	2020	1.45	1.21	1.29	1.06	1.13
	2035	2.13	1.52	1.73	1.15	1.32
	2060	3.25	2.03	2.46	1.31	1.64
	2075	3.93	2.34	2.9	1.4	1.83
	2110	3.93	2.34	2.9	1.4	1.83
Embank ment	2010	1	1	1	1	1
	2020	1.12	1.09	1.16	1.04	1.10
	2035	1.29	1.22	1.39	1.09	1.25
	2060	1.58	1.45	1.78	1.18	1.50
	2075	1.75	1.58	2.01	1.23	1.65
	2110	1.75	1.58	2.01	1.23	1.65
Shingle beach	2010	1	1	1	1	1
	2020	1.12	1.10	1.08	1.04	1.14
	2035	1.29	1.26	1.20	1.10	1.34

		Future overtopping discharge/Present overtopping discharge (Qf/Qp)				
Location		Lincoln-shire	Dun-geness	Lyme Bay	Swansea Bay	Fylde
Defence type	Year					
	2060	1.58	1.52	1.40	1.19	1.68
	2075	1.75	1.68	1.52	1.25	1.88
	2110	1.75	1.68	1.52	1.25	1.88
		= Interpolated values				
		= CDV2075 values				

Table 3.5 Overtopping uplift factors

Determination of uplift zones

CDV2075 provides uplift factors for 5 locations around the England and Wales coastline: Lincolnshire, Dungeness, Lyme Bay, Swansea Bay and Fylde. The uplift factors for these locations have been used to determine values for the whole coastline. The coast was split into 5 uplift zones. The LTIS database uses a number of joint probability regions (JP Regions), the extents of the 5 zones were located to coincide with the extents of the JP Regions.

The extents of the 5 zones were determined using the wave height map provided online by ABPmer (ABPmer, 2011) and the predominant wave direction. Figure 3 shows the CDV2075 locations, uplift zones and JPRegion limits.

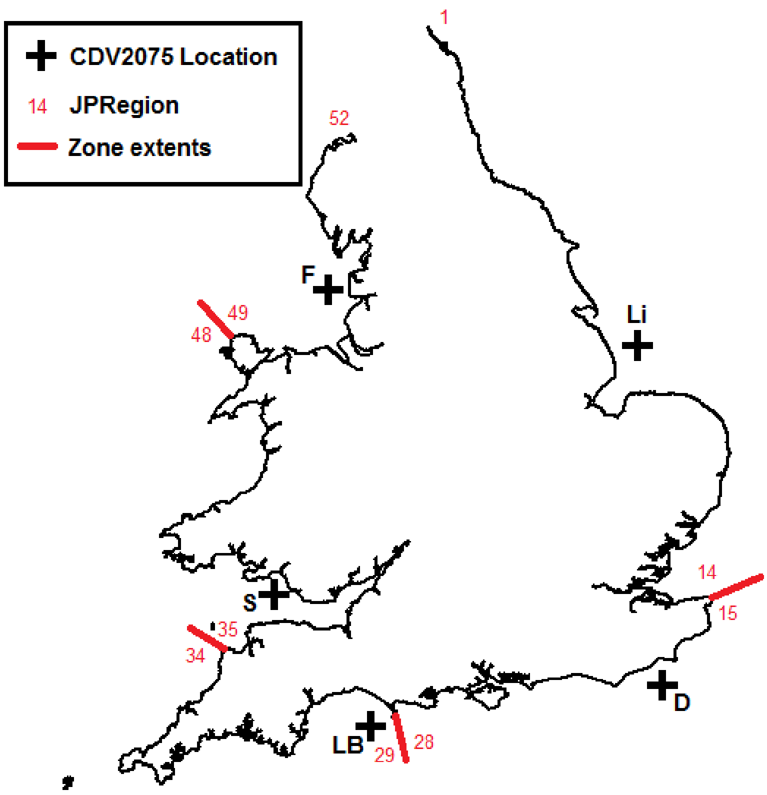


Figure 3 CDV2075 and JP Region location map

Figure 3 provided above is a marked up map showing the ABPmer mapping, licensing restrictions do not allow commercial reproduction of this mapping. Terms of use are available on the website.

Table 3.6 details the CDV2075 locations, the extents of the JP Regions and reasoning for the choice of zone extents.

CDV2075 location	Start	End	Split location	Comments
Lincolnshire (Li)	1	14	North Foreland	Split based on predominant wave source, North Sea/English Channel.
Dungeness (D)	15	28	Portland	Split based on ABPmer wave height map, Lyme Bay has a high uplift factor so has been used for the larger wave heights around the south west peninsula
Lyme Bay (LB)	29	34	Hartland Point	Split based on ABPmer wave height map,
Swansea (S)	35	48	Anglesey	Split based on ABPmer wave height map and the area of coast directly affected by south westerly waves.
Flyde (F)	49	52		

Table 3.6 CDV2075 and corresponding JP Regions

Results

The full result has been provided as an excel file (see Appendix C, overtopping rate changes) and includes the following data columns:

- JPRegion;
- CDV2075 location;
- Defence type;
- Year; and,
- Uplift factor.

An example of the output is shown in Table 3.7

JP Region	CDV2075 location	Defence type	Year	Uplift factor
1	Li	Seawall	2010	1.00
1	Li	Seawall	2020	1.45
1	Li	Seawall	2035	2.13
1	Li	Seawall	2060	3.25
1	Li	Seawall	2075	3.93
1	Li	Seawall	2110	3.93
1	Li	Embankment	2010	1.00
1	Li	Embankment	2020	1.12

JP Region	CDV2075 location	Defence type	Year	Uplift factor
1	Li	Embankment	2035	1.29
1	Li	Embankment	2060	1.58
1	Li	Embankment	2075	1.75
1	Li	Embankment	2110	1.75
1	Li	Shingle Beach	2010	1.00
1	Li	Shingle Beach	2020	1.12
1	Li	Shingle Beach	2035	1.29
1	Li	Shingle Beach	2060	1.58
1	Li	Shingle Beach	2075	1.75
1	Li	Shingle Beach	2110	1.75
2	Li	Seawall	2010	1.00
2	Li	Seawall	2020	1.45

Table 3.7: Output example

Limitations

The uplift factors within CDV2075 are provided for a range of return periods, 1 in 20, 50 and 200 years. No standard correlation exists between these values and so interpolation was not possible.

The 50 year value has been used. The reason is that the use of the 'worst case', i.e. the 20 year value, would result in potentially too much overestimation. This is especially the case for Lyme Bay in particular with Qf/Qp increases of up to 30 times. This is the case because under the present day 20 year storm case overtopping levels are actually quite small, thus even a modest increase will create a large Qf/Qp ratio. Looking across all the other results from CDV2075, the 50 years are more consistent and indeed not much lower than the 20 year uplifts, and thus are still offering a similar order of magnitude change. Future work could consider applying a range of uplift factors for differing return periods.

The coastline has been split into 5 uplift zones, based on high level wave conditions. Applying uplift factors to sections of coast is unrepresentative at this scale of resolution. Future work could consider using more locations for determining the overtopping discharges.

Peak River Flow

The most transparent approach to using the 2011 guidance change factors for the FACET modelling would be to directly adjust the river flows for future epochs. This approach was not undertaken for the LTIS published in 2009/10 and would be hard to implement now because the NaFRA model does not currently directly use river flow information. Also, a brief review of river flow information available in NFCDD shows that, while some flow information is available, it does not provide complete coverage.

The method used for LTIS 2009/10 used regional growth curves to estimate the equivalent change in return period due to a percent change in flow, and then used this change in return period to adjust the water level against return period data (extracted from the NFCDD). The method is described in section 3.3 of the LTIS technical documentation (Halcrow, 2011a) and the key parameters used for LTIS 2009/10 are summarised in section 3.4.3 above.

The updated estimates based on the 2011 guidance required the following preliminary tasks:

i) Equating the river basin districts (against which the change factors are available in the 2011 guidance) with the FSR regions and further to the NaFRA catchments. See Figure 3 below.

ii) Deriving change factors for the time horizons used in LTIS. The 2011 guidance indicates that "the [change factor quoted for] 2020s covers the period 2015 to 2039, the 2050s the period 2040 to 2069, and the 2080s the period 2070 and 2099." Hence the change factors used for the project time horizons are as shown in Table 3.8 below.

River basin district	Baseline ('61-'90)	LTIS target epoch - percentage change in peak flow relative to 2010 (assumed date of current flood estimates)					
mid year	1975	2010	2020	2035	2060	2085	2110
Anglian	0	0	2	4.7	9.7	18	18
Dee	0	0	2	4.7	8.8	13	13
Humber	0	0	2	4.7	8.8	13	13
Northumbria	0	0	2	4.7	8.8	13	13
North West	0	0	3	6.2	11.2	19.5	19.5
South East	0	0	2	6.3	14.7	23	23
Severn	0	0	2	6.3	13.8	18	18
Solway	0	0	3	6.2	10.3	14.5	14.5
South West	0	0	3	6.2	11.2	19.5	19.5
Thames	0	0	2	4.7	9.7	18	18
Tweed	0	0	3	6.2	11.2	19.5	19.5
Western Wales	0	0	3	6.2	11.2	19.5	19.5

Table 3.8 Change in peak flow relative to 2010

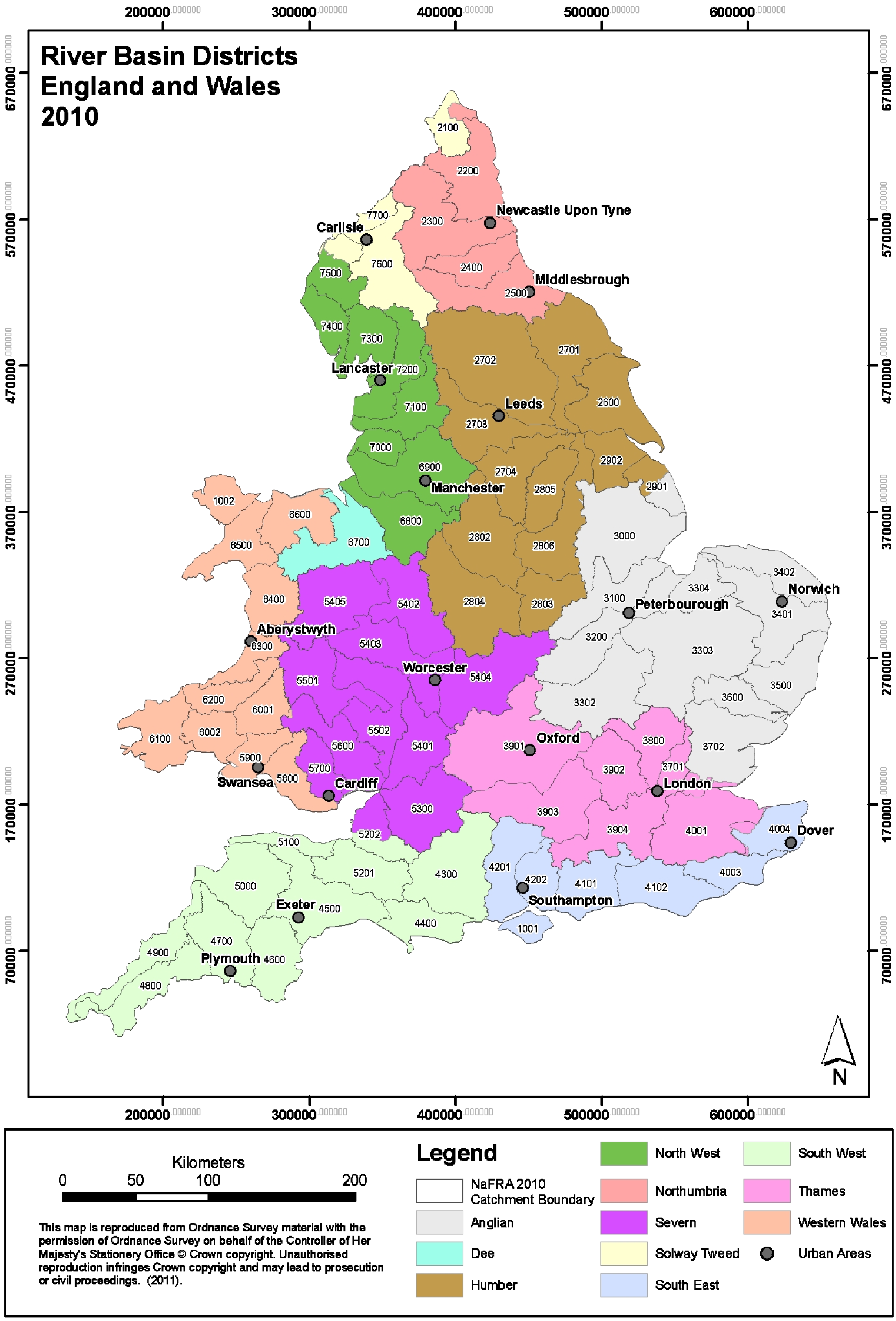


Figure 3.4 River Basin Districts and NaFRA catchments

Table 3.9 Appropriate 2011 guidance time horizon for the LTIS project time horizons

LTIS time horizon	Appropriate 2011 guidance time horizon
2020	2020s (2015 – 2039)
2035	2020s (2015 – 2039)
2060	2050s (2040 – 2069)
2110	2080s (2070 – 2099) – no change factors are available for time horizons > 2099, hence the 2080s change factors are regarded as appropriate

The changes in the year return periods are shown below for one RBD / FSR Region combination, calculated from the percentage change in peak flow, using the calculation tool developed in previous LTIS and NAAR studies. This tool has been used to determine the revised changes to return period for the other RBD/FSR Region combination and used in the NaFRA model.

Table Number	River Basin District:	North West
7	FSR region:	10

Target year	2010	2020	2035	2060	2110
Change to peak flood flows (%)	0	3	6.2	11.2	19.5

Current return period (in 2010)	Future return period in year			
	2020	2035	2060	2110
2	1.8	1.6	1.4	1.2
2.33	2.1	1.9	1.6	1.3
5	4.4	3.8	3.1	2.3
10	8.6	7.4	6.0	4.3
25	21.4	18.2	14.4	10.0
50	42.4	35.9	28.0	19.1
100	84.3	70.7	54.5	36.6
500	414.2	341.5	256.6	165.7
1000	821.8	672.3	499.3	316.8

The climate change guidance (Annex I, paragraph 3 on pg10) implies that the factors apply to return periods > 50 yr. There is no statement on what to apply to RP <50yr and we thus assume the same applies in those cases. Research during preparation of the 2011 guidance looked at 1:2, 1:10, 1:20 and 1:50 year events. The response of catchments to climate change was reasonably consistent across all these return period events. Some additional work looking at 1:100 year events for a limited number of catchments and that too was reasonably consistent. Thus, the confirmed assumption is that the factors given in the 2011 guidance do apply to all return periods. (based on email from B Donovan, 24 Nov 2011)

3.4.5 Climate change and the FACET Expenditure Model

Two sets of climate change factors were included in the FACET Expenditure model, namely:

- Climate change defence replacement cost (DRC2) factor is applied to base replacement cost when defences are replaced with larger assets to account for impacts of climate change
- Defence replacement SOP target cost (DRC3) factor is applied in addition to DRC2 when a replacement defence is required to provide a higher standard of protection (SOP)

Both sets of factors were calculated in the 2008 study based on a technical paper titled *The Impact of climate change upon coastal defence structures by Burgess and Townend*. In this technical paper, climate change impact on structure volume (and cost) of different types of defence structures were presented for four Foresight Futures:

- Global responsibility (lowest impact)
- Local stewardship
- National enterprise, and
- World market (highest impact)

In the 2008 study, the average of local stewardship and national enterprise impact values were used as mean value in uncertainty (Monte Carlo) analysis for coastal defence structures. Global responsibility and world market impacts were used as minimum and maximum bounds respectively for the uncertainty analysis.

Since fluvial defence structures will be not be exposed to all the effects of climate change (e.g. storm surge) considered in the technical paper, a reduction factor of three was estimated, based on relative impacts of different climate change factors (Table 3 of technical paper*)*, for calculating the change in replacement volume (and cost) for these types of defences. In absence of new evidence on how climate change affects the replacement cost of fluvial structures, this reduction factor used in 2008 study can remain unchanged.

Review of factors

Subsequent to the study in 2008, the Environment Agency published a new guidance titled *Adapting to climate change: advice for flood and coastal erosion risk management*, 2011. As part of the LTIS cost review in 2011-12, advice from this guidance was compared against the previous assumptions. Tables 5 and 6 of the guidance note shows change to the relative mean seas level combined with storm surge, the values for which has been summarised below and compared with values used in 2008 study.

	Change to sea level (m) up to year 2080				
	Change to mean sea level (Table 5 of *Adapting to climate change)*	Change to storm surge (Table 6 of *Adapting to climate change)*	Total	Comparable scenario used in 2008 study	Total change considered in 2008 study
H++ scenario	1.07	0.70	1.77	World market	1.81
Upper end estimate	0.54	0.70	1.24	Average of (National enterprise and local stewardship)	1.20

The above table shows that the sea level change values considered in the 2008 study were compatible with the current guidance, and hence it is recommended that both the climate change factors can remain unchanged.

3.5 Inflation and Efficiency

Inflation assumptions can be set within the FACET tool, Table 3.10 below shows the inflation figures as used for the LTIS 2009/10.

Year	Annual inflation
2010 - 2013	2.7%
2014	2.4%
2015 onwards	2.0%

Table 3.10 Example of inflation

Efficiency assumptions can be set within the FACET tool, Table 3.11 below shows the figures as used by the LTIS 2009/10 where inflation figures matched inflation plus 2% until 2015. Beyond 2015 it was assumed that all significant efficiencies had been realised and they would be maintained into the future. This has the effect of realising a 21% efficiency gain on a current baseline by 2015.

Year	Annual efficiency gain
2010 - 2013	4.7%
2014	4.4%
2015 onwards	0%

Table 3.11 Example of efficiencies

3.6 Analysis Units

The underlying analysis is based on the Flood Risk Management Systems as defined in NFCDD (see Appendix B). For coastal erosion, analysis is carried at a Cliff Behaviour Unit (CBU) level or, where not present, at Local Authority level. CBUs have been identified in the Futurecoast project (Futurecoast, 2002). Both are existing classification systems.

To avoid 'double-counting' there is no overlap in the analysis units for flood risk and coast erosion in the LTIS analysis tools.

3.6.1 Flood Risk Analysis Units

The analysis is based on the Flood Risk Management Systems (FRMS) as defined by the Environment Agency. It should be noted that the NaFRA based LTIS Risk Forecast Modelling is to smaller units (50mx50m impact cells). The Expenditure Analysis is based on Flood Areas as defined during NaFRA. A Flood Area is a discrete area bounded by river banks and/or the coast and the Flood Zone 2 boundary (which is approx. 1:1000 year flood plain). In the NaFRA model there is no interaction between Flood Areas.

Where there are properties within the NaFRA Flood Extent, but not within a FRMS, the property numbers and damages are aggregated to the NaFRA Catchment.

Some FRMS areas overlap, and thus the metrics can not be directly compared to the NaFRA Data Products as there will be some 'double' counting of properties.

This is accepted for System Asset Management Plans (SAMPS) as the relevance of reporting numbers is to the FRMS unit itself. From SAMPS 2009/10 report*: Nationally the sum FRMS boundary dataset land area is calculated as "...14.16 million hectares. This area includes nearly 68,000 hectares of overlapping system boundaries..." [overlap of the 68K ha is 0.5% of total area] Impact "for damages this is 0.3% of the NaFRA 2009/10 baseline damages (ie. £10.1mln of the damages to property "duplicated")*.

3.6.2 Coastal Erosion Analysis Units

Within the National Coastal Erosion Risk Mapping (NCERM) project, the coastline is delineated into Cliff Behaviour Units (CBUs) using the CBUs identified in the Futurecoast project. Where the coastline is marked as 'erodible', but not within a CBU, the analysis is carried out on a Local Authority level.

This makes use of an existing classification system and avoids additional, abortive work. The use of CBUs/Local Authority is a similar approach to splitting the floodplain into Flood Risk Management Systems. The coastline is then further delineated to the coast protection/defence assets. Analysis is carried on an individual asset/erosion zone level, and aggregated to CBU/Local Authority level.

4 Risk Forecast Tool

4.1 Overview

The current NaFRA flood risk assessment model[3] has been used to quantify the future risk associated with each LTIS policy option.

Due to the time and processing constraints associated with the project it is not practical to run the NaFRA tool to forecast risk for each year over a 100 year profile.

Four epochs have been assessed using the Risk Forecast Tool:

- Current day - based on the most recent NaFRA model runs (NaFRA 2008)
- +10 year (added for LTIS Improvements 2011 project)
- +25 year (to correspond with the published extent of the long term investment strategy)
- +50 year
- +100 year (in order to align FCDPAG guidance on flood risk assessment and benefit cost analysis)

The NaFRA 2008 model and any subsequent NaFRA Catchment Updates through to the NaFRA 2010/11 baseline were used as the baseline for model runs. An exception is catchment 6600, Conwy for which the NaFRA catchment update from Q1 2011/12 has been included.

The NaFRA model assesses flood risk at 50m grid squares across the country bounded by the current flood zone 2 outlines (which generally equates to the 1:1000 year outline). A number of variables within the model were altered to describe asset size and condition associated with particular policy futures as well as to describe climate change.

The model calculates the probability of flooding in 50m x 50m impact cells. These flood probabilities are used to assign a Flood Likelihood Category (FLC) to each impact cell (very significant, significant, etc). The National Property Point Layer (NRD v1.1) is then compared against the Impact Cells to assess the number of properties for each FLC.

Using this information a number of risk metrics are derived:

- Number of properties at risk, subdivided into 5 risk bands

[3] See RASP and NaFRA Technical documentation

- Very significant likelihood, greater than a 5% chance of flooding in any given year (1 in 20 chance);
- Significant likelihood, 5% (1 in 20) or less, but greater than 1.3% (1 in 75) chance of flooding in any given year;
- Moderate likelihood, 1.3% (1 in 75) or less, but greater than 0.5% (1 in 200) chance of flooding in any given year;
- Low likelihood, 0.5% (1 in 200) chance of flooding in any given year;
- Very low likelihood, property within flood zone 2 but not subject to flooding (according to the NaFRA model).

- Number of deprived properties at risk, subdivided into 5 risk bands as above.
- Expected annual damage (EAD) to residential and non-residential properties. EAD is calculated based on the **weighted annual average damage method** and is consistent with NaFRA 2010/11 outputs.
- Added for LTIS Improvements 2011 project: Agricultural Land at risk, including average annual damages using the same method as for the SAMPS Benefit Reports.
- Post-processing is used to uplift the EAD for other impacts factors such as risk to life (see section 7).

Flexibility has been incorporated in the tool so that future iterations of the LTIS analysis tool will be able to use the NaFRA model to assess other risk metrics such as:

- Risk metrics associated with other Environment Agency outcome measures such as BAP habitat;
- Risk metrics that assess critical infrastructure at risk.

4.2 Key variables

4.2.1 Variation of water levels

Climate change assumptions affect water levels (loading on the assets) at each epoch assessed. Using the methodology described in section 3.4 water level data sets were generated for the 39 return periods assessed within the NaFRA model. The increasing peak water levels have the effect of increasing overtopping and increasing the loading on defences resulting in an increase likelihood of breach.

4.2.2 Variation of asset condition

Asset deterioration predictions have been incorporated into the model using the national asset deterioration curves included in Appendix C. Asset deterioration rates have been estimated as part of the NaFRA project for 60 different asset types (see Appendix C, RASP Defence Sub Classes). The asset condition was assessed at each epoch and is dependant on the policy option. Policy 1 and Policy 6 assume the more rapid ‘no maintenance’ deterioration whilst the remaining policies use a ‘with maintenance’ deterioration rate (see Appendix C).

In 2011/12 the asset condition deterioration curves used for the Risk Forecast and Expenditure Forecast modelling have been updated based on information available from the Long Term Costing – Methods and Software Modelling (SC080039, Phase 2). The deterioration curves were peer-reviewed and finalised in October 2011 under the SC080039 project.

4.2.3 Variation in asset standard of protection

The baseline standard of protection was set in accordance with the NaFRA 2010/11 project. As assets reach the end of their life and are replaced the crest level is assessed and set to the required value according to the policy option being analysed.

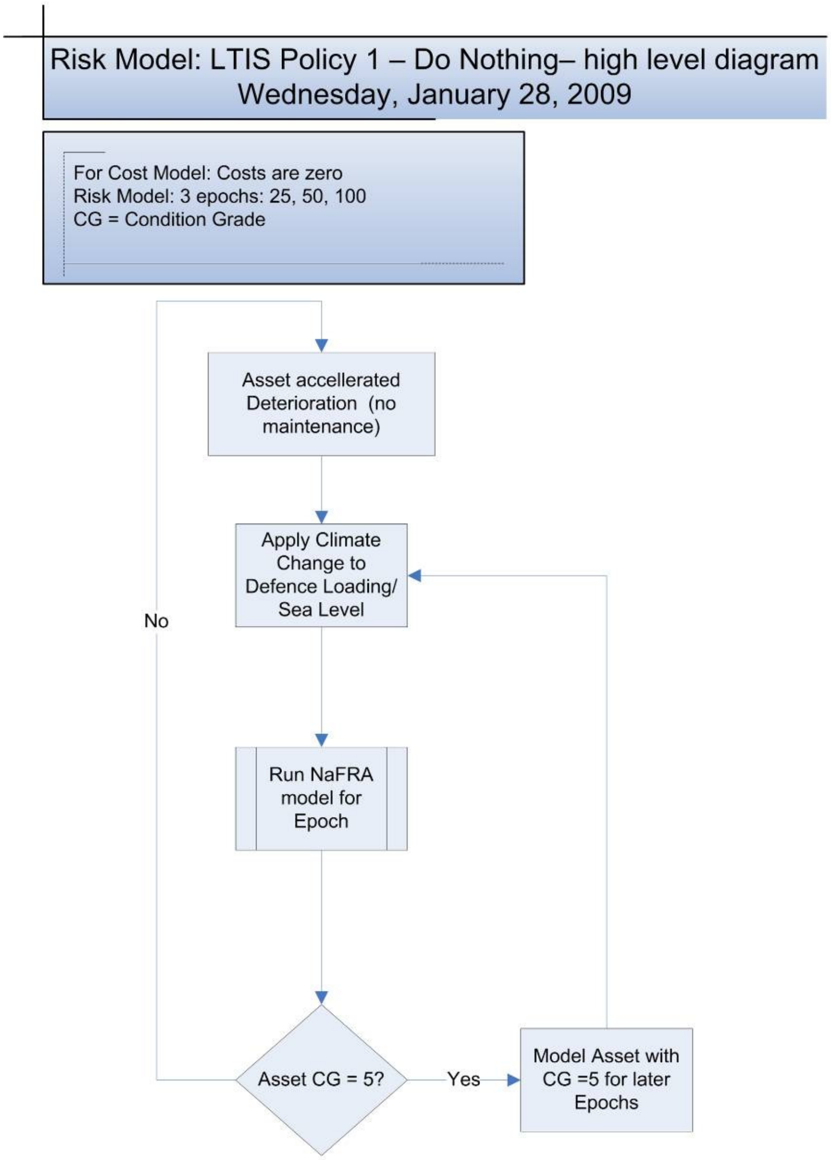
Assets are replaced when they reach condition grade 5. When replaced, the condition grade is set to 1 and the defence re-starts deterioration according to the asset deterioration curves.

4.3 Application of policies

4.3.1 Policy 1

Policy 1 does not have replacement requirements. Assets deteriorate to condition grade 5 and remain at that state for the remainder of the epochs. Asset deterioration takes place faster, according to the 'without maintenance' deterioration curve (see Appendix C).

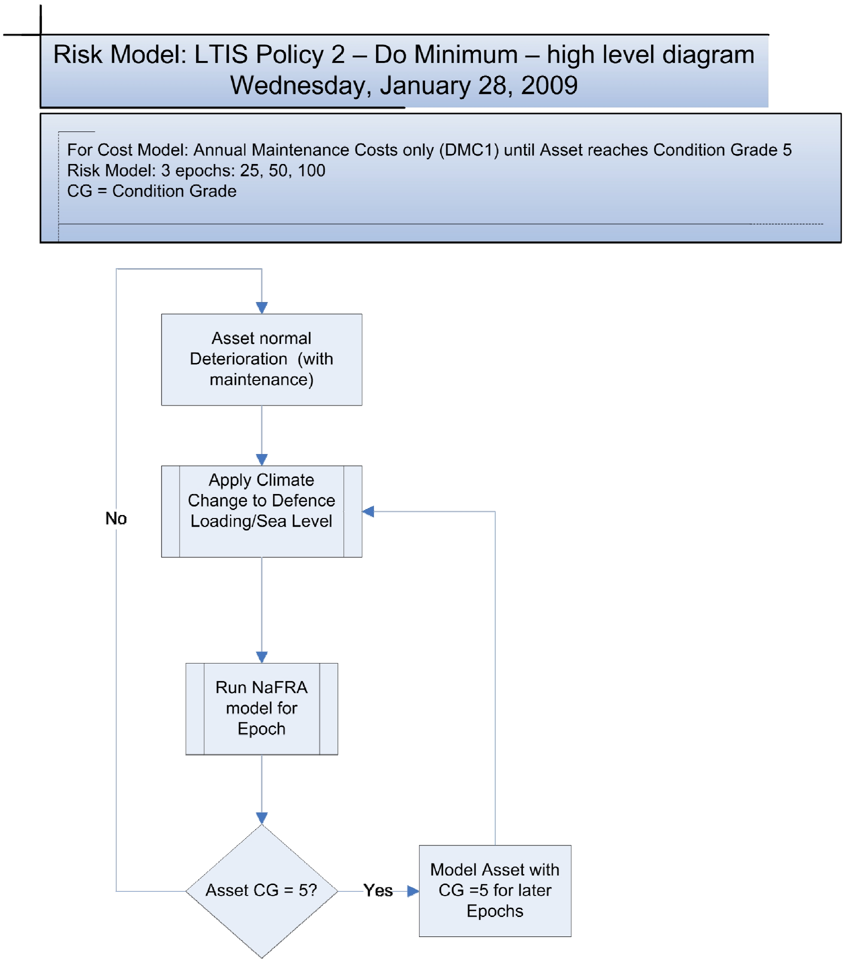
The implementation of this policy in the NaFRA models has been reviewed in late 2011 and found to be correct.



4.3.2 Policy 2

Policy 2 does not have replacement requirements. Assets deteriorate to condition grade 5 and for the remainder of the epochs remain at that state. Assets deteriorate under a 'normal maintenance' regime (See Appendix C).

The implementation of this policy in the NaFRA models has been reviewed in late 2011 and found to be correct.

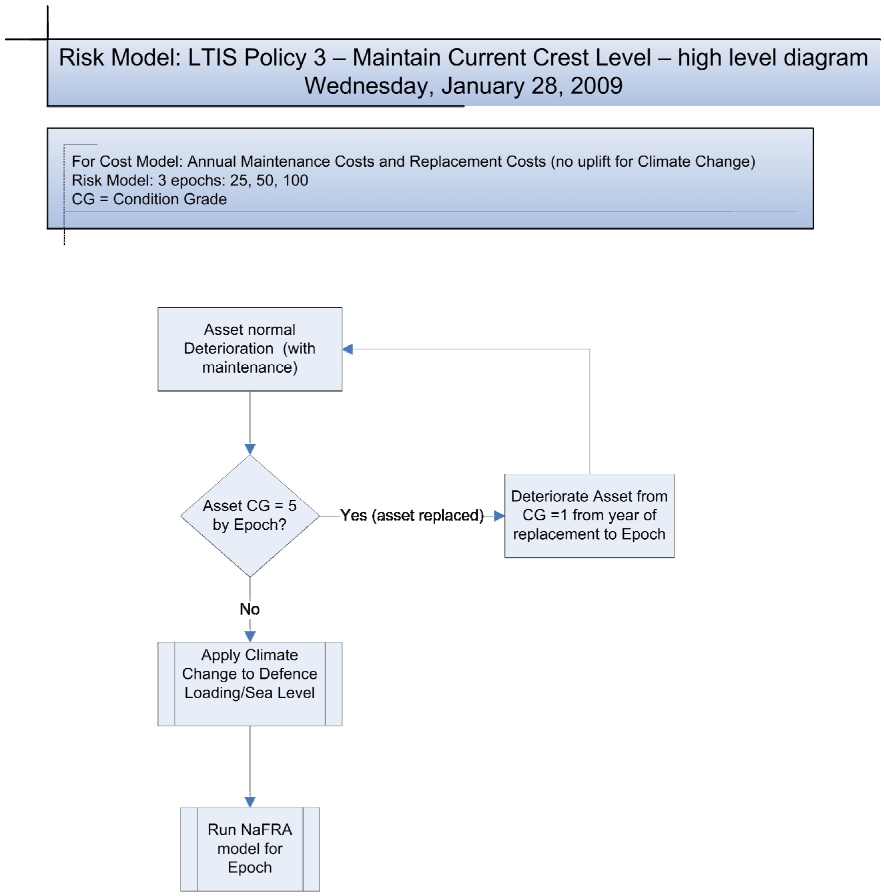


4.3.3 Policy 3 and Policy 6

Policy 3 replaces assets with new assets at their current crest level. This effectively downgrades the standard of protection as water levels increase due to climate change. The policy assumes that no new assets are constructed therefore areas which are currently protected by naturally high ground will also have effectively reducing standards of protection.

Policy 6 has been implemented for the LTIS Improvements 2011 project, using the same workflow as for Policy 3, but referencing the 'no maintenance' asset deterioration curve. This thus results in earlier replacement of assets ('like-for-like'), but faster deterioration in the asset condition grade.

The implementation of Policy 3 in the NaFRA models has been reviewed in late 2011 and found that the assets were not set to condition grade 1 after replacement, and for coastal models assets deterioration was incorrectly implemented. This has been corrected and showed a better defence condition for a minority of assets in the fluvial model i.e. 1.1% at year 25, 5% at year 50 and 7.2% at Year 100. In the coastal model the majority of defences had a condition change. After changing the replacement function in the coastal models, most assets (50%) have a better condition grade for epochs 25 and 100, whilst in epoch 50 most (50%) assets have a lower condition grade. The impact on the risk outputs is limited for the fluvial model to small changes in the flood probability for a small proportion of impact cells, but for 90% of the impact cells there is no change. Where it does change (<10% of impact cells), change in the probability value is under 25%. For the coastal models the change in flood probability is again largely unchanged (73% for epoch 25, 87% for epoch 50, 98% for epoch 100) – where the model outputs do change it is largely a reduction of the probability of less than 25%. Implementation of Policy 6 is new and has been checked.



4.3.4 Policy 4

Policy 4 assumes that the level of risk remains the same across the epochs therefore no model runs were carried out and the flood area risk profile remains constant. The final NaFRA 2010/11 outputs are taken for all epochs (NaFRA 2011/12 for Conwy, catchment 6600).

4.3.5 Policy 5

Policy 5 assumes that the standard of protection is improved to keep up with climate change. Where assets are currently below a 1 in 75 standard of protection, the assets are upgraded to a crest level associated with a 1 in 75 standard of protection (in line with climate change predictions).

It is recognised that assets often work in conjunction with other assets to provide protection to a flood area therefore upgrading an individual asset would not result in an improvement to the standard of protection as water levels would result in overtopping of adjacent assets and outflanking of the improved asset. To address this, the model upgrades all of the assets within a flood area at the replacement date of the first asset failure, where the assets are below the 1:75 standard of protection. A flood area is defined within the NaFRA model as a geographic area that is bounded by the edge of the flood plain and river bank / coastline. Water in the NaFRA models does not pass from one flood area to another therefore the assets associated with a single flood area will act in unison to protect that flood area.

Policy 5 also identifies areas which are protected by high ground. If flood areas are protected in part by natural ground, which is below a 1 in 75 year standard of protection, then the model assumes that new defences (embankment) are built on the natural ground at the time of the first asset replacement within the flood area.

If a flood area is entirely protected by natural ground that is below a 1 in 75 standard of protection the area is upgraded to 1 in 75. The upgrade date is determined by the consequence rating of the flood area the assets protect. Consequence ratings are described in Appendix B.2. Flood areas protected only by natural high ground that do not contain property are <u>not</u> upgraded.

Consequence rating	Upgrade date
High	By year 25
Medium	Between year 25 and 50
Low	Between year 50 and 100

Figure 4.1 below outlines the decision flow chart used to apply policy 5.

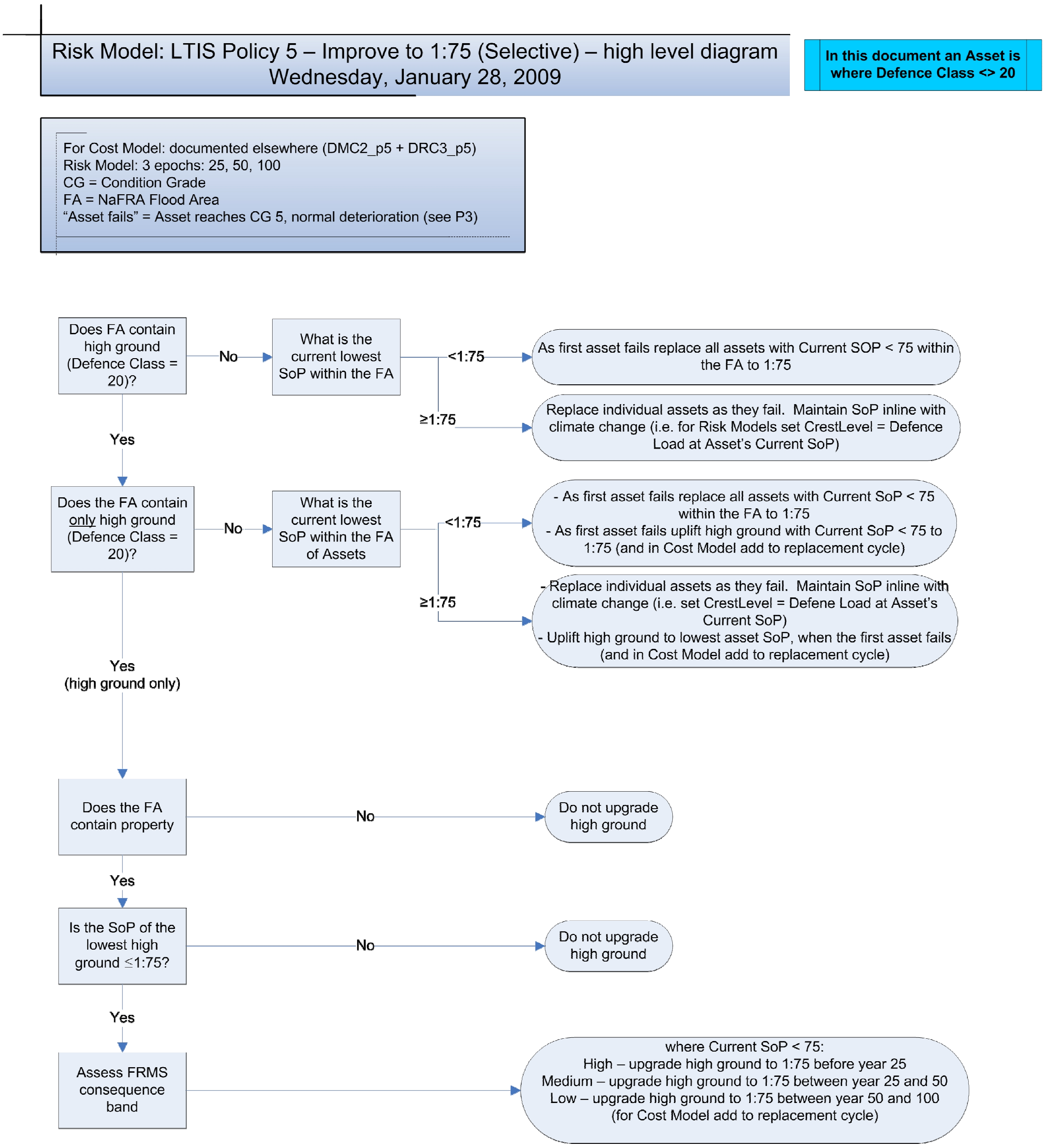


Figure 4.1 Policy 5 - Flow Diagram

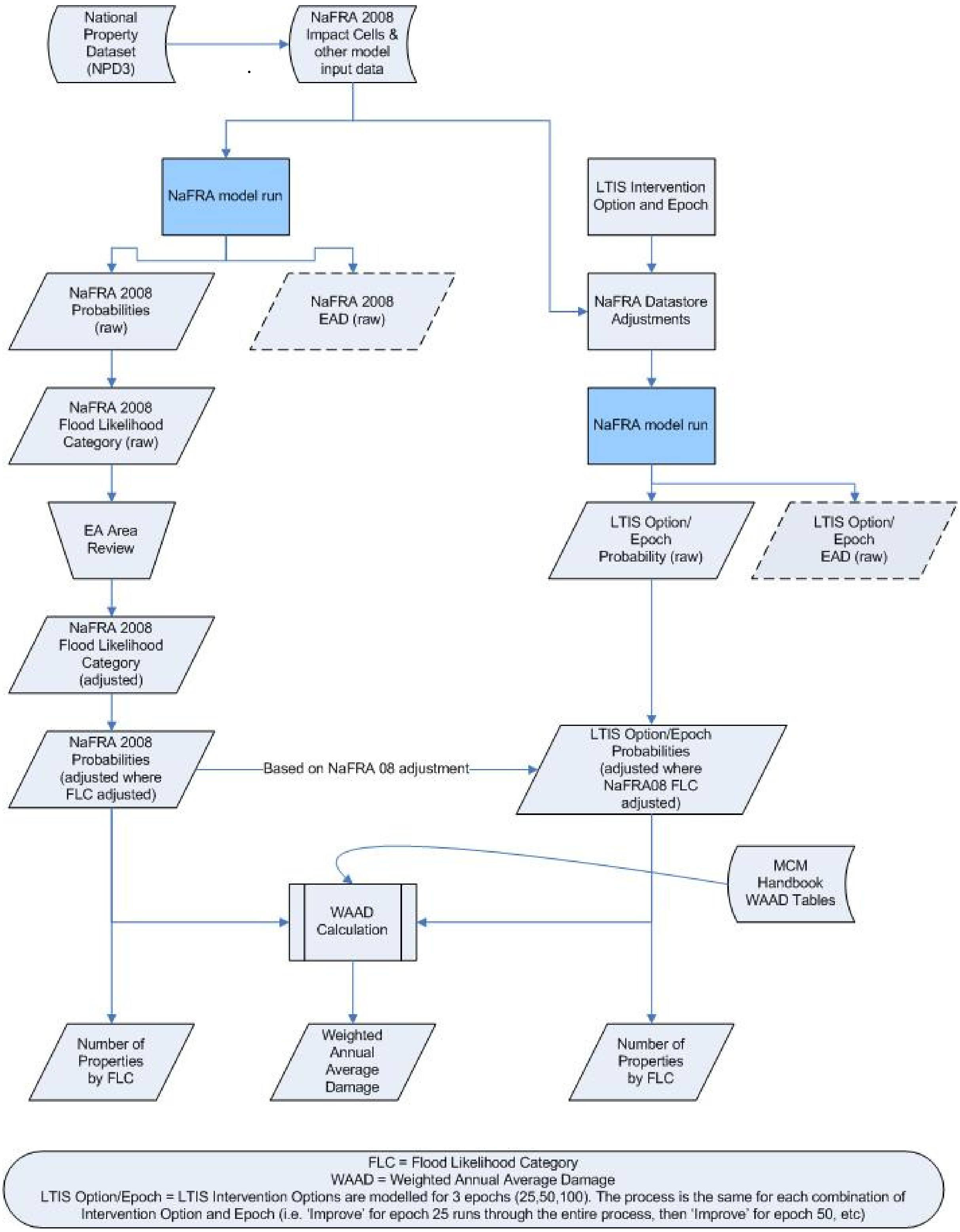
The risk model for Policy 5 has been adjusted to automatically override the Flood Likelihood Category to a maximum of Moderate in Flood Areas where the assets have been improved to the 1:75 standard of protection.

The implementation of this policy in the NaFRA models has been reviewed in late 2011 and found to be correct.

4.4 Assessment of damages

This section describes the process to adjust the Flood Likelihood Categories and probabilities as well as damages of the LTIS future scenarios (Year 10, 25, 50 and 100). These adjustments have been based on Environment Agency recommendations, as implemented for NaFRA 2008 and also for subsequent catchment updates. The diagram below shows the interaction of the processes of NaFRA 2008 and LTIS models (risk assessment). LTIS expenditure analysis is described in section 5 and is an independent process.

Reference to NaFRA 2008 in the figure below means the latest NaFRA catchment model. Note that for LTIS Improvements 2011 project a fourth epoch is added (Year 10).


National Property Dataset (NPD3)
NaFRA 2008 Impact Cells & other model input data
NaFRA model run
LTIS Intervention Option and Epoch
NaFRA 2008 Probabilities (raw)
NaFRA 2008 EAD (raw)
NaFRA Datastore Adjustments
NaFRA 2008 Flood Likelihood Category (raw)
NaFRA model run
EA Area Review
LTIS Option/ Epoch Probability (raw)
LTIS Option/ Epoch EAD (raw)
NaFRA 2008 Flood Likelihood Category (adjusted)
NaFRA 2008 Probabilities (adjusted where FLC adjusted)
Based on NaFRA 08 adjustment
LTIS Option/Epoch Probabilities (adjusted where NaFRA08 FLC adjusted)
MCM Handbook WAAD Tables
WAAD Calculation
Number of Properties by FLC
Weighted Annual Average Damage
Number of Properties by FLC
FLC = Flood Likelihood Category
WAAD = Weighted Annual Average Damage
LTIS Option/Epoch = LTIS Intervention Options are modelled for 3 epochs (25,50,100). The process is the same for each combination of Intervention Option and Epoch (i.e. 'Improve' for epoch 25 runs through the entire process, then 'Improve' for epoch 50, etc)

4.4.1 NaFRA flood likelihood adjustments

In NaFRA the damages are calculated for each impact cell as the model iterates through the permutations of defence failures in a flood area. The information generated for each permutation is not stored for efficiency reasons (but can be stored if needed for a sample area). In other words the calculation of damages is embedded within the model calculating the probabilities. It is not a post-process/additional tool that takes input tables. From the permutations some summarised data is held for depth/probability for each impact cell.

NaFRA reports the probability of flooding for each Impact Cell, where the flood depth exceeds 0m. An Impact Cell is a 50m x 50m grid cell in the flood plain.

Flood Likelihood Category adjustments

The flood probabilities are used to assign a Flood Likelihood Category to each impact cell (very significant, significant, etc). The National Receptor Dataset Property Point Layer (NRD) is then compared against the Impact Cells to assess the number of properties for each Flood Likelihood Category (FLC).

Prior to the NaFRA 2008 Area Output Review automatic amendments to the Flood Likelihood Category were applied as follows:

- If an Impact Cell is inside a Flood Storage Area or Lake (based on EA NFCDD and Lake Layer) the FLC is set to Very Significant
- If an Impact Cell has an FLC of Very Significant or Significant AND falls outside Flood Zone 3, the FLC is set to Moderate.

These NaFRA 'raw' results were assessed by Area teams and adjusted if local evidence indicates discrepancies in the FLC.

These are amendments to the Flood Likelihood Category (FLC) only, not to the modelled probability. These have been adjusted by the NaFRA Project Team using the method below.

Flood probability adjustments

Where an Impact Cell FLC has been adjusted, a new probability has been assigned for NaFRA. In impact cells where the FLC has not been changed it is assumed that the probability is also correct. Each of the 5 flood likelihood categories is assigned a representative flood probability that can be applied to each impact cell that is adjusted. The values for each category can be found in Table 4.1 below (note the table presents percentage probabilities). These are based on taking average values per FLC from raw NaFRA 2008 model output results within 8 catchments, selected randomly 1 from each region.

Table 4.1 NaFRA Normalised Average % Probabilities

Flood Likelihood Band	Normalised Average % probabilities across 8 catchments	Standard Deviation	Comment
Very Low	0.00	0.00	Where the NaFRA 08 model produces no flooding as a valid model output (0% probability) it falls into the Very Low category. Using a WAAD value of £0 for Very Low impact cells will be consistent with this.
Low	0.23	0.15	
Moderate	0.90	0.24	
Significant	3.39	1.23	
Very Significant	17.51	10.33	
No Result	No Value	No Value	No damage value will be calculated; this is consistent with the outputs from the NaFRA 08 model.

Damages and property counts

Following adjustment of the probability, the damages and the number of properties per FLC will also be adjusted.

The NaFRA project reports damages using the MCM Weighted Annual Average Damage method, rather than the estimated annual damages calculated in the NaFRA models. Reasons and background for this decision are reported in the NaFRA project. To remain consistent, the LTIS model outputs are also based on the MCM Weighted Annual Average Damage method. This is further explored in section 4.4.3.

4.4.2 LTIS adjustments

Flood Likelihood Category and Property Counts

Assignment of the Flood Likelihood Category (FLC) to each Impact Cell is based on the probability percentage for that Cell.

For the LTIS future scenarios, the probability percentage needs to be adjusted first (see section 4.4.1 above). Once this is complete, the Flood Likelihood Category can be re-assigned and the residential and non-residential property counts per FLC can be updated.

Methodology for probability percentage change in LTIS future runs

In order to reflect the FLC adjustment into the future, the probability for each Impact Cell has been adjusted with the relative change made in the NaFRA 2008 model for that Impact Cell.

The tables and figures below show two fictional examples of an increase and a decrease in the NaFRA 2008 Flood Likelihood Category for an individual Impact Cell based on a relative adjustment. Note these are extreme examples of very high changes to illustrate the method, and not representative of typical changes.

Impact Cell 123	Probability	FLC	RP[4]
NaFRA08	0.0030	Low	338
NaFRA08 new Probability	0.0339	Significant	29
Change in 08 Probability (Factor)	10.4653	-	-
LTIS Year 25 Probability	0.0033	Low	303
LTIS Year 50 Probability	0.0051	Moderate	196
LTIS Year 100 Probability	0.0139	Significant	72
LTIS Year 25 Probability - adjusted	0.0378	Significant	26
LTIS Year 50 Probability - adjusted	0.0586	Very Significant	17
LTIS Year 100 Probability - adjusted	0.1594	Very Significant	6

Impact Cell 456	Probability	FLC	RP[4]
NaFRA08	0.5657	Very Significant	2
NaFRA08 new Probability	0.0090	Moderate	111
Change in 08 Probability (Factor)	-0.9841	-	-
LTIS Year 25 Probability	0.5884	Very Significant	2
LTIS Year 50 Probability	0.5970	Very Significant	2
LTIS Year 100 Probability	0.6399	Very Significant	2
LTIS Year 25 Probability - adjusted	0.0094	Moderate	107
LTIS Year 50 Probability - adjusted	0.0095	Moderate	105
LTIS Year 100 Probability - adjusted	0.0102	Moderate	98

The table below summarises just the probability information from the two examples above.

[4] RP is reciprocal of the probability

	NaFRA08	Year 25	Year 50	Year 100	Change Factor
Original IC123	0.0030	0.0033	0.0051	0.0139	
Original IC456	0.5657	0.5884	0.5970	0.6399	
Adjusted IC123	0.0339	0.0378	0.0586	0.1594	10.4653
Adjusted IC456	0.0090	0.0094	0.0095	0.0102	-0.9841

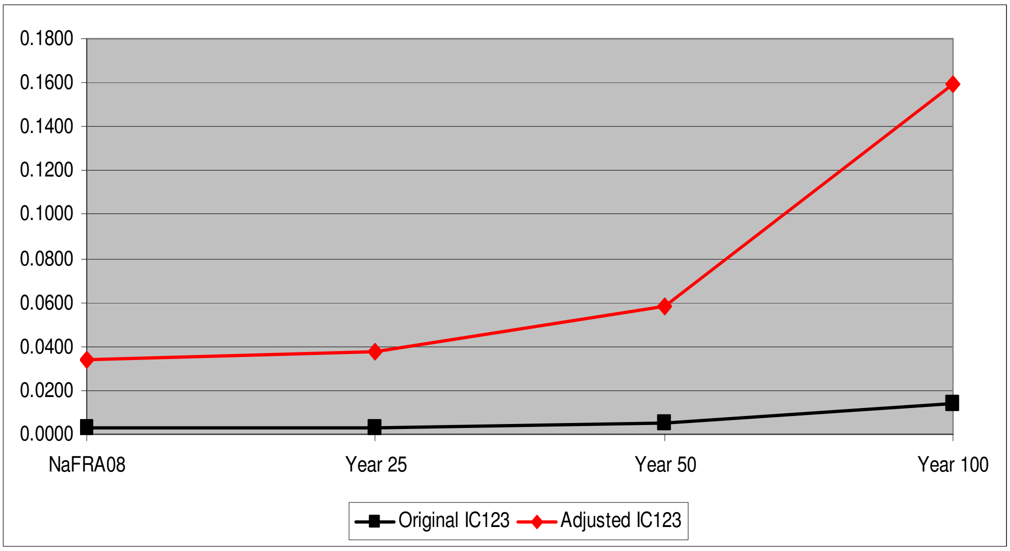


Figure 4.2 Adjusted Probabilities for Impact Cell 123 (relative)

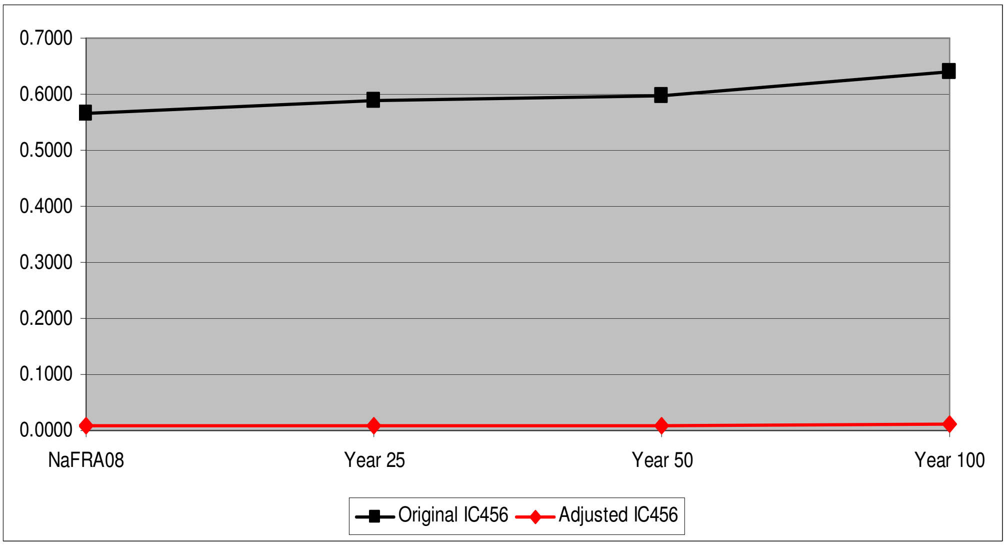


Figure 4.3 Adjusted Probabilities for Impact Cell 456 (relative)

Probability Adjustment Rules (technical text)

The general equation for adjusting the probabilities is as follows:

LTISadjPC = LTISprobPC + ([LTISprobPC]*[ChangeFactor]).

Where:

ChangeFactor = If [NaFRA_ProbPC]>0 then [adjNaFRAProb_PC]-[NaFRA_ProbPC]) / [NaFRA_ProbPC], otherwise no change (0).

Where:

- LTISprobPC = the calculated probability for LTIS future scenario
- NaFRA_ProbPC = the calculated probability from NaFRA (unadjusted)
- adjNaFRAProb_PC = the NaFRA final probability (adjusted, as published)

Where NaFRA FLC has been adjusted, the percentage of the adjustment is calculated as follows:

- *Where NaFRA probability (unadjusted) > 0*, then calculate percentage change (can be negative) and adjust the LTIS future probabilities with that percentage change.
- *Where NaFRA probability (unadjusted) = 0*, then assume a small probability percentage of 0.0999 (1:1001) for NaFRA
- *Where the LTIS Probability = 0*, set the LTIS adjusted probability to the adjusted NaFRA probability.
- *Where NaFRA FLC has been adjusted to 'No Result'*, set the LTIS adjusted probabilities to No Result (9999) for all epochs.
- Excluding the 'No Result' category, c*heck the adjusted LTIS probabilities are between 0% and 100%* and respectively set to 0 (where <0) or 100 (where >100)

It should be noted that the probabilities are adjusted only for those cells that had their Flood Likelihood Category adjusted as part of the NaFRA review process. There is a risk that underlying potential under- or overestimate of probability will remain in Impact Cells that have not been adjusted. This risk is reduced as far as possible within the NaFRA project through the Areas review process and the NaFRA project board have approved the probabilities through the approval of the flood likelihood categories.

Additionally, the following checks and, where needed, adjustments are made on the full model outputs (i.e. not restricted to impact cells where NaFRA adjustments have been made in NaFRA Area Output Review):

- *Where an impact cell is located in the Active Floodplain*, set the probability to 'Very Significant' (new in 2011)
- *Where an impact cell is located in the Disconnected Floodplain*, set the probability to 'No Result' (new in 2011)
- *Where no probability is calculated in the LTIS models*, set the probability to the NaFRA adjusted probability (new in 2011)

4.4.3 Calculation of Damages (property)

The underlying methodology to be applied for calculating the damages in the LTIS models will be the same as for the NaFRA project. Reported damages are split to residential and non-residential property types.

MCM Weighted Annual Average Damage Method

The MCM method for WAAD calculation is aimed at Strategy Study level where knowledge of flood depth and return period is poor but where the Standard of Protection (SoP), property type and numbers are known.

The tables in the MCM do not provide a distinction of damages to flood depth, but reports typical damages based on Standard of Protection. Therefore, the depth/probability curves generated in the NaFRA Models for each Impact Cell can not be fully used for the WAAD analysis. The impact of changing flood probability is represented but it is not possible to directly link to the impact on flood depths due to climate change or intervention strategy using the depth/probability curves.

Instead, the reciprocal of the probability of exceeding flood depths > 0m for each Impact Cell is used as a proxy of the Standard of Protection provided in that Impact Cell. The probability of flood depth exceeding 0m for each Impact Cell will increase with Climate Change as well as increase/decrease with each LTIS Intervention Option. Using the flood probability also ensures that the manual adjustments made to these by Area Reviews can be incorporated easily (see section 4.4.1 above).

The MCM Handbook gives typical damages for a relatively small number of Standard of Protection values, especially so for residential properties. The WAAD calculation tool developed does interpolate the typical damages between them. Typical damages for probabilities smaller than the given upper SoP band in the MCM tables have been set to typical damages of the highest SoP reported in the table. This may need to be reviewed, though there is no known evidence base to which extent to adjust the typical damages with increasing SoP. For example, Table 4.2 below is from Table 5.1 from the MCM Handbook and shows the typical damages from SoP 200 to 1000 (low probability) for Factory Bulk Class are set to 0.4/m^2. This results in an overestimation of damages for the low probabilities. It should be noted that the 200 year typical damages are half the 100 year typical damages, suggesting that the analysis underpinning the MCM tables is reliable up to a return period of 100 years.

A brief review was carried out to estimate the potential differences between using the WAAD method and using a full depth/ damage method. A number of potential factors were identified that could lead to WAAD giving different results and these were evaluated – see section 7.

The MCM update from summer 2010 includes separate typical damage tables to account for properties with and without basements. This has been included in the standard WAAD calculations as used for NaFRA, SAMPS and FACET.

Table 4.2 Example from Multi-Coloured Handbook

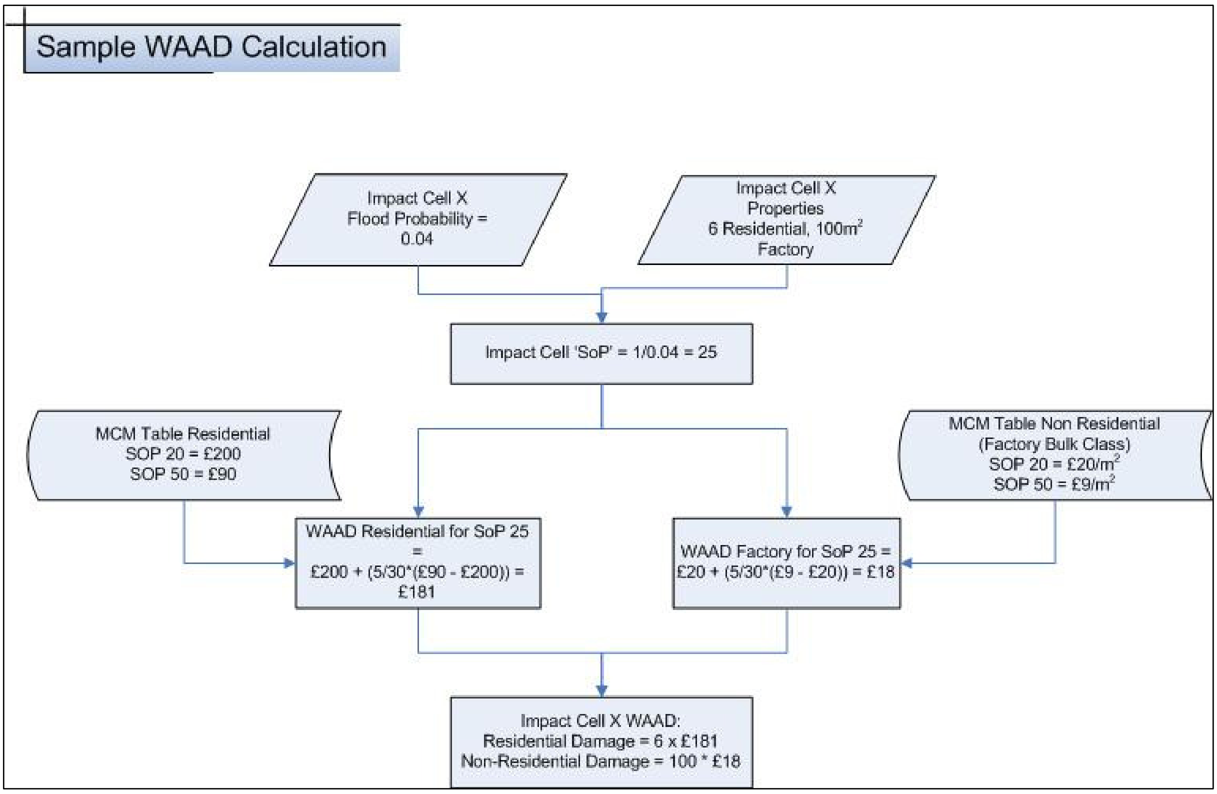
Table 5.1b Weighted annual average damage by standard of protection *without Basement*

Standard of Protection	Factory Bulk Class (£/m2)	Retail Bulk Class (£/m2)	Warehouse Bulk Class (£/m2)	Office/ other Bulk Class (£/m2)	*Non-Bulk (£/m2)*
None	26.9	32.2	25.8	25.2	25.8
2	25.0	29.9	24.0	23.4	24.0
3	23.1	27.6	22.3	21.6	22.2
4	21.2	25.4	20.5	19.9	20.4
5	19.2	23.1	18.7	18.1	18.6
6	17.7	21.2	17.2	15.2	17.0
7	16.1	19.3	15.6	12.4	15.5
8	14.6	17.4	14.1	9.5	14
9	13.0	15.5	12.6	6.7	12.5
10	11.4	13.6	11.0	10.6	10.9
15	9.7	11.6	9.4	7.8	9.3
20	7.9	9.5	7.7	5.1	7.6
25	6.2	7.4	6.0	5.7	5.9
30	5.5	6.6	5.4	4.8	5.3
35	4.9	5.8	4.7	4.0	4.7
40	4.2	5.0	4.1	3.1	4.0
45	3.6	4.2	3.5	2.2	3.4
50	2.9	3.5	2.8	2.7	2.8
55	2.7	3.2	2.6	2.4	2.6
60	2.5	2.9	2.4	2.1	2.4
65	2.2	2.7	2.2	1.9	2.1
70	2.0	2.4	2.0	1.6	1.9
75	1.8	2.2	1.8	1.3	1.7
80	1.6	1.9	1.6	1.1	1.5
85	1.4	1.6	1.3	0.8	1.3
90	1.2	1.4	1.1	0.6	1.1
95	0.9	1.1	0.9	0.3	0.9
100	0.7	0.9	0.7	0.7	0.7
200	0.4	0.4	0.4	0.3	0.3

Calculation of WAAD

Below is a worked example of the calculation of WAAD[5] for a fictional Impact Cell X which has 6 residential properties and 100m^2 of non-residential (MCM factory bulk class).

[5] Internal ref: see \\swin-fs-03\....\WNISAT\Specification\WAADcalc.vsd



Adjustments to WAAD Damages

Saline damage adjustment

The MCM tables do not make a distinction between saline and freshwater flooding. Therefore it is recommended in the MCM that the WAAD damages are uplifted by 10%.

For LTIS (and NaFRA) it is applied at an Impact Cell level to those cells within the tidal flood zone 2 extent.

Inflation

The MCM WAAD Tables baseline is summer 2010. The resultant damages from the WAAD calculation have not been increased by inflation.

> Note: the published LTIS 2009/10 was based on the previous MCM with a 2005 baseline, and a 8.3% inflation was applied to obtain figures to the then baseline year 2008 approximately in line with the increase in GDP over that period

Inflation for damages in each of the future epochs has not been applied on the NaFRA model outputs. However, the policy analysis tool includes functionality to explicitly apply inflation.

4.4.4 Calculation of Damages (Agriculture)

The underlying methodology applied for calculating the damages and hectares to Agricultural Land in the LTIS is the same as applied for the System Asset Management Plan (SAMPS) Benefit Reports.

Damages to agricultural land are calculated using the 1:250k Agricultural Land Classification (ALC) datasets for England and Wales and the modelled flood probabilities for each scenario. See Appendix C.5 for explanation of the Grades.

The damage cost per hectare for each land class applied is based on the methodology described in 'The Benefits of Flood and Coastal Risk Management: A Manual of Assessment Techniques' (Penning-Rowsell et al., 2005). These figures can be seen in Table 4.3 below.

Table 4.3. Agricultural Damage (£/ha) by Land Class

	ALC Grade				
	1	**2**	**3**	**4**	**5**
£/ha	1,16	770	280	50	20

Using these figures the agricultural damages are calculated as:

£Annual Damages = Annual Flood Probability x Land Area (ha) by Class x Agricultural Damage (£/ha) by Class.

4.4.5 Interpretation of key LTIS variables

The table below summarises how the key LTIS variables are reflected in the proposed WAAD methodology. These expected results were verified using a sample of early catchment outputs from the LTIS risk model runs

Variable	Result[6]
Policy	Policy will be reflected in a change in probability in an impact cell over time associated with increase/reduction in protection afforded by assets. This will result in a variation in estimated annual average damage.
Climate change	Climate change will result in a change in probability in an impact cell over time associated with increase in water level. This equates to a reduction in protection afforded by assets resulting in a variation in estimated annual average damage.
Inflation	Inflation will result in an adjustment to the damages per SoP in the WAAD tables. MCM damage tables are baselined summer 2010 and have not been inflated. Inflationary increases associated with each epoch need to be applied in the Policy Analysis Tool.
Efficiency	Not applicable to risk calculation

[6] Impact of each variable is assessed in isolation here. In practice a number of variables interact in each intervention option.

4.5 Risk Assessment for Coastal Erosion

The assessment of future coastal erosion is based on preliminary, though largely validated, model outputs from the National Coast Erosion Risk Mapping project (NCERM) on future coast erosion.

At the time of the LTIS extract of data from NCERM database (November 2011), the fast majority of erodible frontages in England and Wales had been assessed by Local Authorities, the Environment Agency and Halcrow, and were validated against information from Shoreline Management Plans (SMP2).

NCERM models the 5%, 50% and 95% confidence limits of the erosion predictions. In order to be consistent with the data being presented for flooding, the 50%-ile erosion zones have been used. The number of properties that could be at risk has been assessed over four epochs: 0 to 10 years, 10 to 25 years, 25 to 50 years and 50 to 100 years.

4.5.1 Erosion Risk Reporting in FACET

Impacts of coastal erosion are included but defined differently from Flood Categories: for each Epoch, the number of *properties lost* (0 at Year 0) and the number of *properties at risk* (inside the Year 0-100 erosion zone) are provided.

4.5.2 Climate Change impact on erosion – discussion

It must be emphasised that meaningful future assessments can only be made by users for their local coast due to their good local knowledge. Broadscale assessments based on generic national/regional changes to input data should not be undertaken in this way as the results will be highly inaccurate and misleading at the local level due to the lack of local interpretation needed to ensure that parameters are varied in an appropriate way, which will vary with location.

Coastal erosion is dependant on two factors - the prevailing nearshore conditions and the geotechnical properties of the coast. It is necessary to consider how climate change will affect the range of characteristics that comprise each of these factors in order to determine its overall impact on predicted future coastal erosion.

Considering the nearshore climate in the first instance, this is comprised of a number of features (e.g. wave climate, water levels, currents, sediment transport, bathymetry and their associated normal ranges), each of which will have different sensitivities to the mechanisms of climate change and thus be affected in different ways. The nature and magnitude of these effects will also be highly dependant on the particular location and orientation of coastline - thus the effects of climate change will vary along the coast.

Considering geotechnical characteristics, these also vary along the coast and climate change will affect coast with different geotechnical properties in different ways - for instance a coastline comprised of granite cliffs will not suffer any significant increase in erosion due to larger waves caused by climate change even if it is in a very exposed location, whilst chalk cliffs will always erode more quickly when subjected to more aggressive wave action. As well as basic geology, the nature of the coast also needs to be considered, for instance is it low-lying or cliffs, are cliffs simple and stable or complex cliffs liable to landslides. For the NCERM project, the original dataset used to represent geotechnical conditions along the coast was the original unconstrained erosion dataset produced by the Futurecoast project. This project considered the geotechnical properties of the coast of England and Wales and estimated ranges of potential erosion rates along the coast. These predictions included consideration of the susceptibility to key climate change impacts that are most relevant to erosion, namely, sea level rise, storm surges, wave climate and precipitation. This assessment was revisited during NCERM using the UKCP09 scenarios to consider whether the range of erosion predicted was still applicable. This concluded that for simple cliffs it was, but for complex cliffs the uncertainty was so onerous that these areas should be treated differently in the published erosion maps.

Thus, **climate change impacts are not and cannot be considered in absolute terms** such as definite erosion rates or ranges of erosion rates - there is too much uncertainty involved and there are not direct linear links between changes in climatic conditions and erosion rates. It is also worth noting that the existing research on links between climate change impacts and erosion is virtually non-existent.

The NCERM project does not use average erosion rates - they are banded due to the inherent uncertainty in their prediction, as they were in Futurecoast.

For the purposes of FACET, assessment of erosion is carried out using the 50%ile erosion assessment, thus contravening the NCERM advice. However, this is necessary in order to facilitate the analysis of economic impacts alongside that for the national flood risk assessment. For FACET the national or regional assessment is an indicative analysis, and not aiming to accurately assess local impacts.

4.5.3 Economic Assessment

Properties at risk from coastal erosion are based on the same National Receptor Dataset Property Point Layer (NRDv1.1) that is used to assess properties at risk from flooding (NaFRA 2010/11). Within the LTIS, flood risk is the primary mechanism, i.e. the erosion analysis (as NCERM) does not assess erosion in low-lying, flood prone areas. For that reason, properties inside Flood Zone 2 have been excluded from the coastal erosion analysis.

The NRD does not contain market valuations for residential property nor non-residential property. The data was obtained for properties outside Flood Zone 2 and inside the 100 year unconstrained erosion line from Land Registry for residential properties (Land Registry, 2011), and Office for National Statistics for non-residential property (ONS, 2008).

For non-residential property the average rateable value per m^2 is multiplied by the property floor area (present in NRD), and in line with advice in the Multi Coloured Manual multiplied by 10 to obtain the capital value. The rateable value is available to the MCM bulk classes for each Local Authority.

For residential property the market value of March 2011 is taken from the Land Registry by Local Authority and by house type (present in NRD).

Some property types are excluded from the property analysis in line with Environment Agency guidance for property counts, and as applied for NaFRA and the Flood Map for Surface Water Map based property counts.

The economic damages are calculated as total over each epoch. For FACET these totals are then averaged over the number of years in the epoch to obtain a nominal 'average annual' economic damage.

5 Expenditure Forecast Tool

5.1 Introduction

The following section outlines the method used in the expenditure tool.

The tool follows the same principals as the rest of FACET. Asset deterioration is assessed over time to understand when they would need replacing. At that replacement date a decision is made about the size of the asset that is rebuilt. Both maintenance and replacement expenditure is assessed within this model.

The expenditure forecast tool involves fewer computations than the risk forecast tool therefore it can be run at yearly intervals, as opposed to epochs.

5.2 Source of asset information

Asset information is taken from the NFCDD dataset (February 2011). Information used for analysis included:

- Asset type[7]
- Length
- Current condition grade
- Asset category – fluvial, tidal or coastal

Coast protection assets (taken from NCERM, November 2011)

To ensure the coast protection assets are distinct from flood defences, five new coast protection classes have been added to the master RASP classification (see Appendix C), in line with the classification used in NCERM.

5.3 Cost Updates for 2011

For LTIS Improvements 2011 the costs and confidence rating were updated in the following way:

- All costs were inflated to Q4 2010/11 prices using the BIS Output Prices Indices. This supersedes the Construction Output Price Index (COPI) for new Public Works (non-roads) index used in 2008 study. Since a different index has been used, all costs were updated from their original base. Unlike the original costs calculated in 2008 a separate indices was used for Capital (replacement) and Maintenance costs.

---

[7] RASP classification is utilised in the NaFRA models and carried into the LTIS processes. The classification is reproduced in Appendix C

- A draft of the Environment Agency Evidence Project SC080039 Long Term Costing report 2011 (Environment Agency, 2011b) was used as the primary source of new data. The report took data from a number of sources and these were used for the FACET update in order to refine the cost and increase the confidence ratio. On defence classes where more data was available the cost was refined and/or the confidence ratio was increased. Where a range was given in the Long Term Costing report either an average was taken or the same assumption on size and length etc was used as for the LTIS 2009/10 assessment of typical costs (for example, average wall heights and culvert sizes).
- The new sources of data were:
  - Environment Agency (2010). FCRM Asset Management, Maintenance Standards, V2
  - Scottish Natural Heritage (2000). A Guide to Managing Coastal Erosion in Beach/Dune Systems
  - Environment Agency's Flood Risk Management Estimating Guide (2007 version)
  - The EAs Unit Cost Database (UCD) 2010
- The interpretation in the draft Long Term Costing report (SC080039, Environment Agency, 2011b) of the UCD 2010 was checked and found that the costs were consistent.

> All replacement costs were updated to Q4 2010/11 prices (with the new index), which has reduced all prices by 9%. Due to the new data sets a few costs have reduced further but the majority of changes due to additional data has increased the cost of the defence classes by up to double in some cases. It should be noted that other than the universal 9% decrease, only 30% of costs were further updated.
>
> The only change to the maintenance costs is inflation to Q4 2010/11 prices, and two confidences grades were increased due to additional costs from the Environment Agency's UCD.

5.4 Source of typical maintenance costs

Maintenance costs, derived from NADNAC information was incorporated into the model. Where possible, this was compared against information from the TE2100 study. Baseline maintenance costs were based on costs per unit length of assets (see Table 5.1 Typical Maintenance Costs below)

For LTIS Improvements 2011, the only change to the maintenance costs is inflation to Q4 2010/11 prices, and two confidences grades were increased due to additional costs from the EA's UCD.

Table 5.1 Typical Maintenance Costs

	Price base	2010/11 Q4 prices				
Defence Class	£Cost/km/yr Price base Q1 2006	Price base under (B) uplifted	Exemplar Site	Long Term Costing report £Cost/km/yr	Percentage of base costs	Confidence rating (1 = high, 5 = low)
(A)	(B)	(C)	(D)	(E)	(F) = (D)/(C)	
1	£4,813	£5,645	£0	£0	0%	5
2	£4,813	£5,645	£0	£0	0%	5
3	£4,813	£5,645	£0	£0	0%	5
4	£8,245	£9,671	£0	£217	0%	5
5	£8,245	£9,671	£2,985	£217	31%	4
6	£8,245	£9,671	£3,469	£217	36%	4
7	£4,064	£4,767	£0	£0	0%	5
8	£4,064	£4,767	£0	£0	0%	5
9	£4,064	£4,767	£2,775	£0	58%	4
10	£2,879	£3,377	£2,054	£2,637	61%	4
11	£2,879	£3,377	£0	£0	0%	5
12	£2,879	£3,377	£2,365	£0	70%	4
13	£2,879	£3,377	£0	£0	0%	5
14	£4,813	£5,645	£0	£0	0%	5
15	£4,813	£5,645	£0	£0	0%	5
16	£4,813	£5,645	£0	£0	0%	5
17	£2,879	£3,377	£0	£0	0%	5
18	£2,879	£3,377	£0	£0	0%	5
19	£2,879	£3,377	£3,561	£0	105%	1
20	£2,879	£3,377	£0	£0	0%	5
21	£4,129	£4,843	£0	£2,818	0%	5
22	£4,184	£4,908	£0	£0	0%	5
23	£4,184	£4,908	£7,589	£0	155%	3
24	£4,184	£4,908	£2,775	£0	57%	3
25	£12,107	£14,201	£0	£0	0%	5
26	£12,107	£14,201	£0	£0	0%	5
27	£12,107	£14,201	£0	£0	0%	5
28	£6,441	£7,555	£0	£0	0%	5
29	£6,441	£7,555	£2,985	£0	40%	4
30	£6,441	£7,555	£3,469	£0	46%	4
31	£3,815	£4,475	£2,054	£0	46%	4
32	£3,815	£4,475	£2,365	£0	53%	3

	Price base	2010/11 Q4 prices				
Defence Class	£Cost/km/yr Price base Q1 2006	Price base under (B) uplifted	Exemplar Site	Long Term Costing report £Cost/km/yr	Percentage of base costs	Confidence rating (1 = high, 5 = low)
(A)	(B)	(C)	(D)	(E)	(F) = (D)/(C)	
33	£3,815	£4,475	£3,561	£0	80%	2
34	£8,311	£9,748	£0	£0	0%	5
35	£8,311	£9,748	£0	£0	0%	5
36	£8,311	£9,748	£0	£0	0%	5
37	£0	£0	£0	£0		5
38	£26,702	£31,320	£0	£0	0%	5
39	£4,813	£5,645	£0	£0	0%	5
40	£4,813	£5,645	£0	£0	0%	5
41	£8,245	£9,671	£0	£0	0%	5
42	£8,245	£9,671	£0	£0	0%	5
43	£4,064	£4,767	£0	£0	0%	5
44	£4,064	£4,767	£7,589	£0	159%	4
45	£2,879	£3,377	£0	£0	0%	5
46	£2,879	£3,377	£0	£0	0%	5
47	£2,879	£3,377	£0	£0	0%	5
48	£4,813	£5,645	£0	£0	0%	5
49	£4,813	£5,645	£0	£0	0%	5
50	£2,879	£3,377	£0	£0	0%	5
51	£2,879	£3,377	£0	£0	0%	5
52	£4,184	£4,908	£0	£0	0%	5
53	£4,184	£4,908	£0	£0	0%	5
54	£12,107	£14,201	£0	£0	0%	5
55	£12,107	£14,201	£0	£0	0%	5
56	£6,441	£7,555	£0	£0	0%	5
57	£6,441	£7,555	£0	£0	0%	5
58	£3,815	£4,475	£0	£0	0%	5
59	£3,815	£4,475	£0	£0	0%	5
60	£3,815	£4,475	£0	£0	0%	5
61	£3,815	£4,475	£0	£0	0%	5

Appendix C contains the full listing utilised in the Expenditure Forecast Tool, including typical costs for coast protection assets.

5.5 Source of typical replacement costs

5.5.1 National Assessment of Defence Needs And Costs (NADNAC)

NADNAC data provides maintenance cost for all defence classes and replacement cost for majority of them.

Construction Output Price Index[8] (COPI) for new Public Works (non-roads) has been used to inflate NADNAC cost from 2006 Q1 to 2008 Q2. Replacement costs have been uplifted to Q4 2010/11 using the BIS output price index for All new Construction (COPI).

5.5.2 Unit Cost Database (UCD) and Long Term Costing (SC080039)

In UCD, replacement costs information is provided for different structure types, e.g. walls, embankments, culverts etc. These broad categorisations have been applied to relevant defence classes. Average costs of each type of asset have been taken from the UCD, assuming average construction duration. No maintenance cost information is available in UCD.

COPI factor was used to inflate UCD cost from 2006 Q1 to the 2010/11 base.

The interpretation in the draft Long Term Costing report (SC080039, Environment Agency, 2011b) of the UCD 2010 was checked and found that the costs were consistent. The information has been used to inform the confidence rating given to the costs. See also section 5.3.

5.5.3 Thames Estuary 2100 (TE2100) project

The TE2100 project developed replacement costs for 15 'exemplar sites' in the Thames Estuary. The exemplar sites represented the broad range of asses found within the estuary. These exemplar defence types have been applied to relevant defence classes. Assumptions were made when assigning the defence classes to the exemplar sites as the exemplar sites were often made up of a number of different defence types. Where a number of defence types exist, the principal structure that provided the protection is used to map to defence classes.

Prices were inflated to the 2010/11 base.

5.5.4 FACET Asset Replacement Costs

Based on the data sources described in the previous sub sections typical replacement costs were established for FACET expenditure modelling.

[8] BERR Quarterly building price and cost indices

Where an asset is replaced it is assumed that it will be replaced by a similar asset type. It is recognised that this is an over simplification and that an area currently protected by a flood wall may be protected in the future by upstream storage however it is assumed that replacing with like for like defences represents a proxy cost for other types of structural interventions.

For LTIS Improvements 2011, all costs were updated to Q4 2010/11 prices (with the new index), which has reduced all prices by 9%. Due to the new data sets a few costs have reduced further but the majority of changes due to additional data has increased the cost of the defence classes by up to double in some cases. It should be noted that other than the universal 9% decrease, only 30% of costs were further updated. For these additional 30%, the confidence class was increased, if there was a good correlation between all the sources, which will increase accuracy in the LTIS model.

Table 5.3 below gives a breakdown of replacement cost by defence class from these sources for the flood defences.

For costs of coast protection engineering judgement was used to assess typical costs through mapping the coast protection types to an equivalent flood defence in Table 5.2

Appendix C contains the lookup tables used for the Expenditure Forecast Tool, which are from the Table 5.3 below. Costs by asset type are held by defence type (Fluvial, Tidal or Coastal) and by EA Region. Note though that cost values are not differentiated by region or defence protection type in this update to the FACET.

Table 5.2 Coast Protection Asset typical replacement costs

Class No	Asset Description	Equivalent RASP Defence Class (if appropriate)	Cost per linear kilometre (£)	Comments
100	Embankment	51: Type 2, W, CP, Flexible: Slopes or embankments	£ 1,891,085	
110	Gabions	39: Type 1, W, FP, Gabions: Vertical walls	£ 1,105,758	
120	Natural	COST NOT REQUIRED		
130	Revetment	*59: Type 6, W, CP, Perm: Dykes or embankments- cost not used*	£ 4,732,221	Flood defence cost too low for a coastal revetment. Increased value per km.
140	Seawall	26: Type 5, CP, Conc: Vertical walls	£ 7,499,071	
150	Timber Structures	No RASP type. *Timber structures will include assets such as timber groynes and timber breastwork.*	£ 1,325,022	A typical replacement cost for a timber groyne is £100k. Using an indicative spacing of 75m per groyne, there would be 14 groynes per kilometre

Table 5.3 Typical Replacement Costs

Defence Class		NADNAC - Total Project Cost per km		Average cost from TE2100 exemplar sites per km		TE2100 cost as % of NADNAC cost	Unit Cost Database prices per km		UCD cost as % of NADNAC cost	Adopted cost per km		Comment/ Assumption	Confidence rating
		2006 Q1	2010/11	2007 Q4	2010/11		2006 Q1	2010/11		Source	Value		
1	Type 1, FP, Gabions	x	£957,402							NADNAC	£957,402	Note 1 Only change is update to 2011 prices	5
2	Type 1, CP, Gabions	x	£957,402							NADNAC	£957,402	Note 1 Only change is update to 2011 prices	5
3	Type 1, RP, Gabions	x	£957,402							NADNAC	£957,402	Note 1 Only change is update to 2011 prices	5
4	Type 1, FP, B&M	£5,113,114	£5,284,695		£0	0%	£4,710,000	£4,868,054	92%	NADNAC	£5,284,695	close match with unit cost database Only change is update to 2011 prices	2
5	Type 1, CP, B&M	£5,162,717	£5,335,963	£2,520,000	£2,423,336	45%	£4,710,000	£4,868,054	91%	NADNAC	£5,335,963	close match with unit cost database Only change is update to 2011 prices	2
6	Type 1, RP, B&M	£5,267,262	£5,444,016	£2,760,000	£2,654,130	49%	£4,710,000	£4,868,054	89%	NADNAC	£5,444,016	close match with unit cost database Only change is update to 2011 prices	2
7	Type 1, FP, Piles	£1,585,356	£1,638,556		£0	0%	£2,139,000	£2,210,779	135%	UCD (2010)	£2,048,769	Update to UCD 2011 prices, no change in confidence	3
8	Type 1, CP, Piles	£1,635,685	£1,690,574		£0	0%	£2,139,000	£2,210,779	131%	UCD (2010)	£2,048,769	Update to UCD 2011 prices, no change in confidence	3
9	Type 1, RP, Piles	£1,729,398	£1,787,431	£5,180,000	£4,981,302	279%	£2,139,000	£2,210,779	124%	UCD (2010)	£2,048,769	Update to UCD 2011 prices, no change in confidence	3
10	Type 2, FP, Turf	£803,644	£830,612		£0	0%	£824,000	£851,651	103%	UCD (2010)	£1,093,183	Update to UCD 2011 prices, no change in confidence	2
11	Type 2, FP, Rigid	£1,336,029	£1,380,862		£0	0%		£0	0%	NADNAC	£1,380,862	Only change is update to 2011 prices	5
12	Type 2, CP, Rigid	x	£1,909,756							NADNAC	£1,909,756	Same as defence class 13 Only change is update to 2011 prices	5
13	Type 2, RP, Rigid	£1,847,751	£1,909,756		£0	0%		£0	0%	NADNAC	£1,909,756	Only change is update to 2011 prices	5
14	Type 2, FP, Rip-rap	£1,124,628	£1,162,367		£0	0%		£0	0%	NADNAC	£1,162,367	Only change is update to 2011 prices	5
15	Type 2, CP, Rip-rap	£1,242,650	£1,284,350		£0	0%		£0	0%	NADNAC	£1,284,350	Only change is update to 2011 prices	5
16	Type 2, RP, Rip-rap	£1,637,393	£1,692,339		£0	0%		£0	0%	NADNAC	£1,692,339	Only change is update to 2011 prices	5

Defence Class		NADNAC - Total Project Cost per km		Average cost from TE2100 exemplar sites per km		TE2100 cost as % of NADNAC cost	Unit Cost Database prices per km		UCD cost as % of NADNAC cost	Adopted cost per km		Comment/ Assumption	Confidence rating
		2006 Q1	2010/11	2007 Q4	2010/11		2006 Q1	2010/11		Source	Value		
17	Type 2, FP, Flexible	x	£1,847,844							NADNAC	£1,847,844	Same as defence class 19 Only change is update to 2011 prices	2
18	Type 2, CP, Flexible	x	£1,847,844							NADNAC	£1,847,844	Same as defence class 19 Only change is update to 2011 prices	2
19	Type 2, RP, Flexible	£1,787,849	£1,847,844	£2,160,000	£2,077,145	112%		£0	0%	NADNAC	£1,847,844	close match with TE2100 Only change is update to 2011 prices	2
20	Type 3, High Ground	x									£0		5
21	Type 4, Culverts	x					£1,520,000	£1,571,007		UCD (2010)	£1,571,007	cost of 200m*4.4m culvert used as average size Update to UCD 2010 and then to 2011 prices, no change in confidence	3
22	Type 5, FP, Piles	x	£3,277,112					£4,421,557	135%	NADNAC	£3,277,112	Changed to NADNAC inflated price and confidence increased as better correlation to UCD 2011	2
23	Type 5, CP, Piles	x	£3,381,147					£4,421,557	131%	NADNAC	£3,381,147	Changed to NADNAC inflated price and confidence increased as better correlation to UCD 2011	2
24	Type 5, RP, Piles	x	£3,574,863					£4,421,557	124%	NADNAC	£3,574,863	Changed to NADNAC inflated price and confidence increased as better correlation to UCD 2011	2
25	Type 5, FP, Conc	x	£7,214,385							NADNAC	£7,214,385	Same as defence class 26 Increase in confidence due to UCD 2010 agreeing closely with NADNAC cost	3
26	Type 5, CP, Conc	£6,980,152	£7,214,385		£0	0%		£0	0%	NADNAC	£7,214,385	Increase in confidence due to UCD 2010 agreeing closely with NADNAC cost	3
27	Type 5, RP, Conc	£7,345,040	£7,591,518		£0	0%		£0	0%	NADNAC	£7,591,518	Increase in confidence due to UCD 2010 agreeing closely with NADNAC cost	3
28	Type 5, FP, B&M	x	£7,277,771							NADNAC	£7,277,771	Same as defence class 29 Only change is update to 2011 prices	5
29	Type 5, CP, B&M	£7,041,480	£7,277,771	£2,520,000	£2,423,336	33%		£0	0%	NADNAC	£7,277,771	Only change is update to 2011 prices	5

Defence Class		NADNAC - Total Project Cost per km		Average cost from TE2100 exemplar sites per km		TE2100 cost as % of NADNAC cost	Unit Cost Database prices per km		UCD cost as % of NADNAC cost	Adopted cost per km		Comment/ Assumption	Confidence rating
		2006 Q1	2010/11	2007 Q4	2010/11		2006 Q1	2010/11		Source	Value		
30	Type 5, RP, B&M	£7,406,323	£7,654,857	£2,760,000	£2,654,130	35%		£0	0%	NADNAC	£7,654,857	Only change is update to 2011 prices	5
31	Type 6, FP, Perm	£1,275,861	£1,318,676	£6,636,000	£6,381,452	484%		£0	0%	Average of all except TE2100	£2,346,575	Additional costs which correlate reasonable, and average was used and confidence increased	2
32	Type 6, CP, Perm	x	£1,318,676							Average of All	£2,346,575	Same as defence class 31 Additional costs which correlate reasonable, and average was used and confidence increased	1
33	Type 6, RP, Perm	x	£1,318,676							Average of All	£2,346,575	Same as defence class 32 Additional costs which correlate reasonable, and average was used and confidence increased	1
34	Type 6, FP, Imperm	£1,336,029	£1,380,862		£0	0%		£0	0%	Average of All	£3,023,789	Additional costs which correlate reasonable, and average was used and confidence increased	2
35	Type 6, CP, Imperm	x	£1,380,862							Average of All	£3,023,789	Same as defence class 34 Additional costs which correlate reasonable, and average was used and confidence increased	2
36	Type 6, RP, Imperm	x	£1,380,862							Average of All	£3,023,789	Same as defence class 34 Additional costs which correlate reasonable, and average was used and confidence increased	2
37	Type 7, Dune	x	£0							UCD 2010	£2,182,570	No value previously	5
38	Type 7, Shingle	£3,068,962	£3,171,947		£0	0%		£0	0%	NADNAC	£3,171,947	Only change is update to 2011 prices	5
39	Type 1, W, FP, Gabions	x	£1,063,780							NADNAC	£1,063,780	Same as defence class 40 Only change is update to 2011 prices	5
40	Type 1, W, CP, Gabions	£1,029,242	£1,063,780		£0	0%		£0	0%	NADNAC	£1,063,780	Only change is update to 2011 prices	5
41	Type 1, W, FP, B&M	£5,113,114	£5,284,695		£0	0%	£4,710,000	£4,868,054	92%	NADNAC	£5,284,695	close match with unit cost database Only change is update to 2011 prices	2
42	Type 1, W, CP, B&M	£5,195,783	£5,370,138		£0	0%	£4,710,000	£4,868,054	91%	NADNAC	£5,370,138	close match with unit cost database Only change is update to 2011 prices	2

Defence Class		NADNAC - Total Project Cost per km		Average cost from TE2100 exemplar sites per km		TE2100 cost as % of NADNAC cost	Unit Cost Database prices per km		UCD cost as % of NADNAC cost	Adopted cost per km		Comment/ Assumption	Confidence rating
		2006 Q1	2010/11	2007 Q4	2010/11		2006 Q1	2010/11		Source	Value		
43	Type 1, W, FP, Piles	x	£1,725,240							Unit cost database	£2,139,000	Same as defence class 44 Only change is update to 2011 prices	5
44	Type 1, W, CP, Piles	£1,669,226	£1,725,240	£6,636,000	£6,381,452	370%	£2,139,000	£2,210,779	128%	Unit cost database	£2,139,000	median value Only change is update to 2011 prices	4
45	Type 2, W, FP, Turf	£995,476	£1,028,881	£1,080,000	£1,038,573	101%	£1,008,000	£1,041,826	101%	UCD (2010)	£1,336,113	close match with unit cost database and TE2100 Update to UCD 2011 prices, no change in confidence	1
46	Type 2, W, FP, Rigid	£1,526,537	£1,577,763		£0	0%		£0	0%	NADNAC	£1,577,763	Only change is update to 2011 prices	5
47	Type 2, W, CP, Rigid	x	£1,577,763							NADNAC	£1,577,763	Same as defence class 46 Only change is update to 2011 prices	5
48	Type 2, W, FP, Rip-rap	£1,315,577	£1,359,724		£0	0%		£0	0%	NADNAC	£1,359,724	Only change is update to 2011 prices	5
49	Type 2, W, CP, Rip-rap	£1,609,736	£1,663,754		£0	0%		£0	0%	NADNAC	£1,663,754	Only change is update to 2011 prices	5
50	Type 2, W, FP, Flexible	£1,466,473	£1,515,684		£0	0%		£0	0%	NADNAC	£1,515,684	Only change is update to 2011 prices	5
51	Type 2, W, CP, Flexible	£1,760,226	£1,819,294		£0	0%		£0	0%	NADNAC	£1,819,294	Only change is update to 2011 prices	5
52	Type 5, W, FP, Piles	x	£3,277,112		£0	0%		£4,421,557	135%	UCD (2010)	£3,277,112	Same as defence class 22 Reduced confidence as it appears to be set too high in 2008 (was 3)	5
53	Type 5, W, CP, Piles	x	£3,381,147	£6,636,000	£6,381,452	370%		£4,421,557	128%	Average	£4,693,378	Same as defence class 23 Only change is update to 2011 prices	4
54	Type 5, W, FP, Conc	x	£7,333,668							NADNAC	£7,333,668	Same as defence class 55 Only change is update to 2011 prices	5
55	Type 5, W, CP, Conc	£7,095,562	£7,333,668		£0	0%		£0	0%	NADNAC	£7,333,668	Only change is update to 2011 prices	5
56	Type 5, W, FP, B&M	x	£7,397,030							NADNAC	£7,397,030	Same as defence class 57 Only change is update to 2011 prices	5
57	Type 5, W, CP, B&M	£7,156,867	£7,397,030		£0	0%		£0	0%	NADNAC	£7,397,030	Only change is update to 2011 prices	5
58	Type 6, W, FP, Perm	£1,466,473	£1,515,684		£0	0%		£0	0%	Average of All	£2,395,827	Additional costs which correlate reasonable, and average was used and confidence increased	1

Defence Class		NADNAC - Total Project Cost per km		Average cost from TE2100 exemplar sites per km		TE2100 cost as % of NADNAC cost	Unit Cost Database prices per km		UCD cost as % of NADNAC cost	Adopted cost per km		Comment/ Assumption	Confidence rating
		2006 Q1	2010/11	2007 Q4	2010/11		2006 Q1	2010/11		Source	Value		
59	Type 6, W, CP, Perm	£1,759,715	£1,818,766		£0	0%		£0	0%	Average of All	£2,471,598	Additional costs which correlate reasonable, and average was used and confidence increased	1
60	Type 6, W, FP, Imperm	£1,526,537	£1,577,763		£0	0%		£0	0%	Average of All	£3,089,423	Additional costs which correlate reasonable, and average was used and confidence increased	2
61	Type 6, W, CP, Imperm	£1,820,127	£1,881,205		£0	0%		£0	0%	Average of All	£3,190,570	Additional costs which correlate reasonable, and average was used and confidence increased	2

Note 1: Narrow Gabions (not in NADNAC, 2006 dataset) cost = 90% of wide gabion cost (defence class 40)

"x" indicates data unavailable in NADNAC

5.6 Modelling uncertainty

Replacement and maintenance costs have a range of uncertainty. This is due to a number of factors including:

- Variation in defence location. Urban defences may be harder to access therefore more costly to replace than the average.
- Variation in construction costs. Construction rates vary from London to (for example) the North East
- Variation in asset type within the defence class
- Variation in asset size

In order to reflect this uncertainty Monte Carlo analysis was used to derive confidence banded outputs. An assessment was made into the confidence associated with the input variables. A standardised weighting method was used based on the following rational:

- FCD PAG advises the use of optimum bias factor of 60% for flood defence cost estimates during feasibility studies. This factor has been used as the "average" upper bound. The other upper bound values were based on this value.
- It is more likely for the final project costs to exceed estimates (budget over-run), than project completed below budget. Lower bound factors are, therefore, less than that of the upper bounds.

Confidence Rating	Description	@Risk factors	
		Lower	Upper
1	High confidence in cost data	- 20%	+ 40%
2	Good	- 25%	+ 50%
3	Average	- 30%	+ 60%
4	Poor	- 30%	+ 80%
5	Minimum	- 35%	+ 100%

Where little or no comparative data was available, or where the comparative data gave different results a low confidence score was applied.

5.7 Application of policy options

The following variables were assessed to have a significant impact on expenditure on assets:

- Variation in asset condition – used for all policies
- Baseline replacement cost – used in policies 3, 4, 5 and 6
- Climate change uplift factor – used in Policies 4 and 5
- SoP uplift factor – used in policy 5
- Baseline maintenance cost – used in policies 2, 3, 4 and 5
- Deterioration maintenance uplift factor – used in policies 2, 3, 4 and 5

The application of these variables is discussed in more detail in the sections below.

5.8 Variation of asset condition

Asset deterioration predictions have been incorporated into the model using the national asset deterioration curves included in Appendix C, curves for the Coast Protection Assets have been added.

Asset deterioration rates have been estimated as part of the NaFRA project for 60 different asset types and the four coast protection asset types (Appendix C, Condition and Replacement).

An asset's condition is assessed at each year and is dependent on the policy option. Policy 1 and 6 use an accelerated 'no maintenance' deterioration whilst the remaining policies use a 'with maintenance' deterioration rate (Appendix C).

In 2011/12 the asset condition deterioration curves used for the Risk Forecast and Expenditure Forecast modelling have been updated based on information available from Asset deterioration and whole life costing. The deterioration curves were peer-reviewed and finalised in October 2011 (Environment Agency, 2012a)

5.9 Variation of maintenance cost

A maintenance uplift factor was included to account for findings from the TE2100 project that maintenance costs increase in-line with defence deterioration. An asset that is condition grade 3 will cost more to maintain than an asset that is condition grade 1. Figure 5.1 shows the relationship between maintenance cost and condition grade.

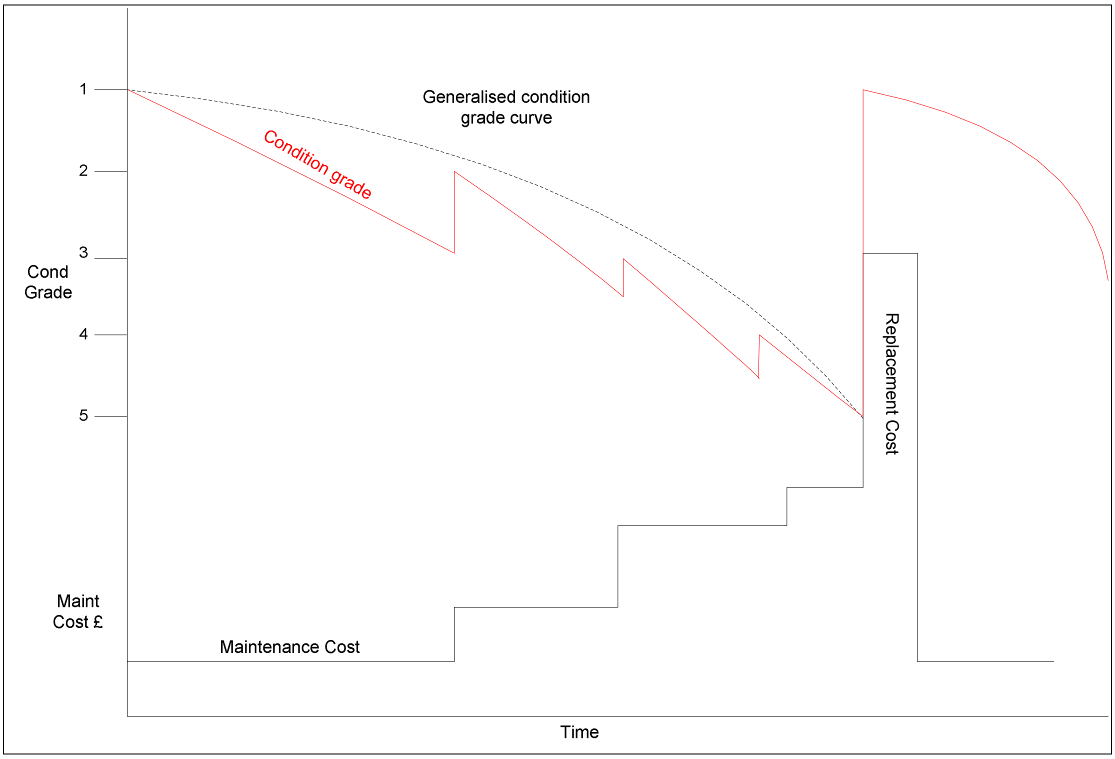


Figure 5.1 Diagram depicting relationship between maintenance cost and condition grade

5.9.1 Policy 1

For Policy 1 the maintenance costs are set to £0. No costs are included in the LTIS related to health & safety, removal of the asset, etc.

Implementation of Policy 1 for the risk assessment assumes that active assets are operational. Costs for maintaining and operating these assets are currently not modelled within FACET.

5.9.2 Policy 2

Assets are maintained until they reach condition grade 5. The maintenance costs are set to a fixed amount per annum thereafter (currently this is set to £0 per annum).

The maintenance uplift factor related to the condition grade of the asset is applied to the annual maintenance costs.

5.9.3 Policy 3, 4 and 5

For these policies the annual asset maintenance costs are calculated as for Policy 2 including the condition grade uplift. The difference is that the asset is being replaced and the cycle of maintenance restarts with the asset at condition grade 1.

5.9.4 Policy 6

For Policy 6 the maintenance costs are set to £0. The asset is being replaced and the cycle of asset deterioration restarts with the asset at condition grade 1. The accelerated, no-maintenance asset deterioration curve is applied.

5.10 Variation of replacement cost

5.10.1 Policies 1 and 2

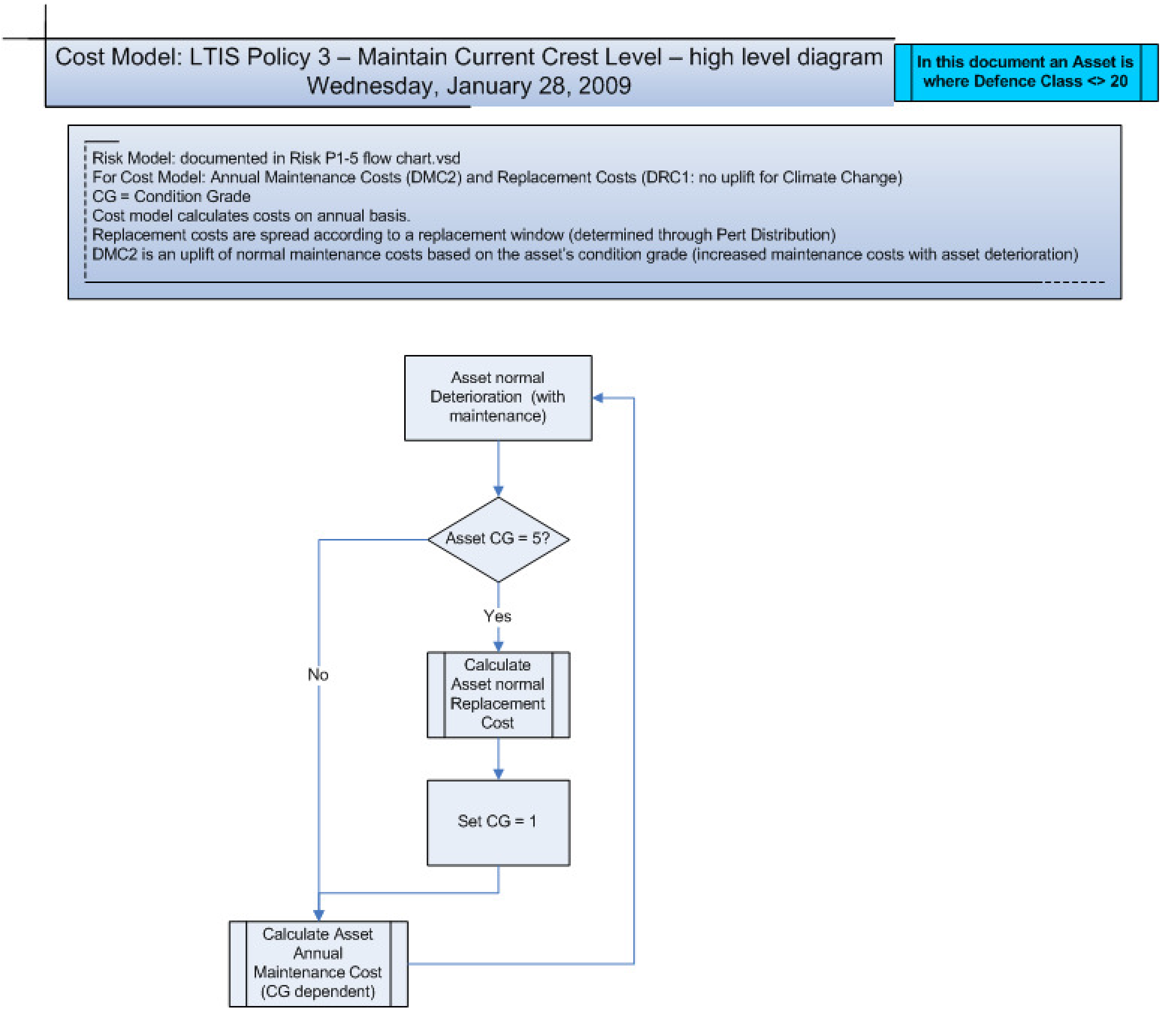
Policies 1 and 2 do not need an assessment of replacement cost. Replacement costs are only required for policies 3-6.

5.10.2 Policy 3 and 6 replacement cost

It is assumed that as assets are replaced with assets of a similar size the replacement cost will not increase over time. The impacts of inflation and efficiency are added as a post processing activity. Current day replacement costs for each of the 60 flood defence classes and 4 coast protection types were collated from a number of sources as described in section 5.5.

The diagram below gives an overview of the Expenditure Tool implementation of LTIS Policy 3 and 6.

Note: for Policy 6 the no-maintenance deterioration curve is applied.



5.10.3 Policy 4 replacement cost

The replacement costs assumed for policy 4 build on the baseline replacement cost used in policy 3. A climate change uplift factor is applied to the baseline replacement costs to reflect the increasing size of asset required to keep pace with increasing water levels associated with climate change.

The assessment of policy 4 also contains analysis of areas that are currently protected by natural ground. As climate change drives increases in water levels these areas are going to be subjected to a reducing standard of protection therefore the policy needs to account for the construction of new defences in these areas. However the application of a blanket increase in natural ground levels would have resulted in the costing of new assets in flood areas that either did not contain property or areas protected by naturally high ground which provided an adequate standard of protection even when climate changes was accounted for.

In order to provide target construction of new assets (assumed to be earth flood embankments) the decision flow chart in Figure 5.2 below was used. In summary it identified flood areas that contained property and were only protected to a low standard of protection by natural ground. In flood areas that were protected by engineered defences and natural ground the decision process assessed whether the natural ground provided a lower standard of protection when compared to the engineered defences. If this was the case then it was assumed that an earth embankment was constructed on the natural ground to match the maximum standard of protection provided by the engineered defences. The construction of this new earth embankment coincided with the earliest replacement date of the engineered defences in that flood area.

Where a flood area (containing properties and having a standard of protection less that 1 in 75) was protected by natural ground only, the upgrade date (construction of new earth embankment) could not be triggered by the deterioration of any engineered assets. Therefore upgrade was triggered by the consequence rating of the flood area

Consequence rating	Upgrade date
High	By year 25
Medium	Between year 25 and 50
Low	Between year 50 and 100

As the expenditure tool models yearly spend it was assumed that this upgrade would occur in the mid point year (for example year 13 for high consequence areas) but the cost of upgrade spread across the timeframe between epochs to avoid unrealistic spikes in the investment profile.

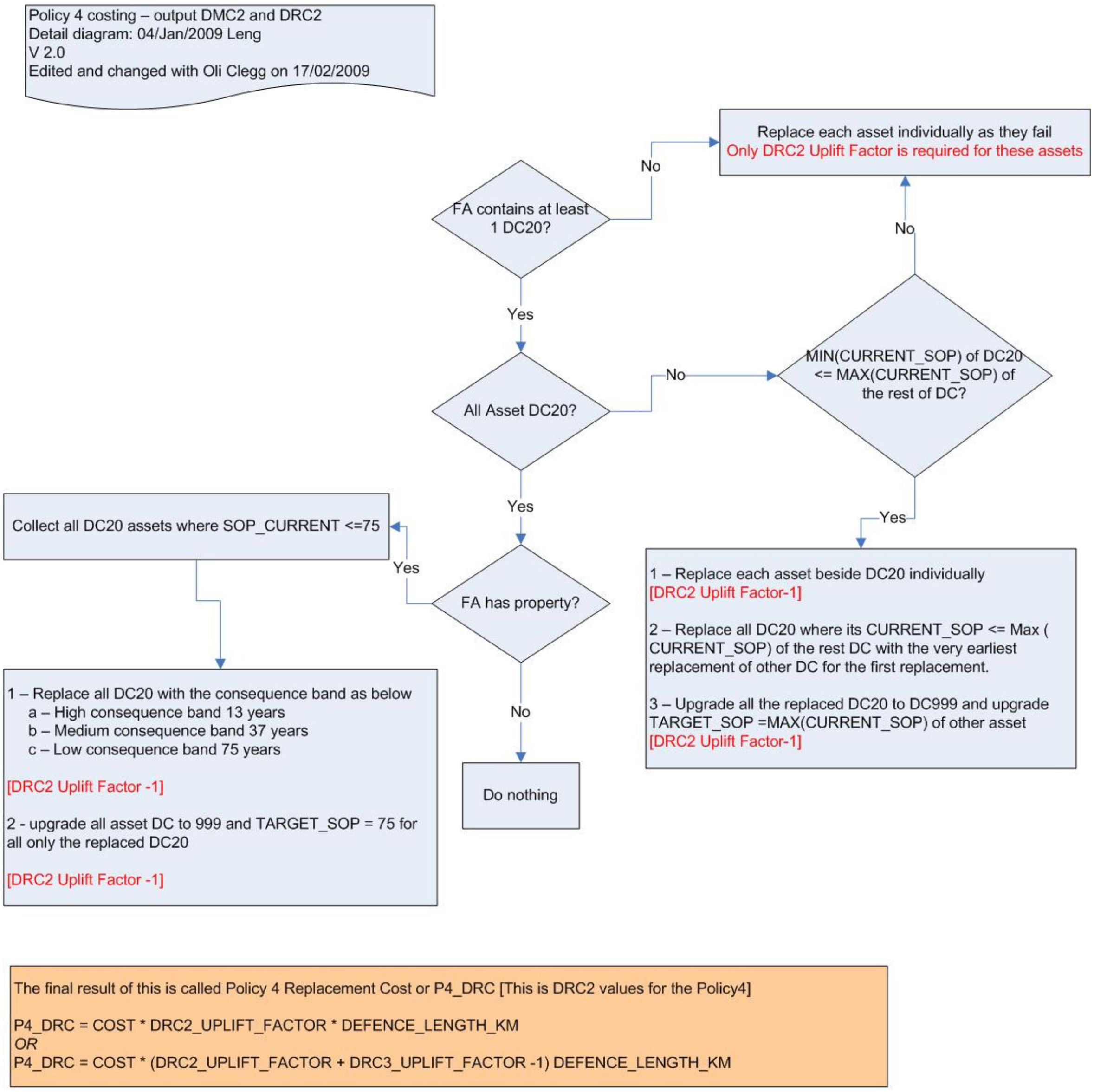


Figure 5.2 Policy 4 expenditure Flow Chart

5.10.4 Policy 5 replacement cost

Replacement costs for policy 5 build on policy 4 costs but also include an uplift factor to account for a changing standard of protection.

This factor assessed the change in replacement cost from increasing an asset standard of protection to 1 in 75. Where an asset currently protects to greater than 1 in 75 then the SoP uplift factor = 1 however the defence will still be subject to climate change uplift factor, as for Policy 4.

In order for a flood area to have an increased standard of protection all of the assets protecting that flood area have to be upgraded. In order to reflect this fact the model upgrades all assets within a flood area at the first replacement date regardless of the condition grade of the remaining defences.

In a similar method to policy 4 targeted new build assets were included in the assessment of cost. For flood areas where there is a mixture of natural ground and engineered defences the natural ground is upgraded to 1 in 75 (where necessary) at the first replacement date of engineered assets within the flood area. For flood areas where there is only natural ground that is protecting properties, the natural ground is upgraded according to the consequence rating, as shown in the table below.

Consequence rating	Upgrade date
High	By year 25
Medium	Between year 25 and 50
Low	Between year 50 and 100

As the expenditure tool models yearly spend it was assumed that this upgrade would occur in the mid point year (for example year 13 for high consequence areas) but the cost of upgrade spread across the timeframe between epochs to avoid unrealistic spikes in the investment profile.

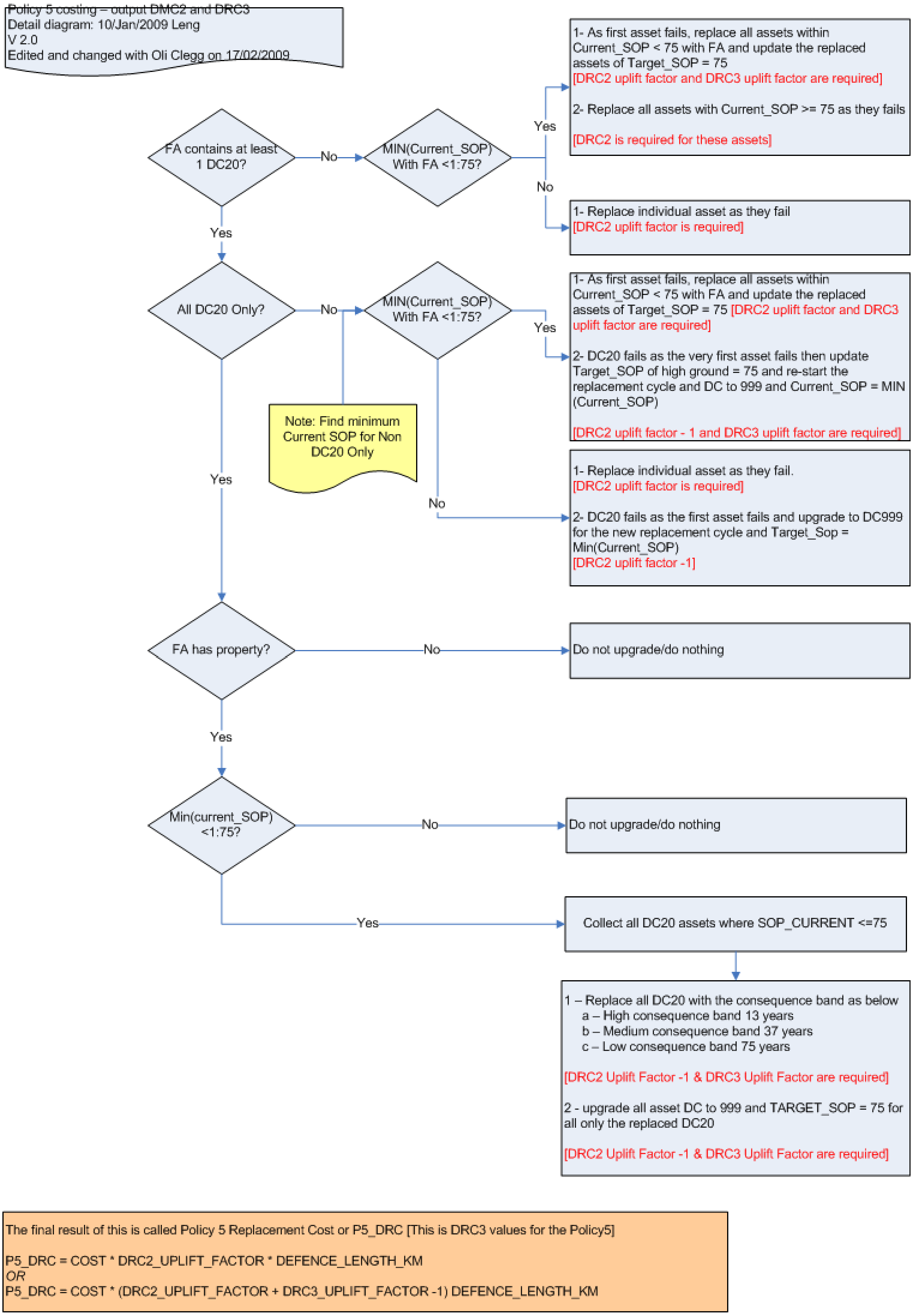


Figure 5.3 Policy Expenditure Flow Chart

5.10.5 Spread of replacement costs

It is recognised that assets, even of the same defence class, will deteriorate at differing rates. The deterioration rate curves contain estimates for fastest, slowest and best estimate deterioration rates. In order to assess the replacement date the best estimate curve was used. However the resultant replacement costs were not applied to a single year as this would result in an unrealistic expenditure profile with significant spikes in required expenditure. In order to smooth out these spikes replacement costs for individual assets were spread across a replacement window identified in the deterioration curves. The replacement window was assumed to be the time between an asset reaching the start of condition grade 4 (fastest deterioration estimate) and condition grade 5 (slowest estimate). The replacement windows are listed in Appendix C. Figure 5.4 below gives a worked example.

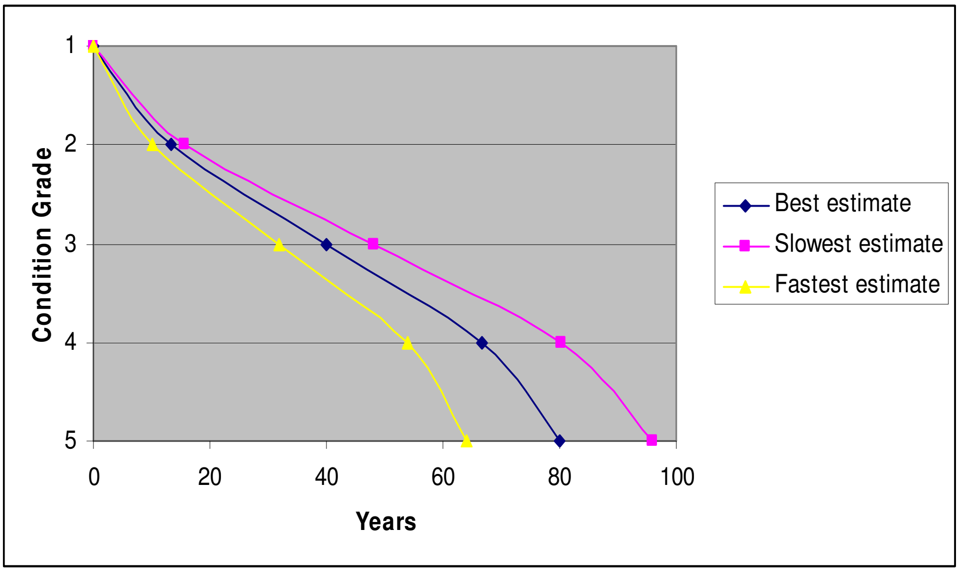


Figure 5.4 Condition Deterioration

- Assume the asset is at condition grade 1
- Replacement date = time taken to reach condition grade 5 = 80 years
- Replacement window start = fastest estimate time taken to reach CG 4 = 54 years
- Replacement window close = slowest estimate to reach CG5 = 96 years
- Replacement window = 42 years

5.11 Coast protection expenditure assessment

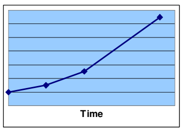
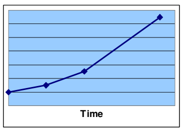
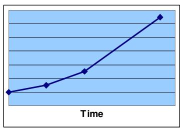
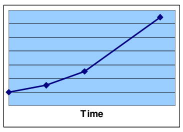
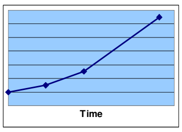
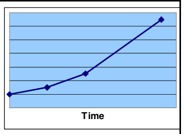
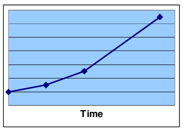
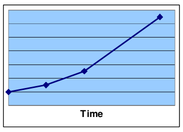
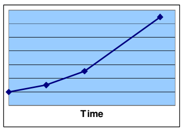
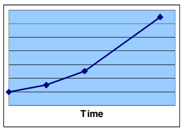
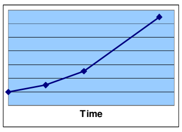
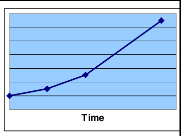
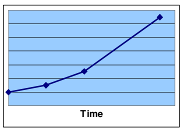
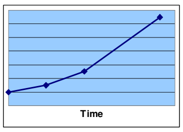
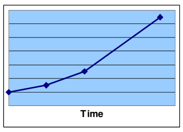
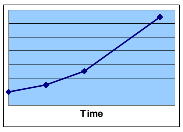
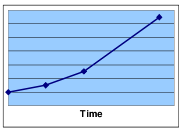
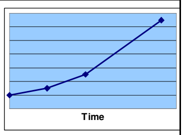
Coastal Erosion assets were evaluated for LTIS Policy 1 (Do Nothing, zero-costs) and LTIS Policy 4 in the same way as flood defence assets. Specific defence classes and associated typical maintenance and replacement costs were added to enable coast erosion asset specific expenditure to be included. The typical cost values applied are discussed in section 5.4, 5.5 and listed in the tables in Appendix C.

6 Policy Analysis Tool

6.1 Overview

Data from the NaFRA risk model and the expenditure model are aggregated to a flood risk management system (FRMS) scale and form a database of possible policy options and their associated costs and consequences. Equally, the data from the coastal erosion risk and expenditure model are aggregated to Cliff Behaviour Units (CBU).

FRMS contain discrete sets of assets that work in unison to protect an area. An example of a matrix of results held per FRMS is included below.

	LTIS Policy 1	LTIS Policy 2	LTIS Policy 3	LTIS Policy 4	LTIS Policy 5	LTIS Policy 6
Expenditure Profile (£, annual)						
Damages - EAD (£, Epochs 0, 10, 25, 50, 100)						
Property at risk (No. Epochs 0, 10, 25, 50,100)						

The policy analysis tool enables the user to pick specific policy options for each FRMS/CBU based on a number of decision rules described in this chapter:

- evaluating the FRMS/CBU published policy in section 6.2;
- evaluating the optimal policy in section 6.3;
- evaluating a user-set policy in section 6.4.

Key items to understand about the Policy Analysis Tool:

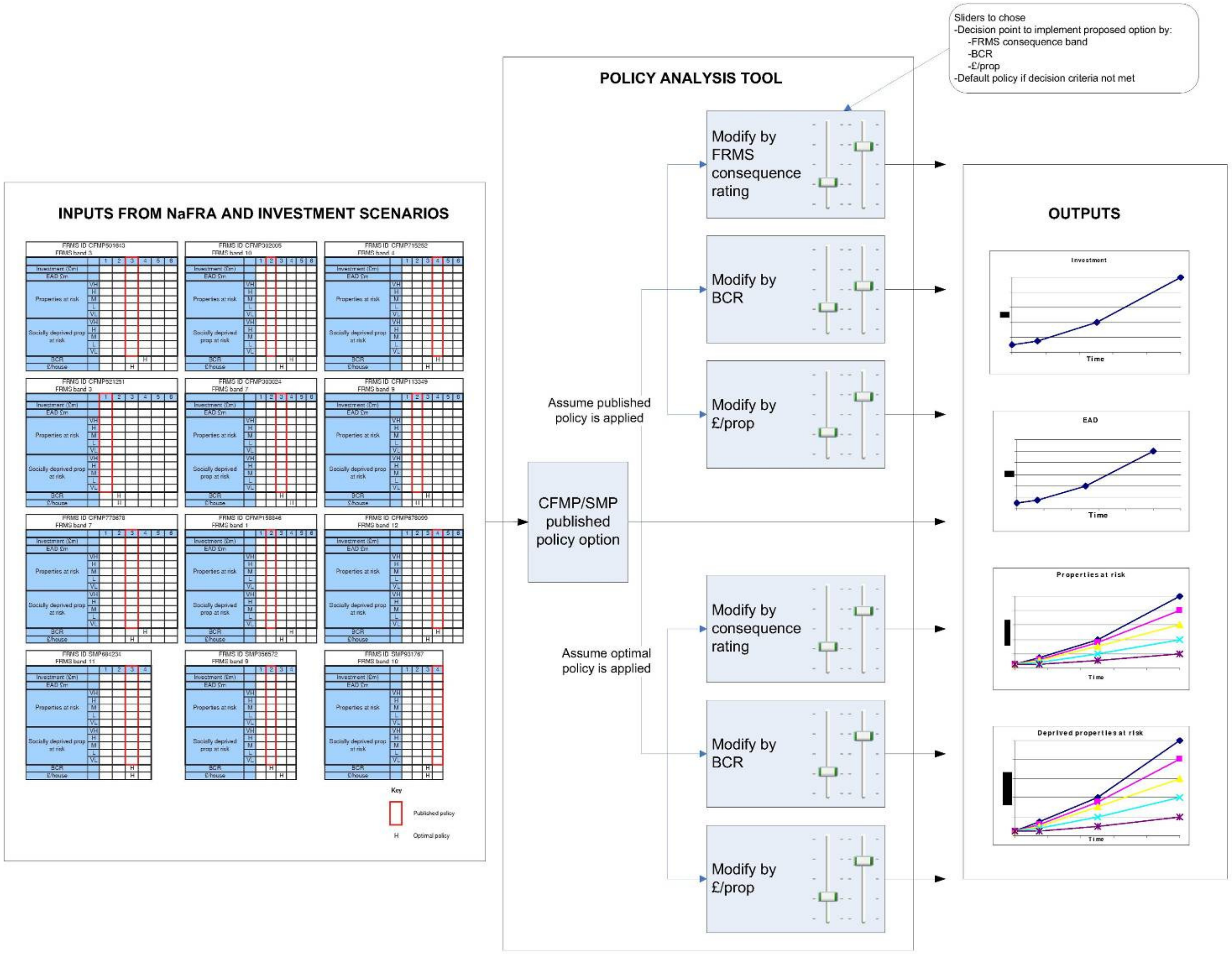
- FRMS are categorised by an assessment of the consequence associated with a flood event in that unit by the Environment Agency (through an accepted set of criteria). Equally CBU have been defined, by the consultant, using a customised erosion risk consequence matrix (see Appendix B.3)
- For BCR and Cost per Property analysis, the user is able to pick a comparison **baseline policy** from LTIS policies do nothing, do minimum or maintain current
- For BCR and Cost per Property analysis, the user is able to pick a **evaluation period**, from year 0 to any of the following 4 epochs (10, 25, 50 ,100)
- The **default policy** is the policy set when a FRMS/CBU does not meet the criteria. The default policy is likely to be set to do nothing or do minimum, but

can in principle be varied to any policy through the use of the consequence rating matrix.

- The **benefit-cost ratio** and the **cost-per-property calculation** are based on the 50%ile cost profile for an FRMS and, where selected by the end-user references the user-defined discount factors.

Guidance on how to use the tool is provided in the “Policy Analysis Tool User Guide”.

A chart is included below to summarise the logic used in the policy analysis tool.


Sliders to chose
-Decision point to implement proposed option by:
-FRMS consequence band
-BCR
-£/prop
-Default policy if decision criteria not met
POLICY ANALYSIS TOOL
INPUTS FROM NaFRA AND INVESTMENT SCENARIOS
Modify by FRMS consequence rating
Modify by BCR
Modify by £/prop
Assume published policy is applied
CFMP/SMP published policy option
Assume optimal policy is applied
Modify by consequence rating
Modify by BCR
Modify by £/prop
OUTPUTS
Investment
Time
EAD
Time
Properties at risk
Time
Deprived properties at risk
Time
Key
Published policy
Optimal policy

6.2 Prioritisation method 1 – utilising Published Policy

The first method of prioritisation assumes that the published policy is implemented and answers the question – what is the investment profile if FRMS are protected in-line with the published policy?

Note this method has not been utilised for the LTIS due to great uncertainty in the validity of mapping published policies from CFMP's and SMP's to respectively each FRMS and Coastal Behaviour Unit (CBU).

The published policy can be assessed in terms of:

- Benefit cost ratio. Based on change in EAD vs. change in investment requirement against a baseline and over a user-set evaluation period; or
- Cost per property protected[9]. The analysis tool calculates the number of properties protected (compared to the baseline) against the investment requirement to identify the cost per property for each FRMS.

The user defines either a BCR threshold or cost per property threshold. FRMS meeting the threshold will have the published policy selected, whilst FRMS where the published policy does not meet the threshold the default policy as set by the user is selected.

The BCR and cost per property (CPP) can be assessed in a few ways. The options available are listed below:

- Assess on the optimal average BCR or CPP over a specific timeframe, also referred to as the evaluation period.
- Assess the CPP at all (or some) epochs and discount the results to the present day to determine the optimal CPP. ('Apply Discount Factor'). BCR is always discounted.

[9] Properties protected assumed to mean those that move Likelihood Band or beyond a certain probability threshold – for example, out of Very Significant & Significant (baseline Do Nothing – based on guidance from Treasury Green Book)

6.3 Prioritisation method 2 – selecting Optimised Policy

The second method of prioritisation is assuming that the optimal policy is to be implemented and answers the question – what is the investment profile if FRMS are protected in-line with the optimal policy for each FRMS/CBU?

This method of optimisation assumes that the user is not constrained to implement the published policy in each FRMS. The analysis tool determines the optimal LTIS Policy based on two possible selection criteria:

- Optimal benefit cost ratio threshold. Based on change in damages vs change in investment requirement against a baseline policy.
- Least cost per property protected threshold. The analysis tool calculates the number of properties protected against the investment requirement to identify the optimal policy in each FRMS/CBU.

The user also sets either a BCR threshold or cost per property threshold. FRMS where the calculated threshold for the optimum policy meets the threshold have the optimal policy implemented, whilst the other FRMS receive the default policy as set by the user. The default policy is likely to be set to do nothing or do minimum, but can in principle be varied to any policy through the use of the consequence rating matrix.

The BCR and cost per property (CPP) can be assessed in a few ways. The options available are listed below:

- Assess on the optimal average BCR or CPP over a specific timeframe, also referred to as the evaluation period.
- Assess the CPP at all (or some) epochs and discount the results to the present day to determine the optimal CPP. (‘Apply Discount Factor’). BCR is always discounted.

6.4 Prioritisation method 3 – utilising a consequence rating based Policy

Each FRMS, and CBU for coast erosion, has a given a Consequence Rating. The tool can, for each ‘box’ in the consequence rate matrix, apply a particular LTIS Policy (see Appendix B.2 and B.3 for the respective consequence matrices).

The analysis tool determines the selected LTIS Policy based on three possible selection criteria:

- Threshold benefit cost ratio. Based on change in EAD vs change in investment requirement for the selected LTIS Policy against a baseline.
- Least cost per property protected. The analysis tool calculates the number of properties protected against the investment requirement for the user-selected policy.

Halcrow

- A straight application of the user selected LTIS policy as set in the Consequence Rating matrix. This method is also known as the 'Consequence Override Analysis'.

The analysis selects the user-specified policy choice for each FRMS, and for BCR and CPP analysis checks if that meets the set threshold. Where the selected policy for the FRMS does not meet the threshold, the default policy is applied.

The user's policy selection is through the use of the FRMS consequence rating matrix, thus enabling definition of a specific policy for each consequence rating. Note that the user can set the option if a policy upgrade from the user-set policy to the default policy is allowed or not (default is 'allowed').

6.5 Policy Analysis Tool Outputs

See section 7 for the description of the data delivery.

The delivery of the FACET Policy Analysis Tool to the Environment Agency includes:

- Delivery of an LTIS analysis tool with a rudimentary interface that knowledgeable users can operate;
- The tool gives the ability to consider, at a national scale (England or Wales), application of a selection of FCERM policies;
- The impact of LTIS policy options is assessed at 5 epochs (including current day) at an FRMS\CBU scale based on a database of potential policy futures for each FRMS\CBU. Output metrics for the database are (per epoch):
  - Investment requirement
  - Estimate annual damages
  - Properties at risk subdivided by flood risk banding
  - Properties at risk or 'lost' from coastal erosion
  - Agricultural Land at risk

The policy analysis tool enables knowledgeable users to pick from the database of policy futures per FRMS to prioritise application of these policies by FRMS so that investment need and residual risk can be determined. Prioritisation is by the measures as described in section 6.2 and 6.4. The User Guide is included as Part 2 to this report.

The policy analysis tool provides the following outputs

- Investment profile (£) with confidence limits
- Economic (£) flood risk\coast erosion risk profile over same period as investment profile
- Number of properties at risk profile over same period as investment profile, including separate outputs for properties at risk in top 20% of ranked deprived areas. This is based on the Multiple Deprivation Index for England, and for Wales on the Multiple Deprivation Index for Wales.

- All outputs are to a 100 year horizon. The user is able to select to display outputs to 10, 25, 50 or 100 year;
- Erosion properties lost and number of properties at risk of erosion are reported separately, but appear on the same graphs as for flooding

The Environment Agency has been supplied with a secure, standalone laptop with the latest LTIS output database and PAT tool installed. The delivery does not include the Expenditure Forecast Tool or the Risk Forecast Tool and related datasets. These can currently not be delivered because of the constraints on size of the database on the laptop. The Risk Forecast Tool is an overarching term for the NaFRA future model runs and requires specialist software and a large number of databases – the summarised outputs from the models are included in the PAT database.

7 Outputs and Uplifts

7.1 What the tool produces

The tool has the facility to export the analysis graph outputs to CSV (spreadsheet) formatted files. For each analysis run a log file is created and for batch run analysis a spreadsheet compatible output is generated. These contain:

- Time series of cost
- Expected Annual Damage produced by WAAD
- Number of properties (residential and non-residential) by likelihood band
- Number of hectares of agricultural land at moderate or significant risk

Additionally, for validation purposes, FRMS level analysis outputs can be exported.

More detail on these outputs can be found in the User Guide.

7.2 Uplifts added

Two post-processing uplifts can be added to the outputs from the expenditure forecast tool. These uplifts can be set by the user in the PAT interface (see User Guide).

Costs can be uplifted to account for mechanical, electrical instrumentation, control and automation (MEICA) assets. It was not possible to utilise the information in the MEICA database to assess how deterioration rates, replacement costs and maintenance costs would vary with policy choice as the database did not hold the information necessary to carry out this analysis (for example the assets were not geo-referenced). Analysis carried out by the Environment Agency indicated that costs associated with MEICA assets equalled 17% of the expenditure required for NFCDD based assets.

Unit costs can be uplifted by a further 16% to account for costs incurred in asset improvement, replacement and maintenance over and above the contract costs as captured by the unit cost database. The costs are therefore defined in a way which is consistent with the overall baseline national investment allocated to assets.

8 Post Processing

Post processing (ie outside FACET) depends to a great extent on the policy questions to be addressed. Typically this will involve the following types of analysis:

- Constructing discounted cash flows for costs and damages. Costs are output by FACET for each year so fit easily into a standard discounting table. Damages are output for a limited selection of years so damages in intervening years will normally need to be interpolated. Section 8.1 outlines factors for adjusting the basic NaFRA property damages to account for wider economic impacts of flooding.
- Comparison between scenarios. Outcomes can be compared using standard appraisal measures such as benefit/cost ratio, net benefits (i.e. benefits-costs) etc, It is relatively straightforward to set up spreadsheets to carry out this type of analysis on FACET outputs though the capability is at this time not included in the FACET tool itself.
- Summaries of other outputs such as mean expenditure, annual increase in expenditure, and changes in numbers of properties in a given flood likelihood category. Again these can easily be produced in spreadsheets having imported the FACET output files.

8.1 Estimation of costs and benefits of Flood Risk Management

The FACET model only includes impacts on (residential and non-residential) properties. Table 8.1 shows recommendation for post-processing the outputs from the FACET tool to allow for:

- Optimism bias in the cost estimates. For LTIS 2010/11 and in line with HM Treasury's Green Book and the latest revisions of the PAG guidance, the 95%ile cost estimates were used in the calculation of the benefit-cost ratios of the scenarios in LTIS.
- Adjusting the benefits or avoided damage estimates to allow for important omitted impacts and considerations. The central estimate factor of 2.05 (range 1.75 – 2.54) described in the Table 8.1 could be applied to the damages to account for these.

Table 8.1 Factors for adjusting cost and damage items in FACET findings

Factor	Effects on estimates	Evidence base	How Handle
Allow for any possible Optimism bias in cost estimates in FACET	About 30% increase in costs	HMT Green Book and PAG supplementary guidance. But FACET is based on actual costs of measures in UCD (not early estimates). So is any additional optimism bias factor needed? But need to allow for possibility that in practice we would optimise the asset renewal and replacement measures	Use 95%ile cost estimates, which allow for upper ranges in dates for asset renewal and cost estimates in Unit cost data base.
Include income growth and property price increase[10]	Not included		It is recommended not to allow for increase in property prices, as in appraisal practice current prices are considered.
Indirect losses[10]	11% (10%-13%) based on: * 5% (5 -7%) for emergency services * 5% (5-6%) for temporary accommodation		It is not recommended to include losses to businesses as they are not considered for options appraisal purposes.
Agriculture[10]	3% (2% - 4%)		
Risk to life[10]	16% (11–22%)		The 2007 floods report estimated that risk to life accounted for 16% of residential benefits.

[10] taken from Environment Agency, 2012b

Factor	Effects on estimates	Evidence base	How Handle
Infrastructure, transport, schools, leisure[10]	43% (38-60%), based on: * 5% for vehicles and roads * 18% for utilities * 8% for local government infrastructure * 13% for communications		Uplift factors are calculated by considering the 2007 floods report (as % of total property damages, for each damage category)
Use WAAD instead of depth damage	J Chatterton independent review of economics in NaFR08 identified factors but not quantified them. Subsequent mtg and analysis gave: WAAD Underestimates: * Flood depths limited to 1.2m whereas floods occur and have impacts at up to 3m (basis for MCM damage costs assessment). *Small effect (0.1-0.2%). So ignore.* * Basement damage not included. *Non-residential Property (NRP) underestimate = 20-60%. NRP = 46% of total property damages.* => *underestimate = 9-28% with central estimate of 18%.* Little or no underestimation in WAAD for residential properties; *so ignored.* * Breaching not fully included in WAAD (but breaching effects on flood probability are included. *Not allowed for* * Based on limited residential property data and not differentiated by different property type. *Not allowed for.* Effect unknown / variable: * Source data based on 1980s analysis * limited geographic area(Midlands) (but uplifted). Is this representative of all England? NaFRA08 economic investigation calculated WAAD to give about 50% of the damages compared with the depth / damage method BUT a proportion of this is due to the raw NaFRA results which, in some areas, over-estimate flood depths.		Uplift property benefits to allow for underestimates by 18% (range 9% - 28%)

9 Overview of changes from LTIS 2009/10

This section summarises the changes made for the April 2012 FACET modelling from the modelling carried out for LTIS 2009/10.

9.1 Data inputs

9.1.1 Risk Forecast data

Flood risk forecast model input data

LTIS 2009/10 was based on NaFRA 2008 year end, which was the last full national update of all NaFRA catchments and the first to include the Rapid Flood Spreading Model (RFSM).

The FACET update 2011/12 is based on the catchments from 2008 and all 28 catchments updated since then up to the NaFRA 2010/11 year end baseline. An exception is that the Conwy & Clwyd catchment update from 2011/12 is also included (catchment 6600).

Note that some catchments have been updated more than once since 2008, the latest update has always been taken. An exception is the 2009/10 update to the South West catchment "Exe, Otter & Axe" (catchment 4500) with a preliminary version of MDSF2 NaFRA model. The catchment model input database is unfortunately not easily transferrable to the NaFRA modelling engine as used for FACET.

Details of the changes to the updated catchments can be found in the *NaFRA Year End and Quarterly Update reporting, notably Appendix G reconciliation of the numbers properties moving flood likelihood category since the previous update, Appendix H properties by flood likelihood category and Q – WAAD* for both the 2009/10 and 2010/11 updates. For the 2010/11 updates reference can be made to *NaFRA 2010/11 Appendix A* which contains a history of all updates and manual changes made from NaFRA 2008 onwards.

Flood risk and climate change

Approach to climate change for flood risk assessment into the future has been changed significantly for coastal flood risk (see 3.4.4). Whereas the main guidance document for LTIS2009/10 was the Defra Guidance Note (2006) and early outputs from UKCP09, for the FACET update the Environment Agency climate change advice (*Environment Agency, 2011a*) has been referenced.

Coastal overtopping rates adjustment

For the LTIS 2009/10 coastal NaFRA models, a pragmatic approach was adopted for representing climate change. The approach was to reduce the defence crest- and toe levels, as well as the floodplain in line with the sea level change (Defra Guidance 2006). This approach meant that the complex overtopping rate tables did not need to be adjusted.

In the review for the FACET update an alternative approach was identified that could be implemented within the available timeframe (section 3.4.4, sub-section Coastal Overtopping Rates) based on CDV2075 study (HR Wallingford, 2002). This adjusted approach requires further investigation and potential improvements are possible, especially in the way the overtopping rates adjustments are established.

Erosion risk forecast data

At the time of LTIS 2009/10 the National Coast Erosion Risk mapping project was only partially checked, updated and validated by the coastal local authorities. For the FACET update the validation and subsequent publication of the Erosion Mapping Products was over 90% complete after two further validation stages, including Local Authorities and the Environment Agency. Therefore, the certainty in the confidence banding for the outputs used by FACET is significantly better than for LTIS 2009/10.

9.1.2 Expenditure Forecast data

Updated Asset Data from NFCDD for flood defence assets and NCERM coast protection assets from February 2011 and November 2011 respectively (section 5.2).

Typical asset costs (section 5.3) have been updated to 2010/11 baseline in line with inflation.

All replacement costs were updated to Q4 2010/11 prices (with the new index), which has reduced all prices by 9%. Due to the new data sets a few costs have reduced further but the majority of changes due to additional data has increased the cost of the defence classes by up to double in some cases. It should be noted that other than the universal 9% decrease, a third of the asset types were further updated.

The only change to the maintenance costs is inflation to Q4 2010/11 prices, and two confidences grades were increased due to additional costs from the Environment Agency's UCD (section 5.4).

Confidence in the typical asset costing has been updated in just a few cases.

9.1.3 Asset condition deterioration

The asset deterioration curves have been updated from LTIS 2009/10 (section 3.3 and an overview of changes in Table 3.2). These are referenced in both the Risk Forecast modelling and Expenditure Forecast modelling. For some asset classes the change in asset life is significant (generally an increase) compared with LTIS 2009/10 and this has an immediate impact on when assets are being replaced in both the risk and expenditure modelling. The 'replacement window' used to spread the replacement costs in the expenditure model has also widened for many asset types, thus resulting in a generally smoother expenditure profile compared to the expenditure profile from the Policy Analysis Tool from LTIS 2009/10 modelling.

The asset fragility curves have not changed, as both the NaFRA (flooding) and NCERM (erosion) use the best currently available.

9.2 Model runs

The forecast model logic from LTIS2009/10 has largely remained the same, with a few exceptions:

- Addition of a specific LTIS Policy 6 (Replace assets, no maintenance) to the Risk Forecast models (section 4.3.3). For LTIS 2009/10 this LTIS Policy was a late addition and implemented for the Expenditure Forecast model only. The risk was assumed to be represented by LTIS Policy 3 Maintain current crest level.

- Addition of 10-year epoch snapshot to the Risk Forecast models. This addition is not relevant to Expenditure Forecast as that generates annual expenditure profiles.
- Implementation of asset replacement under LTIS Policy 3 has been corrected (section 4.3.3): The impact on the model outputs is limited for the fluvial model to small changes in the flood probability for a small proportion of impact cells, but for 90% of the impact cells there is no change. Where it does change (<10% of impact cells), the change in the probability value is under 25%. For the coastal models the change in flood probability is largely unchanged – where the model outputs do change it is largely a reduction of the probability of less than 25%.

9.3 Outputs for the Policy Analysis Tool

Risk metrics – damage calculation

For the calculation of the flood risk damages, the updated Multi-coloured manual damage tables (summer 2010) have been applied, including adjustments related to the inclusion of a separate damage table for basement properties. This is in line with NaFRA 2010/11.

For the assessment of erosion risk (£), the capital valuation of properties was largely available for LTIS 2009/10 from the National Property Dataset (NPD3, 2008), but supplemented with 'averages' to fill gaps in the information. However, it is not present in the National Receptor Dataset. This data has been specifically generated for the FACET update for those properties in the most extreme erosion zone (100 year, no active intervention) (section 4.5.3).

Risk metrics – property information

The property information is sourced from the National Receptor Dataset v1.1 (published spring 2011) in line with NaFRA 2010/11 and for reasons of consistency has not referenced the later version NRD v2011 (published autumn 2011). For LTIS 2009/10 the predecessor of the NRD, the National Property Dataset (NPD3, 2008) was used.

Impact on the change from NPD3 to NRDv1.1 can be found in NaFRA 2010/11 Reconciliation Report (Halcrow, 2011b) and the series of NRD Reconciliation Reports (Halcrow, 2010, Halcrow, 2011c).

Equivalent comparative reporting does not exist for erosion as the project is just recently reporting on risk to property for the first time.

Risk metrics – Agricultural Land

The flood risk metrics, hectares and damages, for agricultural land has been added for the FACET update.

9.4 FACET Policy Analysis Tool (PAT)

Addition to the interface of:

- Validation Tool and Visualisation thereof;
- Agricultural risk metrics (hectares and damage);
- FRMS-level output of Analysis Run results;
- User experience improvements to the PAT Batch Run functionality

10 References

Burgess and Townend, 2001. The Impact Of Climate Change Upon Coastal Defence Structures, Kevin Burgess & Ian Townend, 2001

Townend and Burgess, 2004. Methodology For Assessing The Impact Of Climate Change Upon Coastal Defence Structures, Ian Townend & Kevin Burgess, ICCE 2004 abstract number: 1054

Environment Agency, 2011a. Adapting to Climate Change, Advice for Flood and Coastal Erosion Risk Management Authorities (GEHO0711BTZU-E-E) ***and*** *Adapting to Climate Change, Advice for Flood and Coastal Erosion Risk Management Authorities in Wales (Nov 2011)*

Environment Agency, 2011b. EA R&D Project SC080039 Long Term Costing (draft) - Generic cost estimation and supporting specific flood risk measure guidance documents)

Environment Agency, 2012a. EA R&D Project SC060078 Phase 1 and Phase 2 'Asset deterioration and whole life costing' under the Sustainable Asset Management Theme.

Environment Agency, 2012b. Internal note: Updating uplift factors for benefit estimation, 15 March 2012

Halcrow, 2012a. FACET Sensitivity & Uncertainty Report (2012)

Halcrow, 2011a. Long Term Investment Strategy, Modelling Documentation, Part 1 – Technical Documentation, March 2011

Halcrow, 2011b. Consolidation and Reporting Impact on NaFRA following move from NPD to NRD, September 2011

Halcrow, 2011c: National Receptor Dataset - NRD Update 2011, Reconciliation Report, Halcrow Group Ltd, June 2011

Halcrow, 2010: National Receptor Dataset, Reconciliation Reporting, July 2010 and National Receptor Dataset, Reconciliation Report v1.0 – v1.1, Halcrow Group Ltd, December 2010

Halcrow, 2001a NAAR National Assessment of Assets at Risk, 2001

PAMS Guidance on determining asset deterioration and the use of condition grade deterioration curve, Explanations to condition grade deterioration curves MSF 9_1 v7.pdf

HR Wallingford, 2002a. Coastal Defence Vulnerability 2075, Report SR590. Report by HR Wallingford for Department for the Environment, Food and Rural Affairs (Defra)

ABPmer, 2011a. WEBvision – Renewables (Wave) Version .1.0. Available online: http://vision.abpmer.net/renewables. Last accessed 13th January 2012.

ONS, 2008. Commercial and Industrial Floorspace and Rateable Value Statistics (2005 Revaluation), 2008

Land Registry, 2011. www.landregistry.gov.uk/house-prices Report by Location, Household type breakdown report

Penning-Rowsell et al., 2005. Middlesex University Flood Hazard Research Centre (2005), The benefits of flood and coastal risk management: a handbook of assessment techniques, *Middlesex University Press, ISBN 1 904750 51 6. a.k.a."The Multi-Coloured Manual" (MCM).*

Appendices

Appendices A to D

Appendix A Variables used associated with CFMP/SMP Policy Options

A.1 Variables used to model investment and risk associated with CFMP and SMP Policy Options

	Implication on NaFRA model	Implication on cost model
CFMP policy 1	-Water level increases over time -Defences deteriorate at an accelerated rate and are not replaced as they fail -No maintenance	-No maintenance cost -Defences not replaced as they fail -Poss need a contribution of H&S works
CFMP2	-Water level increases . -Defences deteriorate at standard rates but are not replaced when fail	-Standard maintenance cost/deterioration rate -£0 replacement cost
CFMP3	-Water level increases . -Defences deteriorate at standard rates -Are replaced like for like (crest remains the same) when fail	-Standard maintenance cost/deterioration rate -Assets replaced like for like
CFMP4	-Water level increases . -Defences deteriorate at standard rates -Defences replaced to provide current SoP assuming CC Damages remain the same ONLY PRESENT DAY RUN NEEDED	-Standard maintenance cost/deterioration rate -Replaced with bigger structures to meet CC -Use NaFRA to identify where additional/bigger defences would be needed
CFMP5	-Water level increases . -Defences deteriorate at standard rates . -Defences replaced with bigger defences (over and above CC requirements to satisfy the average indicative standard of req)	-Standard maintenance cost/deterioration rate -Replaced with bigger structures to meet CC and more -Use NaFRA to identify where additional defences/bigger defences would be needed
CFMP6	As CFMP 1 NO ADDITIONAL RUNS NEEDED	As CFMP 1 investment factor for breaching defences
SMP1	-Water level increases over time -Defences deteriorate at an accelerated rate and are not replaced as they fail -No maintenance	-No maintenance cost -Defences not replaced as they fail -Poss need a contribution of H&S works
SMP2	*Property at significant or very significant risk:* -Water level increases -Defences deteriorate at standard rates but are not replaced when fail *Property at less than significant risk:* -Current SoP maintained assuming CC	-Standard maintenance cost/deterioration rate for existing assets -Proxy cost of existing structure replacement with weighting for new location

SMP3	-Water level increases -Defences deteriorate at standard rates -Defences replaced to provide current SoP assuming CC Damages remain the same ONLY PRESENT DAY RUN NEEDED	-Standard maintenance cost/deterioration rate -Replaced with bigger structures to meet CC -Use NaFRA to identify where additional/bigger defences would be needed
SMP4	-Water level increases. -Defences deteriorate at standard rates. -Defences replaced with bigger defences (over and above CC requirements to satisfy the average indicative standard of req)	-Standard maintenance cost/deterioration rate -Replaced with bigger structures to meet CC and more -Use NaFRA to identify where additional defences/bigger defences would be needed

A.2 Variables implementation SMP policies for Coastal Erosion

A.2.1 Applying SMP Policies in LTIS Tool for Erosion

There are four generic Shoreline Management Plan (SMP) policies:

- No Active Intervention (NAI)
- Hold the Line (HTL)
- Advance the Line (ATL)
- Managed Realignment (MR)

For the purposes of erosion risk, Advance the Line can be excluded. The policy of Managed Realignment in relation to erosion frontages within SMP2 is being applied as a degree of intervention between NAI and HTL, whereby the rate of erosion is reduced compared to the NAI scenario.

At present, we do not propose to model MR policies. MR policies are subject to significant local variations and that degree of site specific variations would be hard to represent in a national level tool when there is only partial completion of the second generation SMPs (SMP2). Current indications are that on 3% of erosion frontages are assigned an MR policy.

Two scenarios have been considered for coastal erosion:

- No Active Intervention (Policy 1)
- Hold the Line where currently protected (Policy 4)

Application of Cost Factors to SMP Policies

SMP Policy	Asset Replacement	Asset Maintenance
NAI = LTIS Policy 1	None	None
HTL = LTIS Policy 4	Like for like with uplift for climate change mitigation	Throughout epoch, including condition grade related uplift

Calculation of erosion damages to property

Numbers and capital value of properties are assessed for the entire epoch, based in the National Receptor Dataset Property Point Layer (NRD PPL).

The formal risk banding for the Outcome Measures for Erosion Risk Management are shown in the table below.

Coastal Erosion Risk Management	Outcome Measures banding	LTIS Epochs
Short Term	<10 years	0 - 10 years
Short/Med. Term	10 - 20 years	10 - 25 years
Medium Term	20 - 50 years	25 - 50 years
Long Term	50 – 200 years	50 – 100 years

A property is 'at risk' from erosion when it is located within the 0-100 year erosion zone under the No Active Intervention scenario.

A property is 'lost' when it is located within the erosion zone of a particular epoch for a policy. It is then not counted again for the following epochs.

Erosion damages are calculated using property capital value, derived from Land Registry and Office for National Statistics information as advised in the Multi-Coloured Manual. Erosion damages are totals for properties within the erosion zone for a full epoch.

Appendix B Supporting information

B.1 Land use classifications and indicative standards of protection

For final implementation, FACET Policy 5 was adjusted to Improve selectively to 1:75 and use of target SoP has been discarded.

B.2 Flood risk management system classification

The FRMS classifications are existing classifications within FRM in the Environment Agency.

Impact of flooding				
HIGH e.g. LUB A/B or Habs Regs sites	1 HIGH	2 HIGH	3 HIGH	4 HIGH
MEDIUM e.g. LUB C, or SSSI's	5 LOW	6 MEDIUM	7 MEDIUM	8 HIGH
LOW e.g. LUB D/E	9 LOW	10 LOW	11 LOW	12 MEDIUM
	Low-Negligable risk to life.	Medium- Time likely to be available for evacuation in event of failure.	High- Little warning of flooding to residential or commercial property	Very High- Little warning of failure. Possible loss of life/major injury. Sudden impact to vulnerable groups.
	e.g. small/medium watercourses, defences protecting agricultural land, Category D FSRs.	e.g. significant watercourses without raised defences, diversion channels, Category C FSRs, etc	e.g raised defences.	e.g. very significant raised defences or category A/B FSRs. Very significant structures.

Potential Impact on People from System Failure

Figure 1. Analysing the Consequence of Failure of an FRM System

Taken from FRMS Definition Work Instruction 358_04, Appendix 1

Descriptive of the FRMS Consequence Ratings:

1. The FRM System provides protection to a Habitats Regulations designated site. A failure would be likely to have a significant effect on the conservation features for which the site was designated. No property is at risk.
2. Large undefended channel through dense urban Area with good telemetry and channel modelling for flood warning purposes. Medium risk to people as time likely to be available to evacuate but flood depths could be significant. LUB A = High.
3. Large undefended channel through dense urban Area where no telemetry and channel modelling exist. Could be a very flashy catchment where little warning time available to evacuate. High risk to people and flood depths could be significant. LUB A = High
4. Major flood barrier. Very High risk to life. LUB A = High.
5. An area of SSSI where no properties are at risk. Failure of the defence would damage the SSSI
6. An area of SSSI behind a defence where a few remote properties are at risk. Failure of the sea wall would damage the SSSI and cause flooding to property.
7. Flood Bank that would retain water above normal ground level in intensive lowland agricultural area with isolated properties close by. High risk to life due to high water level retained but depth would rapidly reduce with distance in the event of a breach. LUB C.
8. Category A Flood Storage Reservoir (FSR) in rural area. By definition (of a Category A reservoir) a breach could endanger lives in a community. Very High risk to life. LUB C.
9. Flood Bank that would retain water above normal ground level and protecting normal floodplain farmland with isolated properties. Low/Medium risk to life. LUB D.
10. Rural area with no environmental designations and no intensive farming practises
11. Rural area with no environmental designations some intensive farming practises. Scattered development with some property at risk from flooding
12. Semi urban / rural community area with no environmental designations. Some Property at risk from flashy type floods very little warning time available.

B.3 Consequence matrix for Coastal Erosion

For flood risk areas, the Tool uses a 12 box consequence of failure matrix to categorise different levels of risk based on receptors (refer to Work Instruction 358_04 “Identification of Flood Risk Management Systems”). A similar, matrix has been developed for the Erosion analysis units.

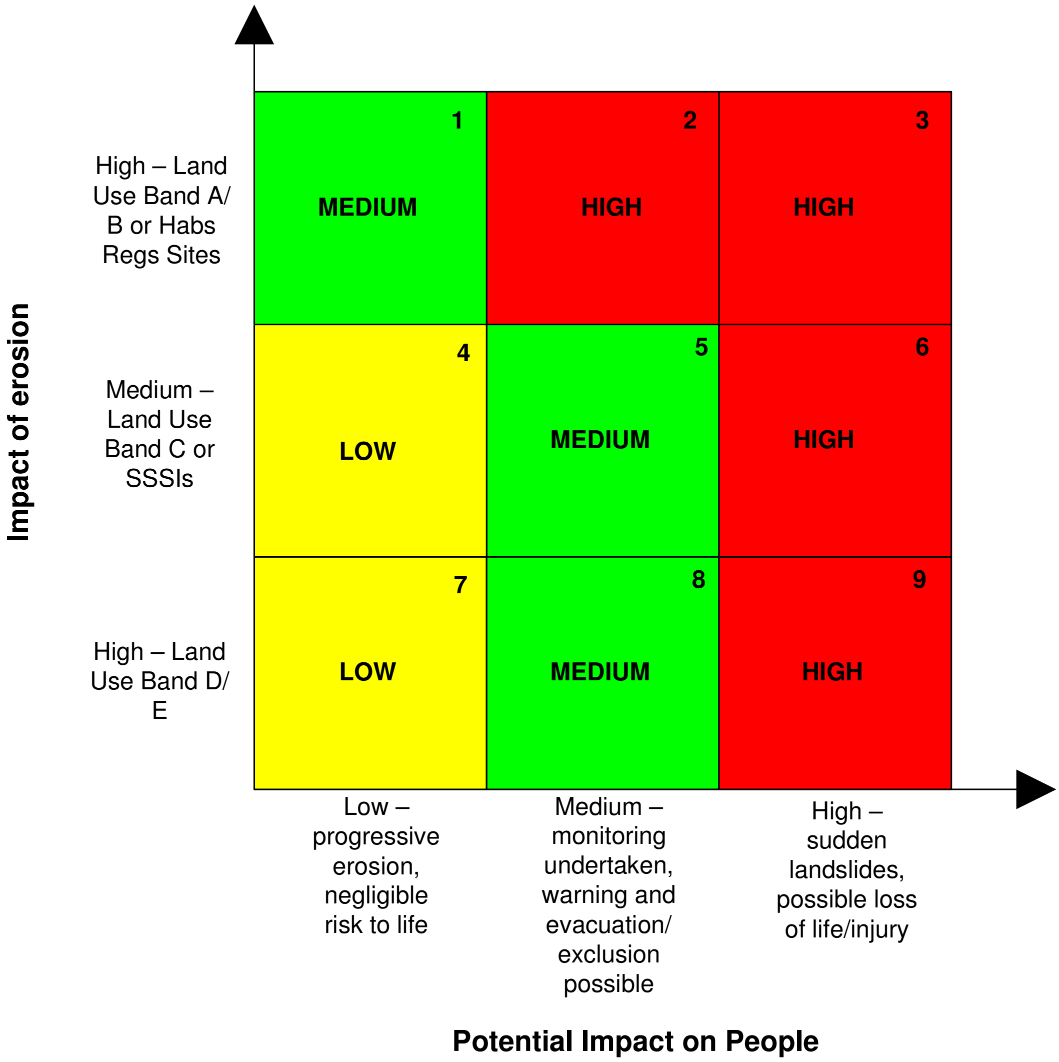


Figure 10.1 FRMS Consequence matrix applied to Coastal Erosion Consequences

Appendix C Reference tables

C.1 General Lookup Tables: Costs and Asset Deterioration

See AppendixC1_LookupTables_v4.xls

C.2 Reference Table Overtopping Rate Changes

See AppendixC2_OvertoppingRateChanges.xls

C.3 Reference Table Mean Sea Level Change

See AppendixC3_MeanSeaLevelChange.xls

C.4 Reference Table Reporting Units by EA Region

See AppendixC4_FACET_ReportingUnitsByEARegion_v1.xls

C.5 Agricultural Land Classification (ALC) lookup

For detailed description of the 5 ALC classes, see http://archive.defra.gov.uk/foodfarm/landmanage/land-use/documents/alc-guidelines-1988.pdf

Grade 1 - excellent quality agricultural land

Grade 2 - very good quality agricultural land

Grade 3 - good to moderate quality agricultural land

Grade 4 - poor quality agricultural land

Grade 5 - very poor quality agricultural land

Appendix D Climate Change: assessment of change in SoP

D.1 Technical Note

See AppendixD1_ISAT TN LTIS & climate change.doc

D.2 Return Period Change factors

See AppendixD2_RPChange.xls

D.3 CCFF Curves

See AppendixD3_ISAT ccffcurves IHR.xls

D.4 NAAR 2001 Appendix E

See AppendixD4_NAAR2001TechReport_appendixE_FluvialCC.pdf

Reproduced from NAAR 2001 Technical Report Annex 12_11_01

Appendix E Data Sources

See AppendixE_DataSources.xls