



Cromer to Winterton Ness Coastal Management Study

Study Report

July 2013

North Norfolk District Council



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Executive Summary

The Cromer to Winterton Ness Coastal Management Study has been commissioned by North Norfolk District Council to assess the assumptions and impacts of the policy recommendations from the Kelling to Lowestoft Ness Shoreline Management Plan (SMP6) (2005).

The recommended SMP6 policies have been assessed alongside a Do Nothing Baseline to allow a comparison of the economic and technical feasibility of the SMP6 recommendations. In addition, the SMP6 recommendations have been further modified to consider any impacts of policy changes and potential impacts of a sediment nourishment event on the coastline in two additional scenarios; the Modified SMP6 Scenario and the SMP6 with Sediment Nourishment Scenario.

This Study has used the SCAPE model to assess and support a more holistic understanding of inter-linked coastal processes along the frontage, current and future coastal defence conditions and an economic assessment associated with each Policy Unit. It has compared the impacts of different management scenarios and assessment of potential new policy epoch gateways for revising the SMP6 recommendations.

The conclusions from this Study set out the positive and negative impacts of each management scenario, in addition to recommending Policy Units at Mundesley and Overstrand for further study at Project Appraisal Report stage.

The current SMP6 recommended policies form a technically feasible option which allows the development of a stable coastline over the long term (100 years). Over the short term (first 20 years) over 200 properties are better protected from erosion (compared to a Do Nothing Baseline) however over the longer term (21-100 years) this study suggests that no properties are better protected from erosion.

The Modified SMP6 Scenario assesses a Hold the Line management over 100 years at Overstrand, Mundesley and Bacton, Walcott and Ostend. 910 properties are better protected from coastal erosion under the Modified SMP6 Scenario compared to the Do Nothing Baseline, however the costs associated with the coastal defence schemes are increased. The coastline formed over 100 years is potentially less stable when compared with the SMP6 Scenario.

The addition of sediment nourishment to the system under the current SMP6 recommendations appears to have a positive effect in reducing erosion rates over the Study frontage, whilst allowing sufficient sediment supply to the south east. Incorporation

of this scenario into further studies would require further discussions on the distribution of costs and benefits between North Norfolk District Council and the Environment Agency. Under this Scenario, as well as under the SMP6 and Modified SMP6 Scenarios, the model results suggest the need for beach nourishment at Sea Palling (Policy Unit 6.13) may be reduced over the medium term to long term (20-100 years).

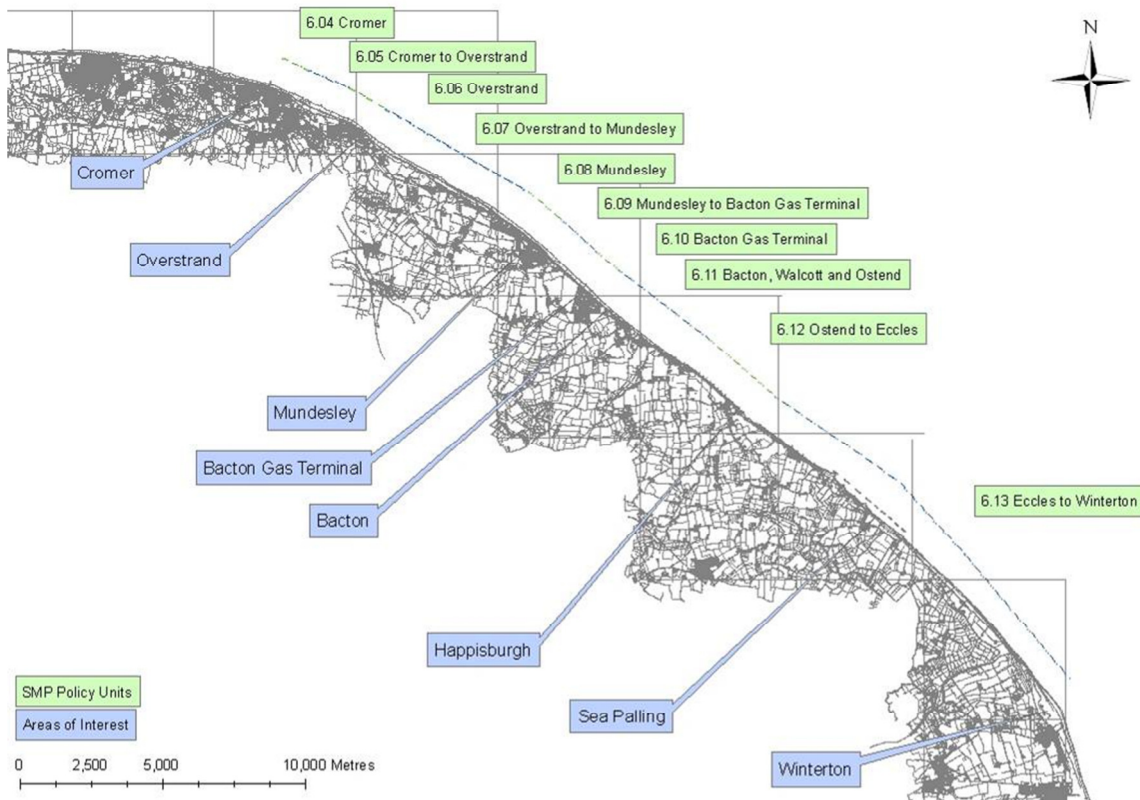
1 Introduction

1.1 Background

The Cromer to Winterton Ness coastline forms part of the 'Kelling to Lowestoft Ness Shoreline Management Plan' (2005). This 35km stretch of coastline is comprised of various coastal defence assets which protect a number of settlements. The Shoreline Management Plan (SMP6) has divided the coastline into a number of individual Policy Units (Figure 1.1). From Cromer to Winterton Ness there are 14 Policy Units defining the management policies for adoption in each Policy Unit from the short term (0-20 years) to the medium (21-50 years) and long term (51-100 years). The recommended management policies from the SMP6 vary considerably along this stretch of coastline with some Policy Units having a recommended management policy of Hold the Line, whilst other Policy Units have a recommended management policy of No Active Intervention or Managed Realignment.

The recommended SMP6 (2005) management policies have been developed under the assumption that the impact of a Hold the Line policy in one area is likely to increase erosion down the coast (i.e. in a south easterly direction) due to limits in sediment supply through longshore drift. This has led to the recommendation of Hold the Line management only in the short (0-20 years) or medium (21-50 years) terms in many Policy Units, with the intention of limiting any long term impacts through reduction in sediment supply along the coastline. However, these assumptions have not previously been tested and the potential economic impacts and social mitigation measures required from various policies were not considered in detail during the development of the SMP6.

Figure 1.1: Map of the Cromer to Winterton Ness coastline showing the Policy Units and main areas of interest.



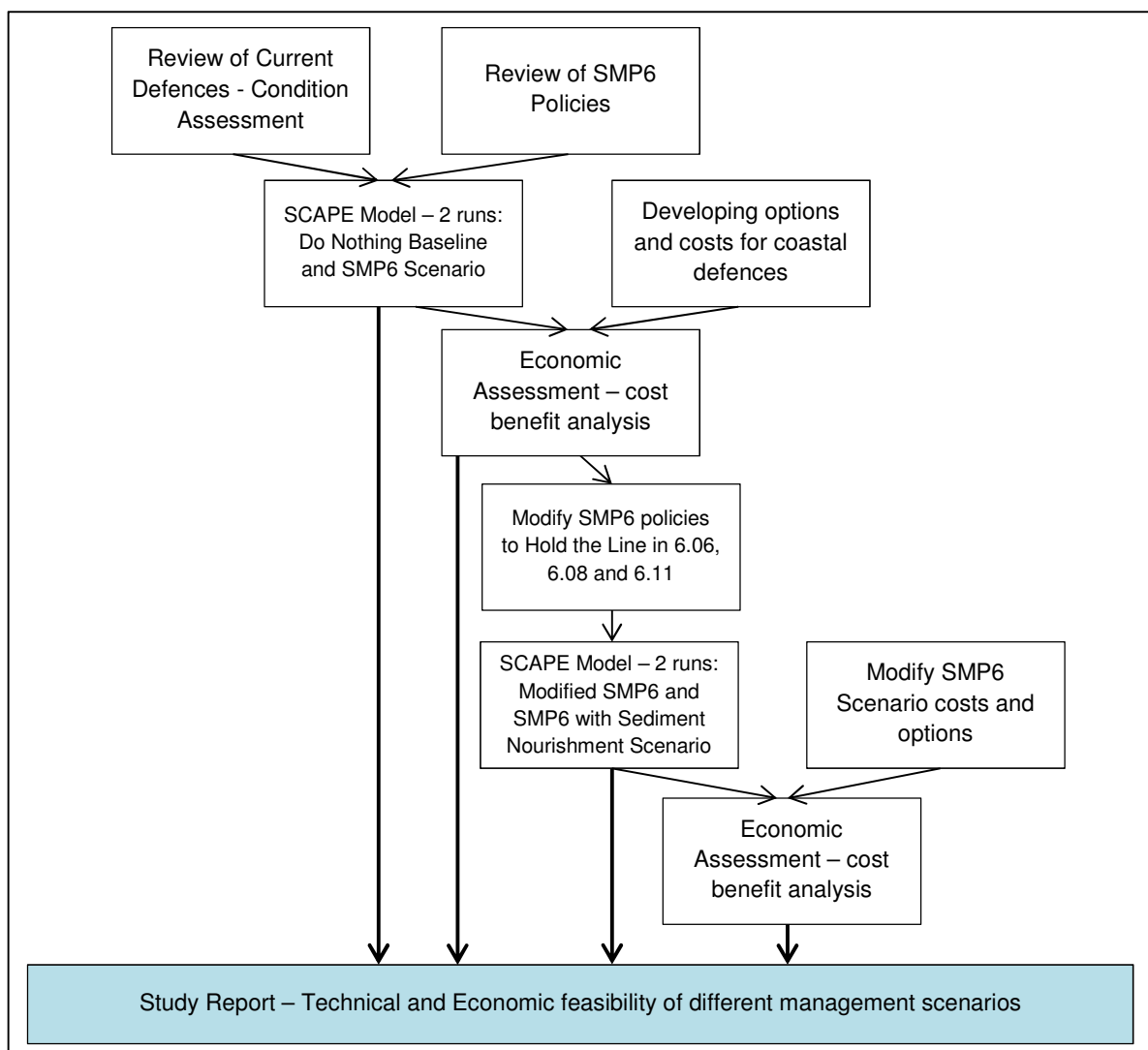
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1.2 Coastal Management Study

North Norfolk District Council (NNDC) has appointed Mott MacDonald to complete a Coastal Management Study to validate and potentially refine the current SMP6 management policies. This Study, whilst not a Strategy Study, was recommended by LPRG (or NRG at the time) as an alternative to a Strategy Study to allow a review of the recommendations from the SMP6 (2005). This Study therefore follows on from the SMP6 (2005) and will provide recommendations for schemes to be taken forward to Project Appraisal Report (PAR) stage.

The Study frontage is comprised of SMP6 Policy Units 6.05 to 6.13 inclusive (Figure 1.1). Policy Unit 6.13 (Eccles to Winterton, including Cart Gap) which is managed by the Environment Agency, has not been included in the economic assessment (Section 3 and Appendix B) due to an existing PAR which covers this frontage which includes detailed coastal defence options, costs and benefits. However, the overall management of the coastline has been considered for all Policy Units (6.04 to 6.13) with potential impacts on sediment movement and coastline geometry assessed for this entire frontage.

This Study has incorporated the holistic understanding of inter-linked coastal processes along the frontage, current and future coastal defence conditions, economic assessment of costs and benefits associated with each Policy Unit. It has compared the impacts of different management options and assessment of new policy epoch gateways for a revised SMP6. The processes taken in developing this Study Report are demonstrated below:



The results from this Study are collated in this main Study Report, however further details are presented in the appendices:

- Appendix A: Condition Survey Report.
- Appendix B: Economic Assessment Report.
- Appendix C: SCAPE Model Analysis Report.

1.3 Aim of the report

The main aim of this Study Report is to bring together the results from the condition survey, SCAPE model and the economic assessment, and provide recommendations for taking forward management scenarios and coastal defence schemes over the short (0-20 years), medium (21-50 years) and long (51-100 years) terms. This report will also set out a framework for funding applications and further studies (such as Project Appraisal Reports (PARs)).

This Report has been structured to assess the large scale impact of the management scenarios on the entire coastline, before discussing the impact of the management scenarios on each Policy Unit individually followed with a summary of potential policy options and funding:

- Section 2 presents the results from the SCAPE model for the whole coastline, particularly focussing on how different management scenarios could affect the overall shape of the coastline and the longshore sediment flux supply to the frontage at Cart Gap (SMP6 Unit 6.13).
- Section 3 considers each SMP6 Policy Unit individually, assessing the combined impact of the economic assessment and SCAPE model outputs, and whether there is the technical or economic justification for developing a coastal defence scheme within the Policy Units.
- Section 4 looks at the recommended management policies from the Study and identifies Policy Units along the frontage which are recommended to be taken forward to PAR stage.
- Section 5 assesses potential funding for the schemes identified in Section 4, detailing potential sources of external funding to close any gaps identified in the Partnership Funding Scores (Appendix B).

It is important to note that the discussions within this report are based on interpretations of the results from the SCAPE model. Although the SCAPE model provides an indication of how coastal processes may change and impact recession rates under different management scenarios, the results only show potential impact and the model may not provide a complete representation of what could happen under different management scenarios.

2 Erosion of the North Norfolk Coast over 100 years

2.1 Management Scenarios

To fully investigate the potential impact of implementing management scenarios on coastal erosion on the North Norfolk Coast over the next 100 years, a range of management scenarios has been considered within this assessment:

- **Do Nothing Baseline:** The Do Nothing Baseline assumes the current defences are left to fail and no further works (capital nor maintenance) are undertaken. This is used as a baseline scenario in the economic assessment to calculate the benefits of implementing coastal defence schemes (i.e. a Do Something Scenario) as recommended in the FCRM AG (2010). In this Study, the Do Nothing Baseline is compared to the rates and sequences of coastal erosion under other management scenarios.
- **SMP6 Scenario:** The SMP6 Scenario considers the erosion of the coastline under the recommended policies from the SMP6 (2005). This means erosion is delayed in Policy Units with a recommended Hold the Line policy. In these areas with a Hold the Line policy, the residual life of the defences has been extended throughout the Hold the Line epoch so that the defences do not fail until the specified time.
- **Modified SMP6 Scenario:** The Modified SMP6 Scenario considers the potential impacts of modifying the SMP6 policies in only three Policy Units (6.06, 6.08 and 6.11) by extending the Hold the Line policies over the long term (100 years).
- **SMP6 with Sediment Nourishment Scenario:** The SMP6 with Sediment Nourishment Scenario considers a sediment nourishment event every four years along the north west of the frontage (by Overstrand in Policy Units 6.05, 6.06 and 6.07) (see Section 2.3.4 for reasons for this location). The management policies (Hold the Line, Managed Realignment and No Active Intervention) along the frontage are the same as under the SMP6 Scenario so that the benefits of carrying out sediment nourishment on the entire study frontage can be assessed. The Environment Agency currently carries out a similar nourishment event at Sea Palling (Policy Unit 6.13) approximately every four years. Therefore this Scenario tests whether this recharge could be moved further north up the coastline and still benefit the entire frontage.

The SCAPE model calculates the sediment flux along the frontage. One of the important values to assess in the evaluation of the management scenarios is the sediment flux supply at Cart Gap, which is by the boundary between Policy Unit 6.12 and 6.13. It is vital that the volume of sediment supplied to this frontage does not decrease to ensure significant impacts to the frontages further along the coastline are not realised. This area of coastline is particularly vulnerable to loss of sediment and the Environment Agency currently carries out sediment recharge in the area to combat this. The overall impact of each management scenario on the frontage, both in terms of patterns of recession of the coastline and changes in sediment flux being supplied at the south eastern section of the frontage (at Policy Unit 6.13) is discussed below. Further detailed analysis for each individual SMP6 Policy Unit is presented in Section 3 of this Study Report.

2.2 The SCAPE Model

The SCAPE model (developed by the Tyndall Centre) has been used to assess potential erosion for the Study frontage over the next 100 years. Utilisation of the SCAPE model has the benefit of enabling a more

holistic and integrated assessment of the whole coastline compared to assessment which only focus on individual Policy Units. The SCAPE model allows consideration of how the policy in one area of the frontage may impact the coastal processes in an area further along the frontage by assessing longshore sediment transport processes.

The SCAPE model set-up (described in more detail in Appendix C) uses information from the condition survey (Appendix A) to assign the current defences along the coastline a residual life. This residual life is then altered to reflect a particular management policy. The model is run using regional hydrodynamic and sediment conditions, using the latest sea level rise guidance from UKCP09 to account for predicted future climate change.

The SCAPE model is a useful tool for assessing the potential erosion to the North Norfolk coast in a holistic assessment. To enable this assessment, particular assumptions within the SCAPE model need to be understood in the interpretation of the results, and the impacts these have on the economic assessment along the coastline. Although these assumptions are acceptable for this large scale Study, certain assumptions may need to be assessed in more detail at Project Appraisal Report (PAR) Stage. The main assumptions relevant to the interpretation of the results (further assumptions relating to the set-up of the model are presented in Appendix C) are:

- Although the SCAPE model units broadly reflect the SMP6 Policy Units, there are areas of overlap. The effect of this overlap is not significant at this high level Study, however specific boundaries for coastal management would need to be considered at PAR stage.
- The type of defences and residual life of defences has been averaged across each SCAPE Unit. This is appropriate for this high level Study however increased detail should be assessed at PAR stage. This could result in increased phasing of works within Policy Units.
- The impact of implementing Managed Realignment on the erosion of the coastline has not been captured in the SCAPE model results. This is because the SCAPE model contains information only on the residual life the defences and not on the maintenance of the defences. However, realistically implementing Managed Realignment is likely to decrease coastal recession rates. Therefore the erosion included within this Study in areas with a Managed Realignment policy are likely to represent worst case scenarios.
- The results from the SCAPE model have been used to calculate erosion for the economic assessment. Although the SCAPE model is advantageous in allowing a holistic approach to assessing erosion over the coastline, this large scale approach is at a more broad scale than the economic assessment, which is split into the SMP6 units. This means that the Do Nothing Baseline which has been used as a baseline for the economics is the Do Nothing Baseline for the whole coastline. Therefore in some areas (such as Policy Units 6.06 and 6.11) more properties appear to be eroded under the SMP6 Scenario compared to the Do Nothing Baseline. It is important to note that this does not suggest a Do Nothing Baseline is more beneficial, this would be only true if it was implemented over the entire coastline. At a Policy Unit scale, the Do Nothing Baseline (under the assumption that the SMP6 Scenario is implemented in all other Policy Units) would show even greater rates of erosion. The Do Nothing Scenario is used as a realistic baseline for this Study as this Study is focussing on the holistic management of the coastline. However, at a PAR stage, for the purposes of the economic assessment, the Do Nothing baseline would be taken for the specific Policy Unit only and therefore results from the economic assessment would be less conservative.

- The SCAPE model assesses erosion to the toe of defences and cliffs. In areas with timber revetment or timber groyne defences, it is assumed that erosion may still occur if sediment levels drop sufficiently, even if the defence structure has not 'failed' (i.e. the residual life of the defence has not been reached).

2.3 Results

2.3.1 Do Nothing Baseline

Introduction

The Do Nothing Baseline assumed that the current defences are left to deteriorate and no further works or maintenance are undertaken along the coastline. This Scenario does not represent a potential management option, but rather gives a baseline to compare with the different management scenarios along the frontage. Figure 2.1 presents the predicted erosion map of the frontage under a Do Nothing Baseline.

Overall change in geometry of the coastline

In terms of the spatial erosion extent under the Do Nothing Baseline, although there are a variety of defences with varying associated residual lives, the long term (0-100 years) erosion extent over the entire frontage is relatively uniform and straight between Policy Units. The main observations of coastal erosion under this Scenario suggest that the retreat of the coastline under coastal erosion appears to act to maintain an equilibrium shape, for example:

- In Area A (Figure 2.1) where the coastline profile is currently relatively uniform, the resulting 100 year coastline is also relatively uniform.
- In the Area B (Figure 2.1) around Mundesley (SCAPE units 45-48) increased erosion compared to the adjacent areas of the frontage can be seen to act to straighten the coastline.
- In Area C (Figure 2.1) when the current coastline is uneven, such as SCAPE units 58 and 59, the erosion processes over 100 years can be seen to smooth the geometry of the coastline.

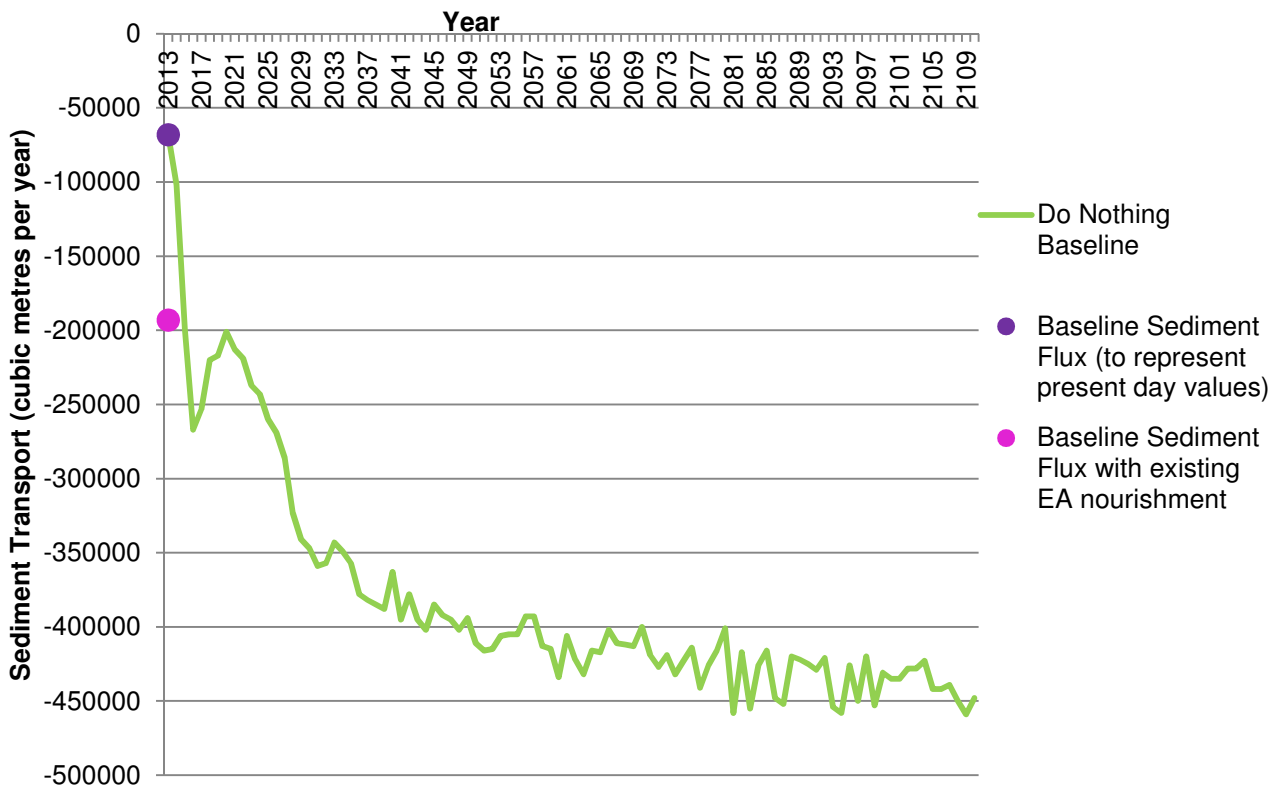
In terms of the temporal assessment of erosion, there is generally less erosion over 100 years (particularly in years 50-100) at the south eastern end of the frontage (Policy Units 6.11 and 6.12) compared to the rest of the frontage. This could be explained through the influence of increased sediment supply to these Policy Units from longshore drift from the eroding areas further updrift. This sediment would provide increased protection to the toe of the defences and cliffs in Policy Units 6.11 and 6.12, thus slowing rates of coastal erosion and retreat of the coastline.

Impact of Do Nothing Baseline on sediment movement and management at Policy Unit 6.13

Figure 2.2 shows that there is a general increase in sediment flux at Cart Gap over the 100 years. This is due to an increase in the length of eroding coastline throughout the 100 years as defences fail. The rate of increase in sediment flux levels out from approximately year 50, representing the coastline tending towards an equilibrium profile. When compared to the current day baselines (see Figure 2.2) from 2015, the

average annual sediment flux is greater than current estimated rates. This therefore suggests that this scenario would be sustainable with regards to management of the frontages at Policy Unit 6.13 as sufficient sediment supply is likely to be delivered to the frontage to enable the current management to continue.

Figure 2.2: Graph to show annual sediment flux at Cart Gap (Policy Unit 6.13) under the Do Nothing Baseline from the SCAPE model 50%ile results. Annual sediment flux is calculated on a 10 year average (i.e. the value shown for year 2025 is the annual average between 2010 and 2020). A negative sediment transport rate indicates a southerly transport direction. Two baseline scenarios are shown. The Baseline Sediment Flux represents the current sediment flux (taken from the 2013 values from the model). The Baseline Sediment Flux with existing EA nourishment represents the current sediment flux with an additional 500,000m³ every four years (an annual addition of 125,000m³) to represent approximately the additional sediment nourishment the Environment Agency currently undertakes.



Summary

The Do Nothing Baseline provides a baseline Scenario to compare against the impact of different management policies. Although it is not a suggested management solution, it is clear that under the Do Nothing Baseline the coastline establishes an approximate equilibrium. This is shown both through the geometry of the 100 year coastline in Figure 2.1 and the levelling out of sediment flux rates in Figure 2.2.

This 100 year coastline would enable continued efficient management of the frontage at Policy Unit 6.13 through the increased sediment transport rates seen over the 100 years.

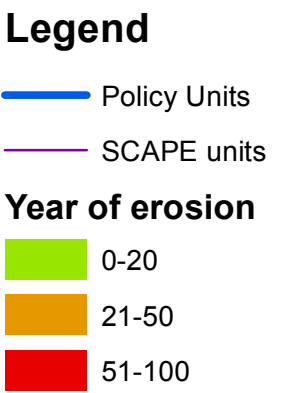
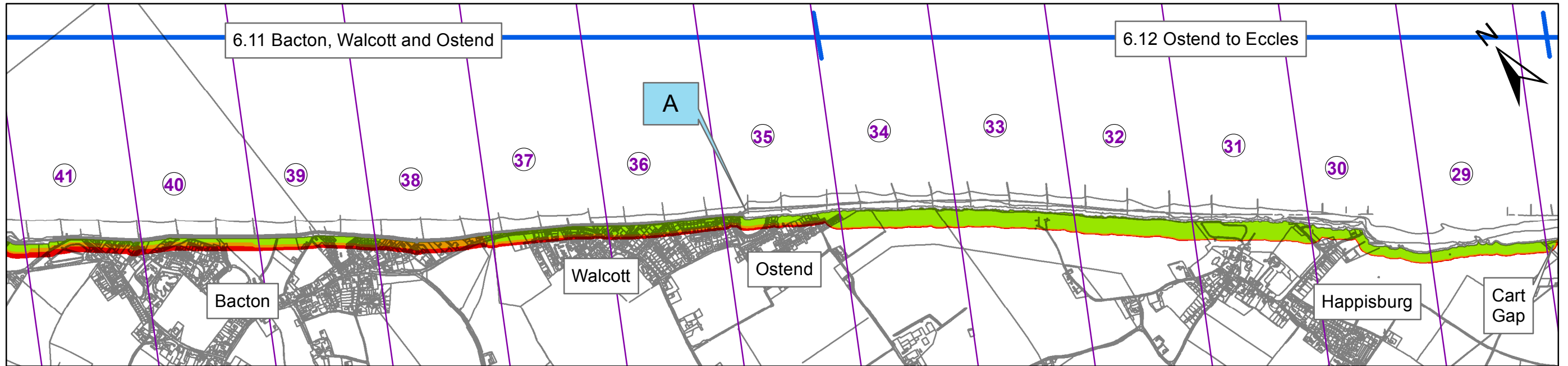
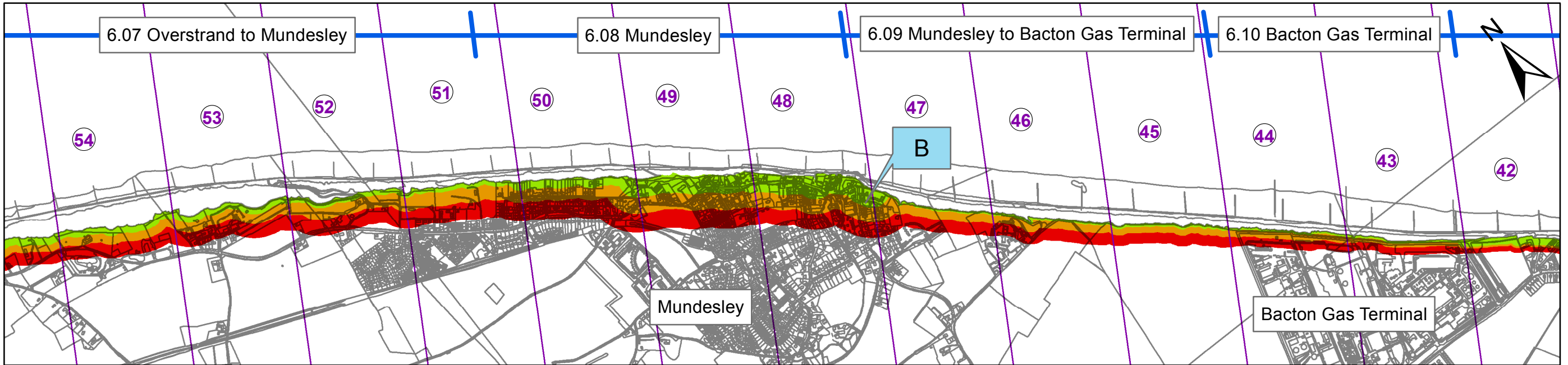
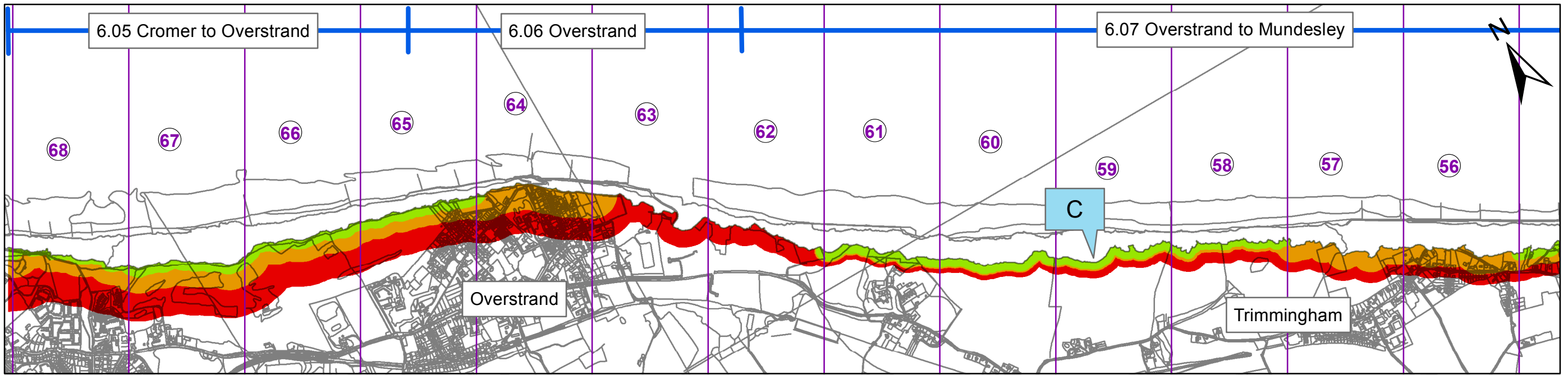


Figure 2.1 Do Nothing

2.3.2 SMP6 Scenario

Introduction

The SMP6 Scenario incorporates the recommended policies from the SMP6 (2005) which are summarised in Table 2.1. The SCAPE model results show no erosion under Hold the Line policies. Figure 2.3 displays the predicted erosion of the frontage under the SMP6 Scenario.

Table 2.1: Management scenarios as recommended under the SMP6 (Note: No Active Intervention can be considered as the Do Nothing Baseline)

SMP6 Policy Unit	Short term (0-20 years)	Medium term (21-50 years)	Long term (51-100 years)
6.05 Cromer to Overstrand	Managed Realignment	No Active Intervention	No Active Intervention
6.06 Overstrand	Hold the Line	Managed Realignment	Managed Realignment
6.07 Overstrand to Mundesley	Managed Realignment	No Active Intervention	No Active Intervention
6.08 Mundesley	Hold the Line	Hold the Line	Managed Realignment
6.09 Mundesley to Bacton Gas Terminal	Managed Realignment	No Active Intervention	No Active Intervention
6.10 Bacton Gas Terminal	Hold the Line	Hold the Line	Hold the Line
6.11 Bacton Walcott and Ostend	Hold the Line	Managed Realignment	Managed Realignment
6.12 Ostend to Eccles	Managed Realignment	Managed Realignment	Managed Realignment
6.13 Eccles to Winterton	Hold the Line	Hold the Line	Hold the Line

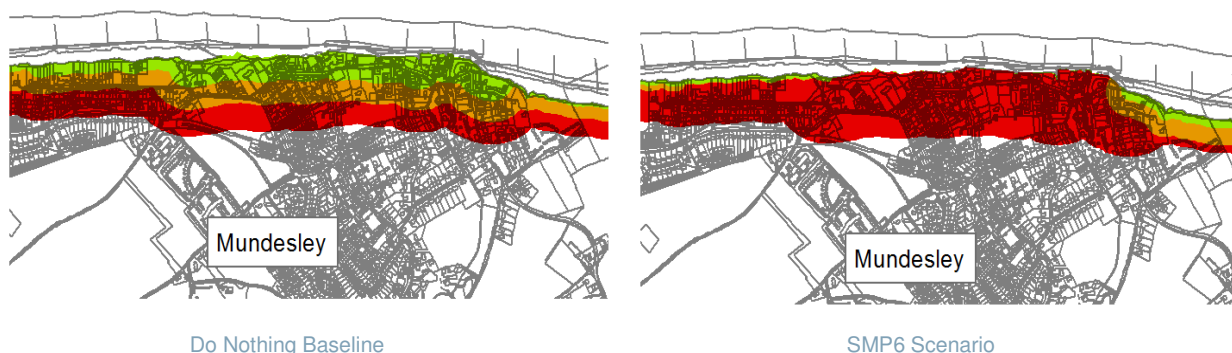
Overall change in geometry of coastline

A reduction in the damages from coastal erosion compared with the Do Nothing Baseline, particularly in the short (0-20 years) and medium term (21-50 years) occurs under the SMP6 Scenario. However, as can be observed from Figure 2.1 and 2.3, there does not appear to be a significant overall change in the retreat of the coastline over 100 years between the SMP6 Scenario and the Do Nothing Baseline. This can be explained through the increased erosion rates experienced once the defences are left to fail. This occurs because during the period where a stretch of the coastline is held under the SMP6 policy, the surrounding areas of coastline experience retreat, increasing the exposure of the stretch of coastline under a Hold the Line management to coastal erosion. The increased erosion rates experienced once the defences fail act to re-establish an equilibrium geometry which is formed under the Do Nothing Baseline.

Policy Unit 6.08 (Mundesley) exemplifies these processes which act to create an equilibrium geometric shape of the coastline (see Figure 2.4). Although very little erosion occurs within the short (0-20 years) and medium term (21-50 years), the 100 year erosion line is very similar to that under the Do Nothing Baseline. This can be explained through the creation of a headland type feature under the medium term (0-50 years) whilst the defences are maintained, causing this area to become increasingly exposed to wave action. Therefore, once the defences are left to fail after year 50, the coastline is very vulnerable to coastal erosion and erosion of the coastline acts to even out the coastline (or to make the geometry more uniform). A similar mechanism can be seen to act at Policy Unit 6.11 (Bacton, Walcott and Ostend).

Figure 2.4: Diagram to exemplify the erosion process seen at Mundesley, where increased exposure lead to increased erosion. The Do Nothing Baseline and SMP6 Scenario show similar 100 year erosion.

KEY: Green – erosion 0-20 years, Orange – erosion 21-50 years, Red – erosion 51-100 years.



An assumption within the SCAPE model for considering the impacts of the implementation of the SMP6 policies is that there is no representation of the Managed Realignment policy. Rather, this policy is represented as a No Active Intervention scenario within the model. In reality, it is likely that recession rates would be reduced under a Managed Realignment management option as some maintenance would still be carried out on the defences to sustain their remaining residual life. It is considered that this does not have a significant impact on the comparative analysis within this Study as the impact will be similar across all Policy Units. Therefore patterns of shoreline retreat are likely to be comparable between different management scenarios.

In some Policy Units (particularly 6.06 and 6.11), the amount of retreat of the coastline over 100 years is greater under the SMP6 Scenario than compared with the Do Nothing Baseline. This can be explained by:

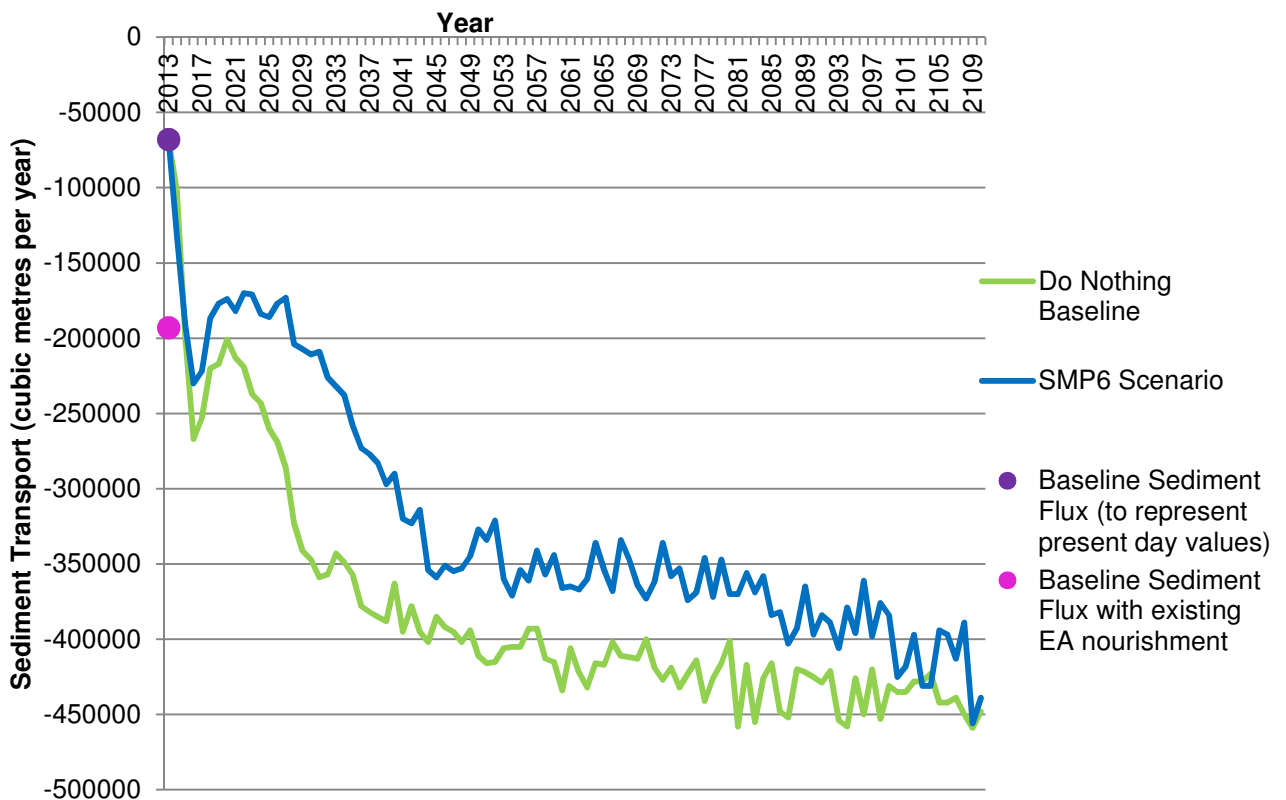
- In the SCAPE model sediment is assumed to be transported longshore over approximately 16km of frontage updrift from the Study frontage. Under a Do Nothing Baseline this sediment decreases the exposure to coastal erosion at the toe of the coastal defences and cliffs, therefore decreasing coastal erosion rates.
- Under the SMP6 Scenario, Hold the Line policies at Cromer and Sheringham updrift along the coastline decrease the sediment supply, hence providing less 'buffering' to the toe of the coastal defences and cliffs.

The results under the SMP6 Scenario demonstrate the importance of sediment supply along the frontage, and the potential for adverse impacts when this sediment is reduced. Although this may suggest that a Do Nothing Baseline is more technically robust when compared to the SMP6 Scenario, this would only be the case if the coastline updrift of the Study frontage (by Sheringham and Cromer) also implemented a Do Nothing policy. However, realistically these urban areas are likely to hold the defences and therefore the Do Nothing Baseline for the Study frontage would show increased erosion rates compared to the SMP6 Scenario.

Impact of SMP6 Scenario on sediment movement and management at Policy Unit 6.13

The sediment flux delivered to the frontage at Cart Gap increases with time due to increased erosion of the frontage and subsequent release of sediments for longshore drift (Figure 2.5). When compared with the Do Nothing Baseline, the increase in sediment flux over the medium term (0-50 years) is less rapid. This is due to Hold the Line policies which limit the erosion and therefore sediment supply to the frontage. However, over the 100 years, the sediment flux at Cart Gap is almost identical between the Do Nothing Baseline and the SMP6 Scenario (Figure 2.5). This supports the explanation above and indicates that the SMP6 Scenario is just as technically sustainable over the 100 years when compared with the Do Nothing Baseline. There is unlikely to be any negative impact on the frontage at Policy Unit 6.13 as the sediment flux does not drop below the current baseline values. In addition, from approximately year 30 onwards, the predicted sediment flux from the model is greater than the baseline flux with sediment recharge, suggesting the EA could potentially reduce sediment nourishment along the beaches at Policy Unit 6.13 in the medium to long term (20-100 years). However, on-going monitoring would be needed as this baseline does not include potential impacts of sea level rise which may increase offshore/alongshore sediment transport and therefore could increase the amount of recharge needed under current day management.

Figure 2.5: Graph to show annual sediment flux at Cart Gap (Policy Unit 6.13) under the Do Nothing Baseline and SMP6 Scenario from the SCAPE model 50%ile results. Annual sediment flux is calculated on a 10 year average (i.e. the value shown for year 2025 is the annual average between 2010 and 2020). A negative sediment transport rate indicates a southerly transport direction. Two baseline scenarios are shown. The Baseline Sediment Flux represents the current sediment flux (taken from the 2013 values from the model). The Baseline Sediment Flux with existing EA nourishment represents the current sediment flux with an additional 500,000m³ every four years (an annual addition of 125,000m³) to represent approximately the additional sediment nourishment the Environment Agency currently undertakes.



Summary

Under the SMP6 Scenario, erosion is restricted along parts of the frontage under a Hold the Line policy. However, increased erosion over the long term (51-100 years) occurs. The results from the SCAPE model suggest the coastline would approach an equilibrium shape, similar to that under the Do Nothing Baseline over the 100 years. Additionally, although a small reduction in sediment transport rates at Policy Unit 6.13 is shown in the short term (0-20 years), over the 100 years there is an increase in sediment supply which would enable continued management of Policy Unit 6.13. The advantage of the SMP6 Scenario is that there is a delay in the erosion of the frontages where the highest densities of properties are sited (for example at Overstrand, Mundesley, Bacton, Walcott and Ostend). This delay in erosion would facilitate appropriate time for community adaptation to the potential increasing risk of coastal erosion. Results from the SCAPE model suggest that this delay in erosion would not significantly affect the long term sustainability of the coastline or management of Policy Unit 6.13.

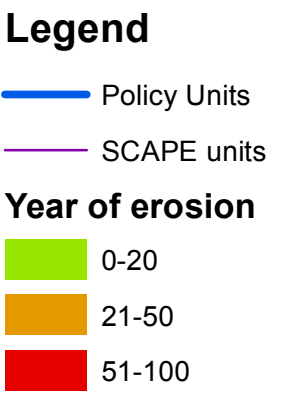
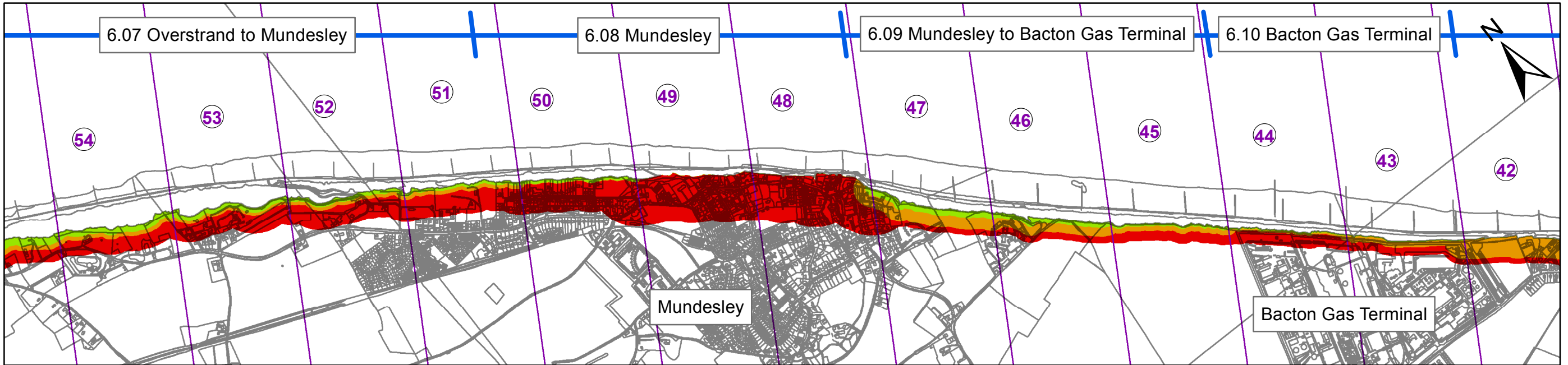
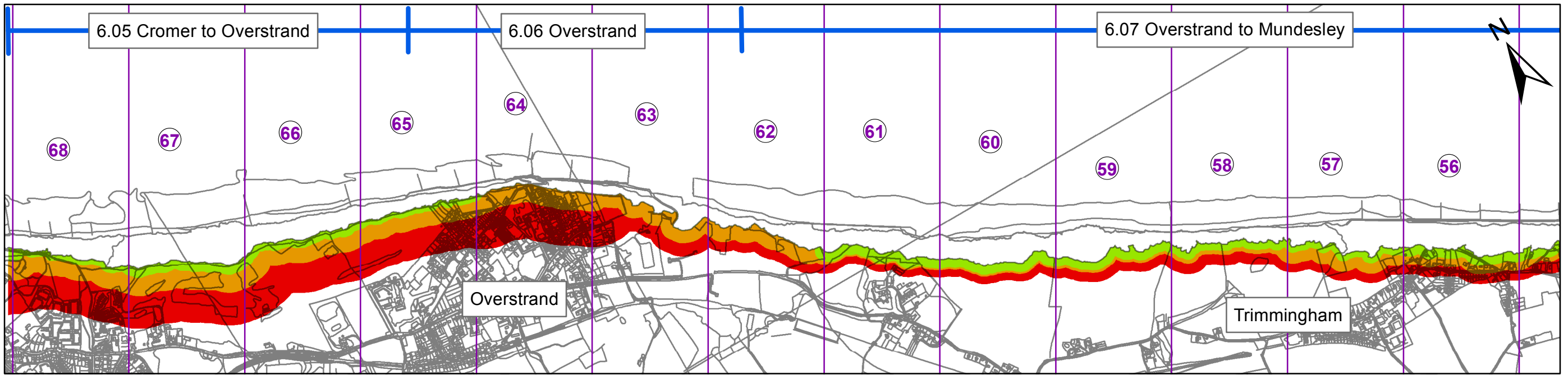


Figure 2.3 SMP6 Scenario

2.3.3 Modified SMP6 Scenario

Introduction

The Modified SMP6 Scenario looks at slightly modified policies from the SMP6 Scenario, summarised in Table 2.2. This Scenario has been run to compare the impact of modifying the SMP6 management policies in only three areas (Policy Units 6.06, 6.08 and 6.11) to extend the Hold the Line management policies over the 100 years. These three Policy Units are important areas due to the high density of residential, commercial and infrastructure assets at risk from coastal erosion (particularly when compared with the other Policy Units). Figure 2.6 displays the predicted erosion of the frontage under the Modified SMP6 Scenario.

Table 2.2: Modified SMP6 management policies (where the management policy has been modified compared to the SMP6 Scenario, it is highlighted in red).

SMP6 Policy Unit	Short term (0-20 years)	Medium term (21-50 years)	Long term (51-100 years)
6.05 Cromer to Overstrand	Managed Realignment	No Active Intervention	No Active Intervention
6.06 Overstrand	Hold the Line	Hold the Line	Hold the Line
6.07 Overstrand to Mundesley	Managed Realignment	No Active Intervention	No Active Intervention
6.08 Mundesley	Hold the Line	Hold the Line	Hold the Line
6.09 Mundesley to Bacton Gas Terminal	Managed Realignment	No Active Intervention	No Active Intervention
6.10 Bacton Gas Terminal	Hold the Line	Hold the Line	Hold the Line
6.11 Bacton Walcott and Ostend	Hold the Line	Hold the Line	Hold the Line
6.12 Ostend to Eccles	Managed Realignment	Managed Realignment	Managed Realignment
6.13 Eccles to Winterton	Hold the Line	Hold the Line	Hold the Line

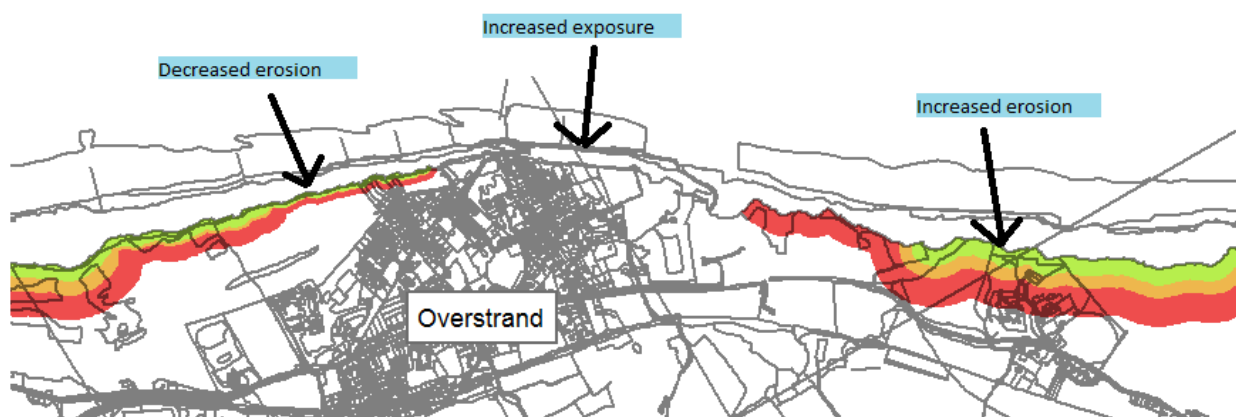
Overall change in geometry of coastline

Under the Modified SMP6 Scenario, the erosion pattern along the frontage becomes much more uneven than when compared to the Do Nothing Baseline and SMP6 Scenario. The impact of Holding the Line in the long term restricts erosion in these Policy Units as adjacent areas of coastline retreat back. This creates exposed buttresses which are increasingly vulnerable to wave action and therefore erosion. This formation is unlikely to be sustainable in the long term.

Creation of exposed buttresses can create a build-up of sediment to the north west of the Policy Unit under Hold the Line management (consequently reducing recession rates) and limits the sediment supply to the south east of the section (consequently increasing recession rates) (Figure 2.7). The increased erosion rates in the Policy Units contributes to the exposure of the Policy Units under Hold the Line management and hence exaggerates the resulting non-uniform geometry of the coast. Similarly to under the SMP6 Scenario, Policy Units under a Hold the Line management policy become increasingly exposed to coastal erosion in the future. However, due to the increased length of time for which the Hold the Line management is adopted in the Modified SMP6 Scenario, the impacts may be greater under the Modified

SMP6 Scenario compared to the SMP6 Scenario and therefore may increase future maintenance costs and decrease the long term stability of the coastline.

Figure 2.7: Diagram to show impact of Hold the Line policy on surrounding areas of coast using the example of Policy Unit 6.06.



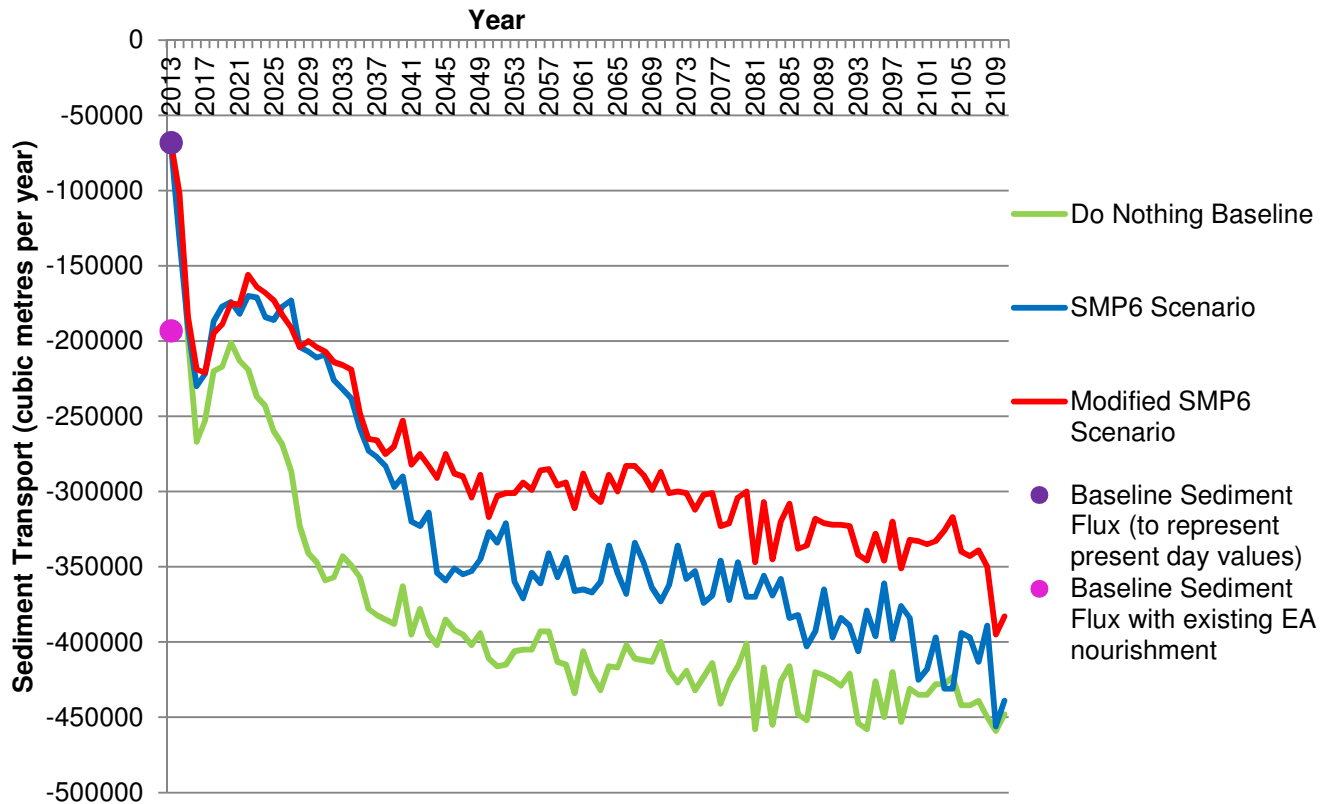
Impact of Modified SMP6 Scenario on sediment movement and management at Policy Unit 6.13

Sediment transport rates increase over the 100 years under the Modified SMP6 Scenario due to the increase in erosion of the frontages as coastal defences fail (Figure 2.8).

The sediment flux rates at Cart Gap (Policy Unit 6.13) are reduced under the Modified SMP6 Scenario when compared with the Do Nothing Baseline and SMP6 Scenario (Figure 2.8). This is due to a Hold the Line policy over the long term (0-100 years) in Policy Units 6.06, 6.08, 6.10 and 6.11. A Hold the Line policy decreases the erosion in these Policy Units, hence decreasing the amount of sediment being made available in the system for longshore transport along the frontage to Cart Gap.

Despite this reduction in sediment transport rates when compared with the SMP6 Scenario and Do Nothing Baseline, the sediment transport rate is still greater than both the baseline (over years 0-100) and the baseline with sediment recharge (20-100 years) values. Therefore the results from the SCAPE model suggest that the sediment transport rates could be sufficient to continue to allow efficient management of the frontage at Policy Unit 6.13. From approximately 2030 onwards, the predicted sediment flux from the model is greater than the baseline flux with sediment recharge, suggesting the EA could potentially reduce sediment nourishment along the beaches at Policy Unit 6.13 in the medium to long term (20-100 years). However, on-going monitoring would be needed as this baseline does not include potential impacts of sea level rise which may increase offshore/alongshore sediment transport and therefore could increase the amount of recharge needed under current day management.

Figure 2.8: Graph to show annual sediment flux at Cart Gap (Policy Unit 6.13) under the Do Nothing Baseline, SMP6 and Modified SMP6 Scenarios from the SCAPE model 50%ile results. Annual sediment flux is calculated on a 10 year average (i.e. the value shown for year 2025 is the annual average between 2010 and 2020). A negative sediment transport rate indicates a southerly transport direction. Two baseline scenarios are shown. The Baseline Sediment Flux represents the current sediment flux (taken from the 2013 values from the model). The Baseline Sediment Flux with existing EA nourishment represents the current sediment flux with an additional 500,000m³ every four years (an annual addition of 125,000m³) to represent approximately the additional sediment nourishment the Environment Agency currently undertakes.



Summary

Over the 100 years, the sediment supply under the Modified SMP6 Scenario, although reduced when compared to the SMP6 Scenario, is likely to be just as technically feasible. An increase in sediment transport rates when compared to current baseline estimates suggest continued management of Policy Unit 6.13 would not be adversely impacted. However, it is worth noting that the resulting coastline after 100 years is likely to be much less stable than that which is formed under the SMP6 Scenario due to the formation of exposed Policy Units where the Hold the Line management has been extended. This instability could increase the risk of erosion to exposed properties after 100 years.

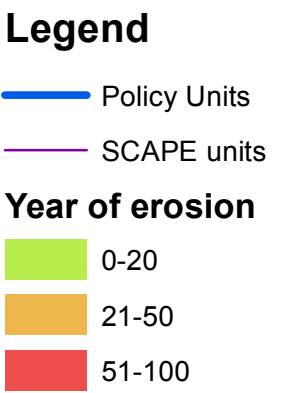
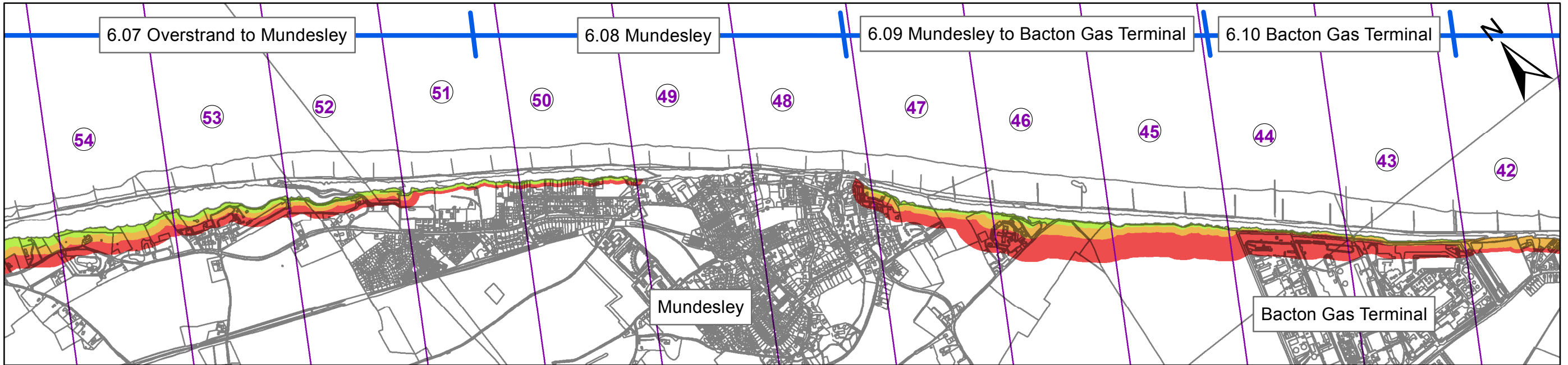
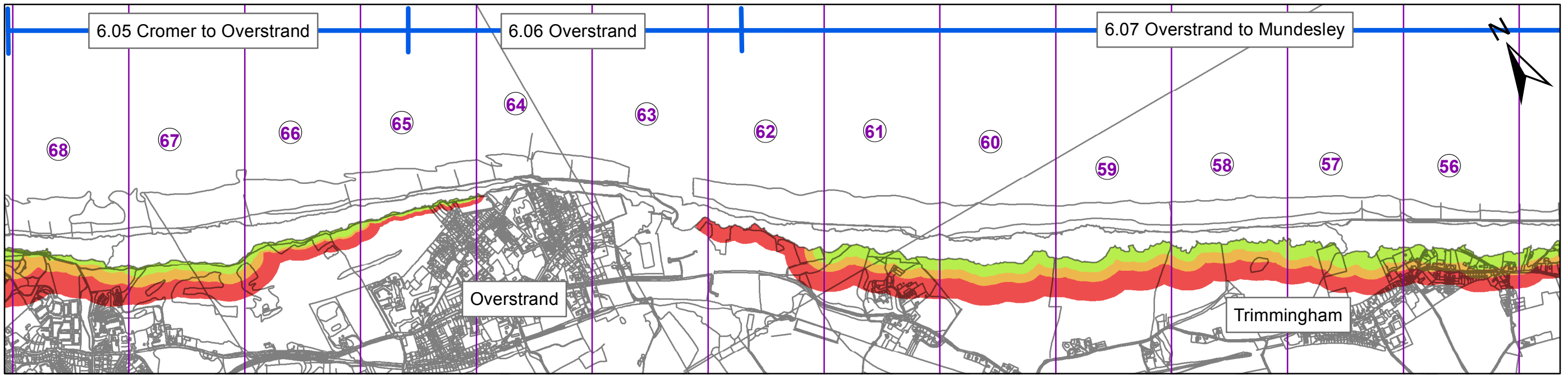


Figure 2.6 Modified SMP6 Scenario

2.3.4 SMP6 with Sediment Nourishment Scenario

Introduction

Figure 2.9 displays the erosion of the frontage under the SMP6 with Sediment Nourishment Scenario. This scenario is a replica of the SMP6 Scenario with the addition of 500,000m³ of beach material placed along SCAPE model units 58-67 every four years (Figure 2.9). This sediment nourishment has been designed to reflect the sediment nourishment currently carried out by the Environment Agency at Cart Gap (north west section of Policy Unit 6.13). The results therefore allow an investigation into the potential impact of simply moving the sediment nourishment event further updrift to potentially influence a greater length of coastline. The site of the sediment nourishment was chosen due to a number of reasons:

- Placement of the sediment further west of Cromer would increase the risk of the sediment not being transported along the length of the frontage. This risk is increased because: the coastline at Cromer has a small change in orientation, the pier at Cromer could trap sediment and the long term (0-100 years) Hold the Line policy is likely to encourage build-up of sediment updrift of Cromer.
- Due to the above reasons, the area where the sediment is likely to have the greatest impact is just east of Cromer and therefore the first 10 SCAPE units east of Cromer have been used to place the additional sediment.
- It is better to place the sediment over a wider area to prevent overloading on area, which may encourage only localised impacts and offshore transport (although this would not have been captured in the SCAPE model). 100m³ of sediment per m length equates to an area roughly 4m by 50m which gives an appropriate beach slope (1:12.5).

Overall change in geometry of coastline

Figure 2.9 clearly shows a decrease in coastline recession rates for the SMP6 with Sediment Nourishment Scenario when compared with the SMP6 Scenario. This is unsurprising as previous results have shown increases in sediment supply through longshore drift can act as a 'buffer' to the coastline and defences, reducing the exposure to coastal erosion of the toe of the coastal defences and cliffs along the frontage. This impact is greatest to the north west of the study frontage (Policy Units 6.05, 6.06 and 6.07) close to where the nourishment is undertaken and the reduction in recession rates decreases towards the south east (Policy Units 6.08, 6.09, 6.10, 6.11, 6.12). However, results show there are still noticeable differences between the SMP6 and SMP6 with Sediment Nourishment Scenarios, particularly at the town of Overstrand.

Figure 2.9 (when compared with Figure 2.3) also shows the reduced uniformity in the geometry of the coastline under the SMP6 with Sediment Nourishment Scenario compared to the SMP6 Scenario. In some SCAPE Units (such as 57 and 62, no erosion occurs over the long term (0-100 years) due to the impact of the sediment input. This variance in effect of the sediment on the erosion of the coastline is likely to be due to a number of local factors including:

- **Orientation of coastline** – sharp changes in orientation of the coastline could cause build-up of sediment restricting input into the adjacent SCAPE units but increasing local protection from coastal erosion in the area of build-up.

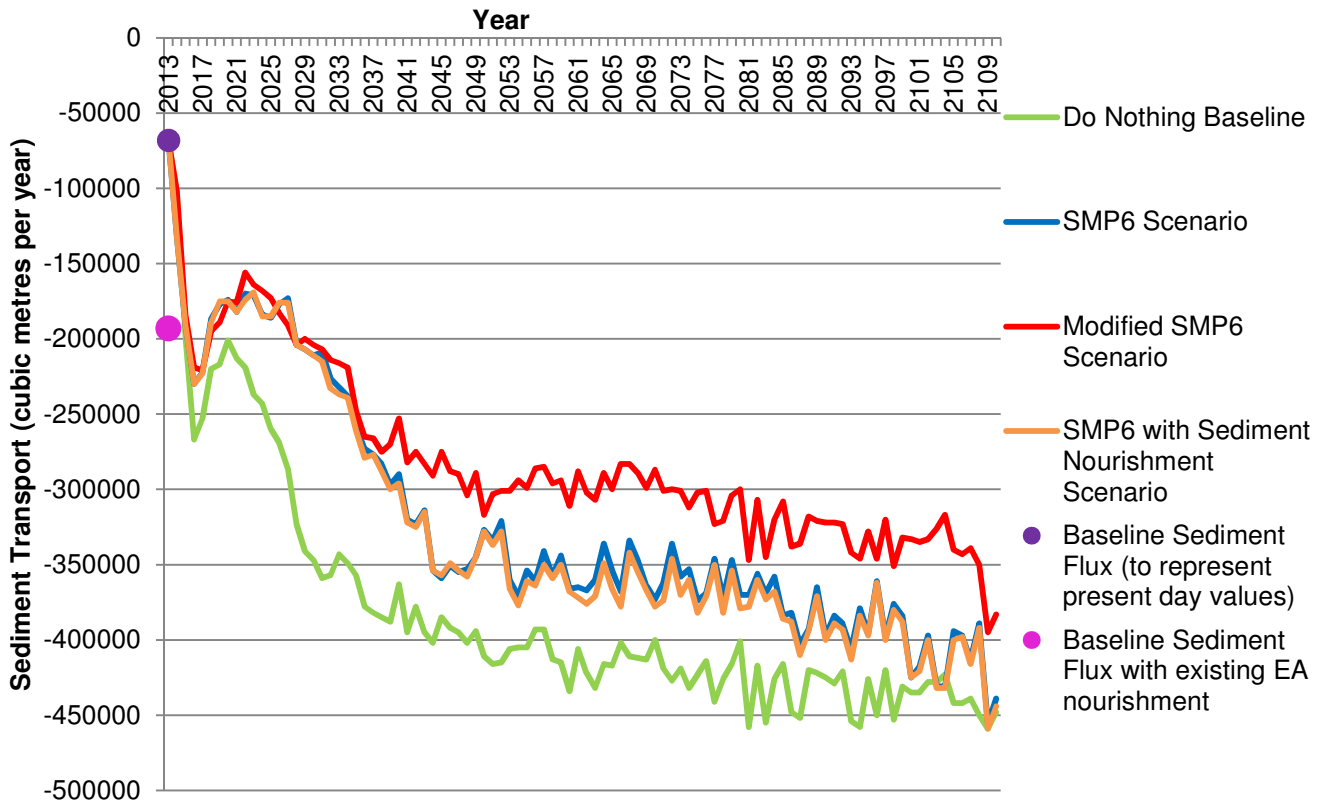
- **Residual life of defences** – it is important to note that the residual life of the defences along the coastline varies and therefore although similar processes may be acting on the coastline in adjacent SCAPE units, the residual life of the defences may vary.

Impact of SMP6 with Sediment Nourishment Scenario on sediment movement and management at Policy Unit 6.13

The overall sediment flux at Cart Gap in the SMP6 with Sediment Nourishment Scenario is slightly increased compared to the sediment flux under the SMP6 Scenario (Figure 2.10). However, this increase is very small and the difference between the SMP6 and SMP6 with Sediment Nourishment Scenarios is negligible. Overall potential impacts on Policy Unit 6.13 are therefore the same as the discussion in Section 2.3.2. From approximately year 30 onwards, the predicted sediment flux from the model is greater than the baseline flux with sediment recharge, suggesting the EA could potentially reduce sediment nourishment along the beaches at Policy Unit 6.13 in the medium to long term (20-100 years). However, on-going monitoring would be needed as this baseline does not include potential impacts of sea level rise which may increase offshore/alongshore sediment transport and therefore could increase the amount of recharge needed under current day management.

This is likely to be explained through the reduced erosion rates along the frontage due to the additional sediment providing increased protection to the toe of the defences and cliffs. Therefore, the SCAPE model results show a balance between the additional sediment entered into the system as sediment nourishment, and the decrease in sediment being produced along the frontage due to decreased coastal erosion rates.

Figure 2.10: Graph to show annual sediment flux at Cart Gap (Policy Unit 6.13) under the Do Nothing Baseline, SMP6, Modified SMP6 and SMP6 with Sediment Nourishment Scenarios from the SCAPE model 50%ile results. Annual sediment flux is calculated on a 10 year average (i.e. the value shown for year 2025 is the annual average between 2010 and 2020). A negative sediment transport rate indicates a southerly transport direction. Two baseline scenarios are shown. The Baseline Sediment Flux represents the current sediment flux (taken from the 2013 values from the model). The Baseline Sediment Flux with existing EA nourishment represents the current sediment flux with an additional 500,000m³ every four years (an annual addition of 125,000m³) to represent approximately the additional sediment nourishment the Environment Agency currently undertakes.



Summary

An advantage of this Scenario over the SMP6 Scenario is that there is overall reduced erosion of the coastline. However, this is not evenly distributed over the frontage and therefore does slightly increase the non-uniformity of the coastline. This may potentially increase erosion risk to exposed areas after 100 years, however the results from the SCAPE model suggest this impact could be minimal.

There is reduced erosion of the frontage under the SMP6 with Sediment Nourishment Scenario when compared with the SMP6 Scenario and the Do Nothing Baseline. The resulting impacts on Policy Unit 6.13 are, however, likely to be very similar to the potential impacts under the SMP6 Scenario (see Section 2.3.2) as the sediment transport rates along the frontage are very similar to the rates under the SMP6

Scenario. This is due to the decreased erosion rates of the frontage under this Scenario, which replaces the increased sediment input. Despite this, there is still as significant increase in sediment transport rates over the 100 years when compared with the baseline sediment flux.

The purpose of this Scenario was to assess whether initial modelling suggested a Scenario where sediment nourishment was undertaken at the north western end of the frontage would be technically feasible. Initial model results here suggest it would be, however further studies would be needed to assess potential offshore sediment transport in addition to optimising the volumes, frequency and site of the sediment nourishment. Within this Study, it has been assumed that no additional costs are associated with this Scenario when compared with the SMP6 Scenario as the nourishment is simply a relocation of the current nourishment carried out by the Environment Agency at Cart Gap. The SCAPE model results suggest that this is potentially a realistic assumption, although on-going monitoring and management would be needed particularly in the first 10 years.

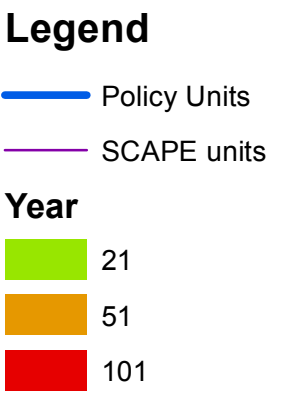
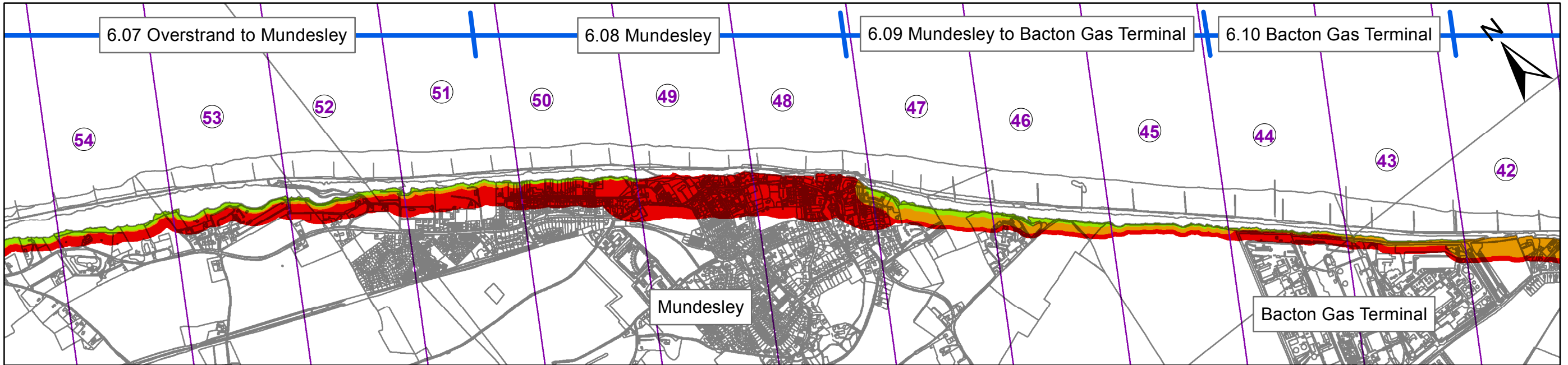
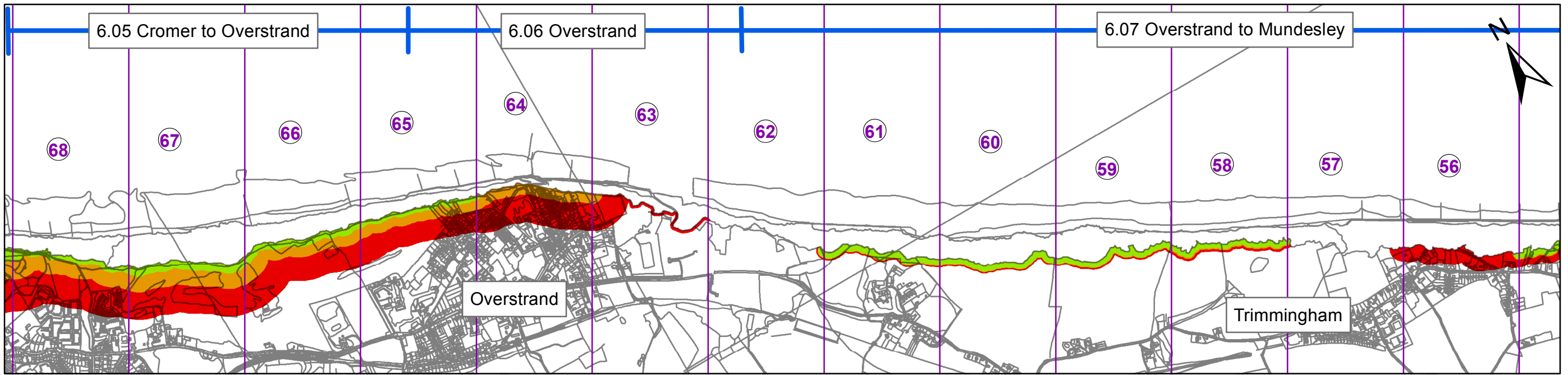


Figure 2.9 SMP6 with Beach Nourishment Scenario

3 Economic Assessment

An economic assessment has been carried out for SMP6 Policy Units 6.06 to 6.12 under each management scenario. This assessment, combined with an in-depth analysis of the results from the SCAPE model, provides an overview for each Policy Unit. This has been focussed to allow informed decisions on the management of the Study frontage, taking into consideration impacts of management strategies on the different areas along the coastline. This subsequently allows identification of Policy units where further work is needed to identify capital schemes to implement coastal defences. Results from the SCAPE model and Economic Assessment are summarised below for each Policy Unit individually. Further details on the current condition of defences, outputs from the SCAPE models and the economic assessment can be found in the Appendices to this Study Report.

Benefits relating to potential impacts on tourism have not been included within the economic assessment. Consideration of potential impacts on tourism have been considered in the Economic Report (Appendix B), and results suggest that inclusion of tourism benefits could significantly increase benefit cost ratios and Partnership Funding scores. Therefore the economic assessment within this Study can be considered as a conservative approach. Further detailed assessment of potential impacts on tourism will be needed to allow appropriate consideration of the benefits associated. This may involve a Contingent Valuation Survey at PAR stage.

3.1 6.05 Cromer to Overstrand

Policy Unit Overview

In this Policy Unit, under the SCAPE model assessment, there are no residential properties at risk from erosion over the long term (100 years) under any of the management scenarios. There are three commercial properties at risk from coastal erosion: The Cromer Country Club, The Royal Cromer Golf Club and the Lighthouse.

Results from SCAPE model and Economic Assessment

The patterns of coastal recession in this Policy Unit are very similar between each management scenario.

- The SMP6 Scenario sees a slight increase in the rate of erosion compared to the Do Nothing Baseline due to the reduced sediment being supplied from the frontage at Cromer (which has a SMP6 management recommendation of Hold the Line in the long term (0-100 years)).
- There is reduced erosion to the east of this Policy Unit under the Modified SMP6 Policy due to the build-up of sediment at Overstrand, where the policy is modified to Hold the Line in the long term (0-100 years).
- Under the SMP6 with Sediment Nourishment Scenario there is decreased erosion compared to the SMP6 Scenario and Do Nothing Baseline.

Despite these variances between the management scenarios, both the Country Club and Golf Course are still partly at risk from coastal erosion under all management scenarios and therefore there is no difference in the economic assessment for each management scenario.

Summary/Policy Recommendations

The SMP6 policy recommendation for this Policy Unit is Managed Realignment in the short term (0-20 years) with No Active Intervention in years 21-100. As there are very few properties at risk from coastal erosion in this area, the benefit cost ratios for a scheme are all below 1.0. This means that a capital scheme would not be economically justified and the SMP6 recommended management policies are likely to be the most technically and economically justified for this Policy Unit.

3.2 6.06 Overstrand

Policy Unit Overview

At Overstrand, there are 199 commercial and residential properties at risk in the long term (0-100 years) under the Do Nothing Baseline. The SMP6 policy recommendations for this area are to Hold the Line in the short term (0-20 years) then let the coastline retreat under a Managed Realignment policy in the medium and long term (21-100 years).

Results from SCAPE model and Economic Assessment

The SCAPE model has not taken into account the impact of the Managed Realignment policy. This is likely to have the overall effect of reducing the rate of retreat in under the SMP6 Scenario. In addition, increased erosion seen in the model is likely to be a reflection of the current defence types (particularly where the current defences are timber groynes and timber revetment which do not provide full protection from coastal erosion). However the majority of the options proposed and costed in this economic assessment are an improvement on the existing defences, which would be sufficient to reduce erosion of the coastline. To capture this in the economic assessment, a 20 year delay was applied to the year of loss for the properties. This is to reflect the short term (20 years) Hold the Line defence options which were included in the costs. The costs for social mitigation under Managed Realignment have not been included within the assessment and therefore benefits under the Managed Realignment epochs may be slightly exaggerated.

Do Nothing Baseline

Under a Do Nothing Baseline, there is no erosion in the short or medium term (0-50 years) in SCAPE Unit 63 to the east of the SMP6 Unit. This is likely to occur due to the supply of sediment from SCAPE Units 64 and 65 which helps to increase the protection to the toe of the defences and cliffs until the coastline to the west of the Policy Unit has eroded. This causes SCAPE unit 63 to become more exposed to coastal erosion.

SMP6 Scenario

The results from the SCAPE model suggest that under the SMP6 Scenario, there is increased erosion over the 100 years compared to the Do Nothing Baseline. There is reduced erosion under the SMP6 Scenario when compared with the Do Nothing Baseline in the short and medium term (0-50 years) in SCAPE Units 64 and 65, however increased erosion in the medium term (21-50 years) in SCAPE Unit 63. This is due to reduced input of sediment from the Cromer frontage and therefore increased exposure of the defences to coastal erosion.

Modified SMP6 Scenario

The benefit cost ratios associated with the modified SMP6 Scenario are higher for the majority of the management options in this Policy Unit. Along with potential economic savings from not re-locating communities (which have not been included within this assessment but would increase the cost of a Managed Realignment policy), this policy option is more economically justifiable compared to the SMP6 Scenario.

SMP6 with Sediment Nourishment Scenario

Under the SMP6 with Sediment Nourishment Scenario, there are 57 commercial and residential houses better protected from erosion compared to the Do Nothing Baseline (this is 103 residential and commercial properties better protected compared to the SMP6 Scenario). The benefits, and therefore the benefit cost ratios are therefore increased compared to the SMP6 Scenario (however the majority are still lower when compared with the Modified SMP6 Scenario). The costs associated with the sediment nourishment have not been included within this assessment as it has been assumed that the sediment nourishment is a re-location of the current sediment nourishment undertaken by the Environment Agency at Cart Gap (Policy Unit 6.13).

Funding for a coastal defence scheme at Overstrand

Partnership Funding scores are very low for the SMP6 and SMP6 with Sediment Nourishment Scenarios. This is likely to be due to a number of assumptions within the SCAPE model which reduce the overall number of houses better protected from coastal erosion when compared to the Do Nothing Baseline:

- The Do Nothing Baseline used as a baseline in this economic assessment is the Do Nothing Baseline for the whole coastline. At PAR stage, the Do Nothing Baseline would assess the impact of 'doing nothing' in this Policy Unit, whilst implementing the recommended managements in the surrounding Policy Units. Therefore sediment input would be reduced and the Do Nothing Baseline would show further increased erosion extent (hence giving increased number of houses better protected).
- As discussed above, the SCAPE model only represents the current, not proposed defence options. The large difference caused by the input of sediment under the SMP6 with Sediment Nourishment Scenario shows the impact of improving the current defences. At PAR stage, it is suggested that the SCAPE model could be run with a scenario showing improvements to the defences.

Summary/Policy Recommendations

The economic assessment indicates that there are sufficient benefits to justify a capital scheme, although further detailed assessment is required to assess the specific potential funding which would be available from Flood Defence Grant in Aid (FDGiA). It is recommended that this Policy Unit is taken forward to PAR stage.

3.3 6.07 Overstrand to Mundesley

Policy Unit Overview

In this Policy Unit, there are 116 residential and commercial properties at risk under the Do Nothing Baseline over the Policy Unit which approximately 6km in length.

Results from SCAPE model and Economic Assessment

- Under the SMP6 Scenario, erosion occurs earlier compared to the Do Nothing Baseline in SCAPE Units 56 and 57 due to the reduced sediment input in the short term (0-20 years) from Overstrand, hence exposing the toe of the defences and cliffs to coastal erosion.
- Under the Modified SMP6 Scenario, there is an increase in erosion over the whole Policy Unit compared to the Do Nothing Baseline and SMP6 Scenario due to the reduced sediment being supplied from the frontage at Overstrand over the 100 years.
- There is reduced erosion to the east of this Policy Unit under the Modified SMP6 Scenario, most likely due to the build-up of sediment at Mundesley, where the policy is changed to Hold the Line for the long term (0-100 years).
- Under the SMP6 with Sediment Nourishment Scenario, there is a large reduction in the rate of recession of the coastline at this Policy Unit, highlighting the potential influence of input of sediment to this area to reduce erosion rates.

Summary/Policy Recommendations

The SMP6 recommendation for this Policy Unit is Managed Realignment in the short term (0-20 years) with No Active Intervention in the medium and long term (years 21-100). There are very few benefits in this area and the cost benefit ratio for a scheme is below 1.0 under the SMP6 Scenario. Under the Modified SMP6 Scenario, the benefits are negative as they are greater than when compared with the Do Nothing Baseline. The coastal defence options proposed are maintenance options and they would not achieve FDGiA funding. However, it is clear that should a sediment nourishment scheme be considered, either for the whole coastline or for the area of coastline at Overstrand, there would be positive impacts associated with the impact on this Policy Unit which could reduce the burden on the maintenance costs where defences remain.

3.4 6.08 Mundesley

Policy Unit Overview

At Mundesley, there are 478 commercial and residential properties at risk in the long term (0-100 years) under the Do Nothing Baseline. The SMP6 policy recommendations for this Policy Unit are to Hold the Line in the short and medium term (0-50 years), then let the coastline retreat under a Managed Realignment policy in the long term (51-100 years).

Results from SCAPE model and Economic Assessment

Under the SMP6 Scenario, although there is no erosion in the short term and medium term (0-50 years) due to the defences being maintained/replaced, the erosion in the long term is accelerated so that the overall (i.e. 100 year) shoreline recession is very similar when compared with the Do Nothing Baseline. This can be explained through the creation of a headland type feature under the medium term (0-50 years) whilst the defences are maintained, causing this area to become increasingly exposed to wave action as the surrounding areas of coastline undergo retreat. Therefore, once the defences are left to fail after year 50, the coastline would potentially be more vulnerable to coastal erosion. This erosion of the coastline will act to 'even' out the coastline (or to make the geometry more uniform). This means that although there are the benefits of not losing houses in the short and medium term (0-50 years), only 56 houses are better protected from coastal erosion overall in the long term (0-100 years) under the SMP6 Scenario.

The option of Hold the Line over the 100 years was investigated. The Modified SMP6 Scenario has 455 commercial and residential properties better protected from coastal erosion over the 100 years. The benefit cost ratios associated with this Policy Unit are over 1.0 under the Modified SMP6 Scenario, although are slightly lower than the benefit cost ratios associated with the SMP6 Scenario. This is explained as the majority of properties under the SMP6 Scenario are at risk from erosion only in the long term (51-100 years), and therefore values have been discounted to a greater extent. However, due to the large overall number of properties better protected from coastal erosion over the 100 years under the Modified SMP6 Scenario (compared to the SMP6 Scenario), Partnership Funding scores are increased compared to the SMP6 Scenario (Partnership Funding scores are weighted with increased numbers of properties 'better protected' from erosion). More FDGiA funding is therefore likely to be available under the Modified SMP6 Scenario.

Under the SMP6 with Sediment Nourishment Scenario, a very similar pattern is observed when compared with the results from the SMP6 Scenario, however erosion rates are slightly lower and therefore 96 (compared to 56 under the SMP6 Scenario) commercial and residential properties are better protected from coastal erosion over the 100 years. It could therefore be suggested that sediment nourishment to the north west of this Policy Unit could have a positive impact on this Policy Unit, reducing the risk of coastal erosion (which will reduce the number of properties at risk from erosion or could decrease the cost of implementing coastal defences and maintenance costs).

Summary/Policy Recommendations

In summary, the SMP6, Modified SMP6 and SMP6 with Sediment Nourishment Scenarios show high benefit cost ratios and Partnership Funding scores. Therefore there are enough benefits to justify a capital scheme (for either the medium term (0-50 years) or long term (0-100 years)) and therefore it is recommended that this area is considered within a PAR.

3.5 6.09 Mundesley to Bacton Gas Terminal

Policy Unit Overview

In this Policy Unit, there are 43 residential and commercial properties at risk under the Do Nothing Baseline.

Results from SCAPE model and Economic Assessment

The overall patterns of erosion are very similar between each management scenario, however there are some key temporal differences.

- Under the SMP6 Scenario there is an increased rate of erosion in the short term (years 0-20) due to a reduction in the supply of sediment from Mundesley, hence increasing the exposure of the toe of the defences to erosion.
- Under the Modified SMP6 Scenario there is an increase in erosion when compared to the Do Nothing Baseline and SMP6 Scenario due to the long term (0-100 years) reduction in sediment being supplied from the frontage at Mundesley.
- Erosion rates are decreased under the SMP6 with Sediment Nourishment Scenario due to the increase in sediment supply (hence decreasing the exposure of the defences to coastal erosion).

Summary/Policy Recommendations

The SMP6 recommendation for this Policy Unit is Managed Realignment in the short term (0-20 years) with No Active Intervention in years 21-100. Under the SMP6 Scenario, there is very little protection of properties along the frontage in the long term (0-100 years). However, because the erosion of the properties in the western section is delayed in the SMP6 Scenario, this creates benefits of around £1.1 million which creates positive cost benefit ratios. This is a consequence of the small cross-over between the SCAPE unit 48 and the Policy Units 6.08 and 6.09. Therefore these benefits are a consequence of the Hold the Line policy at Mundesley and do not represent a justification for implementing a scheme along this section of the frontage. It would be recommended that at PAR stage, the area at Mundesley is extended slightly to cover this area of residential houses.

Under the Modified SMP6 Scenario, the benefits are negative as they are greater than when compared with the Do Nothing Baseline. As this Policy Unit does not have a Hold the Line Policy, the options proposed are maintenance options and therefore would not achieve FDGiA funding. It is clear that should a beach nourishment scheme be considered, either for the whole coastline or for the area around Mundesley, there would be positive impacts associated with the impact on this Policy Unit. This could reduce maintenance burden on North Norfolk District Council.

In summary a capital scheme would not be economically justified and the SMP6 policy recommendation, which will involve small maintenance costs to safely manage the retreat of the coastline, is likely to be the most sustainable management policy, both technically and economically, over the next 100 years.

3.6 6.10 Bacton Gas Terminal

Policy Unit Overview

At Policy Unit 6.10, the only asset at risk from coastal erosion is Bacton Gas Terminal. As there are no residential properties at risk along this frontage, a coastal defence scheme is unlikely be funded by Flood Defence Grant in Aid (FDGiA) funding. Funding would therefore need to be obtained from private investment. For this reason, the Partnership Funding calculations were not applied to this frontage.

Results from SCAPE model and Economic Assessment

Although the management in this Policy Unit is Hold the Line over the long term (0-100 years), the SCAPE results show erosion over the 100 years. This is because this area is currently mainly protected by timber revetment and timber groynes. The SCAPE model assumes that once beach levels drop below a particular level, these type of defences are not enough to stop erosion of the frontage. The options for this frontage have therefore been developed to include a rock revetment feature. This is a heavier defences type which will be sufficient to Hold the Line and no erosion in reality would occur. To capture this in the economic assessment, the Do Nothing damages have been counted as the benefits under the SMP6, Modified SMP6 and SMP6 with Sediment Nourishment Scenarios. It is therefore important to consider that this may have an increased impact on Policy Units to the south east of this frontage as in reality, it is likely that less sediment will be supplied down the frontage.

Summary/Policy Recommendations

The benefit cost ratios for this frontage show that a scheme to Hold the Line over the long term is economically justified in this area. However, as this Policy Unit would not go through the approval process for FDGiA, it would not be taken through to PAR stage, but rather developed separately with ongoing discussions with private investors.

3.7 6.11 Bacton, Walcott and Ostend

Policy Unit Overview

In this Policy Unit, the locations of the properties are widely distributed across the frontage. Under a Do Nothing Baseline, 201 commercial and residential properties are at risk from coastal erosion over the (approximately) 4km length of frontage. There are additional flood and infrastructure damages associated with this frontage which have been incorporated into the economic analysis (see Appendix B for more detail).

Results from SCAPE model and Economic Assessment

- Under the SMP6 Scenario, there is no erosion of the coastline shown in the SCAPE model over the short term (0-20 years) due to implementation of the Hold the Line policy. Once the defences are left to fail in year 21, increased erosion rates occur and over the 100 years, more erosion occurs under the

SMP6 Scenario than the Do Nothing Baseline. This is likely to be due to a similar mechanism as is suggested at Overstrand (Section 3.2) whereby the coastal defences at Bacton Gas Terminal limit the sediment supply to the frontage at Policy Unit 6.11. This provides less buffering of erosion down drift.

- Under the Modified SMP6 Scenario no erosion occurs over the long term as a Hold the Line management has been implemented over the 100 years. However, due to the length of the coastline and the limited benefits along it, the Modified SMP6 Scenario does not give an economically justified scheme (benefit cost ratios are all under 1.0).
- Under the SMP6 with Sediment Nourishment Scenario, the erosion of the coastline is reduced, but not significantly enough to increase the benefit cost ratios.
- The benefit cost ratios under all management scenarios are below 1.0 suggesting a scheme would not be economically justifiable.

Summary/Policy Recommendations

In summary, for this Policy Unit, neither the SMP6, Modified SMP6 nor the SMP6 with Sediment Nourishment Scenarios show an economically justified scheme. It is important to recognise that although the SMP6 Scenario shows increased erosion compared to the Do Nothing Baseline, if the SMP6 policies are implemented further up the coastline (Policy Units 6.05-6.10) the erosion in this Policy Unit under a Do Nothing Baseline would be accelerated (as mentioned previously in section 2.2). Therefore the Do Nothing Baseline used in this assessment is a very conservative baseline and with further detailed study there is likely to be the increase in benefits associated with all management scenarios.

From the assessment carried out along this frontage, it is recommended that part of this frontage could be split into further sub units with only part of them carried through to PAR stage as this may produce a more economically justified scheme. It is considered that particularly the area by Walcott would be justifiable for a capital scheme to Hold the Line in the short (0-20 years) or medium (21-50 years) term. This is because this area has a higher density of commercial and residential properties than the rest of the frontage at Policy Unit 6.11, in addition to benefits associated with coastal erosion of the B1159 road and benefits associated with flooding. An alternative recommendation for this frontage could be to take this Policy Unit through to PAR stage but only consider it on a 20 year timescale (i.e. costs and benefits both limited to 20 years). This would increase the benefit cost ratios as there is no erosion of properties under the SMP6 Scenario within the first 20 years, increasing the difference between damages under a Do Nothing Baseline and damages under the SMP6 Scenario. The benefits therefore would exceed the costs of implementing a coastal defence scheme for the short term (0-20 years).

3.8 6.12 Ostend to Eccles

Policy Unit Overview

In this Policy Unit, there are only 2 residential properties at risk from erosion over the long term (100 years) under the Do Nothing Baseline. Most of the land along this frontage is agricultural.

Results from SCAPE model and Economic Assessment

The patterns of erosion are very similar between each management scenario.

- Under the SMP6 Scenario there is a small increase in erosion in the short term (0-20 years) compared to the Do Nothing Baseline due to the reduced sediment being supplied from the frontage at Bacton, Walcott and Ostend.
- There is increased erosion over the 100 years under the SMP6 Modified Scenario due to the implementation of Hold the Line over the 100 years at Bacton, Walcott and Ostend.
- There is a small decrease in erosion under the SMP6 with Sediment Nourishment Scenario, however this makes very little difference when compared to the location of assets along the frontage.

There is a general reduction in coastal erosion to the east of this Unit under the SMP6, Modified SMP6 and SMP6 with Sediment Nourishment Scenarios due to the build-up of sediment at Cart Gap, where the recommended SMP6 management is Hold the Line over the 100 years.

Summary/Policy Recommendations

The SMP6 recommendation for this Policy Unit is Managed Realignment in the long term (0-100 years). As there are very few properties at risk from coastal erosion in this area, the cost benefit ratios for a scheme in this area are all below 1.0. This means that a capital scheme would not be economically justified and the SMP6 policy recommendation is likely to be the most sustainable management policy, both technically and economically, over the next 100 years.

4 Proposed Management Options

A summary of the recommended management for each Policy Unit is presented in Table 4.1.

Table 4.1: Summary of implications of different policy scenarios on the different Policy Units

SMP6 Policy Unit	Summary of economics and erosion
6.05 Cromer to Overstrand	Very few benefits in this area and therefore a capital scheme cannot be economically justified. The SMP6 policies of Managed Realignment in short term (0-20 years) and No Active Intervention in the long term (21-100 years) are recommended to be taken forward.
6.06 Overstrand	A scheme can be economically justified under the SMP6, Modified SMP6 and SMP6 with Sediment Nourishment Scenarios. Although Partnership Funding Scores are relatively low, this is likely to be a consequence of the assumptions used within the SCAPE model. It is recommended that this Policy Unit is taken forward to PAR stage for further investigations/study.
6.07 Overstrand to Mundesley	Very few benefits in this area and therefore a capital scheme cannot be economically justified. The SMP6 policies of Managed Realignment in short term (0-20 years) and No Active Intervention in the long term (21-100 years) are recommended to be taken forward.
6.08 Mundesley	A scheme can be economically justified under the SMP6, Modified SMP6 and SMP6 with Sediment Nourishment Scenarios. The resulting 100 year coastline geometry under the Modified SMP6 and SMP6 with Sediment Nourishment Scenarios are suggested to be less stable compared to the SMP6 Scenario, however all scenarios are suggested to be technically and economically justified over the 100 year life. It is recommended that this Policy Unit is taken forward to PAR stage for further investigations/study.
6.09 Mundesley to Bacton Gas Terminal	Very few benefits in this area and therefore a capital scheme cannot be economically justified. The SMP6 policies of Managed Realignment in short term (0-20 years) and No Active Intervention in the long term (21-100 years) are recommended to be taken forward.
6.10 Bacton Gas Terminal	A scheme can be economically justified under the SMP6, Modified SMP6 and SMP6 with Sediment Nourishment Scenarios. This Policy Unit would not be eligible for FDGiA funding and therefore would be developed through discussions with private investors. However, a coastal defence scheme for this area is economically and technically justified.
6.11 Bacton Walcott and Ostend	A scheme is not economically justified within this section under the SMP6, Modified SMP6 or SMP6 with Sediment Nourishment Scenario. However, due to assumptions of the SCAPE model, benefit cost ratios are likely to be under-estimated. It is recommended that if this Policy Unit was further sub-divided, areas of this coastline with higher concentrations of assets could be justified for capital schemes at PAR stage.
6.12 Ostend to Eccles	Very few benefits in this area and therefore a capital scheme cannot be economically justified. The SMP6 policy of Managed Realignment in long term (0-100 years) is recommended to be taken forward.
6.13 Eccles to Winterton	Although this Policy Unit was not considered in detailed in the economic assessment, analysis of the SCAPE model results suggest that the increased sediment supply through erosion of the coastline provided under all management scenarios will allow continued sustainable management of the frontage at 6.13. Increases in the sediment supply could reduce the need for nourishment over 100 years at Policy Unit 6.13.

Table 4.2 shows the houses 'better protected from erosion' compared to the Do Nothing Baseline for each management scenario. It is clear from this table that the Modified SMP6 Scenario provides protection to more houses when compared with the SMP6 and SMP6 with Sediment Nourishment Scenarios.

Table 4.2: Total number of residential and commercial properties better protected from coastal erosion under the different management Scenarios (minus numbers show where more properties are lost under the SMP6 Scenario compared with the Do Nothing Baseline).

	SMP6 Scenario	Modified SMP6 Scenario	SMP6 with Sediment Nourishment Scenario
Short Term (0-20 years)	225	196	233
Medium Term (21-50 years)	-20	252	55
Long Term (51-100 years)	-338	329	-172
Total (0-100 years)	-133	777	116

4.1 Summary of options and costs for the frontage

The two main areas recommended to take through to PAR stage at this point are 6.06 Overstrand and 6.08 Mundesley. Policy unit 6.08 (Mundesley) has already been entered into the MTP in June 2013. In addition, Policy Unit 6.11 (Bacton, Walcott and Ostend) is recommended to either be further split into smaller units or taken through to PAR stage for the short term (0-20 years). At PAR stage, these areas would be considered in further details with opportunities for external funding considered (see Section 5 of this report).

Table 4.3 displays the overall cost over the frontage. The overall costs have been worked out using the highest and lowest option costs to provide a range of potential values. All values have 60% optimism bias included (and so are likely to be upper level ranges) and both the PV (i.e. discounted) costs and cash costs are presented. The costs associated with the SMP6 with Sediment Nourishment Scenario have not been included as these are the same as the SMP6 Scenario. It is important to note that part of this sum may be eligible for FDGiA funding or private investment. Potential contributions to funding are discussed further in Section 5.

Table 4.3: Total costs over the entire study frontage (SMP6 Policy Units 6.05-6.12) and potential funding contributors. All costs include 60% optimism bias.

	SMP6 Scenario		Modified SMP6 Scenario	
	PV Cost (£k)	Cash Cost (£k)	PV Cost (£k)	Cash Cost (£k)
Maximum	27,266	44,505	29,117	57,273
Minimum	15,473	25,799	19,395	34,666

4.2 Summary of the technical and economic impacts of each Scenario

A summary of the technical and economic advantages and disadvantages for each management scenario (with the exception of the Do Nothing Baseline) are presented in Table 4.3.

Table 4.4: Table to summarise the technical and economic feasibility of each management scenario.
Each box has been assigned a colour: **Green – positive impact, Orange – neutral impact, Red – negative impact.**

Scenario	Technical Feasibility – Overall Geometry of the coastline	Technical Feasibility – Sediment supply at Policy Unit 6.13	Economic Feasibility – Costs associated with implementing scenario	Economic Feasibility – Benefits associated with implementing scenario
SMP6 Scenario	Over the long term shows a stable coastline	Sediment transport rates increase over 100 years as defences fail and the coastline erodes. SCAPE model suggests no adverse impacts on Policy Unit 6.13.	Potential range of cash costs over 100 years = £26 million-45 million Potential additional costs of community adaptation to erosion.	133 more properties at risk from erosion over 100 years compared to the Do Nothing Baseline**
Modified SMP6 Scenario	Over the long term exposed areas could be at increased risk of erosion and therefore not sustainable after 100 years	Sediment transport rates increase over 100 years as defences fail and the coastline erodes. Decreased sediment flux when compared with the SMP6 Scenario however still increased rates when compared with current day baselines. SCAPE model suggests no adverse impacts on Policy Unit 6.13.	Potential range of cash costs over 100 years = £35 million-57 million Increase costs associated with Hold the Line policy over 100 years.	777 less properties at risk from erosion over 100 years compared to the Do Nothing Baseline
SMP6 with Sediment Nourishment Scenario	Similar to the SMP6 Scenario however small areas where sediment may build up could decrease the stability of the coastline over 100 years	Sediment transport rates increase over 100 years as defences fail and the coastline erodes. SCAPE model suggests no adverse impacts on Policy Unit 6.13.	Potential range of cash costs over 100 years = £26 million-45 million Costs the same as under the SMP6 Scenario. Potential saving in local maintenance costs due to increased sediment supply in some units (however this has not been captured in this assessment)	116 less properties at risk from erosion over 100 years compared to the Do Nothing Baseline

** Note the property values at risk from erosion are likely to decrease (and hence benefits are likely to increase) at PAR stage due to assumptions taken in the SCAPE model (see Section 2.2)

5 Future Funding

5.1 External Funding Contributions

Although both Policy Units 6.06 and 6.08 have benefit cost ratios over 1.0 and therefore are likely to obtain Flood Defence Grant in Aid (FDGiA) funding, it is likely that external funding contributions will also be needed. This will be particularly true at Overstrand where the current Partnership Funding Scores for the majority of the Options are below 100% (see Appendix B: Economic Assessment Report for more detail). The following table lists potential external funding opportunities which will need to be considered in more detail during PAR stage. These are taken from 'Partnership funding and collaborative delivery of local flood risk management' (DEFRA, 2012) and previous experience of the Project Team.

Table 5.1: Possible external funding contributions to follow up at PAR stage.

Type of funding	Brief description of funding source	Comments
S106 (Town and County Planning Act)	Contributions from developers, linked to specific developments and the infrastructure required to make them acceptable in planning terms.	This is less likely to be relevant as there are not many developments in the area. However it could apply for any tourist developments such as holiday parks.
Coastal communities fund	Working with the 'Big Fund' coastal communities can draw on the Fund to support imaginative and innovative projects that promote jobs and growth and help to build stronger and more diverse local economies. These organisations can include: charities, social enterprises, voluntary organisations, local businesses as well as local authorities and local enterprise partnerships.	This may be applicable – further investigations would be needed to determine whether there were funds available
Growing Places Fund	The Growing Places Fund may provide £500m to enable the development of local funds to address infrastructure constraints, promoting economic growth and the delivery of jobs and houses.	To be explored at PAR stage
Regional Growth Fund	The Regional Growth Fund (RGF) is now operating across England from 2011 to 2015. It supports projects and programmes with significant potential for economic growth.	To be explored at PAR stage.
Local Asset Backed Vehicles,	LABVs are a form of public and private sector partnership that allow public sector bodies to use their assets (usually land and buildings) to attract long-term investment from the private sector in order to deliver socio-economic development and regeneration.	Unlikely to be applicable as no main retail areas but to be explored in further detail at PAR stage.
EU grants	EU Structure Fund, European Regional Development Fund, Solidarity Fund –emergency only Various grants and development funds available either as one-offs or on a regular basis from the European Union	To be explored at PAR stage. Potential timings of these various funds are important and should be investigated as early on as possible
Private beneficiary investment	Voluntary contributions from private beneficiaries of flood risk management. Could include local businesses, landlords, etc.	To be explored at PAR stage
Water company investment	Funds raised through the price review process. Water companies are able to invest in some types of surface water management, and increased resilience for their assets.	Anglian Water has assets at risk along the frontages (such as a pumping station) and therefore discussions around contributions to funding would be encouraged.
Council Tax	Funds raised through taxation on local householders, without applying a	Could be discussed/explored

Type of funding	Brief description of funding source	Comments
Precept	burden to those who do not live at risk.	at PAR stage
Trusts, community groups, NGOs	Formation of a legal entity to channel revenue raising into additional flood and coastal defence and other relevant projects	To be explored at PAR stage
Regional Flood and Coastal Committee (RFCC) Local Levy	Money raised from LLFAs for additional flood risk and coastal erosion management priorities not funded by FDGiA	To be explored at PAR stage
Lottery funding	Funding provided by the National Lottery for projects benefiting UK heritage	To be explored at PAR stage
Council Reserves	As implementing a capital scheme is likely to reduce maintenance spend compared to current values, some of this money could be used as a contribution to the capital works	To be explored at PAR stage
Tax Incremental Finance	This is a public financing method that is used as a subsidy for redevelopment or infrastructure projects.	To be explored at PAR stage
Flood Bonds	Flood bonds are a type of climate bon which are fixed-income financial bonds linked to climate change solutions, in this case to protecting from the increasing risk of coastal erosion and flooding due to increasing rates of sea level rise.	To be explored at PAR stage
Community Infrastructure Levy (CIL)	The Community Infrastructure Levy is a new levy that local authorities in England and Wales can choose to charge on new developments in their area. The money can be used to support development by funding infrastructure that the council, local community or neighbourhoods want – such as a new flood defence scheme.	This is unlikely to be applicable from previous study by North Norfolk District Council.

Appendices

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Appendix A. Condition Assessment Report

Appendix B. Economic Assessment Report

Appendix C. SCAPE Model Report