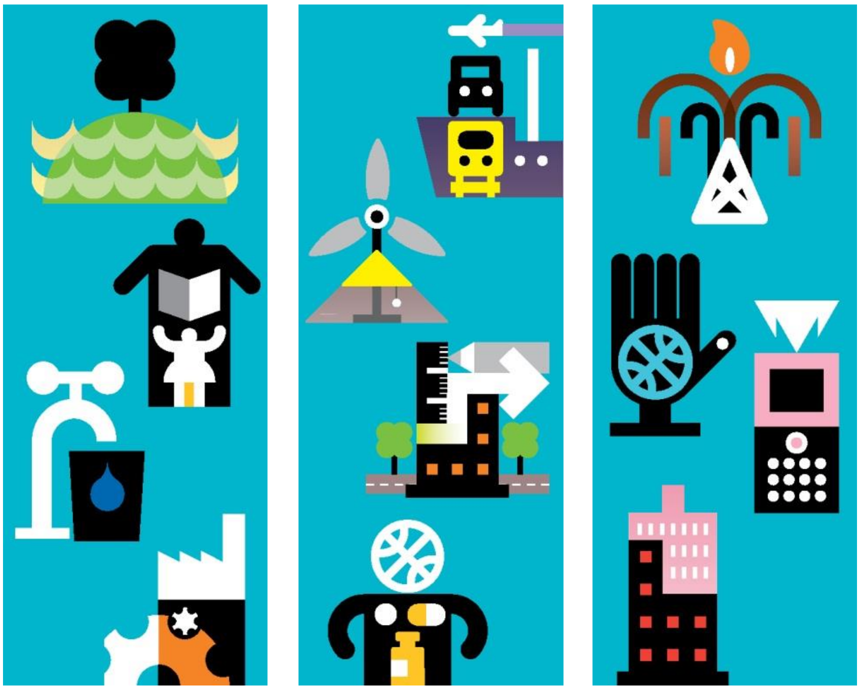

Robin Hood's Bay Project Appraisal Report

Appendix K: Erosion Assessment Technical Note

February 2016

Scarborough Borough Council

Mott MacDonald

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Mott MacDonald

Contents

1 Introduction

1.1 Background on the Study

Site walkovers and condition surveys carried out by Mott MacDonald in 2013 have determined the current seawall protecting Robin Hood’s Bay is reaching the end of its residual life. The Shoreline Management Plan 2 (River Tyne to Flamborough Head) policy for Robin Hood’s Bay over the next 100 years is to Hold the Line (Royal Haskoning, 2007). Therefore capital works need to be implemented over the next 100 years along the Robin Hood’s Bay frontage to manage the coastal erosion risks to local people and the developed, natural and historic environments.

An Economic Assessment (part of the main Project Appraisal Report) will support the development of a Project Appraisal Report (PAR) for business case applications for Flood Defence Grant in Aid (FDGiA) in accordance with the new Flood and Coastal Resilience Partnership Funding Scheme.

In order to assess the business case for capital works, an economic assessment of the costs and benefits of implementing works needs to be undertaken. This involves an assessment of potential coastal erosion and shoreline retreat over the next 100 years in order to calculate the benefits of implementing the schemes.

1.2 Introduction to coastal geology/ geomorphology

The village is built on the shoulders of land either side of the Kings Beck valley. The valley cuts steeply into the predominantly grey Lias cliffs that are a part of the ‘Robin Hood’s Bay Dome’ geological formation. The bedrock is overlain by glacial till and as a result is subject to mass movement and rapid cliff retreat. Much of the area lays within a large scale multiple rotational landslide system which is a combination of overlying ancient landslides, which evolved following the Devensian glaciation and much more recent landslide units (Risknat, 2014). The main cause of instability at the site is due to coastal erosion, which has lead to the over steepening of the slope and resultant failure (Risknat, 2014). There is a risk that if erosion was allowed to continue at the cliff toe it would lead to the reactivation of the large multiple-rotational landslide complex and the smaller surficial mudslides, slumps and shallow rotational slides (Risknat, 2014).

The cliffs have been protected by the seawall since approximately 1975. Prior to this historical records state that since 1780 when a large landslide destroyed much of the road into the village, over 200 cottages have been lost to marine erosion (Risknat, 2014). Since the wall has been developed the natural geomorphological response of the coastline to wave energy has been controlled. As a result, little change in shoreline position has occurred.

Figure 1.1: The seawall at the Headland fronting onto the Magnesian Limestone foreshore

1.3 Purpose of this Technical Note

The purpose of this Technical Note is to outline how the erosion assessment has been undertaken including the key assumptions and their potential impact on the subsequent benefit assessment.

2 Assessment Approach

2.1 Do Nothing Scenario

The existing coastal defences have been assessed in terms of their risk of coastal erosion under a 'Do Nothing' scenario i.e. assuming that no maintenance takes place. The key aim of considering the 'Do nothing' scenario is to understand the potential changes to the coastline from the current and future coastal processes. This is linked to an understanding of historical erosion and sea level trends, in addition to other examples in similar coastal geomorphological settings and applying these to the protection afforded by the current condition of structures.

The robustness and accuracy of 'Do nothing' scenarios are influenced by many factors, which include, but are not limited to;

- The availability of historical trend analysis for the specific frontages under consideration;
- The availability of cliff and general recession scenarios that could be similar to those viable at Robin Hood's Bay;
- The accuracy of condition survey results for existing structures;
- Knowledge of the nature and distribution of different geological units and how these may react to ongoing failure and erosion in the future;
- Records of the location and value of assets that would be impacted by erosion overtime;
- Future events and conditions that are the forcing mechanisms for coastal erosion i.e. water levels, climate change, storm events etc.

2.2 Residual lives of the seawall

This assessment has assumed that the seawall will fail at a time dependent upon its residual life i.e. if a defence has 10 years remaining life then the defences will be assumed to collapse and effectively 'disappear' in year 11. The residual life of the seawall has been estimated and recorded within the Condition survey Report carried out by Mott MacDonald (2014), in accordance with the CAM Manual (Environment Agency, 2009). Estimated residual lives of the defences are outlined in Table 2.1 below. The table summarises the condition grading's of the seawall and their estimated residual lives.

Table 2.1: Summary of Residual Life

Structural Element	Length	2014 Condition Rating	Residual Life (Years)
Masonary seawall at southern end	10m	Poor	10
Concrete seawall and promenade	160m	Fair	10
Interface between concrete seawall and cliff	10m	Poor	0

Once the defences have failed, erosion of the coast is assumed to occur. It is assumed that once the wall is lost the promenade will also be lost immediately.

Coastal erosion/ retreat has been projected into the future based on recession scenarios of the coastline. From this assessment we have identified when various assets in terms of property, buildings, roads, utilities and environmental features will be impacted.

Historical Trend Analysis
Specific rates for shoreline erosion have been identified using the Historical Trend Analysis Rule (HTAR). The HTAR is a model relating the rate of shoreline retreat to the rate of sea level rise (NRC, 1997; Leatherman, 1988, 1989 cited in Bray et al, 1992). In order to effectively calculate the potential extent of future erosion, the current residual life of the defences in each section and historical rates of retreat were examined.

Future shoreline retreat rates have been estimated using the HTAR equation below:

$$\mathbf{R_2 = \left(\frac{R_1}{S_1}\right) . S_2}$$

Where: S_1 *= historical sea level rise rate (m/yr)*

S_2 *= future sea level rise rate (m/yr)*

R_1 *= historical retreat rate (m/yr)*

R_2 *= future retreat rate (m/yr)*

The HTAR is a commonly used approach for the assessment of shoreline retreat over defined periods. This approach however is relatively simplistic as the HTAR assumes that sea level rise is the dominant cause of coastal recession and other factors such as the wave climate remain constant. In reality it is likely that wave heights and potential energies will increase with climate change. However this a valid assumption to make during periods of rapid relative sea level rise (Bray et al, 1992). Results also indicate that the shoreline erosion occurs every year whereas in reality there may be a time lag where the coastal profile is adjusting to new wave conditions.

The HTAR also ignores the influence of longshore drift (and therefore potential accretion) but it has been argued that the HTAR is calibrated to local coastal processes and environments due to use of location specific historical erosion rates as inputs (Leathernan, 1988; Gornitz, 1991 cited in Bray et al 1992). Other authors (e.g. Leatherman, 1988) also suggest that HTAR analysis may actually cause an underestimation of future shoreline erosion due to lack of consideration of longshore drift i.e. longshore drift would cause sediment to be moved down drift and away from the frontage, thereby exposing the frontage further.

3 Calculation Inputs

3.1 Historical Sea Level Rise (S_1)

For the whole study area the rate of historical sea level rise (S_1) has been taken to be 2mm/ year based on mean sea level data from 1985 to 2010 measured at Whitby from the Permanent Service for Mean Sea Level Website (Appendix A).

3.2 Future Sea Level Rise

Future sea level rise rates (S_2) are based on the UKCP09 data (95th percentile) outputs as recommended in the most recent Environment Agency guidance (EA, 2011). Retreat rates have been calculated under a Medium Emission Scenario as suggested by the EA (2011). Projected sea level rise for Robin Hood's Bay over the next 100 years is summarised in Table 3.1 below.

Table 3.1: Projected sea level rise at Robin Hood's Bay over the next 100 years (medium emission scenario)

Year	Cumulative sea level rise (medium scenario) (m)
Current day i.e. 2015	0
2015-2040	0.261
2015-2065	0.433
2015-2090	0.632
2015-2115	0.854

Source: UKCP09 User Interface

3.3 Historical Retreat Rate (R_1)

Historical retreat rates (R1) taken from the Robin Hoods Bay Coastal Strategy Study report (Scarborough Borough Council, 2012). The retreat rate of 0.3m/year is based on the undefended section north of the sea wall. This rate has been chosen as it is believed the cliff protected by the sea wall will retreat at a similar rate if the wall was not present due to similar geology and coastal conditions and the increased likelihood of mass movement failures and landsliding.

3.4 Assumptions

Some key assumptions have been made in the calculation of the erosion rates:

- It is assumed that as soon as the seawall fails the promenade will also fail as they are part of the same defence feature
- It is assumed that at the time of failure the cliff line will retreat 3.7m to account for the failure of the anchors in the wall and a further 5m as a result of the landslide that will occur.

4 Calculation Outputs

4.1 Future Retreat Rates (R_2)

Table 4.1 shows a summary of cumulative retreat at Robin Hood’s Bay. Retreat rates for each year can be found in Appendix B.

Table 4.1: Cumulative shoreline retreat (m) over the next 100 years

Year	Cumulative retreat
2015	0
2020	0
2025	9.01
2030	10.83
2035	12.70
2040	14.64
2045	16.64
2050	18.76
2055	20.89
2060	23.08
2065	25.39
2070	27.76
2075	30.14
2080	32.64
2085	35.20
2090	37.83
2095	40.51
2100	43.26
2105	46.08
2110	48.89
2115	51.70

4.2 Geographic information Systems (GIS)

The calculated retreat rates were ‘buffered’ in GIS to create a map of projected erosion over the next 100 years.

A shapefile was downloaded from the Environment Agency National Receptor Database (NRD) and loaded into ArcMAP to enable identification of the properties along the frontage. The erosion lines were overlaid with the property data to enable calculation of the number of properties at risk within each erosion zone. This search produced 179 residential and commercial properties that would be at risk of eroding on the next 100 years under the Medium Emissions Scenario (Table 4.2 and Figure 4.1).

The year in which an asset is considered to be at risk from erosion is dependent on both the location of the property and/or when services or infrastructure to the property are lost. Therefore the properties are considered to be at risk when the seaward edge of the property, or the road needed for access to the property comes within 5m of an erosion line. This is more representative of the year of loss of a property than taking the year of loss of the central point of the property. Therefore in reality some properties may be 'lost' in the assessment before actually falling into the sea. The timing of the loss of property is important because it determines the discount value applied during the valuation of assets.

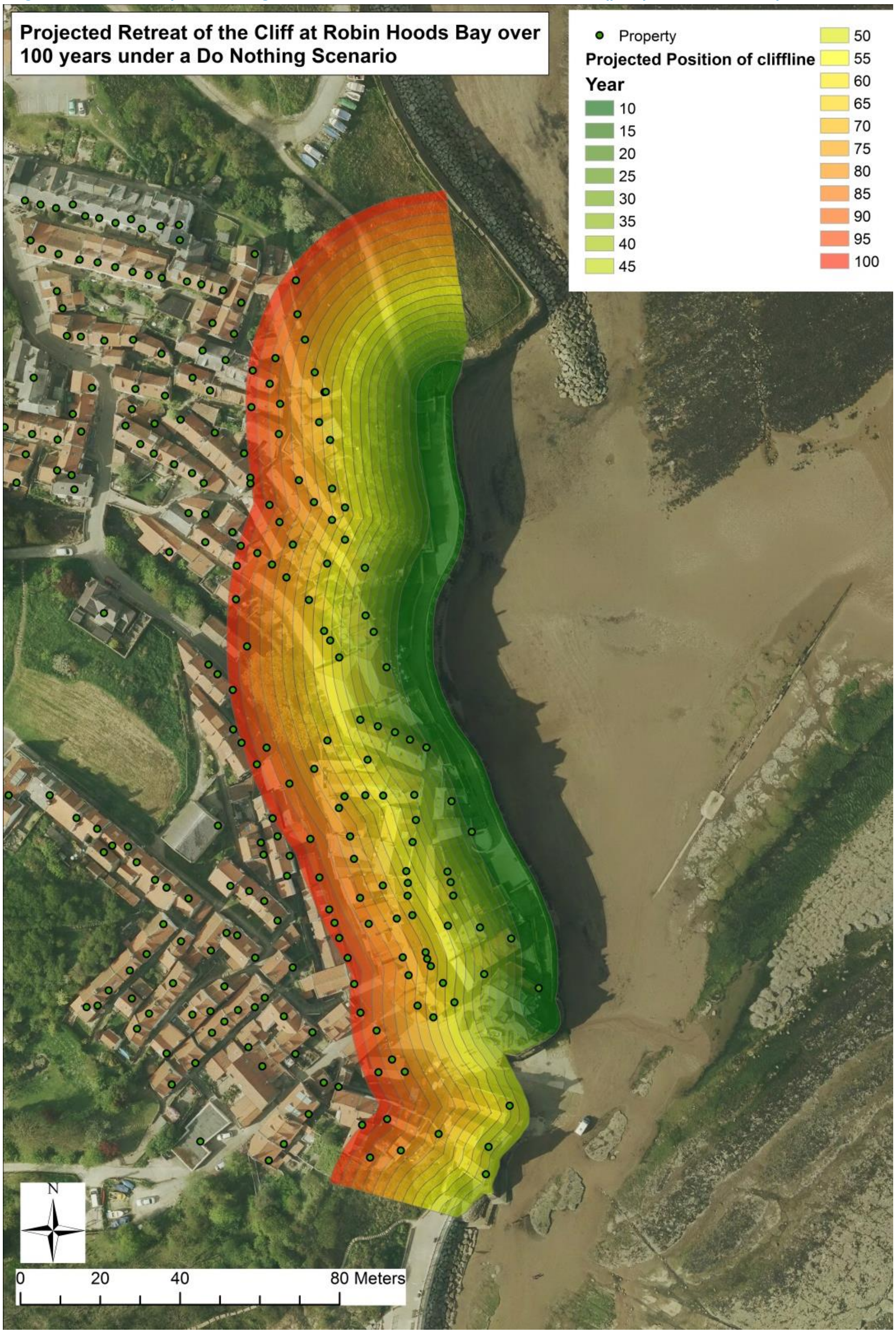
Key assumptions in calculating property erosion and values are:

- Counting of properties at risk from erosion includes a 5m search distance – assuming that once a property is 5m from the edge of the cliff it is too dangerous to inhabit.
- Comparison of properties and erosion lines within the GIS were also checked manually – if part of a property or access to the property goes early (i.e. before the point for the property in GIS), the erosion year of the property will be adjusted accordingly.
- Values of properties have been taken from values taken from Zoopla (www.zoopla.com). Commercial property values were assessed using the Valuation Office Agency (www.voa.gov.uk)

Table 4.2: The total number of properties lost over the next 100 years at Robin Hoods Bay

Year	Residential Properties	Commercial Properties	Total
0-20	8	3	11
21-50	20	2	22
51-100	135	11	146
Total	163	16	179

Figure 4.1: Map showing individual buffered erosion lines (properties are represented as green dots)



Source: Aerial Photography from Channel Coastal Observatory (2014)

5 Sea Level Rise Sensitivity Tests

5.1 Mean relative sea level rise

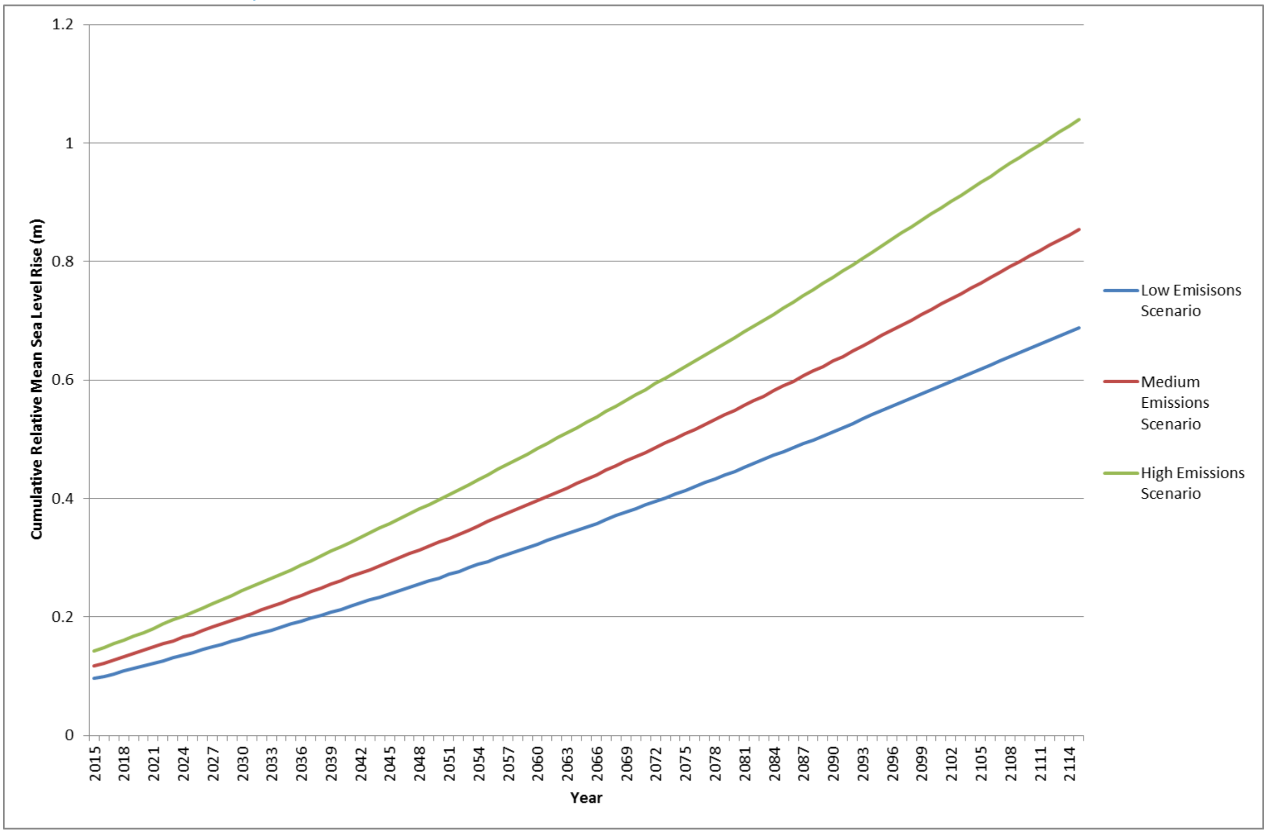
Mean relative sea level rise will increase the risk of coastal erosion in the UK. Sea level rise is generally split into two mechanisms: eustatic change and isostatic change. Robin Hoods Bay is in a near stable area and therefore not affected by isostatic change, however it is affected by global eustatic sea level rise (generally accepted to be caused through a number of direct and indirect impacts of global temperature rise) thus causing an overall acceleration in mean relative sea level rise. Due to the complex feedbacks and interactions between factors thought to cause eustatic sea level rise, predicting future sea level rise is very difficult. This difficulty is further complicated as future rates of eustatic sea level rise will be dependent on many social factors such as population growth and fuel consumption. Therefore, despite the significant impact future sea level rise will have on coastal erosion, projections of future rates of sea level rise have levels of uncertainty associated with them. It is therefore important to consider potential impacts this uncertainty could have for sustainable coastal management options at Hartlepool.

5.2 UKCP09 Scenarios

Data published by UKCP09 on relative mean sea level rise follows the three climate change projections emission scenarios developed by the IPCC Special Report on Emissions Scenarios (Nakicenovic et al., 2000). Within UKCP09 the emission scenarios are labelled based on their relative greenhouse gas emissions levels – High (SRES A1F1), Medium (SRES A1B1) and Low (SRES B1). These projections account for future land level movements and regional oceanographic effects.

The A1F1 ‘High’ emissions scenario describes a future world of very rapid economic growth by fossil-fuel intensive use, global population that peaks in mid-century and declines thereafter and the rapid introduction of new nadmore efficient technologies. The A1B ‘Medium’ emissions scenario includes the same assumptions as A1F1 but not relying too heavily on one particular energy source. The B1 ‘Low’ emission scenario describes a world with the same global population, that peaks in mid-century and declines therafter but with rapid change in economic structures towards a service and information economy, with reductions in material intensity and the introduction of clean and resource-efficient technologies. The range of sea level rise projections as noted by the low, medium and high emission scenarios show the uncertainty associated with these projections (demonstrated in Figure 5.1). In all cases, relative mean sea level rise increases exponentially in time. The medium SRES emission scenario data (95th percentile) is recommended for calculation of potential shoreline retreat in the guidance. Sensitivity testing has therefore been undertaken to assess the level of impact on erosion assessments if the Low (lower limit) or High (upper limit) Emission Scenario has been adopted.

Figure 5.1: Cumulative relative mean sea level rise projections for low, medium and high emission scenarios (95%ile taken for each scenario)



Source: UKCP09

5.3 Sensitivity Testing

Once the defences ‘fail’, erosion is assumed to start. Erosion calculated under a ‘Do Nothing’ scenario, i.e. expected erosion if no further works were done to the existing defences and no new defences were built. Assessment of the ‘Do Nothing’ scenario enables a baseline to which economics for ‘Do Something’ options can be compared with. Estimates of projected sea level rise were only given until 2100 and therefore they were extrapolated to 2115 using the 2011 EA guidance. Table 5.1 summarises the differences in erosion for each of the 100 year projections, assuming the seawall fails in year 10.

Table 5.1: Projected cumulative shoreline erosion over 100 years under different emission scenarios (based on sea wall failure in year 10)

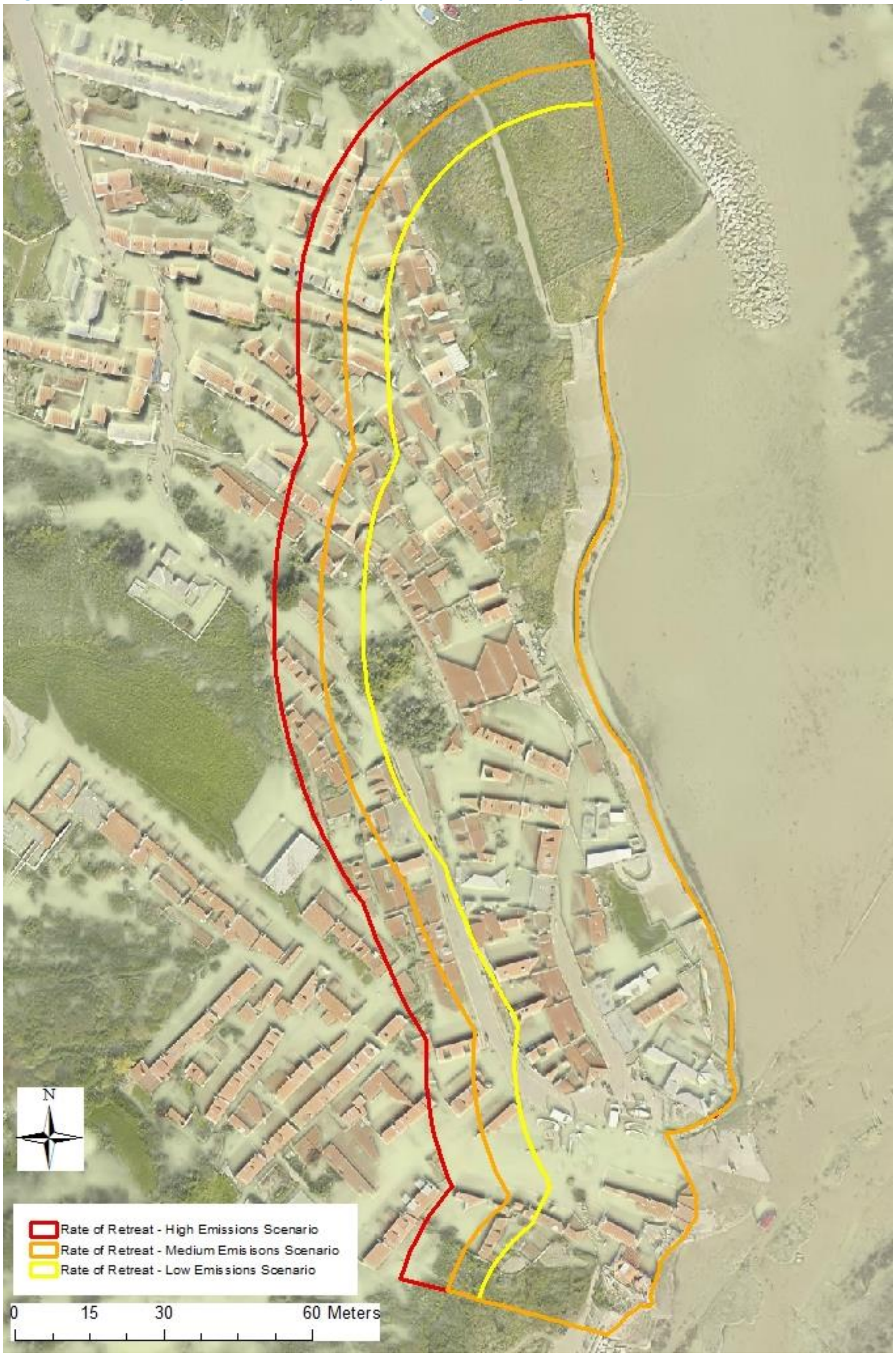
Total cumulative shoreline erosion over 100 years (m)		
Low emission scenario	Medium emission scenario	High emission scenario
43.2 m	51.7m	61.1m

Figure 3.2 show a comparison between the different estimated shorelines, based on failure of the seawall in year 10, created from the emission scenarios. The difference between high and low scenarios is 17.9m. A summary of the differences in the cumulative recession rates are presented in Table 5.2.

Table 5.2: Difference in projected cumulative shoreline erosion over 100 years (based on failure of seawall in year 10) under different emission scenarios

Difference in cumulative erosion over 100 years (m)		
Between the low and medium emission scenario	Between the medium and high emission scenario	Between the low and high emission scenario
8.5m	9.4m	17.9m

Figure 5.2: 100 year erosion line projections for High, Medium and Low Emissions Scenarios



5.3.1 Implications of sensitivity analysis

The main impact associated with the sensitivity of sea level rise is the calculation of benefits taken from the damages under a ‘Do Nothing’ scenario. The main impact on calculated benefits would be through the number of residential properties at risk form coastal erosion over the 100 years as assessed in the FDGiA Partnership Funding Spreadsheet. Table 5.3 below compares the change in number of properties at risk under the Low and High Emission Scenarios.

Table 5.3: Additional number of residential properties at risk from erosion under High and Low Emission Scenarios compared to the Medium Emission Scenario

Year	Additional number of properties at risk under the High Emission Scenario	Fewer number of properties at risk under the Low Emission Scenario
0-20	2	0
20-50	13	5
50-100	15	25
Total	30	30

Under the Low Emissions Scenario there would be 30 less properties at risk from erosion, which would reduce the benefits of implementing a scheme, thus also reducing the Benefit Cost Ratio and the Partnership Funding score. However, it is important to recognise that in Robin Hoods Bay, a proportion of the benefits arise from tourism; walkers following the Cleveland Way and the Coast to Coast walks and generally visiting the village itself. Under the High Emission Scenario, 30 more properties are at risk from coastal erosion which would only further enforce the economic justification for a scheme.

It has been important to consider potential impacts of all aspects of sea level rise on the management options for Robin Hood’s Bay, however due to the large uncertainties and transient nature of climate change this is difficult. Ongoing monitoring will therefore be important to support adaptive management and to any further changes as and when they occur.

This erosion technical note has outlined the various steps and assumptions made in undertaking the coastal erosion assessment for the Robin Hood’s PAR over the next 100 years. However it must be remembered that there is significant uncertainty not only with potential sea level rise over the next 100 years but also potential changes in wave energy, which could accelerate coastal erosion in the future; so all results are a conservative estimate of future changes.

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