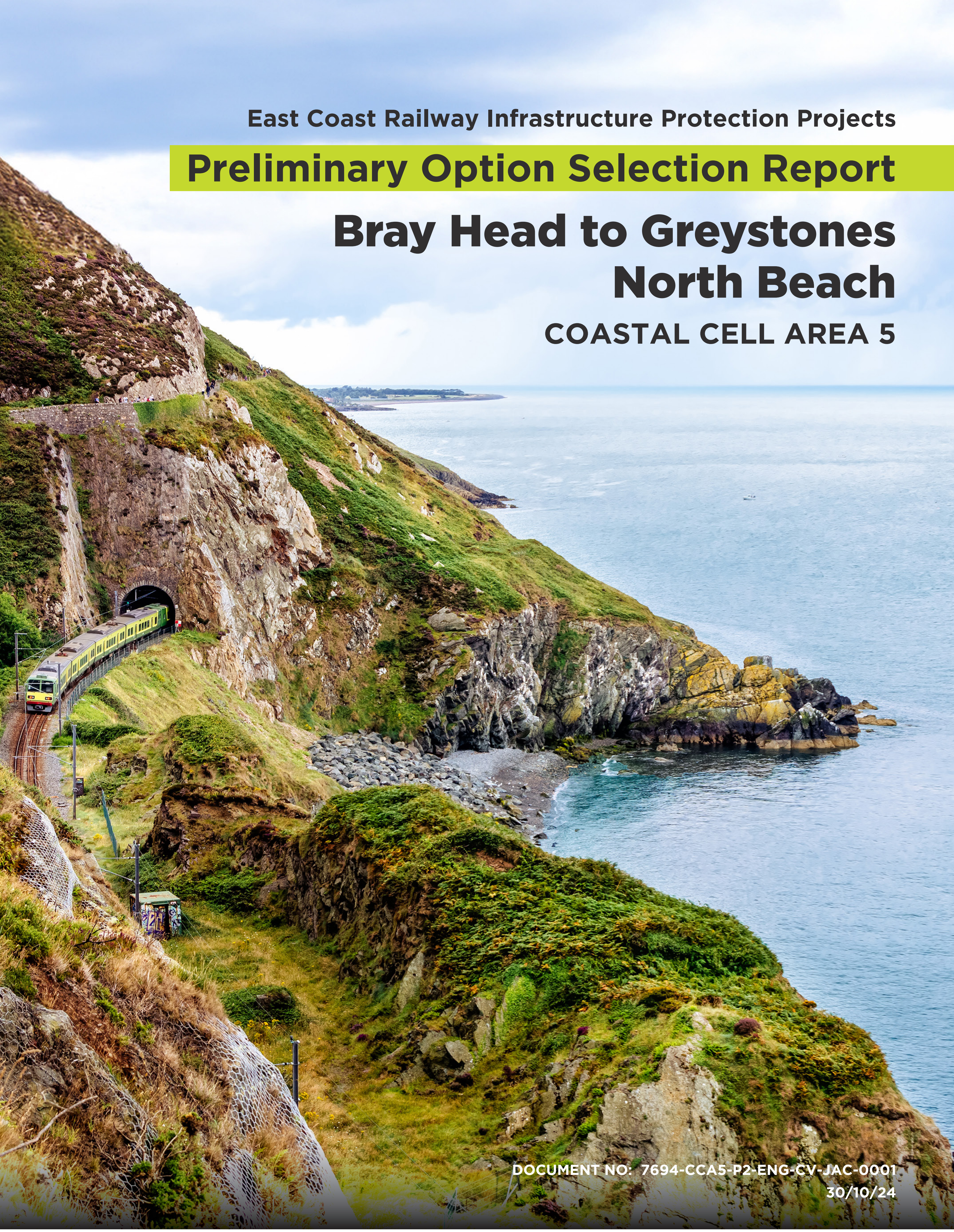

East Coast Railway Infrastructure Protection Projects

Preliminary Option Selection Report

Bray Head to Greystones North Beach

COASTAL CELL AREA 5

DOCUMENT NO: 7694-CCA5-P2-ENG-CV-JAC-0001

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Rialtas na hÉireann Government of Ireland

Tionscadal Éireann Project Ireland 2040

NTA Údarás Náisiúnta Iompair National Transport Authority

Jacobs

ECRIPP Iarnród Éireann Irish Rail

Iarnród Éireann Irish Rail

Executive Summary

The east coast of Ireland is prone to coastal erosion due to the nature of the geology forming the coastline and the generally low-lying topography between headlands. Along the coast, Iarnród Éireann Irish Rail (IÉ) operates and maintains a safe rail network. The section of railway between Dublin and Wicklow is situated close to the high tide mark, except at Bray Head and Killiney where it is raised up onto, and occasionally tunnelled through, the cliff faces. Disruption to train services caused by storm events and resultant damage to infrastructure is becoming increasingly common; with climate change and related sea level rise expected to be a contributing factor, with disruption predicted to significantly increase in the future. Maintenance works carried out to respond to the effects of coastal erosion and flooding on the railway line and supporting infrastructure result in increasing disruption to existing services and may render the line unviable in this area in the future. If left unmanaged, there is a risk that the railway route and surrounding land will be lost to the sea.

Recognising the urgency of taking action and the need for a strategic approach, IÉ established the East Coast Railway Infrastructure Protection Projects (ECRIPP). The primary aim of ECRIPP is to provide improved coastal protection works against predicted climate change effects of sea level rise and coastal erosion on the east coast railway corridor between Merrion Gates (Co. Dublin) and Wicklow Harbour (Co. Wicklow). Five key locations along the railway route (known as Coastal Cell Areas (CCAs)) were identified as requiring protection to increase resilience to coastal erosion and coastal flooding as a result of climate change. <u>This document provides the Preliminary Option Selection Report for CCA5 - Bray Head to Greystones North Beach (hereafter referred to as "the Project").</u>

This document forms part of the "Phase 2 Concept Feasibility and Options" stage of the Project. The aim of this report is to investigate coastal protection measures and identify the Emerging Preferred Option and Scheme to manage the main coastal risks. This is for the purposes of ongoing technical and environmental analysis, as well as consultation and engagement with the public and potentially affected property owners.

The Phase 2 stage of the Project comprises option selection, concept design development and public consultation. An options assessment has been carried out to identify the Emerging Preferred Option and the Scheme to be taken forward under the Project. The options assessment was undertaken having regard to the Infrastructure Guidelines and associated guidance.

CCA5 is the section of coast that stretches from Bray Head at Naylors Cove, to Greystones North Beach, north of Greystones Harbour. This frontage is formed of hard rock cliffs at Bray Head to the north of the CCA, with intermittent coastal defences between the tunnelled sections. At Greystones North Beach to the south of the CCA, beach fronts soft cliffs. The frontage is mostly rural, with the train line running along the coastline in and out of tunnels. Many of the defences and tunnel structures have shown signs of past damage or failures in the form of undermining, rock falls and land slips. It is often noted that rock falls can temporarily close the line along this frontage. The main hazards here are related to cliff instability above and below the railway, and coastal defence undermining below the railway. Beach erosion at the northern and southern parts of the CCA are increasing exposure of the coastline to other hazards. The options assessment identified two sub-cells: CCA5-A Bray Head; CCA5-B Greystones Cliffs (See Figure ES below).

The vulnerability of the sub-cells to different hazard scenarios varies, but in general:

- At the northern and southern margins of Greystones North Beach, the beaches are narrower and suffer from more seasonal and storm variation. These are the locations where losses of beach material will expose the cliffs to the other failure modes.
- Many of the beaches within the CCA have been drawn down over time (material lost offshore) resulting in an increased risk of wave overtopping, structural failure (due to increased wave height at the structure) and toe scour (undermining).
- Bray Head structures that have not been improved with rock armour placed at their toe in last 20 years are more vulnerable to wave overtopping, toe scour and structural failure.
- The soft cliffs south of Tunnel 4 at Greystones Cliffs are vulnerable to the impact of toe erosion and cliff retreat.
- The soft cliffs above railway bedrock cuttings between Tunnel 3 and 4 at Bray Head and Greystones Cliffs are most vulnerable to rainfall and groundwater induced cliff failures.
- Most of Bray Head is vulnerable to rockfalls.

The initial step of the optioneering assessment identified the Long List of Options comprising a range of interventions and measures that could be used to provide a long-term approach to manage the coastal erosion and coastal flooding risks to the railway line (inclusive of predicted climate change impacts). Through a process of option screening a Short List of Options was identified comprising those options that are likely to be technically feasible.

The Short List of Options passed through to the Multi-Criteria Assessment (MCA) stage where the key risks, opportunities, advantages and disadvantages of the short list options were identified. The MCA identified the leading options as follows (See Figure ES below):

- **Option A**: comprises rock revetments seaward of some of the more exposed existing masonry structures at Bray Head (CCA5-A) to prevent loss of the foreshore and dissipate wave energy, and rock headlands with managed cliff recession at Greystones Cliffs (CCA5-B) to dissipate wave energy, reduce wave run up and overtopping. In between the rock headlands the cliffs will recede until an equilibrium is reached, forming stable bays between the headlands.
- **Option B:** comprises rock revetments seaward of existing masonry structures at Bray Head (CCA5-A) to prevent loss of the foreshore and dissipate wave energy, and a series of rock groynes and beach nourishment along the beach at Greystones Cliffs (CCA5-B). This option will improve the size and stabilise the beach along the frontage, however this beach will need to be periodically renourished to maintain the Standard of Protection.
- **Option C**: comprises rock revetments seaward of existing masonry structures at Bray Head (CCA5-A) to prevent loss of the foreshore and dissipate wave energy, and rock revetment for the full length of Greystones Cliffs (CCA5-B). This option is similar to Option A but involves defending the whole of the cliff rather than allowing recession of the cliffs in places and the formation of bays.

These options all meet the scheme objectives, the requirements for the minimum 50-year design life and provide the required standard of protection. The options protect the shoreline using upgraded defences to improve the standard of protection. These options were progressed to Concept Design level and have been modelled and costed. The output of this analysis combined with the MCA has **identified the Emerging Preferred Option (EPO) as Option A**.

The next stage of the optioneering assessment identifies the works to be delivered under the Project (the Scheme). The works for the Emerging Preferred Option (EPO) within each sub-cell of the CCA were prioritised based on the current vulnerability of the railway to coastal hazards. The Implementation Options (IOs) consider the timeframe for implementing works based on hazards changing in line with climate change impacts. IOs were developed for the CCA, identifying options for prioritising works to align within increasing coastal hazard and risk to the railway. The IOs considered are as follows:

- **IO1**: deliver the full EPO Option A under ECRIPP to protect to 2100 regardless of whether works are needed now. Works comprises rock revetments seaward of existing masonry structures at Bray Head (CCA5-A) and rock headlands with managed cliff recession at Greystones Cliffs (CCA5-B).
- **IO2**: deliver most works of the EPO Option A under ECRIPP to protect to 2075 but defer the southern rock headland (CCA5-B) into the longer term until needed.
- **IO3**: deliver parts of the EPO Option A under ECRIPP needed by 2050 and defer some works into the longer term until they are needed. Works are to deliver all rock revetment works at Bray Head (CCA5-A) but defer all rock headland works at Greystones North Beach (CCA5-B).
- **IO4**: Do Minimum – do not progress any of the works under the EPO but undertake reactive works as needed.

These options were assessed using MCA to identify the Emerging Preferred Scheme (EPS) to be delivered under the Project and develop the corresponding concept designs. The MCA has **identified the Emerging Preferred Scheme (EPS) as Implementation Option 2 (IO2)** comprising:

- Rock revetments seaward of some of the more exposed existing masonry structures at Bray Head (CCA5-A)
- Two rock headlands at Greystones North Beach with managed cliff recession at Greystones Cliffs (CCA5-B). (See Figure ES below).

The Emerging Preferred Scheme will deliver a minimum of 50 years (2075) protection to the railway line against coastal erosion hazards at locations where the railway line would be at risk in the next 25 years (2050) if no capital works were undertaken. The capital works delivered under this Project will form part of the longer term works likely needed to extend the protection of the railway line to 2100.

This Preliminary Option Selection Report (POSR) identifying the Emerging Preferred Scheme (EPS) is a key document that is presented through the stakeholder engagement and public consultation process. Comments and feedback received during Public Consultation 1 (PC1) will be used to prepare the Option Selection Report (OSR), which will identify the Preferred Scheme to be taken forward to the "Phase 3 Preliminary Design" stage of the Project.

Preliminary design will develop the Phase 2 Concept Designs to provide increased certainty on the structure geometry and detailing. This stage of design will consider in more detail the interfaces with the existing structures through the development of a 3D design. Further work will be undertaken to consider how the works will be constructed and how construction impacts can be avoided or mitigated.

The Preliminary Design Report will be presented for further public consultation and feedback which feeds into Reference Design and culminates with statutory consultation as part of statutory consent applications.

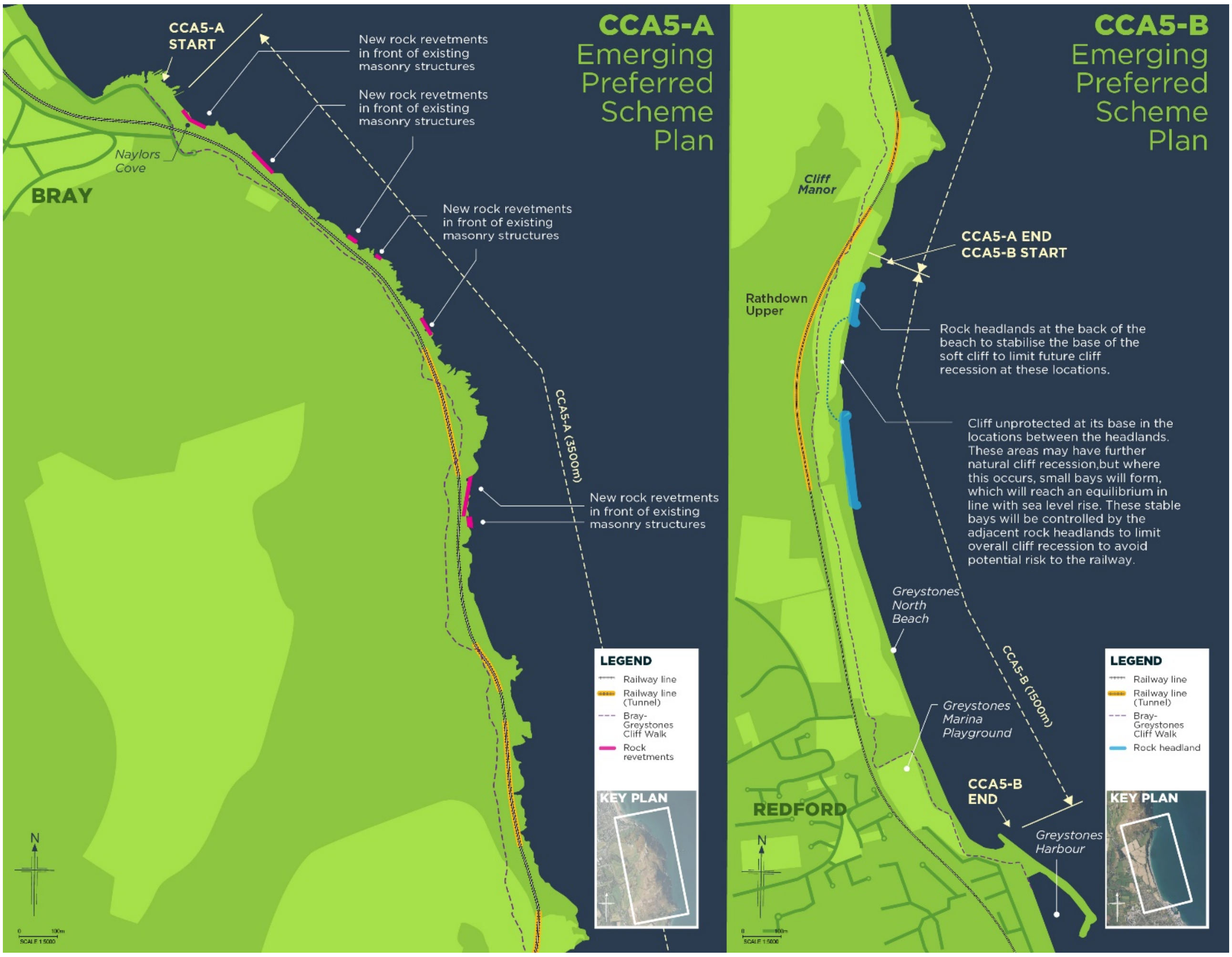

Figure ES: CCA5 Emerging Preferred Scheme Plan

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Acronyms and abbreviations

AA	Appropriate Assessment
ACA	Architectural Conservation Area
APIS	Authorisation for Placing in Service
CAF	Common Appraisal Framework
CCAs	Coastal Cell Areas
CFRAM	Catchment Flood Risk Assessment and Management
DCC	Dublin City Council
DEFRA	Department for Environment, Food and Rural Affairs
DLR	Dún Laoghaire Rathdown
DTTAS	Department of Transport Tourism and Sport
ECRIPP	East Coast Railway Infrastructure Protection Projects
EMRA	Eastern & Midlands Region Assembly
EPO	Emerging Preferred Option
EPS	Emerging Preferred Scheme
GDA	Greater Dublin Area
GDATS	Greater Dublin Area Transport Strategy
GHG	Green House Gas
HSE	Health, Safety and Environment
IÉ	Iarnród Éireann
IROPI	Imperative Reasons of Overriding Public Interest
LAP	Local Area Plan
LL	Long List
MAC	Marine Area Consent
MARA	Maritime Area Regulatory Authority
MCA	Multi-Criteria Assessment
MDC	Multi-disciplinary Consultant
MSO	Marine Survey Office
NDP	National Development Plan
NMPF	National Marine Planning Framework
NPF	National Planning Framework
NPO	National Policy Objective
NPWS	National Parks and Wildlife Services

NSO	National Strategic Outcomes
NTA	National Transport Authority
OPW	Office of Public Works
PC	Public Consultation
pNHAs	Proposed Natural Heritage Areas
RIBA	Royal Institute of British Architects
RPO	Regional Policy Objectives
RPS	Record of Protected Structures
RSES	Regional Spatial and Economic Strategy
RSO	Regional Strategic Outcomes
SAC	Special Areas of Conservation
SMR	Sites and Monuments Record
SoP	Standard of Protection
SPA	Special Protection Area
TAF	Transport Appraisal Framework
UN SDGs	United Nations Sustainable Development Goals
VAT	Value Added Tax
WFD	Water Framework Directive

1. Introduction

1.1 Projects Overview

Iarnród Éireann Irish Rail (IÉ) operates and maintains a safe rail network on the east coast of Ireland. The Dublin to Wicklow section of this line is a critical part of the rail network, with southside DART, Gorey commuter and Rosslare Europort Intercity services operating along this scenic route.

The railway is situated along the coast close to the high tide mark, except at Bray Head and Killiney where it is raised up onto, and occasionally tunnelled through, the cliff faces. The east coast of Ireland is prone to coastal erosion due to the nature of the unconsolidated glacial till forming the coastline and cliffs as well as the generally low-lying topography between headlands. This has been demonstrated through a number of technical studies over the years carried out by IÉ, the Office of Public Works and the affected County Councils.

Since the railway was opened to Greystones and extended to Wicklow and Rosslare in the mid-1800's there have been many cases of disruption to train services caused by storm events and resultant damage to infrastructure. IÉ records indicate that these incidents are becoming increasingly common and climate change and related rise in sea levels is thought to be a key factor. This necessitates more maintenance works to be carried out to respond to the effects of coastal erosion, wave overtopping and coastal flooding on the rail line and supporting infrastructure. These works result in increasing disruption to existing services and may render the line unviable in this area in the future as more significant climate change impacts become realised. If left unattended, there is a risk that the railway route and surrounding land will be lost to the sea and this risk will increase in line with climate change impacts, particularly sea level rise and increased storminess.

In 2017, IÉ undertook a feasibility study to assess the anticipated increase in maintenance requirements for this area resulting from climate change. This study identified several key areas between Dublin and Wicklow where strategic intervention at this time would enable existing rail services to continue to operate safely with minimal disruption.

Recognising the urgency of taking action and the need for a strategic approach, IÉ established the East Coast Railway Infrastructure Protection Projects (ECRIPP). ECRIPP will be delivered in line with National Transport Authority Project Approval Guidelines. The primary aim of ECRIPP can be summarised as follows:

"Provide improved coastal protection works against predicted climate change effects of sea level rise and coastal erosion on the east coast railway corridor between Merrion Gates (Co. Dublin) and Wicklow Harbour (Co Wicklow)".

Previous studies by IÉ and others identified five key locations along the 65km route running parallel to the Dublin to Rosslare railway line as requiring protection to increase resilience to coastal erosion and coastal flooding as a result of climate change. These coastal cell areas have been assessed as they have experienced incursions to such levels that existing infrastructure is at risk due to coastal erosion and/or flooding.

Under ECRIPP, the five sites or Coastal Cell Areas (CCAs) are considered as separate projects for delivery (Figure 1-1). They are listed below:

- CCA1 Merrion to Dún Laoghaire;
- CCA2/3 Dalkey Tunnel to Shanganagh Bray Wastewater Treatment Plant;
- CCA5 Bray Head to Greystones North Beach;
- CCA6.1 Greystones to Newcastle; and
- CCA6.2 Newcastle to Wicklow Harbour.

This report covers CCA5 (see Figure 1-2), a 7km length of coastline from Bray Head to Greystones North Beach (hereafter referred to as "the Project").

Figure 1-1 Location of Coastal Cell Areas

Figure 1-2 Overview of CCA5

1.2 Project Objectives

The primary focus of this Project is to address and implement protection of the existing railway and coastal infrastructure against the further effects of coastal erosion and flooding due to climate change on the strategically important railway line between Bray Head and Greystones North Beach.

The key objectives of the Project include:

- support the continued safe operation of rail services;
- increase railway infrastructure future resilience to climate change;
- provide improved and sustainable coastal protection works against predicted climate change effects such as sea level rise, coastal erosion and storm surges on the east coast railway corridor;
- secure the railway line for future generations;
- allow for the long-term efficient management and maintenance of the railway corridor; and
- support sustainable low carbon local, regional and international connectivity fostering a low carbon and climate resilient society.

The design objectives of the Project include:

- Provides the required 50 year design life (minimum). This is the service life intended by the design, which is the period of time after installation during which the structure meets or exceeds the structural performance requirements;
- Provides the required 25 years of zero heavy maintenance;
- Provides the required Standard of Protection (SoP) for the railway. The SoP is defined as a 1 in 200 year storm protection level; and
- Identifies the longer term works likely needed to extend the protection of the railway line to 2100.

1.3 Report Purpose

This document provides the Preliminary Option Selection Report for CCA5 – Bray Head to Greystones North Beach, which sits under the "Phase 2 Concept Feasibility and Options" stage of the Project.

This report sets out the process undertaken to assess the alternative protection measures for the selection of the capital works delivered under this Project, and identification of the longer term works likely needed to extend the protection of the railway line.

This report should be read in full in conjunction with associated appendices.

1.3.1 Status of the Design Presented in this Report

This report presents the Emerging Preferred Scheme for the purposes of ongoing technical and environmental analysis, as well as consultation and engagement with the public and potentially affected property owners. In this regard, the Emerging Preferred Scheme will continue to be analysed and recalibrated based on public consultation feedback. This ongoing work will inform the 'Preferred Scheme' which will be published as part of Public Consultation 2 (PC2) when additional surveys and assessments have been completed. The information presented to the public and stakeholders as part of Public Consultation 1 (PC1) is a current snapshot of available information and design development.

The purpose of presenting this Preliminary Option Selection Report is to communicate the current status of the option selection process, the methodology being followed to identify the Emerging Preferred Scheme and to assist in obtaining feedback. As part of the public consultation process, stakeholders, including the public, will be invited to make observations on the Emerging Preferred Scheme for consideration by the Project Team.

1.4 Report Structure

The structure of the remainder of this report is set out as follows:

- Chapter 2: Planning and Policy Context – This chapter outlines the general background information to the Project and summarises the planning and policy context which is relevant to the option selection process.
- Chapter 3: Options Assessment Methodology – This chapter outlines the stepped approach for the options assessment process.
- Chapter 4: Study Area and Problem Definition – This chapter describes the study area, the CCA sub-cells and the hazard scenarios that adversely affect operation of the railway. This includes an assessment of the consequence of hazards and vulnerability of assets to document the risk.
- Chapter 5: Options Assessment – This chapter provides the options assessment results for the CCA, from long list solutions, to developing short list options through Multi Criteria Analysis, to the Emerging Preferred Option and the selection of the Emerging Preferred Scheme.
- Chapter 6: Stakeholder Consultation – This chapter outlines the summary of the non-statutory public consultation and key stakeholder consultation completed to date.
- Chapter 7: Emerging Preferred Scheme – This chapter describes the Emerging Preferred Scheme proposal.

2. Planning and Policy Context

This chapter summarises the relevant planning policy and guidance both for the land-based areas and the marine elements of the Project which are applicable to the options selection process for CCA5. Further detail on planning and policy context can be found in Appendix A Planning and Environmental Constraints Report.

2.1 Land Based Areas

2.1.1 National Policy / Guidance

2.1.1.1 Project Ireland 2040

This Project falls within the remit of Project Ireland 2040. The National Planning Framework (NPF) which was adopted in May 2018 sets out the Government's Strategic Framework to guide development and investment. The NPF pairs with the National Development Plan (NDP) to comprise Project Ireland 2040. The NDP was originally published in 2018 for the period 2018-2027 but this has been reviewed and re-published for the period 2021-2030.

2.1.1.1.1 National Development Plan (NDP) 2021 - 2030

Within the NDP, National Strategic Outcomes (NSO) 2 'Enhanced Regional Accessibility' is of particular relevance to the Project. A key part of this outcome is the protection of public transport infrastructure.

Further detail on the objectives outlined in the NDP can be found in Appendix A.

2.1.1.1.2 National Planning Framework (NPF) 2018 - 2030

National Policy Objectives (NPO's) outlined within the NPF that are of relevance to the proposed Project are NPO 40, NPO 41a and NPO 41b. The referenced NPOs seek to ensure the strategic development of ports, sustainable development of city regions and regional/rural areas, ensure effective management of Irelands coastal resource and address the effects of sea level changes, coastal flooding and erosion.

Further detail on the objectives outlined in the NPF can be found in Appendix A.

2.1.1.2 Transport Climate Change Sectoral Adaptation Plan 2019

The Transport Climate Change Sectoral Adaptation Plan recognises the risk of climate change impact on the Irish transport sector and its infrastructure. The plan sets out adaptation measures to protect the transport sector. The plan references the Eastern Rail Corridor, of which a section includes the proposed Project, as a case study to show the coastal erosion impacts already incurred in this region.

The Plan has an overarching adaptation goal which is to "*ensure that the sector can fulfil its continuing economic, social and environmental objectives by ensuring that transport infrastructure is safeguarded from the impacts of climate change*."

Further detail on the plan can be found in Appendix A.

2.1.2 Coastal Change Management Strategy

The Coastal Change Management Strategy was published by the OPW in 2023 to provide a roadmap for responding to coastal change management in a structured and planned way to provide the basis for a long term strategy for an integrated and coordinated approach to coastal change management.

It includes a range of policy related to communication, data and research related to numerous matter including coastal change management plans, rick management, sustainable management of the coastline, the need for high quality data to support decision making and the importance of research.

Appendix A sets out those policy's/approached of particular relevance to the Project.

2.1.3 Regional Policy / Guidance

2.1.3.1 Regional Spatial and Economic Strategy (RSES) 2019-2031

2.1.3.1.1 Eastern & Midlands Region RSES

The Project falls into the remit of the Eastern & Midlands Regional Assembly (EMRA). The EMRA RSES outlines a number of Regional Strategic Outcomes (RSO's) and Regional Policy Objectives (RPO's) that relate to the Project.

An overall objective of the EMRA RSES is to protect and enhance strategic connections which includes the Eastern Corridor (rail link to Rosslare Europort). This strategic connection is identified as a key growth enabler for the region. Objectives that are of importance to the Project are outlined in Appendix A.

2.1.3.1.2 Southern Region RSES

Whilst the Project does not fall within this geographical area, the proposed Project connection to Rosslare Europort and the population along the eastern coast are of relevance. Wexford town is identified as a key town in the Southern Region RSES and it has a number of objectives that are of importance to the Project which are outlined in Appendix A.

2.1.3.2 Greater Dublin Area Transport Strategy 2022 – 2042

The Project falls within the remit of the Greater Dublin Area Transport Strategy (GDATS) 2022 – 2042. . The GDATS outlines a number of policy objectives to support the proposed Project through climate change proofing existing public infrastructure, enhancement of sustainable transport provision and improving connectivity within the Greater Dublin Area (GDA). Appendix A provides an overview of the GDATS 2022-2042.

2.1.4 Local Policy / Guidance

2.1.4.1 Wicklow County Council

The Wicklow County Development Plan 2022 – 2028 was adopted on the 12th September 2022 and came into effect on the 23rd of October 2022.

CCA5 is located entirely within the functional area of Wicklow County Council (WCC). The Plan sets out a strategic spatial planning framework for guiding the physical, economic and social development of the County. The land use zonings of the key areas are not set out as part of the Plan, these areas and the map-based objectives are set out within the specific Local Area Plans (LAP); these plans are to be read in conjunction with the County Development Plan. Not all of the ARUPs defined works areas are within zoned lands.

2.1.4.1.1 Bray Municipal District Local Area Plan 2018 – 2024

The Bray Municipal District LAP was adopted on the 14th May 2018 and came into effect on the 10th June 2018. The Northern section of CCA5 is within the Bray Municipal District LAP from Convent Avenue to Fiddlers Bridge.

2.1.4.1.2 Greystones Delgany and Kilcoole LAP 2013 -2019

Following an amalgamation of LAP's the Greystones Delgany and Kilcoole LAP was adopted in 2013. CCA5 extends within the Greystones Delgany and Kilcoole LAP from the Cliff Road to Mount Haven.

Action Plan 4 (South Beach), the objective of which is, as follows:

"Development of lands as an extension to the established town centre with a mix of retail, offices and public buildings, with residential uses interspersed to command public spaces and the South Beach. Provision of active frontage to Mill Road. maximize views from the development of the coast and sea. Improvements to the security and amenity of pedestrian access to South Beach. Provision of the majority of car-parking in underground or part underground, under podium or multi-storey format. If Provision of a 'park-and-ride' site of an appropriate scale. Any development proposal shall include a public playground and outdoor adult gymnasium, of

appropriate size, in consultation with the Community and Enterprise Section of the Council. These facilities shall be located within reasonable access of South Beach."

2.1.4.1.3 Wicklow Climate Action Plan

The Wicklow Climate Action Plan 2024 – 2029 was launched on the 21 December 2023. The plan is split into eight key goals categorised under five thematic areas: Governance and leadership, Built Environment and Transport, Natural Environment and Green Infrastructure, Communities Resilience and Transition and Sustainability and Resource Management.

The key targets and principles of importance to the Project are set out in Appendix A.

2.2 Marine Elements

2.2.1 National Marine Planning Framework (NMPF) 2040

The NMPF was published in July 2021 and is intended as the marine equivalent to the National Planning Framework (NPF). It provides the following in regard to the marine area:

- "set a clear direction for managing our seas;
- clarify objectives and priorities; and
- direct decision makers, users and stakeholders towards strategic, plan-led, and efficient use of our marine resources."

In regard to coastal erosion and flood defence works it sets out the following under Climate Change Policy 1:

"*Proposals should demonstrate how they:*

- avoid contribution to adverse changes to physical features of the coast;
- enhance, restore or recreate habitats that provide a flood defence or carbon sequestration ecosystem services where possible.

Where potential significant adverse impacts upon habitats that provide a flood defence or carbon sequestration ecosystem services are identified, these must be in order of preference and in accordance with legal requirements, be:

a) avoided,

b) minimised,

c) mitigated,

d) if it is not possible to mitigate significant adverse impacts, the reasons for proceeding must be set out.

This policy should be included as part of statutory environmental assessments where such assessments are required."

In addition to the above and again in regard to coastal erosion and flood defence, the NMPF acknowledges that the Office for Public Works (OPW) "*have functions and responsibilities in relation to coastal protection and coastal flooding*." It continues to outline the OPWs role, as follows:

- "Undertaking risk assessments associated with coastal flooding and coastal erosion at selected coastal sites making use of innovative technologies and methodologies;
- Provision of an advisory service in relation to coastal flooding and coastal erosion to support the preparation of annual coastal protection funding programmes, the Catchment Flood Risk Assessment and Management (CFRAM) programme, and to inform broader policy development; and
- Maintenance of coastal protection schemes constructed under the Coast Protection Act, 1963."

As well as general guidance for marine development the NMPF also includes Marine Map Based Objectives and Marine Spatially specific policy objectives. The section below includes a series of tables highlighting objectives applicable to this coastal cell area.

Appendix A incudes at Table 1-1 and 1-2 NMPF Marine Map Based Objectives (MMBOs) and Marine Spatially Specific Policy Objectives (SSPOs) relevant to CCA 5.

3. Options Assessment Methodology

3.1 Introduction

This chapter sets out the methodology followed in undertaking the options assessment and the selection of the Emerging Preferred Scheme for the Phase 2 optioneering process.

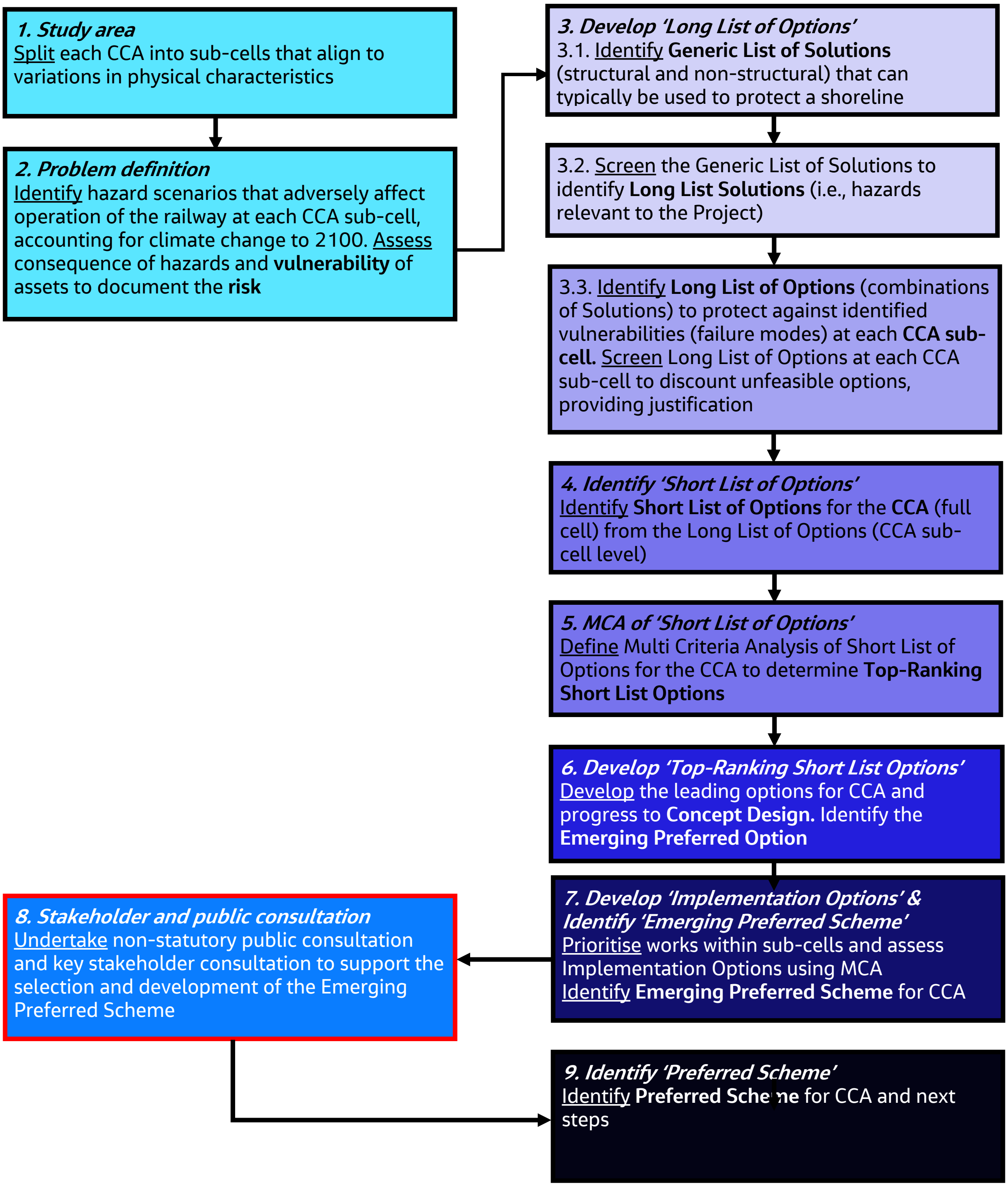

Figure 3-1 Flow chart summarising optioneering process

The flow chart in Figure 3-1 provides a summary of the overall options assessment methodology adopted for the Project.

3.2 Step 1: Study Area

The spatial model for this assessment uses sub-cells, also termed coastal/cliff behaviour units. These are a subdivision of the Coastal Cell Areas (CCAs), based on the variation in physical characteristics, including the geology, geomorphology, shoreline topography and orientation, and existing defence type.

The sub-cell delineation aligns with environmental constraints/characteristics where required, such as terrestrial/marine habitats and environmental designations. These sub-cells are then defined by a unique reference, description and associated shoreline chainage.

3.3 Step 2: Problem Definition

The hazard scenarios (failure modes) are identified and summarised for each CCA sub-cell based on the physical characteristics and existing defence forms of the sub-cell, accounting for climate change. These failure modes cover a range of scenarios including wave overtopping of structures, foreshore/beach lowering, beach/cliff erosion.

The potential consequences of these hazard scenarios to the railway with existing defences are identified for each sub-cell. In some cases, hazard scenarios may result in minor to moderate impact on the railway, interrupting services from less than a day to up to a month. Whilst other hazard scenarios may result in more significant impacts to operation of the railway whereby the line is severed and there is a risk of derailment. Different hazard scenarios and associated consequences give rise to relative differences in risk between the CCA sub-cells. The evaluation of risk for each sub-cell supports decision-making on locations where engineering will be required to mitigate risk to the railway, and locations where risk is negligible and does not need engineering intervention.

At this stage, a detailed description of the Do Nothing option for the CCA is provided as a baseline case against which all maintain or improve options are assessed against. The Do Nothing details how existing protection measures (natural systems and manmade coastal defences) would be expected to degrade and fail in the absence of any maintenance and how this will lead to increased disruption and eventual abandonment of the railway line. The Do Nothing option will be considered as a “walk away” solution, with only provision for making the area safe, for example through signage and fencing.

3.4 Step 3: Develop ‘Long List of Options’

The Long List of Options considers the range of interventions and measures that could be used to meet the Project objectives of protecting the railway line from coastal erosion and flooding.

The approach to identifying the Long List of Options is summarised as follows:

1. Generic List of Solutions: generic list of structural and non-structural coastal engineering solutions.
2. Long List of Solutions: screening of Generic List of Solutions for those that could be considered for.
3. Suitability Matrix and Long List of Options: Identification of options (combinations of solutions) for each CCA sub-cell.

These tasks are described in detail below.

<u>Step 3.1 Generic List of Solutions</u>

A Generic List of Solutions lists the full range of possible engineering measures that can be used to protect a shoreline. This is not specific to the Project area or any specific location, but outlines the full range of structural, non-structural options and nature-based solutions, regardless of whether they could be viable for any of the ECRIPP projects. This separates out the key elements of a coastal defence system.

The Generic List of Solutions includes options for materials and basic technical descriptions of how each solution works and key information such as high level benefits and negatives. The list summarises what failure mode each solution addresses and whether the solution addresses erosion and/or flooding hazards.

Step 3.2 Long List of Solutions

The Generic List of Solutions are screened to robustly discount solutions that are not considered to be feasible measures to meet the Project objectives at any location. Clear reasons for discounting are provided to serve as a baseline for the environmental assessment process. At this stage solutions are not discounted on environmental or economic grounds unless there is a clear reason for the option not to progress due to environmental and or economic reasons. Reasons for discounting solutions include:

- Solutions that do not address the hazards or failure modes;
- Solutions that will have significant and unacceptable negative impacts on the local and wider area;
- Solution does not have a proven track record or design standards in the proposed environment;
- Solution would pose significant and unacceptable constructability and HSE challenges;
- Solution has no benefit over an alternative but similar preferable solution;
- Solutions that will not meet the Project requirements of providing long-term flood and coastal protection; and
- Solutions that will have an unacceptably high maintenance burden.

The requirement for a minimum 50-year Design Life (to 2075) and 25 years zero heavy maintenance is factored into the solutions taken forward:

- Each Solution is appraised against the requirement to achieve the design life for all new structures. The design life is the period of time after installation during which the structure meets or exceeds the performance requirements. Where this is not considered possible, the long list solution is screened out.
- Each Solution is assessed on the anticipated maintenance burden over its design life. High maintenance solutions are generally discounted. This is assessed as follows:
  - Low – only occasional monitoring and occasional repair is expected to be required to retain Standard of Protection of the defence
  - Medium – regular monitoring and regular light maintenance is expected to be required
  - High – regular monitoring and regular heavy maintenance and/or rebuilding of asset.

In some instances, it is necessary to retain a solution that independently is not considered technically feasible, but when combined with another solution to form a hybrid solution it would become technically feasible. These solutions are combined to form options at the CCA long list stage.

Do Nothing and Do Minimum Options are retained as baseline scenarios as described below.

- **Do Nothing –** this is the 'walk away' option. The current approach to managing the defences would stop; no repairs, maintenance or upgrades would be undertaken i.e., the solution represents a walk away from all maintenance and not just a walk away from the Project. Over time the structures will fail and closure of the railway line will be necessary as CCAs progressively become unsafe to operate. There will be costs involved with managing the Health, Safety and Environment (HSE) risks of the structures failing (e.g. signage or fencing to prevent access) but there will be no inspection, maintenance or repair costs involved.
- **Do Minimum –** this represents the current maintenance regime of ongoing monitoring and reactive repairs. Beyond inspections and ongoing maintenance on an as needed basis, there is little opportunity for a strategic, long-term planning of works under the Do Minimum option to proactively upgrade defences. Works are undertaken to repair the defences as required to protect the railway line. This will eventually lead to very high levels of disruption and the likely loss of the service in the longer term as the line becomes economically unviable due to disruptions and almost continual emergency works to maintain defences.
- **Do Something –** this term represents all intervention options considered under the Project to proactively maintain coastal defences to safeguard the continued operation of the railway. The remaining Solutions that are retained for more detailed screening at the CCA level will become the Long List Solutions.

Step 3.3 Suitability Matrix and Long List of Options

Requirements for each CCA sub-cell (hazard, failure modes) are cross-referenced in a suitability matrix against the Long List Solutions to identify the Long List of Options for each CCA sub-cell. The Options for each CCA sub-cell are comprised of combinations of Solutions.

Options are further screened at this stage to discount options that will not meet the objectives or technical requirements for the given CCA sub-cell accompanied by a clear reason for discounting to serve as a baseline for the environmental assessment process. Innovation and sustainability are critical factors that are considered at this stage.

3.5 Step 4: Identify 'Short List of Options'

A range of Short List Options for the CCA are identified by summarising combinations of sub-cell solutions (Long List Options on a sub-cell level) to form an overall CCA Short List of Options. The Short List of Options comprise those options which are likely to be technically feasible.

For many of the Short List Options, the same solution (Long List Option) is applied across all sub-cells. In some cases, a Short List Option can comprise different solutions across the sub-cells. Where combinations of solutions are grouped together, these have been combined based on engineering judgement to provide a coherent and complimentary approach for the overall CCA.

3.6 Step 5: MCA of 'Short List of Options'

The Short List of Options pass through to the Multi-Criteria Assessment (MCA) stage where the key risks, opportunities, advantages and disadvantages are identified. The leading options from the MCA (Top Ranking Short List Options) are then developed to concept level design sufficient to inform the preliminary options costing stage.

An MCA has been developed having regard to the Department of Transport Tourism and Sport (DTTAS), Common Appraisal Framework (CAF) for Transport Project and Programmes March 2016 (updated October 2020) for options assessment. A further sensitivity analysis was undertaken to address changes due to the Transport Appraisal Framework (TAF) Guidelines (Department of Transport, June 2023).

MCA can be used to describe any structured approach to determine overall preferences among alternative options, where the options should accomplish multiple objectives. The term covers a wide range of techniques that share the aim of combining a range of positive and negative effects in a single framework to allow for easier comparison of alternative options in decision-making (CAF, 2016).

The MCA was undertaken to consolidate the quantifiable and non-quantifiable impacts associated with the Short List of Options. MCA establishes preferences between options by reference to an explicit set of objectives that the decision-making body has identified, and for which it has established measurable criteria to assess the extent to which the objectives have been achieved.

3.6.1 Multi-Criteria Analysis Criteria

A modified, project-specific options assessment criteria was established in order to capture an appreciation of the constraints and opportunities within the study area as well as the defined technical aims and objectives of the Project. These were tailored to have commonality to the CAF guidelines where practical, and to include additional criteria where necessary.

The CAF Guidelines (DTTAS, 2016) require projects to undergo a multi-criteria analysis under a common set of CAF core criteria described in Table 3-1. Two additional core criteria have been included in this MCA:

- **Engineering/Technical** criteria were added to the assessment to capture the technical aims of the Project.
- **Planning Risk** in regard to the potential for non-compliance with applicable planning policy has been reviewed. By including this consideration within the assessment, it allows the MCA to identify options that are potentially more suitable from a consenting perspective at each location. Furthermore, consideration of planning risks highlights those options considered to have greater potential to be stalled and/or refused in the planning process. This is particularly important as each location has different requirements, sensitive receptors and ecological designations.

The CAF Guidelines are used as a basis to inform the development of the respective sub-criterion which are adapted based on project-specific aims and objectives, as shown in Table 3-1. The criteria and sub-criterion are the measures of performance by which the options are assessed.

Table 3-1 Modified MCA core criteria and objectives

Core Criteria	Objective	Description
Economy	Land Use & Third Party Assets	Impact on to third party land and property – cost.
	Capital expenditure	Total cost for implementation of option
	Maintenance expenditure	Costs associated with Operational & Maintenance
Safety	Health & Safety (Construction)	Health and safety risk and effect of options during construction.
	Health & Safety (Design Life)	Health and safety risk and effect of options during design life.
Accessibility & Social Inclusion	Community	Risk or opportunity for social/community infrastructure (e.g., schools and educational facilities, libraries, community centres, local and central government offices, emergency services facilities, health centres, religious centres, sports facilities, playgrounds, local cultural heritage sites, etc.) and Local Employment.
	Access	Maintenance of existing and where possible create new access to public and private property (e.g., access to properties, adjoining beaches, coves, headlands, maintenance of continuity of walking routes).
	Social & Recreation Facilities	Maintain existing and where possible create new social, recreational and community facilities (e.g., creation of new beach or extended beach area).
Integration	Compatibility with Development Plans	Compatibility to County Development Plans, Local Area Plans.
	Compatibility with Climate Adaptation Plans	Compatibility with relevant plans and strategies to climate adaptation.
	Compatibility with Transport Plans	Compatibility with relevant plans and strategies to transport.
Environment	Biodiversity	Significant negative impacts on sites of ecological importance and opportunities for significant positive impacts on sites of ecological importance i.e. "incorporation of Ecological engineering features (as required under National Biodiversity Plan)" .
	Landscape & visual & Seascape	Significant effects on protected views/ key views/landscape character (both positive & negative);
	Archaeology, Architectural & Cultural Heritage	Overall effect on cultural, archaeological and architecture heritage resource. Likely effects on RPS, National Monuments, SMRs, Conservation areas, etc. Number of designated sites/structures (by level of protection)
	Noise and Vibration	Estimated number of sensitive receptors likely to be affected by construction related noise with the scheme.
	Air Quality	Local air quality effects associated with construction phase of the Project.
	Carbon Management	Relative assessment of embodied GHG emissions per option
	Water Resources	Overall potential significant effects on water resource attributes likely to be affected during construction and operation. WFD and status to be considered

Core Criteria	Objective	Description
	Geology and Soils	Likely impact on geological resources based on preliminary/likely construction details.
	Material & Circular Economy	Quantity of material required, type of material and opportunities for reuse. Material Balance.
	Waste	Waste generation, compliance with circular economy
	Traffic & Transport	Likely impacts on traffic & transport
Engineering / Technical	Constructability	Complexity of construction, translating into construction programme and cost risk. Requirement for specialist/marine plant
	Rail service impact	Impact on rail services during construction (severity/duration of impacts)
	Reliance on maintenance	Reliance on monitoring, maintenance and/or adaptation to provide consistent Standard of Protection.
	Adaptation	Options for future coastal defence adaptation in line with realised climate change impacts
	Residual risk	Susceptibility to Speed/criticality of defence failure should it become compromised (exceeding standard or due to poor maintenance).
Planning Risk	Consenting risk	Compliance with applicable planning policy, IROPI

3.6.2 MCA Scoring

The assessment undertaken is of a comparative nature (options compared against each other). This is based on the CAF criteria and based on professional judgement in respect of the items to be qualitatively evaluated, and comprehensively assessed against the key relevant criteria in accordance with good industry practice.

The assessment compared the relevant Short List of Options, identifying and summarising the comparative merits and disadvantages of each alternative under all the applicable criteria and sub-criteria leading to the Top-Ranking Short List Options. A comparative assessment was undertaken for each option developed, where in general, for each positively scored option there must be an opposing negatively scored option.

Table 3-2 provides an overview of the comparative colour coded scale for assessing the criteria and sub-criterion. For illustrative purposes, this scale is colour coded with advantageous options graded to 'dark green' and disadvantaged options graded to 'red'.

Table 3-2 Comparative Colour Coded Scale for Assessing the Criteria and Sub-Criteria

Colour/Score	Description
Red	Significant disadvantages over other options
Orange	Some disadvantages over other options
Yellow	Similar to other options
Light Green	Some advantages over other options
Dark Green	Significant advantages over other options

For each individual assessment the parameter and associated criteria and sub criteria are considered, and options are compared against each other based on the comparative scale, ranging from having 'significant advantages over other options' to having 'significant comparative disadvantages over other options'. Options that are comparable were assigned 'comparable across all other options'. Options were compared under each criterion, before those criteria are aggregated to give a summary score for each parameter. The aggregated assessment considers the potential impacts and significance of those impacts when compared with the other options being assessed. The aggregated scores are compared to establish the options with more advantages over other options arriving at the Top-Ranking Short List Options. The MCAs are presented in the MCA matrices contained in the individual chapters in this report. The justification for the scoring for the options under each sub-criterion are detailed in the MCA matrices.

NOTE: A degree of professional judgement was used by the specialists undertaking the assessment. For example, environmental criterion assessments take into consideration the comparative likely potential impact and the degree of significance of the environmental factor to be impacted which is reflected in the aggregated summary ranking of that criterion.

3.7 Step 6: Step 6: Develop 'Top-Ranking Short List Options' & Identify 'Emerging Preferred Option

The Top-Ranking Short List Options for the CCA are determined from the MCA analysis of Short List of Options, as described in Step 5. These options are progressed to Concept Design level, whereby the engineered solutions are described and presented, and the options are modelled and costed.

The Emerging Preferred Option (EPO) to be taken forward is identified from the Top-Ranking Short List Options. A summary of the metrics supporting the identification of the EPO are provided, describing the key outcomes of the MCA, including the advantages, disadvantages and risks.

3.8 Step 7: Develop 'Implementation Options' & Identify 'Emerging Preferred Scheme'

The works for the Emerging Preferred Option (EPO) within each sub-cell of the CCA were prioritised based on the current vulnerability of the railway to coastal hazards. This identifies when works would need to be undertaken to protect the railway line in the short-term (to 2050), medium-term (to 2075) and long-term (to 2100).

The priorities on a sub-cell basis were identified through consideration of the following aspects:

- Where coastal erosion and shoreline recession is active, what land buffer is there between the shoreline and the railway. Where this buffer is minimal, the works are assigned a higher priority. Conversely, if there is a large buffer of land it is preferable to allow the coastline to evolve naturally and assign a lower priority.
- Does longshore coastal modelling undertaken under ECRIPP indicate the future shoreline (considering climate change impacts) as being erosional or accretional into the future. This is assessed alongside the buffer to identify priorities. Where beaches are the primary defence of a shoreline, how susceptible are they to cross-shore erosion during a storm, resulting in a risk of erosion or wave overtopping at the back of the beach. This is assessed through coastal analysis and modelling. The larger the beach cross section, in combination with the stability of the beach (factors include beach material size and longshore sediment transport), the lower the priority for works.
- For cliffed sections of coastline, does wave overtopping of the shoreline realise a risk of toe erosion of the cliff and how does this risk increase in line with climate change impacts. Vertical cliffs recede in a more controlled and predictable manner but complex slumping cliffs require a larger buffer to the railway line to accommodate uncertainty and works would have a higher priority if this buffer is minimal.
- For low-lying sections of railway, does wave overtopping lead to a risk of damage to the railway infrastructure or failure of the back of the defence and how does this vary in line with climate change impacts. Where high overtopping rates risk service disruption or damage, a higher priority is assigned.
- Are existing structures vulnerable to undermining due to lowering of the foreshore. Structures that are at higher risk of undermining and could lead to a sudden collapse are given a higher priority.
- How vulnerable is the existing defence to catastrophic failure due to wave impact forces or wave overtopping which could lead to an immediate undermining risk to the railway. The higher the vulnerability, the higher the priority.
- Is a reactive and piecemeal approach to maintenance of the existing structures feasible to protect the railway. Where structures could fail quickly and maintenance access is difficult this would be classed as a higher priority.

Implementation Options were developed for the CCA, identifying options for prioritising works to align within increasing coastal hazard and risk to the railway, in line with realised climate change impacts and coastal change. These options were assessed using an MCA analysis undertaken having regard to the Transport Appraisal Framework (TAF) Guidelines (Department of Transport, June 2023) to identify the Emerging Preferred Scheme (EPS) capital works to be delivered under the Project.

A summary of the metrics supporting the identification of the Emerging Preferred Scheme (EPS) are provided, describing the key outcomes of the MCA, including the advantages, disadvantages and risks.

3.9 Step 8: Non-Statutory Stakeholder and public consultation

Stakeholder engagement and consultation during the design process is a key element to the delivery of the Project. The purpose of these consultations is to engage the public in the scheme’s delivery process, inform the public of the statutory process and likely timescales, seek the public’s cooperation and understanding of the Project and to capture local knowledge to inform the design.

Public participation is welcomed and encouraged throughout the design development process. It is planned that there will be two non-statutory public consultation stages which provide the opportunity to learn about the design development and provide feedback which will inform the next stage as appropriate. Public Consultation 1 will be in Phase 2 on the Emerging Preferred Scheme. Feedback received during public consultation one will be used to inform subsequent designs before Public Consultation 2 in Phase 3 on the Preferred Scheme. Figure 3-2 provides a roadmap to the public consultation process.

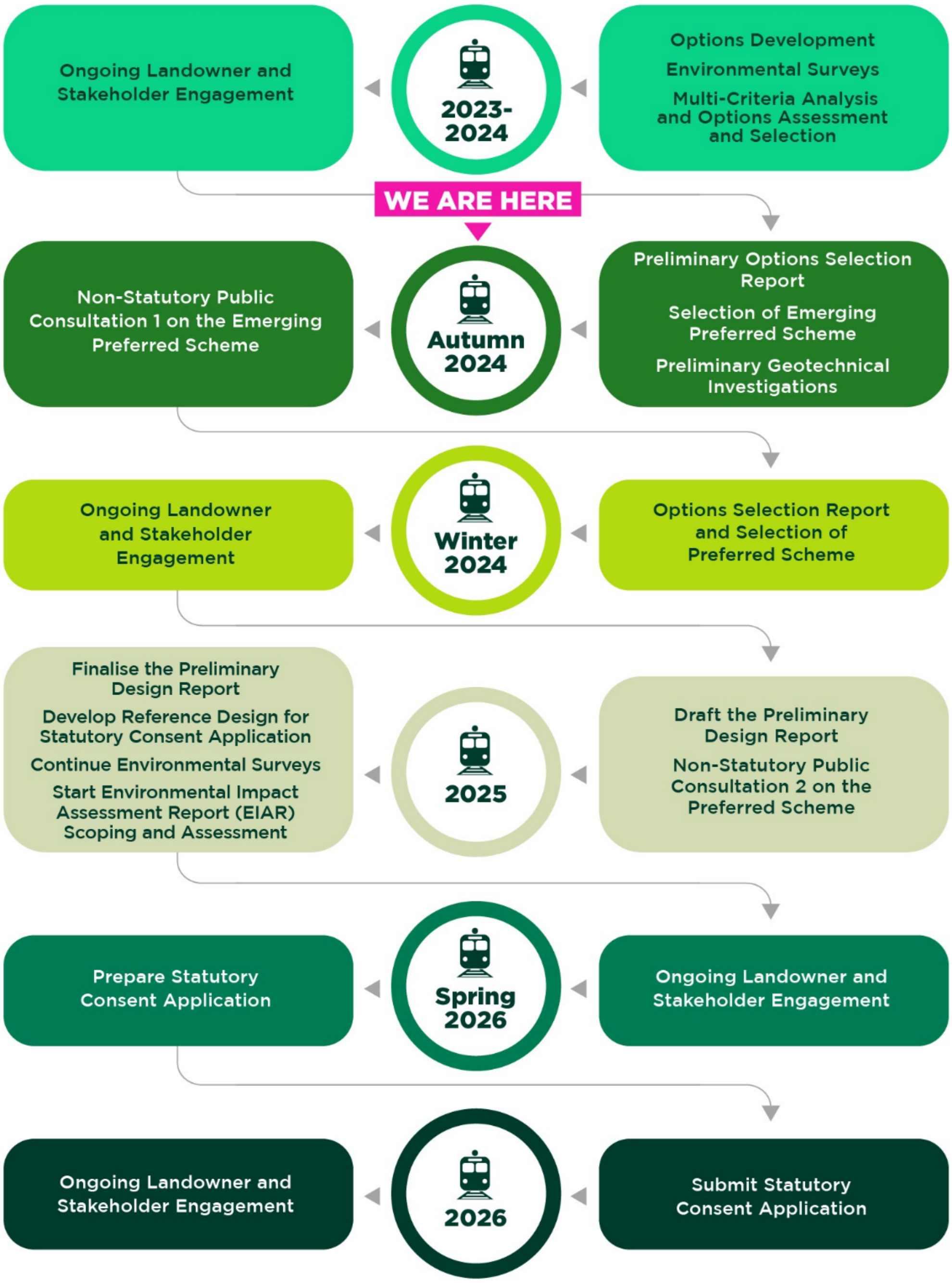

Figure 3-2 Public consultation roadmap

3.10 Step 9: Identify 'Preferred Scheme'

The Preferred Scheme is confirmed following consultation with the public and key stakeholders. Each engineered component of the Preferred Scheme is described, and a preliminary outline of the key delivery areas is provided.

The future Project phases to develop and deliver the Preferred Scheme are described in the concluding section of this report.

4. Study Area

4.1 Coastal Cell Area CCA5

The Project area is divided into Coastal Cell Areas (CCA). CCA5 is the section of coast that stretches from Bray Head at Naylors Cove to Greystones North Beach; north of Greystones Harbour. This frontage is formed of hard rock cliffs for 4km at Bray Head in the north of the CCA, with intermittent coastal defences between the tunnelled sections. Some of these defended sections are as long as 100m. At Greystones North Beach in the south of the CCA there is 3km of beach fronting soft cliffs.

The frontage is mostly rural, with the train line running along the coastline in and out of tunnels. Many of the defences and tunnel structures have shown signs of past damage or failures in the form of undermining, rock falls and land slips. It is often noted that rock falls can temporarily close the line along this frontage. The main hazards here are related to cliff instability above and below the railway and coastal defence undermining below the railway. Beach erosion at the northern and southern parts of the CCA are increasing exposure of the coastline to other hazards.

CCA5 is located within a number of designated sites which are outlined in Section 4.3.

4.2 Identification of Coastal Sub-Cells

CCA5 has been divided into two sub-cells based on the variation in physical characteristics, including the geomorphology, shoreline topography and orientation, environmental constraints, and existing defence type and the exposure due to different failure modes. The CCA sub-cells are shown and described in Figure 4-1 and Table 4-1. A photographic record showing the key defences and physical characteristics of each sub-cell are in Appendix B.

Further subdivision of the sub-cells for prioritisation of works is described in Section 5.6.

4.3 Environmental Constraints

In order to understand the baseline conditions of CCA5, a Planning and Environmental Constraints Report was produced. This report outlines constraints for a number of environmental topics which include:

- Biodiversity
- Soils & Geology
- Waste
- Hydrogeology
- Hydrology
- Landscape, Seascape & Visual
- Archaeology & Cultural heritage
- Air Quality & Climate
- Noise & Vibration
- Population & Human Health
- Traffic & Transport
- Material Assets

A summary of the constraints for CCA5 is included within this section. It should be noted this is a high level overview of some key constraints that were identified. The Planning and Environmental Constraints Report has been included as part of Appendix A.

4.3.1 Biodiversity

The main biodiversity constraints identified include:

- European and Nationally designated sites Bray Head SAC (Code 000714) and Bray Head pNHA (Code 000714).
- Bray Head is important to seabird colonies. Peregrine Falcon, an Annex I species of the EU Birds Directive, breeds at the site, as do Raven and Kestrel.
- Characteristic bird species of the heath areas include Stonechat, Whitethroat, Linnet and Skylark.

- The principal habitat in this area is dry heath on Bray Head. Rocky sea cliffs form the majority of the seaward boundary of this area.

These ecological constraints have been considered by the design team with the intention to reduce any potential impacts on the qualifying interests.

4.3.2 Soils & Geology

The main constraints for soils and geology that were found are as follows:

- Steep topography around the Bray area;
- Potential locations of variable ground;
- The Bray area has been shown to have a high landslide susceptibility rating;
- Some EPA surface watercourses intersect the railway line through at the southern end of the cell;
- Potential sources of contamination:
  - Urban areas/made ground noted around Bray Head and Greystones
  - Rail line
- Several geological faults and thrusts intersect the railway line within the cell;
- Moderate to extreme areas of groundwater vulnerability;
- High to very high potential for granular aggregates;
- Moderate to very high crushed rock aggregate potentials;
- Bray Head area has been noted as a Geological Heritage Audited Site.

4.3.3 Hydrology

The main constraints for hydrology that were found are as follows:

- Waterbodies:
  - One river sub-basin: Kilruddery_Deerpark_010
  - One Coastal waterbody: Southwestern Irish Sea - Killiney Bay (HA10)
- Areas subject to flood risk includes the coastal area from Rathdown Upper as far south as Greystones.

4.3.4 Landscape, Seascape & Visual

The main constraints for Landscape, Seascape & Visual that were found are as follows:

- Various no. of woodland trees under Tree Protection Order (TPO B8 Bray Head)
- Special Amenity Area Order (SAAO) – Bray to Greystones Cliff Walk
- One no. Prospect – Bray to Greystones Cliff Walk
- Seascape Character Area (SCA) – SCA 14 Irish Sea, Sandbanks and Broad Bays.
- Seascape Coastal Type (STC) - SCT7 - Broad Estuarine Bays and Complex Low Plateau and Cliff Coastline

4.3.5 Archaeology & Cultural Heritage

The main constraints for archaeology & cultural heritage that were found are as follows:

- Three Recorded Monuments
- 15. No. SMR Sites
- One Undesignated Key Constraints:
  - One historic railway line: Bray to Wicklow

4.3.6 Air Quality & Climate

No significant constraints have been identified in relation to air quality and climate. However, there are air quality sensitive receptors that were identified within the study area. These include but are not limited to:

- Residential Properties;
- Designated Habitats (e.g., SAC or SPA) and Ecologically Sensitive Areas;
- Amenity/Recreational Areas;

- Educational Facilities; and
- Healthcare Facilities.

4.3.7 Noise & Vibration

No significant constraints have been identified in relation to noise and vibration. However, there are a range of noise sensitive receptors that have been identified within the study area. These include but are not limited to:

- Residential Properties;
- Schools;
- Hospitals;
- Heritage Buildings;
- Designated Habitats (e.g., SAC or SPA) and Ecologically Sensitive Areas;
- Place of worship or entertainment; and
- Commercial buildings with noise/vibration sensitive equipment i.e., recording studios or research and manufacturing facilities.

4.3.8 Population & Human Health

No significant constraints have been identified in relation to population & human health. A baseline review was undertaken to identify local receptors which include but are not limited to:

- Residential Properties;
- Schools;
- Hospitals;
- Commercial buildings; and
- Recreational facilities.

Figure 4-1 CCA5 sub-cells

4.4 Hazard Identification and Failure Modes

The existing defence forms and their exposure to different hazards (failure modes) have been identified for the CCA sub-cells. The Long List of Solutions (Section 5.1.2) are considered against the same list of hazards for each sub-cell.

The failures modes identified for the Project encompass the following:

- **OT**: Wave overtopping leading to structural damage behind the defence and/or erosion of rear embankment slope (and disruption to services)
- **ST**: Structural failure of existing hard defences from wave impact (covers blocks/rocks displacement, concrete loosing strength/cover, mortar loss leading to voids, overloading retaining walls etc)
- **TS**: Toe scour at structures in response to storm conditions leading to undermining of structures (episodic and relatively localised)
- **BE**: Beach erosion and retreat of the shoreline in the longer term in line with sea level rise (long-term trend caused by lack of sediment supply affecting larger areas)
- **TE**: Toe erosion of cliffs leading to undercutting, oversteepening and cliff recession, predominantly through mudslides. Erosion will be greater in times of low beach levels coincident with storms
- **GW**: Cliff failure through elevated groundwater levels that raise pore water pressures, weaken 'soft cliff' materials and promote failure. Failures triggered by persistent wet weather (high antecedent rainfall).
- **RF**: Rock falls and other bedrock failures associated with weathered and weakened rock slopes in cuttings, natural sea cliffs and crags above the railway. Includes mobilisation of existing screes. Weathering driven by seasonal freeze-thaw. Failure may be triggered by exceptional rainfall, seasonal thaw or extreme dry conditions.

A summary of the existing defence forms and their hazard exposure is provided below in Table 4-1.

4.5 The Do Nothing Scenario

The coastal hazards could present a range of risks to the railway operations if there are no intervention measures to manage coastal erosion and flooding hazards.

Table 4-2 describes the potential failure modes associated with the various coastal hazards (identified in Section 4.4) and provides a commentary on how risks to the railway could manifest in the absence of intervention measures. This represents the Do Nothing scenario. The table also identifies the most vulnerable sections of the frontage under each failure mode.

Intervention measures range from current maintenance and reactive repairs through to strategic and holistic improvement of the defences under the Project.

Table 4-1 Defence forms and failure modes at each CCA sub-cell

Sub-cell	Name	Defence form and hazard exposure	Failure modes						
			Wave overtopping	Structural failure	Toe scour	Beach erosion	Toe erosion	Ground water	Rockfall
CCA5-A	Bray Head	Hard rock cliffs with railway perched on cliff in cutting or bench supported by retaining structures at gullies. Cutting slopes predominantly benefit from netting and rock bolting with some catch fences. Limited drainage in place to control debris runouts from higher on Bray Head. High wave exposure at base of cliffs and little/no beach. Cliff erosion, failure of below line gully structures and rock falls from above the line are main hazards. Coastal structures to be upgraded were identified through dilapidation survey and considered independently (not together on a CCA sub-cell basis).	✓	✓	✓	✓	✓	✓	✓
CCA5-B	Greystones Cliffs	Soft cliffs, with bedrock cropping out at toe in northern part. Failures in northern part comprise shallow mudslides in debris mantling the cliff and former railway cutting, with very limited headscarp retreat. These are triggered by toe erosion and surface water runoff. In central and southern cliffs, failures comprise shallow mudslides that cause significant rates of headscarp retreat. Failures driven by low beach levels and toe erosion.				✓	✓	✓	

Table 4-2 Risk to the railway due to various failure modes in Do Nothing scenario

Hazard/ Failure Mode	Risk to the railway (vulnerability) in the Do Nothing scenario	Most vulnerable areas
Wave Overtopping	• Wave overtopping is currently a medium risk to the stability of gully structures supporting the railway around Bray Head in CCA5. This risk will increase significantly with sea level rise projections. There are no structures at Greystones North Beach, hence no risk. • During storms, where waves propagate to the defence line during high tide events, wave overtopping has historically led to localised erosion of the top aprons of the gully structures below the railway. This presents a structural and geotechnical stability problem rather than a flooding problem because of the elevation of the railway. • The most likely impact is the continued degradation of the structure aprons and/or retaining structures above the apron. This would necessitate a repair of these structures, or potentially result in the closure of the line in a Do Nothing scenario. The likelihood of a sudden failure of the entire embankment is possible and there have been cases where this has happened in the past, the worst of which resulted in a train derailment. • As sea levels rise and the structures deteriorate over time, the likelihood of wave overtopping causing a structural failure that undermines of the railway will increase significantly until this becomes a likely event in a large storm. • In the Do Nothing scenario repairs would not be undertaken, and the line would ultimately have to be closed following a storm of sufficient magnitude to cause structural failure resulting from wave overtopping. There is a very high probability this would occur in the longer term in the Do Nothing scenario based on this failure mode.	• The vulnerability at a location is directly linked to the storm wave height /direction /period, water level (all of which vary for a given storm), the defence form/height and the foreshore levels. • Vulnerability varies, but in general those Bray Head structures that have not been improved with rock armour placed at their toes in the last c. 20 years are the most vulnerable to wave overtopping leading to failure.
Structural Failure	• Structural failure of the current defences (where present) is currently a high risk to railway operations at Bray Head in CCA5. This risk will increase appreciably with sea level risk projections as larger waves would reach the defences/unprotected slopes/cliffs on a more regular basis. • Irish Rail has historically maintained the defence to repair sections where the existing masonry walls and upper retaining walls have been damaged. Historical, this damage has typically been where walls blocks have been dislodged during storms (where large waves propagate to the defence line during high tide events). These dislodged blocks open-up holes in the walls and these can quickly result in the loss of fill material and large voids if not repaired quickly. This leads to a loss of stability of the upper sections of defence. • In the Do Nothing scenario, holes in the defence would not be repaired and the overall structural integrity of the defence would be severely compromised. This would quickly lead to the undermining and failure of the upper parts of the structure forcing the closure of the line. There is a very high probability this would occur in the longer term in the Do Nothing scenario based on this failure mode.	• The vulnerability at a location is directly linked to the storm wave height /direction /period, water level (all of which vary for a given storm), the defence form/height and the foreshore levels. • Vulnerability varies, but in general those Bray Head structures that have not been improved with rock armour placed at their toes in the last c. 20 years are the most vulnerable to wave overtopping leading to failure.

	• As sea levels rise, larger waves will reach the defence line, and this increases the risk that more significant holes could propagate quickly during a storm event. This could potentially cause a sudden and catastrophic collapse of the upper parts of the revetment, undermining the railway line and could potentially result in a derailment risk.	
Toe Scour	• At CCA5, the risk of scour undermining the defences at Bray Head is linked directly to the general foreshore/beach levels ahead of a storm (refer to the beach erosion failure mode below). • Toe scour is currently assessed a medium risk to railway operations in CCA5, but it is localised. This risk will increase significantly with sea level rise projections allowing larger waves to reach the defence line and cause more significant scour in-front of the existing structures. • Historically there is evidence of scour of the beach/foreshore leading to an undermining of defences and failure/damage to the defences. Sometimes the full depth of scour during the peak of a storm event is not known as the scour hole can fill back up with foreshore material as the tide level/storm reduces. Also, the depth of the toe is still unconfirmed. • Should the defence toe become undermined and exposed in a storm event, the risk to the railway is similar to the structural failure mode. This could result in a quick and catastrophic failure and could potentially result in a derailment risk. • In the Do Nothing scenario the undermined defence would not be repaired and the failure would eventually undermine the upper sections of the defence leading to a compromise in the overall structural integrity of the defence that would force the closure of the line on safety grounds. There is a high probability this would occur in the longer term in the Do Nothing scenario based on this failure mode.	• The vulnerability at a location is directly linked to the storm wave height /direction /period, water level (all of which vary for a given storm), the defence form/height and the foreshore levels. • Vulnerability varies, but in general those Bray Head structures that have not been improved with rock armour placed at their toes in the last c. 20 years are the most vulnerable to wave overtopping and failure. The vulnerability at a location is directly linked to the storm wave height/ direction/ period, water level (all of which vary for a given storm) and the defence condition/ form /toe depth.
Beach Erosion	• An unprotected shingle beach fronts the soft cliffs in Greystones North Beach. The beach provides the first line of defence against the sea and protects the toe of these cliffs. • Beach material is susceptible to being drawn alongshore/offshore in storm conditions to expose the underlying clay platform and reducing the protection of the toe of the soft cliffs leading to increased rates of cliff toe erosion (see below). • Beach erosion is currently assessed a low risk to railway operations in CCA5 given beach erosion on its own will not lead directly to a risk to the railway. However, it will lead to cliff toe erosion and eventual cliff headscarp retreat at Greystones North Beach. There is a significant buffer until the railway alignment is threatened. At Bray Head, the further loss of rocky beaches will increase the risk of the other failure modes above. • This indirect risk will increase with sea level rise due to the relative reduction in beach volume above the high tide level (the beach is the main coastal defence through this cell and there is no new source of beach material feeding into the cell to increase beach levels in line with sea level rise). Climate change will also lead to a change in the coastal processes in Greystones North Beach resulting in increased erosion rates (where material will be pulled offshore and lost).	• There is a tendency for more stability in the centre of Greystones North Beach where the beaches are wider. The risk of beach loss here is lower (inclusive of climate change impacts). • Long term erosional trends are more pronounced at the northern and southern margins of the bay where the beaches are currently narrower and suffer from more seasonal and storm variation. These are the locations where losses of beach material will expose the cliffs to the other failure modes. • There are limited beaches fronting some of the structures at Bray Head. Many of these beaches have been drawn down over time (material lost offshore) resulting in an increased risk of wave overtopping, structural failure (due to increased wave height at the structure) and toe scour (undermining).

	• In the Do Nothing scenario, the beach volume relative to mean sea level will reduce and accelerated losses of material offshore would be expected. This will not directly put the railway at risk, but it will increase the likelihood of the other failure modes impacting the railway.	
Toe Erosion	• Toe erosion during storms and/or in times of low beach levels have caused retreat of soft cliffs formed in weak glacial sediments that is measurable in historical maps and aerial photos covering the last c. 150 years. Cliffs formed in bedrock may also have retreated, but the rate is too low or too localised to be recorded. • Under a Do Nothing scenario toe erosion is expected to increase if sea-levels rise or beaches diminish in size, which will allow waves to break more frequently at the cliff toe. • Projected erosion of soft cliffs under sea-level rise suggests that a section of the railway is at moderate risk in the long term at Greystones.	• Soft cliffs are located at Greystones North Beach, where cliff retreat rates have been high in the recent historical period. However, risk is generally low because the railway is inland. The exception is the southern portal of Tunnel 4, where the combined impacts of cliff retreat and gully erosion threaten the railway by 2100.
Rainfall or Groundwater Induced Cliff Failure	• Elevated pore water pressures caused by sustained wet weather weaken soft cliffs and promote cliff failures that may cause cliff retreat or debris runout, even where beaches are healthy and there is negligible toe erosion. • Debris runout and mudslides have historically impacted the railway between Tunnels 3 and 4 at Bray Head, where weak material above a bedrock cutting has been mobilised and run out onto the line. These slopes have since been stabilised with soil netting and drainage. It is understood that netting is susceptible to damage in scrub fires and drainage requires regular maintenance to be fully effective. • Under a Do Nothing scenario the risk of rainfall-induced failures will increase as existing mitigation measures become less effective. Debris runout to the railway may lead to temporary closure of the line and may cause derailment.	• Soft cliffs above bedrock cuttings are present between Tunnels 3 and 4 on Bray Head
Rockfall	• Rockfalls have impacted the railway around most of Bray Head over the historical period and high risk sections now benefit from rock netting, bolting and catch fences. • Rock falls are typically associated with weaker and/or weathered bedrock located along faults or gullies. Triggers are likely to comprise freeze thaw in winter and sustained wet weather. It is assumed that most failures originate from cutting slopes above the line, but it is also possible that some failures originate from natural slopes higher up Bray Head, above the coastal footpath and 'carriage path'. • Under a Do Nothing scenario, rock fall risk will increase as existing mitigation measures fail and new areas of unstable rock develop.	• Most of Bray Head is vulnerable to rock falls

5. Options Assessment

This section provides the results of the Options Assessment, from identifying the Long List of Options (Section 5.1) and the Short List of Options (Section 5.2), through to the Multi Criteria Analysis (Section 5.3), identifying the Top-Ranking Short List Options for Concept Design (Section 5.4) and determining the Emerging Preferred Option (Section 5.5).

5.1 Long List of Options

The Long List of Options considers the range of interventions measures that could be used to meet the Project objectives of protecting the railway line from coastal erosion and flooding. Through a process of screening, this is reduced to a Short List of Options.

The approach to identifying the Long List of Options is summarised as follows:

1. Generic List of Solutions: generic list of structural and non-structural coastal engineering solutions.
2. Long List of Solutions: screening of Generic List of Solutions for those that could be considered.
3. Suitability Matrix and Long List of Options: Identification of options (combinations of solutions) for each CCA sub-cell.

The results of the Long List Options process are presented in Section 5.1.3 in Table 5-6 and Table 5-7.

5.1.1 Generic List of Solutions

The Generic List of Solutions lists the full range of possible engineering measures that can be used to protect a shoreline. This is not specific to the Project or to a given CCA or location but outlines the full range of structural, non-structural options and nature-based solutions, regardless of whether they could be viable for the Project. Hybrid solutions combine elements of structural and nature-based and are considered as combined solutions at a CCA-level. An overview of these solutions is provided in

Table 5-1.

Table 5-1 Overview of generic list of solutions to protect a shoreline.

Structural	Nature-based	Non-structural	Hybrid
Seawalls	Beach nourishment	Floodplain policy and management	Managed realignment
Revetments	Dune restoration	Flood proofing and impact reduction	Ecologically enhanced vertical walls
Breakwaters	Shellfish reefs	Flood warning and preparedness	Breakwaters with beach nourishment
Groynes	Saltmarsh	Relocation	
Sills	Seagrass beds		
Embankments			
Rock netting			

5.1.2 Long List of Solutions

The Generic List of Solutions have been screened to identify options that can be discounted at this stage as not applicable to the Project or any sub-cell. The screening of the Generic List of Solutions is provided in Table 5-2, Table 5-3 and Table 5-4, for the structural, nature-based and non-structural solutions, respectively. The tables provide:

- Long List (LL) ID, name and description of the Solution,
- Design life and maintenance burden information,
- Whether the Solution is retained or discounted, coloured green and red in the table,
- Reasoning for discounting the Solution, based on whether or not the solution meets the Project objectives as outlined in Section 3.4.

The remaining Solutions that are retained for more detailed screening at the CCA sub-cell level are the Long List of Solutions.

Table 5-2 Long list of structural solutions.

ID	Solution	Description	Meets minimum design life?	Maintenance burden	Retained or discounted	Reason for discounting	Failure mode addressed						
							OT	ST	TS	BE	TE	GW	RF
LL04	Detached Breakwaters - emergent rock or concrete armour units	Large offshore structures which dissipate wave energy due to their size, roughness and presence of voids. This reduces the wave heights at the shoreline defences	Yes	Low	Retained					✓			
LL05	Detached Breakwaters - caissons	Large monolithic offshore structures which block waves due to their size. This reduces the wave heights at the shoreline defences	Yes	Low	Discounted	Technically feasible but discounted because: No distinct advantages over rock or concrete armour units; higher uncertainty in design, cost etc.				✓			
LL06	Detached Breakwaters - submerged reefs	Offshore structures which are fully below the normal tidal water level, reducing some of the wave transmission to the shoreline	Yes	Low	Discounted	Does not promote salient growth and will have limited impact on shorter period waves such as those seen in the study area				✓			
LL07	Attached Breakwaters - rock	Rock structures which extend from the shoreline into the nearshore and are large enough to dissipate wave energy under storm conditions	Yes	Low	Retained				✓	✓	✓		
LL08	Revetment - rock	Sloping rock structure along the shoreline which has a rough surface to dissipate wave energy and reduce wave overtopping	Yes	Low	Retained		✓	✓	✓		✓		
LL09	Revetment - concrete armour units	Sloping structure formed of precast concrete armour units along the shoreline which has a rough surface to dissipate wave energy and reduce wave overtopping	Yes	Low	Retained		✓	✓	✓		✓		
LL10	Revetment - smooth concrete	Sloping structure formed of precast or in-situ smooth concrete slabs.	Yes	Medium	Discounted	Requires more frequent maintenance and performs less well than other revetment solutions		✓	✓				
LL11	Revetment - stepped concrete	Stepped structure formed of precast or in-situ smooth concrete slabs. Steps dissipate some wave energy and allow some reduction in wave overtopping	Yes	Medium	Retained		✓	✓	✓				
LL12	Revetment - masonry	Sloping masonry structure similar to the existing defences in CCA1	Yes	High	Discounted	Requires more frequent maintenance and performs less well than other revetment solutions		✓	✓				
LL13	Revetment - open stone asphalt	Sloping structure formed of a bitumen-bound aggregate. Provides limited dissipation of wave energy due to the open layer structure	No	Medium	Discounted	Uncertainty in design life in more exposed locations (such as this). Could be viable as more of a maintenance measure.		✓	✓		✓		
LL14	Revetment - gabions	Sloping or stepped structure formed of wire cages filled with small stone. Provides some dissipation of wave energy and some reduction in wave overtopping	No	High	Discounted	Design life in the marine environment is limited to approximately 10 years and does not meet project requirements		✓	✓		✓		
LL15	Revetment - geo containers	Containers formed with UV-stabilised geotextile fabric and filled with sand	No	High	Discounted	Design life is unproven and is not expected to meet project requirements		✓	✓		✓		
LL16	Toe Protection - rock	Low-profile rock structure which provides added stability and erosion protection to existing structures and/or soft cliffs	Yes	Low	Retained				✓		✓		
LL17	Toe Protection - geotubes	Containers formed with UV-stabilised geotextile fabric and filled with sand	No	High	Discounted	Design life is unproven and is not expected to meet project requirements			✓		✓		

LL18	Toe Protection - gabions	Low-profile gabion structure formed of wire cages filled with small stone. Provides added stability and erosion protection to existing structures and/or soft cliffs	No	High	Retained	Although design life and maintenance burden do not meet the project requirements, these may be appropriate in areas of lower exposure and as part of cliff toe protection. This option is retained as a measure that can be replaced in the future and/or used alongside other measures to provide long term protection.			✓		✓		
LL19	Toe Protection - steel sheet piles	Steel sheet piles installed at the toe of existing structures and/or soft cliffs to provide added stability and erosion protection. Structure may exacerbate beach loss as vertical structures reflect more wave energy	Yes	Medium	Retained	Needs to be used as part of a combined solution, either to provide toe support as part of a revetment solution or with other scour protection in front of cliffs. Fully discounted as a stand-alone solution in the active zone			✓		✓		
LL20	Toe Protection - rubber tyres	Used rubber tyres are lashed together (for example in a honeycomb pattern) to protect existing structures and/or soft cliffs. Tyres can also be filled with stone, sand or concrete to increase their weight.	No	High	Discounted	Not suitable for high wave energy environments; does not have the robustness required for these locations. There are also concerns that material would degrade contaminating the sea/adjacent habitats			✓		✓		
LL21	Groynes - rock	Linear rock structure constructed perpendicular to the shoreline which helps retain beach material in place. Different plan configurations are possible, such as fish-tail and y-shaped groynes	Yes	Low	Retained	Note that groynes as a standalone measure will only be appropriate where there existing beach material is abundant. Elsewhere, beach nourishment would be likely to create a long-term solution			✓	✓	✓		
LL22	Groynes - timber	Linear timber pile and planking structure constructed perpendicular to the shoreline which helps retain beach materials in place.	No	High	Discounted	Timber groynes typically have a design life of less than 50 years in the marine environment and therefore do not have the required design life. They also require more maintenance than rock groynes			✓	✓	✓		
LL23	Vertical Seawall - concrete wall	Large vertical or near-vertical impermeable concrete structure designed to withstand high wave forces; may include a bullnose or recurve element to help reduce wave overtopping. A seawall can accommodate a promenade or other amenity feature	Yes	Low	Retained		✓	✓			✓		
LL24	Vertical Seawall - sheet piles	Steel sheet piles installed as prevention from wave overtopping; may include a concrete capping beam. Likely to require toe protection	Yes	Medium	Retained	As a combined solution with rock toe protection or as a set-back wall to reduce maintenance burden	✓	✓			✓		
LL25	Vertical Seawall - masonry	Large vertical or near-vertical impermeable masonry structure designed to withstand high wave forces. A seawall can accommodate a promenade or other amenity feature.	Yes	Medium	Discounted	Would require large volumes of rock, quarried and shaped into blocks; very labour-intensive and does not have any additional technical advantages when compared to a concrete seawall	✓	✓			✓		
LL26	Embankments / Levees	Linear grassed earth structure providing flood protection; typically used along riverbanks	Yes	Medium	Discounted	Not suitable for a coastal setting without a revetment or other protection							
LL27	Sills	Installation of a low rock structure in front of existing eroding banks to retain sediment behind. Depending on availability of suitable material, accretion may occur naturally, or recharge may be needed. Can also be used to form a perched beach reducing the footprint and volume of material import to create a beach.	No	Medium	Discounted	Best suited to low energy environments where there is a wide intertidal area; not technically feasible for an open coast frontage			✓	✓	✓		
LL28	Set back flood wall	Low vertical wall, typically made of concrete, masonry or steel sheet piles which is located behind the primary defence where it does not need to withstand direct wave impact; may be installed behind a promenade or beach nourishment	Yes	Low	Retained		✓						

LL29	Rebuild existing structures to required height	Dismantle and re-build the existing defences to meet current design standards and the required level to reduce wave overtopping. This may have a lower overall carbon footprint.	Yes	Medium	Discounted	The integrity of the existing materials is uncertain; this would also increase the vulnerability of the railway during the construction period and substantial temporary works would be needed to allow the railway to remain operational.	✓	✓					
LL30	Temporary flood defences (demountable?)	Includes flood gates and inflatable defences which can be deployed when needed.	No	High	Discounted	Need regular inspections and maintenance to know they can be deployed as needed. Not suitable for the scale of interventions needed to deliver resilience. May be suitable at very discrete locations where existing access to the beach needs to be maintained (e.g., at level crossings)	✓						
LL43	Soft cliff stabilisation - deep drainage systems	Deep drainage for landslide stabilisation employing 'passive' gravity drains, or 'active' pumped/syphon systems.	Yes	High	Discounted	Cliff instability is not driven by movement on deep shear surfaces.						✓	
LL44	Soft cliff stabilisation - shallow drainage systems	Surface water management to prevent and redirect flows discharging over the cliff	No	Medium	Retained	Will require periodic maintenance to ensure drains are cleared. Although the option is not able to provide protection on its own, this option is retained as a measure that can be replaced in the future and/or used alongside other measures to provide long term protection.						✓	
LL45	Hard cliff stabilisation - rock netting	Technically feasible and appropriate but 100 year design life for netting/bolting materials is not currently possible in the industry.	No	Medium	Retained	Currently available manufacturers' equipment has a limited design life and will require periodic maintenance. Although the option is not able to provide the required design life, this option is retained as a measure that can be replaced in the future and/or used alongside other measures to provide long term protection. New products may become available in the future.							✓
LL46	Hard cliff stabilisation - rock bolting	Technically feasible and appropriate but 100 year design life for netting/bolting materials is not currently possible.	No	Medium	Retained	Currently available manufacturers' equipment has a limited design life and will require periodic maintenance. Although the option is not able to provide the required design life, this option is retained as a measure that can be replaced in the future and/or used alongside other measures to provide long term protection. New products may become available in the future.							✓
LL47	Hard cliff stabilisation - large scale reprofiling	Reprofiling of Bray Head is not feasible given the volumes of rock needing removal. It may be feasible to undertake very localised reprofiling and/or removal of loose blocks.	Yes	Low	Discounted	Large-scale reprofiling of Bray Head is not feasible, but localised removal of loose blocks may be undertaken in tandem with other rock slope stabilisation measures.							✓
LL48	Hard cliff stabilisation - catch fences	Suitable for certain locations, but fences need maintenance after each rock-fall event.	No	High	Retained	Catch fences have a limited design life and will require periodic maintenance, particularly after a rock fall event. Although the option is not able to provide the required design life, this option is retained as a measure that can be replaced in the future and/or used alongside other measures to provide long term protection.							✓
LL49	Rock fall protection - rock fall shelter	Engineered structures with open sides that that extend from existing tunnels and protect the railway from falling debris.	Yes	Medium	Retained								✓
LL50	Rock fall protection - new/extended tunnels	Engineered structures with closed sides that protects the railway from falling debris and/or new tunnelled sections	Yes	Medium	Discounted	Localised new tunnels will be prohibitively expensive and are unlikely to be feasible given restrictions of railway alignment							✓

Table 5-3 Long list of nature-based solutions.

ID	Solution	Description	Meets minimum design life?	Maintenance burden	Retained or discounted	Reason for discounting	Failure mode addressed						
							OT	ST	TS	BE	TE	GW	RF
LL32	Beach Nourishment - beach recharge	Supplementing the existing beach periodically with suitable material (shingle, sand or a mixture to match the existing beach) to increase beach volumes, reduce erosion and toe scour at flood defences and/or soft cliffs. Usually requires control structures (groynes or breakwaters) to retain the material.	No	Medium	Retained	Although the option is not able to provide the required design life, this option is retained as a measure that can be replaced in the future and/or used alongside other measures to provide long term protection.			✓	✓	✓		
LL33	Beach Nourishment - beach recycling	Moving existing beach material from areas of accretion downdrift to areas of erosion updrift. This is best suited to areas where there is a well-defined longshore movement of beach material which accumulates at the downdrift end of a beach. Recycling activities would typically be undertaken annually.	No	High	Discounted	Will not achieve the required design life and needs significant and frequent maintenance. Therefore, does not meet needs of the project			✓	✓	✓		
LL34	Sand engine	Supplementing the existing beach with a very large recharge of suitable material (shingle, sand or a mixture to match the existing beach) to increase beach volumes, reduce erosion and toe scour at flood defences. Material is placed in the nearshore and waves/currents allowed to distribute naturally.	No	Medium	Discounted	Will not achieve the required design life. None of the beaches are sand beaches; the beaches are generally a sand-shingle mix. From a technical perspective, shingle would be preferred but this is un-proven.			✓	✓	✓		
LL35	Dune regeneration	Stabilisation and enhancement of existing dune systems to deliver additional resilience. Stabilisation could involve planting, thatching and fencing to trap windblown sand	No	Medium	Retained	Note: only relevant where dunes already exist at very specific locations along the study area. Although the option is not able to provide a long design life, this option is retained as a measure that can be replaced in the future and/or used alongside other measures to provide long term protection.			✓	✓			
LL36	Vegetated features (e.g. saltmarsh)	Restoration or planting of saltmarsh or other vegetated features.	No	N/A	Discounted	Does not address any of the failure modes; there is no saltmarsh present in the study area and wave exposure is too great							
LL37	Maritime forests	Restoration or planting of kelp	No	N/A	Discounted	Does not address any of the failure modes; there is no kelp present and needs to be subtidal							
LL38	Oyster, mussel and coral reefs	Construction of sub-tidal or intertidal reefs using a suitable material for settlement by oysters or mussels.	No	N/A	Discounted	Structures are likely to be small in scale and therefore have limited influence on failure modes.							
LL39	Sea grass beds	Installation of intertidal or sub-tidal beds of sea grass. Provides ecosystem benefits including carbon sequestration.	No	N/A	Discounted	Needs sheltered waters; does not address any of the failure modes							

Table 5-4 Long list of non-structural solutions.

ID	Solution	Description	Meets minimum design life?	Maintenance burden	Retained or discounted	Reason for discounting	Failure mode addressed						
							OT	ST	TS	BE	TE	GW	RF
LL01	Do nothing	No further maintenance and intervention/repair only where required for public safety	No	Medium	Retained	Retained as a baseline option for the MCA							
LL02	Do minimum	Continue patch repairs/upgrades and reactive maintenance	No	High	Retained	Retained as a baseline option for the MCA							
LL03	Relocation of the railway	Construction of a new railway line with an inland or lower hazard route	Yes	Low	Retained	Low maintenance for defences; railway assets would be comparable to existing	✓	✓	✓	✓	✓	✓	✓
LL40	Floodplain policy and management measures	Managing flood and erosion risk by not allowing vulnerable infrastructure within zone of significant risk; typically, a government-led planning policy limiting future development rather than retrospectively to existing development	Yes	N/A	Discounted	Policy and management measures would not address any of the failure modes							
LL41	Flood proofing and impact reduction measures	Localised protection to individual assets/buildings to improve resilience to flooding. This might include demountable gates protecting doors and windows preventing flow into the assets/buildings. Would often be combined with a flood warning system to allow deployment in time.	Yes	N/A	Discounted	Flood proofing and impact reduction measures are best suited to critical assets in discrete locations; this may be appropriate for isolated structures along the railway (e.g., critical signalling infrastructure) but cannot be practically achieved along the whole study area	✓						
LL42	Flood warning and preparedness measures	Can reduce risk to life but will not prevent damage to the railway.	Yes	N/A	Discounted	Flood warning and preparedness measures would not address any of the failure modes							

5.1.3 Suitability Matrix and Long List Options

The Long List of Solutions have been cross-referenced against the failure modes addressed by each Solution and their suitability in addressing hazard exposure in each CCA sub-cell, as summarised in Table 5-5. Where the Solution can protect against the identified hazards for a given sub-cell, then it is marked as Y (Yes), thus identifying that it has the potential to be used as a Solution in that sub-cell. If the identified hazards are not present in a given sub-cell, then the Solution is marked as N (No) and it is not carried through as a viable Solution. These have enabled a Long List of Options (combinations of Solutions) for each CCA sub-cell to be identified.

The Long List of Options were then screened to discount options that will not meet the objectives or technical requirements for the given CCA sub-cell. The Long List of Options for each CCA sub-cell and reasons for discounting certain options in each sub-cell is provided in Table 5-6 and Table 5-7.

Table 5-5 Suitability matrix of long list solutions for each CCA sub-cell.

Long List Ref	Solution	Failure mode addressed by solution*							CCA5-A	CCA5-B
		OT	ST	TS	BE	TE	GW	RF		
LL01	Do nothing								N/A	N/A
LL02	Do minimum								N/A	N/A
LL03	Relocation of the railway	✓	✓	✓	✓	✓	✓	✓	Y	Y
LL04	Detached Breakwaters - emergent rock or concrete armour units				✓				Y	Y
LL07	Attached Breakwaters - rock			✓	✓	✓			N	N
LL08	Revetment - rock	✓	✓	✓		✓			Y	Y
LL09	Revetment - concrete armour units	✓	✓	✓		✓			N	N
LL11	Revetment - stepped concrete	✓	✓	✓					N	N
LL16	Toe Protection - rock			✓		✓			Y	N
LL18	Toe Protection - gabions			✓		✓			N	N
LL19	Toe Protection - steel sheet piles			✓		✓			N	N
LL21	Groynes - rock			✓	✓	✓			N	Y
LL23	Vertical Seawall - concrete wall	✓	✓			✓			N	Y
LL24	Vertical Seawall – sheet piles	✓	✓			✓			N	N
LL28	Set back flood wall	✓							N	N
LL32	Beach Nourishment - beach recharge			✓	✓	✓			N	Y
LL35	Dune regeneration			✓	✓				N	N
LL44	Soft cliff stabilisation - shallow drainage systems						✓		N	Y
LL45	Hard cliff stabilisation - rock netting							✓	Y	N
LL46	Hard cliff stabilisation - rock bolting							✓	Y	N
LL48	Hard cliff stabilisation - catch fences							✓	Y	N
LL49	Rock fall protection - rock fall shelter							✓	Y	N

*Note: OT - Wave overtopping; ST - Structural failure; TS - Toe scour; BE - Beach erosion; TE - Toe erosion; GW - Cliff failure through elevated groundwater levels; RF – Rock falls; Y=Yes; N=No; N/A=Not Applicable

Table 5-6 Long list options for CCA5-A for Bray Head.

Sub-cell	Long List Options - Bray Head
CCA5-A - Bray Head	1. Do minimum (LL02) 2. Realignment of railway landward (LL03) 3. Full rock revetment and rock toe protection in-front of existing masonry retaining walls (LL08 & LL16) 4. Upgrade of existing coastal structures (various options will be considered on a structure-by-structure basis) 5. Detached breakwaters (no nourishment) (LL04) 6. Cliff stabilisation – rock netting (potentially with grouting of natural fissures) and catch fences at current undefended areas. Upgrades to drainage management (LL45, LL46 & 48) 7. Rockfall shelters at high-risk areas of cliff (open sided to maintain sea views) (LL49) The above options will be considered for each of the structures identified for upgrade. Option for deferring coastal interventions. Deferment would require ongoing wall/revetment monitoring, minor repairs until the major upgrade works are required. Cliff stabilisation measures are not recommended for deferment. Long list solutions discounted for this specific location (with reason): • Groynes, nourishment and raised seawall (technically very difficult to create a beach in this location due to direction of dominant waves and depth of water). • Detached breakwaters with nourishment (technically very difficult to create a beach in this location due to direction of dominant waves and depth of water) • Deep drainage of cliffs (mechanisms of cliff failure at Bray Head will not be affected by deep drainage measures) • New/extended tunnels are prohibitively expensive and adversely affect views from the train

Table 5-7 Long list options for CCA5-B for Greystones Cliffs.

Sub-cell	Long List Options - Greystones Cliffs
CCA5-B - Greystones Cliffs	1. Do minimum (LL02) 2. Realignment of railway landward (LL03) 3. Upgrade of existing coastal structures 4. Continuous Rock Revetments (no nourishment), localised improvement to drainage (LL08) 5. Discontinuous Rock Revetments with managed realignment (no nourishment), localised improvement to drainage (LL08) 6. Concrete Seawalls (no nourishment), localised improvement to drainage (LL23) 7. Detached Breakwaters (LL04) 8. Breakwaters with nourishment (LL04, LL32) 9. Groynes with nourishment (LL21, LL32) The above options will be considered for each of the structures identified for upgrade. Long list solutions discounted for this specific location (with reason): • Toe protection is not relevant as there are no structures to protect the toe of (LL16, LL18 & LL19).

5.2 Short List of Options

The technically feasible sub-cell Long List of Solutions that were screened and taken forward from the previous stage (Section 5.1) are combined and presented as a Short List of Options on a CCA-wide basis. In many cases these options have the same solution applied across all sub-cells, but in other cases they comprise different solutions between the sub-cells. Where various combinations of solutions are grouped together, these have been combined based on engineering judgement to provide a coherent and complimentary approach for the overall cell.

The Short List of Options for the overall CCA are presented in (Table 5-8). This list includes the Do Nothing option (no works, including no maintenance) as Option 1 and the Do Minimum option (allows for reactive maintenance only) as Option 2. Option 3 (Relocation) has been removed from the short list options due to the significant cost and absence of policy associated with tunnelling through Bray Head compared to the other short-listed options hence no further analysis has been carried out. Option 1 and 2 also do not meet the Project objectives but are included to serve as baseline options against which the strategic and planned upgrade of defences is delivered through the Project. All remaining “Do Something” options (Options 3 to 10) meet the scheme objectives, the requirements for design life and provide the required Standard of Protection.

As presented in Table 5-8, Options 7 and 8 include detached breakwaters across both sub cells to prevent erosion of the cliffs. All other options (excluding Option 1 to 3) involve upgrading the existing structures in CCA5-A combined with a range of solutions in CCA5-B. Options 4 to 6 all involve structures at the toe of the cliffs behind Greystones North Beach to prevent erosion (Option 4 being a rock revetment along the full length of CCA5-B compared to Option 5 which involves rock revetments at specific locations and Option 6 is a variation of Option 4 using concrete units rather than rock). Options 7 to 10 all involve using beach control structures (breakwaters and groynes) to create a beach to protect the cliffs from erosion.

Table 5-8 Overview of short list options for CCA5

Option	CCA5-A Bray Head	CCA5-B Greystones Cliffs
1. Do Nothing	N/A	N/A
2. Do Minimum	Do Minimum	Do Minimum
4. Rock Revetments	Upgrade of existing coastal structures (options appraised by structure)	Rock revetment (continual)
5. Rock revetments with managed realignment	Upgrade of existing coastal structures (options appraised by structure)	Rock revetment (headland sections) and managed realignment
6. Concrete Seawall	Upgrade of existing coastal structures (options appraised by structure)	Concrete seawall with rock toe protection
7. Detached Breakwaters (no nourishment)	Detached breakwaters (no nourishment)	Detached breakwaters
8. Breakwaters with nourishment	Detached breakwaters (no nourishment)	Detached breakwaters with nourishment
9. Groynes with nourishment	Upgrade of existing coastal structures (options appraised by structure)	Groynes with nourishment
10. Groynes and breakwater with nourishment	Upgrade of existing coastal structures (options appraised by structure)	Groynes and breakwater with nourishment

5.3 Multi-Criteria Analysis

Following the development of the Short List of Options, an MCA was carried out to identify the Top-Ranking Short List Options to be brought forward to concept design.

The MCA identified the key risks, opportunities, advantages and disadvantages for each of the Short List of Options

As outlined in Section 3.6, the MCA contains seven core criteria which are further broken down into sub-criteria.

All options were assessed using the criteria in

Table 3-2. Section 5.3.1 provides a summary of the outcome from the detailed MCA analysis. The full MCA sheet can be found within Appendix D.

5.3.1 MCA Outcomes

5.3.1.1 Economy

5.3.1.1.1 Land Use & Third Party Assets

Options 1 & 2 have a significant advantage over other options as they do not propose any works which would impact on third party land or incur property costs.

Options 4-10 are comparable to each other as they have similar impacts on lands owned by Wicklow County Council. There are no impacts on third party lands as a result of any options.

5.3.1.1.2 Capital Expenditure

Option 1 & 2 have significant advantages over other options as they require no to minimal capital costs respectively.

Option 5 has significant advantages over other options due to significantly less rock requirements compared to other options which reduces the capital expenditure.

Option 4 & 9 have some advantages over other options. While Option 4 requires a large amount of rock, the rock would be delivered via barge from the sea. It is assumed that the rock would be moved into place using land-based plant which has lower costs than using marine based plant. Option 9 requires less rock compared to Option 4; however, the incorporation of beach nourishment increases the capital expenditure for this option.

Options 6, 7 & 10 have some disadvantages over other options. These three options have high costs for capital expenditure due to the requirement for cofferdams to construct the concrete seawalls for Option 6 and complexity of construction and requirement for marine based plant for all three.

Option 8 is the least cost-effective solution and has significant disadvantages over other options. It is similar to Option 7 in relation to costs for construction of breakwaters with the addition of beach nourishment. Marine based plant would be required for this option.

5.3.1.1.3 Maintenance Expenditure

Option 1 has significant advantages over other options as it does not incur any maintenance measures.

Options 4 & 5 have significant advantages over other options for operational costs. Some maintenance may be required however this will be infrequent. Should repair works be needed, this could reasonably be carried out from the beach which would negate the need for any specialist/marine based plant.

Options 6 has some advantages over other options. This option would have slightly higher maintenance costs compared to Options 4 & 5 as the concrete seawall would require more frequent maintenances and repairs. This repairs/maintenance would be straight forward and wouldn’t require specialist/marine based plant.

Options 2, 7, 9 & 10 have some disadvantages over other options. Option 9 have advantages over Option 8 as any maintenance of the groynes could be undertaken using land-based plant. However, the beaches for Options 9 & 10 would still require regular monitoring and maintenance and potential nourishment within the design life meaning this option has disadvantages over Options 4 to 7. Option 2 would require reactive maintenance, which would become more frequent and expensive over time.

Option 8 is the least cost-effective solution and has significant disadvantages over other options. A combination of beach nourishment with requires frequent monitoring and potential maintenance through beach recharge with requirement for marine based plant for maintenance of the breakwaters.

5.3.1.2 Safety

5.3.1.2.1 Health & Safety (Construction)

Options 1 & 5 have significant advantages over other options. Option 1 requires no construction and therefore no construction risks. Option 5 also has a significant advantage over other options. For construction risk, the rock armour can be handled by land-based equipment and would not require marine handling beyond the transport of rock to the site. This is similar to Option 4 in nature however its smaller footprint reduces the construction health and safety risk.

Options 4 & 9 have some advantages over other options. Construction of rock armour revetments and groynes for these options can be carried out exclusively using land-based plant, which removes the risk from marine works during construction. However, rock deliveries will require marine plant and working in the marine area does pose a risk particularly in relation to weather events. Potential for night-time working to bring rocks ashore at high tides. Groynes are an easier structure compared to breakwaters to construct and therefore gives Option 9 some advantages over options proposing breakwaters.

Options 2, 7, 8 & 10 all have some disadvantages over other options. Option 2 has disadvantages as it requires ad-hoc repair works that would only be carried out due to immediate risk to the railway. Options 7, 8 & 10 require construction of marine structures in open water that require exclusive marine equipment which has increased safety risks.

Option 6 has significant disadvantages over other options. The proposal of a concrete seawall carries an increased construction H&S risk. Excavation would be required to install the sea wall and scour protection which could result in a cofferdam being used to create a dry environment for the works to be carried out.

5.3.1.2.2 Health & Safety (Design Life)

Option 9 has significant advantages over other options. For operational health and safety, renourishment will be required during the design life of these options. Public notifications of these works will mitigate any public H&S risks. Installation of groynes will increase beach material on one side of the groyne which can lead to a difference in beach levels. However, as a result of a larger beach, access will be improved to this area and will reduce the potential for any members of the public being cut off by the tide.

Options 4, 5, 8 & 10 have some advantages over other options. For operational health and safety, there is a risk of the public walking/climbing on the rock revetments. Warning signs should be installed to deter this from happening. Access to the beach will be limited by the installation of the rock revetments. However, over time the beaches fronting these structures will erode. Option 4 has greater potential for maintaining public access on the landward side of the revetments. For Option 4, the cliffs located either side of the rock headlands will be left undefended as part of this option which creates a potential for landslides as the cliffs erode and become undermined. Maintenance of the rock revetments will be minimal which reduces maintenance operational health and safety risks. For Option 8 the breakwaters will create larger beaches improving access along the foreshore. Option 10 is a combination of Options 8 and 9 and therefore combines the advantages and disadvantage of these options.

Options 2, 6 & 7 come out as having some disadvantages over other options. For Option 2, reactive works to repair the existing defences would be required. These would not be planned and could lead to limited access and increase in potential for members of the public to be cut off by the tide. For Option 6, the rock toe protection may become exposed if beach levels are lowered following storm events. This could result in a trip hazard for members of the public. Access to the beach will be severely impacted as a result of the seawall and toe protection footprints. For Options 7 members of the public may swim out to the breakwaters however erection of warning signs should be implemented to mitigate this risk. Detached breakwaters may change the conditions of currents which could pose risks to swimmers in the area.

Option 1 has significant disadvantages over other options as no interventions would be proposed to prevent cliff failures or landslides which could lead to a catastrophic event onto the railway line and beaches below.

5.3.1.3 Accessibility and Social Inclusion:

5.3.1.3.1 Community

Options 5, 7, 8, 9 & 10 have some advantages over other options for community facilities. Options 8-10 provide an enhancement of amenity beach area by providing beach nourishment which would contribute positively to the amenity value of the area. Option 5 has some advantages as placement of rock revetment is limited compared to Option 4 which limits impact on access and therefore the usage of the amenity beach area. Option 7 would have the amenity beach largely remain the same as is. All of these options could have the potential to impact on the recreational use of the beach.

Option 2, 4 & 6 have some disadvantages over other options for community. Option 2 proposes reactive repair works. This would result with existing occurrences of erosion and damage. Minimal works could lead to the impact on train services and potential loss of the Bray to Greystones Coastal Cliff Walk. For Option 4, placement of rock revetments along the southern extent of CCA5 would restrict the use and amenity value of the existing beach area. For Option 6, while impact on the beach area is limited initially, it would eventually be lost as a result of reflection against the proposed structure.

Option 1 has significant disadvantages over other options for community. Under this option, no works would be proposed which could result in continued coastal erosion and potential impacts to the rail line and access to the amenity beach area. This could prevent the beach area being used in the future.

5.3.1.3.2 Access

Option 8 has significant advantages over other options as it does not affect any existing access points to the beach and enhances access along the length of the beach amenity area as a result of the beach nourishment.

Option 5, 7, 9 & 10 have some advantages over other options. For Option 5, the proposed rock revetment would be placed in three locations on Greystones Beach. This limits potential impacts on the amenity beach area compared to Option 4. Some access may be restricted at these two specific sections which could impact some social & recreational facilities in this area. However, the majority of the existing social & recreational facilities will be unaffected during the operational phase. Option 7 has some advantages over other options as access to the existing amenity beach area is not impacted due to the detached breakwaters being located within the marine area. Option 9 has some advantages over other options as the beach nourishment will enhance the existing amenity beach area along the southern section of CCA5. Groyne placement may limit some access along the beach area. Option 10 combines the same advantages and disadvantages from Options 7 & 9.

Option 2, 4 & 6 have some disadvantages over other options. For Option 2, impacts as a result of reactive repair works could lead to the loss of the Bray to Greystones Cliff Walk. For Option 4, the rock revetment would be placed along the entire southern extent of the coastline at Greystones North Beach. Access to the amenity beach area would be impacted which would reduce the ability for members of the public and recreational facilities to use this area. Option 6 also has some disadvantages over other options as while access would only be limited initially, the amenity beach area would eventually be lost as a result of coastal processes against the concrete seawall and eventually the ability for members of the public and recreational facilities would be lost.

Option 1 has significant disadvantages over other options for access. Under this option, no works would be proposed which could result in continued coastal erosion and potential impacts to the rail line and access to the amenity beach area. This also has the potential to impact the Bray to Greystones Coastal Cliff Walk which could lead to its complete loss.

5.3.1.3.3 Social & Recreation Facilities

Options 2, 5, 7, 8, 9 & 10 have some advantages over other options for recreational use. Options 8-10 provide an enhancement of amenity beach area by providing beach nourishment which would contribute positively to the amenity value of the area. Option 5 has some advantages as placement of rock revetment is limited compared to Option 4 which limits impact on access and therefore the usage of the amenity beach area. Option 7 would have the amenity beach largely remain the same as is. All of these options could have the potential to impact on the recreational use of the beach.

Options 4 & 6 have some disadvantages over other options for recreational use. For Option 4, placement of rock revetments along the southern extent of CCA5 would restrict the use of the existing beach area. For Option 6, while impact on the beach area is limited initially, it would eventually be lost as a result of reflection against the proposed structure.

Option 1 has significant disadvantages over other options for recreational use. Under this option, no works would be proposed which could result in continued coastal erosion and potential impacts to the rail line, access to the beach area and potential loss of the Bray to Greystones Coastal Cliff Walk.

5.3.1.4 Integration

5.3.1.4.1 Compatibility with Development Plans

Option 5 has significant advantages over other options. It aligns with high level coastal protection and coastal area management objectives within the development plans. This option requires less material and less surface area when compared with Option 4. Less infrastructure should potentially reduce impacts upon both the amenity value of the beach as well as biodiversity and protected areas.

Options 4, 6, 8 and 9 have some advantages over other options. Option 4 aligns with coastal protection, coastal area management objectives and protection of the rail line objectives within the development plans. However, the depth of hard engineering works into the beach is more significant than Option 5 (greater potential amenity and biodiversity impacts) and therefore does not score as high. This option has greater integration potential than other options. Option 6 advantages include its alignment with high level coastal protection and coastal area management objectives within the development plan. This option has a smaller footprint than other options which should potentially reduce biodiversity impacts. Option 8 advantages includes the enhancement of the area with beach amenity, coastal recreation amenity and elements of green infrastructure. This option has less concrete and hard infrastructure area, than other options. Option 9 advantages includes the enhancement of the area with beach amenity, coastal recreation amenity and elements of green infrastructure. This option requires much less concrete and hard infrastructure area, than other options

Options 2, 7 and 10 have some disadvantages over other options. Option 2 has some disadvantages as coastal zone management and coastal area protection are identified as important within the relevant development plans. The disadvantage relating to this option is that the minimum works rely on repairs it would not fully achieve the objectives of the plans. Option 7 has some disadvantages it would impact on Marine Policy / Map Based objectives. Given the offshore elements (breakwaters) there is increased potential for impact on Marine Sites and in particular; Fisheries Policy 1 and Protected Marine Sites Policy 2. This option has potential for greater impacts upon the amenity area of the beach as well as water sports and access over time could be impacted. Option 10 has some disadvantages as the use of groynes could split the beach and impact upon its amenity value. Option 10 requires more material compared to Option 9 and includes breakwaters that have greater potential to reduce integration.

Option 1 has significant disadvantages over the other options. The policy within the relevant development plan identifies coastal zone management and protection of the coast as important. This option does not provide any coastal protection or protection for the railway line and therefore is not in line with the aims and objectives of the relevant development plan. Option 1 does not address the issue of climate change which is an overarching concern across high level planning policy.

5.3.1.4.2 Compatibility with Climate Adaptation Plans

Options 5 and 6 have significant advantages over other options as they align with the Transport Climate Change Sectoral Plan (TCCASP) in terms of protecting the coastline and transport assets.

Options 4,7, 8, 9 and 10 have some advantages over other options. They generally align with TCCASP in terms of protecting the coastline and transport assets. However, they potentially have negative marine based impacts and requires significant volumes of material.

Option 2 has some disadvantages over other options. Do minimum would provide some disadvantages over other options as coastal zone management and coastal area protection are identified as important within the relevant development plans. The disadvantage relating to this option is that the minimum works rely on repairs, not a full upgrade would not fully achieve the objectives of the plans which include the need for climate adaptation. The Climate Action Plan 2023 sets out under 15.3.6 (Adaptation) the challenges related to the operation and resilience of the inter alia the rail network. There is a need to go beyond 'patching up' and to prepare for current and future change.

Option 1 has significant disadvantages over the other options. Do nothing would contravene climate objectives such as *Eastern and Midlands Region RSES "RPO 7.3 EMRA will support the use of Integrated Coastal Zone Management (ICZM) to enable collaborative and stakeholder engagement approaches to the management and protection of coastal resources against coastal erosion, flooding and other threats."*

5.3.1.4.3 Compatibility with Transport Plans

Options 4,5,6,7,8,9 and 10 have significant advantages over other options as they will improve the protection of the rail line against climate change impacts, in line with the Transport Strategy's aim to "provide a sustainable, accessible and effective transport system for the Greater Dublin Area which meets the region's climate change requirements, serves the needs of urban and rural communities, and supports economic growth".

The Greater Dublin Area Cycle Network Plan proposes a National Cycle Route, the East Coast Trail, with an indicative route along part of the coastline south of Bray Head (CCA5-B). Providing the intervention works can accommodate the East Coast Trail, this option will support the Transport Strategy.

Option 2 has some disadvantages over other options. Some Disadvantages over Other Options it is expected to involve disruptions to public transport in the short to medium term to conduct repairs as the need arises. The ad hoc repairs will address damage that may occur, but won't build longer-term resilience against potential impacts of flooding or erosion. As per Do Nothing, this is likely to put increasing pressure on the public transport system and challenge its reliability, going against the Transport Strategy's focus on facilitating increased use of sustainable modes.

Option 1 has significant disadvantages over the other options. The NTA's Greater Dublin Area Transport Strategy 2022-2042 outlines the need to ensure resiliency of the public transport network to climate change effects, and specifically mentions potential flooding along the Dublin and Wicklow coastline. Do Nothing will mean no interventions being made to prevent flooding and coastal erosion, which may become increasingly frequent events in the future. While there may be little short-term impact, in the longer term this will put increasing pressure on the public transport to accommodate passengers displaced from rail services. Disruptions to the rail service may result in an unreliable public transport system, causing a mode shift to car travel rather than public transport. This goes against the Transport Strategy's focus on facilitating increased use of sustainable modes.

5.3.1.5 Environmental

5.3.1.5.1 Biodiversity

All options for CCA5-A have similar impacts as other options.

Option 1 would provide an advantage as there would be no construction work and therefore no impact on biodiversity/ protected areas from habitat loss/degradation and disturbance (noise/pollution). There are no Ramsar sites, one SAC (Bray Head SAC), no SPA within CCA5 and one SPA to the south (The Murrough SPA being the closest), no NHA one pHNA (Bray Head) that could be affected in a beneficial way. The natural process of habitat expansion of vegetated sea cliffs and European dry heaths (Qualifying Interest (QI) of Bray Head SAC) and creation of fissures providing supporting habitat for the important sea bird colony at Bray Head and SPA bird species of the nearby Murrough SPA (whose QI bird species utilise this area). No impacts to any QI, from construction and operation as natural processes overall would progress unconstrained.

Option 2 would provide a slight disadvantage in comparison to Option 1 as there would be limited, reactive construction work and therefore minimal impact on biodiversity/ protected areas. There is one SAC (Bray Head SAC) within CCA5 and one pHNA (Bray Head) that could be affected in a minor negative way. Repair works could cause damage and/or loss to QI habitats of the Bray Head SAC and loss of nesting habitat from gully works. Disturbance could be caused to the important sea bird colony and the SPA bird species of the nearby Murrough SPA (whose QI bird species utilise this area) and to a lesser extent marine mammals (seals in particular) that are known to haul out in this area (these QI are designated features of Lambay Island SAC (designated for marine habitats (not impacted) and grey & harbour seals). Natural processes overall would progress relatively unconstrained.

Option 5 at CCA5-A would be similar to Option 2 in that there would be localised and targeted construction work only and therefore minimal impact on biodiversity/ protected areas similar to Option 2 & 4. Option 5 at CCA5-B proposes discrete rock revetment headlands extending into the marine environment. The construction of the headlands would cause disturbance to birds and QI species of nearby SPA/SAC but less so than with Option 4 as only at two locations. Rock works would be undertaken using land-based plant but rock would be delivered using marine plant over high tides. All rock delivery may want to use two high tides, so night working may be requested. Operation may cause habitat loss to birds at those headland locations only.

The proposals for Options 4, 6, 7, 8, 9 & 10 options for CCA5-B all have the potential to cause disturbance during the construction phase, potential loss/change of European and Nationally designated habitats through hydrology changes. Options 7, 8 and 10 have the potential to change tidal movements due to the proposal of breakwaters in these options which may alter feeding opportunities for QI species. Options that propose nourishment may cause disturbance with future maintenance.

5.3.1.5.2 Landscape

Option 4 & 6 have significant advantages over other options. Option 4 proposes natural material for the continual rock revetment. For Option 6, while the concrete seawall contrasts with the natural features of the cliffs, this can be mitigated through the design process. The rock toe protection would help with integrating the concrete wall with the rocky cliffs that are present.

Options 5 & 9 have some advantages over other options. Option 5 is similar to the proposals of Option 4 however the disadvantage of this proposal is intermittent use of rock revetments would generate inconsistency along the coastline which may impact the character of the area. Option 9 would also create inconsistency by having groynes protruding into the coastal waters. As Option 5 would mitigate the loss of sections of beach this is an advantage as it preserves the local character. A similar advantage for Option 9 is that beach nourishment has the potential to enhance the character and recreational amenity of the area.

Options 2 and 10 have some disadvantages over other options. Option 2 includes for reactive interventions. This would compromise the character and quality of the area. Option 10 proposes a single breakwater in the coastal waters. Compared to Option 7 & 8 which also propose breakwaters, the impact is less as the footprint is significantly smaller.

Options 1, 7 & 8 have significant disadvantages over other options. Options 7 & 8 propose large breakwaters in the coastal area generates significant impacts on landscape. Option 1 would generate significant impacts as the continual degradation and erosion as a result of no works.

5.3.1.5.3 Archaeology

Options 4 – 10 are comparable to each other as they all have the potential to impact an SMR site and SMR Zone of Notification. They also have the potential for direct impacts on previously unrecorded archaeological heritage.

Option 2 has some disadvantages over other options as it would result in continued degradation and reactive interventions, would generate a coastline that is in a constant state of repair and disruption, with constant adverse Archaeology, Architectural and Cultural Heritage effects.

Option 1 has a significant disadvantage as it would result in the loss of archaeological features as a result of no works.

5.3.1.5.4 Marine Archaeology

Options 1-2 and 4-6 have significant advantages over other options as no works are proposed within the intertidal or marine elements.

Options 8-10 have some disadvantage over other options as there are potential for significant direct impacts to occur on previously unrecorded wrecks, paleoenvironmental landscapes and material culture both within the sub-tidal areas within the footprint of the breakwaters and the groynes.

Option 7 has significant disadvantages over other options as it has a larger marine footprint.

5.3.1.5.5 Noise & Vibration

Options 4-5 and 7-10 are comparable to each other. All options area of works are set back from Population NSL's and are likely to require night-time works. Options proposing marine elements may have short-term disturbance underwater during construction.

Options 1, 2 & 6 have some disadvantages over other options. While Option 1 would provide some advantages as there would be no construction or maintenance works and therefore no construction related noise or vibration impacts, the long term operational scenario would have some disadvantages compared to other options if rail services are suspended and road traffic on surrounding road network increases. Option 2 would provide similar advantages to Option 1. However, the existing maintenance works will continue as necessary which will be of neutral impact, albeit these will likely intensify in frequency. The long term operational scenario is neutral compared to other options, although the rail service will likely be less reliable and has potential for increased traffic on surrounding road network. Due to the longer term duration of potential impacts, is less advantageous over other options. Option 6 has some disadvantages as while it is similar to other options for impacts on Population NSL's, the nature and duration of the works provide a disadvantage.

5.3.1.5.6 Air Quality

Options 5 & 7 have a significant advantage over other options. Potential for construction phase impacts associated but lower potentially dusty activities compared to other options and some construction vehicle emissions. Construction phase impacts would be likely considered short term and dust mitigation can be put in place. Some advantage due to distance to sensitive receptors.

Option 4 has some advantages over other options as the potential for construction phase impacts associated are lower. Construction phase impacts would be likely considered short term and dust mitigation can be put in place.

Options 6, 8, 9 & 10 have some disadvantages over other options. These options would have the potential for construction phase impacts associated with potentially dusty activities such as beach nourishment, breakwater and groyne construction activities having a higher potential for dust. Option 6 would have a potential dust impact on sensitive ecological receptors in proximity to the seawall installation. Options 8, 9 & 10 assume that structures would be precast to reduce air quality impacts. Ongoing beach nourishment maintenance for Options 8, 9 & 10 would have air quality impacts. Construction phase impacts for Options 6, 8, 9, & 10 would be likely considered short term and dust mitigation can be put in place.

All options apart from Option 1 & 2 have limited operational phase impacts. Implementing these options could facilitate operational phase reliance on public transport and reduce reliance on private vehicles for the long term. Option 7-10 have future beach renourishment requirements.

Options 1 & 2 have significant disadvantages over other options. Option 1 would result in long term operational phase impacts should the rail line be suspended. Option 2 would result in low/not significant construction phase impacts for reactive works. Long-term operation phase impacts may occur as a result of rail line suspensions. Both potential operational impacts would result in increase in local traffic numbers.

5.3.1.5.7 Carbon Management

Options 4-10 facilitate operational phase reliance on public transport and reduce reliance on private vehicles for the long term.

Options 4 & 5 have significant advantages over other options as they had the lowest Whole Life Carbon (tonnes CO_2e) of all options.

Options 7 & 8 have some advantages over other options as they have preferable levels of Whole Life Carbon (tonnes CO_2e) compared to other options.

Options 6, 9 & 10 have some disadvantages over other options as they have unfavourable levels of Whole Life Carbon (tonnes CO_2e) compared to other options.

Options 1 & 2 have significant disadvantages over other options. Both options have low GHG emissions from embodied carbon due to no/minimal construction repair works. However, long-term operation phase impacts may occur as a result of rail line suspensions. Both potential operational impacts would result in increase in local traffic numbers.

5.3.1.5.8 Water Resources

Options 1 & 2 have a significant advantage over other options as Option 1 would require no construction work and therefore no impact on ground water. Option 2 would have minimal construction work with negligible impacts on groundwater.

Options 4, 7, 8, 9 & 10 have some advantages as they will have minimal impacts on groundwater elements due as they don't propose below-ground construction requirements.

Option 6 has some disadvantages over other options as below ground structures may have impacts on groundwater.

5.3.1.5.9 Geology & Soils

Option 4 has significant advantages over other options as there will be minimal disturbance to geological resources within CCA5-A as only upgrades to existing coastal structures are planned. Minimal/moderate disturbance to geological resources is expected within CCA5-B as result of continuous coastal defences.

Options 2, 9 & 10 have some advantages over other options. Option 2 has some advantages in the short term as a result of the minimal disturbance during reactive repair works. However, the mitigation installed may not be sufficient to address erosion of geological resources caused by climate change and may lead to long term impacts. For Options 9 & 10, minimal disturbance of geological resources within CCA5-A which is similar to other options. The combination of beach nourishment, breakwaters and groynes is expected to result in moderate disturbance to geological resources in CCA5-B during the construction phase works for both options.

Options 1, 5, 7 & 8 have some disadvantages over other options. Option 1 has some advantages as no construction work is proposed. However, long term degradation could result in the erosion of local geology. Option 5 may result in minimal/moderate disturbance due to erosion between the discontinuous rock revetments. Options 7 & 8 will have impacts during construction due to breakwater construction and beach nourishment respectively.

Option 6 has significant disadvantages over other options as very high disturbance of geological resources is expected in CCA5-B as a result of the concrete seawalls with rock toe protection. Furthermore, the intrusive nature of the works may release contaminated materials into the wider environment.

5.3.1.5.10 Materials & Circular Economy

Options 1, 2, & 5 have significant advantages over other options as they all have the lowest materials consumption score compared to other options.

Options 4 & 6 have some advantages over other options as they have a comparatively lower materials consumption score compared to other options.

Options 9 & 10 have some disadvantages as they scored a comparatively high materials consumption score compared to other options. However, they did not score as highly as options 7 & 8.

Options 7 & 8 both have significant disadvantages over other options as they scored a comparatively high materials consumption score compared to other options.

5.3.1.5.11 Waste

There should be minimal waste for all options at CCA5 as there are no existing structures and all options involve works in front of the existing cliffs.

Options 1 & 2 have significant advantages over other options as no waste would be generated due to no/minimal works proposals.

Options 4, 5, 8 & 8 have some advantages over other options as wastage from damaged materials have been estimated based on the application of material-specific wastage rates to the quantities of concrete materials that are likely to be used in constructing the option.

Options 6, 9 & 10 have some disadvantages over other options as they have comparatively high wastage potentials.

5.3.1.5.12 Traffic & Transport

Options 4-10 are comparative as minimal operational impact expected to traffic & transport; the intervention works will be localised to the coast and are not anticipated to affect transport systems or travel demand.

Option 2 has some disadvantages as disruptions to transport may be likely due to the requirement for ad-hoc repairs. This may lead to impacts on local roads with increased private car use and over-crowding on bus services.

Option 1 has significant disadvantages over other options as there is potential for significant impacts on rail services. This may lead to impacts on local roads with increased private car use and over-crowding on bus services.

5.3.1.6 Engineering

5.3.1.6.1 Constructability

Options 1 & 5 have a significant advantage over other options. Option 1 does not propose any construction works. Option 5 requires significantly less rock than Option 4 but construction for both options is relatively simple. Following the delivery of rock by marine plant, the revetments can be constructed using land based plant.

Option 4, 9 & 10 has some advantages over other options. Options 9 & 10 require tidal works however are still relatively easy to construct. Beach nourishment is a relatively easy process and quick to complete. Option 4 is similar to Option 5, however the disadvantage being the construction work would be slower.

Options 2, 7 & 8 have some disadvantages over other options. Constructability wise they are similar however for Options 7 & 8 require significantly more materials and require difficult marine work to construct the breakwaters. Option 2 has some disadvantages as it proposes emergency works only.

Option 6 has a significant disadvantage due to the difficulty of constructing a sea wall. Works of this nature may need a cofferdam to create a dry environment to work in. This would be costly, risky and time consuming. Furthermore, the temporary works requirements would be complex.

5.3.1.6.2 Rail Service Impact

Option 1 has a significant advantage as no works are proposed.

Options 4-10 are comparable to each other as the operation of railway line will be minimally impacted as the works are adding to existing infrastructure so no excavation is needed. Irish Rail will require to be notified of works as adjacent to the railway line but this is expected to be low risk.

Option 2 has some disadvantages over other options as ad-hoc emergency works may impact the railway line.

5.3.1.6.3 Reliance On Maintenance

Option 4 has significant advantages over other options as it requires minimal maintenance during the design life.

Options 5, to 7 have some advantages over other options. Option 5 requires regular and post-storm monitoring with additional monitoring of areas between rock headlands to measure the rate of erosion. Option 6 may require more regular repairs compared to the other options due to concrete being the main material proposed in the seawall. Option 7 should require similar frequency of maintenance to Option 4 but the maintenance would be more complex due to the structures being detached and therefore marine based plant being required.

Options 8, 9 & 10 have some disadvantages as they propose beach nourishment which requires regular monitoring and post-storm inspections to inform future beach renourishment needs.

Option 1 has some disadvantages over other options as while there is no requirement for maintenance, significant monitoring would be required to keep the public safe.

Option 2 has significant disadvantages over other options as it relies heavily on monitoring and reactionary maintenance and repairs.

5.3.1.6.4 Adaptation

Option 8, 9 & 10 have significant advantages over other options as there is scope for adaptation through changes in beach nourishment and potential for additional beach structures.

Option 5 has some advantages over other options as additional rock can be added to the bays to account for additional climate change impacts. Option 6 has some advantages as seawall height could be undertaken if required.

Option 2 and Option 4 have some disadvantages over other options. Option 2 has some opportunities for adaptation such as placement of rock armour to reduce erosion. However, as Option 2 proposes ad-hoc reactionary repairs, it would not be possible to properly plan works to create a progressive adaptation approach. Option 4 proposes rock revetments which would be possible to re-build to adapt, but simple bolt on adaptations are not possible.

Option 7 would have some disadvantages as adapting the breakwaters wouldn't be practical. Some beach nourishment could be implemented if required.

Option 1 has a significant disadvantage over other options as there is no works proposed and therefore no opportunity for adaptation.

5.3.1.6.5 Residual Risk

Option 7 has significant advantages over other options as the breakwaters will reduce wave energy to reduce erosion of the cliffs. Failure of breakwaters is typically slow and progressive so sudden failure would not be expected.

Option 4 has some advantages over other options. As a hard engineering option, risk is reduced compared to solutions such as beach nourishment as a significant event is more likely to be stripped out quickly.

Options 8 & 10 are similar as they rely on a nourished beach to provide the erosion protection to the cliffs and the breakwaters to reduce the wave energy so that the design beach is maintained and erosion of the cliffs is prevented.

Options 5, 6 and 9 have some disadvantages. Option 5 has some disadvantages as there is a slightly higher residual risk between rock headlands where erosion rates can vary. Option 6 has some disadvantages as failure of the seawall could be sudden if the beach is lost and the seawall is undermined. Option 9 has some disadvantages as it relies on the beach to provide the protection, if the beach was lost during a storm there would be no protection to erosion at the cliffs.

Option 2 has some disadvantages over other options as small scale, localised repairs can manage risk. However, this is not a long-term option.

Option 1 has a significant disadvantage over other options as no works would occur. This would lead to a degradation of existing defences potentially leading to a catastrophic event.

5.3.1.7 Planning Risk

In regard to planning risk, Options 1 and 2 have significant advantages over the other options as 'do nothing' and 'do minimum' options would require no planning consents and therefore no planning risk.

Options 4, 5, 6, 9 & 10 have some advantages over other options as the proposed upgrade to the coastal defences align with planning policy for long term protection against the backdrop of climate change. The works are likely to be carried out within a Natura 2000 site with the potential for temporary and permanent impacts on the qualifying interests which could increase the potential for the options to undertake the IROPI process. The potential for IROPI increases the planning risk as it will increase the chances that the options will either be refused permission or significantly delayed in their determination. Furthermore, the proposed options have offshore elements that are likely to require a Marine Area Consent (MAC) before any planning application for development permission which further increases the risk and delay associated with consenting the options.

Options 7& 8 have significant disadvantages over other options. Option 7 includes breakwaters which have greater potential to impact upon marine policy and map-based objectives, for example Fisheries Policy 1 and Protected Marine Sites Policy 2. The proposed breakwaters mean that Option 7 has less potential to integrate into the character of the area. Option 8 is a 'soft engineering' option and also includes breakwaters that are also likely to meet with objection given adverse landscape visual impacts.

5.3.2 Summary

A summary of the MCA outcomes are shown in Table 5-9

Options 4, 5 & 9 have been identified as the top-ranking short-list options to be taken forward. The basis for each of these are as follows:

- Option 4 had significant advantages over other options in relation to Environment and Engineering. It has comparative advantages over other options in relation to Economy, Safety, and Planning Risk.
- Option 5 had significant advantages over other options in Economy, Safety, Integration & Planning. It had some advantages over other options in the remaining criteria.
- Option 9 had significant advantages over other options in relation to Safety and some advantages over other options in relation to Accessibility & Social Inclusion, Integration, Engineering and Planning Risk.

These three options will be discussed further in Section 5.4 to identify the Emerging Preferred Option for this CCA.

Table 5-9 Short list MCA outcomes summary

	Option 1	Option 2	Option 4	Option 5	Option 6	Option 7	Option 8	Option 9	Option 10
Economy									
Safety									
Accessibility & Social Inclusion									
Integration									
Environmental									
Engineering									
Planning									

5.4 Top-Ranking Short List Options

The initial optioneering stage (Sections 5.1 & 5.2) identified the Short List of Options from the Long List of Options. The MCA stage (Section 5.3) then identified the three clear top-ranking options from the Short List of Options. For clarity, these Top-Ranking Short List of Options have been re-named as Options A, B and C and are summarised as follows:

- Option A: Rock revetments seaward of existing structures (CCA5-A), Rock Headlands with managed cliff recession (CCA5-B) (Short List Option 5)

- Option B: Rock revetments seaward of existing structures (CCA5-A), Groynes with nourishment (CCA5-B) (Short List Option 9)
- Option C: Rock revetments seaward of existing structures (CCA5-A), Rock revetment (CCA5-B) (Short List Option 4)

These options all meet the scheme objectives, the requirements for design life and provide the required Standard of Protection. The three Top-Ranking Short List Options (Options A, B & C) are described in outline within this section and Appendix E provides concept design drawings of each option. These options were progressed to Concept Design level and have been analysed and costed. This section presents the engineered solutions, summarises the analysis and identifies the Emerging Preferred Option (EPO).

5.4.1 Concept Designs

The concept designs for each of the Top-Ranking Short List Options consider the following:

- Wave climate and extreme water level data for initial analysis has been extracted from detailed hydrodynamic modelling outputs undertaken during Phase 2 of the Project;
- Initial analysis of wave overtopping rates during storm events has been undertaken using EurOtop formulae. This analysis includes an allowance for sea level rise. This analysis informs the required geometry of the improved defences to provide the required Standard of Protection (0.5% Annual Exceedance Probability, also known as a 1 in 200 year storm protection level);
- Initial rock stability calculations have been undertaken using the Van Der Meer methods. This informs the required rock grading to ensure stability of the rock armour to provide the required Standard of Protection;
- The condition of the existing coastal defences has been informed by the visual dilapidation survey undertaken during Phase 2 of the Project;
- Defence type and material selection have been selected to meet the design life and to minimise future maintenance requirements;
- Constructability and technical viability have been considered in the design to ensure the options are feasible;
- Within the bounds of each option form, the impact on the environment and community have been minimised where possible; and
- Health and safety risks during construction and to the public following construction have been considered.

The design work undertaken for the concept design is sufficient to confirm that the options will work from a technical perspective and provide the required SoP for the design horizon and allow comparison between the options. However, the following should be noted:

- All levels and dimensions are preliminary and based on initial concept level analysis. Designs are expected to change through design development (e.g., the size of the rock armour or the geometry of the revetment);
- Typically, only one cross section through each sub-cell has been prepared; as the design is developed there will be multiple cross sections to reflect the changes in the existing ground levels, existing structures and location of the railway line; and
- Details around access points and structures such as outfall and culverts have not been developed at this stage.

The following sections describe the concept designs for Option A, B & C and provides a commentary on the relative advantages and disadvantages for each option.

5.4.1.1 Option A

Option A comprises rock revetments in CCA5-A seaward of the existing structures.

Throughout CCA5-A the railway runs along the cliff passing through a number of gullies and bays where the railway line is supported from below and protected by various masonry and rock structures. The proposed solution here is to place rock armour in front of the existing coastal structures. The rock revetments will resist the loss of the foreshore in front of the masonry structures which leads to undermining, whilst also dissipating wave energy and therefore significantly reducing the wave energy impacting the structures.

Given the precarious position of the railway on the cliffs, access in this area is extremely challenging and the construction of new, replacement structures is not feasible, nor necessary. In 2002 and 2003 rock revetments were successfully constructed in front of a number of the structures around Bray Head and therefore a similar approach is proposed to be extended to the remaining exposed structures.

The rock revetments will comprise a minimum of two layers of graded armour rock. The rock grading has been selected to provide stability over the scheme life using modelled wave conditions that allow for sea level rise. Rock grading size will be confirmed during preliminary design but is expected to be in the range of 6-10 tonnes. This is a large rock grading and is representative of these locations being exposed to large wave conditions. This rock will be of high quality to ensure that it meets and exceeds the design life.

In CCA5-B, Option A comprises three lengths of rock revetments (rock headlands) in front of the most vulnerable sections of the cliffs and railway line. These rock revetments will limit erosion of the cliffs in these locations. In between the rock headlands the cliffs will recede until an equilibrium is reached. This will result in stable bays forming between the headlands.

This option provides a balance between working with nature to allow natural processes to continue whilst also providing protection to the railway line. This is possible in this location as there is a large buffer of between 80m and 150m between the railway line and the edge of the cliffs in CCA5-B. Hence, further retreat of the cliffs can occur without putting the railway line at risk.

The beach in this area is historically very volatile and the beach levels can vary significantly, with significant loss of the beach occurring in storm events. The beach acts as a natural defence to the cliffs as the beach limits the wave energy impacting the cliff toe. The bays between the proposed headlands are approximately 250m long and within these bays, stable beaches will be created as the headlands to the north and south act to retain the beach material. Therefore, the cliff erosion in these bays will be reduced. However, predicting the rate of erosion of the cliffs is complex and therefore the reshaped bays shown in the concept design drawings are indicative only and further analysis will be undertaken during design development.

During design development, further studies will be undertaken to determine the exact location and length of the headlands. For the concept design stage, the headlands have been placed in front of the locations that are considered to be the most vulnerable:

- Headland 1 (southern headland) – This headland is approximately 300m long and although this is a location with the greatest buffer back to the railway line, the cliffs in this area are softer cliffs and therefore more vulnerable to erosion, hence a headland is located here to reduce the erosion risk.
- Headland 2 (middle headland) - Approximately 300m long and provides protection to the railway line Tunnel 4 southern portal. It is also located in front of the point where a stream cuts the cliff and therefore erosion of the cliffs is prevented here as the presence of the stream could lead to increased erosion rates once the toe of the cliff begins eroding. As the rock headlands will be permeable structures (due to the void between the rocks), drainage of the streams should not be restricted by the rock headlands but this will be further considered during design development.
- Headland 3 (northern headland) – this is a smaller headland, approximately 50m long, that will help to form the stable bay between headland 2 and limit erosion in an area where the railway line begins moving closer to the cliff edge (where the cliffs become hard rock).

One risk inherent with this option is that predicting the rate of erosion of the cliffs is complex. Even with additional studies during the design development process, it will not be possible to be 100% accurate in predicting the erosion rates as they are impacted by many factors and there is limited historical data to inform the assessments. However, further studies will provide a better understanding of how the cliffs might reshape.

This option will require periodic monitoring, particularly following storms and it is possible that in the future some additional works may be required in the form off additional rock within the bays if the cliffs are receding at a faster rate than anticipated.

The use of rock armour to manage coastal erosion is commonplace. As the rock headlands are permeable structures, some wave energy will still pass through the headlands to the toe of the cliffs but the energy within the waves reaching the cliffs will be significantly reduced, thereby reducing the cliff erosion potential. The outline geometry of the headlands has been determined through overtopping and wave transmission calculations to limit the impact of waves running up the headlands and impacting the toe of the cliffs. An underlayer and geotextile is placed under the larger rock armour to prevent the washout of beach material through the voids in the rock armour, which could lead to settlement and ultimately failure of the rock structures.

The foreshore (beach) levels in front of and in between the rock headlands will continue to fluctuate with lowering of the beach expected in front of the headlands. The toe of the rock headlands has therefore been designed to account for future lowering of the foreshore to prevent undermining of the headlands.

The Option A concept design proposed for CCA5-B is summarised by Figure 5-1. This is further detailed by the concept design engineering drawings in Appendix E.

The proposals use the following material types: quarried rock (delivered by sea) and geotextile.

The MCA tables in Appendix D provide a detailed commentary on the relative advantages and disadvantages of each of the options against the various core criteria and objectives.

This option's top **advantages** (in comparison to Option B & C) are as follows:

- Low cost and maintenance burden;
- Smaller footprint;
- Maintains access for amenity;
- Low material consumption and waste;
- Preferable option for carbon management; and
- Allows natural processes to continue between the headlands.

This option's top **disadvantages** (in comparison to Option B & C) are as follows:

- Impact on character of visual qualities of the coastline;
- Some uncertainty over how the coastline will reshape;
- Will require monitoring and potential future works to manage erosion risk in the bays; and
- May require relocation of the Bray-Greystones Cliff Walk path in some locations.

Figure 5-1 CCA5-B Option A, B and C Concept Design Plans

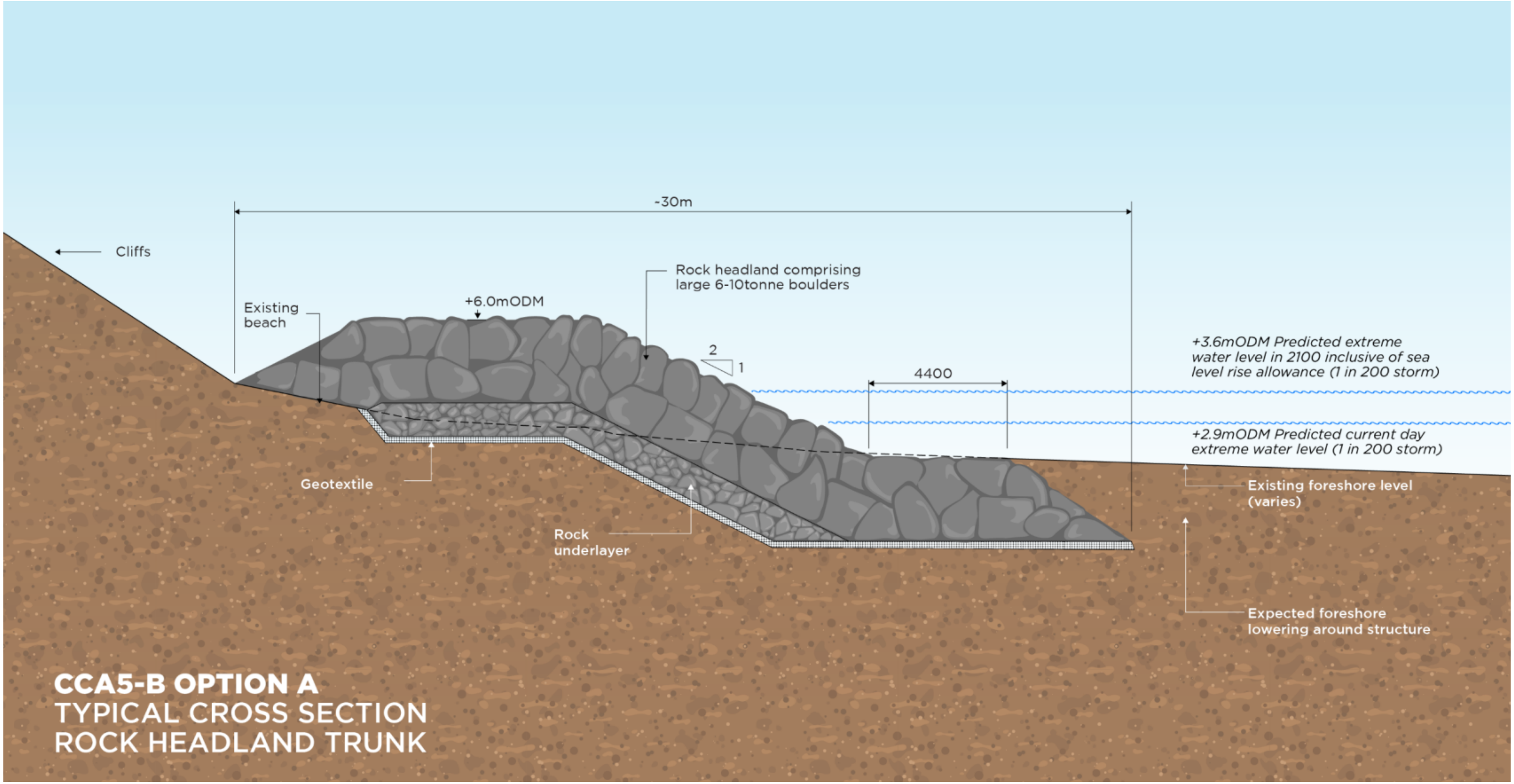

Figure 5-2 CCA5-B Option A typical cross section

5.4.1.2 Option B

The Concept Design for sub-cell CCA5-A is the same as presented for Option A in Section 5.4.1.1.

In CCA5-B, Option B comprises a series of rock groynes and accompanying beach nourishment. The beach nourishment is provided to increase the size of the beach in front of the cliffs, which will reduce the wave action impacting the toe of the cliffs and reduce the rate of erosion of the cliffs. The rock groynes will help to retain the placed beach material.

Beach nourishment involves adding additional beach material (closely matching the existing material) onto the beach to create a larger beach (higher and wider). This acts to reduce the wave energy by reducing the depth leading to breaking the waves on the beach, reducing the wave heights reaching the cliffs and thereby reducing the erosion of the cliffs.

Since beaches are natural systems that respond dynamically to the action of the sea, their form will change over time; the beach may steepen, the crest width of the beach could cut back, and material can be lost either alongshore or cross-shore out to sea. These changes may be cyclical, due to long-term trends, in response to environmental forcing factors, such as declining sediment supply or sea-level rise, or as a result of storm action. As the nature and frequency of storm events cannot be accurately predicted, precise losses and response of the beach cannot be guaranteed and therefore ongoing monitoring is required to ensure that the beach continues to meet the required SoP. Beach monitoring typically involves field surveys of the beach geometry, which can be physical surveys or visual surveys depending on the sensitivity of the beach design and the vulnerability of receptors to damage. It is expected that this beach monitoring can be incorporated into IE's current inspection and data collection programmes. However, a beach management plan is recommended to define responsibilities, frequency of inspections and trigger levels for interventions, such as increased monitoring and/or renourishment.

As a beach is a natural system that responds dynamically to the action of the sea, beach control structures (e.g. groynes) are required to reduce the amount of beach material lost either alongshore or cross-shore.

The orientation of the groynes for concept design has been determined through beach equilibrium bay shape modelling. This involves using the dominant wave direction (derived from the numerical modelling) to estimate the alignment that the beach would naturally orientate to. The beach control structures, in this case the rock groynes, were then orientated to extend out to hold the toe of the beach in the equilibrium position. The anticipated beach maintenance activity will be to bring in additional material to 'top up' the beach (beach re-nourishment) and this will be required at intervals of at least 10 years.

This option will improve the size of the beach and stabilise the beach along the frontage, however access between the bays will be restricted due to the presence of the groynes. Access between the groynes will be provided at the crest of the beach, either by incorporating ramps over the groynes or reducing the height of the groynes at the crest of the beach so that they are buried and access along the beach is maintained.

The Option B concept design proposed is summarised by Figure 5-1. This is further detailed by the concept design engineering drawings in Appendix E.

The proposals use the following material types: quarried rock (delivered by sea), geotextile and beach material (delivered by sea)

The MCA tables in Appendix D provide a detailed commentary on the relative advantages and disadvantages of each of the options against the various core criteria and objectives.

This option's top **advantages** (in comparison to Option A & C) are as follows:

- Enhanced beach amenity; and
- Low waste generation.

This option's top **disadvantages** (in comparison to Option A & C) are as follows:

- High material consumption; and
- Will require ongoing monitoring and maintenance.

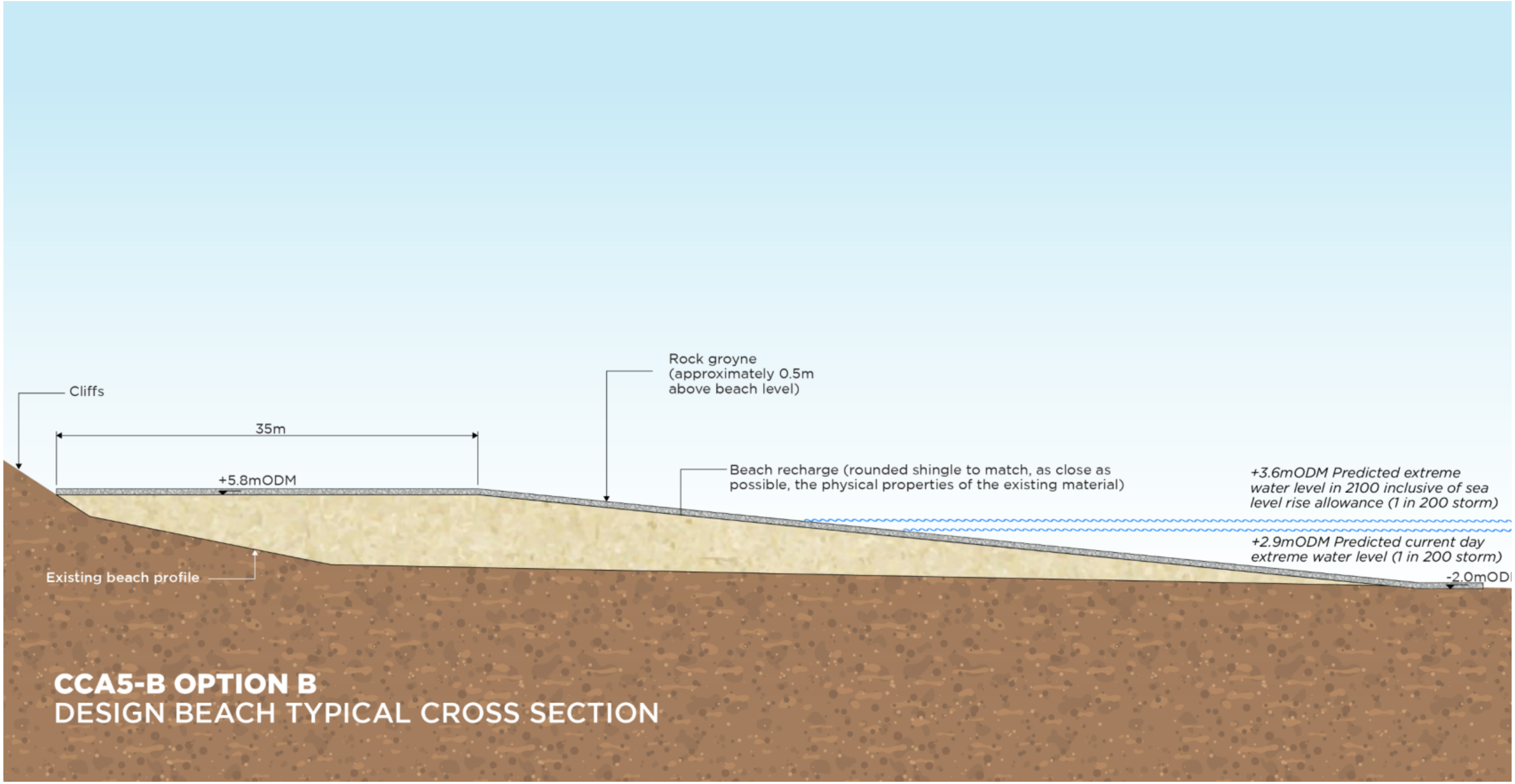

Figure 5-3 CCA5-B Option B typical cross section

5.4.1.3 Option C

The Concept Design for sub-cell CCA5-A is the same as presented for Option A in Section 5.4.1.1.

In CCA5-B, Option C comprises a rock revetment along the full length of CCA5-B.

The rock revetment would be placed at the toe of cliffs and would reduce the erosion of the cliff by limiting the wave energy impacting the toe of the cliffs. This option is similar to Option A but involves defending the whole of the cliff rather than allowing recession of the cliffs in places and the formation of bays.

The geometry of the rock revetment is determined through wave overtopping calculations to determine the height of revetment required to limit the overtopping to such levels that would not erode the cliffs. Rock stability calculations are undertaken to determine the size of rock required for stability under the design event for the duration of the 100 year design life.

Currently the only access to Greystones beach is from the south and it is understood that this beach is primarily used by walkers. The presence of the rock revetment will reduce the useable area of the beach. In addition, this option is likely to lead to lowering of the beach levels in front of the revetment, further reducing the useable beach area at varying states of the tides. This could lead to an increased risk of people becoming trapped and cut-off by the incoming tide. It may therefore be necessary to incorporate additional access points and potentially a walkway along the crest of the revetment.

The proposals use the following material types: quarried rock (delivered by sea) and geotextile.

The MCA tables in Appendix D provide a detailed commentary on the relative advantages and disadvantages of each of the options against the various core criteria and objectives.

This option’s top **advantages** (in comparison to Option A & B) are as follows:

- Low maintenance burden and expenditure; and
- Robust solution.

This option’s top **disadvantages** (in comparison to Option A & B) are as follows:

- High material consumption;
- Reduced beach amenity and access; and
- Reduced access for maintenance.

5.4.2 Cost estimates

A high level cost estimate has been prepared for each of the Top-Ranking Short List Options to enable to a comparison between the cost of the options. Option A is the lowest cost option. Option B is 120% more expensive than Option A and Option C is 45% more expensive then Option A. This is primarily due to it requiring less rock than Option C and there is no requirement for beach nourishment. Option C is the most expensive option due to the combination of rock structures and beach nourishment.

5.5 Emerging Preferred Option

Following the Concept Design, options modelling, options costing and MCA, **the Emerging Preferred Option (EPO) to be taken forward is Option A.**

Table 5-10 provides a summary of how Option A (rock revetments and rock headlands) was identified as the EPO for CCA5. The table below concentrates on the main differentiators between the options.

Table 5-10 Summary of metrics to support the identification of the EPO

Key Metrics	Summary of Outcomes
Meeting objectives	All options meet the scheme objectives outlined in Section 1.2 (for all sub-cells).
Community	Option A does not further restrict the alongshore access to Greystones North Beach for amenity purposes and it somewhat retains the natural shoreline character of the bay. Option B would provide enlarged beaches for amenity but will significantly alter the character and setting of the beach and cliffs. The solution at Option C is similar to Option A, but the extents of rock are more extensive and in the southern section this would likely further restrict the alongshore access to the northern parts of the bay.
Technical	Option A is a non-standard approach that is only viable due to the large buffer between the cliff and the railway line. There will be some technical uncertainty on the extent of cliff retreat between the headlands, but there are future adaptation options. Option B is a standard coastal engineering option, but there will be uncertainty in the future re-nourishment requirements, and this will need a monitoring programme in place to manage. Option C is the most straightforward option to design and carries least technical risk.
Constructability	Option A is relatively straightforward to construct using lower risk/cost land-based construction techniques (following delivery of rock by sea). Option B is more challenging to construct and will be slower to construct due to the need to work around the tides. Option C will be more difficult to construct than Option A in the southern section where the beach is narrow. Option C would also make future plant access to the bay for maintenance more difficult. None of the options will require APIS.
Environmental	Option A has the smallest footprint and allows limited natural cliff regression, which retains some of the geological and ecological features of this cliff. Option B would result in a significant loss of seabed and there would be longer term temporary impacts on future re-nourishment campaigns. Option C has a larger footprint than Option A and will have a larger loss of receding cliff interest.
Sustainability	Option A requires significantly less material than the other options and has the lowest carbon footprint. Option B relies on significant volumes of beach nourishment, which will need to be topped up at regular intervals in the future. Option C sits between Option A and Option B.
Consenting	Option A appears to have a potentially greater alignment with planning policy, it requires less material and surface area, it also has less potential impact upon amenity than other options. This option also scores highly for landscape and will potentially integrate more appropriately than other options. Also, in regard to biodiversity this option scores highly as it will have less potential impact

	upon protected species and sites than other options. It is a combination of the aforementioned that should reduce the risk associated with the consenting process. Options B and C require more material and surface area than Option A which generally increases the potential for impacts and therefore potential for objection. Option C scores the highest in terms of potential to integrate (landscape) but has greater potential impact upon amenity than Option B which on a public beach could give greater cause for objection. Options B and C also have potentially greater impacts upon biodiversity than Option A which increases the consenting risk associated with these options.
Cost	The capital cost for Option A is the lowest cost option. Option B is 120% more expensive than Option A and Option C is 45% more expensive then Option A. The capital cost for Option A comprises 21% facilitation and temporary works, 79% construction works and materials and is subject to 20% allowance for preliminaries, 5% allowance for overheads and profit and 64% risk allowance.

5.6 Implementation Options

This stage of the optioneering assessment identifies the capital works scheme to be delivered under the Project (to be delivered alongside required maintenance of existing structures).

The works for the Emerging Preferred Option A within each sub-cell of the CCA were prioritised based on the current vulnerability of the railway to coastal hazards (Section 5.6.1). Implementation Options were developed for the CCA, identifying options for prioritising works to align within increasing coastal hazard and risk to the railway (Section 5.6.2). These options were assessed using MCA (Sections 5.6.3 and 5.6.4) to identify the Emerging Preferred Scheme (EPS) to be delivered under the Project (Section 5.7).

5.6.1 Works prioritisation

The works within each sub-cell have been defined in

Table 5-11, with their associated priority and justification for the ranking. Refer to Appendix F Works Priorities Drawing which outlines the extent of the works within the sub-cells.

Table 5-11 Works prioritisation justification (EPO Option A)

Sub-cell (length, m)	Description of works (Priority)	Justification for prioritisation
CCA5-A (3,500m)	Rock revetment to protect toe of existing Bray Head structures (8 total) (Priority 1)	Existing masonry and rock structures are serviceable through maintenance. Manage structural risk through inspection and monitoring programme to inform upgrade and repair works as these structures degrade and climate change impacts are realised. Monitor natural cliffed sections for potential instabilities. Works are required to add resilience to some of the existing masonry structures that are directly exposed to wave impact forces to manage the current risk of undermining (from foreshore lowering), structural failures (through wave impact forces) and wave overtopping to prevent destabilisation risk to the railway corridor.
CCA5-B1 (355m)	Install rock revetment headland (priority 2)	The beach fronting the cliffs is relatively narrow and low along this frontage and is susceptible to significant cross-shore changes in profile during storm events. During the storm events the cliffs are vulnerable to erosion from wave overtopping and undermining.

Sub-cell (length, m)	Description of works (Priority)	Justification for prioritisation
		This loss of beach could lead to rapid erosion of the lower parts of the cliffs, which could destabilise upper sections of the cliffs, putting the railway corridor at risk. However, there is a reasonably large buffer between the toe of the cliffs and the railway corridor, so a beach management and response plan could enable a longer deferral of works.
CCA5-B2 (465m)	Install rock revetment headland (priority 2)	As per CCA5-B1
CCA5-B3 (740m)	Install rock revetment headland (priority 3)	As per CCA5-B1. However, the railway corridor along this section is over 100m from the toe of the cliffs and the cliffs are more vertical and erosion rates are more predictable through this subcell. In addition, the beach is maintained, which reduces the risk of erosion of the cliffs.
CCA5-B4 (305m)	No works	No works are required to protect the railway line here

The prioritisation of works for the Emerging Preferred Option A are summarised in Table 5-12.

Table 5-12 Works prioritisation for EPO Option A within CCA sub-cells

Priority	Description of works (sub-cells)	Present day understanding of when works required by
Priority 1	Rock revetments at Bray Head (A)	2030
Priority 2	Northern rock headlands at Greystones N Beach (B1, B2)	2050
Priority 3	Southern rock headland at Greystones N Beach (B3)	2050 – 2075

5.6.2 Implementation Options list

The Implementation Options developed for the CCA are provided in

Table 5-13. This includes various options for prioritising works to align with increasing coastal hazard and risk to the railway line.

Table 5-13 Implementation Options for EPO Option A

Implementation Option	Works to be delivered under Project [comparative cost of IO in comparison to IO1]	Future capital works needed by 2050	Future capital works needed between 2050 to 2075	Future capital works possibly needed beyond 2075
Implementation Option 1 (IO1)	**Priority 1 to 3**	No works needed	No works needed	No works needed

	Rock revetments at Bray Head (A) and rock headlands at Greystones N Beach (B1, B2 and B3) [100%]			
Implementation Option 2 (IO2)	**Priority 1 and 2** Rock revetments at Bray Head (A) and northern rock headlands at Greystones N Beach (B1, and B2) [81%]	No works needed	**Priority 3** Southern rock headland at Greystones N Beach (B3)	No works needed
Implementation Option 3 (IO3)	**Priority 1** Rock revetments at Bray Head (A) [33%]	**Priority 2** Northern rock headlands at Greystones N Beach (B1, B2)	**Priority 3** Southern rock headland at Greystones N Beach (B3)	No works needed
Implementation Option 4 (IO4)	Reactive Maintenance (Do Minimum) [N/A]	Reactive Maintenance	Reactive Maintenance	Reactive Maintenance

5.6.3 MCA Outcomes

A multi-criteria analysis was undertaken having regard to the TAF criteria to identify the Emerging Preferred Scheme.

This section summarises the outcome from the Implementation Option (IO) MCA analysis. The full MCA sheet can be found within Appendix G. Table 5-14 below provides an outline of the results of the analysis for all of the relevant criteria.

5.6.3.1 Economy

IO1 requires very significant capital investment due to the implementation of rock revetments at Bray Head and rock headlands at Greystones north beach. However, it scores more favourably than other IO's for maintenance expenditure as it only requires a routine and post storm monitoring plan, with minimal maintenance throughout the design life.

IO2 differs to IO1 as it does not propose rock headlands in subcell B3 at Greystones north beach. Therefore, it requires less significant capital investment compared to IO1. IO2 is similar to IO1 in terms of maintenance expenditure, however, there may be additional monitoring and maintenance requirements in the area where works are deferred.

IO3 proposes only the rock revetments in Bray Head, with no works at Greystones north beach and as such it requires less significant capital investment in the short term in comparison to the other IO's. However, further investment would be required by 2050, which would increase the overall cost of the works due to economies of scale. This option could also require additional maintenance at Greystones north beach where works have been deferred.

IO4/Do Minimum requires minimal capital investment to carry out reactive repairs and maintenance. While the short term capital investment would not be as significant as the other IO's, there is little cost certainty due to the nature of undertaking extensive and frequent reactive repairs.

5.6.3.2 Safety

IO1, IO2 and IO3 all propose significant amounts of rock revetments at Bray Head, which bring both construction and operational phase health and safety risks. Construction works will be carried out from land which carries less risks than marine works, however, transportation of materials will be handled by marine equipment. Construction of rock revetments at Bray Head will be complex due to access restrictions. During the operational phase, there is the potential that members of the public could climb on the revetments, to discourage this warning signs will be displayed. Revetments will be placed at the toe of the cliffs which will initially limit access along the beach, however, as cliff erosion continues, access along the beach will be created at the landward side of the revetments. Operational maintenance of the revetments should be minimal but cliffs either side of the revetments will be left undefended, as these cliffs continue to erode there is the potential for landslides.

IO1 requires the most significant amount of works in comparison to other IO's so construction health and safety risk is elevated. IO2 has a less significant amount of works than IO1 and so higher construction and operational health and safety scores. IO3 has a less significant amount of works than IO1 and IO2, however, there will be continued erosion and a higher potential need for local remedial works in areas where the works are deferred, increasing the construction and operational health and safety risk.

IO4/Do Minimum proposes no construction works. However, there is a requirement for localised remedial works which could be undertaken under poorer working conditions due to immediate risks to the railway line. These reactive repairs will involve placing rock armour at the toe of the cliffs to prevent further landslides. As these works are not planned they will not be implemented in a holistic manner, this could lead to limited access to certain areas of the beach and increase the potential for members of the public to become trapped or cut off by the tide.

5.6.3.3 Accessibility & Social Inclusion

IO1 proposes rock revetment at a number of locations along the coastline, this will negatively impact access to areas of the beach, reducing the beach amenity area and the public's ability to use the beach for social and recreational purposes. Access to and along the beach will be reduced in areas where rock revetment is proposed, however, the remaining beach amenity area will maintain the level of accessibility it currently possesses.

IO2 will have similar impacts to IO1 but there is a reduced amount of works proposed and therefore impacts will be to a lesser extent than IO1.

IO3 does not propose works at Greystones north beach and so there will be no impacts to accessibility and social inclusion at this location due to construction works. However, the absence of coastal protection measures will result in continued erosion of the cliffs and beach resource at Greystones north beach. Therefore, in the long-term there will be impacts to accessibility, beach amenity and social and recreational usage of the beach at this location.

IO4/Do Minimum proposes that no additional works are carried out over current maintenance programmes and so provides significantly less coastal protection than IO1-3. Occurrences of coastal erosion and/or damage or collapse of existing protection measures will continue and potentially worsen in line with climate change. This continuation of coastal erosion has the potential to negatively impact; operational train services, social and recreational facilities and current beach amenity areas including loss of the Bray to Greystones Coastal Cliff Walk.

5.6.3.4 Integration

All IO's with the exception of IO4/Do Minimum are aligned to development, climate and transport plans. IO1 has some disadvantages due to significant volumes of infrastructure on the beach area reducing the amenity area of the beach and the significant volume of materials required. IO3 and IO4/Do Minimum require less significant volumes of material but do not provide as high a level of protection as IO's 1 and 2. IO4/Do Minimum does not address long term effects associated with climate change and won't increase the rail line's resilience against flooding or erosion. IO2 has advantages over other options as it provides adequate coastal protection in line with objectives, while requiring less material consumption than IO1.

5.6.3.5 Environment

IO1 involves the most extensive protection measures and as such it has the potential for very significant environmental impacts, including noise and vibration, air quality and waste generation. The area of works within this CCA is set back from sensitive receptors which lowers the potential for significant impacts. It also requires a very significant volume of materials and therefore will result in significant carbon emissions in the short term. However, this IO will facilitate operational phase reliance on public transport so will reduce reliance on private vehicles in the long term.

Both IO3 and IO4/Do Minimum propose significantly less works than other IO's and so are less impactful on the environment during the construction phase. However, they do not provide as high a level of protection as IO1 and IO2 which could cause negative environmental impacts in the long term. IO2 avoids utilising significant volumes of materials and associated increase in carbon emissions. Moreover, IO2 offers a robust level of coastal protection and will facilitate operational phase reliance on public transport.

IO's 1, 2 and 3 all involve intermittent implementation of rock revetments at specific locations of the beach at Bray Head, which will cause inconsistency of the coastline, negatively impacting its character and visual qualities. Erosion of unprotected areas between the rock revetment sections may impact geological resources in the long term. Implementation of the northern and southern rock headlands at Greystones north beach occur over a short section of coastline. IO's 1 and 2 are similar in their impact, however, IO1 would construct both headlands together, generating a greater unity of character and lessen the impact of ongoing disruption and intervention. IO3 will have a less significant impact on landscape and visual impacts due to deferral of the rock headlands at Greystones north beach. IO4/Do Minimum will require continued reactive interventions which would compromise the character, quality and amenity of the coastline due to ongoing works.

IO's 1, 2 and 3 would all have minimal impacts on biodiversity as construction work will be targeted. However, there are European sites within and in close proximity to CCA5 that have the potential to be impacted. There are no Ramsar sites, one SAC (Bray Head SAC) within CCA5 and one outside (Lambay Island), no SPA within CCA5 and one SPA to the south (The Murrough SPA), no NHA and one pHNA (Bray Head). Damage and/or loss of QI habitats of Bray Head SAC and loss of nesting habitats could occur as a result of repair works. Disturbance could be caused to the important seabird colony and SPA bird species within Murrough SPA. This disturbance will be most significant for IO1 due to the implementation of both rock headlands at Greystones north beach. This impact is less significant for IO2 and IO3 due to deferral of works at Greystones north beach. IO4/Do Minimum would not significantly impact biodiversity due to no construction works being proposed.

Rock armour will be delivered via trans-shipment and marine delivery and so there is a low risk of impact on archaeological features in the intertidal and marine elements. This risk is most significant for IO1 due to the large volume of material required. There is also the potential for direct and indirect impacts to archaeology, architectural and cultural heritage, these potential impacts reduce as the extent of works reduces. With the exception of IO4/Do Minimum as reactive interventions and continued degradation of the coastline will lead to significant archaeology, architectural and cultural heritage impacts.

5.6.3.6 Engineering

IO1 involves large volumes of rock armour and construction will be simple yet slow due to the scale of the works. However, IO1 carries minimal maintenance burden and has little residual risk due to the hard engineering techniques employed. There will be minimal impact on operation of the rail line in the construction and operational phases. Additional monitoring will be required in the areas in between the rock headlands to monitor the rate of coastal erosion and residual risk at these locations will be elevated compared to the rest of CCA5. Future adaptation for this IO is limited because changes to the rock revetment would be challenging.

IO2 requires less rock armour than IO1 and will have greater opportunities for adaptation as the timing for the final rock headland can be adapted as required. Deferral of the final rock headland means that additional monitoring will be required in this area and residual risk is increased. This IO will have minimal impacts to operation of the rail line.

IO3 has some disadvantages to IO's 1 and 2 because it provides a lower level of coastal protection and therefore will require additional interventions by 2050, this will cause greater impacts to operation of the rail line. Coastal erosion will continue unhindered at areas where the works are deferred and so maintenance requirements are higher and residual risk is increased. Although, less construction works are required this IO does require rock revetment in the most challenging locations. Future adaptation has been accounted for in the design, however, deferring works at Greystones north beach will reduce options for future adaptability.

IO4/Do Minimum requires reactive and ad hoc emergency repairs with an increased requirement for monitoring and maintenance. These emergency repairs would be difficult to plan for and so would cause greater disruption to the rail line than the other IO's planned works. This IO has minimal opportunities for adaptation because coastal erosion will be allowed to continue unhindered and will eventually result in loss of the rail line. There is also increased residual risk associated with this option.

5.6.3.7 Planning Risk

IO's 1, 2 and 3 are in accordance with planning policy as they will enhance coastal protection within CCA5. Works are required within European Sites and so IROPI may be invoked. It is also likely that works will require maritime area consent (MAC). IO4/ Do Minimum does not propose any works and so will not require consents.

5.6.4 Summary

A summary of the MCA outcomes are shown in Table 5-14. Implementation Option 2 has been identified as the Emerging Preferred Scheme to be taken forward. The basis for this is summarised as follows:

- IO2 is the top ranked option under Economy, Safety and Engineering.
- IO2 is ranked as the joint top option for accessibility and social inclusion and second for local environment.
- IO2 is the top ranked option for Climate.

Table 5-14 Implementation Options MCA outcomes summary

	IO1	IO2	IO3	IO4/Do minimum
Economy				
Safety				
Accessibility & Social Inclusion				
Integration				
Environmental				
Engineering				
Planning				

5.7 Emerging Preferred Scheme

The MCA has identified the Emerging Preferred Scheme (EPS) as Implementation Option 2 (IO2) for EPO Option A. The EPS will deliver a minimum of 50 years (2075) protection to the railway line against coastal erosion hazards at locations where the railway line would be at risk in the next 25 years (2050) if no capital works were undertaken. The capital works delivered under this Project will form part of the longer term works likely needed to protect the railway line to 2100.

The works identified under the EPS comprise:

- Rock revetments seaward of some of the more exposed existing masonry structures at Bray Head (CCA5-A)
- Two rock headlands at Greystones North Beach with managed cliff recession at Greystones Cliffs (CCA5-B)

These works are summarised by Figure 5-4 and Figure 5-5.

Further detail regarding the components of the EPS is detailed in Section 7.

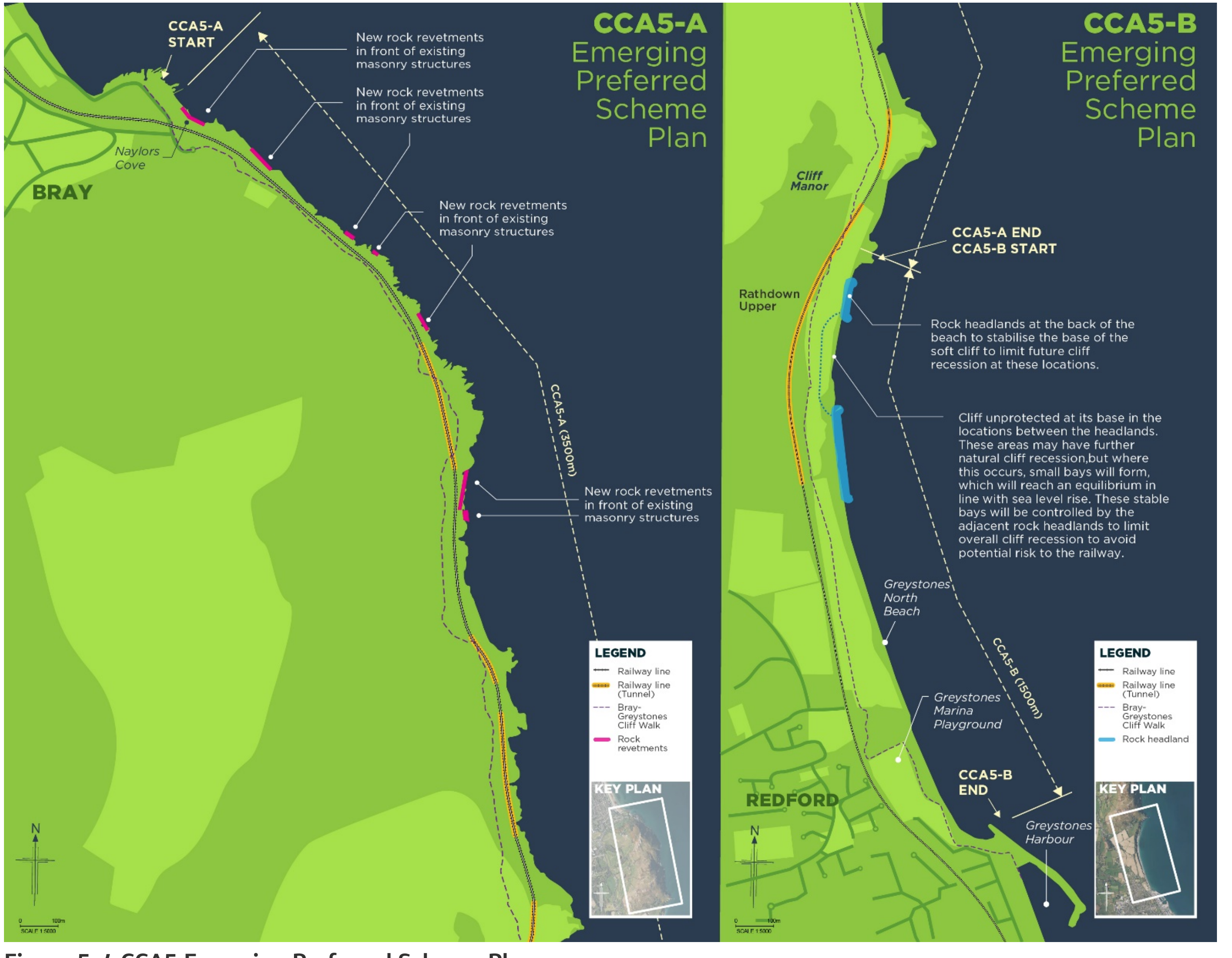

Figure 5-4 CCA5 Emerging Preferred Scheme Plan

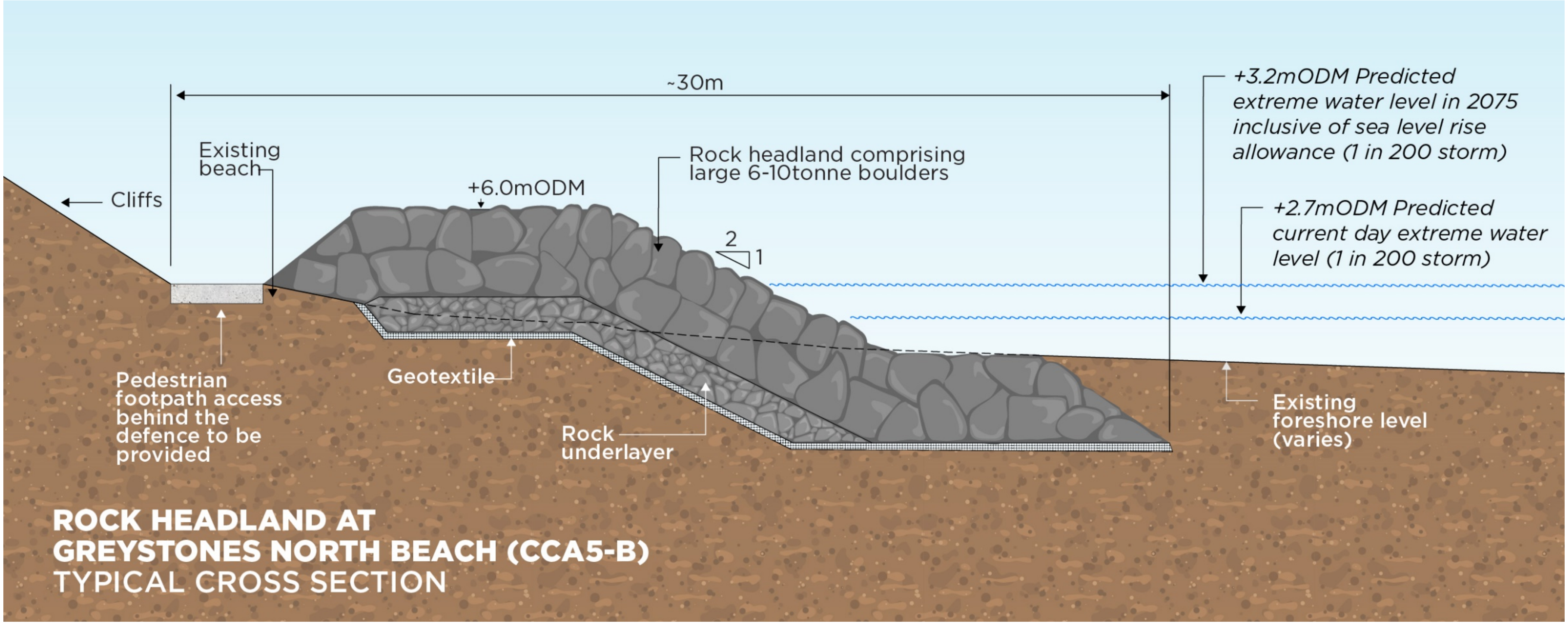

Figure 5-5 CCA5 Emerging Preferred Scheme Section at Greystones North Beach

6. Stakeholder and Public Consultation

This section is draft for public consultation. This section will be updated following the public consultation to summarise the key outputs of this consultation process.

To ensure consultation and engagement is carried out in a transparent and meaningful way, and that the views of all stakeholders are considered in the development of the Project, the consultation process will be compliant with all applicable legislative, planning and best practise requirements.

The Project will consult with members of the public, statutory stakeholders and all interested stakeholders subject to review and where applicable, consideration has been given to ensure compliance with the following:

- The Aarhus Convention - Public Participation Directive 2003/35/EC;
- Freedom of Information Act 2014;
- Planning and Development Acts 2000 – 2018;
- Access to Information on the Environment (AIE) Regulations;
- The General Data Protection Regulation 2016;
- Regulation of Lobbying Act 2015;
- Transport (Railway Infrastructure) Act 2001, as amended;
- European SEA Directive 2001/42/EC;
- European Habitats Directive 92/43/EEC; and
- European EIA Directive 2014/52/EU.

6.1 Non-Statutory Public Consultation

Public consultation on the Emerging Preferred Scheme is on a non-statutory basis and is a key element in ensuring that stakeholders, landowners and the public can contribute to the development of the design. Consultation with the public will ensure the Project is capturing and addressing specific local concerns.

Public consultation is running for four weeks to seek feedback on the Emerging Preferred Scheme. The Project is facilitating an in-person event open to the public and all stakeholders with members of the Project team in attendance to provide guidance to those making submissions. This event is taking place in a venue near the coastal cell area to facilitate local residents, business and landowners. Key design concepts will be presented and visually displayed with opportunities to give feedback directly to the Project team.

All consultation information will be available online and to download on the Project website. Members of the public can submit feedback via email, post, a survey/questionnaire and via phone.

6.2 Key Stakeholder Consultation

Pre consultation briefings with technical stakeholders has taken place throughout the option selection process. This includes but not limited to National Parks and Wildlife Services (NPWS), Birdwatch Ireland, Office of Public Works and Local Authorities. This engagement has helped build and foster open, supportive relationships between the Project and technical stakeholders.

Further briefings will be offered to key stakeholders to support the consultation process on the Emerging Preferred Scheme including key environmental organisations, statutory bodies, elected representatives, business representative organisations, landowners, key opinion informers and local residents' groups.

7. Emerging Preferred Scheme

This section is draft for public consultation. It outlines the Emerging Preferred Scheme identified in Section 5. This section will be amended and updated following the public consultation and the 'Emerging Preferred Scheme' will be renamed 'Preferred Scheme'.

7.1 Emerging Preferred Scheme

The Emerging Preferred Scheme (EPS) to be taken forward comprises rock revetments seaward of some of the more exposed existing masonry structures at Bray Head (CCA5-A) to prevent loss of the foreshore and dissipate wave energy, and two rock headlands at Greystones North Beach with managed cliff recession at Greystones Cliffs (CCA5-B) to dissipate wave energy, reduce wave run up and overtopping leading to erosion of the cliffs. In between the rock headlands the cliffs will recede until an equilibrium is reached, forming stable bays between the headlands.

Further detail regarding the components of the EPS is detailed below. In all cases, a minimum 50-year design life is provided.

7.1.1 Rock Revetments for CCA5-A

Rock revetments will be placed in front of the existing masonry structures. The existing structures are at risk of undermining due to erosion at the toe. The rock revetments will prevent the loss of the foreshore in front of the masonry structures which leads to undermining, whilst also dissipating wave energy and therefore significantly reducing the wave energy impacting the structures.

The rock revetments will comprise a minimum of two layers of graded armour rock. The rock grading has been selected to provide stability over the scheme life using modelled wave conditions that allow for sea level rise. Rock grading size will be confirmed during preliminary design but is expected to be in the range of 6-10 tonnes. This is a large rock grading and is representative of these locations being exposed to large wave conditions. This rock will be of high quality to ensure that it meets and exceeds the design life.

7.1.2 Rock Headlands

The rock headlands will be constructed on the beach at the toe of the soft cliffs. The southern headland will be approximately 300m long and the northern headland will be approximately 180m long, with a space in-between of approximately 250m (all dimensions to be confirmed during design development). The rock headlands will comprise of two layers of graded armour rock. The rock grading has been selected to provide stability over the scheme life using modelled wave conditions that allow for sea level rise. Rock grading size will be confirmed during preliminary design but is expected to be in the range of 6-10 tonnes. This rock will be of high quality to ensure that it meets and exceeds the design life. It will be placed over an underlayer on high-performance geotextile to minimise the risk of fines being lost through the existing structure.

The rock headlands will dissipate wave energy, reduce wave run up and overtopping. This will reduce the toe erosion of the cliffs behind the rock headlands as the wave energy reaching the toe of the cliffs will be significantly reduced. Erosion of the beach will continue to occur either side of the rock headlands, therefore at either end of the headlands, 'roundheads' will be incorporated at the end of these structures to allow for erosion and lowering of the beach around these structures.

7.1.3 Walkways and Access

The ends of the headlands will turn seawards to improve the stability of the bays between the headlands and to allow for the roundheads to be constructed. Access seaward of these roundheads will be tidally limited, hence alongshore beach access is proposed to be landward of these structures at the toe of the existing cliffs. Natural pathways will be provided.

7.1.4 Drainage

The proposed option will protect the railway line against coastal erosion of the cliffs due to wave action only and will not manage other risks relating to drainage.

7.1.5 Interfaces

The following interfaces will be developed during design development:

- The exact location of the headlands will be determined relative to the existing coastal defences to the south.

7.2 Concept Scheme Constructability

This section provides a preliminary outline of key delivery areas.

7.2.1 Construction methodology

The following construction methodology is an example methodology that may or may not be adopted by the appointed contractor. This methodology highlights one way a contractor may approach the construction of the structure. The contractor may opt for a different approach. This example methodology is used for assisting with cost estimating.

Due to the large volumes of rock armour, it has been assumed that the rock armour material will be procured from overseas and imported by rock barge.

7.2.1.1 CCA5-A

CCA5-A consists of localised rock revetements to protect the existing structures that front the railway line at various points from Naylors Cove to Greystones Cliffs.

Access to these work areas will be extremely challenging and can only be accessed by marine means for the construction of the revetments, with the exception of Naylors Cove which could be accessed by land-based equipment via Strand Road, but this would result in closure of this road to the public to bring in heavy construction plant, equipment and materials. For this reason, it has been assumed that all works would be undertaken by marine.

The grading of the rock armour will be a heavy grading of up to 10-15t (worst case assumed at this stage). To handle this size of rock armour large marine construction equipment will be needed. It is expected that the rock armour would need to be transported by rock barge to the work areas from Dublin Harbour.

To place the rock armour, a large backhoe dredger or crawler crane on a barge will be needed, possibly a jack up barge (JUB). As the radius of the lift may be large this will further increase the need for larger lifting equipment to place the rock. The backhoe or crawler crane may have a grab attachment on it to help place the rock as accurately as possible.

As the water depth is quite deep close to the foreshore a JUB may be needed to get as close as possible to the foreshore. A JUB will be towed using tugs to the work area then the legs are lowered into the seabed. The assumption is that the size of the JUB is specified based on the water depth at the minimum distance from the foreshore it can deploy its legs into the seabed but also lift the rock where needed. If the seabed profile slopes steeply away from the foreshore, then it may not be possible to gain a stable fixing to the seabed. A large backhoe dredger would follow the same process but may be self-propelled and not require a tug. There may be a requirement to break out material to get the JUB closer to the foreshore.

Assuming the equipment can be setup at the workface the rock would be loaded onto a flat top rock barge which would be towed (or self-propelled depending on barge used) and be tethered to the JUB or backhoe. The rock can then be lifted off the barge and placed. This process would continue until the revetment was complete.

This will be a slow process as handling of rock armour of this grading is challenging. As the rock is large the flat top barges can take less of them in one trip.

7.2.1.2 CCA5-B

It would be favourable to avoid bringing the rock on shore via Dublin Harbour as this adds a significant cost to the handling of the material. The contractor may decide to transport the rock by road from the harbour but due to the large volumes of rock, using marine methods may be favourable.

If water depth allows and assuming the rock can entirely be handled by marine the rock could be discharged into marine stockpiles as close to the shoreline as possible. Due to the shallow water depths close to the shoreline there may be a requirement to construct a short causeway to enable land-based equipment to retrieve the rock and take it to the work front and its final position. The use of long reach excavators and articulated dump trucks (ADT's) would facilitate this operation. The rock would be transported to the placing equipment. Taking the largest grading of 6-10t a large sized excavator would be needed to reach the toe of the revetment.

Rock barge deliveries from the supplier would need to be constant to ensure material is available for the installation. Depending on how many work fronts are opened up, this will dictate the frequency of rock deliveries based on the demand of rock from each work front.

It is assumed the structures are constructed sequentially from North to South as access would be somewhere from the South. Depending on where access is made, it may be possible to work on two at one time but at this stage it would be safe to assume the structures are constructed sequentially.

7.2.1.3 Staging areas and compounds

It is expected that the construction phase would be managed from one main site compound. The location of the main site compound will be considered once the Preferred Scheme is known. The main site compound areas will contain the laydown areas for materials and plant.

7.2.2 Construction Risks

In the context of construction there will be many project delivery risks. The most significant risk will be related to the works being undertaken in a marine environment, which limits working windows in accordance with tides and working in a dynamic environment. Rock delivery is anticipated to be via marine routes and therefore will be subject to weather risk. This risk may delay works as marine vessels can only operate below certain wave or swell height conditions.

Access to the foreshore is a key challenge, this may result in more construction vehicle movements on the public road network to reach appropriate crossing points.

Critical health and safety related construction risks are summarised below.

- Unstable ground conditions - Potential for site operatives or plant to become stuck in pockets of soft or lose ground. Instability of plant working in area of low soil strength.
- Existing services - Damage to existing services during construction leading to death or injury to site personnel.
- Delivery of rock – risk of barge being grounded.
- Handling and placement of rock armour - loss of control of rocks (movement due to soft ground conditions/dropped by construction plant).

7.2.2.1 Mitigations

Notwithstanding the above mentioned project delivery risks, these can be mitigated to reduce the impact on the delivery programme. The marine works can be planned to be undertaken during the summer months to reduce the exposure to the poorer weather during the winter months. Appropriate routes for construction traffic can be identified on the existing road network to minimise impact to other road users. Works near the railway can be identified early and discussions with Irish Rail can be happen early to ensure the works can proceed as smoothly as possible.

7.3 Health and Safety

Health and safety have been a key factor in the design and option selection process. Health and safety risks, both during construction and following completion of the Project are considered at every stage of the project, from long list screening through to construction. Risks are eliminated and mitigated where possible, but where a risk cannot be mitigated through design measure, the residual risk is documented and appropriate measures for managing the risk are documented. Health and Safety during the construction phase will be managed by the client and contractor.

8. Conclusions and Next Steps

This section is draft for public consultation. It outlines the conclusions from this Preliminary Options Selection Report. This section will be amended and updated following the public consultation and the 'Emerging Preferred Scheme' will be renamed 'Preferred Scheme'.

8.1 Options Assessment Conclusions

This report has presented the full range of technical solutions to protect the railway from coastal flooding and erosion and has provided evidence for arriving at the Emerging Preferred Scheme comprising rock revetments placed seaward of structures around Bray Head (CCA5_A) and two rock headlands at Greystones North Beach (CCA5-B). These options maintain amenity provision and minimise environmental impact.

8.2 Next steps

This report identifying the Emerging Preferred Scheme is a key deliverable of Phase 2. The future Project phases to develop and deliver the Emerging Preferred Scheme are summarised below:

- Phase 1 – Project Scope and Approval (completed);
- **Phase 2 – Concept, Feasibility and Options (current phase);**
- Phase 3 – Preliminary Design (next phase);
- Phase 4 – Statutory Process (future phase);
- Phase 5a- Detailed Design and Tender Issue (future phase);
- Phase 5b - Contract Award (future phase);
- Phase 6 – Construction; and,
- Phase 7 – Close out.

8.2.1 Design development

The next phase of design is Preliminary Design of the Emerging Preferred Scheme (Phase 3). This will develop the Phase 2 Concept Designs to provide increased certainty on the structure geometry and detailing. This stage of design will consider in more detail the interfaces through the development of a 3D design. Further work will be undertaken to consider how the works will be constructed and how construction impacts can be avoided or mitigated. Comments and feedback from PC1 will be considered as part of the preliminary design works.

8.2.2 Opportunities for consultation and engagement

PC1 provides the public the opportunity to provide commentary on the Emerging Preferred Scheme. Once this information has been reviewed and considered, the Preferred Scheme will be selected to progress to preliminary design. At Public Consultation 2 (PC2), stakeholders will be given another non-statutory consultation opportunity to provide commentary on the Preferred Scheme, which will be documented and considered in the completion of the preliminary design. This will enable the Project to progress to Reference Design that will support the development of the Environmental Impact Assessment (documented in an Environmental Impact Assessment Report). This will support the statutory planning process for the Project. Stakeholders will be afforded the opportunity to engage on the Project again at this point. This consultation will be taken into consideration by the approving authority.

8.2.3 Consenting

The only consenting aspects related to the next stage (Phase 3) are the consents for any remaining site surveys that were not progressed during Phase 2. This is currently limited to further ground investigations and a bathymetric survey. There will be ongoing consultation during Phase 3.

The significant consultation tasks will be delivered under Phase 4 comprising the Environmental Impact Assessment (EIA), Appropriate Assessment, Planning Consent application, Foreshore Consent application and supporting public consultation.

On receipt of permission to undertake surveys by MARA, a subsequent application/s will be made to MARA for the Marine Area Consent (MAC). On receipt of a MAC there are a number of potential consenting ‘routes’ for the subsequent development applications including:

1) Railway Order under the Transport (Railway Infrastructure) Act, 2001 (as amended and substituted);
2) Seventh Schedule Strategic Infrastructure Development (SID) under the Planning and Development (Strategic Infrastructure) Act 2006 and Planning and Development Act, 2000 (as amended);
3) Section 179 ‘Local Authority Own Development’ under the Planning and Development Act, 2000 (as amended) and Part 8 under the Planning and Development Regulations 2001 (as amended); and
4) ‘Local’ Planning Application under the Planning and Development Act, 2000 (as amended) and the Planning and Development Regulations 2001 (as amended).

All of the above consenting ‘routes’ are currently under consideration.

8.2.4 Procurement

The construction procurement will commence following the granting of the consents in Phase 5.

8.2.5 Programme

A high-level indicative programme of the next phases is as follows:

- Phase 2 completion programmed following Public Consultation 1 in Autumn 2024;
- Phase 3 programmed for summer 2024;
- Phase 3 completion autumn 2024; and
- Phase 4 programmed for winter 2024 and throughout 2025.

The programme for phases after planning submission (Phase 5 onwards) is subject to application durations.

9. Glossary

Term	Description
Annual exceedance probability	The probability that a given event will be equalled or exceeded in any one year
Antecedent rainfall	Cumulative rainfall totals over a given period
Beach lowering	Reduction in beach surface elevation over a timescale due to cross-shore and longshore sediment transport.
Beach nourishment	Supplementing the existing beach periodically with suitable material to increase beach volumes, reduce erosion and toe scour at flood defences and/or soft cliffs.
Breakwater	Offshore structure which dissipates wave energy due to their size, roughness and presence of voids. This reduces the wave heights at the shoreline defences
Caisson	A watertight retaining structure used as a foundation
Capital expenditure	Funds used to acquire, upgrade and maintain physical assets (e.g., construction costs)
Capping beam	Steel structures that join pile foundations together to increase their rigidity and reduce movement
Carbon management	An approach to mitigate or reduce carbon (or other greenhouse gas) emissions
Catch fence	A fence designed to catch falling debris and absorb impact
Circular economy	A system which reduces material use, redesigns materials, products, and services to be less resource intensive, and recaptures “waste” as a resource
Cliff recession	Landward retreat of the cliff profile (from cliff toe to cliff top) in response to cliff instability and erosion processes
Climate adaption plan	A plan which sets out measures that protect a community or ecosystem from the effects of climate change, while also building long-term resilience to evolving environmental conditions
Climate change	A change in global or regional climate patterns, in particular a change apparent from the mid to late 20th century onwards and attributed largely to the increased levels of atmospheric carbon dioxide
Climate resilience	Climate resilience is the capacity of social, economic and ecosystems to cope with a hazardous event or trend or disturbance caused by climate change
Coastal Cell Area	A spatial model which subdivides the coast based on the variation in physical characteristics, including the geology, geomorphology, shoreline topography and orientation, and existing defence type
Coastal erosion	Loss or displacement of land, or long-term removal of rocks and sediment along the coastline due natural impact of waves, wind, rain and tides
Coastal flooding	Submergence of normally dry and low-lying land by seawater
Coastal protection	Measures aimed at protecting the coast, assets and inhabitants from coastal flooding and erosion. Coastal protection may involve structural, non-structural or nature-based solutions
Coastal spit	A coastal landform, whereby a stretch of beach material projects out to the sea and is connected to the mainland at one end
Concept level design	Foundational phase of the design process which lays the groundwork for the entire project. The design work undertaken for the concept design is sufficient to confirm that the options will work from a technical perspective and will meet the Project objectives.
Concrete armour	Precast concrete units placed to form breakwaters or revetments to dissipate wave energy
Constructability	Also known as buildability. The extent to which a design facilitates the each and efficiency of construction

Design horizon	The period of time over which the scheme provides the required Standard of Protection (SoP) to the railway line.
Design life	The service life intended by the designer, which is the period of time after installation during which the structure meets or exceeds the performance requirements.
Dilapidation survey	A detailed survey that examines the existing state of the coastal structure
Dune regeneration	Stabilisation and enhancement of existing dune systems to deliver additional resilience
Embankment	Linear grassed earth structure providing flood protection; typically used along riverbanks
Emergency works	Works in response to an event that is unexpected and serious such that it presents a significant risk to human life, health and property or the natural environment and involves the need for immediate action to manage the risk
Feasibility study	An assessment of the practicality of a proposed project plan or method.
Flood proofing	Structural, and non-structural, solutions that can prevent or reduce flood damages to a property or its content.
Flood warning and preparedness	Measures undertaken to better prepare, respond and cope with the immediate aftermath of a flood event
Foreshore	The part of a shore between high- and low-water marks
Freeze-thaw weathering	Form of mechanical weathering whereby water enters cracks in rocks, freezes and expands, widening the cracks. Repetition of this cycle causes gradual break down of the rock.
Gabions	A basket or container filled with earth, stones, or other material
Geomorphology	The interaction between Earth's natural landforms, processes and materials
Geotextile	Permeable fabrics which, when used in association with soil, have the ability to separate, filter, reinforce, protect, or drain
Geotubes/ Geotextile Tubes	Tube shaped bags made of porous, weather-resistant geotextile and filled with sand slurry, to form artificial coastal structures such as breakwaters or levees
Groyne	Linear structure constructed perpendicular to the shoreline which helps retain beach material in place.
High tide mark	A point that represents the maximum rise of a body of water over land
Hydrodynamic modelling	Used in the analysis of coastal hydrodynamic processes, it is employed to simulate major physical phenomena in the coastal region
Maintenance burden	The level of maintenance (repair, monitoring, rebuilding) required over the design life of the structure to retain the Standard of Protection of the coastal defence structure
Managed realignment	A coastal management strategy that involves setting back the line of actively maintained defences to a new line inland and creating inter-tidal habitat between the old and new defences
Mudslides	Mass of typically saturated mud and earth debris that moves downslope
Multi criteria analysis	A structured approach to determine overall preferences among alternative options, where the options should accomplish multiple objectives.
Nature-based solutions	The use of natural materials and processes to reduce erosion and flood risk to coastal infrastructure
Pore water pressure	The pressure of groundwater help within a soil or rock in the gaps between particles
Residual risk	The degree of exposure to a potential hazard that cannot be completely eliminated

Revetment	Sloping or stepped structure built parallel along the shoreline between the low lying beach and higher mainland to protect the coast from erosion and wave overtopping. The revetment may have a smooth or rough surface
Rock netting	A drapery system designed to control rockfall movement by guiding falling debris to a collection point at the toe of the slope
Saltmarsh	Coastal grassland that is regularly flooded by seawater
Sea level rise	An increase in the level of the oceans due to the effects of climate change
Seagrass bed	Intertidal or sub-tidal beds of sea grass. Provides ecosystem benefits including carbon sequestration.
Seawall	Vertical or near-vertical impermeable structure designed to withstand high wave forces and protect the coast from erosion and/or flooding
Shellfish reefs	Sub-tidal or intertidal reefs formed of suitable material for settlement by oysters or mussels.
Sill	A low rock structure in front of existing eroding banks to retain sediment behind.
Standard of Protection	The expected frequency or chance of an event of a certain size occurring. Defined for this project as being a 0.5% Annual Exceedance Probability, also known as a 1 in 200 year storm protection level.
Storm surge	A change in sea level that is caused by a storm event, which can lead to coastal flooding
Toe scour	Occurs when the toe (bottom) of the defence is worn away by the waves and can cause defences to fail.
Unconsolidated glacial till	Unstratified and unsorted debris ranging in size, derived from the erosion and entrainment of rock by glacial ice
Wave exposure	The degree to which a coast is exposed to wave energy
Wave overtopping	The average quantity of water that is discharged per linear meter by waves over a protection structure (e.g., breakwater) whose crest is higher than the still water level

Appendix A. Planning and Environmental Constraints Report

Document Number	Document Title
7694-XX-P2-FEA-EV-JAC-0001	PLANNING AND ENVIRONMENTAL CONSTRAINTS REPORT

Appendix B. Photographic Record

Figure 1 – CCA5-A: The sub-cell is made of a series of natural rock faces and coves/beaches. The image here shows Naylors Cove, the most northerly cove in the sub-cell. Remains of old stairs and baths are present and provide coastal protection, with a rocky foreshore and steep grassed slopes above.

Figure 2 – CCA5-A: In some locations, masonry retaining walls have been installed to support the railway; these also serve as a coastal defence. In this image, the wall is located between two outcrops. In the upper section of the image, rock netting can also be seen, protecting the railway from debris and rockfalls.

Figure 3 – CCA5-A: Another example of an engineered section can be seen here, located between two rock outcrops. The asset is made of a series of masonry walls, gabion baskets, rock anchors and concrete revetment which have been constructed at different stages. Again, rock netting is visible above the railway.

Figure 4 – CCA5-A: The railway within this sub-cell also goes through 4 tunnels, providing both coastal and rock fall protection. In this image, the entrance of Tunnel 1 is visible. A stone bridge/wall is located above the water level, and large boulders are located at the bottom of the asset.

Figure 5 – CCA5-A: The entrance to Tunnel 4 can be seen here, with a rock armour protecting the toe of the asset. The boulders are very large and provide efficient coastal protection. Vegetated slopes are present between the rock armour and the railway. A retaining wall is also present on the right-hand side.

Figure 6 – CCA5-B: The sub-cell consists of a 1.5 km long beach, with a varying width. The northern and central sections of the beach are gently sloping and sandy with some shingle present. Cliffs are present at the back of the beach, with different levels of erosion. In the image here, the cliff is well vegetated.

Figure 7 – CCA5-B: In the southern section of the beach, the cliff has suffered from significant erosion and subsequent landslides. The lack of vegetation highlights the steepness of the cliff and the recent erosion. The beach is also narrower, steeper and has a higher shingle content at this end of the beach.

Appendix C. Options Assessment Supporting Modelling Outputs

Document Number	Document Title
7694-CCA5-P2-MMO-CM-JAC-0001	OPTIONS ASSESSMENT SUPPORTING MODELLING OUTPUTS CCA5

Appendix D. Short List Multi-Criteria Analysis Tables

Document Number	Document Title
7694-CCA5-P2-ENG-CV-JAC-0002	Short List Multi-Criteria Analysis Table CCA5

Appendix E. Option Concept Design Drawings

Document Number	Document Title
7694-CCA5-P2-DWG-CV-JAC-0001	CONCEPT DESIGN CCA 5 SITE LOCATION PLAN
7694-CCA5-P2-DWG-CV-JAC-0100	CONCEPT DESIGN CCA 5A OPTIONS PLAN
7694-CCA5-P2-DWG-CV-JAC-0110	CONCEPT DESIGN CCA 5B OPTION A, B & C PLAN
7694-CCA5-P2-DWG-CV-JAC-0210	CCA5-B CROSS SECTIONS OPTION A
7694-CCA5-P2-DWG-CV-JAC-0211	CCA5-B CROSS SECTIONS OPTION B
7694-CCA5-P2-DWG-CV-JAC-0212	CCA5-B CROSS SECTIONS OPTION C

Appendix F. Works Priorities Drawing

Document Number	Document Title
7694-CCA5-P2-DWG-CV-JAC-0300	CCA 5 COASTAL DEFENCE WORKS PRIORITIES

Appendix G. Implementation Options Multi-Criteria Analysis Tables

Document Number	Document Title
7694-CCA5-P2-ENG-CV-JAC-0003	Implementation Options Multi-Criteria Analysis Table CCA5

Appendix H. Scheme Concept Design Drawings

Document Number	Document Title
7694-CCA5-P2-DWG-CV-JAC-0400	CCA 5 CONCEPT DESIGN PLAN
7694-CCA5-P2-DWG-CV-JAC-0410	CCA 5B CONCEPT DESIGN CROSS SECTIONS

Appendix I. Consultation Report

To be added following Public Consultation 1.