East Coast Railway Infrastructure Protection Projects

Preliminary Option Selection Report

Dalkey Tunnel to Shanganagh-Bray Wastewater Treatment Plant

COASTAL CELL AREA 2/3

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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 unattended, 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. This document provides the Preliminary Option Selection Report for CCA2/3 - Dalkey Tunnel to Shanganagh-Bray Wastewater Treatment Plant (hereafter referred to as "the Project").

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.

CCA2/3 covers the frontage from Dalkey Tunnel to just south of Killiney Martello Tower (near Shanganagh-Bray Wastewater Treatment Plant). This frontage is mainly a rocky outcrop, with a rocky cliffed frontage for the majority and softer cliffs to the south of the frontage. This frontage is typically non-urban with the railway perched at a high level above the coastline. The majority of the frontage are natural cliffs but there are intermittent man-made structures supporting the slopes and the perched railway. In the central and southern parts of the frontage, the cliffs are fronted by a mixed shingle-sand beach. Cliff instability, runoff of water, undermining of the cliffs and slopes by coastal erosion and shore platform lowering are the main hazards in CCA2/3. There is evidence of past failures along both frontages, from toe erosion, failures in superficial material and undermining of structures. The options assessment identified four sub-cells: CCA2/3-A Vico Cliffs; CCA2/3-B Whiterock; CCA2/3-C Killiney Beach; and CCA2/3-D South Killiney (See Figure ES below).

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

- Whiterock is most vulnerable to wave overtopping, toe scour and structural failure. Undermining and structural failures have been recorded in the past. At this location the beach is small and low, and the defences are exposed to direct wave attack with the undersized rock only providing limited protection from toe scour.
- There is a long term erosional trend at the end of the bay around Whiterock and South Killiney 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 defences, slopes and cliffs to the other failure modes.
- The soft cliffs at Killiney Beach and South Killiney are vulnerable to toe erosion, though they have not historically experienced significant rainfall-induced failures.
- The hard rock cliffs above the railway between Whiterock and Vico are vulnerable to rock falls.

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 armour at the toe of existing defences at Vico Cliffs (CCA2/3-A), and rock revetments with repaired/raised walls and rock toe protection where needed through Whiterock, Killiney and South Killiney (CCA2/3-B to CCA2/3-D).
- **Option B**: comprises rock armour at the toe of existing defences at Vico Cliffs (CCA2/3-A), and beach nourishment and beach control structures (rock groynes) repaired/raised walls and rock toe protection where required through Whiterock, Killiney and South Killiney (CCA2/3-B to CCA2/3-D). This option acknowledges that Whiterock and Killiney beaches and the surrounding environment are important and well used amenity locations for the local community and therefore reduces the impact on access and use of the beach.
- **Option C**: comprises rock armour at the toe of existing defences at Vico Cliffs (CCA2/3-A), and beach nourishment and beach control structures (breakwaters) with nourishment and repaired/raised walls and rock toe protection where required through Whiterock, Killiney and South Killiney (CCA2/3-B to CCA2/3-D). Detached breakwaters are advantageous over groynes as they do not impact the beach area, however, they do impact in the nearshore area and will affect the current, swimming and surfing conditions, as well as being visually intrusive from the majority of the beach area.

These options all meet the scheme objectives, the requirements for the minimum 50-year design life and no maintenance for 25 years and provide the required standard of protection. The options all adopt a “Hold the Line” approach by protecting the shoreline on its current alignment 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 armour at the toe of existing defences at Vico Cliffs (CCA2/3-A), and rock revetments with repaired/raised walls and rock toe protection where needed through Whiterock, Killiney and South Killiney (CCA2/3-B to CCA2/3-D).
- **IO2**: deliver most of the EPO Option A under ECRIPP to protect to 2075 and defer some works into the longer term until they are needed. Works are as per IO1, but with works at the far southern end of South Killiney and a small section of revetment at Whiterock deferred.
- **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 comprise rock revetment at Whiterock (CCA2/3-B) and seawall with rock toe protection where need through Killiney (part of CCA2/3-C and D).
- **IO4**: deliver highest priority works only under ECRIPP and defer all other works. Works comprise rock revetment at Whiterock only (CCA2/3-B).
- **IO5**: 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 3 (IO3),** comprising**:**

- Rock revetment at Whiterock (510m length of CCA2/3-B);
- Concrete seawall at Killiney (395m southern part of CCA2/3-C and the 235m northern part of CCA2/3-D). (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 the Reference Design and culminates with statutory consultation as part of statutory consent applications.

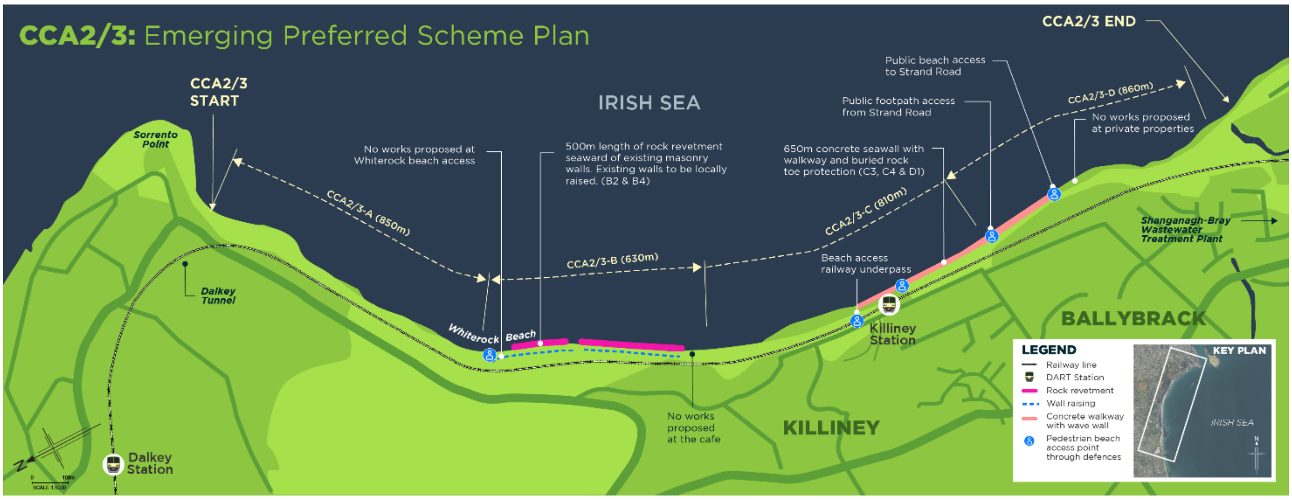

Figure ES 1-1 CCA2/3 Emerging Preferred Scheme Plan

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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
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 CCA2/3 (see Figure 1-2), a 3km length of coastline from Dalkey Tunnel to Shanganagh-Bray Wastewater Treatment Plant (hereafter referred to as "the Project").

Figure 1-1 Location of Coastal Cell Areas

Figure 1-2 Overview of CCA2/3

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 Dalkey Tunnel and Killiney.

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 CCA2/3 – Dalkey Tunnel to Shanganagh-Bray Wastewater Treatment Plant, 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 CCA2/3. 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 Ireland's 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 2019 (hereafter referred to as the Transport Adaptation Plan) recognises the risk of climate change impact on the Irish transport sector and it's 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 policies and approach 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

This Project falls into the remit of the Eastern & Midlands Regional Assembly (EMRA). The EMRA RSES outline 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 draft Greater Dublin Area Transport Strategy (GDATS) 2022 – 2042. GDATS outlines a number of policy objectives to support the proposed Projects 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 Dún Laoghaire Rathdown County Council

The Dún Laoghaire– Rathdown (DLR) County Development Plan 2022 – 2028 was adopted on 10th March 2022 and came into effect on the 21st April 2022. The Plan sets out the primary goals and objectives that will help to guide and shape the proper planning and continuing sustainable development of the County.

CCA2/3 is within the functional area of DLR from Dalkey to Shankill.

Whilst the Project is not specifically mentioned within the Plan, coastal defence is supported. A number of distinct map-based objectives are relevant to the cells within the DLR functional area; notably records of monuments and places which are likely to be Martello towers. A number of protected areas are within the defined works area including Architectural Conservation Areas (ACA's).

The Plan sets out a range of applicable policies including, among others: EI24 – '*Coastal Defence*', EI23 – '*Cross Boundary Flood Management*', GIB8 – '*Coastline Parks and Harbours*', and GIB11 – '*Coastal Area Feasibility Study*'.

CCA2/3 has number of applicable zoning objectives including: Objective A – To provide residential development and improve residential amenity while protecting the existing residential amenities, Objective F – To preserve and provide for open space with ancillary active recreational amenities and Objective SNI – To protect, improve and encourage the provision of sustainable neighbourhood infrastructure.

Further detail of the applicable policies and objectives is provided in Appendix A.

2.1.4.1.1 Dún Laoghaire Rathdown County Council Coastal Strategy

The Coastal Defence Strategy Study was published in September 2010. It was prepared to manage the coastal defence issues within the DLR functional area.

The Dún Laoghaire Rathdown County Development Plan 2022-2028 states that the strategy is currently under review and due to be updated.

The key recommendations and relevant actions to the Project are set out in Appendix A.

2.1.4.1.2 Draft Dún Laoghaire Climate Action Plan

The draft Dún Laoghaire Climate Action Plan 2024 –2029 was published for consultation on the 20th September 2023. The second plan builds upon the first to reduce greenhouse gas emissions and to prepare the region for the impacts of climate change. Flooding and coastal erosion are noted as a risk to critical infrastructure.

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. Appendix A incudes the NMPF Marine Map Based Objectives (MMBOs) and Marine Spatially Specific Policy Objectives (SSPOs) relevant to CCA2/3.

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.

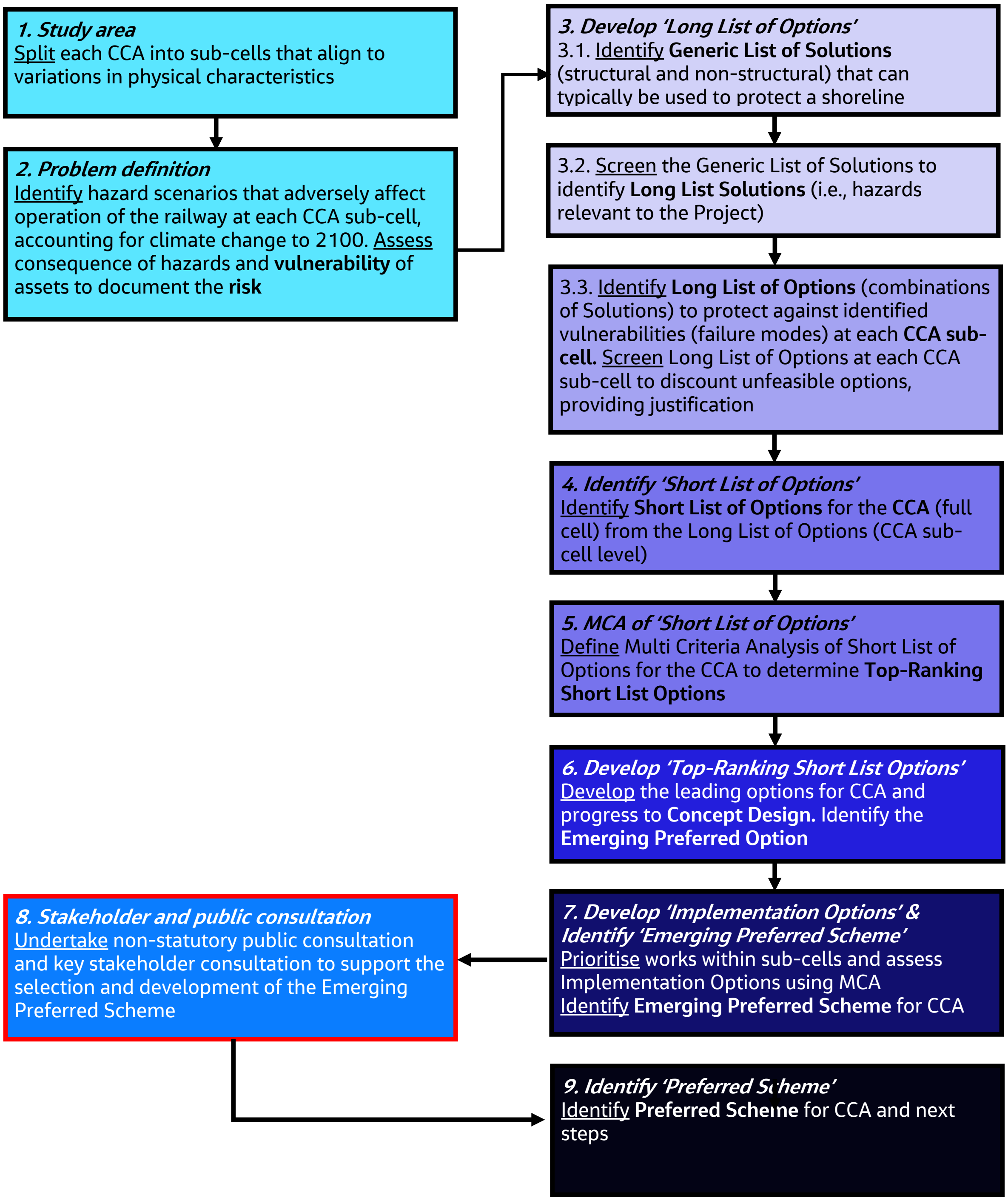

Figure 3-1 Flow Chart Summarising Optioneering Process

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.
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: 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.

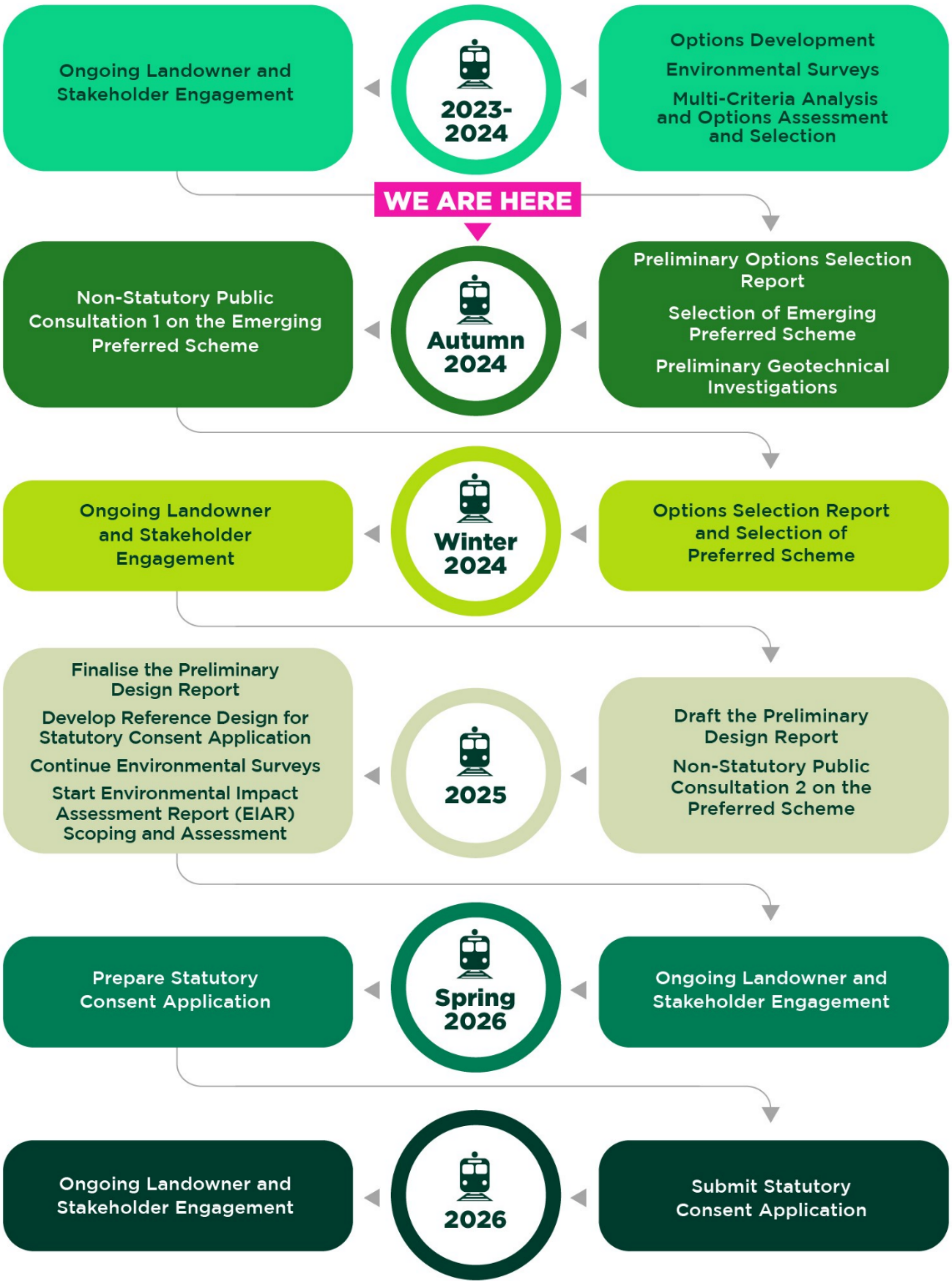

Figure 3-2 Public Consultation Roadmap

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 CCA2/3

The project area is divided into Coastal Cell Areas (CCA). CCA2/3 covers the frontage from Dalkey Tunnel to just south of Killiney Martello Tower (near Shanganagh-Bray Wastewater Treatment Plant). The frontage comprises a mix of natural hard cliffs to the north, engineered cliffs/embankments fronted by a mixed shingle-sand beach in the central section and natural steep cliffs ranging in height from roughly 6-12m fronted by beach to the south.

This frontage is mainly a rocky outcrop, with a rocky cliffed frontage for the majority and softer cliffs to the south of the frontage. This frontage is typically non-urban with the railway perched at a high level above the coastline. The majority of the frontage are natural cliffs but there are intermittent man-made structures supporting the slopes and the perched railway.

Cliff instability, runoff of water, undermining of the cliffs/slopes by coastal erosion and shore platform lowering are the main hazards in CCA2/3. There is evidence of past failures along both frontages, from toe erosion, failures in superficial material and undermining of structures.

4.2 Identification of Coastal Sub-Cells

CCA2/3 has been divided into four 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 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 CCA2/3, 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 CCA2/3 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 designated sites: Dalkey Island SPA (Code 004172) & Rockabill and Dalkey Island SAC (Code 003000)
- Nationally designated sites: Dalkey Coastal Zone and Killiney Hill (Code 001206)

Further ecological constraints within CCA2/3 are:

- This location is a key habitat for the Annex II species Harbour Porpoise within the Irish Sea.
- Habitats such as inshore shallow sand and mudbanks and rocky reefs that are scoured by strong current flow which is believed to be important for Harbour Porpoise.
- This area supports Common Seal and Grey Seal, for which terrestrial haul-out sites occur in immediate proximity.
- Dalkey Islands SPA is both a breeding and a staging site for Sterna Terns. The site is one of only three known sites in the country for Roseate Tern (rare species).

4.3.2 Soils & Geology

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

- Steep topography is noted between Dalkey and Ballybrack;
- From CCA2/3-A to CCA2/3-C, the landslide susceptibility is classified as moderate to very high;
- Some Water Framework Directive (WFD) waterbodies intersect the railway line through the cell;
- Potential sources of contamination:
  - Made ground.
  - Rail line.
- Maulin Formation is identified as a locally important aquifer;
- A former pit located on the drift cliffs of Killiney and at Whiterock, Killiney;
- Areas of high to extreme groundwater vulnerability occur within the vicinity of Dalkey;
- Till derived from granites and exposed bedrock have a high to very high crushed rock aggregate potential;
- Till derived from limestones have a moderate granular aggregate potential; and
- Four areas are classified as a Geological Heritage Audited Site.

4.3.3 Hydrology

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

- Waterbodies:
  - Two river sub-basins: Kill Of The Grange Stream_010 & Shanganagh_010
  - Two Coastal waterbodies: Irish Sea Dublin (HA 09) & Southwestern Irish Sea – Killiney Bay (HA10)

Areas subject to flood risk includes:

- Flooding at Shangannagh along the Shangannagh Stream

4.3.4 Landscape, Seascape & Visual

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

- Six public rights of way
- 32. No. Protected Views
- 2. No Prospects
- Seascape Character Area (SCA) – SCA 15 Dublin Bay
- Seascape Coastal Type (SCT) – Modified Historic Urban Bay, SCT10 & Broad Estuarine Bays and Complex Lower Plateau and Cliff Coastline, SCT7

4.3.5 Archaeology & Cultural Heritage

The main constraints for Archaeology & Cultural Heritage that were found are as follows:

- 15. No. SMR Sites
- Two Undesignated Key Constraints:
  - There is one historic railway line within CCA2/3: Dún Laoghaire to Bray.
  - There is one historic railway station within CCA2/3: Killiney and Ballybrack.

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; and
- Educational 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;
- Educational Facilities;
- Heritage Buildings;
- Designated Habitats (e.g., SAC or SPA) and Ecologically Sensitive Areas; and
- Place of worship or entertainment.

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;
- Educational Facilities;
- Commercial buildings; and
- Recreational facilities.

Figure 4-1 CCA2/3 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
CCA2/3 – General	Dalkey Tunnel to Shanganagh-Bray Wastewater Treatment Plant	At the northern extent a mixture of rocky outcrops and supporting wall, mixed sand/shingle beach with some support structures at slope toe in the middle and soft cliffs at the southern extent	✓	✓	✓	✓	✓	✓	✓
CCA2/3-A	Vico Cliffs	Hard rock cliffs with railway line perched on cliff top supported by retaining structures at gullies. High wave exposure at base of cliffs and little/no beach. Cliff erosion is main hazard. Insignificant overtopping risk.		✓			✓		✓
CCA2/3-B	Whiterock	Narrow beach fronting vertical seawalls in high wave exposure environment. Undermining, overtopping and/or structural failure of existing structures leading to slope failure is the main risk.	✓	✓	✓	✓	✓		
CCA2/3-C	Killiney Beach	Stable, wide beach fronting low retaining walls. Longer term undermining, overtopping and/or structural failure of existing structures leading to slope failure is the main risk.	✓	✓	✓	✓	✓		
CCA2/3-D	South Killiney	Beach fronting soft/steep cliffs. Longer term undermining, overtopping and/or structural failure of existing structures leading to cliff failure is the main risk.	✓	✓	✓	✓	✓	✓	

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 low to medium risk to the stability of embankments supporting the railway in CCA2/3. This risk will increase significantly with sea level rise projections. • During storms, where waves propagate to the defence line during high tide events, wave overtopping has historically led to localised erosion of the top face of the embankments below the railway. Hence, this presents as an erosion and geotechnical stability problem rather than a flooding problem (as the railway through this area is elevated). • The most likely impact is the loss of material at the bottom of the embankment necessitating a repair, or potentially the closure of the line in a Do Nothing scenario. The likelihood of a sudden failure of the entire embankment and a potential derailment is unlikely, but possible. • As sea levels rise, the likelihood of erosion and the undermining 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 erosion 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. • In addition to the risk to the railway operation and assets covered by the Project scope of work, wave overtopping presents a significant risk to pedestrians using footpaths and amenity areas.	• 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 beach levels. • Vulnerability varies, but in general Whiterock is the most vulnerable and there have been failures here in the past. There is a lower risk through the southern sections of Killiney Beach (south of the railway station).
Structural Failure	• Structural failure of existing defences is currently a high risk to railway operations in CCA2/3. 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 and there would be a loss of protective beach material from the frontage. • Irish Rail has historically maintained the defence to repair sections where the existing masonry walls and slopes have been damaged. In the past, damage has occurred where revetment masonry wall blocks have been dislodged during storms, allowing large waves to propagate to the defence line during high tide events. Dislodged blocks open-up holes in the walls that can quickly worsen if not repaired. This leads to a loss of embankment material behind the defences. • In the Do Nothing scenario, holes in the defence and loss of embankment material would propagate and the overall structural integrity of the defence/slope would be compromised. This would eventually lead to the undermining and failure of the upper parts of the revetment/line 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. • 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	• 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 beach levels. • Vulnerability varies, but in general Whiterock is the most vulnerable (there have been failures here in the past). There is a lower risk through Vico Cliffs and the southern sections of Killiney Beach.

Hazard/ Failure Mode	Risk to the railway (vulnerability) in the Do Nothing scenario	Most vulnerable areas
	and catastrophic collapse of the upper parts of the revetment, undermining the railway line and could potentially result in a derailment risk. • There would also be an increasing risk of a sudden collapse of amenity areas/footpaths leading to an increased public health and safety risk. This would likely lead the council eventually having to close these amenity areas to manage this risk.	
Toe Scour	• At CCA2/3, the risk of scour undermining the defence 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 as a medium risk to railway operations in CCA2/3, 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. However, sometimes the full depth of scour during the peak of a storm event is uncertain because the scoured void rapidly re-fills with foreshore material. As noted above, toe depth of existing structures will be confirmed by proposed site investigations, which may change the risk rating. • 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) and the defence condition/ form /toe depth. • Hence, vulnerability varies, but the area where undermining has occurred in the past and is most likely to occur again in the future is at Whiterock. At this location the beach is small/low and the defences are exposed to direct wave attack with the undersized rock only providing limited protection from this failure mode. • There are a few defences through the rest of Killiney, but these are less susceptible to undermining due to relatively healthy beach levels. There is no immediate risk to the railway in the event the council's gabion wall is undermined.
Beach Erosion	• For the CCA2/3 frontages where there are beaches, all of the other hazards are directly linked to the beach/foreshore levels. There are extensive and relatively healthy shingle beaches protecting the railway embankments/cliffs in the centre of Killiney Beach. • Beach erosion is currently assessed a medium risk to railway operations in CCA2/3, but this is an undirect risk given beach erosion will lead to one of the other failure modes. This 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 the bay resulting in increased erosion rates (where material will be pulled offshore and lost).	• Coastal modelling has shown the tendency for long term accretion in the centre of the bay where the beaches are more stable and wider. The risk of beach loss here is lower (inclusive of climate change impacts). • Long term erosional trends are more pronounced at the ends of the bay (at Whiterock and South Killiney) 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 defences, slopes and cliffs to the other failure modes.

Hazard/ Failure Mode	Risk to the railway (vulnerability) in the Do Nothing scenario	Most vulnerable areas
	• 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 the railway is at low risk over the long term but could be impacted under more extreme sea-level rise projections. Erosion will be more severe if the beach at Killiney is lost.	• Soft cliffs are located at Killiney Beach and South Killiney, which are at a low risk of toe erosion. Other areas are located on bedrock that is eroding at a much lower rate.
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 Killiney Station and Whiterock, where material above retaining walls has been mobilised and runout onto the line. These slopes have since been stabilised. Assessment of their current condition and future risk to the railway is uncertain and beyond the scope of the Project. • Under a Do Nothing scenario rainfall-induced failures will continue irrespective of the amount of toe erosion. The rate of retreat may increase under projections of increased rainfall. • Projected erosion of soft cliffs suggests that the railway is at low risk over the long term but could be impacted under more extreme climate change projections. • Reactivation of slopes above retaining walls between Killiney Station and Whiterock would pose a high risk to the railway.	• Soft cliffs are located at Killiney Beach and South Killiney, which are at a low risk of toe erosion and have historically not experienced significant rainfall-induced failures. Other areas are located on bedrock that is eroding at a much lower rate. • Soft cliffs above retaining walls are present between Killiney Station and Whiterock.
Rock Falls	• Rockfalls have impacted the railway between Whiterock and Vico in the past and this area now benefits from localised rock netting and catch fencing at areas of risk. • Under a Do Nothing scenario, existing mitigation measures could fail, leading to a moderate to high risk of rockfall.	• The hard rock cliffs above the railway between Whiterock and Vico are 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 and 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, Table 5-6 to Table 5-10.

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 a specific location but outlines the full range of structural, non-structural options and nature-based solutions, regardless of whether they could be viable. 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 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				✓		✓		

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
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	Yes	Low	Retained		✓						

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
		defence where it does not need to withstand direct wave impact; may be installed behind a promenade or beach nourishment											
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 a long 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 a long 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								✓

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
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	Wwill 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. Seagrass is present in CCA1	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 5-10.

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

Long List Ref	Solution	Failure mode addressed by solution*							CCA2/3 – A	CCA2/3 – B	CCA2/3 – C	CCA2/3 – D
		OT	ST	TS	BE	TE	GW	RF				
LL01	Do nothing								N/A	N/A	N/A	N/A
LL02	Do minimum								N/A	N/A	N/A	N/A
LL03	Relocation of the railway	✓	✓	✓	✓	✓	✓	✓	N	N	N	N
LL04	Detached Breakwaters – emergent rock or concrete armour units				✓				Y	Y	Y	Y
LL07	Attached Breakwaters – rock			✓	✓	✓			N	Y	N	N
LL08	Revetment – rock	✓	✓	✓		✓			Y	Y	Y	Y
LL09	Revetment – concrete armour units	✓	✓	✓		✓			N	N	N	N
LL11	Revetment – stepped concrete	✓	✓	✓					N	Y	N	N
LL16	Toe Protection – rock			✓		✓			N	Y	Y	Y
LL18	Toe Protection – gabions			✓		✓			N	N	N	N
LL19	Toe Protection – steel sheet piles			✓		✓			N	N	Y	Y
LL21	Groynes – rock			✓	✓	✓			N	Y	Y	Y
LL23	Vertical Seawall – concrete wall	✓	✓			✓			N	Y	Y	Y
LL24	Vertical Seawall – sheet piles	✓	✓			✓			N	N	N	N
LL28	Set back flood wall	✓							N	N	N	N
LL32	Beach Nourishment – beach recharge			✓	✓	✓			N	Y	Y	Y
LL35	Dune regeneration			✓	✓				N	N	N	N
LL44	Soft cliff stabilisation – shallow drainage systems						✓		N	N	N	N
LL45	Hard cliff stabilisation – rock netting							✓	Y	N	N	N
LL46	Hard cliff stabilisation – rock bolting							✓	Y	N	N	N
LL48	Hard cliff stabilisation – catch fences							✓	N	N	N	N
LL49	Rock fall protection – rock fall shelter							✓	N	N	N	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 CCA2/3 (general) from Vico Cliffs to South Killiney

Sub-cell	Long List Options – Vico Cliffs to South Killiney
CCA2/3 – General	• Do nothing (LL01) • Do minimum (LL02) • Detached breakwaters (no nourishment) (LL04) • Rock revetment (toe protection) in-front of existing masonry retaining walls (LL08) • Toe Protection – rock (LL16) • Toe Protection – sheet piles (LL19) • Groynes – rock (LL21) • Vertical seawall – concrete wall (LL23) • Beach nourishment – beach recharge (LL32) • Hard rock cliff stabilisation – bolting and netting of loose blocks (potentially with grouting of natural fissures) (LL46, LL47) • Concrete steeped revetment and rock toe protection Option for deferring interventions above, pending further assessment work. Deferment would require ongoing wall/revetment monitoring, minor repairs until the major upgrade works are required. Long list solutions discounted generally in CCA2/3 (with reason): • Relocation of the railway (LL03) – would require numerous new tunnels therefore not feasible from a costing perspective • Revetment – concrete armour units (LL09) –(no benefit over rock revetment, would be more expensive and have a greater visual impact) • Toe Protection – gabions (LL18) (would not provide the required SoP) • Vertical seawall – sheet piles (LL24) (no advantage over concrete seawall) • Set back flood wall (LL28) (not appropriate at this location due to the presence of the cliffs)

Sub-cell	Long List Options – Vico Cliffs to South Killiney
	• Dune regeneration (LL35) (no dunes in this location) • Soft cliff stabilisation (LL44) (not a technically viable solution in this location)

Table 5-7 Long list options for CCA2/3 – A for Vico Cliffs.

Sub-cell	Long List Options – Vico Cliffs
CCA2/3 – A Vico Cliffs	1. Do nothing (LL01) 2. Do minimum (LL02) 3. Rock revetment (toe protection) in-front of existing masonry retaining walls (LL08) 4. Increase bulk of existing rock revetment (LL08) 5. Detached breakwaters (no nourishment) (LL04) 6. Hard rock cliff stabilisation – bolting and netting of loose blocks (potentially with grouting of natural fissures) (LL45, LL46) Option for deferring interventions above, pending further assessment work. Deferment would require ongoing wall/revetment monitoring, minor repairs until the major upgrade works are required. Long list solutions discounted for this specific location (with reason): • Concrete seawall in-front of existing walls (in comparison to rock and shotcrete solutions, this would require a very complex design with very difficult access, larger footprint, toe protection, increased carbon, increased maintenance, has less future adaptation options and no residual material value at end of life) • 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) • Attached breakwaters – rock (not appropriate at this location)

Table 5-8 Long list options for CCA2/3 – B for Whiterock

Sub-cell	Long List Options – Whiterock
CCA2/3 – B Whiterock	1. Do nothing (LL01) 2. Do minimum (LL02) 3. Rock revetment in-front of existing wall (LL08) 4. Detached breakwaters and strengthened and raised seawall (no nourishment) (LL04, LL23) 5. Detached and attached breakwaters with nourishment and repaired seawall (LL04, LL07, LL32) 6. Concrete stepped revetment in-front of existing wall with walkway and raised seawall and rock toe protection (LL11, LL16, LL23) 7. Groynes, nourishment and repaired and raised seawall (LL21, LL32, LL23) Long list solutions discounted for this specific location (with reason): • Concrete seawall and rock toe protection (in comparison to rock solution requires larger footprint that would cut off access to Killiney from Whiterock, higher back wall, toe protection, increased carbon, increased maintenance, has less future adaptation options and no residual material value at end of life) • Toe protection – sheet piles (would not provide the required SoP) • Hard cliff stabilisation – rock netting (not appropriate in this location)

Table 5-9 Long list options for CCA2/3 – C for Killiney Beach.

<table>
<tr><th>Sub-cell</th><th>Long List Options – Killiney Beach</th></tr>
<tr><td>CCA2/3 – C

Killiney Beach</td><td>1. Do nothing (LL01)
2. Do minimum (LL02)
3. Rock revetment (LL08)
4. Concrete seawall with sheet piles and rock toe protection (LL23, LL19, LL16)
5. Detached breakwaters (no nourishment) (LL04)
6. Detached breakwaters with nourishment (LL04, LL32)
7. Groynes with nourishment (LL21, LL32)
8. Beach nourishment (no control) with low concrete wave wall (LL32, LL23)

Option for deferring interventions above, pending further assessment work. Deferment would require beach monitoring.

Long list solutions discounted for this specific location (with reason):
• Attached breakwaters – rock (not appropriate at this location)
• Concrete stepped revetment (in comparison to rock solution requires larger footprint, higher back wall, toe protection, increased carbon, increased maintenance, has less future adaptation options and no residual material value at end of life)
• Hard cliff stabilisation – rock netting (not appropriate in this location)</td></tr>
</table>

Table 5-10 Long list options for CCA2/3 – D for South Killiney.

Sub-cell	Long List Options – South Killiney
CCA2/3 – D South Killiney	1. Do nothing (LL01) 2. Do minimum (LL02) 3. Rock revetment and rock toe protection (LL08, LL16) 4. Concrete seawall with sheet piles and rock toe protection (LL23, LL19, LL16) 5. Detached breakwaters (no nourishment) and rock toe protection (LL04, LL16) 6. Detached breakwaters with nourishment and rock toe protection (LL04, LL32, LL16) 7. Groynes with nourishment and rock toe protection (LL21, LL32, LL16) 8. Beach nourishment (no control) with low concrete wave wall (LL32, LL23) Option for deferring interventions above, pending further assessment work. Deferment would require beach monitoring. Long list solutions discounted for this specific location (with reason): • Attached breakwaters – rock (not appropriate at this location) • Concrete stepped revetment (in comparison to rock solution requires larger footprint, higher back wall, toe protection, increased carbon, increased maintenance, has less future adaptation options and no residual material value at end of life) • Netting and soil nailing of soft cliffs without toe protection measures (natural or engineered) will not stop cliff recession and are not recommended. • Deep drainage of the cliffs is not suitable. The cliff failure mechanism is dominated by toe erosion triggering shallow failures, and groundwater has a limited role.

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 5-11). 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. These two options do not meet 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 8) meet the scheme objectives, the requirements for design life and provide the required Standard of Protection.

As presented in Table 5-11, with the exception of Option 5, all options include Rock toe protection and improving rock revetments at CCA2/3-A (Vico Cliffs). Options 3 and 4 both involve hard engineering structures at the shoreline to protect the cliff and existing structures at CCA2/3-B to D (Whiterock to South Killiney) whereas Options 5 to 8 use variations on beach control structures and beach nourishment to use the beach to protect the cliffs and existing structures from erosion.

Table 5-11 Overview of short list options for CCA2/3.

Option	CCA2/3 – A Vico Cliffs	CCA2/3 – B Whiterock	CCA2/3 – C Killiney Beach	CCA2/3 – D South Killiney
1. Do Nothing	N/A	N/A	N/A	N/A
2. Do Minimum	Do Minimum	Do Minimum	Do Minimum	Do Minimum
3. Rock Revetments	Rock toe protection and improve rock revetment. Localised hard rock cliff stabilisation – bolting and netting of loose blocks (potentially with grouting of natural fissures)	Rock revetment (without public walkway) and repaired/raised seawall	Rock revetment	Rock revetment and rock toe protection
4. Concrete Seawalls	Rock toe protection and improve rock revetment. Localised hard rock cliff stabilisation – bolting and netting of loose blocks (potentially with grouting of natural fissures)	Concrete stepped revetment in-front of existing wall (repaired) with walkway and rock toe protection	Concrete seawall with rock toe protection	Concrete seawall with rock toe protection
5. Detached Breakwaters (no nourishment)	Detached breakwaters (no nourishment). Localised hard rock cliff stabilisation – bolting and netting of loose blocks (potentially with grouting of natural fissures)	Detached breakwaters and strengthened and raised seawall	Detached Breakwaters (no nourishment)	Detached Breakwaters (no nourishment) and rock toe protection
6. Breakwaters with nourishment	Rock toe protection and improve rock revetment. Localised hard rock cliff stabilisation – bolting and netting of loose blocks (potentially with grouting of natural fissures)	Detached and attached breakwaters with nourishment and repaired/raised seawall	Detached breakwaters with nourishment	Detached breakwaters with nourishment and rock toe protection
7. Groynes with nourishment	Rock toe protection and improve rock revetment. Localised hard rock cliff stabilisation – bolting and netting of loose blocks (potentially with grouting of natural fissures)	Groynes with nourishment and repaired/raised seawall	Groynes with nourishment	Groynes with nourishment and rock toe protection
8. Nourishment with/without wave walls and breakwaters	Rock toe protection and improve rock revetment. Localised hard rock cliff stabilisation – bolting and netting of loose blocks (potentially with grouting of natural fissures)	Detached and attached breakwaters with nourishment and repaired/raised seawall	Beach nourishment (no control) with low concrete wave wall	Beach nourishment (no control) with low concrete wall and rock toe protection

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 3.6.1, the MCA contains seven core criteria which are further broken down into sub-criteria. By using the core criteria, the MCA process could identify any "showstoppers". While an option may be technically feasible, other factors such as economic or environmental could rule it out.

Section 5.3.1 outlines the outcome from the 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 3-8 are comparable to each other as 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 3 has significant advantages over other options as it is assumed that the mixture of landside construction and marine works will be cheaper than other options. This option also has significantly less material requirements to construct.

Options 4 & 7 have some advantages over other options. Option 4 requires less rock compared to Option 3, however the concrete structures may require significant temporary works which increases the cost over Option 3. Option 7 has lower construction costs over Options 5 & 6 as it doesn't require marine works, however this option proposes beach nourishment which requires a dredger to pump and obtain the material will make it more costly over Option 3.

Options 5 & 8 have some disadvantages over other options as the cost of constructing the breakwaters would be higher than other options. Option 8 proposes less detached breakwaters compared to other options however the cost of the attached breakwater, concrete seawall and increased beach nourishment will offset this advantage.

Option 6 has significant disadvantages over other options as the number of breakwaters proposed are the highest of all options. This option also proposes beach nourishment which incurs additional costs.

5.3.1.1.3 Maintenance Expenditure

Option 1 has significant advantages over other options as it does not incur any maintenance measures. Option 3 also has significant advantages over other options as the rock structures should require minimal maintenance during design life and a routine and post-storm monitoring plan.

Options 4 & 5 have some advantages over other options as they both have minimal maintenance costs throughout their design life. Option 4 requires a routine and post-storm monitoring plan.

Options 6, 7 & 8 have some disadvantages over other options as regular monitoring of the beaches will be required. Some maintenance to reshape the beaches and potential renourishment will be required throughout the design life.

Option 2 would have a significant disadvantage as works proposed are ad hoc and emergency repairs which are difficult to plan and typically cost inefficient.

5.3.1.2 Safety

5.3.1.2.1 Health & Safety (Construction)

Option 1 has a significant advantage over other options as no construction works would take place.

Options 3 & 7 have some advantages over other options as works are relatively straight forward as there is no extensive excavation required. For Option 3 the rock armour can largely be handled by less-risky land-based plant (following marine material delivery). For Option 7 the rock can be handled by less risky land-based plant, but there is some additional risk associated with the beach nourishment.

Options 5, 6 & 8 have some disadvantages over other options as these options propose breakwaters which require marine works to construct.

Option 2 has significant disadvantages over other options as it relies on unplanned emergency repair works in a difficult coastal environment, which typically carries a higher risk than planned works. Option 4 also has significant disadvantages over other options as there is a need to excavate to construct the concrete seawall in a marine environment. Works could require a cofferdam which increases the health and safety risk of this option.

5.3.1.2.2 Health & Safety (Design Life)

Options 6, 7 & 8 have significant advantages over other options as they propose beach nourishment. This increases access on the beach by creating larger, wider and safer beaches.

Option 3 has some advantages over other options. There is a risk of the public walking/climbing on the revetments. There is also the potential for the revetments to reduce the usable area of the beach which could lead to members of the public being cut off by the tide, but this can be mitigated by providing access points through the revetments. Maintenance of the revetments should be very limited and therefore maintenance related H&S risks should be minimal.

Options 4 & 5 have some disadvantages over other options. Similar to Option 3, both options have elements of rock structures on land in the form of revetments or rock toe protection and therefore carry similar risks. However, Option 4 proposes complex concrete seawalls at Whiterock and Option 5 proposes detached breakwaters. Both of these structures carry extra risk for beach users and swimmers.

Option 1 & 2 have significant disadvantages over other options as no interventions other than reactive emergency works in Option 2 are proposed. This could result in failure of the existing defences and impacts on the railway and the publicly accessible areas rendering them unsafe.

5.3.1.3 Accessibility & Social Inclusion

5.3.1.3.1 Community

Options 5, 6, 7 & 8 have some advantages over other options as the beach areas will primarily stay the same. However, hard structures proposed in these options may have some disadvantages for recreational use of the beach.

Option 2 would have some disadvantages over other options as it proposes reactive repair works which would result in further erosion and damage to areas used by the public and an impact on operational train services. For Options 3 & 4, the placement of rock/concrete seawall along the coastline would restrict the use and amenity value of the existing beach area.

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 6 & 8 have significant advantages over other options. Both options propose an enhanced beach amenity area and will not impact on any existing access points to the beach. Access will likely be improved as a result of beach nourishment.

Options 5 & 7 have some advantages over other options as the majority of existing access points will be maintained. For Option 5 only one access point has been identified to be directly impacted from the proposed seawall and for Option 7 the groynes have the potential to limit access along the beach.

Option 2 would have some disadvantages over other options as it proposes reactive repair works. This would result with continuous erosion of the beach which will limit access to and along the beach over time. Options 3 & 4 also have some disadvantages as the imposition of the hard structures may impact the existing alongshore access.

Option 1 has significant disadvantages over other options for access. Under this option, no works would be proposed which would result in continued coastal erosion and direct impacts to the rail line and access to the amenity beach area.

5.3.1.3.3 Social & Recreational Facilities

Options 2, 6, 7 & 8 have some advantages over other options as the beach areas will primarily stay the same or be enlarged. However, some hard structures proposed in these options may have some disadvantages for recreational use of the beach, particularly surfers. Option 2 has some advantages, however, over time continued erosion will potentially impact on existing social and recreational facilities at this location.

For Options 3 & 4, the placement of rock/concrete seawall along the coastline would restrict the use and amenity value of the existing beach area. For Option 5, the detached breakwaters have the potential to impact recreational activities, particularly watersports.

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 direct impacts to the rail line and access to the beach area.

5.3.1.4 Integration

5.3.1.4.1 Compatibility with Development Plans

Option 4 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 a smaller footprint area when compared with Option 3 and scores highly for integration (landscape) as it includes more 'compact' defences that are more likely to retain existing shoreline characteristics than other options.

Option 3 has some advantages over other options. It aligns with high level coastal protection and coastal area management objectives within the development plans. Option 3 scores highly (but not as high as Option 4) for integration (landscape) as it is of a scale appropriate to the existing character. The rock toe results in the loss of some of the beach reducing the coastal recreation amenity.

Option 2, 5, 6, 7 & 8 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 works would only be undertaken to maintain the existing defences with no improvements to account for climate change and therefore the objectives of the plans would not be met. Options 5, 6, 7 & 8 have some disadvantages as they would impact on Marine Policy / Map Based objectives with a greater potential for impact upon marine sites than other options.

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 3, 5 & 7 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 require significant volumes of material.

Options 2, 4, 6 & 8 have some disadvantages over other options. Option 2 has some disadvantages over other options. Coastal zone management and coastal area protection are identified as important within the relevant Development Plans. The disadvantage relating to this option is that works would only be undertaken to maintain the existing defences with no improvements to account for climate change and therefore the objectives of the plans which include the need for climate adaptation would not be met. 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. While Options 4, 6 & 8 align with the TCCSAP by protecting the existing rail infrastructure, they require a significant volume of materials for the hard structures and beach nourishment which is a disadvantage in terms of carbon footprint.

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 3-8 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 using part of the coastline near Killiney Beach (CCA2/3-D). Providing the intervention works can accommodate the East Coast Trail, this option will support the Transport Strategy.

Option 2 has some disadvantages 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 Environment

5.3.1.5.1 Biodiversity

Option 1 will provide significant advantages over other options as there would be no construction work and therefore, no resulting biodiversity loss, degradation or disturbance (noise/pollution). European and nationally designated species and habitats would avoid the construction and operational effects that come with other options and natural processes would be able to proceed unconstrained.

Option 2 has some advantages as there is less impacts from the targeted emergency works. In the short to medium term these potential effects will be less so than the following options which require a greater magnitude of construction. However, both Options 1 and 2 present greater issues in the long term than other options. This is due to the habitat loss that will occur due to unmanaged coastal erosion. There is also the potential that the existing rail line could release embedded oils and contaminate the shore and sea.

Options 3-8 are comparable to each other as impacts from construction and operation and similar for each option. Construction works such as construction of hard structures, upgrade of existing structures, beach nourishment and marine structures have the potential to impact GI species. For operation, any increased access to the beach areas may increase disturbance on QI birds and marine mammals.

5.3.1.5.2 Landscape, Visual & Seascape

Option 4 has significant advantages over other options as there is an opportunity to incorporate more compact defences that tie in with existing walling and features associated with the amenity use of sections of this coastline.

Option 3 & 7 have some advantages over other options as both options propose rock structures that are natural material that would tie in with the context of this stretch of coastline. However, compared to Option 4, Option 3 requires a larger land-take which would have a negative impact. Option 7 proposes groynes which will contrast along the shoreline.

Options 2 & 8 have some disadvantages over other options. Option 2 has disadvantages as continued reactive intervention would compromise the character of the area by relying on a patchwork of reactive intervention measures. Option 8 has similar impacts to Option 5 & 6 due to the breakwaters. However, the smaller footprint of this option reduces the impact.

Options 1, 5 & 6 have significant disadvantages over other options. Option 1 has significant disadvantages as the continual coastal erosion at its current rate will result in significant deterioration of the coastal landscape. Options 6 & 7 propose detached breakwaters which would generate significant landscape impacts and is not consistent with the character of the area.

5.3.1.5.3 Archaeology, Architectural & Cultural Heritage

Options 3, 7 & 8 have some advantages over other options. They have no potential to directly or indirectly impact the identified SMR sites but there are potential indirect setting and visual impacts to NIAH and RPS sites. Unrecorded material culture and archaeological heritage (if present on site) has the potential to be directly impacted by these options.

Option 2 has some disadvantages over other options. Allowing continued disruption to the coastline through reactive interventions would cause adverse effects to archaeology, architectural and cultural heritage sites. Options 4 & 5 have some disadvantages as they do have the potential to impact on one SMR Zone of Notification and the potential for significant indirect setting and visual impacts to occur on one SMR site.

Option 1 has significant disadvantages over all ‘do something’ options. Allowing continued disruption to the coastline would cause significant adverse effects to archaeology, architectural and cultural heritage sites.

5.3.1.5.4 Marine Archaeology

Options 1 & 2 have significant advantages over other options as no works are proposed within the intertidal or marine elements. Options 3 & 4 have significant advantages over other options as there are no works proposed within the intertidal or marine elements.

Options 5, 7 & 8 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.

Option 6 has significant disadvantages over other options as it has a larger marine footprint.

5.3.1.5.5 Noise & Vibration

Options 3, 5-8 are comparable to each other and have some advantages over other options. There will be temporary and short-term impacts due to construction but no long-term operational impacts. Short-term construction noise from the mobile plant will be localised and temporary.

Option 4 has some disadvantages over other options as it involves more intrusive construction works which are closer to Noise Sensitive Locations compared to other options. Options 1 & 2 have some disadvantages over other options. In the short term 'do something' options will have a greater noise impact than Options 1 and 2 due to the proposal of construction works. However, Options 1 & 2 will have long-term operational impacts due to increased likelihood of a less reliable/disrupted rail network which will increase road traffic levels and therefore transport related noise levels.

5.3.1.5.6 Air Quality

Options 3-8 will have a long-term positive operational impact due to maintaining the existing rail line and so reducing reliance on private vehicles.

Options 3-5 have significant advantages over other options as although there are potential construction impacts such as vehicle emissions and dust, there is no beach nourishment maintenance required. Construction phase impacts would be likely considered short term and dust mitigation can be put in place.

Options 6 -8 have some advantages over other options. While they have similar impacts as 3-5, the proposal of beach nourishment increases the risk of dust impacts and requirement for ongoing monitoring and maintenance.

Options 1 and 2 have significant disadvantages over all other options due to the potential for long-term operational impacts that would occur as a result of the rail line being disrupted/suspended. Option 2 also has some potential dust and air pollution impacts as a result of general construction.

5.3.1.5.7 Carbon Management

Options 3, 4, 5, 6, 7 & 8 facilitate operational phase reliance on public transport and reduce reliance on private vehicles for the long term.

Options 4 & 7 have significant advantages over other options as they had the lowest Whole Life Carbon (tonnes CO2e) of all options.

Options 6 & 8 have some advantages over other options as they have preferable levels of Whole Life Carbon (tonnes CO2e) compared to other options.

Options 3 & 5 have some disadvantages over other options as they have unfavourable levels of Whole Life Carbon (tonnes CO2e) 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 significant advantages over other options. 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 3, 6 & 7 have some advantages over other options as they will have minimal impacts on groundwater elements as there are no proposed below-ground construction requirements.

Options 4, 5 & 8 have some disadvantages over other options as below ground structures may have impacts on groundwater.

5.3.1.5.9 Geology & Soils

Option 5 has significant advantages over other options because the mitigation measures proposed will have minimal/moderate impacts to localised areas.

Options 2, 3, 6, 7 & 8 have some advantages over other options. In the short-term, Option 2 has no significant impacts, in the medium to long term the minimal interventions may not be sufficient to protect the coastline from erosion due to climate change. Options 3, 6, 7 & 8 will result in minimal/moderate impacts but are advantageous due to the anticipated level and scale of disturbance caused.

Option 1 has some disadvantages over other options, there will be no impacts in the short term but in the medium to long term climate change may cause erosion of the local geology.

Option 4 has significant disadvantages as the concrete sea walls with rock toes protection will cause high disturbance to geological resources in CCA2/3-C and CCA2/3-D, as well as the other proposed features having a minimal/moderate impact on geology. The proposed defences may also result in the release of contamination from a former mine at Whiterock.

5.3.1.5.10 Materials & Circular Economy

Options 1, 2, & 3 have significant advantages over other options as they all have the lowest materials consumption score compared to other options.

Options 4 & 7 have some advantages over other options as they have a lower materials consumption score compared to other options.

Option 5 has some disadvantages as it scored a high materials consumption score compared to other options. However, it did not score as highly as options 6 & 8.

Options 6 & 8 have significant disadvantages over other options as they scored a very high materials consumption score compared to other options.

5.3.1.5.11 Waste

Options 1 & 2 have significant advantages over other options as no waste would be generated due to no/minimal works proposals. Options 6 & 7 also have significant advantages over other options because no waste will be generated from the removal of existing structures and they have comparatively low wastage potentials.

Options 3 & 8 have some advantages over other options as minimal waste would be generated from removal of existing structures and they have comparatively low wastage potentials.

Options 4 & 5 have some disadvantages over other options as they have comparatively high wastage potentials.

5.3.1.5.12 Traffic & Transport

Options 3- 8 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, within this CCA the road network is further inland than the rail line. 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 & 3 have a significant advantage over other options. Option 1 does not propose any construction works. Option 3 has a comparatively low materials requirement compared to other options. Despite this, it is a significant amount of rock to deliver and place. Following the delivery of rock by marine plant, the revetments can be constructed using land-based plant. Construction of rock revetments are slow, but straightforward.

Option 7 has some advantages over other options. While similar in nature to Option 5 & 6, groynes are generally smaller structures and easier to construct.

Option 2, 6 & 8 have some disadvantages over other options. Option 2 has some disadvantages as it proposes emergency works only, which would be reactive and could prove difficult to construct quickly in a marine environment. Option 6 is similar to Option 5 however the footprint is smaller than Option 5 which reduces the construction complexity. Option 8 is similar to Option 7 but with the addition of concrete seawalls which increase the complexity of this option.

Option 4 & 5 have significant disadvantages over other options. Option 4 has significant disadvantages due to the difficulty of constructing large concrete structures, some of which are in a marine environment. Works for the seawall may need a cofferdam to create a dry environment to work in. Works for the concrete revetment are complex and costly. Option 5 proposes a large number of detached breakwaters which are challenging to construct in open water. Option 5 has a bigger footprint of breakwaters compared to other options hence the lower score.

5.3.1.6.2 Rail Service Impact

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

Options 3-8 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 extended disruptions to the rail service 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

Options 3, 4 & 5 have some advantages over other options. All options require a routine and post-storm monitoring plan but they will require minimal maintenance during design life. These options may also require inspection and maintenance for concrete netting and rock bolting. Option 4 may require patch works to the concrete seawall, but this would be infrequent.

Option 1 has some disadvantages over other options as although there is no requirement for maintenance, monitoring would be required to keep the public safe. Options 6-8 have some disadvantages over other options. While they have the same requirements as Options 3-5, these options propose beach nourishment. As beach levels will require ongoing monitoring and maintenance of beach nourishment. A monitoring programme will be required to ensure beach levels are consistent to provide the required Standard of Protection.

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 has a significant advantage over other options as it could be adapted to account for changes in climate change, either through increased nourishment, maintenance or raising of seawall.

Options 3, 4, 6, & 7 have some advantages over other options. Similar to Option 8, Options 6 & 7 can be adapted through increased nourishment and maintenance of structures. Option 3 could have beach nourishment introduced but additional beach control structures such as groynes or breakwaters may be required to efficiently hold the beach. In addition, rock revetments can be added to or rebuilt relatively easily if required. For Option 4, the seawall could potentially be raised if required.

Option 5 have some disadvantages as although beach nourishment could potentially be in the future, but the breakwater design would not be efficient to hold this material.

Option 1 & 2 have significant disadvantages over other options as there is no works/minimal works proposed and therefore limited opportunity for adaptation.

5.3.1.6.5 Residual Risk

Options 5 has significant advantages over other options as failure of the breakwater would be slow progressive failure and even if damaged the breakwaters would still be effective in reducing the wave energy at the shoreline.

Option 4 has some advantages over other options as failure of the revetment would be slow and progressive so sudden and catastrophic failure is unlikely.

Option 2 has disadvantages over other options as failure of concrete seawalls can be sudden.

Options 6 to 8 all rely on beach to prevent erosion. Under a significant storm event large than the design event there is potential for significant erosion of the beach which would result in increased wave energy at the shoreline.

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. Option 2 also has significant disadvantages over other options as small scale, localised repairs can manage risk in the short-term, but it would not eliminate weaknesses in the existing hard defence, which could lead to rapid failure.

5.3.1.7 Planning Risk

In regard to planning risk, Options 1 and 2 have significant advantages over the other options as they would require little or no planning consents and consequently no or limited planning risk.

Options 3, 4, 7 & 8 have some advantages over other options as the proposed upgrades to the coastal defences align with planning policy for long term protection against the backdrop of climate change. Options 3, 4 & 7 score highly for integration (landscape) and this will help to reduce the potential for third party objection. Options 3 & 7 require less volume of material than other options. Option 7 & 8 score highly for access and amenity, again helping to reduce potential for third party objection. However, the works across all options 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.

Option 5 & 6 have some disadvantages over other options. Options 5 and 6 scores poorly for landscape and a lack of integration, including the use of breakwaters, is also likely to attract objection.

5.3.2 Summary

A summary of the MCA outcomes are shown in Table 5-12.

Options 3, 6 & 7 have been identified as the Top-Ranking Short List Options to be taken forward. The basis for each of these options are as follows:

- Option 3 is the top-ranked option for Integration and joint top in Environmental with Option 7. Option 3 scored comparatively well with Economy, Safety, Engineering and Planning.
- Option 6 is the joint top-ranking option with Option 8 for Accessibility & Social Inclusion
- Option 7 is the joint top-ranking option in Safety and Integration. Option 7 scores comparatively well with Accessibility & Social Inclusion, Integration and Planning.

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

Table 5-12 Short list MCA Outcomes Summary

	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6	Option 7	Option 8
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 toe protection and improve existing structures (CCA2/3-A). Rock Revetment with repaired/raised walls and rock toe protection where needed (CCA2/3-B to D) (Short List Option 3)
- Option B: Rock toe protection and improve existing structures (CCA2/3-A). Rock groynes with beach nourishment and repaired/raised walls and rock toe protection where required (Short List Option 7)
- Option C: Rock toe protection and improve existing structures (CCA2/3-A). Rock Breakwaters with nourishment and repaired/raised walls and rock toe protection where required (Short List Option 6)

During design development it became apparent that concrete wave walls at the rear of the beach in sub-cells CCA2/3-C and CCA2/3-D should be included in all options to provide additional protection to the toe of the cliffs whilst also allowing existing public footpath to be incorporated. This has therefore been taken forward into the concept design development.

These options all meet the scheme objectives, the requirements for design life and provide the required Standard of Protection. The options all adopt a “Hold the Line” approach by protecting the shoreline on its current alignment using upgraded defences to improve the 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 modelled and costed. This section presents the engineered solutions, summarises the modelling and costing 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 considers 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 level 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 and raised walls for the full coastal cell. These revetments will vary in form along the frontage relative to the wave exposure, foreshore type/level, the geometry of the existing defences and to integrate with the various natural and man-made shoreline features.

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

CCA2/3-A mainly comprises hard cliffs however there are two inlets where the railway line sits on a large masonry wall exposed to wave action. Access to these locations is extremely challenging and only possible via marine plant. Therefore, the only feasible option in these locations is to place rock armour at the toe of the existing structures. This rock armour will prevent undermining of the structures as well as dissipating the wave energy before it reaches the structures and therefore protecting the structures from structural damage which could ultimately lead to failure of the walls supporting the railway line.

In CCA2/3-B there is an existing masonry wall at the toe of the cliffs/engineered slopes with some rock protection at the toe to the north of the bay (Whiterock Beach area). The structural condition of this wall is not known but it will not be sufficient to protect the cliffs/slopes against erosion over the Project design horizon. A full height rock revetment is proposed in front of the existing wall under this option. The addition of good quality rock to manage coastal flooding and erosion risk is commonplace as the rock revetment will dissipate wave energy therefore protecting the existing wall from wave impact. However, to prevent wave run-up and overtopping onto the base of the cliffs causing erosion of the toe of the cliffs, the required height of the revetment is likely to be higher than the existing walls. Therefore, it has also been assumed that raising of the existing walls will also be required.

The main assumption of this option is that the existing masonry walls will remain in-situ and the raised walls will be added on top of the existing wall. This assumption will be confirmed following analysis of the ground investigation data that is to be collected. The visual dilapidation survey results combined with what is known of the make-up of the existing defences supports the assumption that these structures will be able to take the additional loading. However, this remains a key risk.

In CCA2/3-C (Killiney Beach), the rock revetment and raised wall will continue as far as the café. No works are proposed in front of the café as the railway line here is protected by a large masonry wall to the rear of the café, and access to the café will be maintained. The rock revetement and raised wall will then continue between the café and the existing gabions at Killiney Beach car park and underpass.

South of the gabions, there is an existing concrete path at the rear of the beach for about 150m. This will be incorporated into the proposed works and extended to the south of CCA2/3-C and into CCA2/3-D. The existing concrete path will be raised and there will be a wave wall to the front and rear of the path. The rock revetment will extend up to the front wall and this will dissipate wave energy and reduce wave overtopping onto the path. The rear wave wall will provide some additional slope stability to the toe of the cliffs whilst also protecting the toe of the cliff from overtopping from larger waves.

CCA2/3-D will be a continuation of the revetment and raised concrete path in CCA2/3-C. To the south of CCA2/3-D, just north of the river outlet a buried rock bund is proposed to prevent longer term erosion of the beach impacting the railway line. This is applicable to all options.

The geometry of the rock revetment is determined through wave overtopping calculations to determine the height of revetment required to limit the overtopping. 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.

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, particularly in the Whiterock beach area. 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), geotextile and reinforced concrete (in-situ and pre-cast).

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:

- Non-complex and comparatively low-cost construction;
- Minimal maintenance burden and expenditure;
- Robust solution;
- Reduced impact on swimming and surfing conditions;
- Low material consumption and waste;
- Preferable option for carbon management; and
- Low impact on noise, vibration and air quality.

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

- Impact on access and amenity at Whiterock Beach;
- Beach will continue to lower in front of the revetment; and
- Rock revetments will have potential for adverse landscape / seascape and visual effects.

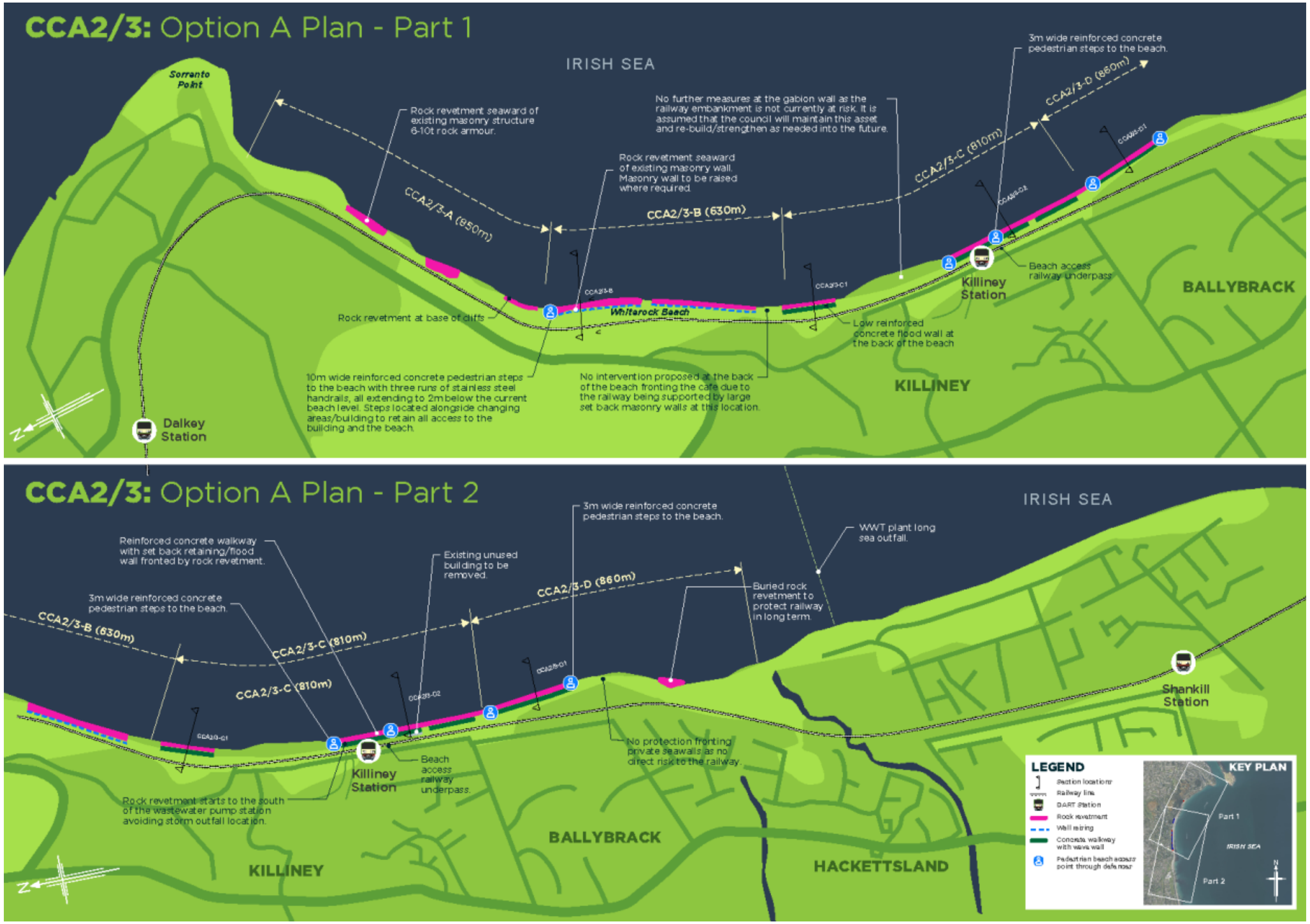

Figure 5-1 CCA2/3 Option A Concept Design Plan

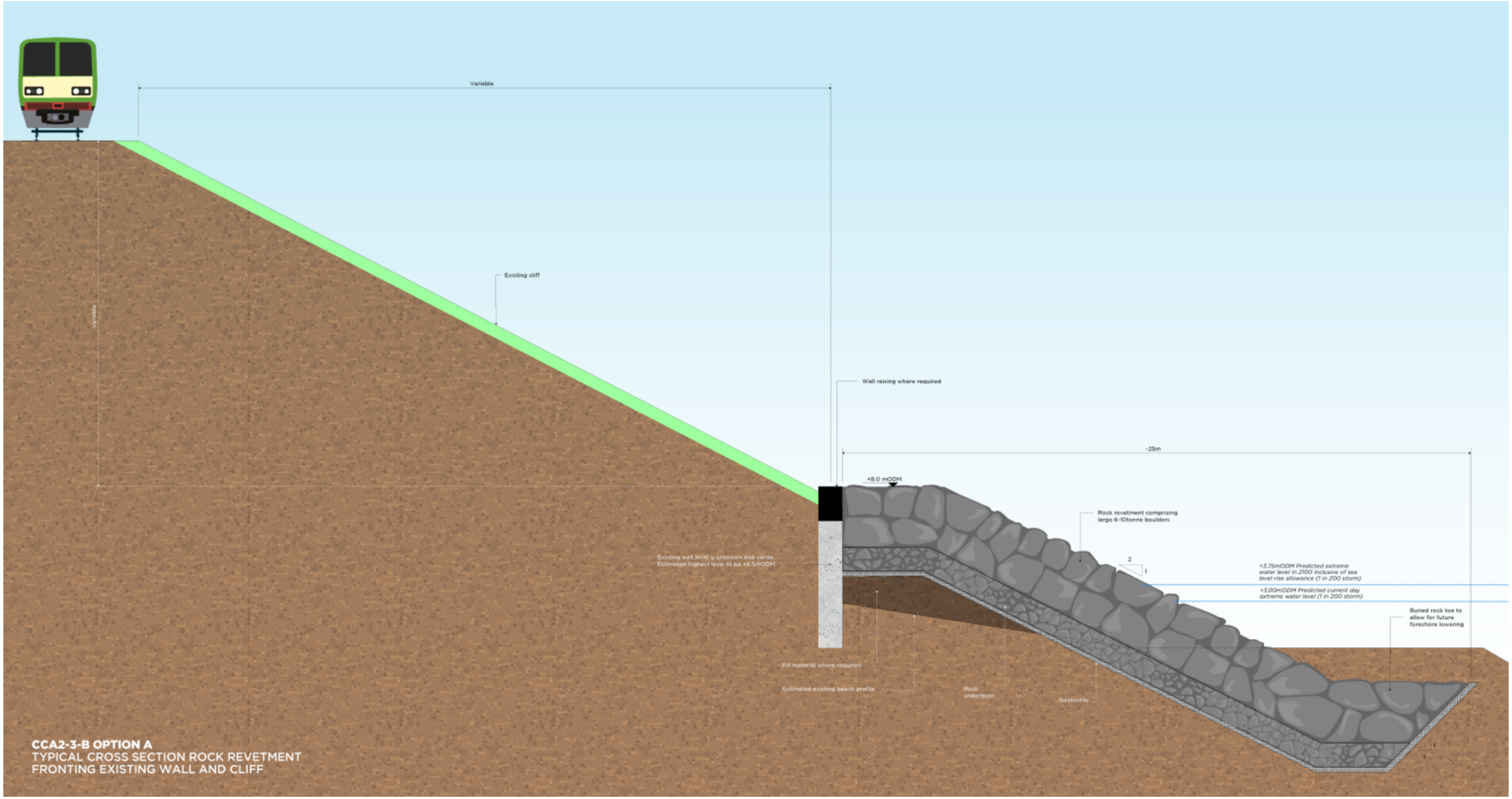

Figure 5-2 CCA2/3-B Option A Typical Cross Section

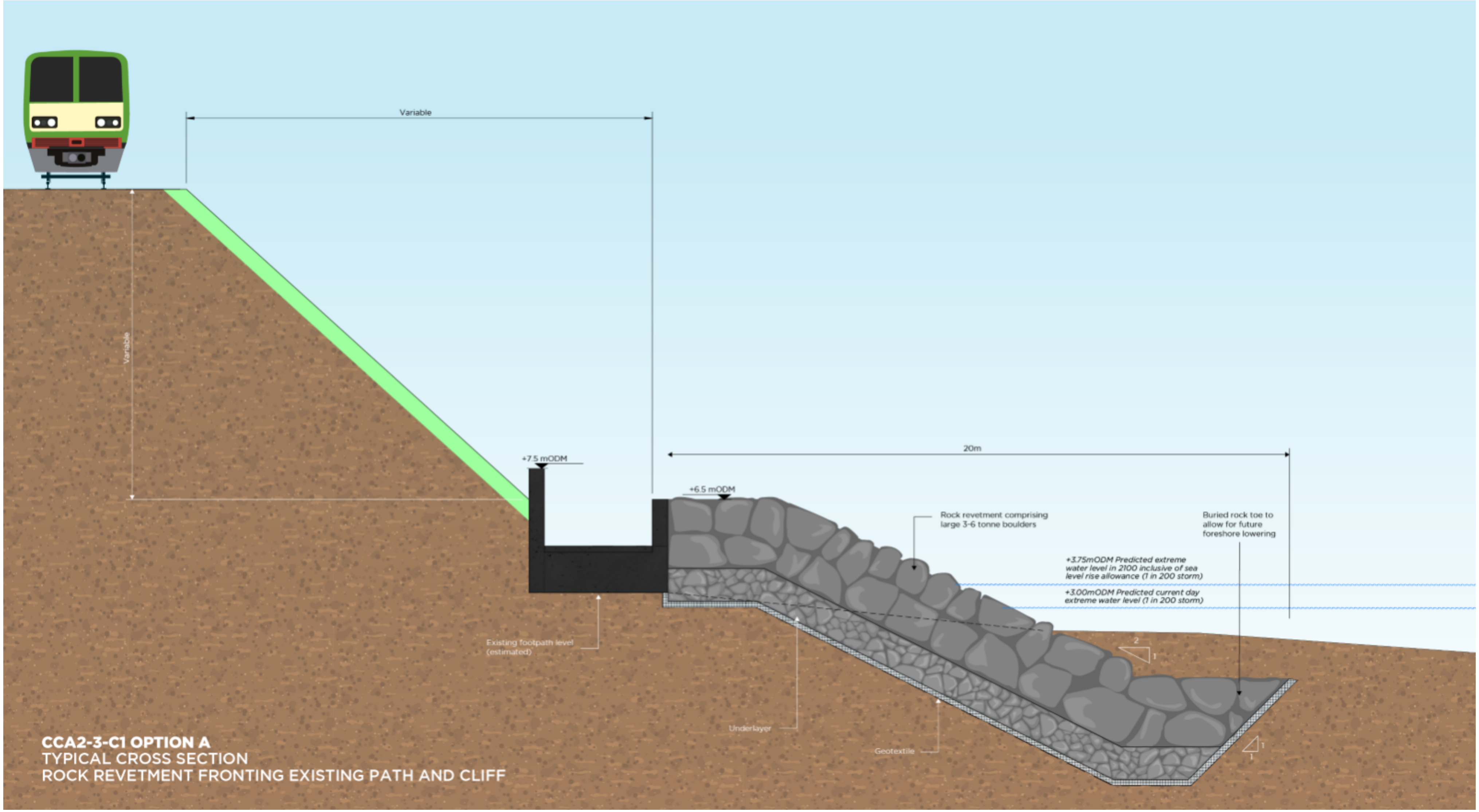

Figure 5-3 CCA2/3-C Option A Typical Cross Section

5.4.1.2 Option B

The Concept Design for sub-cells CCA2/3-A is the same as presented for Option A in Section 5.4.1.1.

In the remaining sub-cells, Option B comprises beach nourishment and beach control structures (rock groynes) with raised seawalls at the rear of the beach. This option acknowledges that Whiterock and Killiney beaches and the surrounding environment are important and well used amenity locations for the local community and therefore reduces the impact on access and use of the beach. Whereas Option A dissipates all wave energy at the shoreline, Option B uses the beach to dissipate wave energy before it reaches the shoreline. As a beach is a natural system that responds dynamically to the action of the sea, its form will change over time; the beach slope may steepen, the crest width of the beach could cut back, and material can be lost either alongshore or cross-shore out to sea. Beach control structures (the rock groynes) are designed to minimise the losses of beach material. However, even with beach control structures in place, any scheme involving beach nourishment must be planned to include periodic monitoring and maintenance to ensure the beach is sufficient to perform its function. Initial numerical modelling of this option indicates the beach would require 'topping up' with additional material approximately every ten years to prevent the beach eroding back to the shoreline and to maintain a beach that provides protection to the existing structures and cliffs at the shoreline. This option would require a Beach Management Plan to be prepared which sets out the maintenance and monitoring requirements for the beach and defines the responsible parties.

A major advantage of beach management solutions is their adaptability over the longer term. The Option B concept design proposed for each of the sub-cells is summarised by Figure 5-4. This is further detailed by the concept design engineering drawings in Appendix E.

5.4.1.2.1 CCA2/3-B (Whiterock Beach)

The beach at Whiterock is known to be a well-used amenity beach, however with future climate change the beach is expected to erode and access to the beach around the rock outcrop to the south of Whiterock beach will limit access and use of the beach. The railway line in this location is on top of the cliffs/engineered slopes. At Whiterock beach the railway line is supported by a larger masonry wall with a small rock outcrop at the toe. To the south of the beach, the railway line sits at the top of soft cliffs/engineered slopes, the toe of which are protected by a masonry wall at the base with some ad hoc rock protection at the toe of the wall. Protecting the masonry walls and cliffs from wave impact and subsequent erosion or undermining is key to protecting the railway line. Along the section of soft cliffs, it is also important to prevent wave overtopping the top of the existing masonry wall and eroding the base of the cliffs.

This option involves beach nourishment at Whiterock, which 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 structures. However, a beach alone is unlikely to provide the required SoP because as water levels rise, the height of the beach that would be needed to reduce the wave height sufficiently would be too high to be feasible. Therefore, raising of the existing masonry walls at the toe of the cliffs/slopes will still be required with this option.

There are various approaches in how the required SoP over the design horizon can be achieved through beach management and associated beach control structures. Two approaches are outlined below but combinations of these options are also possible (i.e. initially placing a beach for a 25-year design horizon):

1. At the time of construction, accept a high initial capital cost and place the design beach required to provide the SoP for year 2100. This will likely result in the beach suffering higher losses over the longer term due to the beach profile extending into deeper water/more exposed conditions during the earlier part of the design horizon. However, future maintenance and associated costs will be for addressing those losses rather than future capital works, therefore, future spend should be reduced and it should be unnecessary to have to intervene in short term (as the beach has been designed for sea level rise allowance, which has not yet been realised over the short term). Due to the significant initial renourishment required, this approach may be resisted by the public and statutory authorities as it will be a sudden and drastic change in the character of the beach; and
2. Adopt an adaptive and phased approach whereby the initial works provide the SoP for a defined period. Regular renourishment would then be required to consistently provide the SoP over the design horizon.

For example, every 10 years the beach is renourished and at these interim periods the beach size is increased to respond to climate change. This option will have a significantly lower capital cost but increased maintenance costs. This option will avoid over-design of the beach required for the option above as the design requirements can be re-assessed at each intervention period based on beach monitoring data. This option is likely to be more acceptable to stakeholders due to the progressive building of the beach volume.

For the purposes of the concept stage design, option 1 has been assumed.

The size and profile of the renourished beach is determined through wave overtopping and wave runup calculations to determine the height and width of beach required to reduce the waves impacting the existing structures. The design beach accounts for predicted losses over the period between recharge campaigns (assumed to be ten years) which have been estimated through numerical modelling (see Appendix C for details)

Beach control structures, (groynes) are included to hold the beach material. The proposed Y shaped rock groynes serve two purposes. The 'Y' section of the groyne dissipates some of the wave energy of the incoming waves and therefore the beach behind these sections is generally more stable as it is exposed to less wave action. Therefore, the groynes have been positioned with the 'y' sections in front of the more vulnerable sections of the existing walls. The groynes also prevent the transport of beach material along the beach and keep it within each bay resulting in stable beaches being formed. Numerical modelling was undertaken to determine the best layout of the groynes. Appendix C provides details of the analysis and proposed layout.

Wave overtopping calculations will inform the height increase required for the walls and the required wall height will vary depending on wave exposure and the structure geometry. The height increase will be reduced as much as possible during later stages of design.

5.4.1.2.2 CCA2/3-C and CCA2/3-D (Killiney Beach)

The existing beach at Killiney is relatively healthy and stable, and long-term accretion of the beach is predicted in this area (Appendix C). Therefore, in this section less beach control structures are required to hold the renourished beach. The height and width of the existing beach will be increased through beach nourishment to reduce the wave action at the shoreline. Similar to Option A, the existing footpath will be raised to provide a formal path at the rear of the beach with a wall to the rear to prevent waves reaching the toe of the cliffs.

To the south of this section (south of Killiney Beach Car park and the gabion baskets), the beach naturally becomes slightly lower and narrower, therefore this is reflected in the proposed design beach profile. Rather than trying to significantly increase the size of the beach in this area, which would require a number of beach control structures to maintain it, less beach recharge will be placed in this area and the existing footpath at the rear of the beach will be extended and raised. A sheet pile and rock toe protection is included to prevent undermining of the rear wall if the beach levels do drop.

For concept stage, at the very south of this section a rock groyne is included to prevent any loss of the beach material to the south. The need for this groyne would be assessed through further numerical modelling during design development.

The proposals use the following material types: quarried rock (delivered by sea), geotextile, reinforced concrete (in-situ and pre-cast), beach material (delivered by sea) and sheet piles.

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:

- Improved amenity and access at Whiterock;
- High adaptability;
- Scored well for H&S; and
- Scored well for air quality, carbon management, water resources, geology and soils.

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

- Will require ongoing monitoring and maintenance;
- Groynes and nourishment will change wave conditions resulting in surfing impact; and

Lower score for materials, maintenance and circular economy due to beach nourishment.

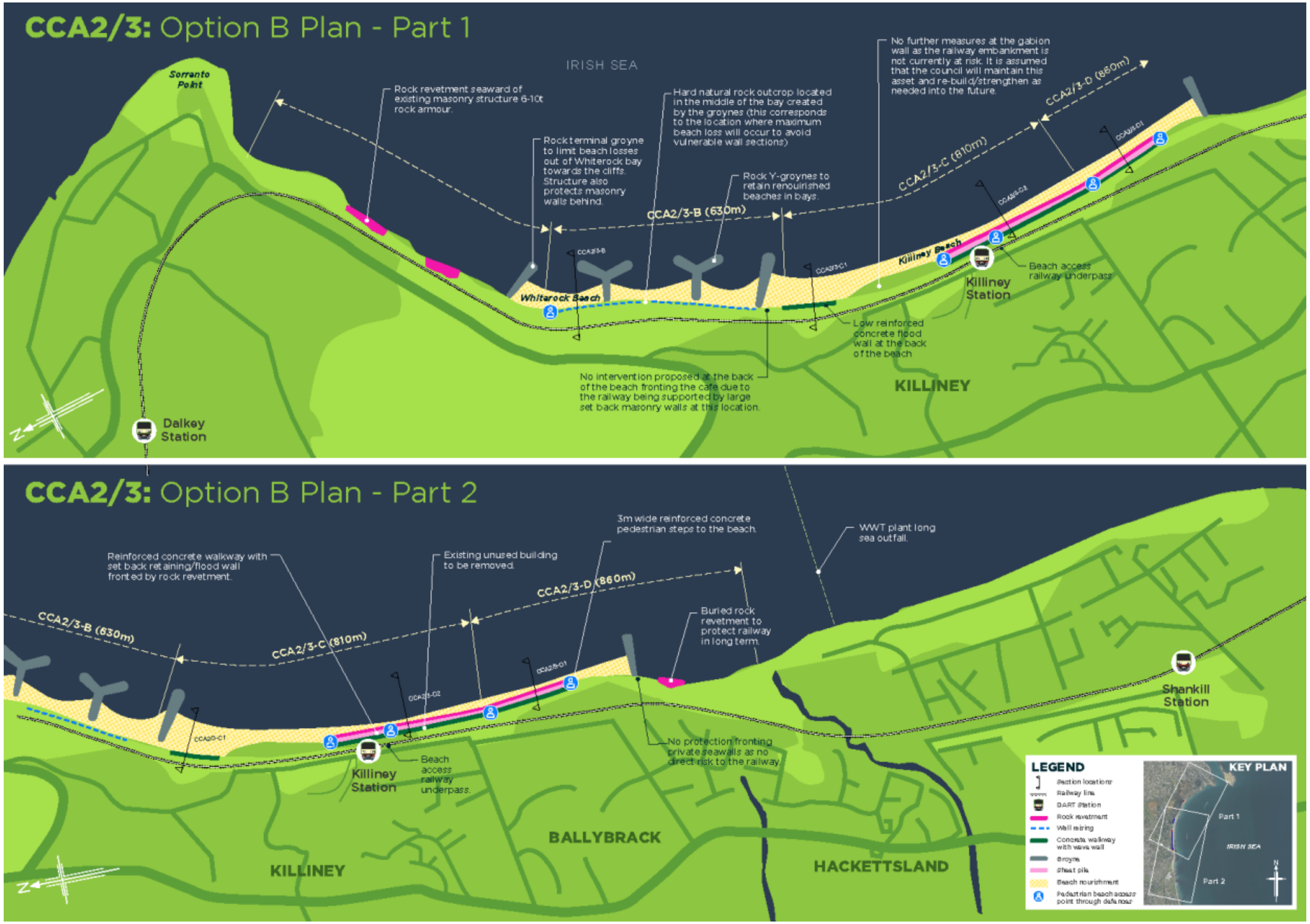

Figure 5-4 CCA2/3 Option B Concept Design Plan

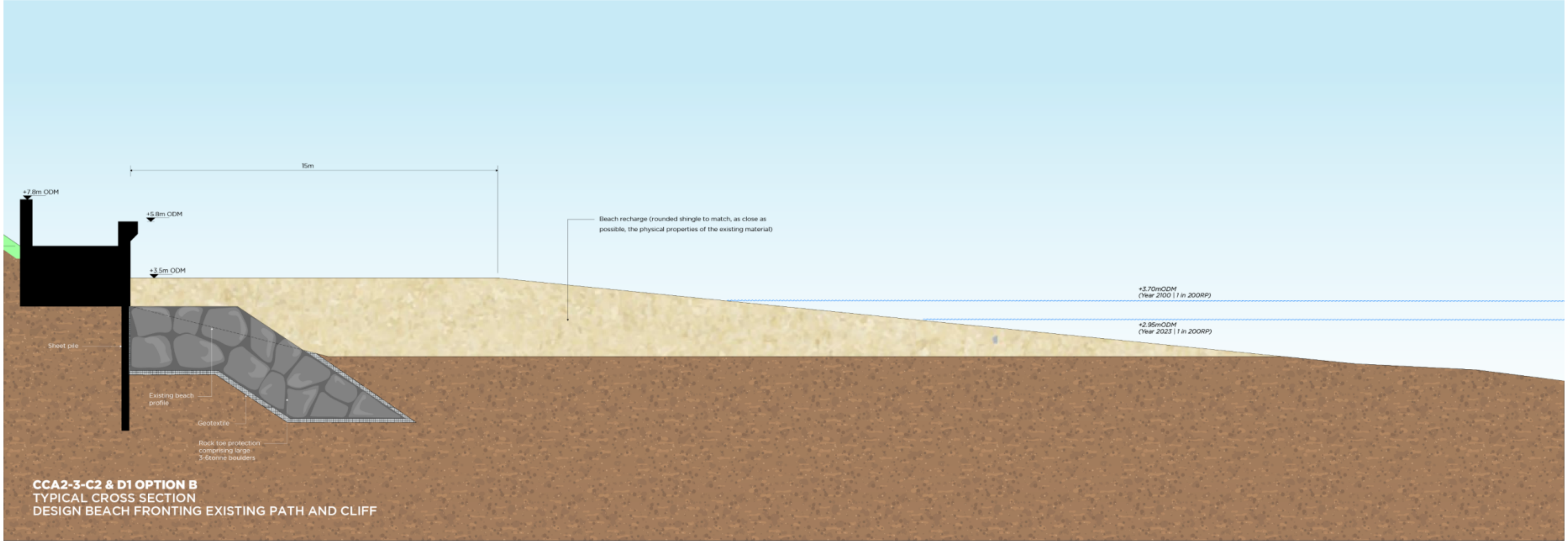

Figure 5-5 CCA2/3-D1 Option B typical cross section

5.4.1.3 Option C

The Concept Design for sub-cell CCA2/3-A is the same as for Option A in Section 5.4.1.1.

In the remaining sub-cells, Option C is similar to Option B in that it uses the beach and beach control structures to provide the protection against erosion to the railway line but Option C uses detached breakwaters rather than groynes to hold the beach and reduce the wave energy.

The Option C concept design proposed for each of the sub-cells is summarised by Figure 5-6. This is further detailed by the concept design engineering drawings in Appendix E.

Detached breakwaters dissipate the energy of the incoming waves thereby reducing the erosion in the lee of the breakwaters. Detached breakwaters are advantageous over groynes as they do not impact the beach area, however, they do create a significant impact in the nearshore area and will affect the current, swimming and surfing conditions, as well as being visually intrusive from the majority of the beach area.

Typically, the beach accretes behind the breakwaters, forming 'tombolos' and erodes between the breakwaters. The amount of erosion between the breakwaters depends on the length of the breakwaters, the spacing between them and the distance offshore of the breakwaters. Therefore, it is important to ensure the correct layout of the breakwaters to avoid significant erosion in between them which could even increase erosion compared to the existing scenario. For the concept stage design, two breakwaters are proposed at CCA2/3-B and C where the cliffs and existing structures are most vulnerable to erosion. Numerical modelling was undertaken for this layout which indicated that in the lee of the northern breakwater the accretion would be relatively small (approximately 5m) and between the breakwaters, erosion of the beach back to the shoreline would occur within a ten year period if recharge was not included. The erosion in the shadow zone is due to this location being close to a region of diverging sediment transport. Thus, a reduction in the transport in the shadow causes the transport rate to increase northwards and southwards from the middle of the shadow zone. This modelling suggests that similar to Option B, beach nourishment with a beach crest width of approximately 20m would be required to prevent the beach cutting back to the shoreline in a ten year period. This allows for some cut-back of the crest during storms which is not accounted for in the sediment transport modelling.

Given the results of the modelling, a sensitivity analysis was undertaken to assess the effect of three breakwaters in CCA2/3-B and C. The results showed some improvement compared to two breakwaters, with slightly more accretion occurring behind the northern breakwater (8.0m) in years 1 to 5 and erosion of approximately 10m in the northern bay. Therefore, this layout would still need significant capital beach nourishment. The concept design has assumed that 2 breakwaters will be required with beach nourishment with a 20m beach crest width. However, further modelling and analysis would be required through design development to determine the optimum layout of breakwaters and beach nourishment and an additional breakwater may be required which would have cost implications. There is a high risk that the cost of this option would increase through option development.

To the south of CCA2/3-C and CCA2/3-D Option C is the same as Option B with beach nourishment and raised concrete walls with toe protection at the back of the beach.

The proposals use the following material types: quarried rock (delivered by sea), geotextile, reinforced concrete (in-situ and pre-cast), beach material (delivered by sea) and sheet piles.

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:

- Improved amenity and access along the whole beach;
- High adaptability; and
- Scored well for H&S.

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

- Will require ongoing monitoring and maintenance;
- Significant impact on swimming and surfing conditions;
- High visual impact; and
- Lower score for materials, maintenance and circular economy due to beach nourishment.

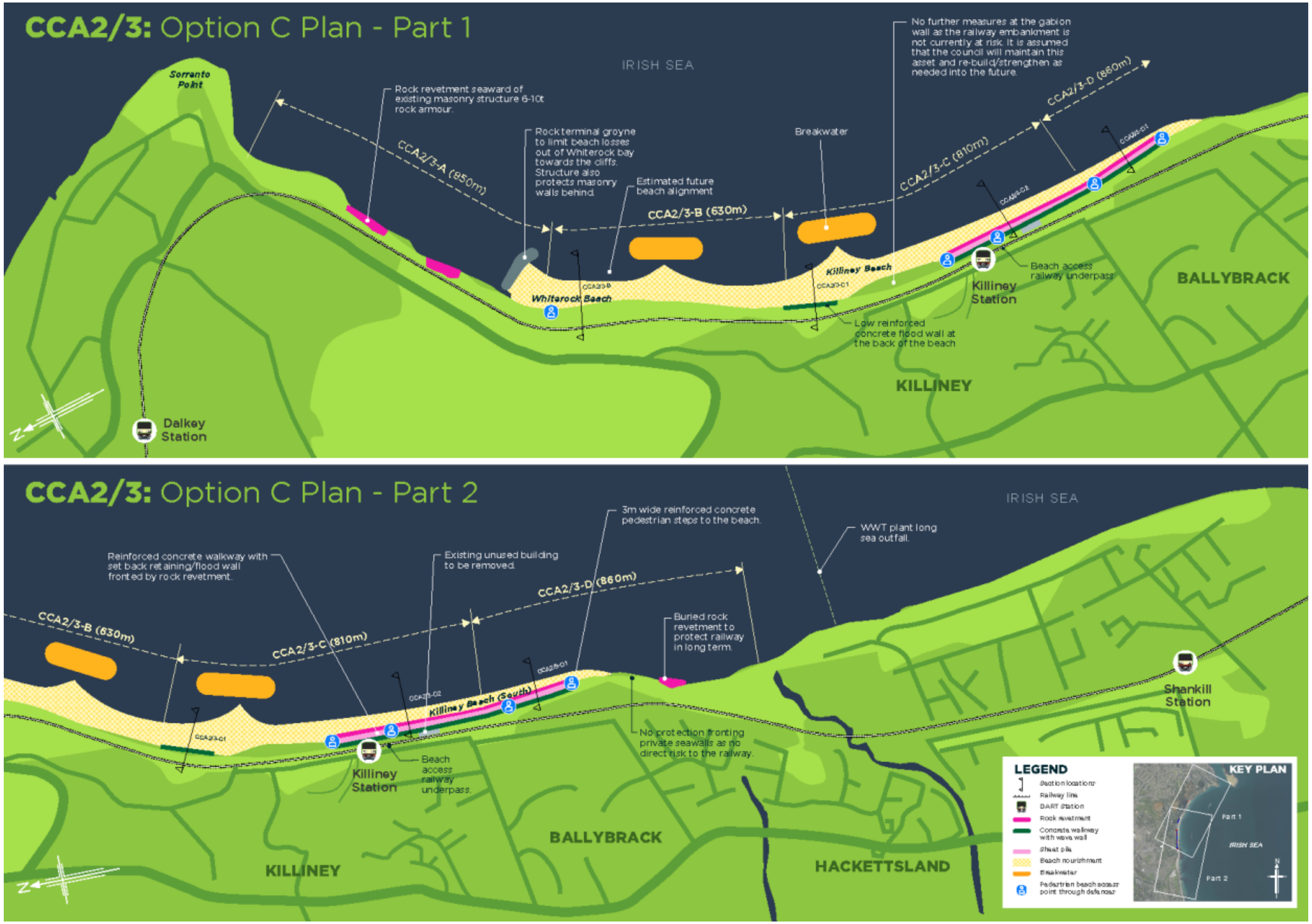

Figure 5-6 CCA2/3 Option C Concept Design Plan

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, with Option B costing 7% more than Option A and Option C costing 53% more than Option A. This is primarily due to Options B and C requiring beach nourishment in addition to the rock structures with has a higher cost. Option C is the most expensive option due to the larger rock volumes, complex construction of the detached breakwaters requiring marine based plant combined with 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 5-13 provides a summary of how Option A (rock revetments) was identified as the EPO for CCA2/3. The table below concentrates on the main differentiators between the options.

Table 5-13 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 retains the character of the frontage by minimising the change in alignment of the bay, resulting in the lowest visual impact when viewed from afar/above. Option C, and to a lesser extent Option B, increases the carrying capacity of the beach for amenity and retains pedestrian access from Killiney Beach to Whiterock Bay, but it has a direct impact on bathing, surfing and the character of the bay. Option C will have the highest visual impact and would introduce additional public H&S bathing risk.
Technical	Option A is a relatively straightforward option to design using standard coastal protection measures. Option B has the highest maintenance obligation and less technical certainty as it relies on the beach to provide the primary defence. Option C also relies on the beach, but the breakwaters provide shelter to high risk areas. Options B & C both rely on future beach monitoring and maintenance to maintain the Standard of Protection, making it a less preferred technical solution.
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 the rockwork and the beach nourishment due to the need to work around the tides. Option C will be more difficult to construct than Option B as it will require marine works to construct the breakwaters. None of the options will require APIS.
Environmental	Option A has the smallest footprint and lowest impact on the marine environment. Option B and Option C both require dredging to provide the beach nourishment material.
Sustainability	Option A minimises the volume of construction materials. In addition to high volumes of materials for the initial construction works, Option B and Option C both rely on future re-nourishment to maintain the Standard of Protection.
Consenting	Option A appears to have a potentially greater alignment with planning policy than Options B and C, however, it does score lower on comparison for amenity and access. Option A has less risk of impacting upon marine underwater archaeology than Option B and C. Options A and B have a similar scoring in terms of potential landscape visual impacts. Options A and C have a lower score than Option B for potential impacts upon on land archaeology. Option C includes breakwaters which reduce its integration and increase its risk of objections based on landscape visual impacts. Option C appears to require a greater volume of material than Options A and B.

Key Metrics	Summary of Outcomes
	All Options include risk of having to undertake IROPI and the potential delay and increased chances of refusal of permission as a consequence. Option C, followed by Option B are considered to have the greatest community and environmental impact and the highest likelihood of stalled or refused permission through the planning process.
Cost	The capital cost for Option A is the lowest cost option. Option B costs 7% more than Option A and Option C costs 53% more than Option A.. The capital cost for Option A comprises 8% facilitation and temporary works, 92% 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.

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 with 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 5-14, with their associated priority and justification for the ranking. Refer to Appendix F for Works Priorities Drawings which outlines the extent of the works within the sub-cells.

Table 5-14 Works prioritisation justification (EPO Option A)

Sub-cell (length, m)	Description of works (Priority)	Justification for prioritisation
CCA2/3-A (890m)	Rock revetment at base of vertical masonry wall (Priority 3)	Existing masonry structures are serviceable through maintenance with no coastal risk of undermining. Manage structural risk through inspection and monitoring programme but works may be needed in the medium term as structures degrade and climate change impacts are realised. Monitor natural cliffed sections for potential instabilities.
CCA2/3-B1 (45m)	Rock revetment at base of vertical masonry wall (Priority 4)	As per CCA2/3-A. Pocket beach and the changing rooms structure provide further protection to the structural walls in this location. Works may be needed in the long term when beach levels drop and as climate change impacts are realised. Manage future risk through coastal monitoring.
CCA2/3-B2 (235m)	Rock revetment at base of vertical masonry wall (Priority 1)	Multiple wall failures in the past and evidence of wave overtopping onto the upper slope and undermining at beach level. Analysis confirms high risk location.
CCA2/3-B3 (55m)	No works required (no priority)	Comprises hard rock outcrop. Rock structures tying in from B2 and B4 will provide further protection to this sub-cell. Monitor natural cliffed sections for potential instabilities.

Sub-cell (length, m)	Description of works (Priority)	Justification for prioritisation
CCA2/3-B4 (275m)	Rock revetment at base of vertical masonry wall (Priority 1)	As CCA2/3-B2.
CCA2/3-C1 (160m)	Rock revetment and concrete seawall (Priority 3)	Beach stable and analysis shows that the beach is currently high/wide enough to provide protection to the set-back railway slope. Works may be needed in the medium term as climate change impacts are realised. Manage future risk through coastal monitoring.
CCA2/3-C2 (260m)	No works required (no priority)	Council maintained seawall protects a buffer of amenity area that protects the set-back railway slope.
CCA2/3-C3 (120m)	Concrete seawall with rock toe protection and walkway (Priority 2) and rock revetment (Priority 3)	Analysis shows the shoreline is vulnerable to wave overtopping leading to erosion and undermining of the railway slope. Future beach erosion combined with climate change impacts present an increasing risk with time supporting an adaptive management approach to works. Manage future risk through coastal monitoring.
CCA2/3-C4 (275m)	Concrete seawall with rock toe protection and walkway (Priority 2) and rock revetment (Priority 3)	As CCA2/3-C3
CCA2/3-D1 (235m)	Concrete seawall with rock toe protection and walkway (Priority 2) and rock revetment (Priority 3)	As CCA2/3-C3
CCA2/3-D2 (325m)	No works required (no priority)	Private property walls protects a buffer of land that protects the set-back slopes supporting the railway from coastal erosion.
CCA2/3-D3 (95m)	Rock revetment (Priority 4)	Analysis shows that the set-back railway line is not vulnerable in the short-medium term. Works may be required in the long term should the beach be lost as climate change impacts are realised. Manage future risk through coastal monitoring.
CCA2/3-D4 (215m)	No works required (no priority)	No risk to the set-back railway identified into the long term. Review this into the future through coastal monitoring.

The prioritisation of works for the Emerging Preferred Option A are summarised in Table 5-15.

Table 5-15 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 revetment at Whiterock (B2 and B4)	2030
Priority 2	Concrete seawall at Killiney (C3, C4, D1)	2050
Priority 3	Rock revetments (A, C1, C3, C4, D1) and concrete seawalls (C1)	2050 – 2075
Priority 4	Rock revetment at Whiterock (B1) and South Killiney (D3)	2075 - 2100

5.6.2 Implementation Options List

The Implementation Options developed for the CCA are provided in Table 5-16. This includes various options for prioritising works to align with increasing coastal hazard and risk to the railway line.

Table 5-16 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 4** Rock revetments (A, B1, B2, B4, C1, C3, C4, D1, D3) and concrete seawalls (C1, C3, C4, D1) [100%]	No works needed	No works needed	No works needed
Implementation Option 2 (IO2)	**Priority 1 to 3** Rock revetment at Whiterock (B2, B4), concrete seawall at Killiney (C3, C4, D1) and Rock revetments (A, B1, C1, C3, C4, D1) and concrete seawalls (C1) [93%]	No works needed	No works needed	**Priority 4** Rock revetment at Whiterock (B1) and South Killiney (D3)
Implementation Option 3 (IO3)	**Priority 1 and 2** Rock revetment at Whiterock (B2, B4) and concrete seawall at Killiney (C3, C4, D1) [46%]	No works needed	**Priority 3** Rock revetments (A, C1, C3, C4, D1) and concrete seawalls (C1)	**Priority 4** Rock revetment at Whiterock (B1) and South Killiney (D3)
Implementation Option 4 (IO4)	**Priority 1** Rock revetment at Whiterock (subcells B2 and B4) [27%]	**Priority 2** Concrete seawall at Killiney (C3, C4, D1)	**Priority 3** Rock revetments (A, C1, C3, C4, D1)	**Priority 4** Rock revetment at Whiterock (B1)

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
			and concrete seawalls (C1)	and South Killiney (D3)
Implementation Option 5 (IO5)	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 5-17 below provides an outline of the results of the analysis for all of the relevant criteria.

5.6.3.1 Economy

Both IO1 & IO2 score similar in relation to economy. Both options require significant capital investment due to the proposal of rock revetments across the majority of CCA2/3. Both IO's would also require a routine and post-storm monitoring plan with minimal maintenance throughout their design life which scores favourably.

IO3 proposes less rock revetments prior to 2050 in comparison to IO1 & IO2 which results in less significant capital investment. However, rock revetments are potentially required post-2050 and therefore further investment would be likely needed then. IO3 is similar to IO1 & IO2 in terms of maintenance expenditure however the minimal maintenance would only be until 2050 whereby the additional rock revetments would be required.

IO4 proposes rock revetments only at subcells B2 and B4 at Whiterock and as such it requires less significant capital investment in comparison to the other IO's. However, further investment would be required by 2050 in addition to the capital works that would be required post 2050. Therefore, this would increase the overall cost of the works due to economies of scale. IO4 would require more monitoring and maintenance of beach in comparison to IO1-3 where works have been deferred.

IO5/Do Minimum requires minimal capital investment to carry out the reactive repairs and maintenance. While the capital investment would not be as significant as the other IO's, the nature of undertaking extensive and frequent reactive repairs and maintenance provides little cost certainty, especially should a wall or slope failure result in the destabilising of the perched railway line and a resultant in the need for a significant and expensive repair.

5.6.3.2 Safety

Both IO1 & IO2 propose significant amounts of rock revetments throughout CCA2/3. The volume of rock revetments proposed as part of these options brings both construction and operational health and safety risks. For construction, works can be carried out from land which reduces the risk compared to marine works (rock would be delivered by sea). However, the amount of construction works proposed in comparison to other IOs increases the construction health and safety risk significantly. For the operational phase, there is potential for members of the public to climb on the revetments increasing the risk of injuries. The volume of rock will also reduce the usable area of the beach particularly in the northern section of the CCA. Should members of the public try to access this area via the headland there is a risk they may get cut off due to high tides. Operational maintenance for both IO's should be minimal.

IO3 reduces the amount of construction required in comparison to IO1 & IO2 which reduces the construction risk significantly. The same operational risks apply with regards to the rock revetments however due to the significant reduction in volume of the proposed revetments this risk can be reduced.

IO4 proposes significantly less work in comparison to IO1-3 and therefore the construction health and safety risk is reduced. While the construction works are reduced, the potential requirement for emergency repair works are increased to manage the risk to the public. Similar to IO1-3 the risk of members of the public interacting with the revetments is present. Due to the lower level of protection that IO4 proposes, overall both construction and operational health and safety risks are high.

IO5/Do Minimum proposes no construction works. However, due to the nature of reactive repair works that would be required the health and safety risk is high. Similar to IO4, this option introduces a much increased health and safety risk due to the low level of protection that currently exists.

5.6.3.3 Accessibility & Social Inclusion

Due to the level of rock proposed as part of IO1 and IO2 options, access to the beach and coastline in this area would be negatively impacted. While existing beach access points will be maintained through these options, access along the beach is likely to be curtailed. However, access at the back of Killiney Beach will be improved.

While IO3 proposes rock revetments at Whiterock, the rock revetments through central/southern Killiney will be deferred which has advantages over IO1 & IO2 for beach access, but it retains the improved access behind the beach. As with the other IOs existing access will be maintained, however less of the beach will be curtailed by the rock revetment which provides advantages over the other IOs.

IO4 proposes less rock revetment than the other options which minimises the impacts on the beach in comparison to the other IO's. However, due to the level of protection that IO4 provides for the coastline through central Killiney, there is an increased likelihood that cliff/slope falls would result in further sections of the beach being fenced off to manage public health and safety risk, which will reduce beach accessibility. IO5/Do Minimum also provides significantly less protection than IO's1-4 and therefore it has a significant disadvantage in comparison to the other options due to the risk of extreme storm events.

5.6.3.4 Integration

All IO's with the exception of IO5/Do minimum are aligned to development, climate and transport plans. However, IO1-4 all impact on Boundary Objective 130 within the Dún-Laoghaire-Rathdown County Development Plan as they have the potential to impact the environmental sensitivities and the character of the area. IO3 provides an advantage over the other options as it provides adequate costal protection in line with the objectives with less material in comparison to IO1 & IO2. While IO4 and IO5/Do Minimum require far less material, neither provide an adequate level of protection and therefore do not provide any advantages.

5.6.3.5 Environment

The extent of works along with the significant amount of material required as part of both IO1 and IO2 has disadvantages in comparison to other IO's. They have the potential to impact nearby European sites, would generate a significant amount of waste and could have the potential to impact the landscape character of CCA2/3. IO3 also has the potential to impact the European sites located nearby, however due to the lesser amount of works proposed and material required this provides an advantage in comparison to IO1 and IO2. Both IO4 and IO5/Do minimum propose significantly less works and therefore less impactful on the environment. However, they do not provide a sufficient level of protection for the coastline which is not a significant advantage over other options.

5.6.3.6 Engineering

Both IO1 & IO2 will require large volumes of rock armour, making construction slow due to the Project's scale. The constructability of these options are challenging as the material is assumed to be delivered by marine plant and the proposals require extensive rock revetment works. The construction will not impact railway operations. Both IO's will need routine and post-storm monitoring but minimal maintenance during their design life. These options have limited adaptability. The residual risk of both options is low. Rock failure is unlikely to be immediate; it would be progressive and unlikely to cause sudden or catastrophic failure.

IO3 requires significantly less rock armour than IO1 and IO2 which reduces the amount of construction required which simplifies the constructability of this option. Similar to IO1&IO2, railway operations will not be impacted during construction. The level of maintenance may increase due to the works that would be deferred in comparison to IO1 & IO2. The design includes provisions for future adaptation as climate change impacts are realised. Rock revetment failure would likely be gradual, not sudden, leading to reduced performance. Concrete seawall failures at C and D could increase cliff erosion risks without causing abrupt failure. Delaying works may weaken existing defences.

IO4 in comparison to the other options will have a shorter construction period due to the reduced amount of works proposed. Railway operations will not be impacted. In comparison to the other IO's, the deferred works may allow coastal erosion to continue, which may require ad hoc and emergency repairs, which could be complex if upper slopes or cliffs supporting the perched railway fail. The design for IO4 includes future adaptation. While rock revetment failure is unlikely to be sudden similar to IO1-3, it provides lesser protection in comparison. There is a slight risk that the deferred works could lead to weaknesses in the existing hard defences within CCA2/3.

The reactive nature of the works that would be required for IO5/Do Minimum along with the increased requirement for monitoring, maintenance and minimal opportunities for adaptation means that this option has significant disadvantages over the other options. There is also an increases risk of rapid failure of the existing defences at CCA2/3.

5.6.3.7 Planning Risk

Both IO1 & IO2 provide protection along the coastline at CCA2/3 for a longer period in comparison to the other options. However, due to the higher potential for environmental impacts of these options there is a higher planning risk involved.

Both IO3 & IO4 require significantly less works in comparison to IO1 & IO2, therefore the impact on the environment is reduced which provides an advantage in comparison to IO1 & IO2. However, as IO3 provides protection for a longer time than IO4, it is considered to have significant advantages.

IO5/No Minimum requires no consents.

5.6.4 Summary

A summary of the MCA outcomes are shown in Table 5-17. Implementation Option 3 for EPO Option A has been identified as the Emerging Preferred Scheme to be taken forward. The basis for this is summarised as follows:

- IO3 is the top-ranked option under Economy, Accessibility & Social Inclusion and Safety.
- IO3 is also top ranked for Climate and joint top rank for Local Environment

Table 5-17 Implementation Options MCA outcomes summary

	IO1	IO2	IO3	IO4	Do min
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 3 (IO3) for EPO Option A**. The Emerging Preferred Scheme (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 revetment at Whiterock (510m length of CCA2/3-B)
- Concrete seawall at Killiney (395m southern part of CCA2/3-C and the 235m northern part of CCA2/3-D).

These works are summarised by

Figure 5-7,

Figure 5-8 and

Figure 5-9.

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

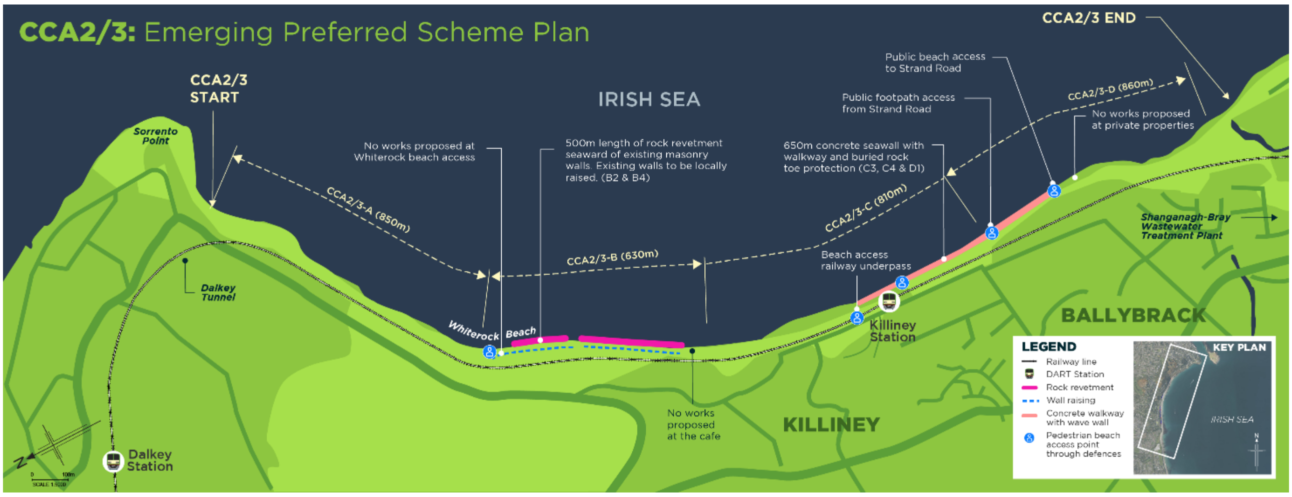

Figure 5-7 CCA2/3 Emerging Preferred Scheme Plan

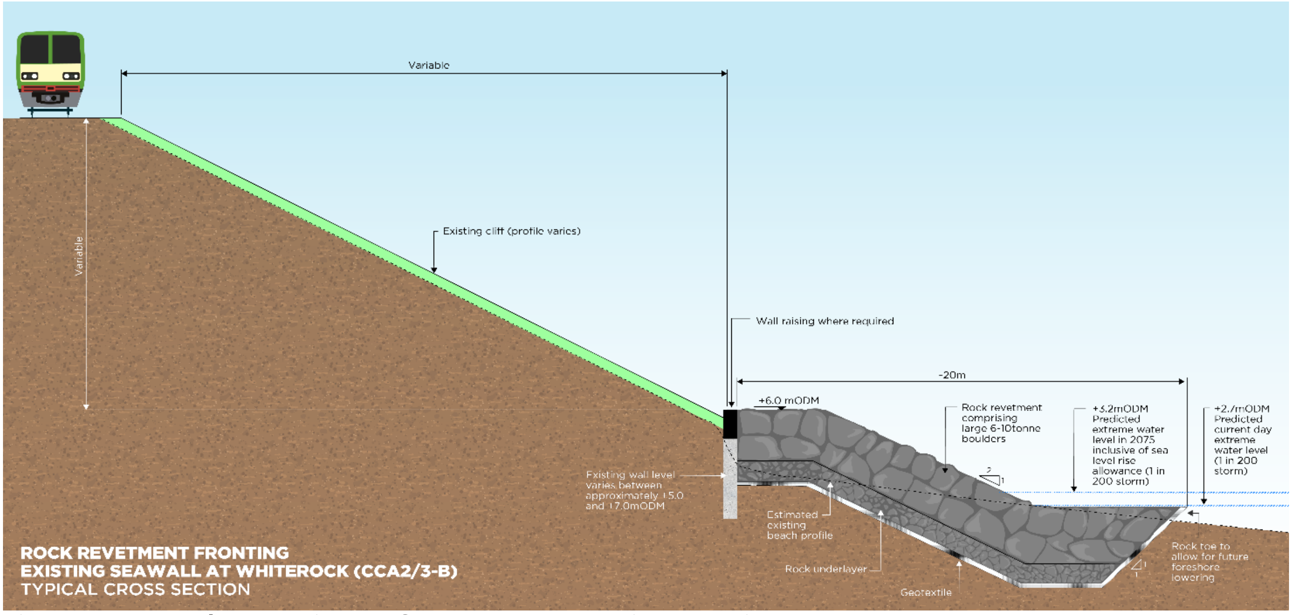

Figure 5-8 CCA2/3 Emerging Preferred Scheme Section at Whiterock

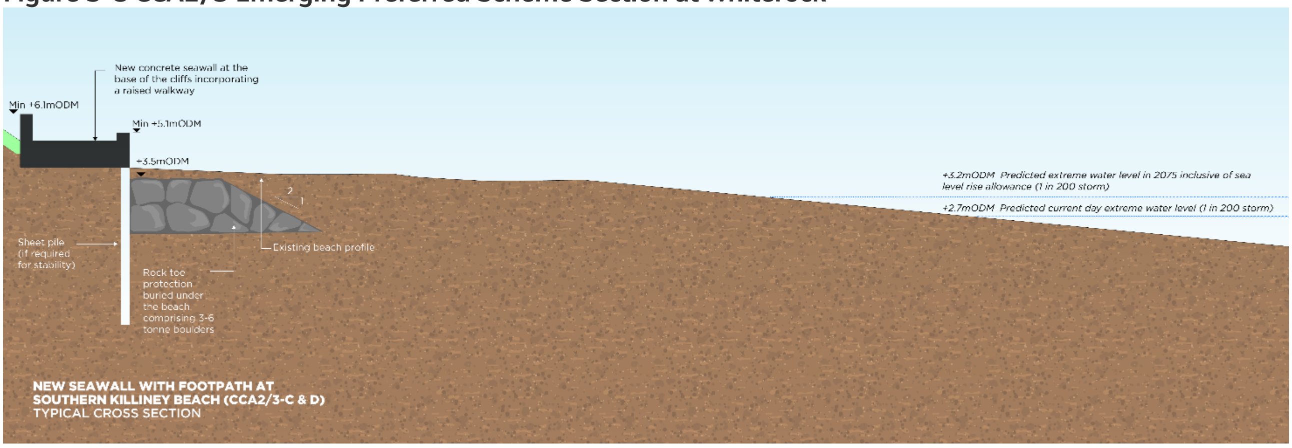

Figure 5-9 CCA2/3 Emerging Preferred Scheme Section at Killiney

6. Non-Statutory 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 with repaired/raised walls at Whiterock and the extension of the walkway to the south of Killiney with a new concrete seawall with rock toe protection.

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 Revetment

A rock revetment will be constructed on the beach in-front of the existing structures at Whiterock. The rock revetment will comprise 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. The rock grading size will be confirmed during preliminary design but is expected to be in the range of 6-10 tonnes grading. This rock will be of high quality to ensure that it meets and exceeds the design life. It will be placed over an underlayer of rock on a high-performance geotextile to minimise the risk of fines being lost through the existing structure.

The rock revetment will absorb wave energy, reduce wave run up and overtopping. This will reduce the height needed for the back wall and it will reduce wave forces on it.

7.1.2 Wall Raising

The raising of existing vertical walls is required at Whiterock to prevent wave action eroding the toe of the cliffs/slopes which could lead to the failure of the slopes/cliffs supporting the railway line.

The existing walls are largely masonry walls from the original railway construction. The masonry is of good quality. Provided wave forces do not increase on this wall and the wall is maintained they have capacity to be raised (following maintenance). At concept design stage, it has been assumed that these will be raised with reinforced concrete.

7.1.3 Seawall with Walkway

In central Killiney beach there are existing walkways along the rear of some sections of the beach. To provide the required Standard of Protection (a 1 in 200 year storm protection level), a new seawall will be constructed south of the existing walkway. This seawall will have upstand wave walls to protect the toe of the slopes/cliffs supporting the railway line. This seawall will incorporate a raised walkway and will provide continuous access along the rear of the beach with access down onto the beach provided at regular intervals. Rock toe protection will be buried in-front of the new seawall to protect the seawall in the event of beach draw down in a storm.

7.1.4 Interfaces

The following interfaces will be developed during design development:

- Tie-in detail to the beach café;
- Access steps – As a minimum, the existing access points to the beach will be maintained. During design development the potential need for additional access points will be reviewed; and
- Services and utilities – All existing services will be identified during preliminary and detailed design and suitable details developed to avoid impact on these services.

7.2 Concept Scheme Constructability

This section provides a preliminary outline of key delivery areas.

7.2.1 Construction Methodology

The Emerging Preferred Scheme being taken forward for CCA2/3 comprises rock revetments, raising of sections of seawall and the extension of existing footpath sections to provide a seawall and walkway. The following methodology is an example of how these structures may be constructed. The appointed contractor may choose to construct the structures in a different way.

The works would need to be split into work fronts to enable a reasonable duration to be achieved. It would be expected that more than one structure would be constructed at any one time via 2 or 3 work fronts.

It has been assumed that the rock armour material will be imported by rock barge. The rock would be discharged into marine stockpiles as close to the shoreline as possible and placed into position using shore based plant.

There is a possibility the beach access point at Station Road could be modified to allow construction equipment onto the beach to allow land-based construction. The rock would still need to be brought to the work areas via marine methods. The use of a temporary causeway may be used to retrieve and place the rock.

Rock barge deliveries 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 from the supplier.

For each work front, one long reach excavator with one articulated dump truck on turnaround would be needed. A long reach excavator would be needed to retrieve the rock at low tide from the marine offload position and place the rock into the dump truck to be moved to a temporary stockpile on the beach. With this approach the rock works could be undertaken with limited tidal restrictions.

The rocks would be placed individually and built up in layers as per the design. Each layer would require to be inspected for compliance.

An allowance should be made for temporary protection of the works due to inclement weather which poses a risk to the partially constructed elements. This may be low risk but should be considered as it has a cost associated with it.

As the rock armour is acting as primary armour, placement to specification is extremely important and this may result in slow progress, especially if areas need to be revisited to bring them into specification. Notwithstanding this, a specialist marine sub-contractor should be able to place rock armour based on the cross section shown in the concept design at around 5-10m per day.

Lengths of existing concrete wall will need to be raised at Whiterock. These may need to be cast in situ due to the varying levels of the existing walls. If this is the case, then this activity could be completed once the underlayer is installed to provide a level platform to work from. The concrete could be imported in and placed with a skip on an excavator or use a mobile concrete pump if it can reach and the volumes of concrete warrant the use of a pump.

For the concrete walkway, the use of precast would be possible and remove the need to transport wet concrete to the work areas which would be significantly challenging in some areas. The concrete walkway would need to be constructed prior to the installation of the rock toe protection as the existing ground levels are favourable for this activity.

The concrete walkway sections could be brought in via road and offloaded at the beach access point and then transported to the work area. Due to the weight of these a mobile crane would be needed to lift into position.

7.2.1.1 Staging Areas and Compounds

It is expected that the construction phase would be managed from one main site compound with smaller satellite compounds along the length of the works providing smaller welfare facilities. The use of the railway is precluded due to the railway being on embankment along the length of CCA2/3.

Any marine plant engaged on the Project would require using Dublin or Dún Laoghaire Harbour for bunkering, crew change, shelter in poor weather etc. so an allowance has been made for these costs.

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.

Critical health and safety related construction risks are summarised below:

- Unstable ground conditions - Damage to existing services during construction leading to death or injury to site personnel;
- Existing services - 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;
- 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); and
- Lifting Operations - Risk of plant overturning during moving or lifting on slope;

7.2.2.1 Mitigations

Notwithstanding the abovementioned 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 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 revetment at Whiterock (sub-cells CCA-B2 and CCA-B4) and concrete seawall at Killiney (sub-cells CCA-C3, CCA-C4, CCA-D1).

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 2025;
- Phase 3 completion winter 2025; and
- Phase 4 programmed for winter 2025 and throughout 2026.

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.

Term	Description
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

Term	Description
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 – CCA2/3-A: The eastern end of the sub-cell is made of a 200m long beach, with steep vegetated cliffs and placed rock protecting the base of the cliff. At the west of the beach, the Vico Baths are located at the bottom of a rock outcrop and are made of a series of concrete steps and rails.

Figure 2 – CCA2/3-A: Vico baths are a series of concrete steps located at the bottom of a rock outcrop, popular for sea bathing. The railway is protected by this natural outcrop and the presence of large boulders in the foreshore.

Figure 3 – CCA2/3-A: The rest of the sub-cell is made of a natural rock face, with a varying cliff height of approximately 40 meters. Rocks which have fallen now make the foreshore and provide additional coastal protection. The upper part of the cliff is stabilised by vegetation.

Figure 4 – CCA2/3-B: This sub-cell is the northern part of Whiterock/Killiney Beach. A 25m high retaining wall can be seen on the right-hand side of the image. Whiterock rock outcrop is also visible where the beach narrows, with some boulders on the beach. A smaller wall is also located between Whiterock outcrop and the 25m high retaining wall, with gabion baskets at the crest.

Figure 5 – CCA2/3-B: The rest of the sub-cell is protected by a 3m high masonry wall, with gabion baskets at the top and small boulders at the bottom. The picture here is taken just after Whiterock Beach outcrop and shows the beach widening in the western direction (left hand-side on the image).

Figure 6 – CCA2/3-C: This sub-cell starts at the café located on Killiney Beach. On the right-hand side, a series of retaining wall can be seen, with the café at the bottom. Vegetated cliffs make the rest of the sub-cell. The beach here is relatively wide and is mostly shingle.

Figure 7 – CCA2/3-C: The rest of the sub-cell is made of the same coarse material beach, with a half meter high upstand wall and vegetated cliffs. Killiney station is located shortly after these concrete stairs and is located at the top of a steep vegetated cliff.

Figure 8 – CCA2/3-D: The sub-cell is in front of several properties which are located between the beach and the railway. The soft cliffs here have suffered from erosion with failures of the slope toe. Vegetation has covered the slip, but uncovered cliff faces can still be seen. The beach is made of the same coarse material.

Figure 9 – CCA2/3-D: The end of the cell is located at the wastewater treatment plant outlet, with a wider beach at this location. Cliffs have reduced significantly here, with private properties located between the beach and the railway. The beach is sandy in the mid-lower beach with coarser material in the upper beach.

Appendix C. Options Assessment Supporting Modelling Outputs

Document Number	Document Title
7694-CCA2_3-P2-MMO-CM-JAC-0001	OPTIONS ASSESSMENT SUPPORTING MODELLING OUTPUTS CCA2/3

Appendix D. Short List Multi-Criteria Analysis Tables

Document Number	Document Title
7694-CCA2_3-P2-ENG-CV-JAC-0002	Short List Multi-Criteria Analysis Table CCA2/3

Appendix E. Option Concept Design Drawings

Document Number	Document Title
7694-CCA2_3-P2-DWG-CV-JAC-0001	CONCEPT DESIGN CCA 2/3 SITE LOCATION PLAN
7694-CCA2_3-P2-DWG-CV-JAC-0100	CONCEPT DESIGN CCA 2/3 OPTION A PLAN
7694-CCA2_3-P2-DWG-CV-JAC-0101	CONCEPT DESIGN CCA 2/3 OPTION B PLAN
7694-CCA2_3-P2-DWG-CV-JAC-0102	CONCEPT DESIGN CCA 2/3 OPTION C PLAN
7694-CCA2_3-P2-DWG-CV-JAC-0200	CCA2/3-B & C CROSS SECTIONS OPTION A
7694-CCA2_3-P2-DWG-CV-JAC-0201	CCA2/3-C2 & D1 CROSS SECTIONS OPTION A
7694-CCA2_3-P2-DWG-CV-JAC-0202	CCA2/3-D2 CROSS SECTIONS OPTION A, B & C
7694-CCA2_3-P2-DWG-CV-JAC-0203	CCA2/3-B, C & D1 BEACH CROSS SECTIONS OPTION B
7694-CCA2_3-P2-DWG-CV-JAC-0204	CCA2/3-B, C & D1 GROYNE CROSS SECTIONS OPTION B
7694-CCA2_3-P2-DWG-CV-JAC-0205	CCA2/3-B, C & D1 BEACH CROSS SECTIONS OPTION C
7694-CCA2_3-P2-DWG-CV-JAC-0206	CCA2/3-B & C BREAKWATER CROSS SECTIONS OPTION C

Appendix F. Works Priorities Drawing

Document Number	Document Title
7694-CCA2_3-P2-DWG-CV-JAC-0300	CCA 2/3 COASTAL DEFENCE WORKS PRIORITIES

Appendix G. Implementation Options Multi-Criteria Analysis Tables

Document Number	Document Title
7694-CCA2_3-P2-ENG-CV-JAC-0003	Multi-Criteria Analysis Implementation Options Table CCA2/3

Appendix H. Scheme Concept Design Drawings

Document Number	Document Title
7694-CCA2_3-P2-DWG-CV-JAC-0400	CCA 2/3 CONCEPT DESIGN PLAN
7694-CCA2_3-P2-DWG-CV-JAC-0410	CCA 2/3-B CONCEPT DESIGN CROSS SECTIONS
7694-CCA2_3-P2-DWG-CV-JAC-0411	CCA 2/3-C & CCA 2/3-D CONCEPT DESIGN CROSS SECTIONS

Appendix I. Consultation Report

To be added following Public Consultation 1.