East Coast Railway Infrastructure Protection Projects

Preliminary Option Selection Report

Merrion to Dún Laoghaire

COASTAL CELL AREA 1

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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 the resultant damage to infrastructure is becoming increasingly common; with climate change and related sea level rise in sea level 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 increase resilience to coastal erosion and coastal flooding as a result of climate change. <u>This document provides the Preliminary Option Selection Report for CCA1 - Merrion to Dún Laoghaire (hereafter referred to as "the Project").</u>

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

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

CCA1 is the section of coast that stretches from Merrion Gates in Dublin through to Seapoint Beach adjacent to Dún Laoghaire Harbour. This frontage is urban with the trainline running along the coastline. Much of this frontage is therefore defended, mostly with masonry revetments with upper seawalls. The foreshore along this frontage is soft sediment, mostly mud and sands. The railway is relatively low-lying and the main hazards along this frontage are wave overtopping and shore platform lowering. The options assessment identified five sub-cells (see Figure ES below): CCA1-A Merrion Gates; CCA1-B Merrion Spit; CCA1-C Booterstown; CCA1-D Blackrock; and CCA1-E Seapoint Beach.

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

- Booterstown, Blackrock and Seapoint are the most frequently subjected to wave overtopping.
- Booterstown, Blackrock and Seapoint are the most frequently subjected to larger waves, and the lower foreshore levels and higher walls increase the risk of structural failures.
- The risk of undermining by toe scour is very low where the revetment ties into outcropping rock, which occurs for much of the defences at Blackrock and Seapoint. Whilst at Booterstown, the lower foreshore is soft, and this will increase the risk of structure undermining failures.
- The coastal processes are most dynamic at the Merrion end of the defences. A coastal spit currently provides some protection to the revetments behind it. If this spit is lost, the failure modes described above become higher risk in this area.
- All areas are subject to coastal risk to railway operations (with the exception of Brighton Vale), and this will increase significantly with sea level rise.

The initial step of the optioneering assessment identified the Long List of Options comprising a range of interventions and measures that could be used 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:

- **Option A**: comprises long lengths of rock revetments placed over the existing masonry revetment and wall raising/replacement from Merrion Gates (CCA1-A) to Seapoint Beach (CCA1-E).
- **Option B**: comprises long lengths of rock revetments placed over the existing masonry revetment and wall raising from Merrion Gates (CCA1-A) to Blackrock (CCA1-D). At Seapoint (CCA1-E), attached breakwaters with beach nourishment are used to dissipate wave energy in the most vulnerable central and eastern sections of the bay, improved and raised seawall and footpath, and concrete revetment steps to replace the rock revetment.
- **Option C**: comprises long lengths of rock revetments placed over the existing masonry revetment and wall raising from Merrion Gates (CCA1-A) to Booterstown (CCA1-C). At Blackrock (CCA1-D) and Seapoint (CCA1-E), concrete steps, walkways and walls will be integrated into the existing environment to provide long term protection to the railway line whilst maintaining amenity provision and minimising environmental impact.

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 C**.

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 with increasing coastal hazard and risk to the railway. The IOs considered are as follows:

- **IO1**: deliver the full EPO Option C under ECRIPP to protect to 2100 regardless of whether works are needed now. Works comprises wall raising for most of the frontage (CCA1-A to E). Additional walls and raised footpaths/accesses at Blackrock (CCA1-D) and Seapoint (CCA1-E) to retain amenity function. Rock revetments placed over the existing masonry revetment at all subcells (CCA1-A to E).
- **IO2**: deliver all wall raising works of the EPO Option C under ECRIPP to protect to 2075 but defer all rock revetment works into the longer term until they are needed.
- **IO3**: deliver parts of the EPO Option C needed by 2050 under ECRIPP and defer some works into the longer term until they are needed. Works are as per IO2, but some wall raising works at the far northern end of the frontage near Merrion are also deferred (CCA1-A & B).
- **IO4**: Do Minimum – do not progress any of the works under the EPO but undertake reactive works as needed.

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

- Raise existing seawalls with reinforced concrete (CCA1-A to E); and,
- Additional seawall sections and raised footpaths/pedestrian accesses to retain amenity function (CCA1-D & E) (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 structures to be constructed 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, reduced or mitigated.

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

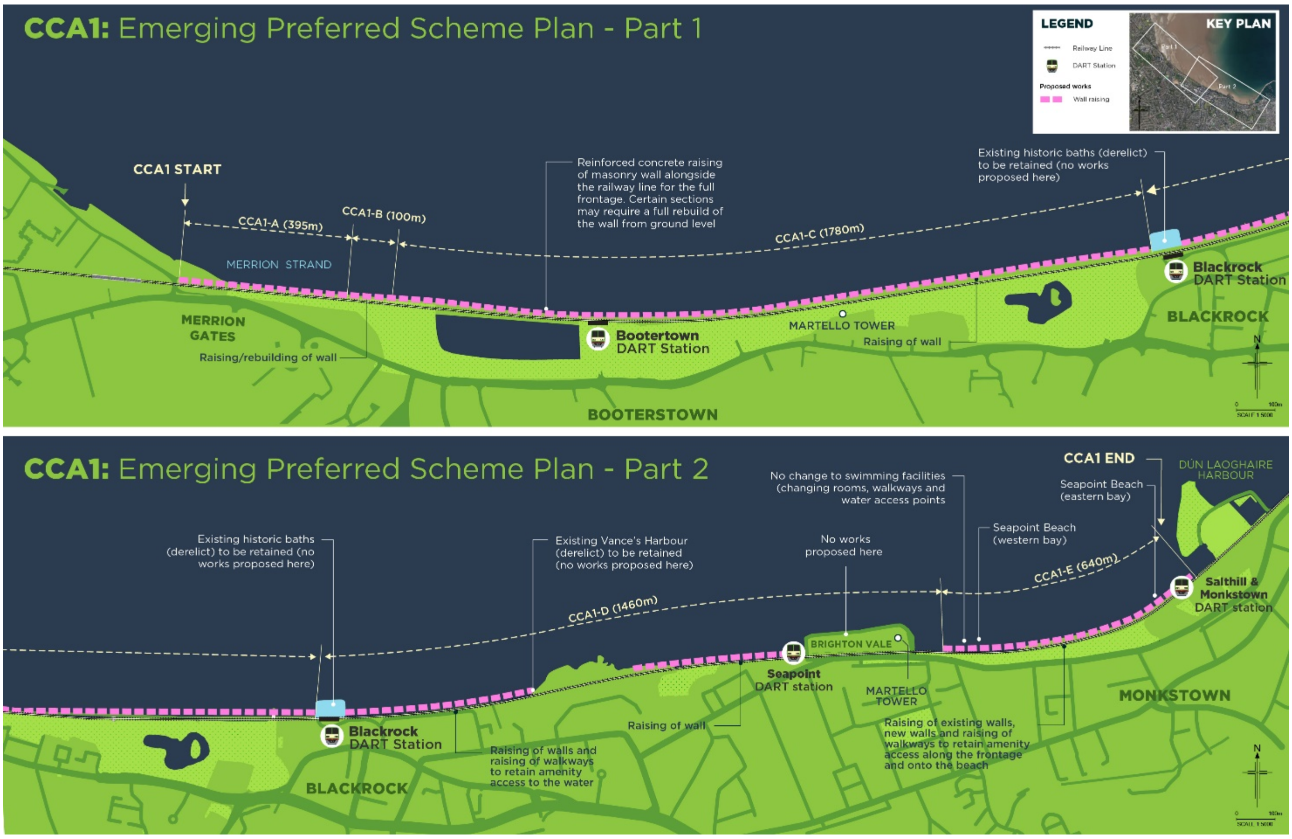

Figure ES: CCA1 Emerging Preferred Scheme Plan

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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 CCA1 (see Figure 1-2), a 4.4km length of coastline from Merrion Gates in Dublin through to Seapoint Beach adjacent to Dún Laoghaire Harbour (hereafter referred to as "the Project").

Figure 1-1 Location of Coastal Cell Areas

Figure 1-2 Overview of CCA1

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 Merrion and Dún Laoghaire.

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 CCA1 - Merrion to Dún Laoghaire, 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 CCA1. Further detail on planning and policy context can be found in Appendix A Planning and Environmental Constraints Report.

2.1 Land Based Areas

2.1.1 National Policy / Guidance

2.1.1.1 Project Ireland 2040

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

2.1.1.1.1 National Development Plan (NDP) 2021 – 2030

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

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

2.1.1.1.2 National Planning Framework (NPF) 2018 – 2030

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

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

2.1.1.2 Transport Climate Change Sectoral Adaptation Plan 2019

The Transport Climate Change Sectoral Adaptation Plan 2019 recognises the risk of climate change impact on the Irish transport sector and its infrastructure. The plan sets out adaptation measures to protect the transport sector. The plan references the Eastern Rail Corridor, of which a section includes the proposed Project, as a case study to show the coastal erosion impacts already incurred in this region.

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

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

2.1.2 Coastal Change Management Strategy

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

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

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

2.1.3 Regional Policy / Guidance

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

2.1.3.1.1 Eastern & Midlands Region RSES

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

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

2.1.3.1.2 Southern Region RSES

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

2.1.3.1.3 Greater Dublin Area Transport Strategy 2022 – 2042

The Project falls within the remit of the Greater Dublin Area Transport Strategy (GDATS) 2022 – 2042. The GDATS outlines a number of policy objectives to support the proposed 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 Dublin City Council

Dublin City Development Plan came into effect on the 14th December 2022. The development plan guides the future growth and development of the DCC area.

CCA1 is located within two local authority functional areas - DCC and Dún Laoghaire Rathdown (DLR). CCA1 will be within DCC from where it commences adjacent to Merrion Gates to the Booterstown Nature Reserve, where responsibility changes to DLR.

Whilst the Project is not specifically mentioned in the Plan it is clear that coastal zone management and the protection of the coastal area is an important matter. The Plan does include Policy SMT23 – *'The Rail Network and Freight Transport'*, which supports working with Iarnród Éireann / Irish Rail to achieve a coordinated approach to improving the rail network.

The Plan sets out a range of applicable policies including, among others: CA29 – 'Coastal Zone Management', SI14 – 'Strategic Flood Risk Assessment', SI18 – 'Protection of Flood Alleviation Infrastructure', GI35 – 'General Protection of Coastal Zone' and SMT23 – 'The Rail Network and Freight Transport'.

CCA1 has a number of applicable zoning objectives including: Z9 'Amenity/Open Space/Green Network', Z7 'Employment/Enterprise', Z10 'Inner Suburban and Inner City Sustainable Mixed Uses', Z1 'Sustainable Residential Neighbourhoods', Z2 'Residential Neighbourhoods (Conservation Areas)', Z3 'Neighbourhood Centres', Z6 'Employment/Enterprise Zones' and Z15 'Community and Institutional Resource Lands (Education, Recreation, Community, Green Infrastructure and Health)'.

The western edge of CCA1 has the following map-based objectives: 'Zone of Archaeological Interest' and 'Site of Archaeological Interest'.

2.1.4.2 Draft Dublin City Climate Action Plan

The Draft Dublin City Climate Action Plan 2024 – 2029 was published for consultation on the 15th 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.

2.1.4.3 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 of 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.

CCA1 is within the functional area of DLR from the Booterstown Nature Reserve.

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.*'

- CCA1 has a number of applicable zoning objectives including:
- Objective DC – To protect, provide for and/or improve mixed-use district centre facilities;
- Objective NC – To protect, provide for and/or improve mixed-use neighbourhood centre facilities;
- Objective W – To provide for waterfront development and harbour-related uses; and
- Objective MTC – To protect, provide for and/or improve major town centre facilities.

Further detail in regard to applicable polices and objectives is provided in Appendix A.

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

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

2.1.4.3.2 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 at Table 1-1 and 1-2 NMPF Marine Map Based Objectives (MMBOs) and Marine Spatially Specific Policy Objectives (SSPOs) relevant to CCA1.

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.

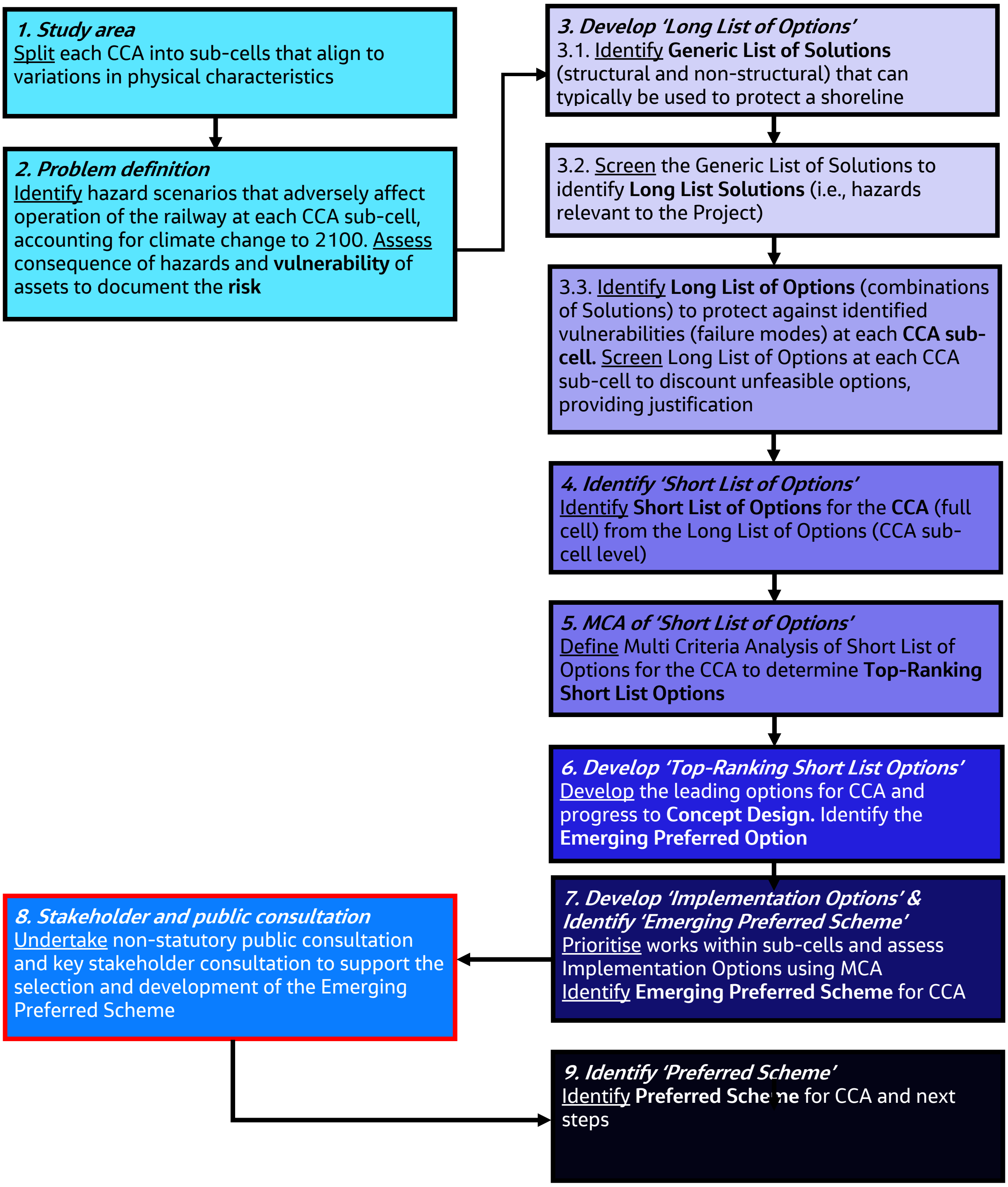


Figure 3-1 Flow chart summarising optioneering process

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: 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.

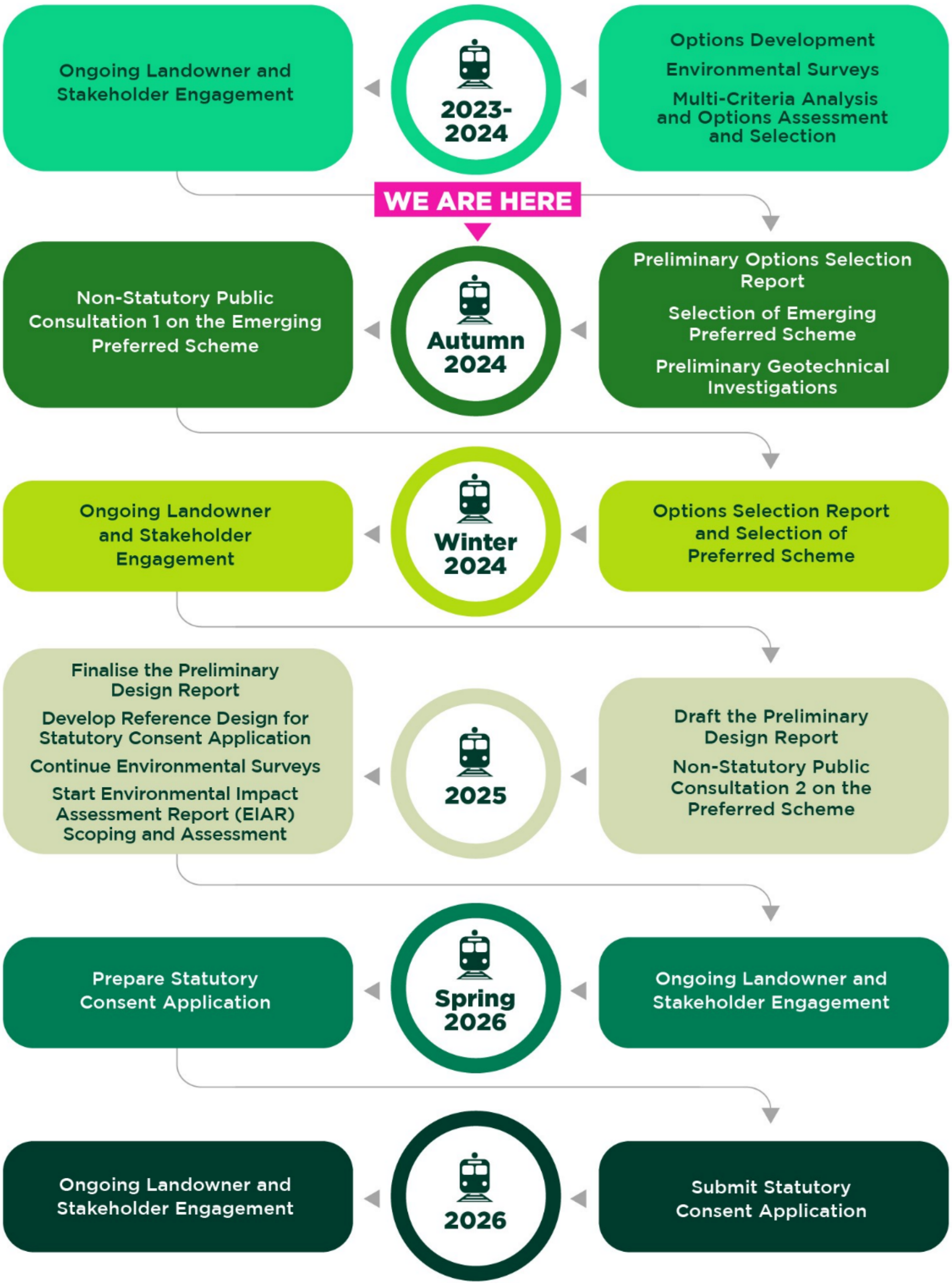


Figure 3-2 Public consultation roadmap

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 CCA1

The Project area is divided into Coastal Cell Areas (CCA). CCA1 is the section of coast that stretches from Merrion to Dún Laoghaire Harbour. This frontage is urban with the trainline running along the coastline. Much of this frontage is therefore defended, mostly with natural stone revetments with recurved seawalls.

The foreshore along this frontage is soft sediment, mostly mud and sands. The railway is relatively low-lying along this frontage and the main hazards along this frontage are wave overtopping and shore platform lowering. CCA1 is located within a number of designated sites which are outlined in Section 4.3.

4.2 Identification of Coastal Sub-Cells

CCA1 has been divided into five sub-cells based on the variation in physical characteristics, including the geomorphology, shoreline topography and orientation, environmental constraints, and existing defence type and the exposure due to different failure modes. The CCA sub-cells are shown and described in Figure 4-1 and Table 4-1. A photographic record showing the key defences and physical characteristics of each sub-cell are in Appendix B.

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

4.3 Environmental Constraints

In order to understand the baseline conditions of CCA1, 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 CCA1 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:

- Internationally designated sites: Sandymount Strand / Tolka Estuary Ramsar (Code 832);
- European designated sites: South Dublin Bay and River Tolka Estuary SPA (Code 004024) and South Dublin Bay SAC (Code 000210); and
- Nationally designated sites: South Dublin Bay pNHA (Code 000210).

Further ecological constraints within CCA1 are:

- An internationally important population of Light-bellied Brent Goose occurs regularly, and newly arrived birds in the autumn feed on the Eelgrass bed at Merrion.
- Several small, sandy beaches with incipient dune formation occur in the northern and western sectors of the site, notably at Merrion/Booterstown.
- Drift line vegetation occurs in association with the embryonic and incipient fore dunes.

- A small area of pioneer saltmarsh now occurs in the lee of an embryonic sand dune just north of Booterstown Station.
- Large numbers of gulls roost in South Dublin Bay
- An important Tern roost in the autumn, regularly holding 2000-3000 terns including Roseate Terns, a species listed on Annex I of the EU Birds Directive.

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

4.3.2 Soils & Geology

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

- Locations of variable ground conditions
- Sporadic areas of moderate to high landslide susceptibility along the coastline
- Some Water Framework Directive (WFD) waterbodies intersect the railway line through the cell
- Potential sources of contamination:
  - Made ground
  - Rail line
- Two geological faults intersect the railway line within the cell. The faults could be reactivated by the works or act as a preferential pathway for land contamination (geotechnical and environmental constraint).
- Area of locally important aquifer
- Moderate to extreme levels of groundwater vulnerability
- Areas of moderate to high potential for granular aggregate potential respectively
- Areas of moderate to high crushed rock aggregate potential
- Areas of historic development are clustered at Merrion, Booterstown and Dunleary
- Blackrock Breccia along the coastline is classified as a Geological Heritage Audited Site

4.3.3 Hydrology

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

- Waterbodies:
  - One river sub-basin: Brewery Stream_ 010
  - One Coastal waterbody: Dublin Bay

Areas subject to flood risk includes:

- Coastal and River Flooding in the vicinity of Merrion Gates;
- Flooding in the Blackrock area associated with the Brewery Stream; and
- Flooding at Brighton Vale and Monkstown.

4.3.4 Landscape, Seascape & Visual

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

- One tree under Tree Protection Order
- Several public rights of way
- 46 no. Protected Views
- Seascape Character Area (SCA) – SCA 15 Dublin Bay

4.3.5 Archaeology & Cultural Heritage

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

- 16. No. SMR Sites
- Two Undesignated Key Constraints:
  - Two historic railway lines: Pearse (Westland Row) to Blackrock; and Blackrock to Dún Laoghaire.
  - Six historic railway stations: Sydney Parade, Merrion, Booterstown, Blackrock, Seapoint and Salthill.

4.3.6 Air Quality & Climate

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

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

4.3.7 Noise & Vibration

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

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

4.3.8 Population & Human Health

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

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

Figure 4-1 CCA1 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
CCA1 - General	Merrion to Monkstown	Continual existing structural coastal defences of varying forms, but generally grouted stone revetment with a low masonry crest wall. Locally there are berms forming pedestrian access along the revetment slope.	✓	✓	✓	✓			
CCA1-A	Merrion Gates	Shoreline has protection from spit and a stable beach. Foreshore levels are consistently high limiting wave exposure under frequent storms. This results in low wave exposure but there is a long-term wave overtopping risk as water levels increase.	✓	✓		✓			
CCA1-B	Merrion Spit	Very low wave exposure under frequent storms due to direct protection from accreting sand spit/beach. Section would only become vulnerable if spit/beach lost. This results in very low wave exposure but there is a long-term wave overtopping risk as water levels increase.	✓	✓		✓			
CCA1-C	Booterstown	Largely continual masonry revetment with upstand seawall and four culverts. Foreshore levels appear relatively stable at present but likely to lower into the future undermining the defence. High maintenance requirement on exposed revetment and regular overtopping.	✓	✓	✓				
CCA1-D	Blackrock	Largely continual masonry revetment with upstand seawall and one culvert. Foreshore largely rocky and stable with two rocky headlands. High maintenance requirement on exposed revetment and regular overtopping.	✓	✓	✓				
CCA1-E	Seapoint Beach	Masonry revetment with concrete apron. Amenity beach (at low tide) flanked by rock headland and seawall. High maintenance requirement on exposed undermined revetment and overtopping.	✓	✓	✓				

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 high risk to railway operations in CCA1. 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 flooding of the railway and disruption of services along CCA1. • In addition to the flooding disruption, wave overtopping has the potential for wash out of ballast, damage/corrosion to electrics, stations, structures, line, overbridges and overhead powerlines. • As sea level rises, the frequency of disruption will increase significantly until this becomes a routine event. Larger storms may cause more significant damage to railway assets necessitating longer shutdowns of the line. • Despite the increased frequency and severity of disruption in line with sea level rise, wave overtopping in isolation is unlikely to present a significant risk to rail users given services will have to be cancelled during these events. However, it will cause inconvenience to passengers and a loss of revenue to Irish Rail. There will be an increasing risk that more significant structural damage will result during a major storm. In the Do Nothing scenario repairs would not be undertaken, and the line would ultimately have to be closed. There is a 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) and the defence form/height. • Vulnerability varies, but in general Booterstown, Blackrock and Seapoint are the areas most frequently subjected to wave overtopping. • All areas are subject to risk to railway operations (with the exception of Brighton Vale) that will increase significantly with sea level rise.
Structural Failure	• Structural failure of existing defences is currently considered to be a high risk to railway operations. This risk will increase with sea level risk projections because increasingly larger waves would reach the defence more regularly. • Irish Rail has maintained the defence to repair sections where the existing masonry revetments and walls have been damaged. Historical, this damage has occurred where revetment masonry blocks have been dislodged during storms (where large waves propagate to the defence line during mid/high tide events). These dislodged blocks open-up holes in the revetment that can quickly propagate if not repaired. • In the Do Nothing scenario, small holes in the defence would propagate and the overall structural integrity of the defence 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 and catastrophic collapse of the upper parts of the revetment, undermining the railway line and potentially causing a derailment.	• 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/ height. • Vulnerability varies, but in general Booterstown, Blackrock and Seapoint are the most frequently subjected to the larger waves and the lower foreshore levels and higher walls increase the risk of failures. • All areas are subject to risk to railway operations (with the exception of Brighton Vale), and this will increase significantly with sea level rise.

	• In addition to the loss of the railway line in the Do Nothing scenario, as the defences fail the railway bund would collapse and there is a risk that the sea would propagate inland and cause extensive coastal flooding to the hinterland. • 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 CCA1, the risk of scour undermining the defence is linked directly to the general foreshore levels ahead of a storm (refer to the beach erosion failure mode below). • Toe scour is currently assessed as a low risk to railway operations in CCA1. The toe depth of the existing structures will be confirmed by proposed site investigations, which may change the risk rating. The risk level 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 revetments. • Historically there has been no evidence of scour of the beach or foreshore leading to undermining and damage or failure of 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. At noted above, toe depth of existing structures will be confirmed by proposed site investigations, which may change the risk rating. • Should the revetment 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, but this is less likely to pose a risk of derailment (with this construction form) given this failure would occur at the bottom of the structure furthest away from the railway line. • 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 medium probability this would occur in the longer term in the Do Nothing scenario based on this failure mode. • As for structural failure, there are associated flooding and public safety risks associated with toe scour.	• 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. • Vulnerability varies, but in general the Booterstown area is the most frequently subjected to the larger waves and the lower unconsolidated foreshore levels and higher walls increase the risk of failures. • The risk of undermining is very low where the revetment ties into outcropping rock, which occurs for much of the defences at Blackrock and Seapoint. • All areas are subject to some risk to railway operations (with the exception of Brighton Vale), and this will increase significantly with sea level rise.
Beach Erosion	• At CCA1, the risk of scour undermining the defence is linked directly to the general foreshore levels ahead of a storm. There are only small sections of defined beaches but there are large lengths of flat intertidal areas immediately seaward of the revetments. The general level of the foreshore at the defence is linked to the coastal processes within the Dublin Bay. • Beach erosion/foreshore lowering is currently assessed a low risk to railway operations. The toe depth of the existing structures will be confirmed by proposed site investigations, which may change the risk rating. The risk level could increase with sea level rise leading to a change in the coastal processes in the bay resulting in beach/foreshore lowering at the defences, which in turn could lead to a gradual undermining of the defences, or the undermining via scour during a storm event. • Refer to the scour failure mode for details on how the defence could fail in this scenario and what the risk could be to the railway line and public.	• The coastal processes are most dynamic at Merrion, where in recent decades there has been enough sediment feed to form a spit. Should this feed continue, the spit could continue to grow, but may eventually break away in a storm event. This spit currently provides some protection to the revetments behind it. If this spit is lost, the failure modes described above become higher risk in this area (but would still remain lower risk in comparison to other areas in CCA1). • For the rest of the sections, the risk distribution is the same as the toe scour where general loss of foreshore levels is less problematic where there is a rocky foreshore, or rock immediately below for the foreshore.

5. Options Assessment

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

5.1 Long List of Options

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

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

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

The results of the Long List Options process are presented in Section 5.1.3, 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 of Solutions.

Table 5-2 Long list of structural solutions.

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

LL17	Toe Protection – geotubes	Containers formed with UV-stabilised geotextile fabric and filled with sand	No	High	Discounted	Design life is unproven and is not expected to meet project requirements			✓		✓		
LL18	Toe Protection – gabions	Low-profile gabion structure formed of wire cages filled with small stone. Provides added stability and erosion protection to existing structures and/or soft cliffs	No	High	Retained	Although design life and maintenance burden do not meet the project requirements, these may be appropriate in areas of lower exposure and as part of cliff toe protection. This option is retained as a measure that can be replaced in the future and/or used alongside other measures to provide long term protection.			✓		✓		
LL19	Toe Protection – steel sheet piles	Steel sheet piles installed at the toe of existing structures and/or soft cliffs to provide added stability and erosion protection. Structure may exacerbate beach loss as vertical structures reflect more wave energy	Yes	Medium	Retained	Needs to be used as part of a combined solution, either to provide toe support as part of a revetment solution or with other scour protection in front of cliffs. Fully discounted as a stand-alone solution in the active zone			✓		✓		
LL20	Toe Protection – rubber tyres	Used rubber tyres are lashed together (for example in a honeycomb pattern) to protect existing structures and/or soft cliffs. Tyres can also be filled with stone, sand or concrete to increase their weight.	No	High	Discounted	Not suitable for high wave energy environments; does not have the robustness required for these locations. There are also concerns that material would degrade contaminating the sea/adjacent habitats			✓		✓		
LL21	Groynes – rock	Linear rock structure constructed perpendicular to the shoreline which helps retain beach material in place. Different plan configurations are possible, such as fish-tail and y-shaped groynes	Yes	Low	Retained	Note that groynes as a standalone measure will only be appropriate where there existing beach material is abundant. Elsewhere, beach nourishment would be likely to create a long-term solution			✓	✓	✓		
LL22	Groynes – timber	Linear timber pile and planking structure constructed perpendicular to the shoreline which helps retain beach materials in place.	No	High	Discounted	Timber groynes typically have a design life of less than 50 years in the marine environment and therefore do not have the required design life. They also require more maintenance than rock groynes			✓	✓	✓		
LL23	Vertical Seawall – concrete wall	Large vertical or near-vertical impermeable concrete structure designed to withstand high wave forces; may include a bullnose or recurve element to help reduce wave overtopping. A seawall can accommodate a promenade or other amenity feature	Yes	Low	Retained		✓	✓			✓		
LL24	Vertical Seawall – sheet piles	Steel sheet piles installed as prevention from wave overtopping; may include a concrete capping beam. Likely to require toe protection	Yes	Medium	Retained	As a combined solution with rock toe protection or as a set-back wall to reduce maintenance burden	✓	✓			✓		
LL25	Vertical Seawall – masonry	Large vertical or near-vertical impermeable masonry structure designed to withstand high wave forces. A seawall can accommodate a promenade or other amenity feature.	Yes	Medium	Discounted	Would require large volumes of rock, quarried and shaped into blocks; very labour-intensive and does not have any additional technical advantages when compared to a concrete seawall	✓	✓			✓		
LL26	Embankments / Levees	Linear grassed earth structure providing flood protection; typically used along riverbanks	Yes	Medium	Discounted	Not suitable for a coastal setting without a revetment or other protection							
LL27	Sills	Installation of a low rock structure in front of existing eroding banks to retain sediment behind. Depending on availability of suitable material, accretion may occur naturally, or recharge may be needed. Can also be used to form a perched beach reducing the footprint and volume of material import to create a beach.	No	Medium	Discounted	Best suited to low energy environments where there is a wide intertidal area; not technically feasible for an open coast frontage			✓	✓	✓		
LL28	Set back flood wall	Low vertical wall, typically made of concrete, masonry or steel sheet piles which is located behind the primary defence where it does not need to withstand direct wave impact; may be installed behind a promenade or beach nourishment	Yes	Low	Retained		✓						

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

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

ID	Solution	Description	Meets minimum design life?	Maintenance burden	Retained or discounted	Reason for discounting	Failure mode addressed						
							OT	ST	TS	BE	TE	GW	RF
LL32	Beach Nourishment - beach recharge	Supplementing the existing beach periodically with suitable material (shingle, sand or a mixture to match the existing beach) to increase beach volumes, reduce erosion and toe scour at flood defences and/or soft cliffs. Usually requires control structures (groynes or breakwaters) to retain the material.	No	Medium	Retained	Although the option is not able to provide the required design life, this option is retained as a measure that can be replaced in the future and/or used alongside other measures to provide long term protection.			✓	✓	✓		
LL33	Beach Nourishment - beach recycling	Moving existing beach material from areas of accretion downdrift to areas of erosion updrift. This is best suited to areas where there is a well-defined longshore movement of beach material which accumulates at the downdrift end of a beach. Recycling activities would typically be undertaken annually.	No	High	Discounted	Will not achieve the required design life and needs significant and frequent maintenance. Therefore, does not meet needs of the project			✓	✓	✓		
LL34	Sand engine	Supplementing the existing beach with a very large recharge of suitable material (shingle, sand or a mixture to match the existing beach) to increase beach volumes, reduce erosion and toe scour at flood defences. Material is placed in the nearshore and waves/currents allowed to distribute naturally.	No	Medium	Discounted	Will not achieve the required design life. None of the beaches are sand beaches; the beaches are generally a sand-shingle mix. From a technical perspective, shingle would be preferred but this is un-proven.			✓	✓	✓		
LL35	Dune regeneration	Stabilisation and enhancement of existing dune systems to deliver additional resilience. Stabilisation could involve planting, thatching and fencing to trap windblown sand	No	Medium	Retained	Note: only relevant where dunes already exist at very specific locations along the study area. Although the option is not able to provide a long design life, this option is retained as a measure that can be replaced in the future and/or used alongside other measures to provide long term protection.			✓	✓			
LL36	Vegetated features (e.g. saltmarsh)	Restoration or planting of saltmarsh or other vegetated features.	No	N/A	Discounted	Does not address any of the failure modes; there is no saltmarsh present in the study area and wave exposure is too great							
LL37	Maritime forests	Restoration or planting of kelp	No	N/A	Discounted	Does not address any of the failure modes; there is no kelp present and needs to be subtidal							
LL38	Oyster, mussel and coral reefs	Construction of sub-tidal or intertidal reefs using a suitable material for settlement by oysters or mussels.	No	N/A	Discounted	Structures are likely to be small in scale and therefore have limited influence on failure modes.							
LL39	Sea grass beds	Installation of intertidal or sub-tidal beds of sea grass. Provides ecosystem benefits including carbon sequestration. 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 discounted across the CCA are provided in Table 5-6. The Long List of Options for each CCA sub-cell and reasons for discounting certain options in each sub-cell is provided in Table 5-7 to 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*							CCA1-A	CCA1-B	CCA1-C	CCA1-D	CCA1-E
		OT	ST	TS	BE	TE	GW	RF					
LL01	Do nothing								N/A	N/A	N/A	N/A	N/A
LL02	Do minimum								N/A	N/A	N/A	N/A	N/A
LL03	Relocation of the railway	✓	✓	✓	✓	✓	✓	✓	N	N	N	N	N
LL04	Detached Breakwaters – emergent rock or concrete armour units				✓				Y	Y	Y	Y	Y
LL07	Attached Breakwaters – rock			✓	✓	✓			N	N	N	N	Y
LL08	Revetment – rock	✓	✓	✓		✓			Y	Y	Y	Y	Y
LL09	Revetment – concrete armour units	✓	✓	✓		✓			Y	Y	Y	Y	Y
LL11	Revetment – stepped concrete	✓	✓	✓					Y	Y	Y	Y	Y
LL16	Toe Protection – rock			✓		✓			Y	Y	Y	Y	Y
LL18	Toe Protection – gabions			✓		✓			N	N	N	N	N
LL19	Toe Protection – steel sheet piles			✓		✓			N	N	N	N	N
LL21	Groynes – rock			✓	✓	✓			Y	Y	Y	Y	Y
LL23	Vertical Seawall – concrete wall	✓	✓			✓			Y	Y	Y	Y	Y
LL24	Vertical Seawall – sheet piles	✓	✓			✓			N	N	Y	Y	Y
LL28	Set back flood wall	✓							Y	Y	Y	Y	Y
LL32	Beach Nourishment – beach recharge			✓	✓	✓			Y	Y	Y	Y	Y
LL35	Dune regeneration			✓	✓				Y	Y	N	N	N
LL44	Soft cliff stabilisation – shallow drainage systems						✓		N	N	N	N	N
LL45	Hard cliff stabilisation – rock netting							✓	N	N	N	N	N
LL46	Hard cliff stabilisation – rock bolting							✓	N	N	N	N	N
LL48	Hard cliff stabilisation – catch fences							✓	N	N	N	N	N
LL49	Rock fall protection – rock fall shelter							✓	N	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 CCA1 (general) from Merrion Gates to Monkstown.

Sub-cell	Long List Options - Merrion Gates to Monkstown
CCA1 - General	1. Do nothing (LL01) 2. Do minimum (LL02) 3. Concrete armour unit revetment in-front of existing wall (LL09) 4. Rock revetment with wall-raising (LL08 + LL28) 5. Concrete seawall with piled foundations fronted by rock toe protection (LL23 + LL16) 6. Detached breakwaters with nourishment and wall-raising (LL04 + LL32 + LL28) 7. Beach and dune stabilisation (LL35) as part of detached breakwaters solution 8. Concrete stepped revetment in-front of existing wall with raised seawall (where needed) and rock toe protection (where needed) (LL11 + LL16) 9. Attached breakwaters with nourishment and improved and raised seawall (or new floodwall if structurally unviable to raise existing) (LL07 + LL28 + LL32) 10. Concrete stepped revetment in-front of existing wall with raised seawall, attached breakwaters and nourishment (LL11 + LL28 + LL07 +LL32) Long list options discounted generally in CCA1 with reason: • Relocation (LL03) – very busy railway line with limited opportunity to retreat landward into an urban area, numerous conflicts would make this technically extremely difficult/expensive and would create significant public resistance Toe protection (LL16, LL18, LL19) – does not improve SoP against wave overtopping and would provide limited protection to the existing structures. However, rock protection toe protection could be used to deal specifically with undermining of other solutions, so is retained as a solution. Cliff stabilisation (LL44, LL45, LL46, LL48, LL49) – Rock falls are not a hazard at CCA1 • Concrete seawall incorporating greenway with piled foundations fronted by rock toe protection (LL23 with LL16) - significant increase in cost, encroachment and carbon in comparison with the non-greenway option)

Table 5-7 Long list options for CCA1-A and CCA1-B from Merrion Gates to Merrion Spit.

Sub-cell	Long List Options - Merrion Gates & Merrion Spit
CCA1-A & CCA1-B	1. Do nothing (LL01) 2. Do minimum (LL02) 3. Concrete armour unit revetment in-front of existing wall (LL09) 4. Rock revetment with wall-raising (LL08 + LL28) 5. Concrete seawall with piled foundations fronted by rock toe protection (LL23 + LL16) 6. Detached breakwaters with nourishment and wall-raising (LL04 + LL32 + LL28) 7. Beach and dune stabilisation (LL35) as part of detached breakwaters solution Long list solutions discounted for this specific location (with reason): • Concrete stepped revetment in-front of existing wall (LL11) – 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 • Groynes, nourishment and raised seawall (LL21 + L28 + LL32) – would interrupt natural spit system and would likely create problems to the north by interfering with natural sediment movements in the northern section of the bay, insufficient sediment in the existing system and it is mostly too fine grained, groynes and required beach nourishment would result in large encroachment over protected intertidal areas, would prevent culverts from discharging (potentially necessitating landward pumping station) and unable to build beach high enough to prevent overtopping to 2100 without additional shoreline structural measures

Table 5-8 Long list options for CCA1-C for Booterstown.

Sub-cell	Long List Options - Booterstown
CCA1-C	1. Do nothing (LL01) 2. Do minimum (LL02) 3. Concrete armour unit revetment in-front of existing wall (LL09) 4. Rock revetment with wall-raising (LL08 + LL28) 5. Seawall with piled foundations fronted by rock toe protection (LL23/LL24 + LL16) 6. Detached breakwaters with nourishment and wall-raising (LL04 + LL32 + LL28) 7. Beach and dune stabilisation (LL35) as part of detached breakwaters solution Long list solutions discounted for this specific location (with reason): • Concrete stepped revetment in-front of existing wall with raised seawall and rock toe protection (LL11 + LL23 + LL16) – 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 Groynes, nourishment and raised seawall (would interrupt feed to natural spit system and would likely create problems to the north by interfering with natural sediment movements in the bay, insufficient sediment in the existing system and it is mostly too fine grained, groynes and required beach nourishment would result in large encroachment over protected intertidal areas, would prevent culverts from discharging (potentially necessitating landward pumping station), high monitoring and maintenance requirement and unable to build beach high enough to prevent overtopping to 2100 without additional shoreline structural measures)

Table 5-9 Long list options for CCA1-D for Blackrock.

Sub-cell	Long List Options - Blackrock
CCA1-D	1. Do nothing 2. Do minimum 3. Concrete armour unit revetment in-front of existing wall (LL09) 4. Rock revetment with wall-raising (LL08 + LL28) 5. Seawall with piled foundations fronted by rock toe protection (LL23/LL24 + LL16) 6. Detached breakwaters with nourishment and wall-raising (LL04 + LL32 + LL28) 7. Concrete stepped revetment in-front of existing wall with raised seawall (where needed) and rock toe protection (where needed) (LL11 + LL16) Long list solutions discounted for this specific location (with reason): • Dune regeneration (LL35) – no dunes in this location. • Groynes, nourishment and raised seawall (LL21 + LL28 + LL32) – would interrupt feed to natural spit system and would likely create problems to the north by interfering with natural sediment movements in the bay, insufficient sediment in the existing system and it is mostly too fine grained, groynes and required beach nourishment would result in large encroachment over protected intertidal areas, would prevent culverts from discharging (potentially necessitating landward pumping station), high monitoring and maintenance requirement and unable to build beach high enough to prevent overtopping to 2100 without additional shoreline structural measures)

Table 5-10 Long list options for CCA1-E for Seapoint Beach.

Sub-cell	Long List Options – Seapoint Beach
CCA1-E	1. Do nothing 2. Do minimum 3. Concrete armour unit revetment in-front of existing wall (LL09) 4. Rock revetment with wall-raising (LL08 + LL28) 5. Seawall with piled foundations fronted by rock toe protection (LL23/LL24 + LL16) 6. Detached breakwaters with nourishment and wall-raising (LL04 + LL32 + LL28) 7. Attached breakwaters with nourishment and improved and raised seawall (or new floodwall if structurally unviable to raise existing) (LL07 + LL28 + LL32) 8. Concrete stepped revetment in-front of existing wall with raised seawall, attached breakwaters and nourishment (LL11 + LL28 + LL07 +LL32) Long list solutions discounted for this specific location (with reason): Dune regeneration (LL35) – no dunes in this location.

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 the Project objectives but are included to serve as baseline options against which the strategic and planned upgrade of defences is delivered through the Project. All remaining "Do Something" options (Options 3 to 9) meet the scheme objectives, the requirements for design life and provide the required Standard of Protection.

As presented in Table 5-11, Options 3 to 6 use the same solution across all sub-cells. Option 7 is a variation on Option 4 where the rock revetment at Seapoint is replaced with a beach scheme comprising beach nourishment and beach control structures in the form of a rock groyne and attached rock breakwater. Option 8 is also a variation of Option 4 where the rock revetments at the swimming areas at Blackrock and Seapoint are replaced with stepped revetments, raised walkways and concrete seawalls to maintain amenity provision. Option 9 is a variation of Option 8 where the shoreline concrete works are replaced with a detached breakwater.

Table 5-11 Overview of short list options for CCA1.

Option	CCA1-A Merrion Gates	CCA1-B Merrion Spit	CCA1-C Booterstown	CCA1-D Blackrock	CCA1-E Seapoint Beach
1. Do Nothing	N/A	N/A	N/A	N/A	N/A
2. Do Minimum	Do Minimum	Do Minimum	Do Minimum	Do Minimum	Do Minimum
3. Concrete armour unit revetments	Concrete armour unit revetment in-front of existing revetment with wall raising as required	Concrete armour unit revetment in-front of existing revetment with wall raising as required	Concrete armour unit revetment in-front of existing revetment with wall raising as required	Concrete armour unit revetment in-front of existing revetment with wall raising as required	Concrete armour unit revetment in-front of existing revetment with wall raising as required
4. Rock Revetment (with raised wall where needed)	Rock revetment in-front of existing revetment with wall raising as required	Rock revetment in-front of existing revetment with wall raising as required	Rock revetment in-front of existing revetment with wall raising as required	Rock revetment in-front of existing revetment with wall raising as required	Rock revetment in-front of existing revetment with wall raising as required
5. Concrete seawall fronted by rock toe	Concrete seawall with piled foundations fronted by rock toe protection	Concrete seawall with piled foundations fronted by rock toe protection	Concrete seawall with piled foundations fronted by rock toe protection	Concrete seawall with piled foundations fronted by rock toe protection	Concrete seawall with piled foundations fronted by rock toe protection
6. Detached breakwater with nourishment and raised seawall (Beach and dune stabilisation where possible)	Detached breakwaters with nourishment, raised wall and beach and dune stabilisation	Detached breakwaters with nourishment, raised wall and beach and dune stabilisation	Detached breakwaters with nourishment and raised seawall	Detached breakwaters with nourishment and raised seawall	Detached breakwaters with nourishment and raised seawall
7. Rock revetment (A-D); attached breakwaters and amenity beach (E)	Rock revetment in-front of existing revetment with wall raising as required	Rock revetment in-front of existing revetment with wall raising as required	Rock revetment in-front of existing revetment with wall raising as required	Rock revetment in-front of existing revetment with wall raising as required	Attached breakwaters with nourishment and improved and raised seawall
8. Rock revetment (A-C); stepped revetment with rock toe protection in amenity frontages (D & E)	Rock revetment in-front of existing revetment with wall raising as required	Rock revetment in-front of existing revetment with wall raising as required	Rock revetment in-front of existing revetment with wall raising as required	Stepped revetment with rock toe protection in amenity frontage (approx. 250m); rock revetment in-front of existing revetment with wall raising as required for the remainder	Stepped revetment with rock toe protection and improved and raised seawalls
9. Rock revetment (A-C); stepped revetment with rock toe protection in amenity frontage of D; detached breakwaters and amenity beach (E)	Rock revetment in-front of existing revetment with wall raising as required	Rock revetment in-front of existing revetment with wall raising as required	Rock revetment in-front of existing revetment with wall raising as required	Stepped revetment with rock toe protection in amenity frontage (approx. 250m); rock revetment in-front of existing revetment with wall raising as required for the remainder	Detached breakwaters with nourishment and raised seawall

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.

All options were assessed using the criteria in Table 3-2. Section 5.3.1 provides a summary of the outcome from the detailed MCA analysis. The full MCA sheet can be found within Appendix D.

5.3.1 MCA Outcomes

5.3.1.1 Economy

5.3.1.1.1 Land Use & Third Party Assets

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

Options 3-9 are comparable to each other as they have similar impacts on lands owned by Dublin City Council and Dún Laoghaire-Rathdown County Council. There are no impacts on third party lands as a result of any options.

5.3.1.1.2 Capital Expenditure

Option 1 & 2 have significant advantages over other options as they require no and minimal capital costs respectively. Option 4 has a significant advantage over other options as it is assumed that the rock can be delivered via barge and can be implemented through land and marine works. This solution is likely to be a quicker construction phase than other options.

Options 7 & 8 have some advantages over other options as they are both similar to Option 4 however Option 7 has an additional cost of beach nourishment and Option 8 has an additional cost to provide replacement amenity areas and access points.

Options 3, 5, 6 and 9 have significant disadvantages over other options. Option 3 requires fabrication of the concrete armour units on site which would require specialist contractors and heavy marine plant. Option 5 would require removal of existing defences, excavation close to the railway and potential use of cofferdams to construct the concrete seawall, which would result in significant cost implications. Option 6 proposes a complex and costly solution to construct along with the requirement for marine plant and significant material for breakwaters and beach nourishment. Option 9 proposes a similar solution to Option 8 however it proposes more expensive breakwaters.

5.3.1.1.3 Maintenance Expenditure

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

Options 3, 4 & 5 have significant advantages over other options for maintenance costs. Some maintenance may be required however this will be infrequent. These options will require a routine and post storm monitoring plan during their design life.

Options 7, 8 & 9 have some advantages over other options as maintenance of the hard structures for all options will be infrequent. Option 7 & 9 require beach monitoring and renourishment. Option 8 has more amenity areas that will need to be maintained to ensure public safety. These options will require routine and post-storm monitoring plans.

Option 2 has significant disadvantages over other options as it relies on reactive repairs and maintenance which would become more frequent and costly over time. Option 6 has some disadvantages over other options as the extensive beaches would still require regular monitoring and maintenance and renourishment within the design life. Breakwaters would require minimal maintenance, but routine marine inspections and monitoring will be needed.

5.3.1.2 Safety

5.3.1.2.1 Health & Safety (Construction)

Options 1 & 4 have significant advantages over other options for construction health and safety. Option 1 requires no construction and therefore no construction risks. Option 4 also has a significant advantage over other options. For construction risk, the rock armour can be delivered by marine equipment but would use land-based plant for handling and transport.

Options 7 & 8 have some advantages over other options. For Option 7 the attached breakwaters will follow a similar construction methodology to the rock revetment, but working out from shore. Option 8 is similar to Option 4 however extensive work on the existing revetments brings increased risks.

Options 2, 3, 6 & 9 have some disadvantages over other options. Option 2 has disadvantages as it requires ad-hoc repair works that would only be carried out due to immediate risk to the railway. For Option 3, there is a significant risk due to transportation and handling of concrete armour units on both land and marine areas. Option 6 has some disadvantages over other options due to requirement of specialist marine equipment and contractors to construct the detached breakwaters. Works are also required adjacent to the railway to construct the raised seawall. Option 9 is similar to Option 6 however the proposed breakwaters have a smaller footprint.

Option 5 has significant disadvantages over other options. The proposal of a concrete seawall carries an increased construction H&S risk due to its location beside the railway. Excavation would be required to install the seawall and scour protection which could result in a cofferdam being used to create a dry environment for the works to be carried out.

5.3.1.2.2 Health & Safety (Design Life)

Options 7 & 8 have significant advantages over other options. Both options are similar to Option 4 however they have significant advantages by not proposing revetments at Blackrock and Seapoint Beach respectively. New amenity area creation for both options will improve health and safety.

Options 3 & 4 have some advantages over other options. For operational health and safety, there is a risk of the public walking/climbing on the revetments. Warning signs should be installed to deter this from happening. Maintenance of the revetments will be minimal which reduces maintenance operational health and safety risks. There is potential for both revetments to reduce the usable area of the beach, which could lead to members of the public being cut off by the tide. This can be mitigated by providing access points through the revetments.

Options 2, 5 & 9 come out as having some disadvantages over other options. For Option 2, reactive works to repair the existing defences would be required. These would not be planned, and it could lead to periods of time where there is health and safety risks prior to the works being carried out. As there is no improvement/upgrades proposed as part of this option, events such as overtopping and flooding onto the railway may increase which poses health and safety risks. For Option 5, the rock toe protection may become exposed if beach levels are lowered following storm events. This could result in a trip hazard for members of the public. The seawall height may lead to a risk if members of the public climb onto the wall. It can also provide an increased risk in the event of wave overtopping that there would be no warning to passersby. For Option 9, during low tides the breakwaters may be emergent, and members of the public may try to access them either through land or by swimming. Erection of warning signs should be implemented to mitigate this risk. Detached breakwaters may change the conditions of currents which could pose risks to swimmers in the area.

Option 1 has significant disadvantages over other options as no interventions would be proposed to prevent failure of the existing defences. Option 6 also has a significant disadvantage over options as it proposes a significant number of breakwaters at a number of public access points. While it is similar to Option 9 in terms of potential impacts, the number of breakwaters proposed significantly increases the risk for this option.

5.3.1.3 Accessibility and Social Inclusion

5.3.1.3.1 Community

Option 6 has significant advantages over other options as placement of proposed structures and undertaking of beach nourishment across the entirety of the CCA will enhance the beach amenity area along the coastline. This would contribute positively to the amenity value of the area.

Options 7, 8 & 9 have some advantages over other options. The placement of rock revetment along the majority of the coastline of this CCA in these options are not considered to be positive in regard to improving the amenity value or public perception of the area. The provision of minor breakwaters and beach nourishment at Seapoint would provide enhanced beach amenity areas at this location, and thereby contribute positively to public perception and amenity value locally. While Options 7, 8 & 9 are similar to Option 6, beach nourishment is only proposed in some areas which reduces the advantages over Option 6.

Option 2 has some disadvantages over options as while existing maintenance operations would take place, occurrences of coastal overtopping will continue and have further impact on the existing defences. Options 3, 4, 5 all have some disadvantages over other options. The placement of revetments for Options 3 & 4 will impact the use and amenity value of the beach for the local community. For Option 5, while initial impact would be limited, the beach amenity area will eventually be lost as a result of reflection against these structures.

Option 1 has significant disadvantages over other options as no works are proposed. This would result in the failure of existing defences and impact on the railway.

5.3.1.3.2 Access

Option 8 has significant advantages over other options as access to Blackrock and Seapoint are maintained and improved.

Options 6, 7 & 9 have some advantages over other options. Option 6 has some advantages as beach nourishment will improve alongshore access across the CCA and raising of existing seawalls will not impact any existing access points. Options 7 & 9 have similar advantages to Option 8 but they differ as they only improve and maintain access at Seapoint.

Options 1, 3, 4, 5 all have some disadvantages over other options. The placement of revetments for Options 3 & 4 will remove the existing access points. However, access steps will be incorporated into the structures to retain access to the amenity beach areas. For Option 5, potential reflections from seawalls may curtail alongshore access. Option 1 has disadvantages as, although in the short term there will be minimal impact to access, in the longer term there will be significant impact to access as the defences deteriorate.

Option 2 has some advantages over other options as there is no impact to existing access points at this location.

5.3.1.3.3 Social & Recreation Facilities

Options 1, 3, 4, 5 all have some disadvantages over other options. The placement of structures for all options will likely remove the publics ability to use the coastline areas for social and recreational activities. For Options 3 & 4 this will be immediate while Option 5 would be an eventual loss through reflection. For Option 1, there will be minimal impact in the short term but the effects of unmitigated climate change will eventually impact these resources.

Options 2, 6, 7, 8 & 9 have some advantages over other options. For Option 2, there are no impacts to existing social and recreational facilities at this location but they may be impacted over time. For Options 6 to 9, while they all provide enhances beach amenity areas, the proposal for hard structures such as breakwaters and revetments may impact the publics ability to use these areas for social and recreational activities.

5.3.1.4 Integration

5.3.1.4.1 Compatibility with Development Plans

Options 7, 8 & 9 have some advantages over other options. All options will provide the enhancement of the area with beach amenity and coastal recreation amenity. These options requires less concrete and hard infrastructure area than other options. In general, these options have less impacts along the length of the coastline (except for Option 9) on comparison with other options.

Options 3 & 5 are comparable to each other as they both align with high level coastal protection and coastal area management objectives within the development plans. They have similar impacts upon amenity and access. In addition, , they both require comparatively less material compared to other options which aligns with the development plan.

Options 2 & 4 have some disadvantages over other options. Option 2 proposed ad-hoc emergency repairs. While that would provide some protection to the existing rail line, it does not fully achieve the urgent action required by the development plan in terms of addressing long term climate change. Option 4 has similarities to Option 3, however as it proposes a larger footprint it has some disadvantages compared to other options.

Option 1 has significant disadvantages over the other options. Policy identifies coastal zone management and protection of the coast as important. This option does not provide any coastal protection and is not in lien with the aims and objectives of the development plan in terms of addressing long term climate change. Option 6 also has a significant disadvantages over other options as it has the potential to impact on marine policy/map based objectives due to larger footprint of breakwaters proposed compared to other options along with significant material requirements.

5.3.1.4.2 Compatibility with Climate Adaptation Plans

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

Options 2, 3, 5 and 6 have some disadvantages over other options. Option 2 would provide some disadvantages over other options as coastal zone management and coastal area protection are identified as important within the relevant development plans. The disadvantage relating to this option is that the minimum works rely on repairs, not a full upgrade would not fully achieve the objectives of the plans which include the need for climate adaptation. The Climate Action Plan 2023 sets out under 15.3.6 (Adaptation) the challenges related to the operation and resilience of the inter alia the rail network. For Options 3, 5 & 6 while they generally meet the requirements of the TCCASP, they require significantly more concrete/material as part of their options which is a disadvantage in terms of carbon footprint to other options.

Option 1 has significant disadvantages over other options as it would contravene climate objectives such as DCC policy objective "CA30 Coastal Zone Management".

5.3.1.4.3 Compatibility with Transport Plans

Options 3 to 9 have significant advantages over other options as they all improve the protection of the rail line against climate change impacts, in line with the Transport Strategy's aim to *"provide a sustainable, accessible and effective transport system for the Greater Dublin Area which meets the region's climate change requirements, serves the needs of urban and rural communities, and supports economic growth"*. The Greater Dublin Area Cycle Network Plan proposes a National Cycle Route, the East Coast Trail, with an indicative route along the coastline throughout CCA1 from Merrion Gates to Dún Laoghaire. Providing the hard structures within these options with consideration of the East Coast Trail will support the Transport Strategy.

Option 2 has some disadvantages over other options. There is potential disruptions to public transport in the short to medium term to conduct emergency 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 Option1, 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 ‘do nothing’ shows significant advantages over other options. It would allow for spit expansion to continue naturally, providing a supporting habitat for SPA birds. Although Option 1 has no potential for construction impacts, in the long-term allowing degradation and eventual collapse of rail line structures may lead to the release of pollutants into the surrounding area.

Options 2, 5 and 8 have some advantages over other options. When compared to other ‘do something’ options Option 5 has a significantly smaller working and operational footprint. In terms of short-term construction impacts, removal of the existing wall will require the use of a cofferdam and has the potential to trigger the release of pollutants. Placement of rock revetments has to be carried out at high tide and so night time works will likely be a necessity. Operational impacts are largely neutral as absence of a crest excludes public access to lands that are used by sea birds and so disturbance to these species will either decrease or remain at current levels. Changes in hydrology could indirectly impact QI habitats but this option is lower risk than others. Option 8 shows some potential construction and operational impacts to biodiversity. It is predicted there will be no significant direct loss to eel grass bed. Changes in hydrology have the potential to indirectly impact QI habitat, in particular eel grass bed. QI bird species would be disturbed by construction and by an increase in public access in the operational phase due to the stepped revetment at Blackrock wall.

Options 3, 4, 7 and 9 have disadvantages to other options, this is largely due to greater extent of construction impacts. All of the above options have the potential to impact hydrology which has a currently unknown impact to eel grass beds and requires further investigation through modelling. They also require the transportation of materials by barge at night which will cause noise and light pollution likely to disturb SPA bird species. Changes to accessibility of the beach discussed previously will also increase public access and in turn increase disturbance to birds. Both the construction and operational phases will have direct impact on QI habitats of South Dublin Bay SAC including loss of mud/sand flats. For options 7 and 9, further direct impacts to habitats during construction have been identified. There are two discrete locations known to possess reef habitat that will be disturbed by the implementation of breakwaters and beach nourishment which will affect hydrology and potentially smother reefs. Sand replenishment will cause repeated disturbance over the long-term.

Finally, Option 6 has significant disadvantages over the other options. Similarly to options 3,4,7 and 9 the implementation of breakwaters and beach nourishment will affect reefs, these interventions are much more extensive for this option and so will have a greater impact. The additional presence of groynes in this option will further exacerbate potential affects of sand placement on surrounding habitats. Pioneer saltmarsh and Annex I species (annual vegetation drift lines) observed north of Booterstown station have the potential to be impacted by changes in hydrology and beach nourishment. This option could cause impacts at a National or International level.

5.3.1.5.2 Landscape, Visual & Seascape

Option 5 has significant advantages over other options, this is due to visual characteristics of the proposed wall and rock toe protection integrating well with the current visual characteristics of the coastline.

Both Options 7 and 8 have advantages over other options. For Option 7, beach nourishment and improvements to current sea wall will improve the amenity and character of Seapoint beach. Obstruction will be avoided through the implementation of a low seawall design and the use of attached rather than detached breakwaters. Option 8 involves the enhancement of current features at Blackrock and Seapoint and so will retain the current landscape. However, sea wall height will be raised which will cause visual obstruction along the rail line.

Options 2, 4 and 9 have disadvantages over other options. Option 2 requires continued and ongoing works which will create adverse effects to the landscape that are continued in nature. For Option 4 the size and form of stone revetments is such that they have the potential to generate adverse visual effects, however, the use of natural materials will allow them to integrate into the landscape better than concrete methods. They will be employed at the coastal edge rather than out at sea which is generally considered to have less visual effect. Beach nourishment in option 9 has potential to enhance the amenity value and character of Seapoint, however, detached breakwaters will have a negative visual effect on the seascape.

Options 1, 3 and 6 have significant disadvantages over other options. For Option 1 this is due to continued degradation and coastal flooding having an adverse effect on the landscape and seascape. The concrete armour units for the Option 3 revetments will stand out from the natural qualities of the coastline; the proposed size and form of the revetments will counteract any attempts to utilise concrete with a more natural character. For Option 6, although regularisation of the sea wall and beach nourishment have the potential to improve the amenity and character of the coastline, the detached breakwaters will generate significant adverse landscape/seascape visual effects. These breakwaters will be utilised consistently in near-shore waters, some of which will be below the low water mark.

5.3.1.5.3 Archaeology, Architectural & Cultural Heritage

Options 3-9 are comparable to each other as they all have the potential to impact an SMR site and SMR Zone of Notification. They also have the potential for direct impacts on previously unrecorded archaeological heritage.

Option 1 & 2 have significant disadvantages over other options as they would result in the loss of archaeological features as a result of continued degradation and coastal flooding as a result of no/minimal emergency repair works respectively.

5.3.1.5.4 Marine Archaeology

Options 1, 2, 3, 4, 5 & 8 have significant advantages over other options as no works are proposed within the intertidal or marine elements.

Options 7 & 9 have some disadvantage over other options as there is potential for significant direct impacts to occur on previously unrecorded wrecks, paleoenvironmental landscapes and material culture both within the sub-tidal areas within the footprint of the breakwaters and beach nourishment dredging and pumping.

Option 6 has significant disadvantages as it has a significantly larger marine footprint and therefore has more potential to impact on previously unrecorded wrecks, paleoenvironmental landscapes and material culture both within the sub-tidal areas within the footprint of the breakwaters and beach nourishment dredging and pumping.

5.3.1.5.5 Noise and Vibration

Options 3, 4, 7, 8 & 9 have some advantages over other options. The noise impacts will come from mobile plant when working in proximity to Noise Sensitive Locations (NSLs). For options proposing breakwaters there are potential for short-term, localised underwater noise impacts. All impacts are predicted to be temporary to short-term.

Options 1, 2, 5 & 6 have some disadvantages over other options. While Option 1 would provide some advantages as there would be no construction or maintenance works and therefore no construction related noise or vibration impacts, the long-term operational scenario would have some disadvantages compared to other options if rail services are suspended and road traffic on surrounding road network increases. Option 2 would provide similar advantages to Option 1. However, the existing maintenance works will continue as necessary which will be of neutral impact, albeit these will likely intensify in frequency. The long-term operational scenario is neutral compared to other options, although the rail service will likely be less reliable and has potential for increased traffic on surrounding road network. Due to the longer-term duration of potential impacts, is less advantageous over other options. For Options 5 & 6 the construction methods for these options are more intrusive and both require night-time rail possessions to carry out. There is potential for noise and vibration impacts on NSLs for both options. For Option 6, there is potential for short-term underwater noise impacts during the construction of breakwaters.

5.3.1.5.6 Air Quality

Options 3, 4, 7, 8 & 9 have some advantages over other options. Construction phase impacts include construction vehicle emissions, beach nourishment where proposed and potential excavation works in options with rock toe proposals. Impacts are likely to be considered short-term and dust mitigation measures can be put in place.

Options 5 & 6 have some disadvantages over other options. Option 6 has a larger footprint of beach nourishment which is will likely have dust impacts. Demolition and removal of the existing revetment and wall as part of Option 5 and long closure of railway during construction is a disadvantage. Structures for Option 5 are assumed to be a mix of precast and on-site batching.

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

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

5.3.1.5.7 Carbon Management

Options 4, 7 & 8 have significant advantages over other options as they had the lowest Whole Life Carbon (tonnes CO_2e) of all options.

Option 9 has some advantages over other options as they have preferable levels of Whole Life Carbon (tonnes CO_2e) compared to other options.

Options 3 & 6 have some disadvantages over other options as they have unfavourable levels of Whole Life Carbon (tonnes CO_2e) compared to other options.

Option 5 has a significant disadvantage as it scores the highest Whole Life Carbon (Tonnes CO_2e) across all 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.

Options 3-9 facilitate operational phase reliance on public transport and reduce reliance on private vehicles for the long term.

5.3.1.5.8 Water Resources

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

Options 3, 4, 7, 8 & 9 have some advantages as there are minimal impacts to groundwater as there is no below ground construction proposed.

Option 5 has some disadvantages as the concrete seawall construction could impact groundwater levels, flow and quality.

5.3.1.5.9 Geology and Soils

Option 2 has significant advantages over other options as there will be minimal disturbance to geological resources due to ad-hoc emergency works are planned.

Option 4 & 8 have some advantages over other options as rock revetments may cause less disturbance overall to geological resources during the construction phase.

Options 3, 7 & 9 are comparable to each other. The revetments have potential to cause disturbance to geological resources and the addition of beach nourishment for Options 7 and 9 may cause moderate disturbance.

Options 1 & 6 have some disadvantages over other options. Option 1 has some advantages as no construction work are proposed. However, long term degradation could result in the erosion of local geology. For Option 6, the beach nourishment and detached breakwaters are expected to cause moderate disturbance.

Option 5 has significant disadvantages over other options as the construction of the concrete seawall and rock toe is likely to involve bulk excavation and cofferdams which will significantly disturb geological resources across the cell. Furthermore, the intrusive nature of the works may release contamination into the wider environment.

5.3.1.5.10 Material & Circular Economy

Options 1, 2, 4 & 8 have significant advantages over other options. Option 1 & 2 have low scores due to no/reactive works respectively. Options 4 & 8 have the lowest materials consumption score compared to other options.

Options 3 has some advantages over other options as it has a comparatively lower materials consumption score compared to other options.

Options 7 & 9 have some disadvantages as they scored a comparatively high materials consumption score compared to other options.

Options 6 has significant disadvantages over other options as it scored a comparatively 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. Option 6 also has a significant advantage over other options as no waste will be generated from removing existing structures. This option scored comparatively low for wastage.

Options 4, 7, 8 & 9 have some advantages over other options. Minimal waste may be generated from removal of existing structures. Wastage from damaged materials has been estimated based on the application of material-specific wastage rates to the quantities of concrete materials that are likely to be used in constructing the options.

Options 3 has some disadvantages over other options as while it is similar to other options in minimal wastage from removal of existing structures, this option scores comparatively high against other options wastage potentials due to the volume of concrete required for this option.

Option 5 has a significant disadvantage over other options as significant waste would be generated from the removal of existing masonry revetments. This option scored the highest compared to other options for wastage potential.

5.3.1.5.12 Traffic and Transport

Options 3-9 are comparative as minimal operational impact expected to traffic & transport; the intervention works will be localised to the coast and are not anticipated to affect transport systems or travel demand.

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

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

5.3.1.6 Engineering

5.3.1.6.1 Constructability

Options 1 & 4 have a significant advantage over other options. Option 1 does not propose any construction works (it only includes for signage to keep the public safe). Construction for Option 4 is relatively simple as it is adding to existing infrastructure, however it would a quick construction period. This could be mitigated by parallel working with other work fronts. Following the delivery of rock by marine plant, the revetments can be constructed using land-based plant.

Options 7 & 8 are comparable to each other. While they are similar to Option 4, Option 7 has the addition of attached breakwaters and Option 8 has more extensive concrete works at Seapoint which will result in more interfaces. However, they are more straightforward than Options 6 & 9 as the attached breakwaters have a smaller footprint for Option 7 and no marine works are required for Option 8.

Options 2, 6 & 9 have some disadvantages over other options. Option 2 has some disadvantages as it proposes emergency works only. Options 6 & 9 are similar in part requiring marine works to construct the detached breakwaters which require specialist marine plant along with challenges of working in open water.

Options 3 & 5 have a significant disadvantage due to the difficulty of constructing concrete structures. For Option 3, production, handling and placing of the concrete units can be challenging and could require specialist plant. Interlocking the armour units is also difficult. For Option 5, construction of a seawall may need a cofferdam to create a dry environment to work in. Works would also require working adjacent to a live rail line. This would be costly, risky and time consuming.

5.3.1.6.2 Rail Service Impact

Option 1 has a significant advantage as no works are proposed. Options 6, 7 & 9 also have significant advantages over other options as there is no impact on the railway during the construction of the breakwaters. However, there may be minimal impact during wall raisings and during beach nourishment.

Options 3, 4 & 8 have some advantages over other options as the operation of railway line will be minimally impacted as the works are adding to existing infrastructure so no excavation is needed. Irish Rail will require to be notified of works as adjacent to the railway line but this is expected to be low risk for all options.

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

Option 5 has significant disadvantages over other options as it requires deep excavation adjacent to the railway. This will require approvals and potential temporary closures to facilitate works.

5.3.1.6.3 Reliance On Maintenance

Options 4 has significant advantages over other options as it require minimal maintenance during the design life, although it will require a routine and post-storm monitoring plan

Options 3, 5, 7, 8 & 9 have some advantages over other options. Option 5 will have regular maintenance and repairs to the concrete seawalls, although as new structures this should be minimal. Options 7 & 9 propose beach nourishment which requires regular monitoring and post-storm inspections to inform future beach renourishment needs. All options require regular and post-storm monitoring. Option 3 & 8 may require more regular repairs compared to the other options due to concrete being the main material proposed in the seawall and stepped revetments for the amenity areas. Maintenance of the rock structures would require minimal maintenance during design life.

Option 1 has some disadvantages over other options as while there is no requirement for maintenance, significant monitoring would be required to keep the public safe. Option 6 also has some disadvantages over other options due to the ongoing monitoring and maintenance to maintain the large beaches to design levels through regular renourishment works.

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 5 has significant advantages over other options as being a new structure there is scope for adaptation through increasing wall heights as needed.

Options 4, 6, 7, 8 & 9 have some advantages over other options as they are designed to account for predicted climate change. For Options 6, 7 & 9 beach level adaptation can be undertaken to account for additional changes. For Option 4 and 8, future raising of the concrete seawall is possible although this may prove tricky due to a reliance on raising existing structures.

Option 3 has some disadvantages as the interlocking nature of the concrete armour units make adaptation challenging.

Options 1 & 2 have a significant disadvantage over other options. For Option 1, there is no works proposed and therefore no opportunity for adaptation. Option 2 has minimal opportunities for adaptation. However, as Option 2 proposes ad-hoc reactionary repairs, it would not be possible to properly plan works to create a progressive adaptation approach.

5.3.1.6.5 Residual Risk

Options 3, 4 and 6 to 9 are comparable as they all rely on hard engineering measures to manage risk and having less reliance on a beach to prevent coastal flooding or wave overtopping. For Options proposing a revetment or seawall, should the defence be compromised failure could be rapid. For Options proposing breakwaters, generally breakwater failure is slow and not catastrophic.

Option 5 has some disadvantages as failure of a concrete seawall can be sudden, compared to rock structures where failure is typically slow and progressive.

Options 1 & 2 have significant disadvantages over other options as for Option 1 no works would occur and Option 2 ad-hoc emergency repairs will not eliminate weaknesses in the existing defences. This would lead to a degradation of existing defences potentially leading to a catastrophic event.

5.3.1.7 Planning Risk

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

Options 5 & 8 have some advantages over other options. Both options propose upgrades to the existing coastal defences. This aligns with planning policy for long term protection against the backdrop of climate change. The works are likely to be carried out within a Natura 2000 Site but to a lesser extent than other options as they don’t propose works in the marine area. The potential for IROPI increases the planning risk as it will increase the chances that the option will either be refused permission or significantly delayed in its determination. Option 5 scores higher for integration (landscape) than any other option and potentially has the smallest footprint into the designated area (with lowest IROPI risk). Option 8 scores comparatively high for integration (landscape) and is a strong option within all criteria within accessibility and social inclusion.

Options 3, 4, 7 & 9 have some disadvantages over other options. The proposed works are within Natura 2000 Site with potential for temporary and permanent impacts on qualifying interests which could invoke IROPI leading to delay and/or greater chance of permission being refused. All options score poorly for biodiversity. Options 3, 4 & 9 score poorly for landscape and a lack of integration is also likely to attract objection.

Option 6 has a significant disadvantage over other options. The proposed works are carried out in Natura 2000 sites with potential to require IROPI leading to increased potential for delay and refusal of planning permission. Option 6 scores the lowest of all options for biodiversity and landscape increasing the potential for objection. It is also ranked the lowest for compatibility with development and climate adaptation plans.

5.3.2 Summary

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

Options 4, 7 and 8 have been identified as the Top-ranking Short List Options to be taken forward. The basis for each of these are as follows:

- Option 4 scored the highest of all options in relation to Economy, Safety, Environmental and Engineering criteria. Option 4 had some comparative advantages over other options in relation to Planning. In terms of Accessibility & Social Inclusion and Integration, Option 4 scored comparable to other options.
- Option 7 scored the highest in relation to Safety, Integration an Engineering criteria. In relation to Economy, Accessibility & Social Inclusion and Environmental, Option 7 has some comparative advantages over other options. In relation to Planning, Option 7 scored comparably to other options.
- Option 8 has a significant comparable advantage over other options in Safety, Accessibility & Social and Environmental criteria. In relation to Economy ,Engineering and Planning Option 8 has a comparative advantage over other options.

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	Option 9
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 Revetment with raised walls (Short List Option 4)
- Option B: Rock revetment with raised walls (A-D); attached breakwaters and amenity beach with raised walls/walkways (E) (Short List Option 7)
- Option C: Rock revetment with raised walls (A-D); stepped revetment with raised walls/walkways and rock toe protection in amenity frontages (D & E) (Short List Option 8)

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. Typical cross sections of the option are shown in Figure 5-2 and Figure 5-3. This is further detailed by the concept design engineering drawings in Appendix E.

The main assumption of this option is that the existing masonry revetments and walls will remain in-situ and the rock revetments and raised walls will be added on top of these existing defences. 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.

The addition of good quality rock around/over existing coastal defences to manage coastal flooding and erosion risk is commonplace. The existing structures through CCA1 are relatively smooth and reflective structures, which results in wave run up and overtopping onto the railway line when high tides combine with waves in Dublin Bay. As an alternative structure face, rock is energy absorbing and significantly reduces wave overtopping. This measure on its own is not enough to provide protection to 2100 inclusive of sea level rise allowances. Hence, the existing upstand walls adjacent to the railway line require raising as well (at all sub-cells). 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 to minimise the visual impact.

Given the proximity of the construction works to the railway, works may require Authorisation for Placing in Service (APIS) approval.

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

No works are proposed at Brighton Vale (eastern section of CCA1-D) as there is no risk to the railway along this frontage.

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;
- 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:

- Significant impact on access and amenity at Seapoint Beach;
- High risk of impacts on biodiversity & possible/probable requirement for IROPI (compared to Option C); and
- Rock revetments will have potential for adverse landscape / seascape and visual effects.

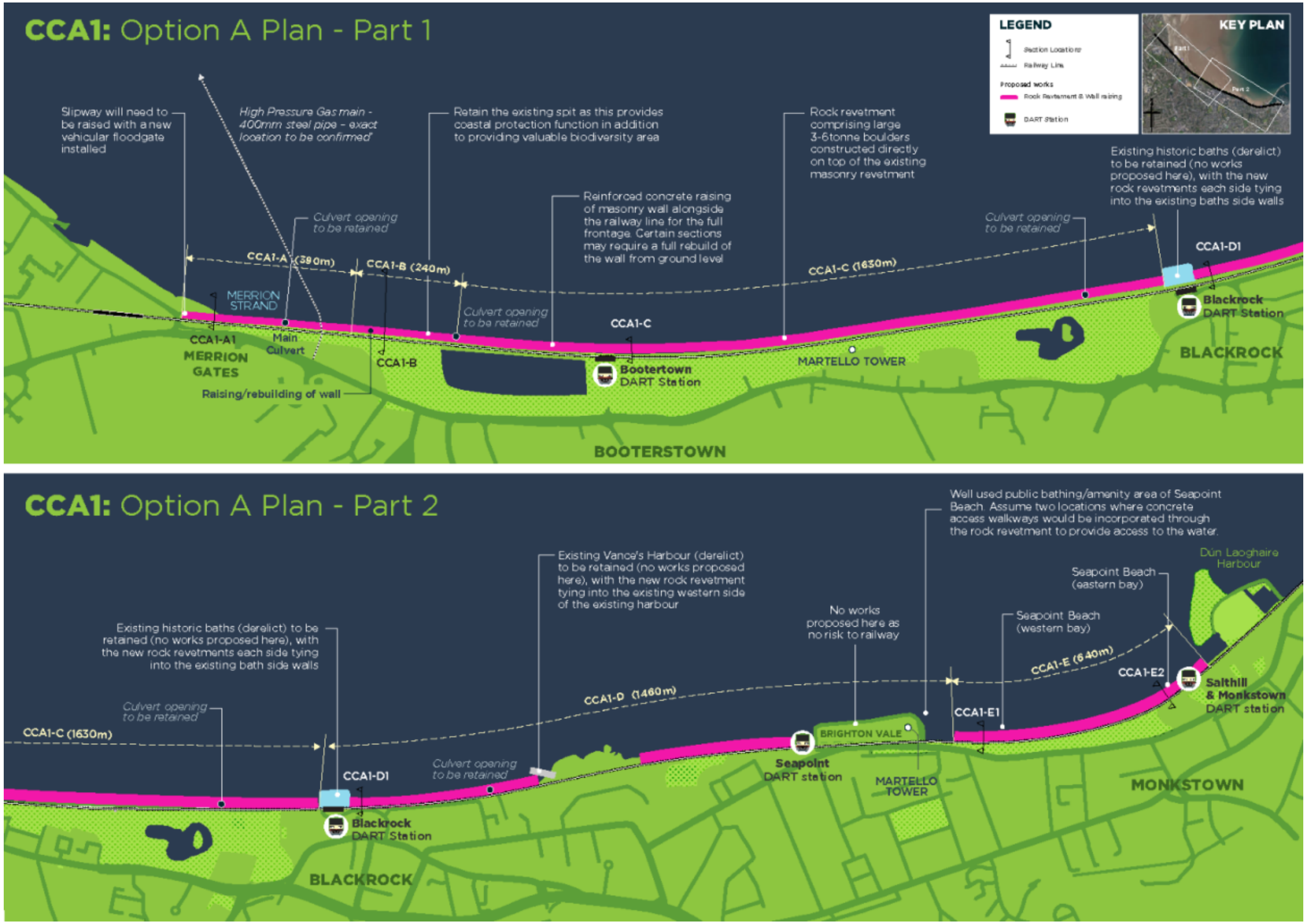


Figure 5-1 CCA1 Option A Concept Design Plan

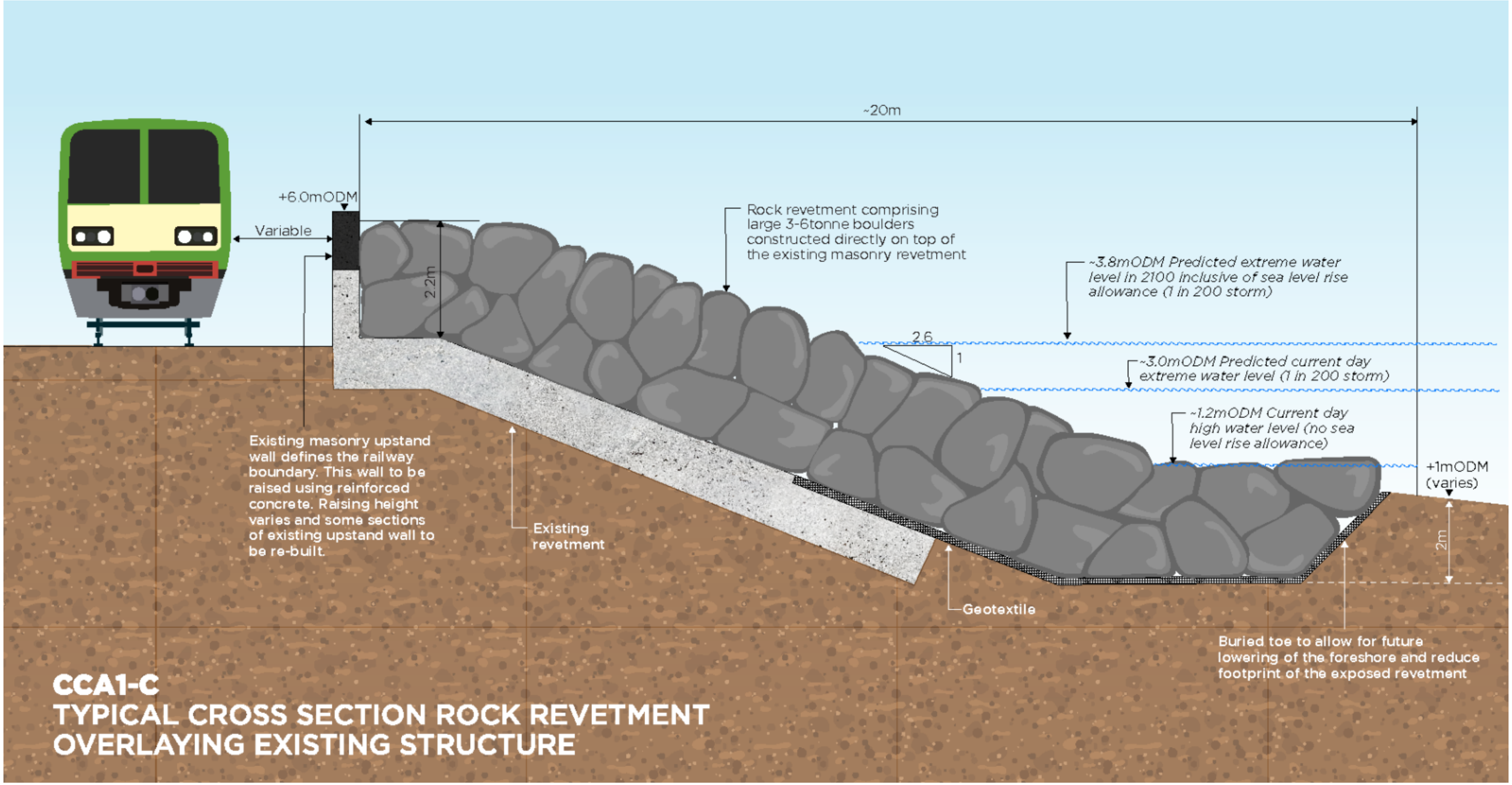


Figure 5-2 CCA1-C Option A typical cross section

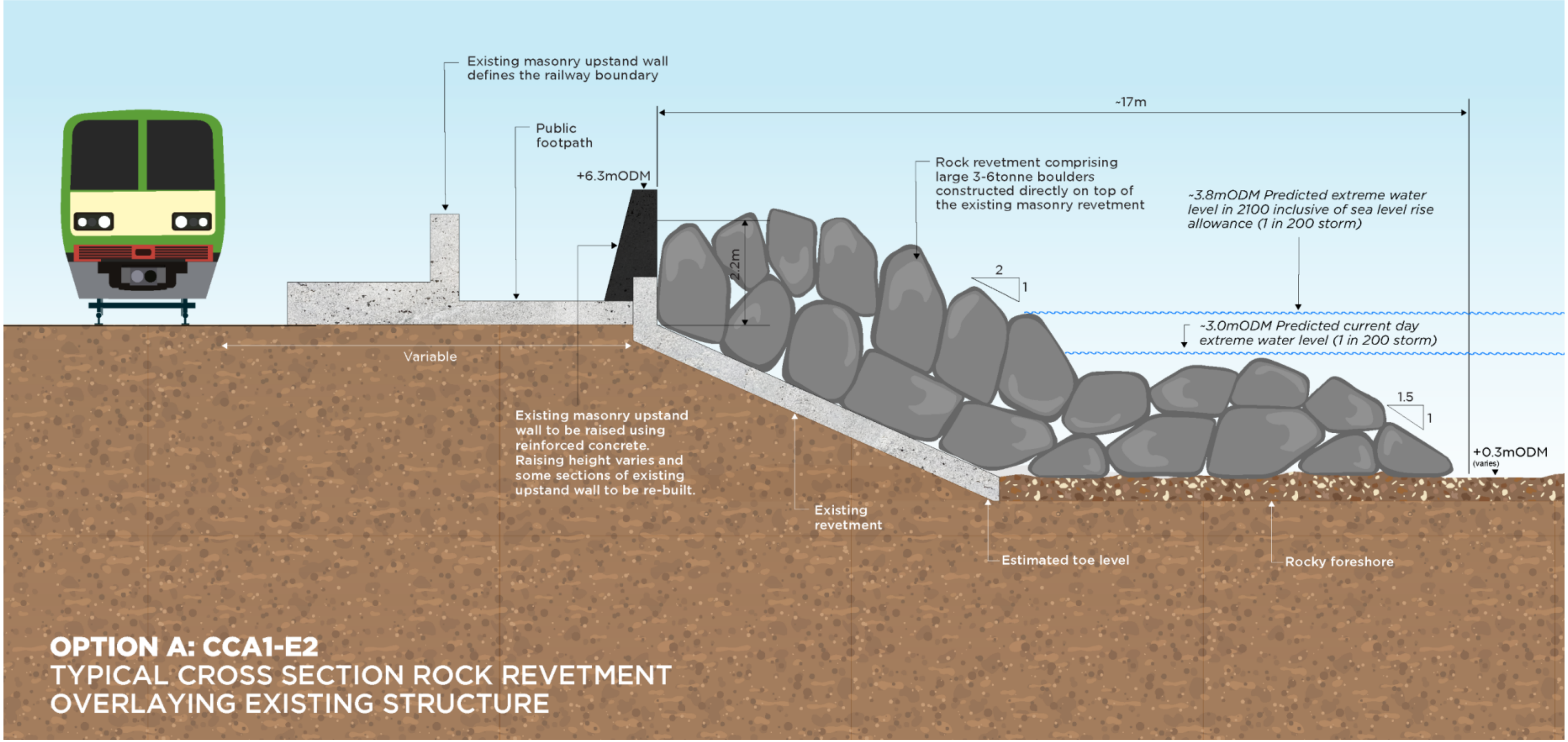


Figure 5-3 CCA1-E Option A typical cross section

5.4.1.2 Option B

The Concept Design for sub-cells CCA1-A, CCA1-B, CCA1-C and CCA1-D is the same as presented for Option A in Section 5.4.1.1.

The variations for Option B are summarised as follows:

- At Seapoint, CCA1-E, attached breakwaters with nourishment and improved and raised seawall/footpath and concrete revetment steps replace the rock revetment.

The alternative design at Seapoint acknowledges that this beach and the surrounding environment is an important and well used amenity destination for the local community. Whereas Option A dissipates all wave energy at the shoreline, Option B uses attached breakwaters to dissipate wave energy in the most vulnerable central and eastern sections of the bay.

The Option B concept design proposed for each of the sub-cells is summarised by Figure 5-4. Typical cross sections of the option are shown in Figure 5-5 (western bay) and Figure 5-6 (eastern bay). This is further detailed by the concept design engineering drawings in Appendix E.

5.4.1.2.1 Western Bay

The western bay comprises a raised rear footpath with concrete stepped revetment sections (providing lower-level amenity access) with raised upstand wave walls and rock toe protection.

A beach nourishment option was discounted in this location due to the amenity and environmental implications: it is understood that this area is highly used by swimmers and increasing the size of the beach would have a negative impact as it would reduce the water depth and therefore increase the distance from the shoreline the swimmers have to go before the water is deep enough to swim in. This area also has frequent rocky outcrops which if covered in beach material would have negative environmental implications.

To provide the required SoP at the western bay an increase in the existing upstand wave wall levels is required. Due to the limited space between the existing upstand walls and the railway line, it is not considered feasible to provide the improved SoP through wall-raising alone. Increasing the size of the stepped revetment sections will help to dissipate wave energy and therefore reduce the wave loading and overtopping on the upstand wall.

Raising the rear footpath level behind the upstand seawall reduces health and safety risks for footpath users. If the existing footpath level was retained, the wave wall would likely be more than 2.0m above the footpath level. This would mean that the majority of footpath users would not have any visibility of the sea from the promenade and would have no visible warning of any waves overtopping the wall onto the footpath. By raising the footpath, the wall height is reduced to approximately 1.2m which will allow visibility for most people whilst also providing a sufficient height of barrier between the promenade and the seaward side of the wall (i.e. not a trip hazard and high enough to discourage people from climbing and walking along the top of the wall).

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 (of the wave wall and footpath) will be reduced as much as possible during later stages of design to minimise the visual impact on rail users.

The rock toe protection is included to prevent undermining of the stepped concrete revetment. Impermeable vertical faces can lead to wave reflections which in turn can result in loss of beach material due to the wave action at the toe of the structure, as the beach material is eroded the underside of the concrete structure can become exposed. Installing rock armour at the toe of the structure dissipates the wave energy whilst also preventing the toe of the concrete structure from becoming exposed.

The geometry of the steps and the promenade will be refined during later design development stages. The use of low carbon concrete in the stepped revetment and wave walls will also be investigated during preliminary design stage.

5.4.1.2.2 Eastern Bay

Option B comprises a shore attached rock armour breakwater at the eastern end of the bay, extending out from the existing breakwater. At the centre of the bay, a 'Y shaped' rock groyne extends out from the shoreline. These two structures will reduce the wave energy reaching the shoreline in the eastern bay as well as minimising the risk of beach material being transported out of the bay. However, these structures alone cannot sufficiently reduce the wave energy to reduce the wave overtopping to the required thresholds alone. Therefore, raising of the wave wall at the top of the existing revetment is also included. The height increase will be reduced as much as possible during later stages of design to minimise the visual impact on rail users.

Beach nourishment is also included in the eastern bay. Beach nourishment involves adding additional beach material (closely matching the existing material) onto the beach to create a larger beach (higher and wider). This acts to reduce the wave energy by reducing the depth and leading to breaking the waves on the beach, reducing the wave heights reaching the revetment and subsequently reducing the overtopping.

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 groyne and breakwater) 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.

At Seapoint, the beach nourishment has been kept relatively small to minimise the level of maintenance, the impact on the amenity use of the area and the potential environmental impact of covering existing seabed with beach material. Its main function is to prevent undermining of the existing revetment and to reduce wave impact on the revetment, particularly the lower part of the revetment. It is anticipated that maintenance of the beach will be to bring in additional material by road to 'top up' the beach (beach re-nourishment) and this will be required at no less than 10 year intervals.

The orientation of the breakwater and groyne for concept design has been determined through numerical modelling to achieve a stable bay shape. This involves using the dominant wave direction (derived from the numerical modelling) to estimate the alignment that the beach would naturally orientate to. The beach control structures, in this case the rock groyne and rock breakwater, were then orientated to extend out to hold the toe of the beach in the equilibrium position. As the eastern bay is known to be used by for sailing, additional attention was paid to the opening between the two structures to reduce the impact on sailing boats coming in and out of the bay.

Given the proximity of the construction works to the railway, works may require Authorisation for Placing in Service (APIS) approval.

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

No works are proposed at Brighton Vale (eastern section of CCA1-D) as there is no risk to the railway along this frontage.

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 bathing conditions and access at Seapoint Beach;
- 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:

- Loss of habitat under breakwaters and beach nourishment where reef habitats are known to occur;
- Highest risk of impacts on biodiversity & possible/probable requirement for IROPI (compared to Option C);
- Lower score for materials, maintenance and circular economy due to beach nourishment; and
- High potential for direct impacts on marine archaeology at Seapoint.

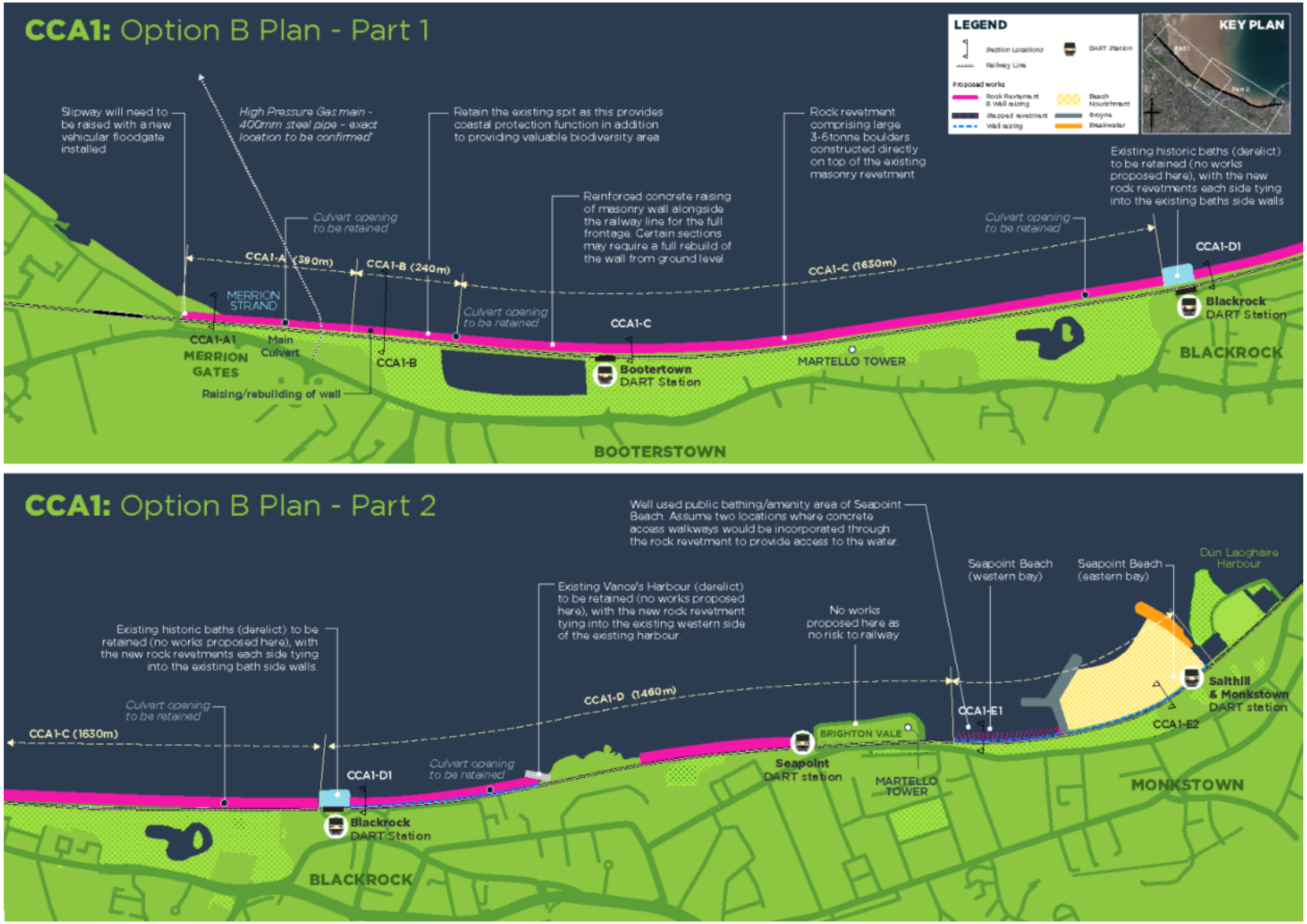


Figure 5-4 CCA1 Option B Concept Design Plan

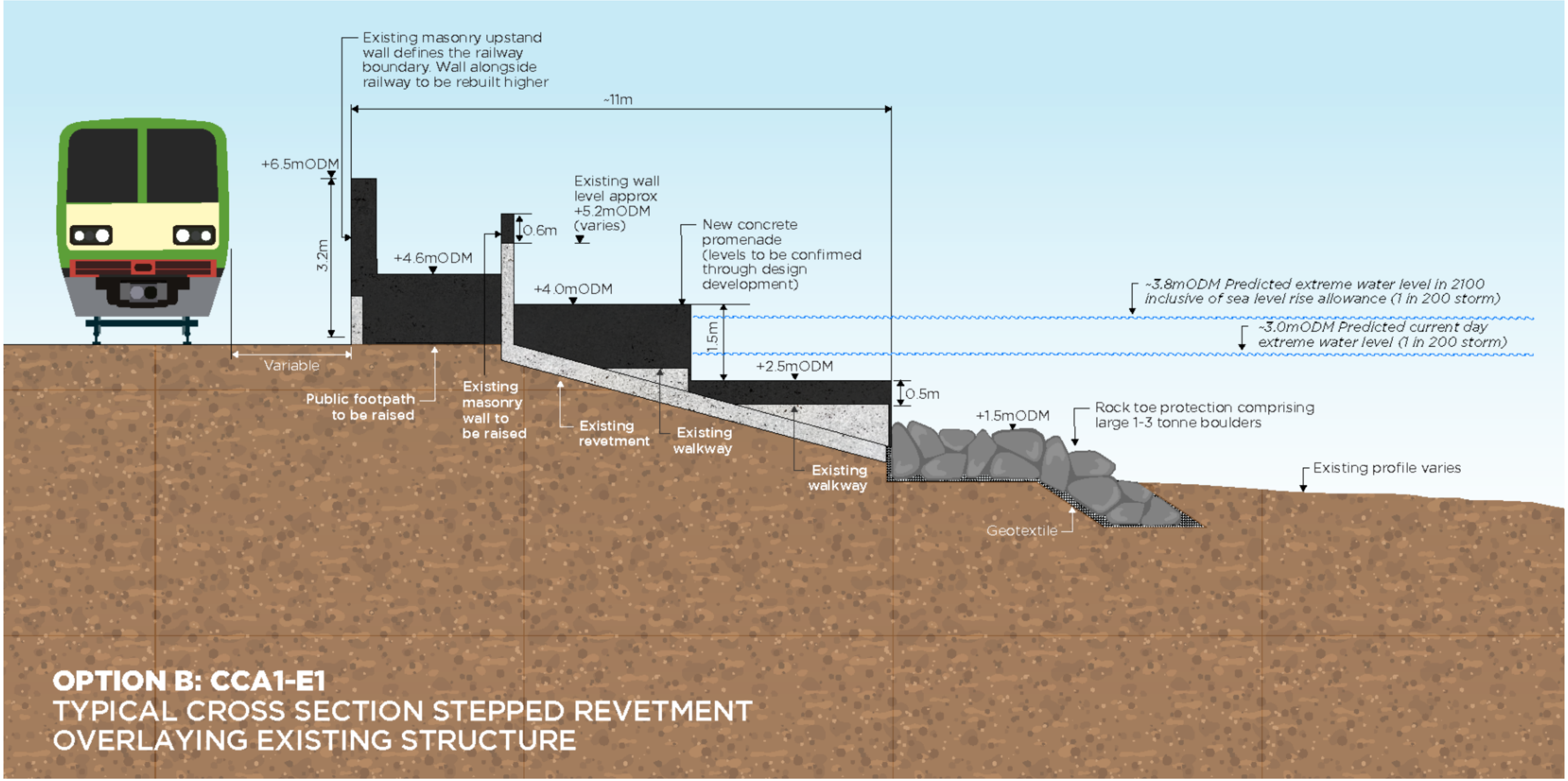


Figure 5-5 CCA1-E Option B typical cross section Western Bay

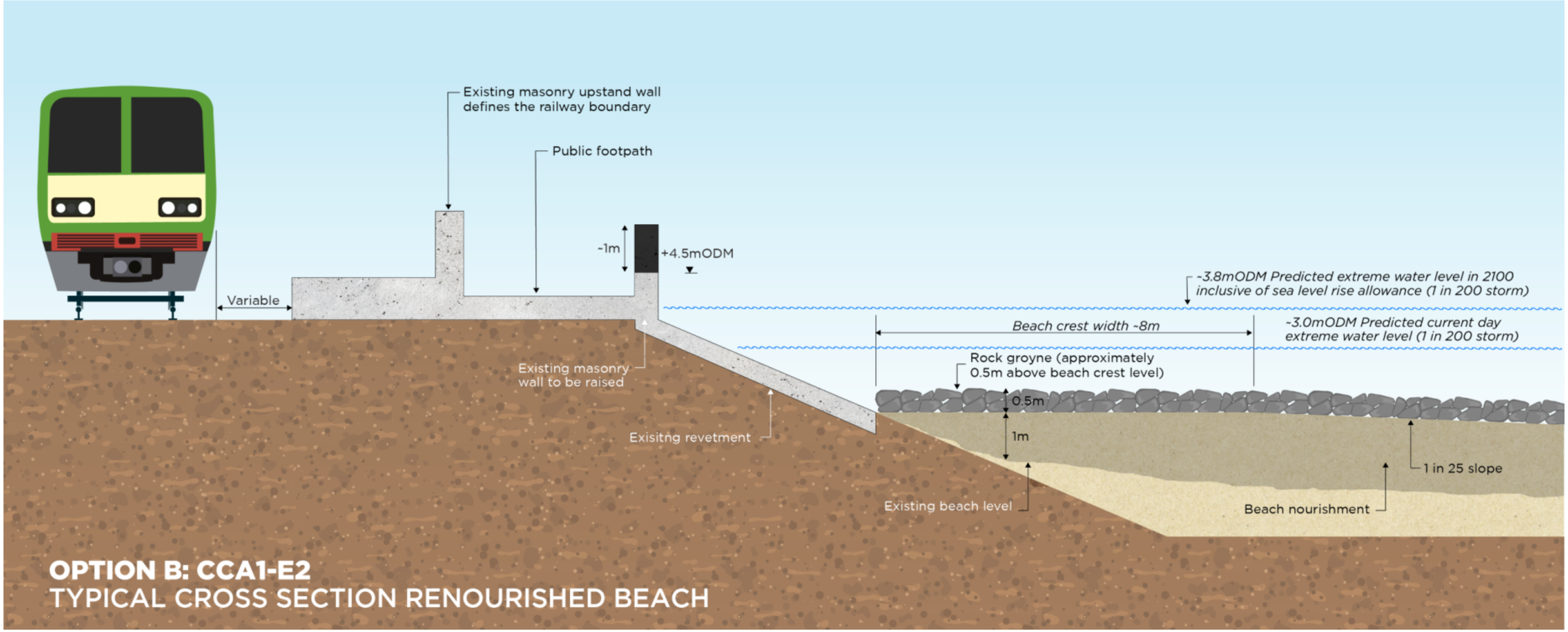


Figure 5-6 CCA1-E Option B typical cross section Eastern Bay

5.4.1.3 Option C

The Concept Design for sub-cells CCA-A, CCA-B and CCA-C is the same as presented for Option A in Section 5.4.1.1.

The variations for Option C are summarised as follows:

- At Blackrock, in the western section of CCA1-D, a concrete stepped revetment replaces the rock revetment; and
- At Seapoint, CCA1-E, concrete stepped revetments with improved and raised seawalls replace the rock revetment.

The alternative design at Blackrock and Seapoint acknowledges that these are well used amenity destinations for the local community and Option C seeks to replicate the amenity provision on a like for like basis.

The Option C concept design proposed for each of the sub-cells is summarised by Figure 5-7. Typical cross sections of the option are shown in Figure 5-8. This is further detailed by the concept design engineering drawings in Appendix E.

At Blackrock (western section of CCA1-D), Option C comprises a stepped concrete revetment with raised wave wall and rock toe protection, overlaying the existing block revetment. The stepped revetment dissipates wave energy whilst also providing amenity use of the revetment and access to the sea for swimming. Similar to Option B, the rock toe protection is included to prevent undermining of the stepped concrete revetment.

The geometry of the steps and the promenade will be refined during later design development stages.

Option C comprises the same solution as Option B along the western bay of Seapoint (CCA1-E).

Along the central section of Seapoint, Option C involves raising the existing promenade level above the existing wall level and creating one wide promenade with a front and rear seawall, with rock toe protection at the base of the wall. This option takes advantage of the existing wider promenade in this location. The addition of a wave wall at the seaward face of the promenade will significantly reduce the wave overtopping reaching the rear wave wall, thereby reducing the required size of the rear wall.

The eastern bay of Seapoint Involves overlaying the existing revetment with reinforced concrete and raising the wave wall and rear footpath level. The existing revetment is in relatively good condition, albeit with some repair works required prior to overlaying the concrete. However, with increased water levels and wave action, increased deterioration of the revetment is expected. The concrete will prevent deterioration of the underlying revetment and the addition of rock toe protection will prevent further undermining of the revetment. As the concrete will not improve the dissipation of wave energy, compared to the existing revetment, the wave wall will also require raising to provide the required Standard of Protection. Similar to the western bay, it is proposed to also raise the rear footpath level to improve the feasibility and constructability of the raised wall along with improving amenity access.

Given the proximity of the construction works to the railway, works may require Authorisation for Placing in Service (APIS) approval.

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 to minimise the visual impact on rail users. The use of low carbon concrete in the stepped revetment and wave walls will also be investigated during preliminary design stage.

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

No works are proposed at Brighton Vale (eastern section of CCA1-D) as there is no risk to the railway along this frontage.

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 access at Blackrock and Seapoint Beach compared to other options

- Low maintenance burden and expenditure;
- Scored well for landscape and visual, air quality, carbon management and waste;
- Scored well for H&S;
- Reduced direct impacts on archaeology, architectural and cultural heritage; and
- Reduced impact on intertidal/reef habitat, hence lowest IROPI risk.

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

- More complex construction for stepped revetment at Blackrock and Seapoint;
- Higher potential for disruption to railway during construction works at Seapoint;
- Higher risk that footpath raising could be problematic due to proximity to railway electrification cables; and
- Increased visual impact for rail users through Seapoint.

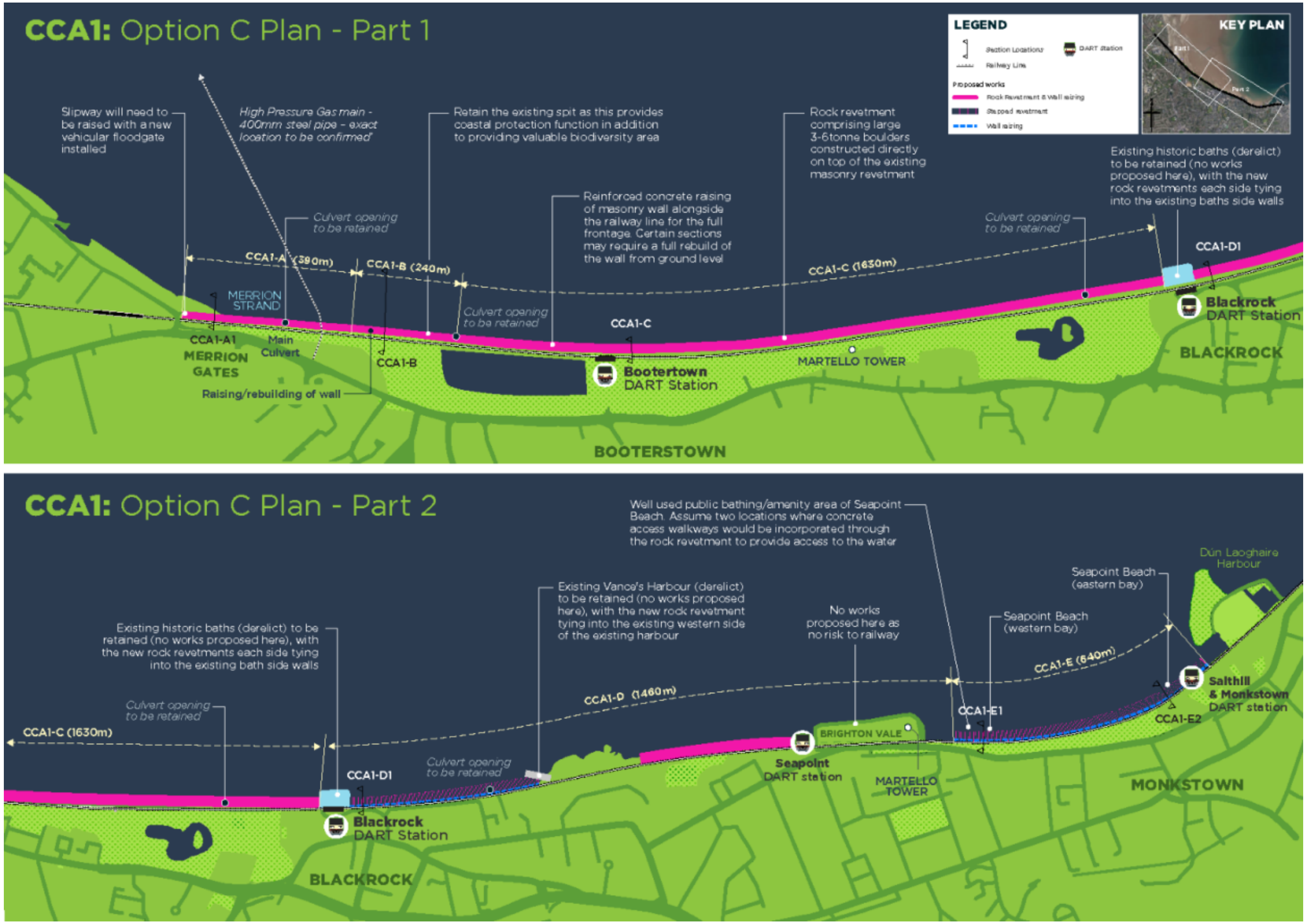


Figure 5-7 CCA1 Option C Concept Design Plan

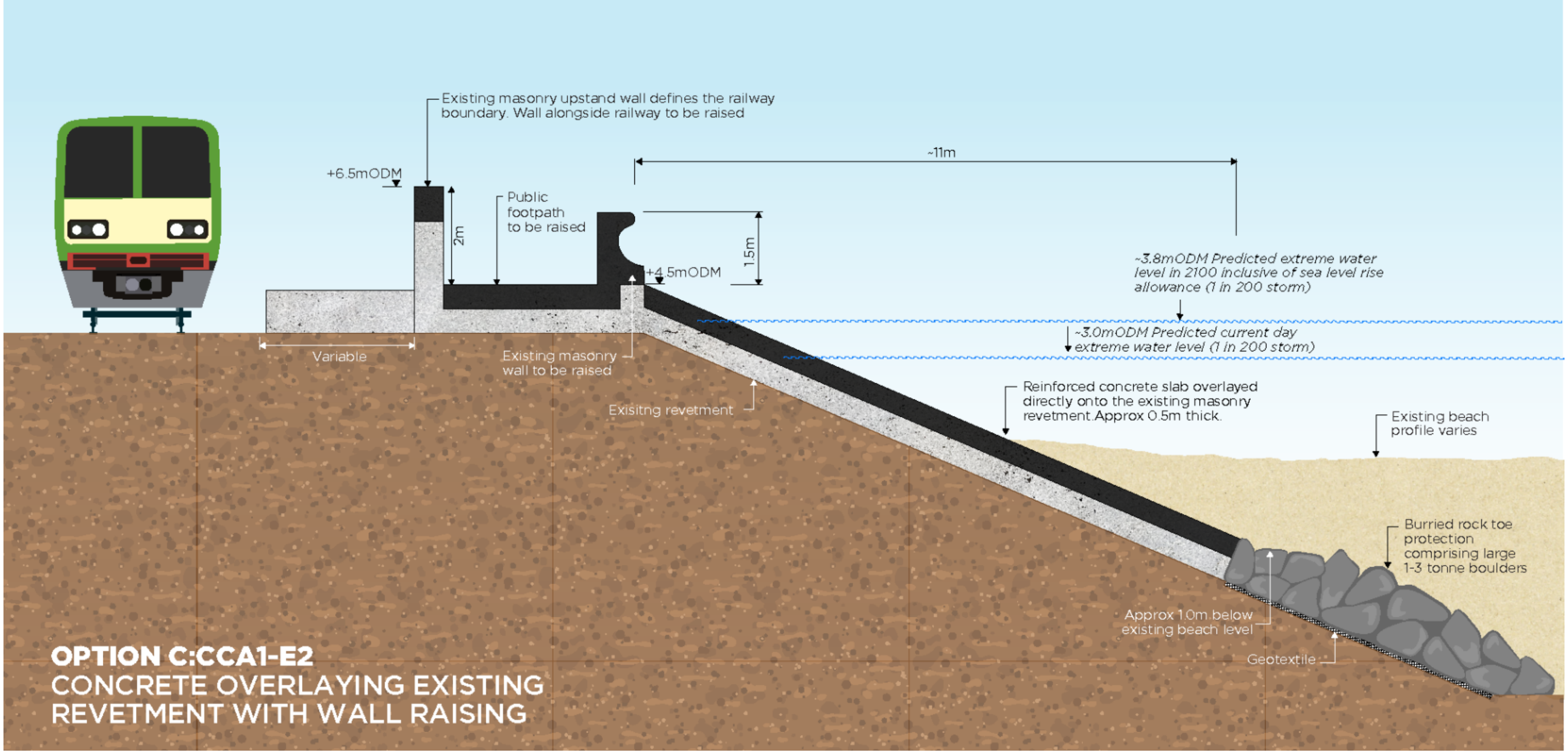


Figure 5-8 CCA1-E Option C typical cross section

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 cost comparison between the options. Option A is the lowest cost option. Option B is 20% more expensive than Option A and Option C is 8% more expensive than Option A. This is primarily due to Options B and C requiring additional structures at Seapoint and Blackrock. Option B is the most expensive option due to the more complex construction of the breakwaters 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 C.**

Table 5-13 provides a summary of how Option C (stepped revetment and wall raising) was identified as the EPO for CCA1. 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 C retains the amenity function and shoreline character at Blackrock and Seapoint and there is the opportunity to mitigate for the increased defence height through landscape design. Option A would likely be unacceptable to the public due to the loss of amenity provision at Blackrock/Seapoint. Although Option B has some positive amenity value at Seapoint, the loss of sailing provision and the change of character is likely to be unacceptable to the public.
Technical	Option C is relatively complex design for Blackrock/Seapoint but it can be a low maintenance option and can be adapted in the future in line with realised climate change impacts. Option A is more straightforward to design at Blackrock/Seapoint and provides a low maintenance solution but there is less opportunity for future adaptation. Option B relies on future beach monitoring and maintenance at Seapoint to maintain the Standard of Protection, making it a less preferred technical solution.
Constructability	Option C will be challenging to construct at Blackrock/Seapoint and will require significant in-situ concrete works, but this more complex work uses lower risk/cost land-based construction techniques. Option A requires significant rock at Seapoint in a relatively constrained bay, which could prove difficult logistically from the marine construction perspective. Option B is significantly more difficult to construct and maintain due to the reliance on significant marine construction. The sourcing of suitable beach material for Option B may also prove challenging. All options may require APIS.
Environmental	Option C has the smallest footprint onto the designated intertidal areas at Blackrock/Seapoint and avoids encouraging the public to areas of ecological sensitivity. Option B would likely be unacceptable due to an unacceptable loss of designated reef habitat.
Sustainability	Option C relies on relatively large volumes of high carbon reinforced concrete at Blackrock/Seapoint, but if this is well designed/constructed this can have a long serviceable life. Option A is the most sustainable solution at Blackrock/Seapoint. Option B relies on significant offshore rock structures, beach nourishment (capital and future maintenance) and high carbon reinforced concrete at Seapoint.
Consenting	Option C appears to have a potentially greater alignment with planning policy than other options. It appears to have the lowest risk in terms of having to go through the 'Imperative reasons of overriding public interest' (IROPI) process and therefore least potential likelihood to be delayed or refused on these grounds. Option A is considered to have the greatest potential impacts upon

	amenity than other options which may increase the potential for objection. Option B is considered to have the greatest environmental impact and the highest likelihood of IROPI and could therefore face consenting difficulties.
Cost	Option A is the lowest cost option. Option B is 20% more expensive than Option A and Option C is 8% more expensive than Option A. The capital cost for Option A comprises 15% facilitation and temporary works, 85% construction works and materials and is subject to 20% allowance for preliminaries, 5% allowance for overheads and profit and 64% risk allowance.

5.6 Implementation Options

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

The works for the Emerging Preferred Option C 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 Works Priorities Drawing which outlines the extent of the works within the sub-cells.

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

Sub-cell (length, m)	Description of works (Priority)	Justification for prioritisation
CCA1-A (395m)	Raising of existing upstand wall (Priority 2) and rock revetment overlaying existing revetment (Priority 3)	Existing revetments are serviceable through maintenance with no coastal risk of undermining. Manage structural performance risk through inspection and monitoring and maintenance programme. Raising of the existing seawalls is required to manage the future risk of wave overtopping leading to railway disruption (by year 2050). Climate change impacts likely to require rock revetments to manage increased overtopping risk in the longer term.
CCA1-B (100m)	Raising of existing upstand wall (Priority 2) and rock revetment overlaying existing revetment (Priority 3)	As per CCA1-A
CCA1-C (1,780m)	Raising of existing upstand wall (Priority 1) and rock revetment overlaying existing revetment (Priority 3)	Existing revetments are serviceable through maintenance with no coastal risk of undermining. Manage structural performance risk through inspection and monitoring and maintenance programme. Raising of the existing seawalls is required to manage the current risk of wave overtopping leading to railway disruption. Climate change impacts likely to require rock revetments to manage increased overtopping risk in the longer term.

Sub-cell (length, m)	Description of works (Priority)	Justification for prioritisation
CCA1-D1 (80m)	No works – historic baths	There is no risk to the railway line here.
CCA1-D2 (200m)	Raising of existing upstand wall and footpaths (Priority 1) and rock revetment overlaying existing revetment (Priority 3)	As per CCA1-C but public access alongshore and to the shoreline needs to be maintained.
CCA1-D3 (295m)	Raising of existing upstand wall (Priority 1) and rock revetment overlaying existing revetment (Priority 3)	As per CCA1-C
CCA1-D4 (180m)	Localised stabilisation of slope with rock to East of Vance's Harbour (maintenance works)	These maintenance works will be delivered outside of ECRIPP.
CCA1-D5 (370m)	Raising of existing upstand wall (Priority 1) and rock revetment overlaying existing revetment (Priority 3)	As per CCA1-C
CCA1-D6 (420m)	No works required to protect railway line (Brighton Vale) (no priority)	There is no risk to the railway line here.
CCA1-E1 (225m)	Raising of front wall, footpath and rear wall (Priority 1) and rock revetment overlaying existing revetment (Priority 3)	Existing revetments are serviceable through maintenance with no coastal risk of undermining. Manage structural performance risk through inspection and monitoring and maintenance programme. Historical issues of wave overtopping here leading to service disruption. Wall raisings are required to protect the railway from current risks from wave overtopping. These risks will increase as climate change impacts are realised. Public access alongshore and to the shoreline needs to be maintained. Climate change impacts likely to require rock revetments to manage increased overtopping risk in the longer term.
CCA1-E2 (90m)	Raising of front wall, footpath and rear wall (Priority 1) and rock revetment overlaying existing revetment (Priority 3)	As per CCA1-E1
CCA1-E3 (355m)	Raising of front wall, footpath and rear wall (Priority 1) and rock revetment overlaying existing revetment (Priority 3)	As per CCA1-E1

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

Table 5-15 Works prioritisation for EPO Option C within CCA sub-cells

Priority	Description of works (sub-cells)	Present day understanding of when works required by
Priority 1	Raising of existing walls (subcells C1, D2, D3, D5, E1, E2 & E3) to provide protection against overtopping to at least 2075. Raised walkways at amenity areas (D2, E1, E2 & E3).	2030
Priority 2	Raising of remaining existing wave walls (subcells A & B) to provide protection against overtopping to at least 2075.	2050
Priority 3	Rock revetment overlaying existing revetment (A, B, C, D2, D3, D5, E1, E2 & E3)	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 C

Implementation Option	Works to be delivered under Project [comparative cost of IO in comparison to IO1]	Future capital works needed by 2050	Future capital works needed between 2050 to 2075	Future capital works possibly needed beyond 2075
Implementation Option 1 (IO1)	**Priority 1 to 3** Raise walls in all subcells and add rock revetments [100%]	No works needed	No works needed	No works needed
Implementation Option 2 (IO2)	**Priority 1 and 2** Raise walls in all subcells [48%]	No works needed	No works needed	**Priority 3** Consider need for rock revetment in all subcells
Implementation Option 3 (IO3)	**Priority 1** Raise walls in C, D and E [44%]	**Priority 2** Raise walls in A & B	No works needed	**Priority 3** Consider need for rock revetment in all subcells
Implementation Option 5 (IO4)	Reactive Maintenance (Do Minimum) [N/A]	Reactive Maintenance	Reactive Maintenance	Reactive Maintenance

5.6.3 MCA Outcomes

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

This section summarises the outcome from the Implementation Option (IO) MCA analysis. The full MCA sheet can be found within Appendix G. Table 5-17 below provides an outline of the results of the analysis for all of the relevant criteria.

5.6.3.1 Economy

IO1 requires very significant capital investment due to the implementation of rock revetments in addition to raising sea walls in all subcells. However, it scores more favourably than other IO's for maintenance expenditure as it only requires a routine and post storm monitoring plan, with minimal maintenance throughout the design life.

IO2 proposes raising sea walls in all sub cells but does not propose rock revetment prior to 2075 so requires less significant capital investment compared to IO1. IO2 is similar to IO1 in terms of maintenance expenditure, however, as this option does not have the protection of rock revetments, additional repair work could be required which will elevate costs.

IO3 proposes raising sea walls only at subcells C, D and E and as such it requires less significant capital investment in the short term in comparison to the other IO's. However, further investment would be required by 2050, which would increase the overall cost of the works due to economies of scale. This option could also require additional maintenance in sub cells A to B where works have been deferred.

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

5.6.3.2 Safety

IO1 proposes significant amounts of rock revetments throughout CCA1, which brings both construction and operational health and safety risks. Construction works will be carried out from land which carries less risks than marine works, however, transportation of materials will be handled by marine equipment. The amount of construction works proposed in comparison to other IO's increases the construction health and safety risks significantly. Furthermore, stepped revetments and associated works will require extensive works on existing revetments and wall raising works immediately adjacent to the railway. For operation, there is a potential risk that members of the public could climb on the revetments, warning signs will be displayed to discourage this. Revetments will also significantly reduce the usable area of the beach which could lead to members of the public being trapped by the tides. This will be mitigated through increased access points through the revetments. Operational maintenance for this IO should be minimal.

IO2 and IO3 have a reduction in the amount of construction required in comparison to IO1 and do not require construction of rock revetments, which reduces the construction risk significantly. Operational risks are also reduced due to the deferral of rock revetment works. IO3 has increased health and safety risks for both the construction and operational phase when compared to IO2. The reduction in the extent of works proposed means that there is a higher potential requirement for emergency repair work. IO3 also provides a higher standard of protection in subcells C to E compared to A and B which could lead to some operational health and safety risks.

IO4/Do Minimum proposes no construction works. However, there is a requirement for localised reactive repair works which carry higher health and safety risks due to immediate risk to the railway and associated poorer working conditions. For operation there is an increased health and safety risk due to deterioration of the existing defences and increased overtopping and flooding of the railway line due to climate change.

5.6.3.3 Accessibility & Social Inclusion

Rock revetments proposed as part of IO1 will negatively impact access to the beach and the public's ability to use the beach for social and recreational purposes will be restricted. However, the provision of stepped revetments at Blackrock and Seapoint would provide enhanced amenity at these locations and beach access will be improved. Access steps will be incorporated to all revetments to ensure any formal and informal access points are maintained.

IO2 will not require any significant interventions such as rock revetments until 2075 at the earliest, so this will not result in an impact on the community resource/amenity until after 2075 should such an intervention be required.

While IO3 also does not propose rock revetments and so carries the same advantages as IO2, it does not provide as robust a standard of coastal protection as IO2. Therefore, in the event of extreme storm events there is a higher likelihood that the local community will be impacted due to flooding and/or damage.

IO4/ Do Minimum provides significantly less protection than IO's 1-3 and therefore it has significant disadvantages in terms of accessibility and social inclusion due to potential risks associated with climate change and damage and/or collapse of existing defences. As coastal erosion continues over time, access to the beach will be somewhat curtailed.

5.6.3.4 Integration

All IO's with exception of IO4/Do Minimum are aligned to development, climate and transport plans. However, the raised sea wall has potential to impact on protected views and amenities within Dun-Laoghaire-Rathdown County Development Plan. IO1 has some disadvantages due to rock revetment reducing the amenity of the beach and potentially impacting SPA/SAC and PNHA. It also requires a significant volume of materials and transport of the same. IO2 has advantages over other options as it provides adequate coastal protection in line with objectives, while requiring less material consumption than IO1 and no rock revetments.

5.6.3.5 Environment

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

Both IO2 and IO3 propose significantly less works than IO1 and so are less impactful on the environment during the construction phase.

IO1 is the only IO that proposes rock revetments before 2075. Rock revetments have the potential to impact sensitive and valuable habitats as well as one Ramsar site (Sandymount Strand/Tolka Estuary), one SAC (South Dublin Bay SAC), several SPA's (South Dublin and River Tolka Estuary SPA being the closest), one pHNA (South Dublin Bay) and one pNHA (Booterstown Marsh). These rock revetments also have the potential to impact the local landscape, archaeology, architectural and cultural heritage, geology and soils and marine archaeology.

IO2 does not involve implementation of rock revetments and so does not carry the associated environmental impacts mentioned above. It also avoids utilising significant volumes of materials and associated increase in carbon emissions. Moreover, IO2 offers a robust level of coastal protection and will facilitate operational phase reliance on public transport.

5.6.3.6 Engineering

IO1 involves extensive rock revetment works, requiring large volumes of rock armour. The constructability of this option is challenging as the material is assumed to be delivered via marine plant and concrete works at Seapoint result in increased interfaces to manage through construction. During construction at Seapoint there is a possible impact on the railway line as there is limited space for constructing the raised rear seawall and raised footpath. However, IO1 carries minimal maintenance burden and has little residual risk due to the hard engineering techniques employed. In the unlikely event of failure of the rock revetment, it would be progressive and unlikely to cause sudden or catastrophic failure. Future adaptation for this IO is limited because changes to the rock revetment would be challenging, there is some potential for raising of the stepped revetments in subcells D and E but this would necessitate raising of the wave walls also.

Removal of the extensive rock revetment works for IO2 and IO3 simplifies the material delivery and tidal working constraints. However, the constraints at Seapoint in terms of space for construction and possible impacts to the rail service still stand. These IO's may require some additional maintenance and carry some residual risk in comparison to IO1, because rock revetments will not be in place to provide protection to the sea wall or existing revetment. Future adaptation has been accounted for in the design because there is the possibility of adding rock revetment in the future. IO3 scores lower than IO2 because it is likely to require future interventions and therefore, additional construction works by 2050.

IO4/Do Minimum requires reactive and ad hoc emergency repairs with an increased requirement for monitoring and maintenance. These emergency repairs would be difficult to plan for and so would cause greater disruption to the rail line than the other IO's planned works. This IO has minimal opportunities for adaptation because coastal erosion will be allowed to continue unhindered and will eventually result in loss of the rail line. There is also an increased risk of rapid failure of the existing hard defences within CCA1.

5.6.3.7 Planning Risk

IO1 will provide the most robust level of protection along the coastline at CCA1 in comparison to other options. However, it has a higher potential for environmental impacts and requires works within European Sites and so it will be difficult to gain consent in the absence of IROPI.

IO2 and IO3 require significantly less works and will not entail elements within European sites and so the consenting risk is reduced in comparison with IO1. IO3 involves the least construction works and so has the lowest consenting risks in the short-term, however, there will be a likely requirement for future consents by 2050.

5.6.4 Summary

A summary of the MCA outcomes are shown in Table 5-17. Implementation Option 2 has been identified as the Emerging Preferred Scheme to be taken forward. The basis for this is summarised as follows:

- IO2 is the top ranked option under Economy, Safety, Accessibility & Social Inclusion, Environment and Engineering.
- IO2 is ranked second for planning after Option 4/Do Minimum.
- IO2 is the top ranked option for Climate.

Table 5-17 Implementation Options MCA outcomes summary

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

Planning				

5.7 Emerging Preferred Scheme

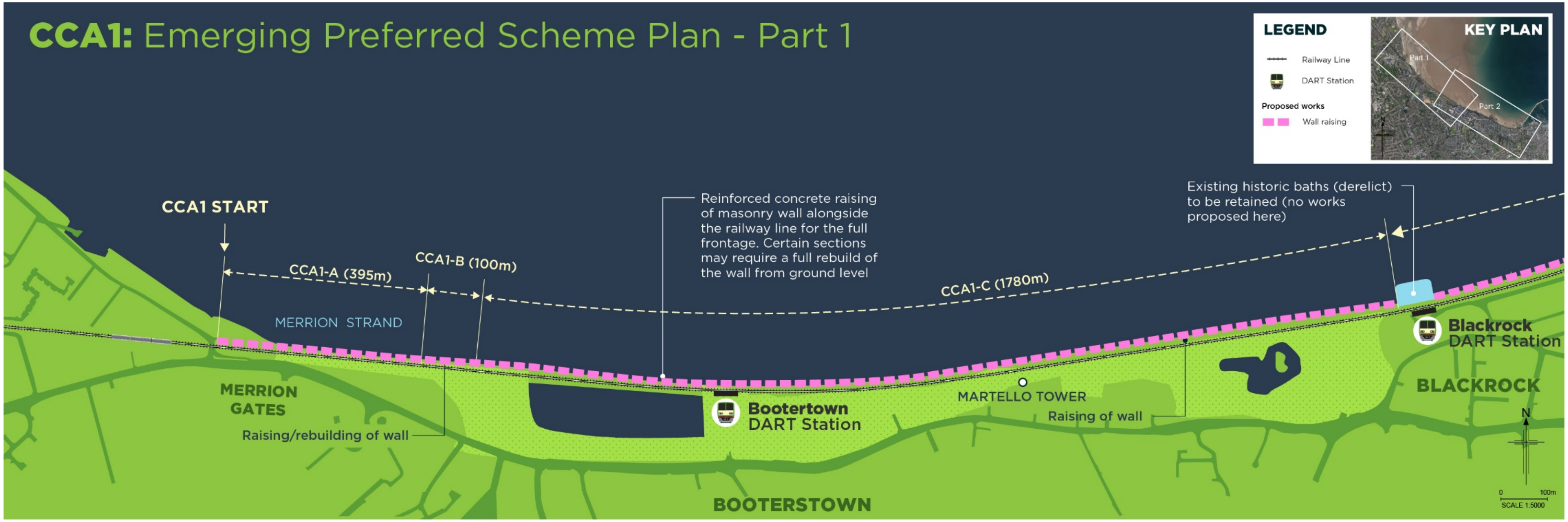
The MCA has identified the Emerging Preferred Scheme (EPS) as Implementation Option 2 for EPO Option C. The EPS will deliver a minimum of 50 years (2075) protection to the railway line against coastal erosion hazards at locations where the railway line would be at risk in the next 25 years (2050) if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

The works identified under the EPS comprise:

- Raise existing seawalls with reinforced concrete (CCA1-A to E)
- Additional seawall sections and raised footpaths/pedestrian accesses to retain amenity function (CCA1-D & E)

These works are summarised by Figure 5-9, Figure 5-10 and Figure 5-11.

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


CCA1: Emerging Preferred Scheme Plan - Part 1
LEGEND
Railway Line
DART Station
Proposed works
Wall raising
KEY PLAN
Part 1
Part 2
CCA1 START
CCA1-A (395m)
CCA1-B (100m)
CCA1-C (1780m)
MERRION STRAND
Reinforced concrete raising of masonry wall alongside the railway line for the full frontage. Certain sections may require a full rebuild of the wall from ground level
Existing historic baths (derelict) to be retained (no works proposed here)
MERRION GATES
Raising/rebuilding of wall
Bootertown DART Station
MARTELLO TOWER
Raising of wall
Blackrock DART Station
BLACKROCK
BOOTERSTOWN
N
0
100m
SCALE 1:5000

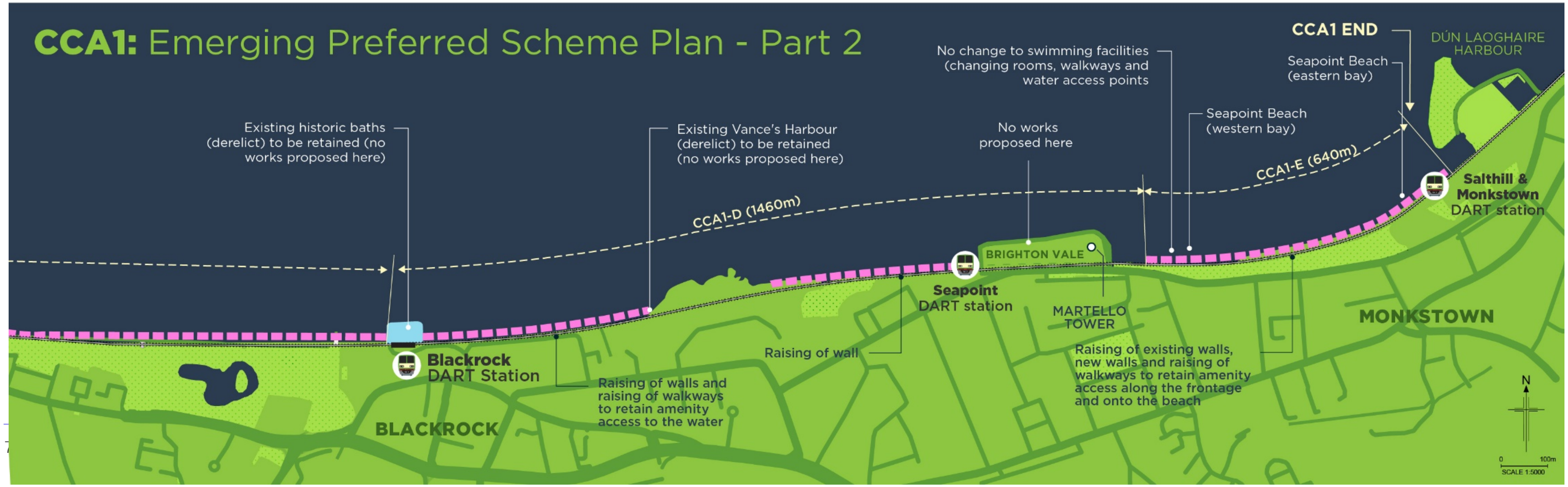

CCA1: Emerging Preferred Scheme Plan - Part 2
CCA1 END
DÚN LAOGHAIRE HARBOUR
No change to swimming facilities (changing rooms, walkways and water access points
Seapoint Beach (eastern bay)
Seapoint Beach (western bay)
Existing historic baths (derelict) to be retained (no works proposed here)
Existing Vance's Harbour (derelict) to be retained (no works proposed here)
No works proposed here
CCA1-E (640m)
CCA1-D (1460m)
Salthill & Monkstown DART station
BRIGHTON VALE
Seapoint DART station
MARTELLO TOWER
Blackrock DART Station
Raising of wall
Raising of walls and raising of walkways to retain amenity access to the water
Raising of existing walls, new walls and raising of walkways to retain amenity access along the frontage and onto the beach
MONKSTOWN
BLACKROCK
N
0
100m
SCALE 1:5000

Figure 5-9 CCA1 Emerging Preferred Scheme Plan

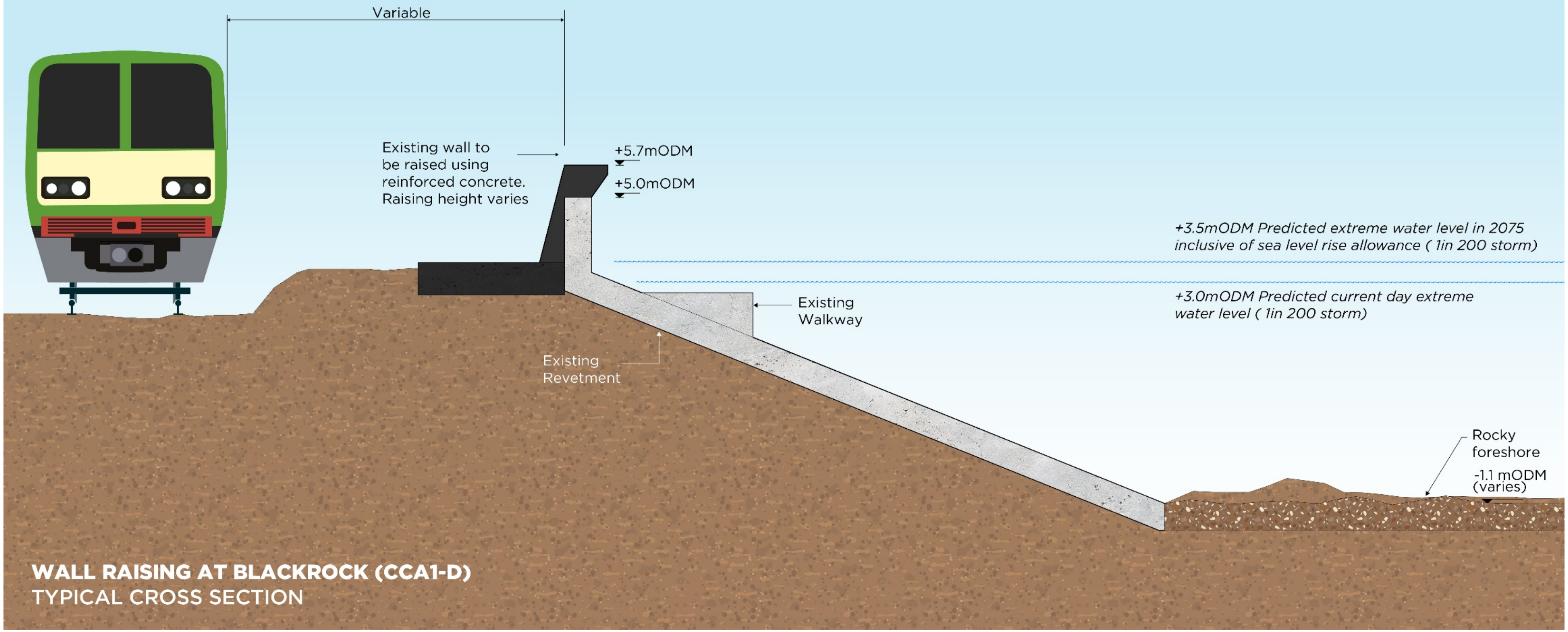


Figure 5-10 CCA1 Emerging Preferred Scheme Section at Blackrock

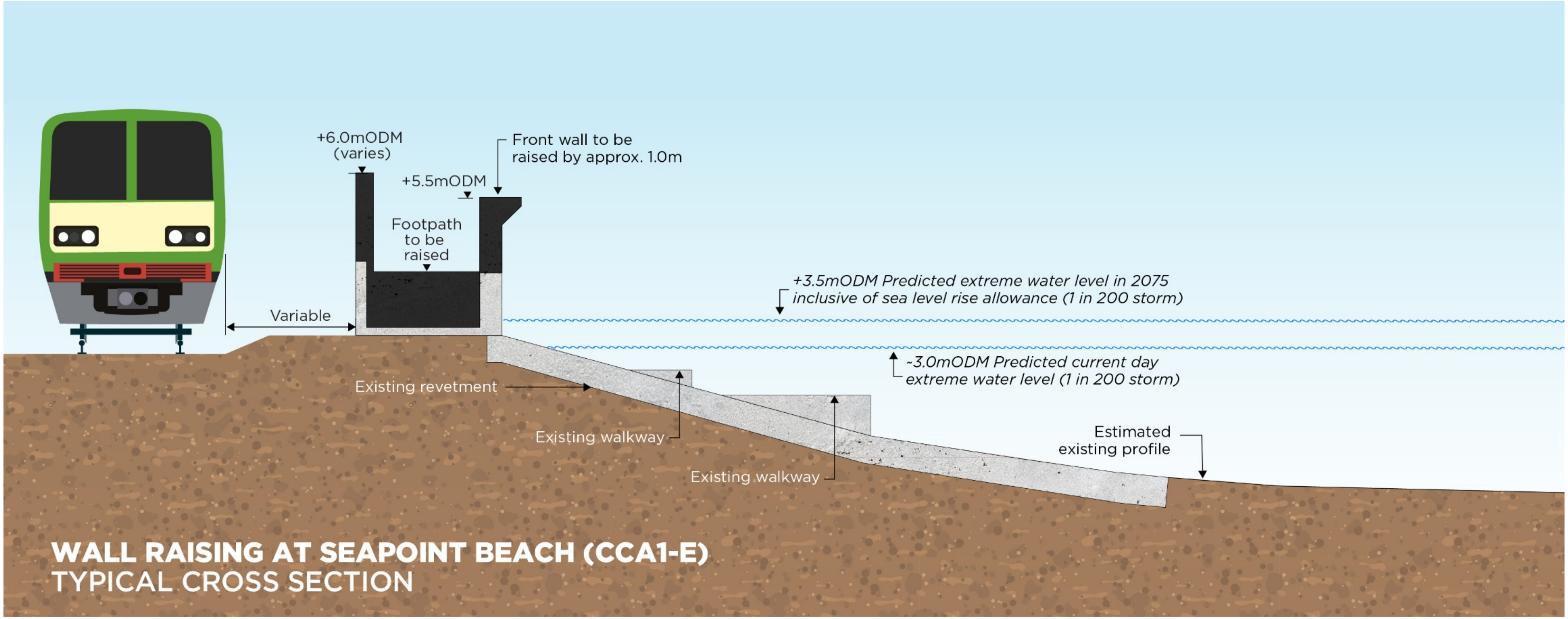


Figure 5-11 CCA1 Emerging Preferred Scheme Section at Seapoint

6. Stakeholder and Public Consultation

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

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

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

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

6.1 Non-Statutory Public Consultation

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

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

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

6.2 Key stakeholder consultation

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

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

7. Emerging Preferred Scheme

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

7.1 Emerging Preferred Scheme

The Emerging Preferred Scheme (EPS) to be taken forward comprises the raising of existing seawalls with reinforced concrete (CCA1-A to E) and additional seawall sections and raised footpaths/pedestrian accesses to retain amenity function (CCA1-D & E). These works will provide long term protection to the railway line whilst maintaining amenity provision and minimising environmental impact.

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 Wall Raising

The raising or rebuilding and raising of existing vertical walls is unavoidable to provide protection of the railway into the future (the walls currently experience wave overtopping during storm events, and this is without considering future sea level rise).

The existing walls are largely masonry walls from the original railway construction. The masonry is of good quality and most sections of the walls are structurally sound. Provided the wall is maintained (especially grouting at the joints), then many of the existing walls have capacity to be raised (following maintenance). At concept design stage, it has been assumed that these will be raised with reinforced concrete. For long sections, this raising could be with pre-cast concrete units, but some areas will require in-situ concrete construction.

At some locations, the existing wall is in poor condition. In these locations, the walls will be taken to ground level and rebuilt with reinforced concrete.

Further analysis will be undertaken during preliminary design, following the results of the ground investigation to determine the details of raising the walls.

7.1.2 Walkways and Steps Raising

At Blackrock and Seapoint, there is existing provision for public access for general amenity, bathing and water sports. The preferred option seeks to provide a like for like amenity provision. To provide the required Standard of Protection to the railway, some of the walkways and steps will be rebuilt and raised. The level transitions and beach access will be remodelled to retain amenity areas and access (alongshore and to the beach).

The existing steps and walkways are in variable condition but these are simple mass concrete structures that are built over the underlying original railway construction revetments (which is still in good condition). The area around the Martello Tower to the east of Seapoint will remain unchanged and the new works will tie into these areas to maintain amenity areas and access. The swimming piers and the beach will remain unchanged.

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 CCA1 raising of existing seawalls with reinforced concrete (CCA1-A to E) and additional seawall sections and raised footpaths/pedestrian accesses to retain amenity function (CCA1-D & E). 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 raised seawalls will be constructed from concrete. Some of the existing seawalls will need to be demolished, other sections can be raised from the existing seawalls. In both cases reinforced concrete will be used to raise the seawalls to a designed level to reduce wave overtopping and protect the railway from wave action. There may be a need to undertake the works to the existing seawalls under a railway possession for safety reasons, but this will be agreed between Irish Rail and the appointed contractor.

Temporary haul roads may need to be constructed to enable the delivery of materials to the site such as concrete, steel reinforcement and formwork. These would be contained to the foreshore and removed once the Project was completed.

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 location of the main site compound will be considered once the Preferred Scheme is known. The main site compound area will contain the laydown areas for materials and plant.

7.2.2 Construction risks

In the context the most significant risk will be related to the works being undertaken in a narrow corridor between a busy and live railway line and a marine environment. This will limit working windows in accordance with train operation and tides and all work will be in a dynamic environment.

Working adjacent to the railway line is a key risk as some of the works may need to be carried out under a railway possession. Railway possessions are typically done during night-time hours to limit the impact on the rail network. Restricting works to night working only on the railway presents risk to the programme for delivery for the scheme.

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.
- Lifting Operations - Risk of plant overturning during moving or lifting on slope.
- Transportation of precast units - Striking of live services overhead rail cables damaging cables and causing train cancellations and delays.

7.2.2.1 Mitigations

Notwithstanding the above mentioned project delivery risks, these can be mitigated to reduce the impact on the delivery programme. 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 long lengths of wall raising. At Blackrock and Seapoint, concrete steps, walkways and walls will be integrated into the existing environment to provide long term protection to the railway line whilst maintaining amenity provision and minimising environmental impact.

8.2 Next Steps

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

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

8.2.1 Design Development

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

8.2.2 Opportunities for consultation and engagement

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

8.2.3 Consenting

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

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

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

1) Railway Order under the Transport (Railway Infrastructure) Act, 2001 (as amended and substituted);

2) Seventh Schedule Strategic Infrastructure Development (SID) under the Planning and Development (Strategic Infrastructure) Act 2006 and Planning and Development Act, 2000 (as amended);

3) Section 179 'Local Authority Own Development' under the Planning and Development Act, 2000 (as amended) and Part 8 under the Planning and Development Regulations 2001 (as amended); and

4) 'Local' Planning Application under the Planning and Development Act, 2000 (as amended) and the Planning and Development Regulations 2001 (as amended).

All of the above consenting 'routes' are currently under consideration.

8.2.4 Procurement

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

8.2.5 Programme

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

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

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

9. Glossary

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

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

Seagrass bed	Intertidal or sub-tidal beds of sea grass. Provides ecosystem benefits including carbon sequestration.
Seawall	Vertical or near-vertical impermeable structure designed to withstand high wave forces and protect the coast from erosion and/or flooding
Shellfish reefs	Sub-tidal or intertidal reefs formed of suitable material for settlement by oysters or mussels.
Sill	A low rock structure in front of existing eroding banks to retain sediment behind.
Standard of Protection	The expected frequency or chance of an event of a certain size occurring. Defined for this Project as being a 0.5% Annual Exceedance Probability, also known as a 1 in 200 year storm protection level.
Storm surge	A change in sea level that is caused by a storm event, which can lead to coastal flooding
Toe scour	Occurs when the toe (bottom) of the defence is worn away by the waves and can cause defences to fail.
Unconsolidated glacial till	Unstratified and unsorted debris ranging in size, derived from the erosion and entrainment of rock by glacial ice
Wave exposure	The degree to which a coast is exposed to wave energy
Wave overtopping	The average quantity of water that is discharged per linear meter by waves over a protection structure (e.g., breakwater) whose crest is higher than the still water level

Appendix A. Planning and Environmental Constraints Report

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

Appendix B. Photographic Record

Figure 1 - CCA1-A: The sub-cell defence consists of a masonry revetment and an upstand wall. The northern half of the sub-cell is protected by a vegetated sand beach, while the southern half has muddy/marshy foreshore which is covered at high tide.

Figure 2 - CCA1-A: A stream located behind the railway and the existing surface water network which discharges to the sea through a series of culverts crossing the revetment. Some of these culverts include a flap gate to prevent upstream flooding during high tide.

Figure 3 - CCA1-B: The sub-cell's engineered section is very similar to CCA1-A, with a masonry revetment and upstand wall close to the railway. In recent years, a sand split has been accumulating in this area, providing additional coastal protection and habitat for birds.

Figure 4 - CCA1-C: The sub-cell consists of a masonry revetment and an upstand wall. The area also includes Booterstown station, where an additional wall upstand has been added in recent years. The foreshore is sandy/silty and fully covered at high tide; algae are visible along the bottom of the defence.

Figure 5 - CCA1-C: Booterstown station's coastal protection is very similar to the rest of the sub-cell, but with a higher upstand wall which protects the public from sea spray. The station is under additional pressure from storm events due to extending further onto the foreshore.

Figure 6 - CCA1-D: The sub-cell's defended section is protected by a masonry revetment and an upstand wall. A concrete walkway has been added along the defences. The foreshore is mainly rocky.

Figure 7 - CCA1-D: Historic baths are located within the northern part of the sub-cell, which are now disused. The remains of the baths are currently providing additional coastal protection, but a masonry revetment and upstand wall are located in front of the railway.

Figure 8 - CCA1-D: In the centre of the sub-cell, a small rocky headland with rocky foreshore is present and provides natural protection to the railway. A masonry wall is present along much of the headland.

Figure 9 - CCA1-D: At the far end of the sub-cell, Brighton Vale is a series of 15 properties located between the railway and the foreshore. There is a continual wall alongside the railway protecting the line.

Figure 10 - CCA1-E: At the west of the sub-cell, there is a rocky outcrop with a Martello tower and a concrete walkway. There are several sets of steps and ramps providing access to the Seapoint Beach bathing area. The foreshore is rocky.

Figure 11 - CCA1-E: Through the sub-cell, the defence is made of a sloping masonry revetment with upstand wall. In this area, a sand beach and rocky foreshore is located at the front of the engineered asset. A walkway runs along the sub-cell.

Figure 12 - CCA1-E: Throughout the sub-cell, the defence is a sloping masonry revetment with upstand wall. A walkway runs along parts of the sub-cell, with a short gravelly beach. There is no foreshore at high tide in the eastern half of this cell.

Appendix C. Options Assessment Supporting Modelling Outputs

Document Number	Document Title
7694-CCA1-P2-MMO-CM-JAC-0001	OPTIONS ASSESSMENT SUPPORTING MODELLING OUTPUTS CCA1

Appendix D. Short List Multi-Criteria Analysis Tables

Document Number	Document Title
7694-CCA1-P2-ENG-CV-JAC-0002	Short List Multi-Criteria Analysis Table CCA1

Appendix E. Option Concept Design Drawings

Document Number	Document Title
7694-CCA1-P2-DWG-CV-JAC-0001	CONCEPT DESIGN CCA 1 SITE LOCATION PLAN
7694-CCA1-P2-DWG-CV-JAC-0100	CONCEPT DESIGN CCA 1 OPTION A PLAN
7694-CCA1-P2-DWG-CV-JAC-0101	CONCEPT DESIGN CCA 1 OPTION B PLAN
7694-CCA1-P2-DWG-CV-JAC-0102	CONCEPT DESIGN CCA 1 OPTION C PLAN
7694-CCA1-P2-DWG-CV-JAC-0200	CCA1-A, CCA1-B & CCA1-C CROSS SECTIONS OPTIONS A, B & C
7694-CCA1-P2-DWG-CV-JAC-0201	CCA1-D CROSS SECTIONS OPTIONS A, B & C
7694-CCA1-P2-DWG-CV-JAC-0202	CCA1-E CROSS SECTIONS OPTIONS A (EAST & WEST)
7694-CCA1-P2-DWG-CV-JAC-0203	CCA1-E CROSS SECTIONS OPTIONS B
7694-CCA1-P2-DWG-CV-JAC-0204	CCA1-E CROSS SECTIONS OPTIONS C

Appendix F. Works Priorities Drawing

Document Number	Document Title
7694-CCA1-P2-DWG-CV-JAC-0300	CCA 1 COASTAL DEFENCE WORKS PRIORITIES

Appendix G. Implementation Options Multi-Criteria Analysis Tables

Document Number	Document Title
7694-CCA1-P2-ENG-CV-JAC-0003	Implementation Options Multi-Criteria Analysis Table CCA1

Appendix H. Scheme Concept Design Drawings

Document Number	Document Title
7694-CCA1-P2-DWG-CV-JAC-0400	CCA 1 CONCEPT DESIGN PLAN
7694-CCA1-P2-DWG-CV-JAC-0410	CCA1-A, CCA1-B & CCA1-C CONCEPT DESIGN CROSS SECTIONS
7694-CCA1-P2-DWG-CV-JAC-0411	CCA1-D CONCEPT DESIGN CROSS SECTIONS
7694-CCA1-P2-DWG-CV-JAC-0412	CCA1-E CONCEPT DESIGN CROSS SECTIONS

Appendix I. Consultation Report

To be added following Public Consultation 1.