Network Rail

# South West Rail Resilience Programme: Colonnade to Coastguards

## Option Selection Report

142630-ARP-REP-EMG-000023

A01 | 20 February 2020



Job number 270561-00

**Ove Arup & Partners Ltd**
63 St Thomas Street
Bristol BS1 6JZ
United Kingdom
www.arup.com

ARUP

# Document verification

ARUP

| | | | | | |
|---|---|---|---|---|---|
| **Job title** | | South West Rail Resilience Programme: Colonnade to Coastguards | | | **Job number** 270561-00 |
| **Document title** | | Option Selection Report | | | **File reference** |
| **Document ref** | | 142630-ARP-REP-EMG-000023 | | | |
| **Revision** | **Date** | **Filename** | Option Selection Report.docx | | |
| P01 | 17 Jan 2020 | **Description** | First draft | | |
| | | | Prepared by | Checked by | Approved by |
| | | Name | [redacted] | [redacted] | |
| | | Signature | | | |
| A01 | 20 Feb 2020 | **Filename** | Option Selection Report v3 JT.docx | | |
| | | **Description** | Issued with DRN | | |
| | | | Prepared by | Checked by | Approved by |
| | | Name | [redacted] | [redacted] | [redacted] |
| | | Signature | | | |
| | | **Filename** | | | |
| | | **Description** | | | |
| | | | Prepared by | Checked by | Approved by |
| | | Name | | | |
| | | Signature | | | |
| | | **Filename** | | | |
| | | **Description** | | | |
| | | | Prepared by | Checked by | Approved by |
| | | Name | | | |
| | | Signature | | | |

**Issue Document verification with document** ✓

# Contents

## Tables

## Figures

# 1 Introduction

Arup has been commissioned by Network Rail to prepare a GRIP 3 Option Selection Report for proposed new sea defences for Dawlish station and adjacent sections of railway as well as an accessible footbridge within the Dawlish station area.

Dawlish station is located on the London Paddington to Plymouth line and is served by trains running between Exeter and Newton Abbot. The section of track considered in this project is MLN1 205m 75ch to 206m 10.5ch which runs parallel to the beach at Dawlish from the Colonnade breakwater to the Coastguard's breakwater (C2C).

This section of railway is included in the South West Rail Resilience Programme by Network Rail. The aim of the scheme is to protect the railway for the next 100 years by improving the existing sea defences, following the emergency repairs that took place in 2014. The C2C project aims to provide protection to the railway and platforms, while still maintaining access to the coastal path and beach front (as seen in Figure 1). Included within the works, is an accessible footbridge within the platform area which will replace the existing barrow crossing at the south-western end of the station.

The report investigates a series of solutions and explains the process of choosing the high-level promenade and seawall option, as well as the new accessible footbridge design. This work was carried out with considerations to Rail, Geotechnics, Maritime, Water, Civil Structures, Telecoms and M&E disciplines. This work was carried out with an emphasis on the buildability of the design as well as considering aspirations for wider a platform 1.

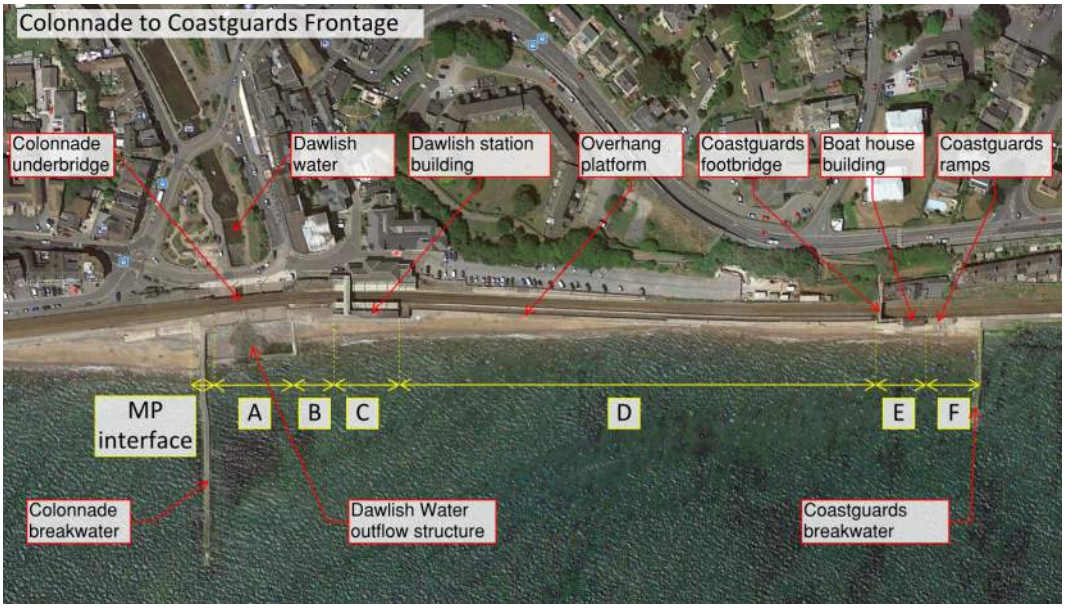



Figure 1 - Section C2C

# 2 Option Selection Process

The primary aim of the project is to provide resilience to the railway. For details on the GRIP 2 (feasibility) stage of the project, please refer to the Feasibility Comparison Report (142630-ARP-REP-ECV-000022).

From the outset of the project the frontage of beach between the two breakwaters was split into several sections to make the design process easier. Each section has its own unique interface with the beach front and the track behind requiring different designs for the separate sections. See Figure 1 for layout.

At the South-Western end of the section is the Marine Parade interface. This is a small section of the Marine Parade section that was specifically designed so that it could act as a connection for this new section of works.

Section A is arguably the most complicated section. This area contains Dawlish Water basin, where the river runs out into the sea, as well as the town gateway area. This area provides access from the town via the Colonnade underbridge, a structure carrying the railway over Dawlish Water.

Section B is a small section of low-level promenade between the town gateway area and the listed station building. At the rear of the promenade are listed colonnades that support the station platform. This area also connects to beach level via a ramp and is the main access to the beach.

Section C is the area around the listed station building. The complication with this section is the building façade that faces the beach as it needs to be displayed as much as feasibly possible. This is the original frontage for the station that has stood since the 1800s and so any work in front of this section is sensitive.

Section D forms the bulk of the section and spans from the end of the station building all the way until the coastguard's footbridge at the North-eastern end of the section. The half closest to the station building has a low-level promenade and a platform overhang supported by wooden colonnades. The northern half consists of the low-level promenade with a narrow platform. A set of stairs leading to the beach is present at the midpoint.

Section E is a wider section that houses the Boathouse building and access to the Coastguards footbridge.

Section F is as wide as section E as it contains the Coastguards boat ramp as well as a link to the next section of promenade beyond the breakwater. This section will need to be similar to the Marine Parade interface, providing access to the beach and the existing promenade as well as offering an opportunity to be extended in the future to potential upgrades of the section beyond.

A key decision during the option selection process was the division of the works into two main parts; ABC & DEF. This meant the bulk of the work involving section D could be accelerated whilst the more intricate details surrounding the town gateway area could be investigated separately.

The option selection process has been aided by numerous workshops relating to the various sections of the project. These have been for specific sections such as a

footbridge workshop, or for the entire project in workshops such as the option selection workshop, outcomes of which can be found in the Option Selection Workshop Summary Report (142630-ARP-REP-EMG-000022).

These meetings have included:

- Clients and associates from Network Rail [redacted]
- Advisory contractors from BAM [redacted]
- Members of staff from Arup in Rail, Water, Maritime, Structures, Geology, Landscape and M&E disciplines [redacted]
- Architects from Knight Architects and members of staff from Arup regarding the footbridge design [redacted]

External meetings have also been held with the RAMs for structures & Buildings, Network Rail's maritime advisor and Network Rail's lift specialists to gather their input on the design decisions and progress.

Meetings with external stakeholders including parties such as the EA, local planning officers, the MMO and the DfT have been held on a montly basis.

For further details of the resilience performance and calculations please refer to the Resilience Comparison Report (document reference number: 142630-ARP-REP-ECV-000023).

For further details of the access and amenities please refer to the General Layout, Access and Amenities Report (document reference number: 142630-ARP-REP-EAR-000004).

# 3 Existing conditions

The location of C2C is at the heart of the town of Dawlish with Dawlish station serving as a key transport link. This section of the report describes the existing conditions at the site which affect the design proposals held within this report.

## 3.1 Topography

The site itself is low level due to its positioning on the coast. The station and tracks are elevated several metres (approx. +7m) above ordnance datum, but the existing promenade is much lower at around +3.8mAOD. Beyond the station, running from the station car park onwards, are large cliffs over 20m AOD. There is access to the top of these from Exeter Road that links to the Coastguards footbridge.

## 3.2 Hydrology

Dawlish Water runs through the town and reaches the sea at the south-western end of the site. It discharges through the Dawlish Water Basin, a build-up of sediment contained by concrete walls.

Figure 2 - Dawlish Water basin interior

Figure 3 - Dawlish Water basin

## 3.3 Geology

Ground investigations were carried out in early 2019 to inform the feasibility and optioneering stages of the project, the results of which can be found in: Ground Investigation Report (GIR) (142630-ARP-REP-EGE-000005 A01). Further ground investigation is planned for January 2020, therefore an updated GIR will be issued with this additional interpreted data.

According to the British Geological Survey mapping (Sheet 339), the underlying bedrock in the Dawlish C2C area is Alphington and Heavitree Breccia formation. Trial pits carried out in December 2019 showed a weaker material in the Dawlish Water area – which aligns with the topographical data. This material is very weak when wet but gains strength as it dries out. Towards the north of the site (near Coastguards) trial pits indicate a much stronger material composed of large cobbles – Dawlish Sandstone formation. Future GI will hopefully confirm where the change from the Alphington and Heavitree Breccia formation in the south to the Dawlish Sandstone formation in the North occurs along the stretch of wall.

## 3.4 Maritime

Disruption to rail services and damage to rail assets occurs from current & future excessive wave overtopping, driven by:

- Sea level rise
- Eroding beach leading to larger waves reaching the sea wall
- Increase in storminess

Existing tidal sea levels are shown in Table 1. The 2015 tide water levels have been adjusted to include projected sea level rise for different epochs. Sea level rise projections are based on the latest UK Climate Projections (UKCP18) and the

RCP4.5 95th percentile scenario. Further detail can be found in the Coastal Modelling Report (142630-ARP-REP-ECV-000021). Approximate water level which includes allowance for sea level rise is also shown in Table 1.

| Tide | Water Level 2015 mODN | Water Level 2017 mODN | Water level 2065 mODN | Water Level 2115 mODN |
|---|---|---|---|---|
| Highest Astronomical Tide (HAT) | N/A | 2.67 | 3.03 | 3.55 |
| Mean High Water Springs (MHWS) | 2.17 | 2.19 | 2.55 | 3.07 |
| Mean High Water Neaps (MHWN) | 0.97 | 0.99 | 1.35 | 1.87 |
| Mean Low Water Neaps (MLWN) | -0.53 | -0.51 | -0.15 | 0.37 |
| Mean Low Water Springs (MLWS) | -1.53 | -1.51 | -1.15 | -0.63 |
| Lowest Astronomical Tide (LAT) | -1.83 | -1.81 | -1.45 | -0.93 |

Table 1 - Tidal levels at the Dawlish frontage

Design extreme water levels are presented in Table 2. These are based on the latest climate change projection UKCP18 using RCP4.5 9th percentile projection and new Environment Agency Coastal Flood Boundary Dataset 2019 (CFBD). Further detail on extreme water levels can be found in the Coastal Modelling Report.

| Return Period | Water Level 2017 (mODN) | Water Level 2065 (mODN) | Water Level 2115 (mODN) |
|---|---|---|---|
| T1 | +2.76 | +3.16 | +3.69 |
| T5 | +2.95 | +3.35 | +3.88 |
| T10 | +3.03 | +3.44 | +3.98 |
| T25 | +3.13 | +3.54 | +4.09 |
| T100 | +3.27 | +3.69 | +4.24 |
| T500 | +3.42 | +3.84 | +4.39 |
| T1000 | +3.48 | +3.90 | +4.45 |

Table 2 - Design extreme water levels

Design wave conditions can be found in the Coastal Modelling Report. Joint Exceedance Curves at -5mAOD for 2017, 2065 & 2115 are presented in

Figure 4 to Figure 6.

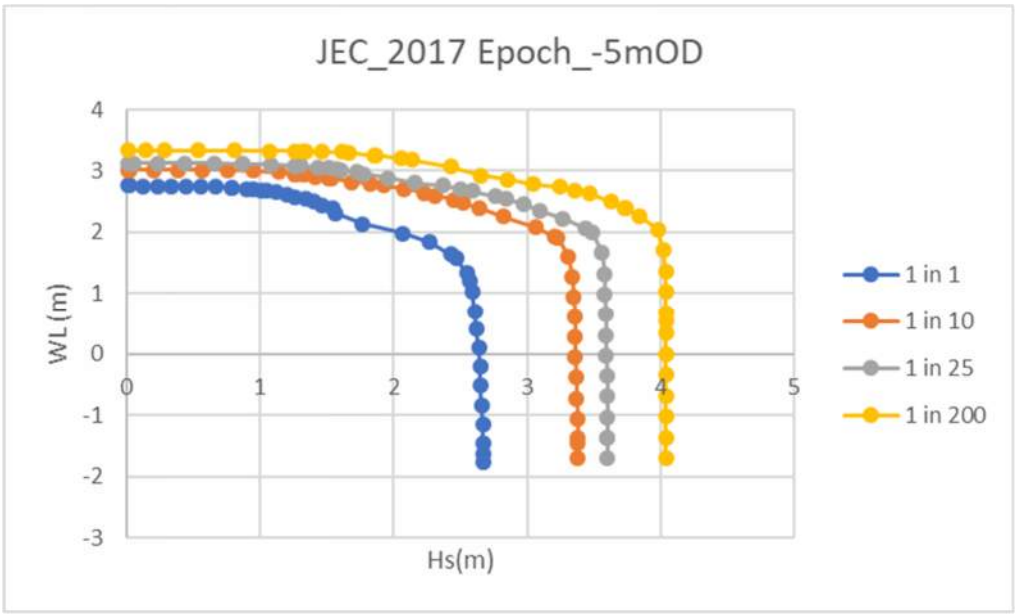



Figure 4 - Joint exceedance curves for present day epoch

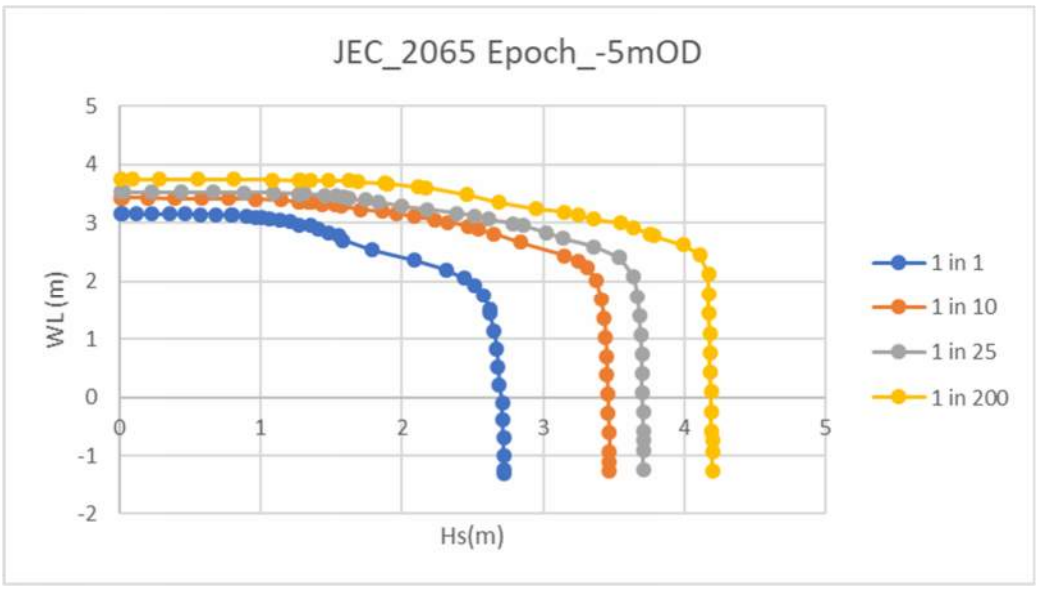



Figure 5 - Joint exceedance curves for 2065 epoch

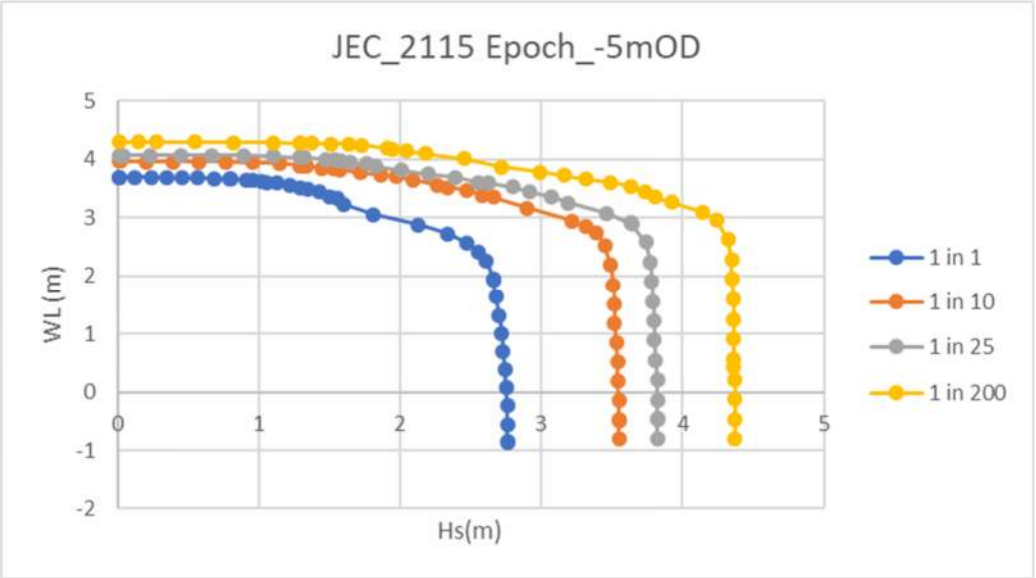



Figure 6 - Joint exceedance curves for 2115 epoch

As described in the Coastal Morphology Study for the wider frontage (142630-ARP-REP-ECV-0000006): The frontage is subject to a general trend of beach lowering which is wave driven. Colonnade and Coastguards breakwaters retain the beach material preventing this to be lost as a consequence of longshore drift. However, the beach is lowering, and this is likely to be from cross-shore processes.

As sea levels rise greater wave energy will reach the beach and the sea wall, and the rate of foreshore loss will increase until the material has been removed to bedrock. Geotechnical analysis indicates that erosion of the underlying bedrock is expected at a rate of about 0.02 m/year. Without recharge, it should be assumed that the beach deposits will not be present in the long term and the rock head will erode.

Various design beach levels are derived from this phenomenon:

- Existing foreshore levels, as determined in the topographic and bathymetric surveys dated May 2018 and March/April 2019.
- A 2065 design beach level across the frontage of -3mODN.
- A 2115 design beach level across the frontage of -4mODN.

If lower beach levels are expected before these epochs, scour protection measures would be required.

# 4 Existing Infrastructure

## 4.1 Site Overview and Historical Context

For further information not covered below please see C2C Heritage Statement (142630-ARP-REP-EAR-000005).

### 4.1.1 Viaduct

The current viaduct structure was built in 1928 to replace the original structure, with works taking place at the same time as the rebuilding of the first station. The public area beneath the viaduct serves as the main access from the town centre to the beach front either side of the Colonnade breakwater. Dawlish Water also flows beneath a portion of the centre span of the viaduct. The current structure has historical interest as part of the group of railway structures in the area, however it is utilitarian in construction, and is neither unique or an example of engineering or technological innovation and has been granted immunity from listing.

### 4.1.2 Dawlish Water Basin and Colonnade Breakwater

Colonnade Breakwater is at the high chainage end of the site and is approximately 125m long. To the land end of the breakwater is the main pedestrian access to the beach at Marine Parade. Adjoining the breakwater is a drainage basin where Dawlish Water discharges into the sea. The basin consists of concrete walls which form a retained area reducing sediment flow from Dawlish Water into the sea.

### 4.1.3 Station Building

The original station was built in 1846, with the current station structure resulting from major rebuilding in 1875 after a fire destroyed the original station. The station consists of two separate buildings, one on each platform. The Italianate frontage added in the rebuilding is of significant architectural and historical note and is one of the major reasons for the station being grade II listed.

The listed title has been understood and included in the option selection process. The station itself was not able to perform to the required resilience criteria. As a result, options were developed to protect this section whilst reducing any impact on the building, in particular the façade. This meant that ramps in front of the building were not preferred due to the changing level across the façade.

Due to its listed status, listed building consent is required in order to carry out any work around the station and platforms which would affect the nature of the station.

### 4.1.4 Platforms

Platforms at the station have a modern asphalt surface with concrete coping stones and the customary yellow line. There are no tactile pavers. The platforms have been extended over time, most notably the up platform to the south (which was rebuilt in the 1940's using available materials of the time and so is supported by re-purposed cast-iron gas lamp pillars), and north over the promenade below, which took place in the early 19th century. This section of the platform has been rebuilt most recently after and as a result of the storms of 2014, with it potentially having been rebuilt a number of times prior to this too.

Towards the lower chainage end the up platform was extended in 1934 and narrows to a point where it is no longer suitable for access by passengers, as enforced by signage. Canopies are provided over the areas of platforms adjacent to the station buildings, these were installed in 1961 replacing earlier steelwork roofs. Additionally, the traditional GWR sign is present on the southern end of the up platform.

### 4.1.5 Promenade

The existing promenade sits between the beach and the station platforms, at around +3.8mOD. Narrow concrete sets of steps between the promenade level and beach level are provided near to the Coastguards boathouse and roughly halfway along the down platform. Behind the basin at the outfall of Dawlish Water the promenade drops to +3.2m as it passes below the viaduct, with a headroom of 2.4m to the soffit. Situated to the rear of the promenade is the existing sea wall, which has been split into two sections (D1 & D2) for clarity.

#### Sea Wall (Section D1)

The existing sea wall that extends from the down platform station building to the end of the wider portion of platform 1 sits to the rear of the promenade, and is topped with the overhanging platform structure, as illustrated in Figure 7 and Figure 8. The overhanging timber structure is supported by evenly spaced timber columns, and the soffit of the structure is formed of timber planks, containing the platform structure. Drainage ducts run through the wall from both the above and below track areas. It has been noted from site visits that some of these ducts are occupied by nesting pigeons.

Beyond the narrowing of platform 1 the sea wall takes on a modified typical section, this time with the platform cantilevering from the top of the sea wall without additional propping support from the promenade. Typical section is shown in Figure 9. The overhang of the platform varies, starting at around 700mm reducing towards the north to a point where the railing is affixed directly to the top of the wall and there is no overhanging extension, see Figure 10 below which shows this transition to the railing being attached to the top of the wall.

This area of the platform atop section D2 is not generally accessible to passengers (enforced by signage) is only used for the disembarkation of passengers wishing to alight from the rearward coaches of 9 car and 5+5 car IET trains.

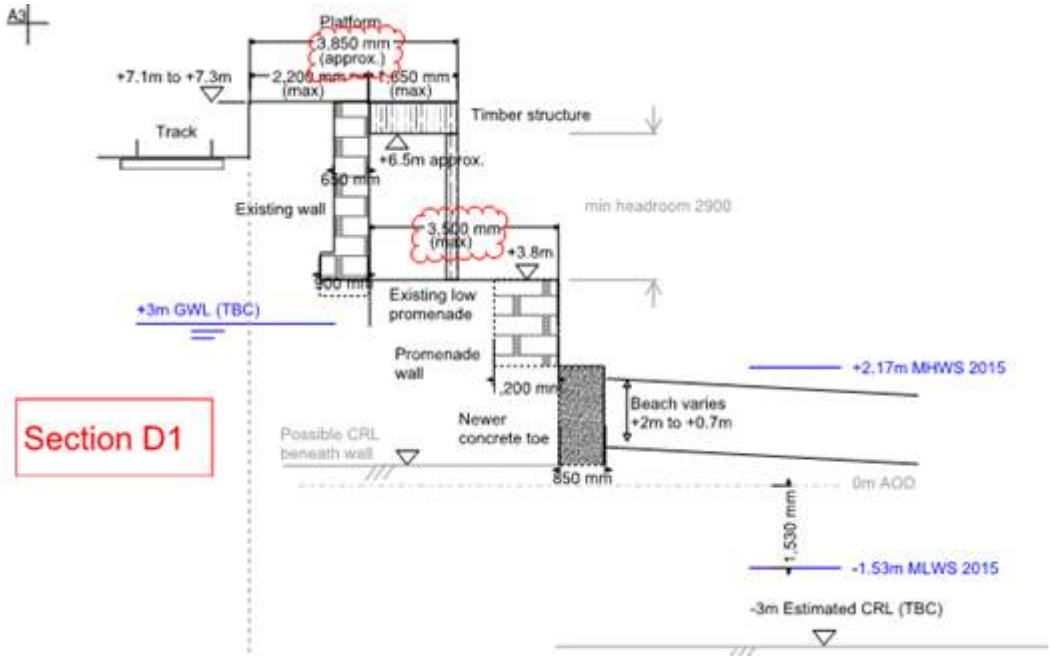



Figure 7 - Sea wall section D1

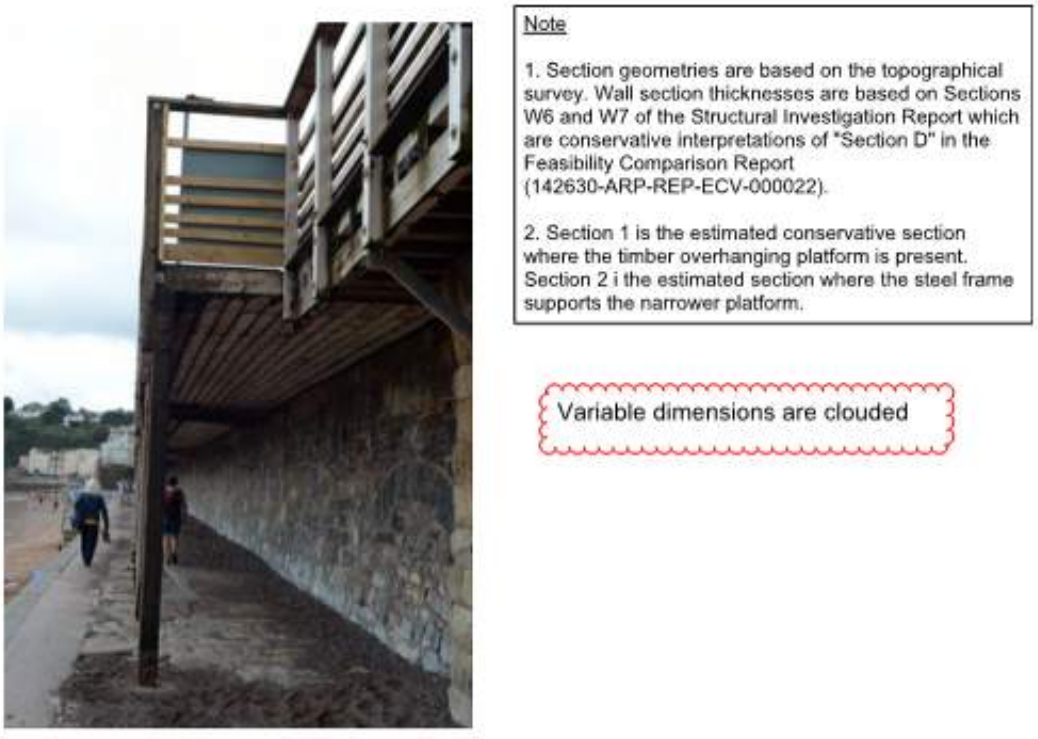



Figure 8 - Section D1 platform overhangSea Wall (Section D2)

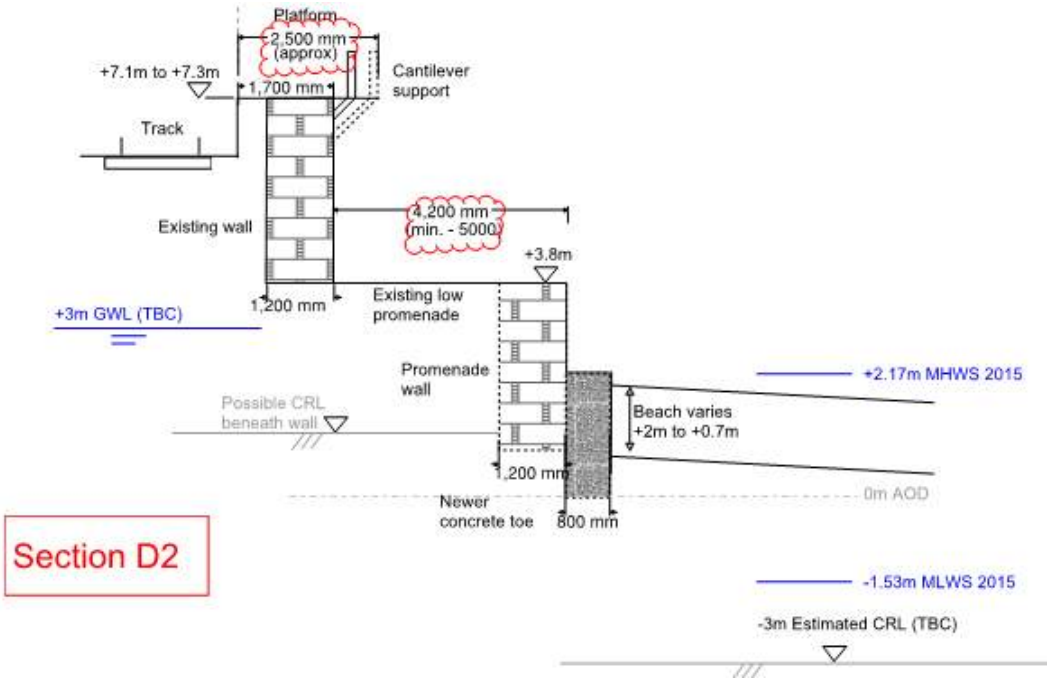
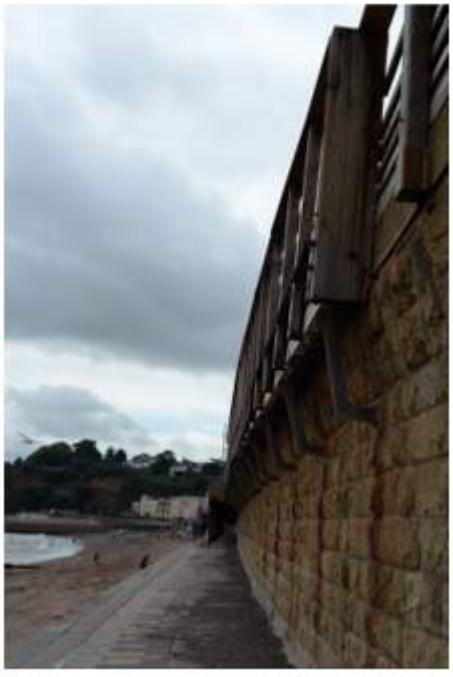



Figure 9 - Sea wall section D2



Note

1. Section geometries are based on the topographical survey. Wall section thicknesses are based on Sections W6 and W7 of the Structural Investigation Report which are conservative interpretations of "Section D" in the Feasibility Comparison Report (142630-ARP-REP-ECV-000022).

2. Section 1 is the estimated conservative section where the timber overhanging platform is present. Section 2 i the estimated section where the steel frame supports the narrower platform.

Variable dimensions are clouded

Figure 10 - Section D2

### 4.1.6 Coastguard's Footbridge

The Coastguard's footbridge is a post tension concrete deck dating back to the early 1950's and is situated towards the north eastern end of the site. This is not a listed structure but does form part of the Brunel heritage railway, and the granite structure of the stairs (along with the adjacent Coastguard's Boathouse) form the surviving elements from the early years of the line. The stairs are not a modern structure and are not compliant with modern standards. It appears that the bridge deck has been replaced with a precast concrete deck which is newer than the stairs. The bridge appears to be in a reasonably good condition, particularly considering the aggressive environment in which it is located.

Figure 11 - Coastguards footbridge

### 4.1.7 Coastguards Boathouse

The Coastguards Boathouse is also part of the Brunel heritage of the area but is also not listed; however, as previously mentioned is some of the oldest structures related to the railway in the area. It was owned by a 3rd party at the start of the scheme and is located just beyond the footbridge at the north eastern end of the site. Network Rail has now purchased the building.

The arched doorway in the southern elevation has been infilled, with the large doors on the north elevation retained. Sections of Bullhead rail have been set in the concrete ramp leading to the large door, presumably once holding some sort of separating structure which has been destroyed by previous storms. The remaining steel sections are significantly corroded, with the web of the rail completely corroded away in some examples.

The roof is in very poor condition, and in December 2019 Network Rail arranged the removal of the tiles of the roof to prevent them being blown onto the track

should a significant storm event occur. However, only the track side face of the roof was cleared, and Network Rail is arranging the removal of the remaining tiles.

### 4.1.8 Coastguards Breakwater

At the low chainage end of the site is Coastguards Breakwater, which is approximately 55m long. At the land end of the breakwater the promenade ramps up to the level of the breakwater, and splits into a pair of ramps, one adjacent to the track connecting to the higher promenade to the north; between this and the breakwater is a second ramp which connects down to the beach level to the north of the breakwater.

## 4.2 Existing Drainage

For the optioneering stage of the scheme, the site has been split into sections A-F as per Figure 12. The track is mostly level along the length of the station, around ~6.4m AOD. This is mainly due to the set level of the viaduct to the south of the station. To the north-east of the station is the lowest area (the start of section D) at ~6.2m AOD and is approximately 80m long (206m 4ch to 206m 8ch), and therefore this is most susceptible to flooding. Beyond this the level rises to ~6.5m AOD at the far north-east (end of section D as well as sections E &F).

The existing drainage at the site is detailed in the Topographic Survey, Drainage and Buried Services Interpretive Report (document reference number: 142630-ARP-REP-EDR-000004). This is summarised in Figure 13 which shows existing track drainage.

- Section A is the Colonnade bridge which was not surveyed and will not be altered.
- Section B between the bridge and station has three existing drains which are blocked but are thought to be below ballast drains.
- Section C, the station, has no apparent drains from the track but is well protected from overtopping.
- Section D has multiple cores through the wall beneath the platform as described below. This is the longest section, and the area that currently floods, and therefore this preliminary drainage design has focussed on this area.
- Section E has no existing drainage as the boathouse blocks the pathway of possible drains.
- Section F is served by a combination of a carrier drains to surface water system, and direct drainage into the sea.


Figure 12 - Aerial view of C2C sections

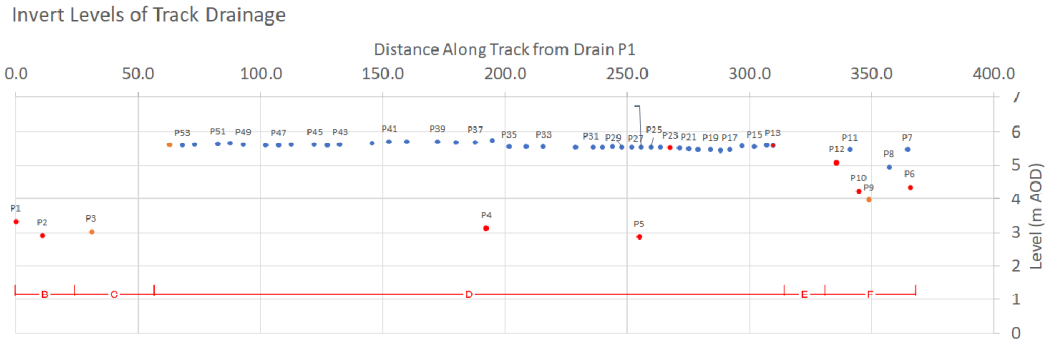



Figure 13 - Invert levels of track drainage as survey blue indicates working drain, red dots indicate a defect in the drain such as a rusted flap valve (high level drains not shown)

In section D site investigations identified three forms of drainage. These are:

- Below ballast drainage. There are 41 drains of 150mm diameter at spacings of 5-10m. These drain from the ballast and discharge to the existing promenade (shown in Figure 13) and were all in a good condition.
- High level track drainage. There are many small drains at ~1m centres which drain onto the existing promenade. These are found well above the sleeper level so are of little benefit in maintaining railway operation.
- Occasional weep holes in the lower promenade which are often covered by beach material

These three types of drainage are indicated in pink in Figure 14 on a typical section in area D.

The car park adjacent to the station has a surface water drain system. However, a portion is not covered by this and currently falls toward the track.

An old sewer outfall pipe runs throughout the beach parallel to the promenade. This is not shown on returns from the statutory service providers and so it is assumed not to be in use. On visiting the site, it was observed that this pipe was broken into sections that were strewn across the beach confirming that it is out of use.

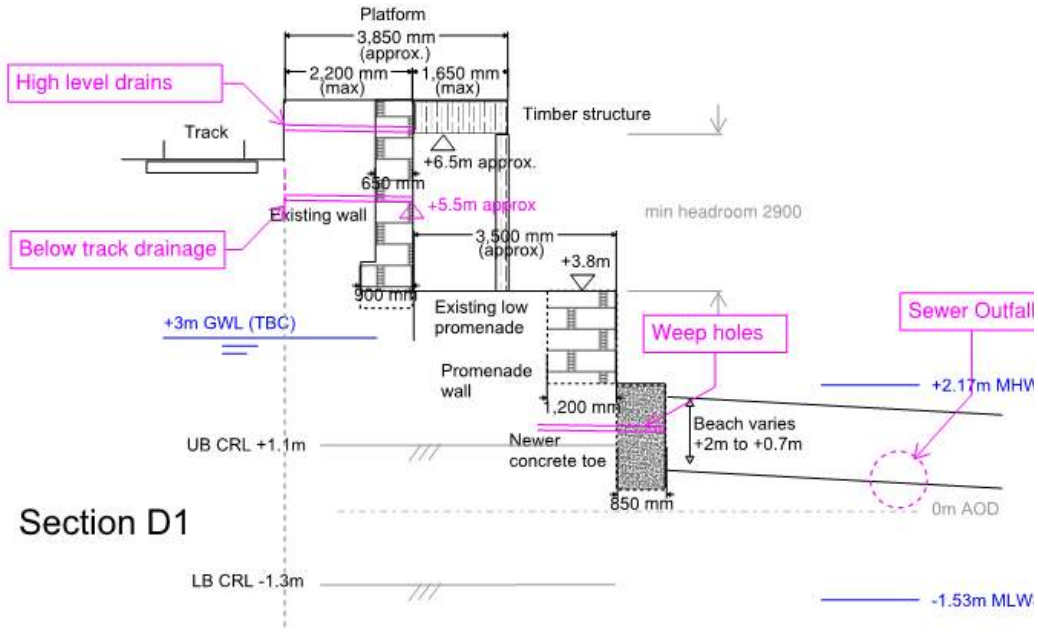



Figure 14 - Existing drainage in section D

Figure 15 - Outfalls onto low promenade

Figure 16 - High level track drainage

# 5 Preferred Design Option Selection

Due to the acceleration of the design for the sections D, E and F, this section will start by presenting the option selection for section D (representing the longest section for the resilience works), followed by sections E and F (representing the interface with Coastguard's footbridge and promenade to Dawlish Warren). And finally, the report will go into the option selection for sections A, B and C.

## 5.1 General considerations

**Access Steps and Ramps**

The following options have been considered:

1. Ramps at both ends of the beach frontage and a ramp at the Coastguards end to connect to the existing ramp north of the breakwater
2. Ramp at Colonnade end, a ramp at the Coastguards end to connect to the existing ramp north of the breakwater and a set of steps to the beach near coastguards
3. As above but with and without a set of central steps.

It has been agreed (RFI 000006) that option 2 will be pursued as this matches the existing situation.

- A new ramp to the beach will replace the existing at Colonnade end
- A set of steps will be provided at the Coastguards end to provide access to the beach
- A ramp will be maintained from the high-level promenade to the north of the existing Coastguards breakwater. Although the purpose of this is historical (i.e. used for boat launching from the boathouse) it represents the only ramped access to the section of sea front north of the breakwater

Two options of ramps gradients to beaches have been considered:

1. A 1:20 ramp
2. A 1:12 ramp with landings

The preferred is option 2 as it limits beach encroachment.

The central set of steps will be provided for a low-level solution but will be omitted for a high-level solution (agreed via RFI 000018). This is due to the substantial height and structure that would be required to provide this and its poor hydraulic performance. This provides a maximum travel distance of circa 150m from the beach to an access compared to an existing of 90m.

**Promenade widths**

A minimum width of 3m (with local reductions for street furniture) has been agreed with NR (through RFI-000006). This has been derived through:

- Confirmation that there is no vehicle access needed
- This allows for two wheelchair users passing each other
- This allows for the promenade to have width restrictions for maintenance

It should be noted that due to the requirement to install the foundations offset from the existing wall, the promenade width is generally greater than 3m

**Amenity benefits**

Along the promenade will have raised areas (by 300mm) at regular intervals to provide visibility to sea for children and those in wheelchairs.

There will also be two key improved areas at the town gateway area in section A and by the existing coastguard's building in sections EF. Section A will be widened into Dawlish water basin due to required vehicle access to Marine Parade. Part of this widening will be turned into a public amenity area with places to sit and prevent congestion in this zone.

Section E&F will follow a similar shape to that of the existing area but will be able to make more use of the space due to the demolition of the Boathouse building. This area will contain raised seating areas providing views of the sea and may include a heritage display of the Coastguards area.

## 5.2 Section D

Section D is the longest section of the project and spans from the end of the station building to the Coastguards footbridge. Despite being the longest section, it is the most consistent section along its length. The feasibility study yielded two main options for consideration at optioneering stage;

1. High-level promenade
2. Low-level promenade

The optioneering for sections D, E & F has been considered under the following headings

- Landscape Options
- Civil Engineering Options
- Maritime Options

### 5.2.1 Section D Landscape Options

**Low level Promenade option**

The low-level option consists of a low-level promenade in front of a seawall that runs from the end of the station building along to the coastguard's footbridge.

The existing promenade level is approximately +3.8mAOD. Two options were considered for the low-level promenade:

1. As existing at 3.8mAOD – considered to likely perform better with regards to overtopping criteria
2. Raised at 4.8mAOD – Provides an equivalent level of protection to existing for pedestrians on the promenade when a predicted 1m sea level rise is included.

It was concluded that a 3.8mAOD low level promenade level would be utilised as this was expected to give the best results for meeting the resilience criteria. Furthermore, the existing path level at Colonnades underbridge is restricted (by headroom) to 3.3mAOD with little prospect of raising the level. Raising the promenade above existing was considered to increase the risk of people using the promenade getting stranded just before Colonnades and having to back track along the promenade to Coastguards in times of high wave action

**High level Promenade option**

The high-level option is made up of a high-level seawall along with a high-level promenade which runs from the station building to the coastguard's footbridge. At the back of the promenade there is a further wall with a platform extension beyond this.

Depending on the design of the sections at each end, there are various options that involve tie-ins such as a ramped section. In some of these options the ramp section starts within section D. Please refer to section 5.3.1 for sketches.

### 5.2.2 Section D Civil Engineering Options – Foundations

## High level Promenade

**Foundation types**

Two primary foundation options have been considered:

Option 1 - Shallow foundation solution (Refer to Figure 17)

Option 2 - Piled Solution (Refer to Figure 18)

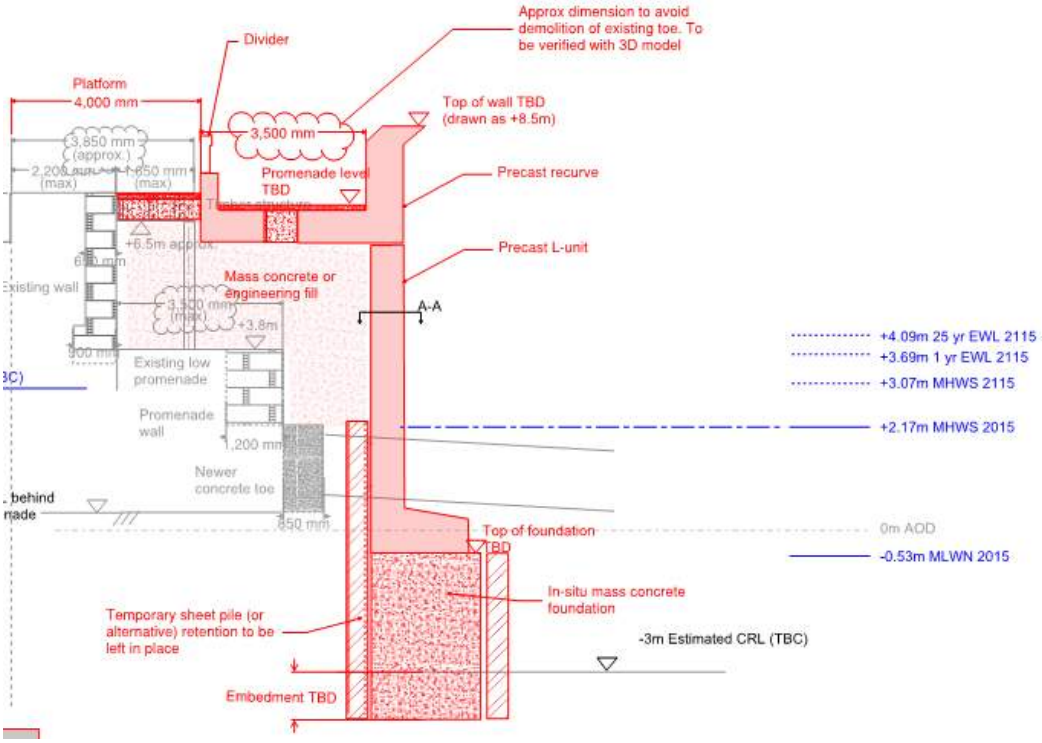



Figure 17 - High level promenade, shallow foundation structural concept

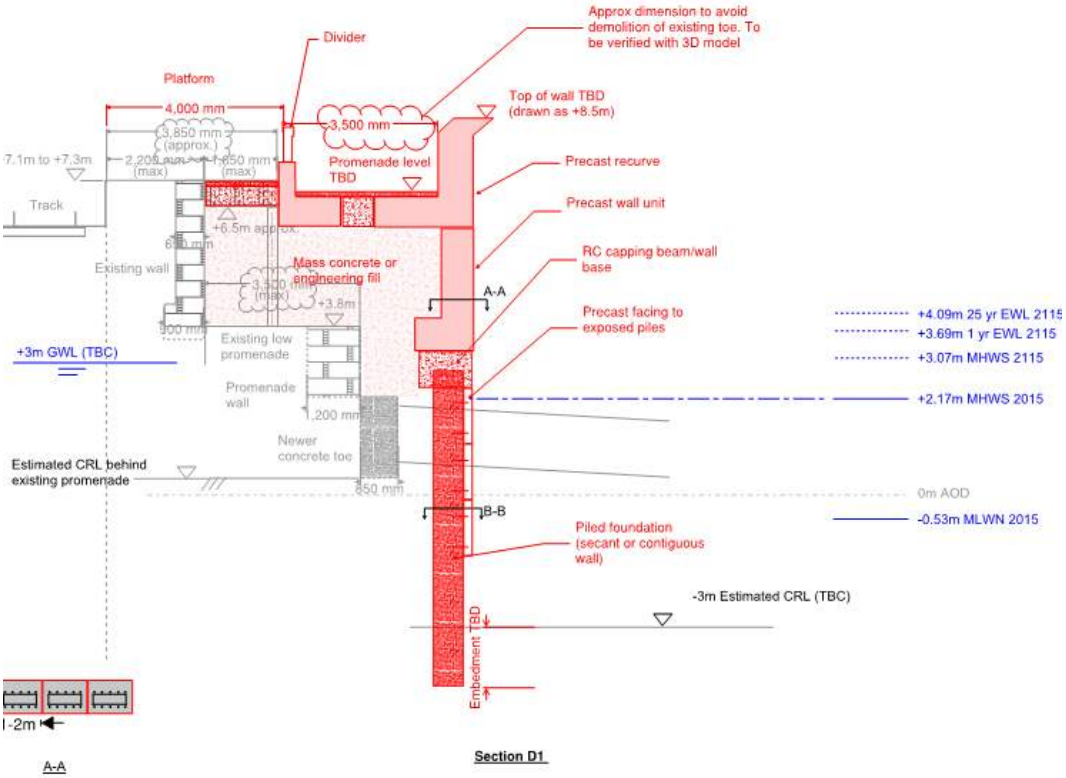



Figure 18 - High level promenade, pile foundation structural concept

Option 1

A shallow foundation solution would be similar to the foundation solution adopted to the adjacent Marine Parade works. Key points to note

- The depth of the intact rock at the north and southern end of the site means that it is probable that a shallow foundation will not be viable in these areas due to extensive temporary works requirements and the overall footprint of the foundation.
- A case can be made for the central section to be constructed off shallow foundations but a number of risks pertaining to the competency and depth of bedrock remain that would be carried through until further GI would be carried out.
- With the additional depth of bedrock compared to Marine Parade the solution would likely increase the risk of significant temporary works being required.
- The size of foundation is sensitive to the assumed rate of erosion of the bedrock and the selected scour design life.

Option 2

A contiguous/secant piled wall solution is being considered (piled from a causeway or jack-up barge). Key points to note:

- This solution would be applicable for the whole length of C2C
- This option is more likely to be suitable for the larger loads expected when compared to Marine Parade (due to increased wall height)

Selected Foundation Option

During our meeting with NR on 29/10/19 we agreed to proceed on the basis on a piled solution. This is for the following reasons:

- A piled option can be applied as a consistent foundation solution for the whole length of C2C
- Based on the current GI, a piled solution carries significantly less risk of buildability issues due to ground conditions
- A piled solution should provide the worst-case design for a planning application in terms of land take for a piling platform
- An argument could be made for shallow foundations in certain areas following additional GI should the contractor determine it as preferable and within the constraints of the planning application
- A workshop with BAM (who have had experience on Marine Parade with a shallow foundation solution) on 22/10/19 indicated a contractor preference for a piled solution
- The piling solution is likely to be a safer solution as it will involve less temporary works and excavations

- A piling solution is more likely to be able to deal with the loads associated with a wall taller than that at Marine Parade

Scour Protection

In general, the levels of the beach and bedrock geology in front of the wall are anticipated to lower over the design life of the structure due to scour. An erosion rate of 0.02m/year (equivalent to 2m over 100 years) has been assumed.

Given the uncertainty in the measurement of this value it is recommended that design of the sea wall allows for some ongoing maintenance of the beach area during the structures design life, including allowance for additional scour protection measures (i.e. in-situ concrete fill etc.) should the need arise. A reactive approach is likely to be more economic in the long run than providing scour protection now that may or may not be needed for the full design life.

## Proposed Pile Type

The following piling methods have been considered:

- Option A - Combi Wall
- Option B - Secant Piled wall
- Option C - Contiguous Piled Wall

Pile Type Option A - Combi Wall

This option involves driving circular hollow steel tubes down to the level of rockhead as a permanent casing. The material within the tube is then augered out and the bore is continued into the rock below the base of the casing to the level required for design. A cage is lowered into the augered section of the pile to provide reinforcement and the pile is concreted to top of casing. U or Z section sheet piles are then vibrated/driven between the adjacent piles to the rock level. Mobilisation of significant pile driving equipment is likely to be unfeasible from both a temporary works perspective and the need to avoid damage to the existing seawalls during driving. Embedment of the sheets into the bedrock is therefore likely to be minimal.

This option was discounted due to its inability to provide scour protection at the locations of the interconnecting U or Z sections over the design life of the structure.

Figure 19 - Combi wall example

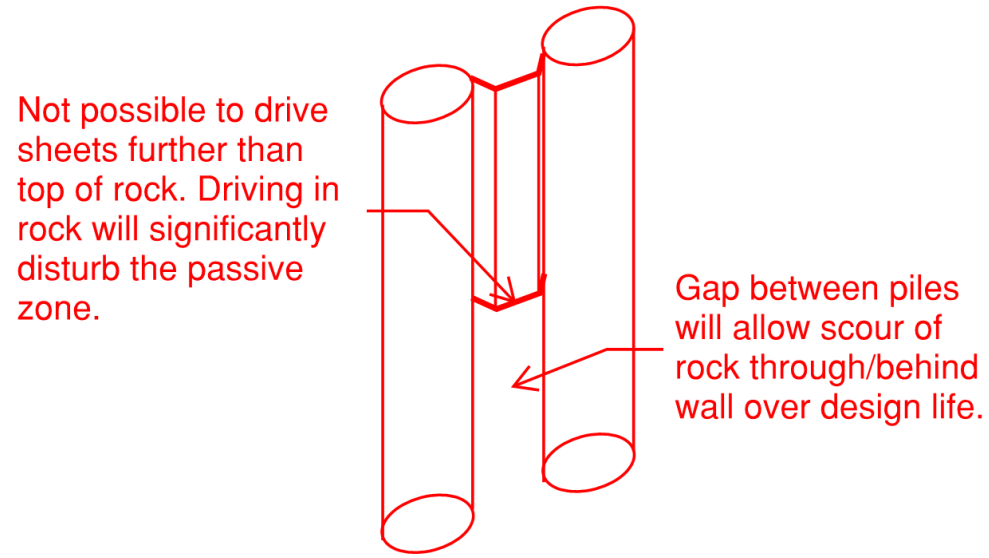



Figure 20 - Combi wall diagram

Pile Type Option B - Secant Piled wall

This option involves a continuous row of overlapping piles used to form the wall structure. Circular hollow steel tubes would be utilised as casing down to rock level to stop loss of concrete through beach deposits (controlling the environmental hazard), with alternate reinforced “male” piles.

This option was discounted due to the requirement to case. Overlapping casing will not possible because the casing is likely to need to be sacrificial to prevent loss of concrete into the sea. The concrete within the unreinforced female piles is also unlikely to be able to withstand the marine loading.

Figure 21 - Secant piled wall

Pile Type Option C - Contiguous Piled Wall

This option is similar to the secant piled wall however the interlocking female piles are removed. The pile spacing is reduced so that the structure acts as a continuous wall and the soil behind the wall arches across the gaps in the piles. The tighter spacing protects the material behind the wall from scour.

Selected Pile Type

The contiguous piled wall (Option C) as the preferred arrangement of the piled wall has been taken further and developed into three viable options. These options vary in capital cost and quantity of risk.

## Proposed Piling Method

The following piling methods have been assessed:

Option A - Cased and augered with small rig off piling mat

Option B - Cased and augered with medium rig off jack up barge – medium cost, medium risk

Option C - CHS with large rig off jack up barge

The method, opportunities and risks of these methods are discussed below

Piling Method Option A - Cased and augered with small rig off piling mat

1. A piling platform is constructed over / in front of the existing low-level promenade.
2. A sacrificial circular hollow steel casing is installed down to rock level.
3. The pile is then augered through the casing and down into the underlying bedrock to the desired embedment.
4. The pile is then concreted with a reinforcement cage and the casing stops concrete spilling out into the sea through the piling platform
5. A facing is added to the contig pile wall down to lowest expected beach level (for aesthetics).

| **Risks/Disadvantages of Cased and augered with small rig off piling mat** | **Opportunities/Advantages of Cased and augered with small rig off piling mat** |
|---|---|
| Significant material required to construct piling mat, particularly if high level promenade option is chosen. Stability of piling mat, particularly during storm events<br>Variable ground, bore collapse, grout loss<br>Small rig, difficulty with obstructions<br>Lost working period and ability to retreat in high tides / storms<br>Spoil management<br>Concrete spill<br>Difficult to "re-open" beach if piling is programmed over summer months | Small rig, manoeuvrable<br>Utilise mainstream 'land-based' construction techniques<br>Quick pile installation<br>Lower capital cost<br>Less dangerous working near the line – smaller mast height<br>Possibility of reuse of piling mat material on beach, behind wall, in breakwater |

Figure 22 - Advantages/Disadvantages of Cased and augered with small rig off piling mat.

Piling Method Option B - Cased and augered with medium rig off jack up barge

1. Jack up barge positioned
2. Piling rig installs sacrificial circular hollow steel casing down to rock level
3. The pile is then augered through the casing and down into the underlying bedrock to the desired embedment.
4. The pile is then concreted (with a reinforcement cage) and the casing stops concrete spilling out into the sea through the piling platform
5. A facing is added to the contig pile wall down to lowest expected beach level (for aesthetics).

| Risks/Disadvantages of Cased and augered with medium rig off jack up barge | Opportunities/Advantages of Cased and augered with medium rig off jack up barge |
|---|---|
| • Variable ground, bore collapse, grout loss<br>• Spoil management<br>• Concrete spill<br>• Medium rig, less manoeuvrable – constraints of barge<br>• Long time (limited tide windows) to move jack up barge<br>• Slower pile installation | • Medium rig better through obstructions<br>• Less working periods lost in high tides / storms<br>• Easier to retreat during storm event<br>• Less material use – no berm<br>• More suitable if high level promenade option chosen – pile finished level (within reason) |

Figure 23 - Advantages/Disadvantages of Cased and augered with medium rig off jack up barge

Piling Method Option C - CHS with large rig off jack up barge

1. Jack up barge positioned
2. Piling rig installs permanent circular hollow steel section to required pile depth
3. The pile is then concreted to fill the space with no soil/rock
4. A facing is added to the contig pile wall down to lowest expected beach level (for aesthetics).

| Risks/Disadvantages of CHS with large rig off jack up barge | Opportunities/Advantages of CHS with large rig off jack up barge |
|---|---|
| • Large rig, less manoeuvrable – constraints of barge<br>• Larger section size for CHS compared to alternative as it is the structural section – lifting larger sections.<br>• Danger using large rig adjacent to line – mast height<br>• Long time (limited tide windows) to move jack up barge?<br>• Slower installation | • Large rig better through obstructions<br>• Less working periods lost in high tides / storms<br>• Easier to retreat during storm event<br>• Less material usage<br>• No separate reinforcement cage required<br>• More suitable if high level promenade option chosen – pile finished level, more likely restore cantilever moments. |

| Risks/Disadvantages of CHS with large rig off jack up barge | Opportunities/Advantages of CHS with large rig off jack up barge |
|---|---|
| • Higher capital cost | • Handles variable ground, bore collapse, grout loss<br>• Reduced spoil compared to both alternatives<br>• Reduced concrete spill – environmental risk |

Figure 24 - Advantages/Disadvantages of CHS with large rig off jack up barge

Selected Piling Method Assumption

Following a number of meetings with Network rail, BAM and piling contractors the working assumption for the design is that option C will be method of working.

## Low level Promenade

### Foundation types

The majority of the foundation solutions presented for the high-level promenade are applicable to the low-level promenade.

The low-level promenade will have an additional set of foundations located under the back wall. The concept sketches can be seen in Figure 25 and Figure 26.

These additional foundations are assumed to be able to be installed by small piling rigs able to manoeuvre between and under the existing promenade such that the foundations can be installed without affecting the existing platform.

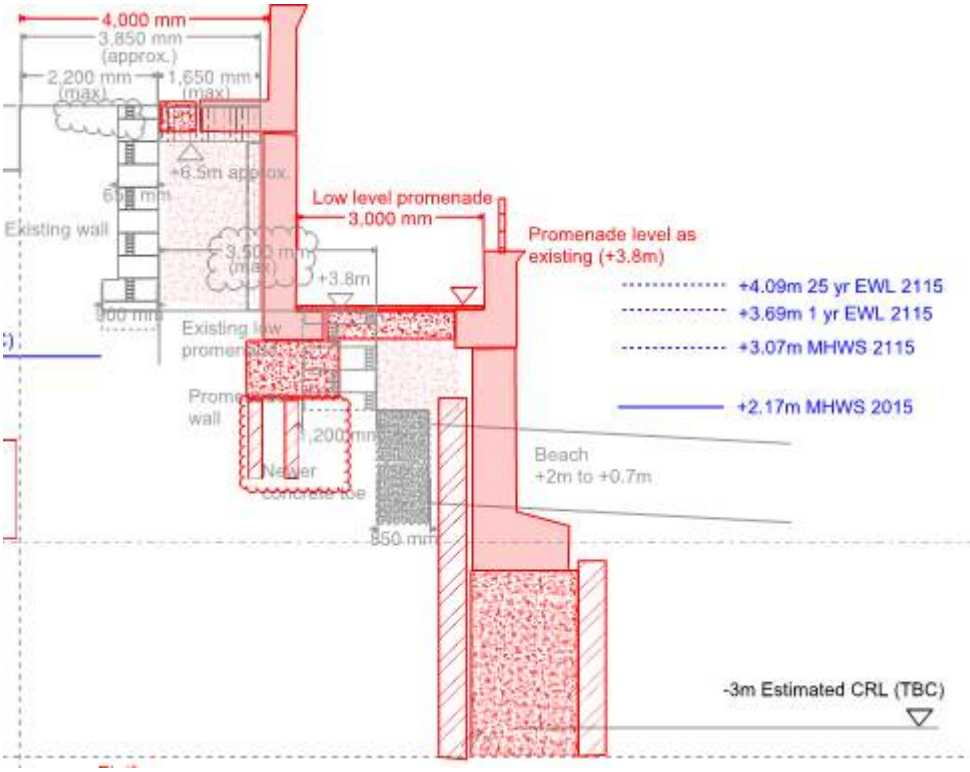



Figure 25 - Low level promenade, shallow foundation structural concept

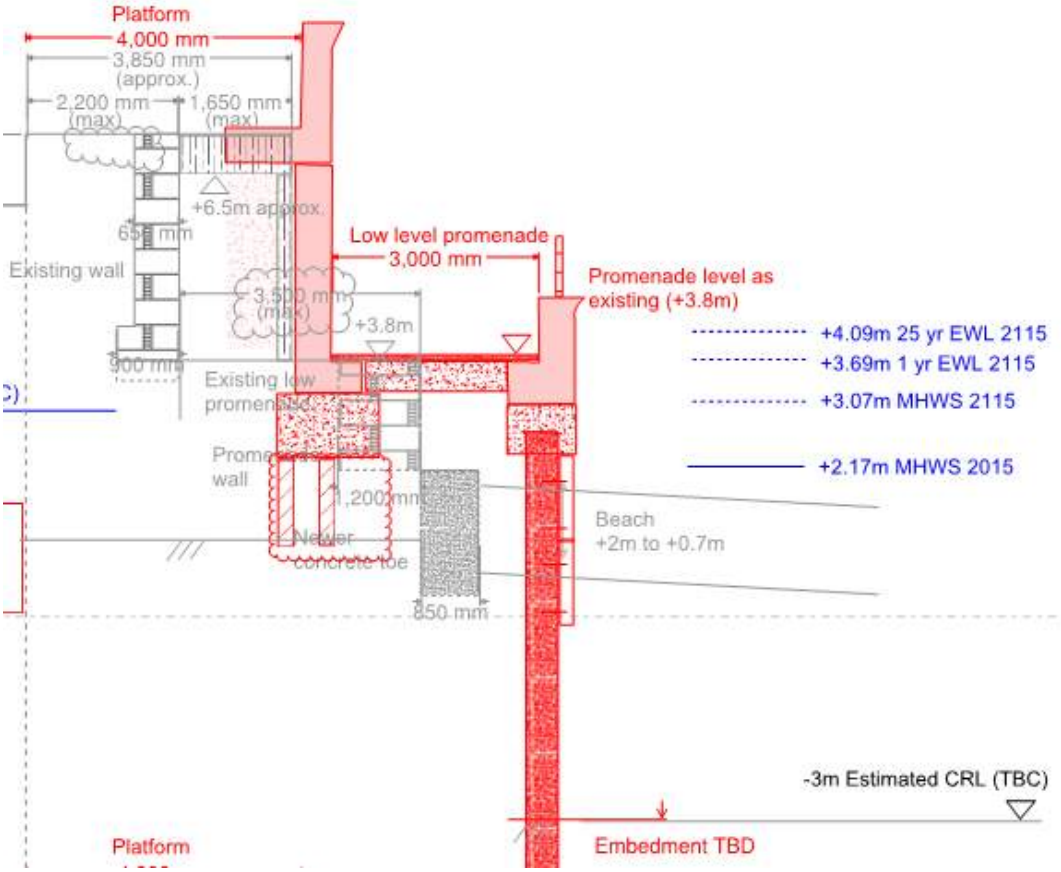



Figure 26 - Low level promenade, pile foundation structural concept

### 5.2.3 Section D Civil Engineering Options - Wall

**High level Promenade**

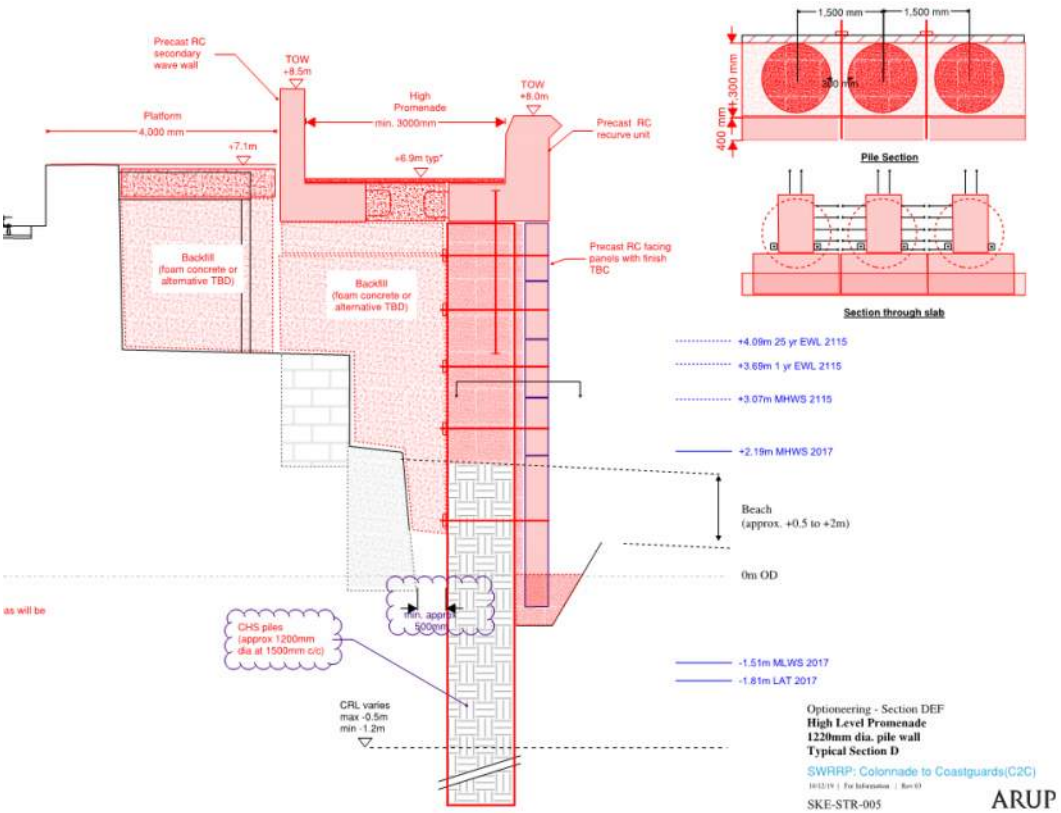



Figure 27 - High level Promenade Structural Concept

The structural concepts for the wall are largely driven by the chosen foundation type and the robustness and durability requirements for a structure in a marine

The following has been considered during the development of the high-level promenade option.

- The Pile Cut-off level – Varying options for the cut-off level of the pile have been considered. An option of a lower cut-off level and additional precast unit were also considered. On the decision to use a Jack Up barge for piling a high cut-off level has been used to omit a precast unit (Due to the higher piling level available from a barge compared to a beach level rig). A high cut-off level also eliminates the need to install precast units within the tidal range.
- A key consideration has been separation of the wall construction from the platform construction. This can facilitate construction of the wall while the existing platform remains operational
- How various elements will be constructed; precast or in-situ. The precast units tend to be the faces that aid protection such as the sea wall, the recurved parapet and the secondary wall. The areas behind/beneath these will be protected by these precast units so can be looser material that is poured on site.

## Low level Promenade

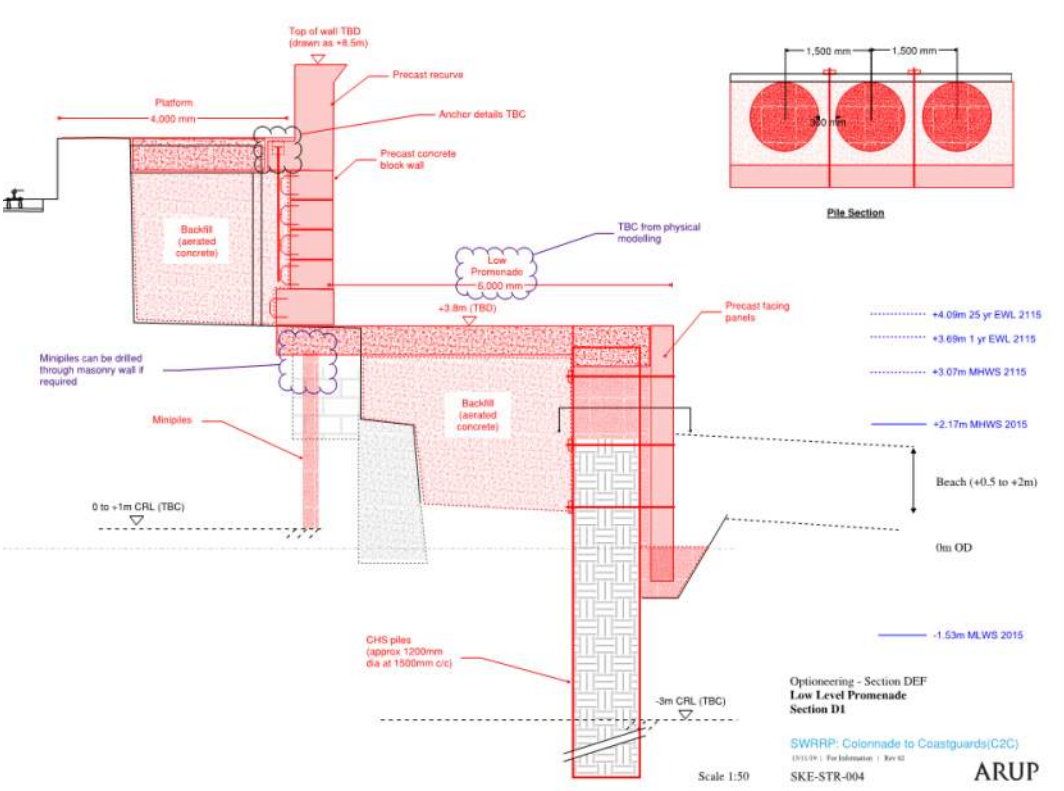



Figure 28 - Low level Promenade Structural Concept

The following has been considered during the development of the low-level promenade option

- A similar secant pile wall to the high-level option can be used to form the promenade wall. This wall provides the scour protection required and acts as the main structural pile. The pile cut-off level is determined to form the new promenade at the same level as the existing promenade as is also above the tidal range.
- The seawall comprises a recurve unit on top of a precast concrete wall, which provides the main resilience to waves. The wall can be constructed from stacked precast blocks anchored into the concrete backfill. This enables greater flexibility in the construction process and facilitates easier transportation to site.
- The seawall can be supported on smaller piles which only need to take vertical load. Horizontal loads from waves are transferred back to the main structural pile at the front of the promenade.
- The lower promenade can be constructed first to form a working platform from which to build the seawall. The seawall construction can also be separated from platform works, allowing the platform to remain operational.

## Handrails and parapets

For the majority of the promenade there is a 1.1m parapet formed as part of the seawall recurve. This provides sufficient protection to falls from the promenade but limits views of the sea for children and those in wheelchairs.

As a result, there are raised areas at regular intervals. These will be 300mm higher than the standard promenade level, reducing the parapet height to 800mm. This will be complimented by a 300mm handrail on top of the parapet at these locations to provide the required edge protection.

## Drainage

### High Promenade Option

There were initially two main options for the drainage of the high-level promenade.

Option 1 involved extending each of the individual existing drains from the track ballast below the promenade and out through the sea wall. This would require a large number (40+) of outlets within the seawall for these existing drains to connect to. Each of these would require an individual detail as each of the drains has to line up with the facing panels, as well as individual non-return valves. As well as this, this drainage solution didn't increase the capacity of the existing drainage which is insufficient to drain the tracks quickly in high volume events.

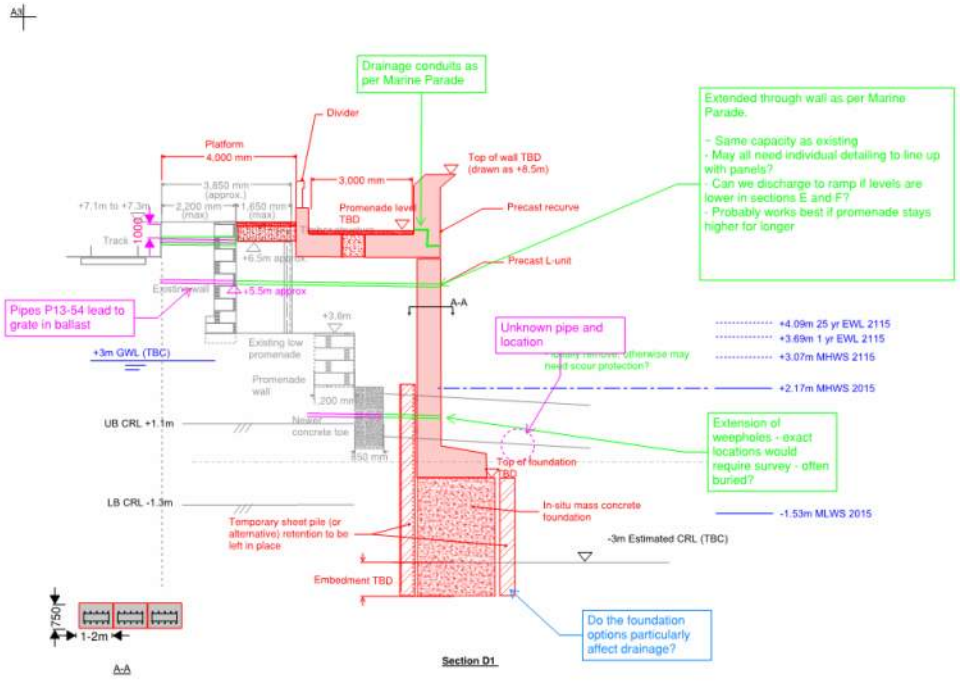



Figure 29 - High level drainage Option 1

Option 2 involves extending the existing drains into a linear carrier drain that runs under the promenade. This meant that the existing drains would connect into one large carrier pipe that would discharge through fewer, larger outfalls. This meant

that there were fewer key details that needed aligning on the seawall making construction easier and improving aesthetics. In addition, high level drains above track level have been added to connect into the carrier drain to drain the track as quickly as possible. The carrier drain can also be connected to the platform drainage system.

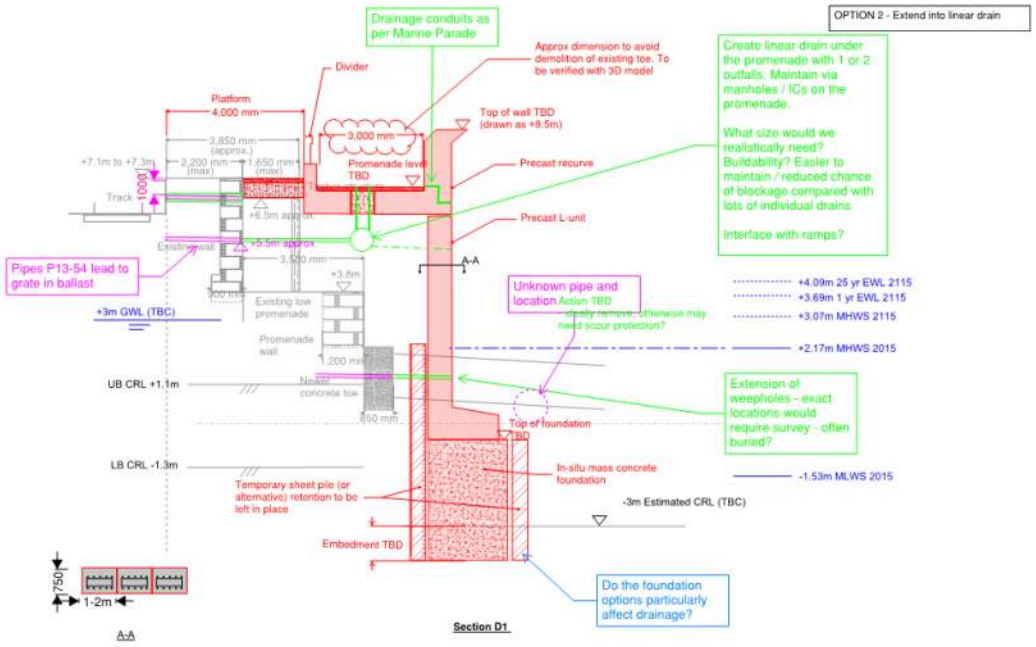



Figure 30 - High level drainage Option 2

For both cases, the promenade or platform drainage at high-level would be achieved through a double 90-degree pipe in each precast recurve unit. These allow the surface to drain but reduce the possibility of water from waves being blasted through back onto the promenade/platform due to the double bend solution. This is the same as the solution for the seawall at Marine Parade.

Proposed drainage for the high promenade is set out below and is shown in Figure 31. This is similar to Option 2, but the linear drain has been moved under the platform to avoid interfering with detailing within the promenade.

Track Drainage -

1. Extend existing ballast drains extend into a collector drain. This would be split into sections with an outfall for each protected by a non-return valve similar to the details used at Marine Parade. The carrier drain would run underneath the new platform to ensure ease of access.
2. Block up existing high-level drains
3. Instead of these high-level drains, emergency relief would be provided by new larger cores under sleeper level at ~50m spacing. These could also be used in conjunction with under-track crossings for pumping concrete, and other services, as discussed at the buildability workshop.

Platform Drainage -

The platform will slope away from track into an ACO drain or similar that would discharge in to the carrier drain.

New high promenade Drainage -

The promenade would be drained similarly to at Marine Parade utilising a double curve drain through the recurve panels to reduce inflow from the sea. On Marine Parade one conduit was provided per panel (2m spacing) and similar spacing is likely to be required here. The promenade would have a slight slope away from track toward these drains of a maximum of 1:50.

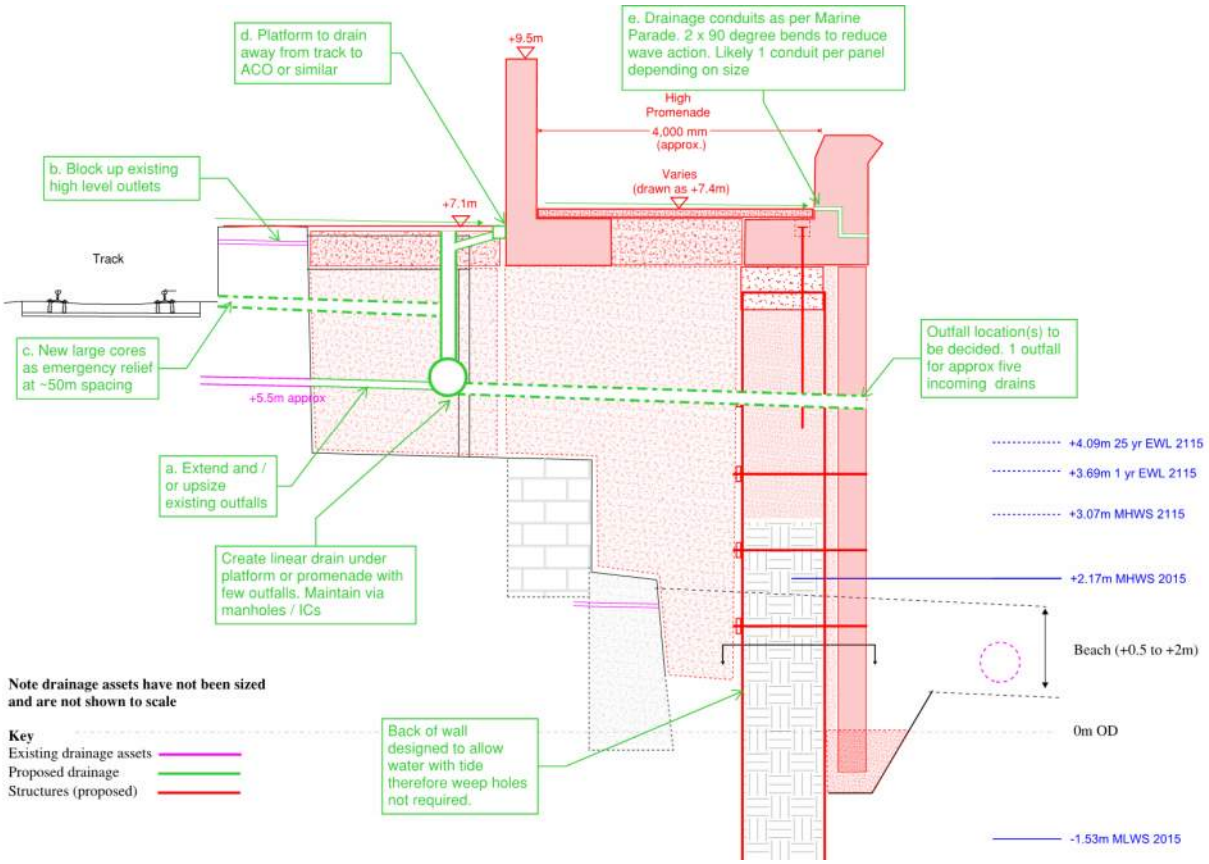



Figure 31 - Proposed drainage for a high promenade option

## Low Promenade Option

The two options for the low-level scenario are almost the same as the high-level options. The only difference is that in these cases, the promenade is too low for the drains to flow underneath.

In Option 1 the 40+ drains would discharge onto the promenade.

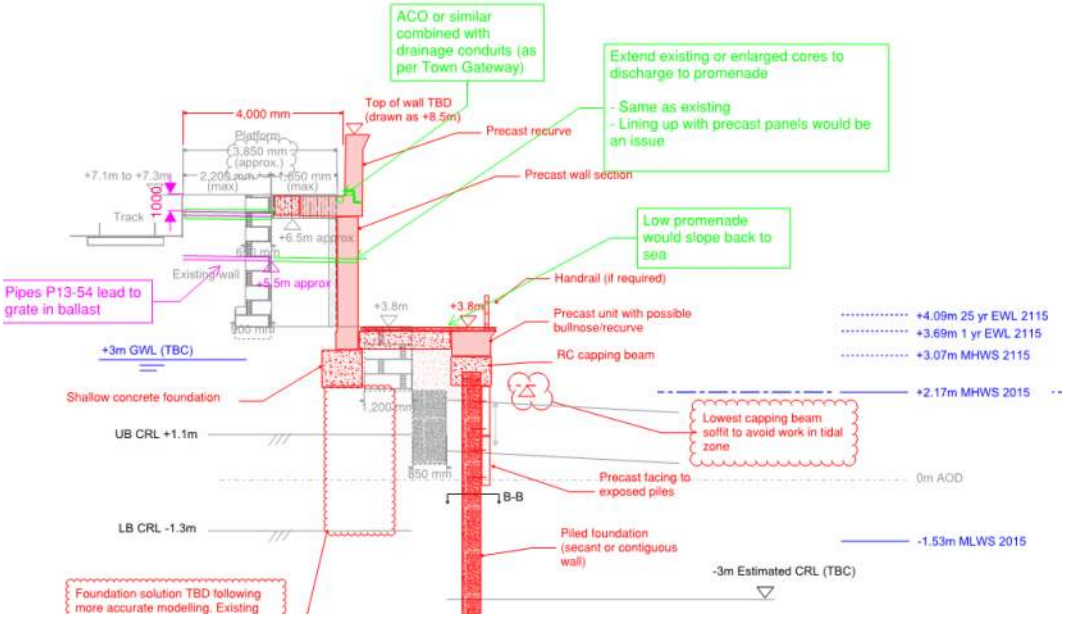



Figure 32 - Low level drainage Option 1

In Option 2 the drain would be positioned linearly within the platform extension and either still discharge onto the low promenade through fewer, but wider, drains or discharge at one location away from the promenade.

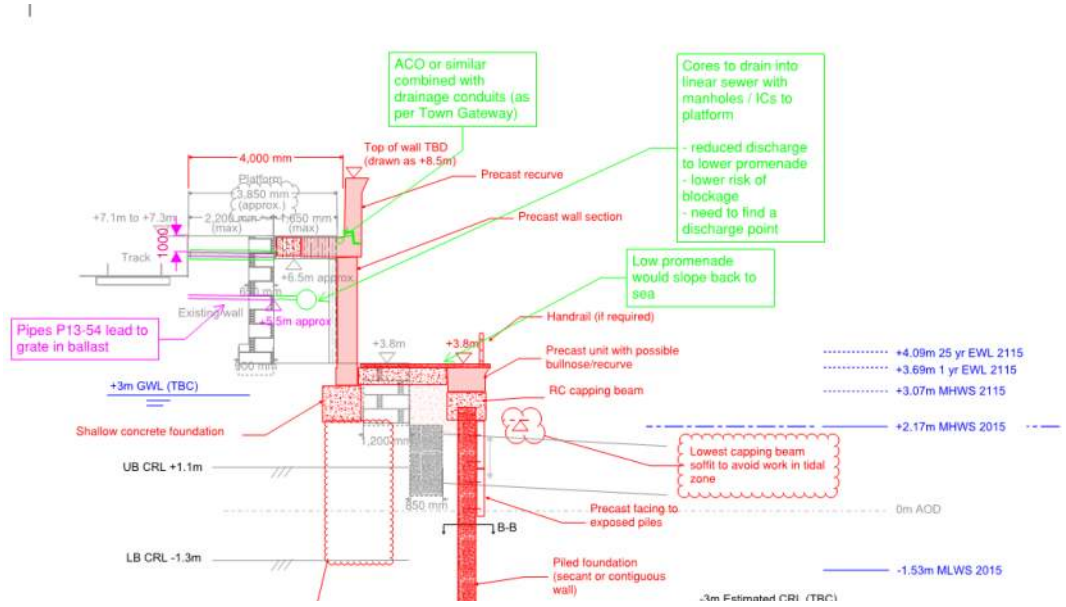



Figure 33 - Low level drainage Option 2

For both cases, the promenade or platform drainage at high-level would be achieved through a double 90-degree pipe in each precast recurve unit. These allow the surface to drain but reduce the possibility of water from waves being blasted through back onto the promenade/platform due to the double bend solution. This is the same as the solution for the seawall at Marine Parade.

Drainage for the low promenade is set out below and is shown in Figure 34.

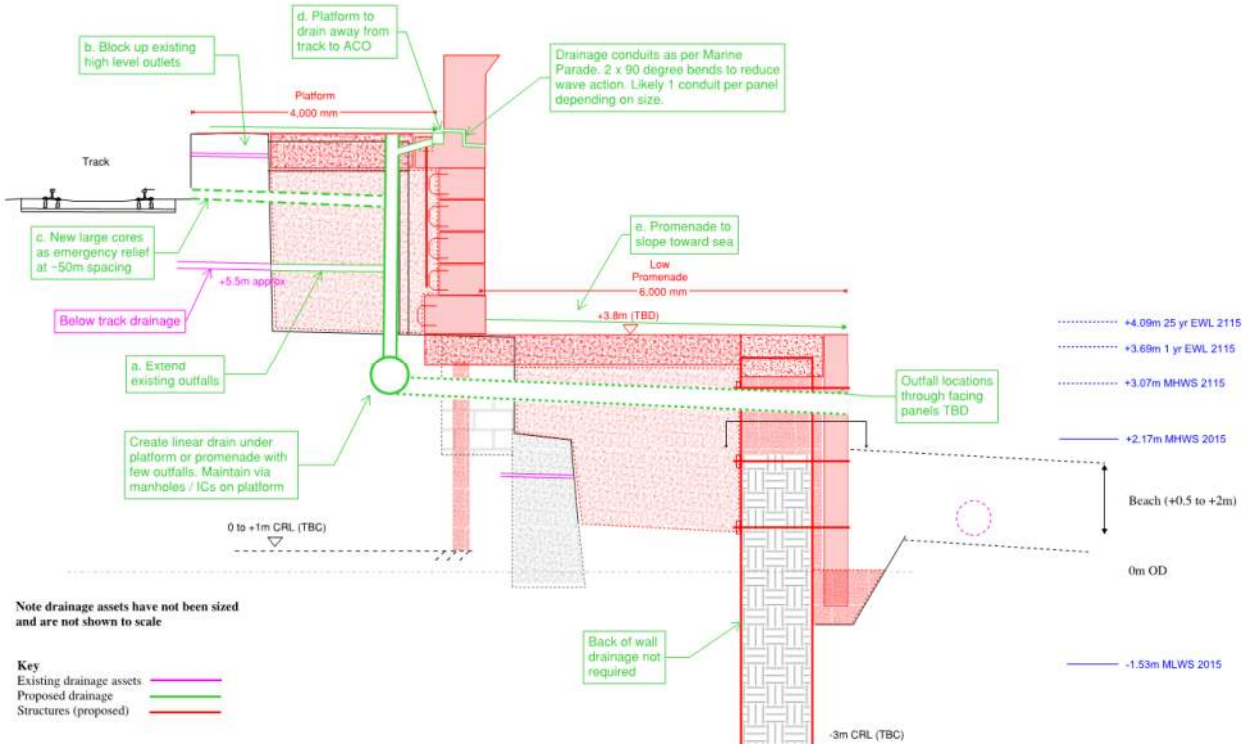



Figure 34 - Proposed drainage for a low promenade option

## Track Drainage

- Extend existing ballast drains extend into a collector drain. This would be split into sections with an outfall for each protected by a non-return valve similar to the details used at Marine Parade. The carrier drain would run underneath the new platform to ensure ease of access. Ideally, this would outfall under the lower promenade, but may require attenuation during high tides.
- Block up existing high-level drains.
- Instead of these high-level drains, emergency relief would be provided by new larger cores under sleeper level at ~50m spacing. These could also be used in conjunction with under-track crossings for pumping concrete, and other services, as discussed at the buildability workshop.

## Platform Drainage

- The platform will slope away from track into an ACO drain or similar. This would either discharge in to the collector drain, or conduits through the recurve panels. It is also possible that a similar detail to Town Gateway is used, where low flows are collected in the ACO drain, but drainage conduits through the recurve are set slightly above the surfacing level to discharge high flows. This prevents low flows from discharging to the lower platform when pedestrians may be present but increases the capacity in a storm event. On Marine Parade one conduit was provided per panel (2m spacing) and similar spacing is likely to be required here.

New low promenade Drainage

- The promenade would have a slight slope (maximum of 1:50) toward the sea allowing free run-off.

### 5.2.4 Section D Maritime Options

For a detailed discussion on Maritime options and design please refer to the 2D Physical Modelling Summary Report (142630-ARP-REP-EVC-000025).

#### Design Criteria

The wave overtopping design criteria has been set as a combination of NR requirements (as per CE-T), Arup's interpretation of the CR-T and Arup's suggestions based on standards. The wave overtopping criteria is presented in Table 3.

Table 3 - Wave Overtopping Design Criteria

**Legend**
**NR criteria as per CR-T**
**Arup's interpretation of CR-T**
**Arup's suggestions based on standards**

| **Performance criteria** | **RP, Design Return Period (years)** | **q, Mean discharge limit (l/s/m)** | **Vmax, Individual maximum overtopping volume (l/m)** |
|---|---|---|---|
| Structural (1) | 1 in 200 | 50 to 200 | N/A |
| Railway operational (2) | 1 in 10 (min)<br>1 in 25 (target) | 10 to 20 | 1000 (equipment)<br>2000 (railway) |
| Passenger (3) (refer to Passenger Overtopping Criteria Note agreed with NR) | 1 in 1 | 0.1 | 20 |
| Pedestrian (4) | 1 in 1 | 0.3 to 1.6 | 600 |

(1) Discharge limit depends on the structure type.

(2) The operational criteria depend on the level of resilience provided and needs to ensure the structure geometry is not overly onerous.

Values lower than target to be agreed based on risk assessment.

(3) q and Vmax limits satisfy "Passengers shall not be knocked over…"

q relaxed from 0.03 l/s/m (unaware pedestrian) provided that the platform is closed during severe events (events greater than 1-in-1 year) and NR ensures that passengers are made aware of possible storms and waves. The method and criteria to make passengers aware is to be agreed and confirmed by NR.

Applicable to high level promenade only.

(4) Discharge limit relaxed by Risk Assessment (142630-ARP-LOG-MPM-000002 Project Hazard Log V3) (0.1l/s/m in CR-T). Requires embedded and additional mitigation measures that must be applied to ensure pedestrian safety during storm events (Resilience Comparison Report).

## Recurve and Wall profile selection

The wall profile and bullnose geometry has been selected considering the following aspects:

- Hydraulic effectiveness
- Buildability & cost
- Previous experience from Marine Parade
- Wall footprint

Different wall profiles; vertical wall, battered wall and recurve wall, were considered as part of the Feasibility Stage. A vertical profile was adopted with a bullnose at the top.

The existing upper wall at Colonnade to Coastguards (C2C) is nearly vertical and the proposed vertical wall is consistent with this. (By contrast, the new battered sea wall profile at Marine Parade matches the profile of the existing historic wall). At C2C it has been decided that the main structural element should be vertical cased piles. Following from this decision, the face of the wall is vertical to align with the vertical piles and to minimise further encroachment into the beach. Installing vertical panels is relatively straightforward compared to sloping panels. The relative hydraulic performance of a vertical sea wall versus a battered profile is complex and subject to many variables. 2D hydraulic model tests for a typical profile at Section D of the seawall showed that the hydraulic performance of the seawall with a vertical profile and a high-level promenade meets the specified requirements for resilience against wave overtopping.

The bullnose was proven very effective reducing wave overtopping during Marine Parade physical modelling. As part of Marine Parade remit, different geometries of the bullnose that form the parapet wall were tested in the 2D-physical laboratory tests. This showed that large overhang at a flat angle was effective in reducing overtopping but resulted in very high wave loads on the parapet. Based on the 2D-physical modelling, the profile adopted for Marine Parade comprises a horizonal extension of the bullnose (overhang) of 450mm and an angle of the

bullnose of 30° (see

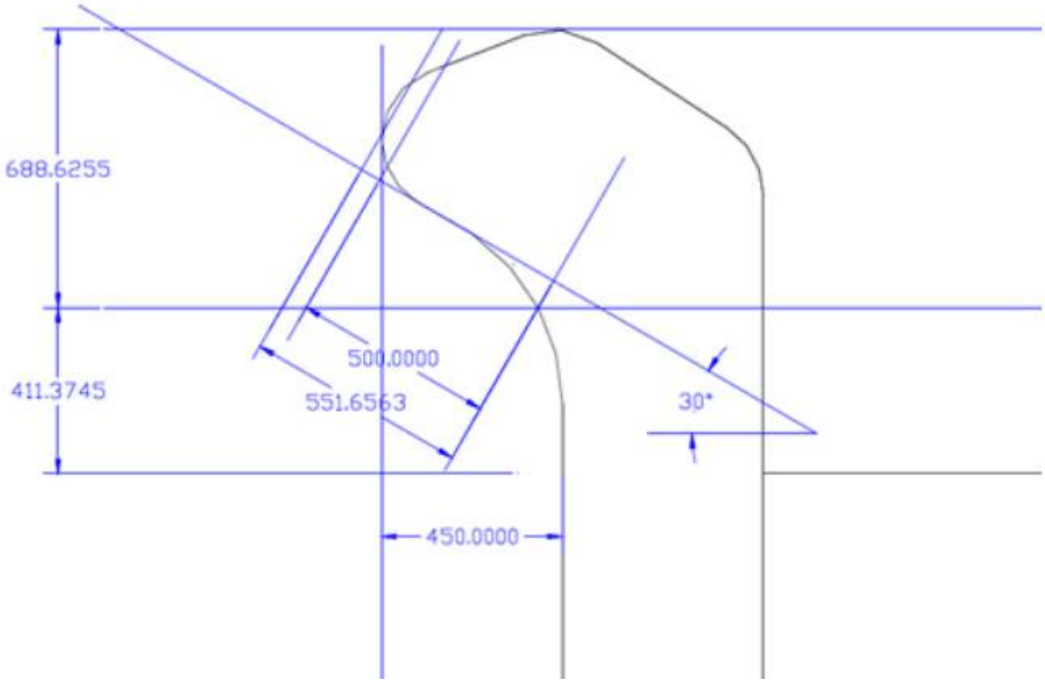



Figure 35). This was shown to give a pragmatic balance between the hydraulic and structural performance.

The same recurve profile is to be used for Colonnade to Coastguards. The parapet wall at C2C is a little wider at the base than at Marine Parade, as it allows the reinforcement to be reduced significantly. At Marine Parade the parapet thickness was minimised to keep within encroachment limits. At C2C the line of encroachment is driven by the desire to avoid a clash between the seawall piles and the existing low-level promenade; the thickness of the parapet does not affect the encroachment.

The benefit of providing irregular surfacing to the wall was considered limited however, it created significant buildability challenges. For this reason, it was not considered further.

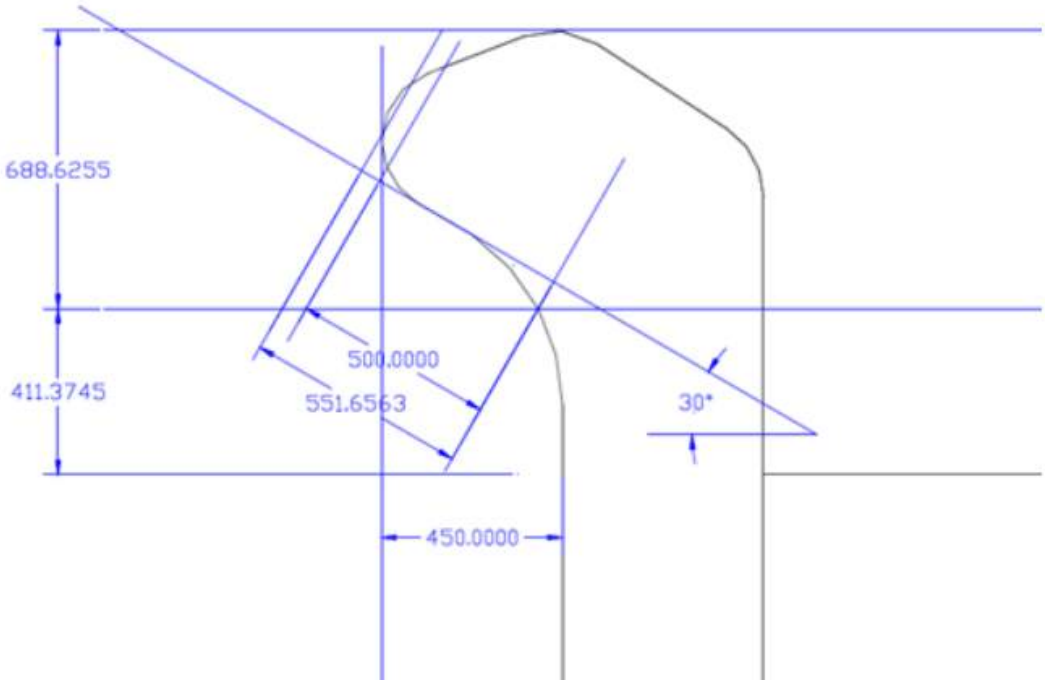



Figure 35 - Marine Parade bullnose detail

## High level Promenade

The overtopping assessment of the high-level Promenade was undertaken in two parts:

1. Based on numerical analysis
2. Validation/refinement of the Numerical Model based on 2D Physical Modelling

### Part 1 - Numerical Analysis

The results of the numerical analysis are contained within the Resilience Comparison Report (document reference number: 142630-ARP-REP-ECV-000023).

It was concluded that based on the overtopping calculations, the design of the seawall is controlled by the passenger criteria.

Based on the numerical analysis the only option which met the unaware passenger criteria (0.3-1.6 l/s/m – as per Table 3) in 2115 was a vertical wall with high promenade with crest level at +9.5mOD or higher and bed level nourished to keep it above +2.0mOD. This assumes a promenade width of 3m.

Following a meeting with NR on 18/10/19 it was agreed that the criteria for pedestrians on the platform could be changed to aware passenger. This is on the basis that the platform would be closed during severe events (events with a return period greater than 1:1) and passengers are made aware of possible storms and waves (method and criteria for announcement to be agreed and confirmed by NR).

Further to the change in criteria, the following options presented themselves in order to meet the passenger criteria:

- Design and construct now to satisfy only the 2065 epoch criteria for passenger resilience with an ability to provide additional protection at a later date
- Design and construct now to satisfy the 2115 epoch criteria for passenger resilience

The rail resilience criteria were met in both above options based on calculations.

Also note that the pedestrian criteria on promenade (as per CR-T) cannot be met for all scenarios and it was assumed a risk assessment approach was acceptable.

Based on overtopping calculations, the following table (Table 4) of options that were derived from the overtopping calculations:

| | **Wall crest level** | **Promenade width** | **Bed Level** | **Epoch criteria met** |
|---|---|---|---|---|
| Option 1 | +8.5 mOD | 6.5m | -1.00mOD | 2065 |
| Option 2 | +8.5 mOD | 3.0m | +2.00mOD * | 2065 |
| Option 3 | +9.5 mOD | 6.5m | -1.00mOD | 2115 |
| Option 4 | +9.5 mOD | 3.0m | +2.00m OD * | 2115 |
| Option 5 | +9.5 mOD | 3.0m | -5.00mOD # | 2115 |
| Option 6 | +8.5 mOD | 3.0m | -5.00mOD # | 2115 |

Table 4 - Numerical Analysis Options for Section D High Level Promenade

*Beach Management Required

# Requires full length platform canopy/deck (possibly installed at a later date)

The following should be considered:

- Keeping the bed level at +2.0mOD implied the necessity of beach maintenance programme at a higher level and large groyne structures to ensure the beach material remained relatively stable and therefore, in place. It is expected the beach nourishment measures will be expensive (significant intervention to existing structures and new groynes).
- Both solutions with a -5.00mOD and -1.00mOD bed level would require a rock apron but it assumed this will be built at a later date when the beach level has dropped.

- For the options which only met the 2065 for the passenger criteria an option could be developed of adding a canopy at a later date. Future raising of the wall height would be challenging due to the promenade level and associated ramps being required to be adjusted also.
    - The structural feasibility and material of a full-length canopy will need further investigation. It could need to be a solid concrete deck to withstand the wave load which would be difficult to make visually appealing.

*Proposed Preferred High-Level Promenade Option from Numerical Analysis*

Following a review with NR on 12/11/19 the following options were presented as non-preferred:

- Option 2 & 4 – These options are non-preferred due to the extensive beach nourishment that would be required. This would have the following challenges:
    - The existing breakwaters would need to be built up to a higher level to maintain the beach
    - Extensive groyne structures would be needed between the existing breakwaters to maintain an even distribution of beach material
    - An ongoing beach maintenance programme would be required
    - The risk of substantial loss of material from severe events remains
    - The area of development would likely trigger an EIA requirement
- Option 1 & 3 – These options are non-preferred due to the significant width of the promenade required. This would have the following challenges:
    - Significant additional fill material and structure increasing the cost
    - Loss of significant amount of beach
    - Height of promenade for option 3 (9.5m high wall) requires even greater extents for access ramps
- Option 5 – This option is not preferred due to the height of the promenade and the greater extent required for access ramps.

The preferred option is Option 6. The following is to be noted:

- Based on overtopping calculations the passenger criteria were not met. However, the structure was to be designed to allow a canopy to be added to the platform at a later date to allow the criteria to be met.
- A secondary wall between the promenade and the platform would be included which would allow for further protection. The height of this would be confirmed by the physical modelling.
- Refer to Figure 36.

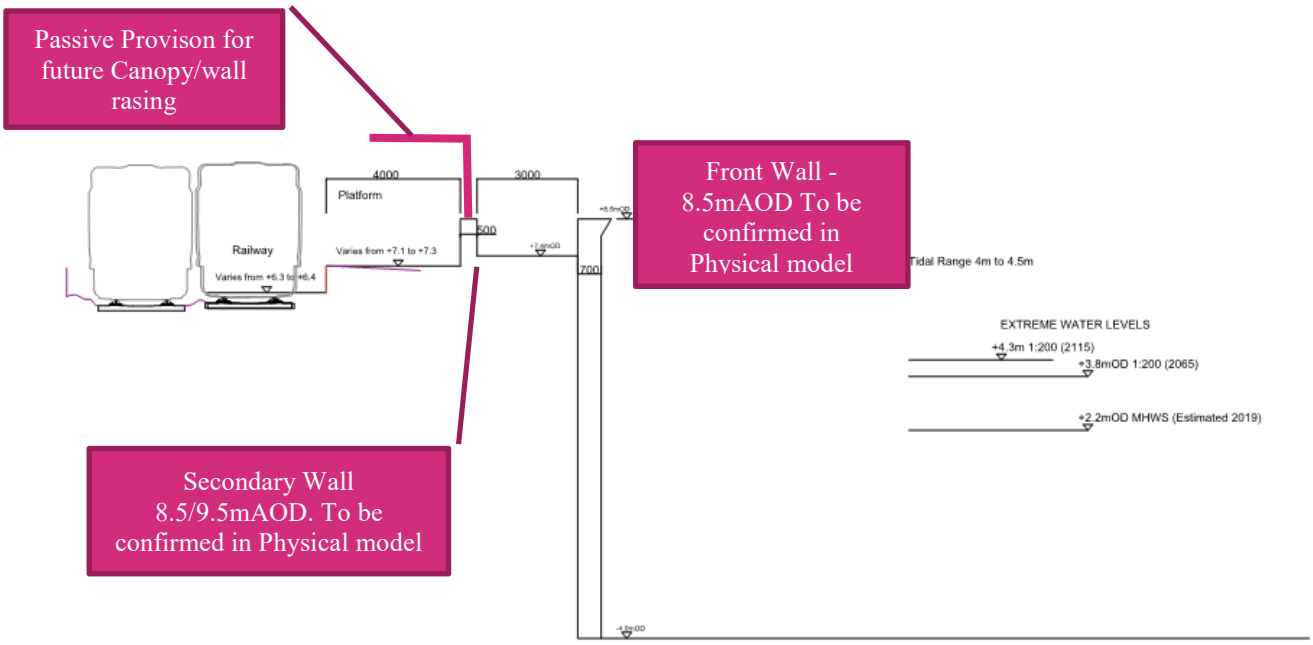



Figure 36 - Recommended Option for high level Promenade following Numerical Modelling

## Part 2 – Physical Modelling

For details refer to 2D Physical Modelling Summary Report (document reference number: 142630-ARP-REP-ECV-000025).

Four 2D physical tests have been completed, refer to Table 5.

| Test Series | Front Recurve Wall Level | Bed Level | Secondary Wall Level |
|---|---|---|---|
| Test D (Option selection test) | 8.0mOD | -4mOD | 8.0mOD |
| Test G (Option selection test) | 8.0mOD | -2mOD | 8.5mOD |
| Test C (Option selection test) | 8.5mOD | -4mOD | 8.5mOD |
| Test H (Verification test) | 8.0mOD | -4mOD | 8.5mOD |

Table 5 - High Level Promenade Physical Tests

The overtopping performance of the different geometries and bed levels tested in the physical modelling for the high-level promenade solution is summarised in Table 6. The green faces indicate satisfaction of the criteria, the red faces indicate dissatisfaction and the orange faces indicate within or close to the allowable limits.

| Performance criteria | Test D | | Test C | | Test G | | Test H | |
|---|---|---|---|---|---|---|---|---|
| | q | $V_{max}$ | q | $V_{max}$ | q | $V_{max}$ | q | $V_{max}$ |
| Railway Operational |  |  |  |  |  |  |  |  |
| Passenger |  |  |  |  |  |  |  |  |
| Pedestrian |  |  |  |  |  |  |  |  |

Table 6 - High level promenade wave overtopping performance. Green faces indicate satisfaction of criteria, red dissatisfaction and orange faces indicate at or close to the allowable limits

Tests (H) have shown that wave overtopping is larger for the low bed level (-4.0mOD) than for the higher tested bed level at -2.0mOD in front of the seawall. However, the **parapet wall with a crest set at +8.0mOD** is adequate in meeting the wave overtopping criteria set for the pedestrians at the promenade level, passengers on the platform and operational railway.

The **set-back wall with a crest set at +8.5mOD** is very effective comparing to its lower elevation (at+8.0mOD). It provides significant reduction in wave overtopping rate; almost 50%.

These are the criteria selected for the AiP design

## Low level Promenade

Numerical methods were not suitable to assess the overtopping performance of the low-level solution. The options were tested in a 2D Physical model.

For details refer to 2D Physical Modelling Summary Report (142630-ARP-REP-ECV-000025).

Four 2D physical tests have been completed, refer to Table 7.

| Test Series | Recurve Wall Level | Bed Level | Promenade width and level |
|---|---|---|---|
| Test A (Option selection test) | +8.5mOD | -4mOD | 6m and +3.8mOD |
| Test B (Option selection test) | +9.5mOD | -4mOD | 3m and +3.8mOD |
| Test F (Option selection test) | +9.5mOD | -2mOD | 3m and +3.8mOD |
| Test E (Option selection test) | +9.5mOD | 0mOD | 3m and +3.8mOD |

Table 7 - Low Level Promenade Physical Tests

The overtopping performance of the different geometries and bed levels tested in the physical modelling for the low-level promenade solution is summarised in Table 8. The green faces indicate satisfaction of the criteria, the red faces indicate dissatisfaction and the orange faces indicate within or close to the allowable limits.

The results from the 2D physical modelling show that the low-level option does not satisfy the passenger nor the pedestrian overtopping criteria. In addition, the low-level promenade presents the following issues:

- Overtopping is much less predictable than for the high-level option. Passenger would perceive that they are in a save area as there is not constant overtopping coming in but suddenly a dangerous single wave occurs. Therefore, passengers next to the parapet have a false sense of security.
- Relaxation of the passenger criteria would be required.
- Promenade will become increasingly unusable with time. It should be noted that the promenade level could not be raised as this would have a negative impact in wave overtopping.

| Performance criteria | Test A | | Test B | | Test F | | Test E | |
|---|---|---|---|---|---|---|---|---|
| | q | $V_{max}$ | q | $V_{max}$ | q | $V_{max}$ | q | $V_{max}$ |
| Railway Operational |  |  |  |  |  |  |  |  |
| Passenger |  |  |  |  |  |  |  |  |
| Pedestrian |  |  |  |  |  |  |  |  |

Table 8 - Low-level promenade wave overtopping performance. Green faces indicate satisfaction of criteria, red dissatisfaction and orange faces indicate at or close to the allowable limits

## Beach Management

Please refer to Beach Management Requirements technical note (142630-ARP-BRF-ECV-000003) for further detail about beach management.

Beach management is required for some of the assessed solutions to provide overtopping to the railway.

Beach management involves capital beach nourishment as well as the installation/upgrade of a range of coastal structures such as fishtail/timber groynes and terminal groynes (Colonnade and Coastguards breakwaters).

In addition, beach reprofiling and beach recharge may be required on a regular basis and after extreme storm events. This would involve a relatively quick response times and reactive beach maintenance in order to not compromise the resilience of the railway for periods of time. This would need to be done by a specialist contractor on call with appropriate marine plant (e.g. landing craft) due to the access constraints of the site.

The benefit of providing a stable beach in front of the seawall could translate in a lower seawall. We estimate the saving in parapet height to be between 1 to 1.5m maximum (assuming that as a minimum, any new seawall would be at or above

the same level as existing, +7.0mOD). The cost saving of this wall height reduction will be relatively small in comparison with the cost of the seawall.

We consider the whole-life cost of any solution involving beach management to be considerably higher than other explored solutions such as high-level promenade with no beach management. There is also a high risk of this solution not meeting the overtopping resilience requirements for periods of time until reactive maintenance occurs. For example, when the beach shape changes during a storm event, the crest width or beach level may fall below the minimums required for resilience. Based on this, we recommend that beach management is not taken forward as a solution for Colonnade to Coastguards frontage.

## Proposed sea wall configuration

The results from the physical modelling tests A to G were used to select the recommended option. This is high-level promenade solution with parapet wall at +8.0mOD and secondary wall at +8.5mOD is adopted.

Physical modelling test Series H, have been undertaken in order to verify the performance of the recommended option at -4m OD bed level (2115 design bed level). Its efficiency in terms of wave overtopping has been confirmed in the laboratory.

This solution meets the mean overtopping discharge limit (q) for all performance criteria for both 2065 and 2115 epochs. The structural criteria in relation to wave overtopping rate is also satisfied; these are the tests under 1:200 wave conditions in 2115.

There is a risk that Vmax may exceed the criterion for railway operation under 1:25yrs conditions in 2115 and bed level low at -4.0mOD; in other words, there might be one single wave that could be excessive for the operation of the railway, despite the mean wave overtopping rate being small. Vmax under 1:25year conditions in 2115 and higher tested bed level (-2.0mOD) maty marginally exceed the railway operation criterion. The risk associated to the exceeding Vmax limit is considered negligible in the medium term and medium to high in the long term.

The following general risks and uncertainties should be noted for design:

- Overtopping results should generally be considered as orders of magnitude
- There are uncertainties in relation to the predicted sea level rise and increased storminess
- Physical model uncertainty margin due to simplified representation of the site conditions.
- There is the risk that limited physical model test conditions such as the following might not represent the most onerous overtopping cases:
    - Wave and water levels
    - Bimodal wave spectra
    - Bed level, foreshore

- Wind effects not accounted for
- 3D effects

### 5.2.5 Section D Chosen option

Following the optioneering process and physical modelling, it was decided that the high-level promenade presented in Figure 37 would be the chosen option.

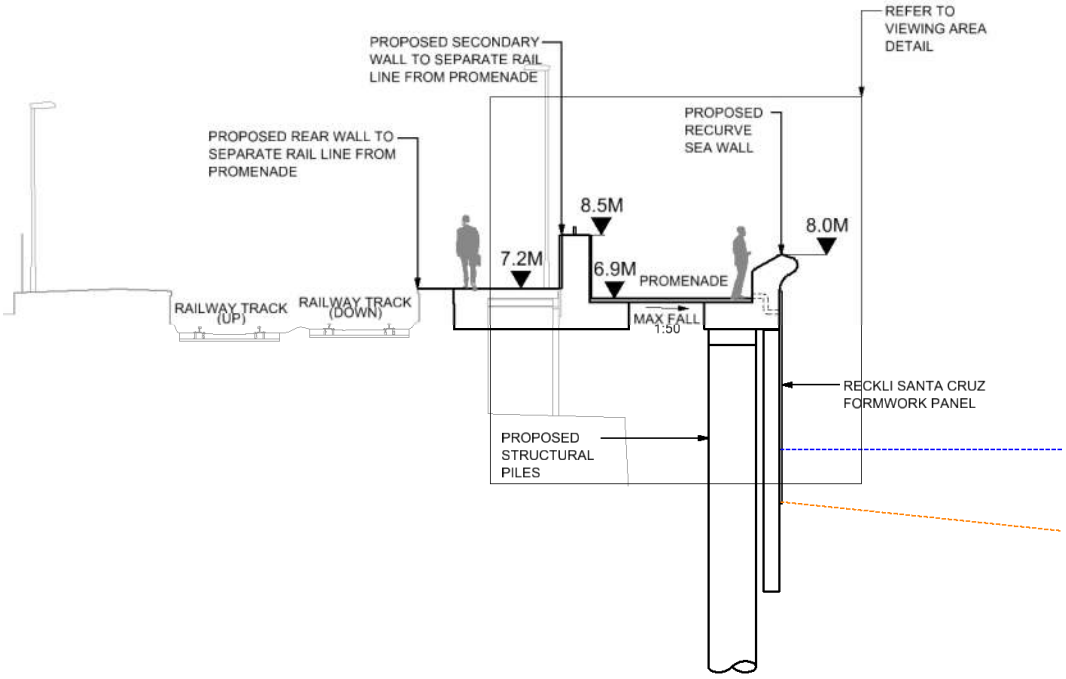



Figure 37 - Section D preferred option

## 5.3 Sections E&F

Sections E&F are located near the Coastguards breakwater and include the footbridge tie-in as well as the interface with the existing promenade beyond the Coastguards breakwater. The feasibility study yielded two main options for consideration at optioneering stage;

1. High-level promenade
2. Low-level promenade.

The optioneering for E&F has been considered under the following headings

- Landscape options
- Civil Engineering Options
- Maritime Options

### 5.3.1 Section E&F Landscape Options

Refer to Section 5.1 for discussions on ramps, promenade width and materials.

## Section E&F Low-Level Promenade option

Various options were considered for the footbridge and breakwater interface. This area is complicated as it needs to integrate with section D, the Coastguard's footbridge and the section beyond the breakwater. All options remove the Coastguard's building due to its dilapidated condition and removing it allows for the space to be reused.

The following options have been considered:

- Option 1 – Sea wall to back of Promenade with gaps
- Option 2 - Sea wall to back of Promenade continuous
- Option 3 – Continuous Angled sea wall
- Option 4 – Sea wall at Front
- Option 5 – Low-level Preferred Option

Option 1 – Sea wall to back of Promenade with gaps

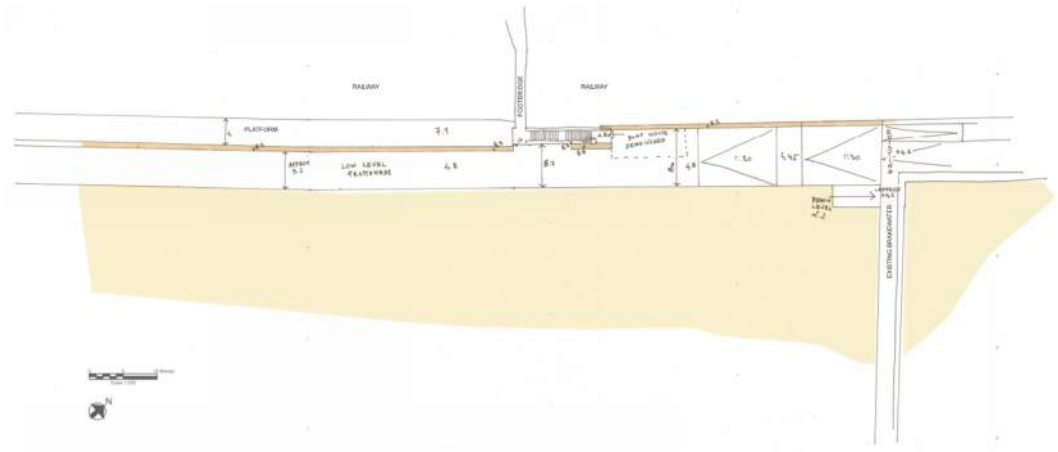


Figure 38 - E&F Low level Promenade Option 1

This option consists of a high-level seawall (assumed +8.5m at this stage) located at the back of the low-level promenade. A first section of wall protects the platforms (from station building to coastguard's footbridge). The existing coastguard's footbridge provides the resilience required up to its intermediate landing, with a second section of wall protecting the lower flight of stairs and extending to provide an overlap with the third section of wall. This last section of wall protecting the tracks runs along the railway fence from the footbridge to the existing breakwater. Due to its proximity to the tracks, this section of wall would be difficult to construct without a possession in place.

Option 2 - Sea wall to back of Promenade continuous

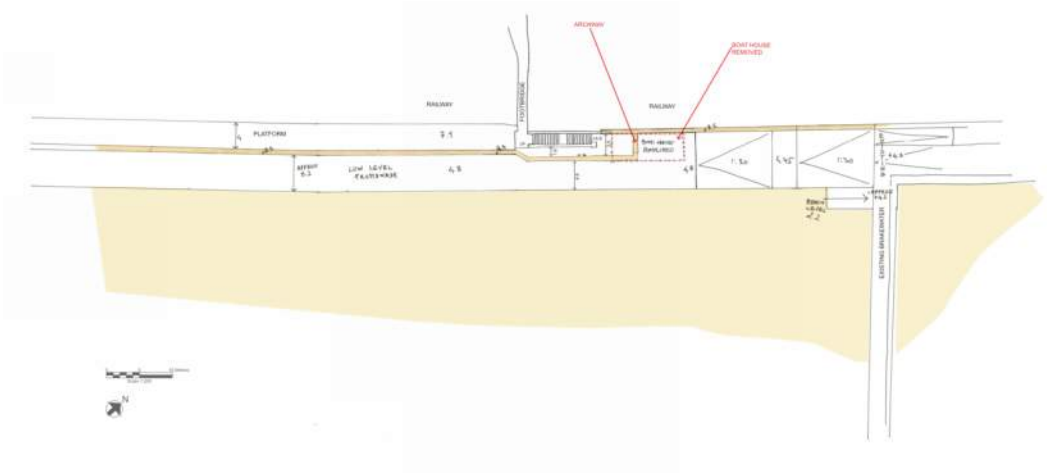


Figure 39 - E&F Low level Promenade option 2

This option is similar to option 1 but uses a seawall instead of the stairs to protect the footbridge section. It consists of a high-level seawall (assumed +8.5m at this stage) located at the back of the low-level promenade. A first section of wall protects the platforms (between the station building and coastguard's footbridge) and links to the second section of wall via an archway, allowing access to the footbridge. The second section of wall overlaps behind the archway and runs from here to the existing breakwater along the alignment of the railway fence, protecting the tracks beyond.

This option would be difficult to construct due to the seawall's proxmitiy to the tracks. Furthermore, the archway area at the end of the stairs creates a corridor effect.

Option 3 – Continuous Angled sea wall

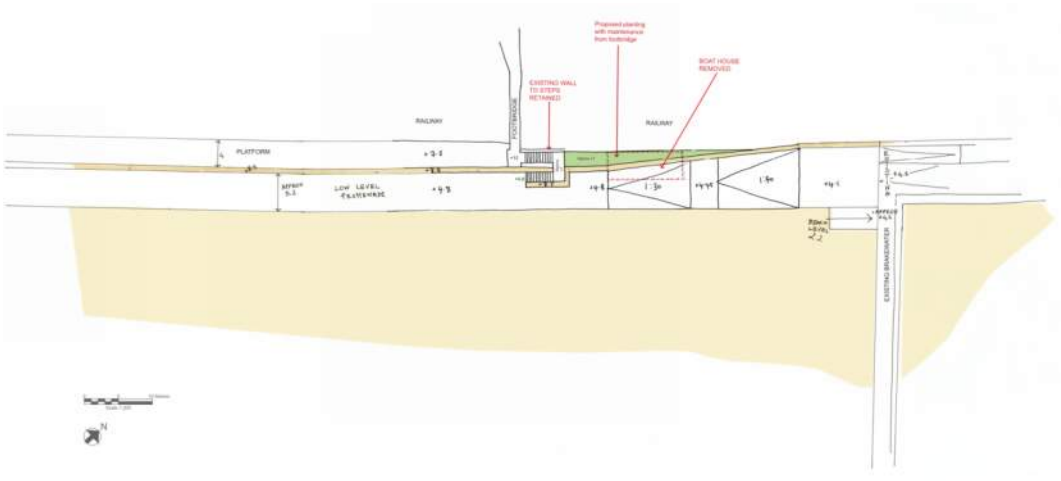


Figure 40 - Continuous Angled sea wall option 3

This option consists of a high-level seawall (assumed +8.5m at this stage) located at the back of the low-level promenade. In this option the existing staircase is

modified to route over the seawall. A first section of wall protects the platforms (between the station building to the modified staircase). The next section of wall overlaps by the modified staircase and runs diagonally to the existing breakwater, protecting the tracks beyond.

This option has several cornered sections of seawall which would concentrate the wave energy. Furthermore, several parts of the promenade lie below the 100-year sea level height of +4.8m.

Option 4 – Sea wall at Front

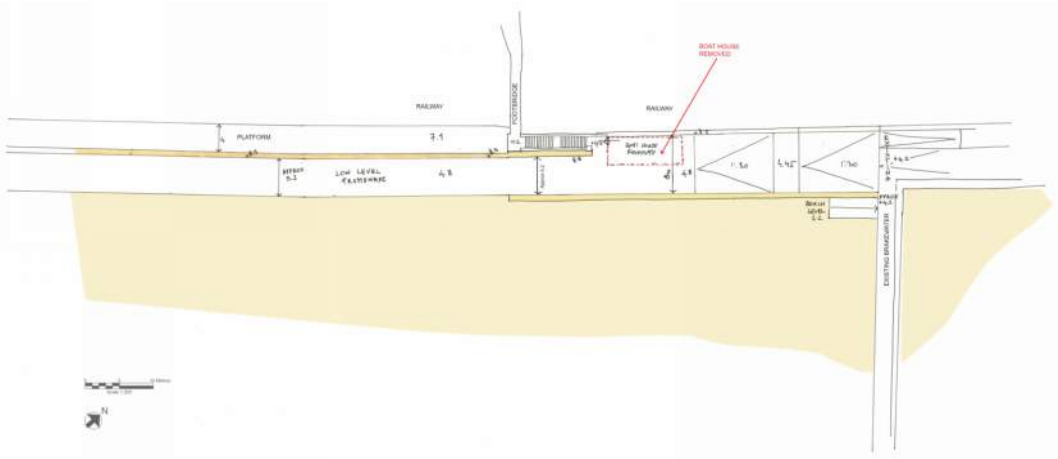


Figure 41 - Option 4 – Sea wall at Front

This option consists of a high-level seawall (assumed +8.5m at this stage) located at the back of the low-level promenade up until the coastguard's footbridge. The high-level seawall then runs at the front of the promenade (at a height of +7.5m) from the footbridge to the existing breakwater. The first section of wall protects the platforms and footbridge then overlaps with the second, lower section at the footbridge, which protects the tracks beyond. As the lower section in this option isn't right up against the tracks it will be easier to construct, however, this creates a large area without a sea view.

Option 5 – Section E&F Low-Level Preferred Option

The chosen option is primarily based on option 3. The main differences are that the modified staircase is now orientated north-east with a longer section of raised promenade near the existing boathouse. These changes provide better resilience to the promenade and allow for a safer egress route for the public coming from Dawlish Warren, via the coastguard's footbridge (+4.8m minimum).

The repositioning of the seawall allows for seaward views along the entire length of the promenade, as opposed to option 4, and mitigates the length of construction work close to the railway.

Finally, the angled section of seawall in line with the footbridge removes any risk of energy traps by eliminating sharp 90° corners.

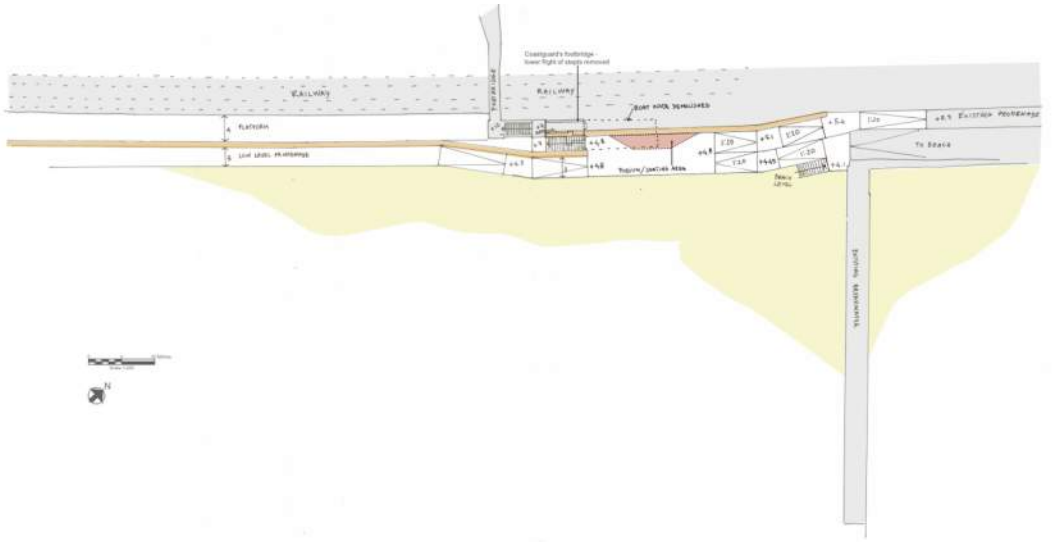


Figure 42 - Section E&F Low-Level Preferred Option

This option has been selected as it provides a high level of resilience to the railway and a nice environment for amenity benefit. The construction works are also set away from existing structures and the railway, enabling an easier instalment.

## Section E&F High-Level Promenade Option

The following options have been considered:

- Option 1 – Retain Boathouse
- Option 2 – Beach Ramp North of Breakwater
- Option 3 – Beach Ramp South of Breakwater
- Option 4 – High-Level Preferred Option (pre-optioneering workshop)
- Option 5 – High-Level Preferred Option (final)

Option 1 – Retain Boathouse

This option consists of a high-level seawall combined with a high-level promenade. This is the last section of wall (assumed +7.5m at this stage) located at the front of the promenade protecting the tracks.

This option avoids the demolition of the boathouse and requires limited modification to the stairs, but the seawall would obscure the sea view and doesn't fully protect the promenade due to limited overlaps between sections.

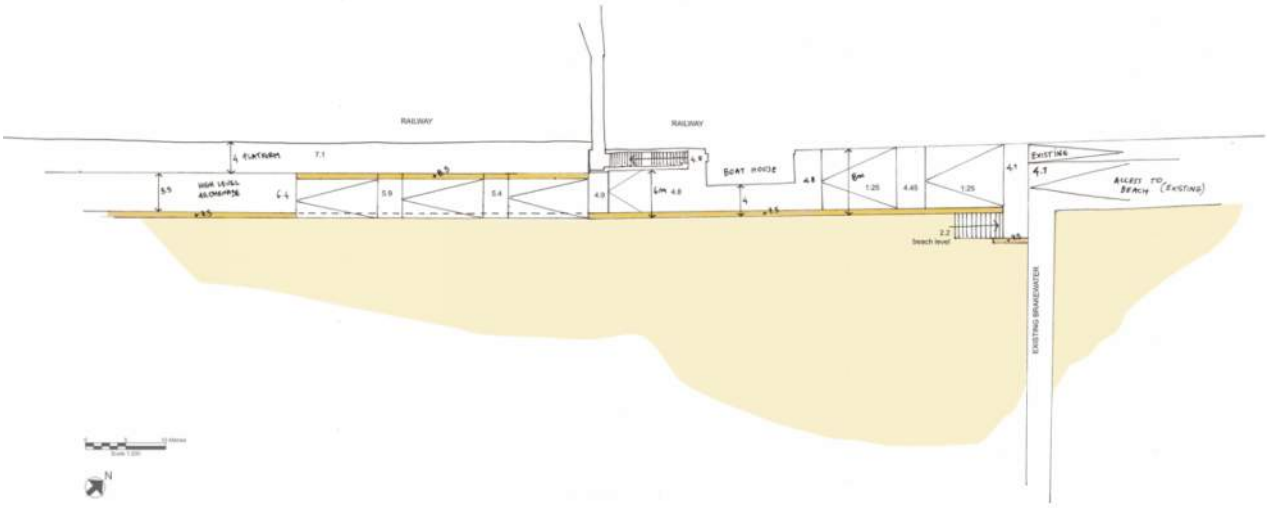



Figure 43 - High level Option 1 – Retain Boathouse

## Option 2 – Beach Ramp North of Breakwater

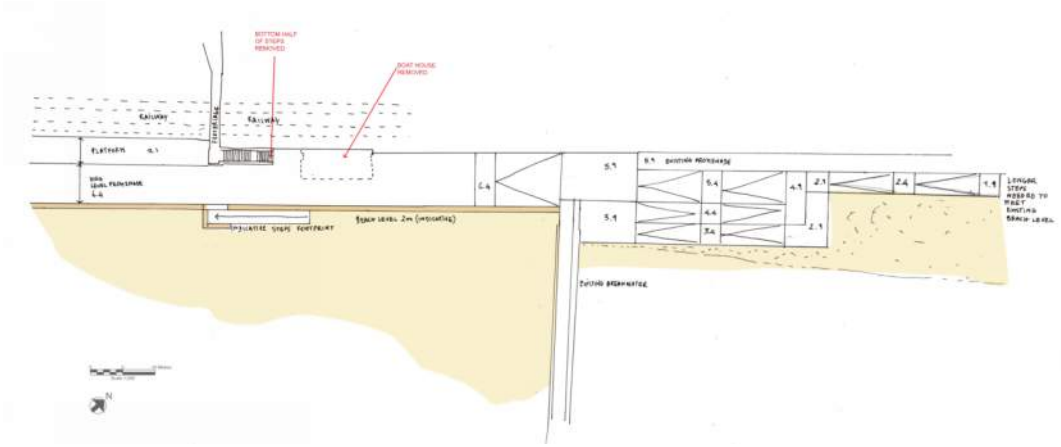



Figure 44 - High level Option 2 – Beach Ramp North of Breakwater

This option consists of a high-level (assumed +7.5m at this stage) seawall located at the front of the high-level promenade. There is one section of wall protecting the platforms, footbridge and tracks, from the station right up to the existing breakwater. This options also offers a set of stairs down to the beach in line with the footbridge, as opposed to by the breakwater.

This option uses one complete seawall which would make the section easier to construct, but the stairs introduce an issue as the 90-degree corner would mean wave energy is concentrated towards a point. There is also extensive work required beyond the breakwater to link to the existing promenade and offer access to beach level.

Option 3 – Beach Ramp South of Breakwater

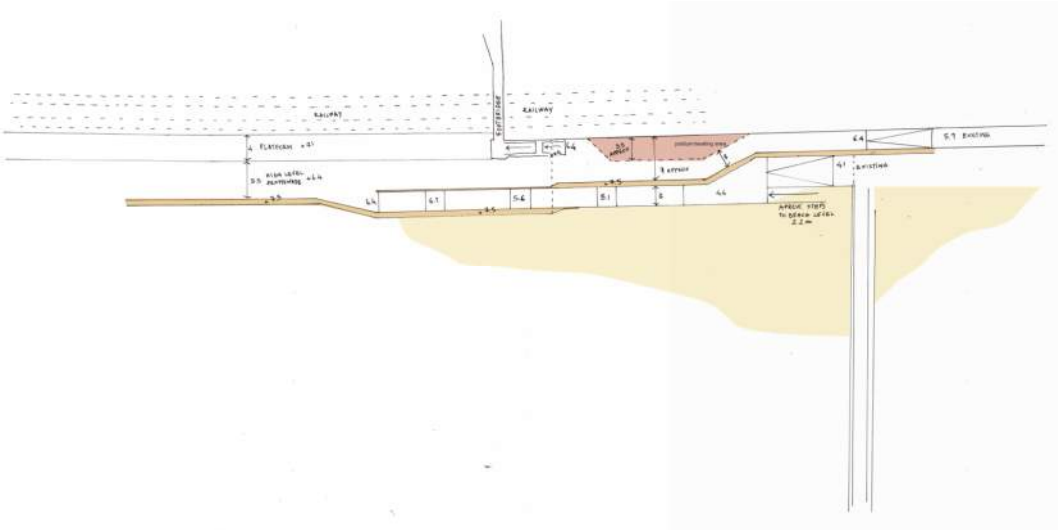


Figure 45 - High level option 3

This option consists of a high-level seawall (assumed +7.5m at this stage) located at the front of the high-level promenade. The first section of wall protecting the platforms and footbridge spans from the station to the footbridge. It angles outwards towards the end of the platform to create a ramped access to the existing coastguard's ramp. The second section runs at the front of the high-level promenade from the footbridge to the breakwater, angling back towards the tracks after the existing boathouse to align with the existing promenade past the breakwater.

This option offers a large amount of open space at the end of the footbridge but requires two tiers of promenade with several changes in direction of the seawall. The front tier may also give a corridor effect at the first few ramps when it is still behind the sea wall.

Option 4 – High-Level Preferred Option (pre-optioneering workshop)

This option is primarily based on option 3. It has been adjusted for a +8.5m high seawall adjacent to the platform.

These changes require extra ramps to connect with the lower the level of the promenade. There are now two extra ramps on the top tier section and two extra ramps on the lower tier section, requiring the lower section to be lengthened to accommodate the extra elevation changes.

This option has been selected as it provides a high level of resilience to the railway and a nice environment for public amenity.

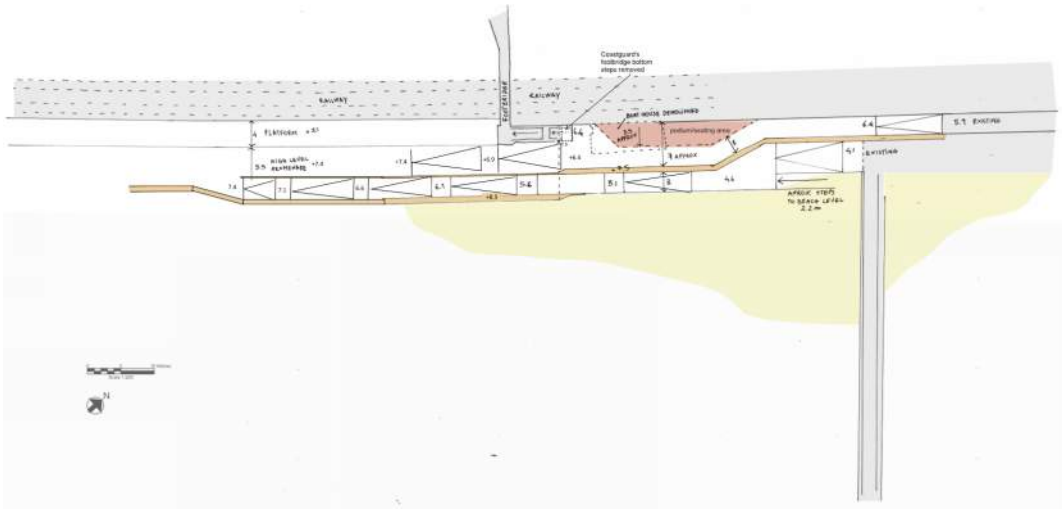


Figure 46 - High level preferred option (pre-optioneering workshop)

## Option 5 – High-Level Preferred Option (final)

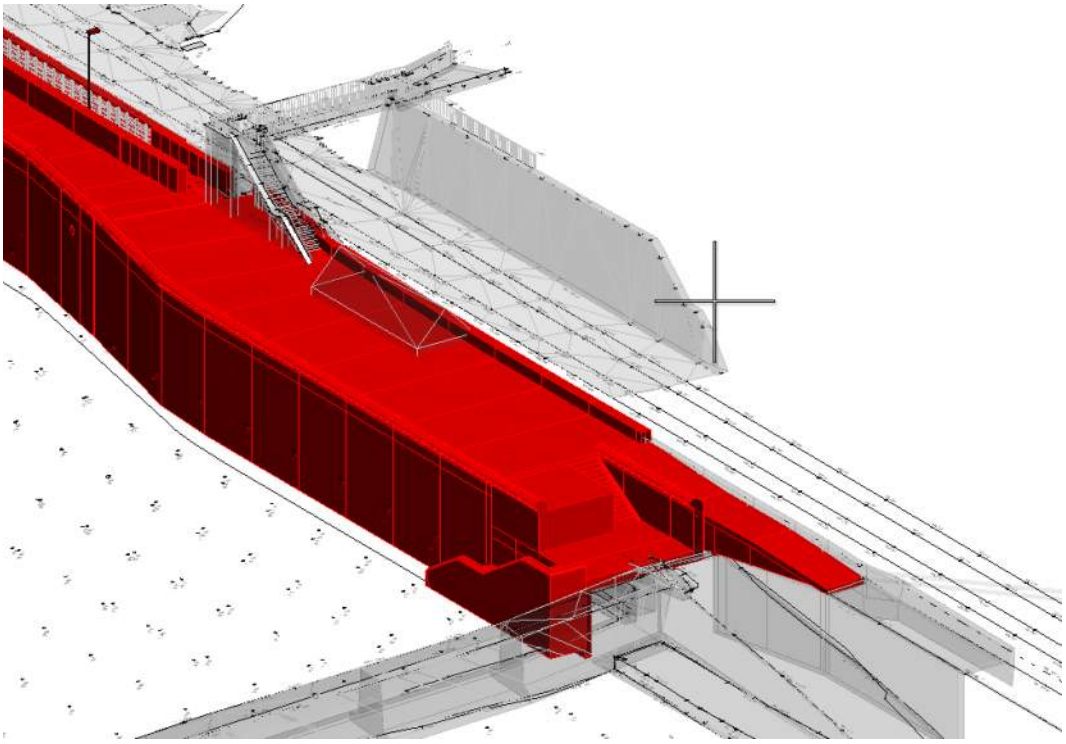


Figure 47 - High level preferred option (final)

During the option selection workshop, Network Rail instructed a change to the CR-T requirement to provide a ramp to the existing coastguard's ramp (leading to the water/beach north of the breakwater). Following this, the design of option 4 was redeveloped to remove the ramp access to the existing Coastguards ramp and optimise the open area.

### 5.3.2 Section E&F Civil Engineering Options

Civil Engineering solutions will largely remain the same as for section D. The following points should be considered in addition:

- Interface with existing breakwater and promenade

The promenade extends further north towards Dawlish Warren. The connection to the next section of the promenade is critical to maintain the coastal path and has been taken into account in the design process – in particular in terms of level.

- Interface with existing coastguard's footbridge and boathouse

The coastguard's footbridge and boathouse reflect the architectural history of the area. The footbridge which connects to Dawlish town has been maintained, with a potential loose of the lower flights of stairs, depending on the final level of the walkway. The boathouse however is to be removed in both low- and high-level preferred options.

- Interface with railway

The back wall of the boathouse is part of the retaining structure for the rail tracks and is therefore to be maintained. The Contractor is to take this into account when planning the demolition sequence of the building.

### 5.3.3 Section E&F Maritime Options

Refer to Resilience Comparison Report (142630-ARP-REP-ECV-000023) and Physical Modelling Summary Report (142630-ARP-REP-ECV-000025) for details.

The cross section of both, low-level and the high-level promenade, options assessed for Section E and F is almost identical to the options assessed for Section D. The main different with Section D is that there is not platform and therefore, the overtopping passenger criteria does not need to be met. The structural and operational railway overtopping criteria apply to Section E and F. Other different with Section D is that the promenade width in Section E &F is up to 4 to 6m wider than in section D and therefore, the distance between the parapet wall and the railway is greater having a positive impact in the overtopping performance.

The selected solution for Section E & F is driven by:

- Continuity to the high-level promenade proposed at Section D. Section E & F are 50m long which is not enough distance to accommodate the transition from high-level to low-level promenade.
- Overtopping resilience performance of the low-level promenade option has been proven not satisfactory in the Physical Modelling.
- Tie in with the existing promenade (+5.9mOD) at the north east side of Coastguards breakwater.

Based on this, the high-level promenade option is selected for Section E and Section F.

The high-level promenade option at Section E and F comprises a front vertical wall with a bullnose on top at +7.5mOD and a secondary wall at a set-back distance from the front wall at +7.5mOD. The same recurve profile as per Section D is proposed. The promenade runs in between the parapet wall and the secondary wall and its width varies from 7.5m to 10.0m approximately.

The parapet level and the secondary wall level have been selected based on engineering judgment informed by the 2D physical modelling results for Section D, Marine Parade 2D physical modelling results and overtopping calculations. The sea wall levels proposed for Section E & F have not been tested in the 2D physical modelling.

Based on overtopping calculations, (refer to Resilience Report 142630-ARP-ECV-000023) the mean discharge limits (q) for railway operational (min), railway operational (target), pedestrian and structural performance criteria are met for both 2065 and 2115 epoch. We also used the dimensionless graphs presented in Figure 22 of the 2D physical modelling report (142630-ARP-REP-ECV-000025) to estimate mean overtopping discharges for a parapet wall level at +7.5mOD. These graphs, derived from the 2D physical modelling testing, provide mean overtopping discharge for different freeboards and concluded that the proposed sea wall levels at Section E and F meet the mean discharge limit criteria.

There is a risk that the individual maximum overtopping volume (Vmax) exceeds the pedestrian criterion in the long term; in other words, there might be one single wave that could be excessive, despite the mean wave overtopping rate being within the limits.

Similarly to Section D, the risk associated to exceeding Vmax rail operational limit is considered negligible in the medium term and high in the long term.

### 5.3.4 Section E&F Chosen option

Following the Option Selection Workshop, option 5 was developed and adopted as the preferred option for the section E and F and is presented in Figure 48 below.

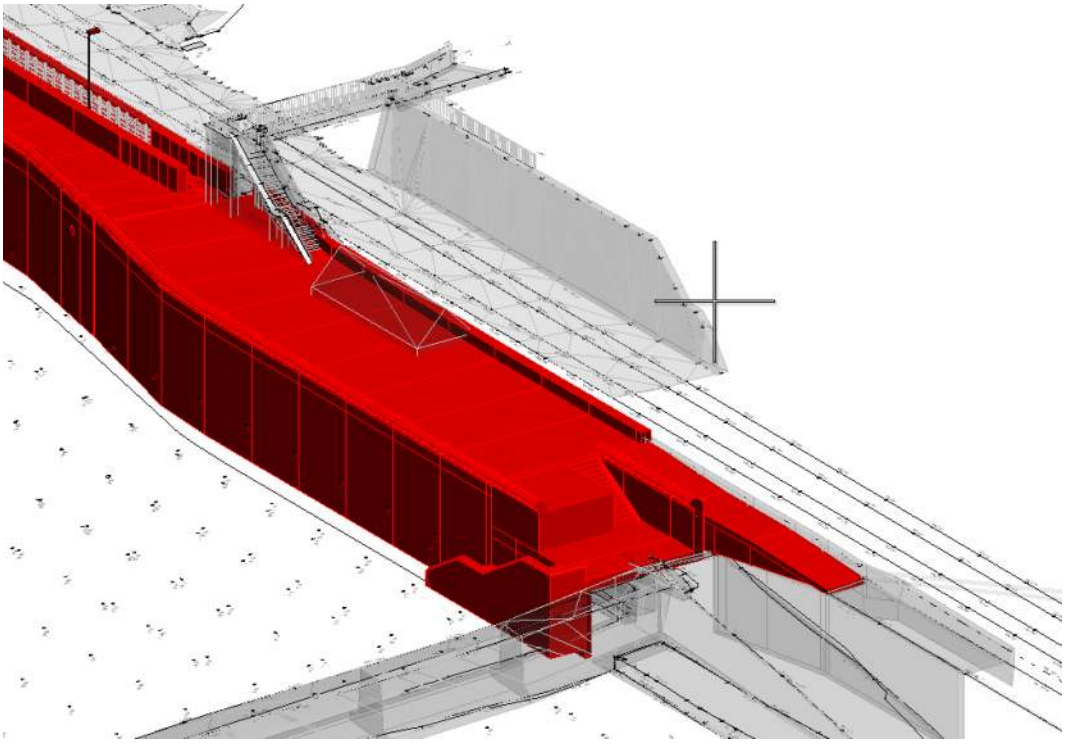


Figure 48 - Section E&F chosen option

## 5.4 Sections A, B & C

Sections A,B & C cover the frontage from the interface with Marine Parade to the northern extent of the station building. This includes the town gateway area, the Dawlish Water basin and the listed station building.

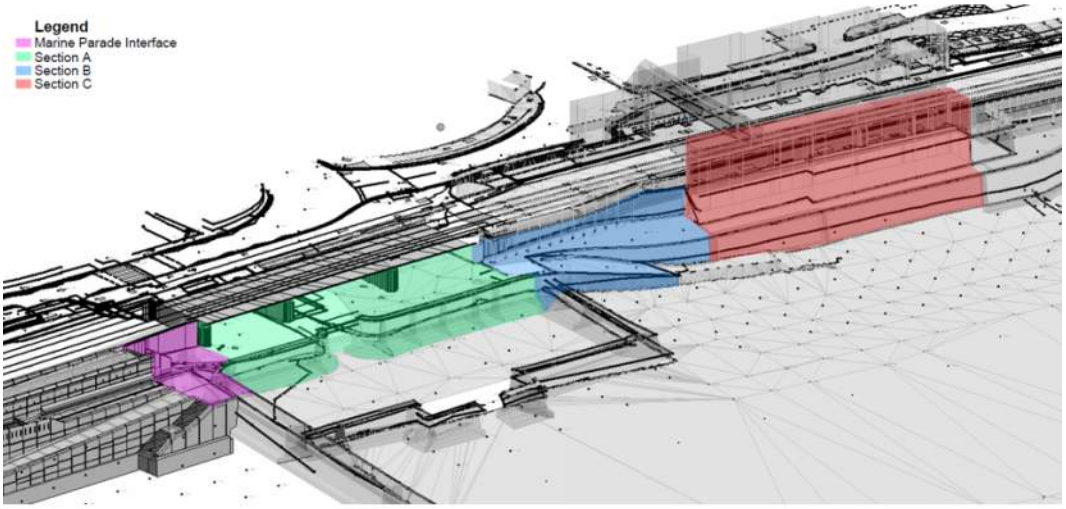



Figure 49 - Section ABC

The feasibility study yielded four principle options:

1. Option 1 - Low promenade at A to high promenade D with offshore breakwater. Section 5.4.2
2. Option 2 - Low promenade at A to low promenade at D with revetment and future replacement of rail bridge at A. Section 5.4.3
3. Option 3 - Low promenade at A to low promenade D with offshore breakwater. Section 5.4.4
4. Option 4 - High promenade at A to high promenade at D with revetment, pedestrian walkway and future replacement of bridge at A. Section 5.4.5

(Sketches included in each relevant section)

It should be noted that further option appraisal is required, for the options above that require a new low-level structure around Dawlish Basin, depending on the outcome of the 3D physical model testing. As such, the feasibility of the preferred option has not been confirmed, but a number of likely feasible options have been appraised.

The following sections describe the option selection process against these four principle options.

Prior to selection of these principle options there were several options that were discounted for various reasons as follows:

- Do nothing A to C – discounted as this did not provide the requisite rail resilience;
- High promenade with an offshore breakwater – discounted due to the considerable additional cost of providing two substantial engineering solutions;
- Low promenade at A to low promenade at D with a high-level wave wall at A – discounted due to the onerous structural requirements of the high level wave wall and the offset that would be required from existing rail bridge and the resulting obstruction of the access steps to Marine Parade;
- Low promenade at A to low promenade at D with a low-level wave wall at A – discounted as this option did not address the overtopping issue and provide the requisite rail resilience;
- High promenade at A to high promenade at D with pedestrian walkway at A and B – discounted as the wave loading on the walkway structure was too onerous and foundations would have been of a prohibitive size and cost;

For Sections ABC this report solely focusses on optioneering of elements. This includes some basic assessments to ensure the principle options are feasible and viable but does not extend to detailed structural calculations. Note that the preferred option will be subject to physical wave modelling in order to inform the detailed design stage.

### 5.4.1 Key design criteria and assumptions

The following design criteria and assumptions were key to the optioneering and recommendations at ABC. These are specific to ABC and further to those described in the Basis of Design Report (document reference number: 142630-ARP-REP-EMF-000007).

i. There will be constraints on the initial capital spend for sub-frontages A, B and C. As such, options for solutions that allow deferral of capital spend – for example to 2065 - may be preferred.

ii. Pedestrian access under the rail bridge is to be maintained. The current clearance between the promenade (at around +3.3mOD) and the underside of the rail bridge shall be maintained.

iii. It is possible that extreme floods through Dawlish Water are partially conveyed through the bridge spans, as well as the culvert through the promenade. As such, any proposed works should look to minimise their hydraulic impact. As a guide, new structures should aim to be lower than the existing wave return wall along the promenade infront of the rail bridge (approx. 3.5mODN). In general, the solutions need to consider the implications on Dawlish Water and flood risk

iv. Both the scenario where Dawlish Water basin is maintained, via appropriate interventions, and the situation where it is not maintained should be considered.

v. The solutions need to consider the implications on Dawlish Water and flood risk. The solutions need to consider the implications on Dawlish Water and fluvial flood risk. Dawlish Water is known to flood regularly from fluvial events, both in the upper catchment and near Station Road. An initial assessment carried out by the Environment Agency showed that the more severe floods are associated with high river flows, but in periods of heavy rainfall flooding occurs in the lower reaches at high tides.

   The initial assessment and modelling carried out by the EA showed that the main constriction on Dawlish Water is Jubilee Bridge, slightly upstream of the railway line. The capacity of this bridge would need to be increased to reduce flood risk before works in Section A would influence fluvial flooding. The preferred option for works by the EA was Natural Flood Management measures in the upper catchment to reduce flows downstream, and therefore works in the town centre may not be necessary at all.

   Therefore, the proposed solutions must not reduce the capacity of the existing culvert and outlet, in order to prevent it becoming the main restriction on the river. There may also be ‘quick wins’ that could be achieved on the project to help with flood risk, such as clearing debris from the existing culvert. As the works are expected to reduce overtopping, they will restrict flooding of Dawlish Water due to high tides.

The design of section A should also ensure that it does not restrict overland flows when the river does flood. For instance, not using upstands or fencing that could either collect debris or back up water.

It is suggested that the works are discussed with the EA in terms of flood risk to Dawlish Water before a design is finalised.

vi. The railway operational criteria apply at sub-frontages A, B and C. At sub-frontage B existing platform will be closed, as it is no longer required with proposed access-for-all bridge, and as such the passenger criteria does not apply. At sub-frontage C the passenger criteria apply, and the potential for reliance on the existing station building and canopy for resilience should be considered.

vii. Pedestrian resilience criteria on the low-level promenade do not apply, except in the case that a high-level promenade is provided to the landside of the proposed defence, in which case the pedestrian criteria would apply to this area.

viii. The requirements from Teignbridge District Council (refer to the Basis of Design 142630-ARP-REP-EMF-000007) should be respected.

ix. In the case of a high-level continuous promenade across the entire scheme, it is not required to provide ramped access from any high-level promenade to the foreshore at ABC, as it is accepted that the ramp at Marine Parade can be used and that an additional long length ramp would not be advantageous. Stepped access is required.

x. The existing Colonnade breakwater structure will remain in place (i.e. be maintained in their current form) for the duration of the proposed scheme. We note that Colonnade breakwater is likely to provide minimal sheltering from waves in the latter epoch in more extreme events, due to its low crest level relative to future water levels and the predominant south-easterly wave direction being parallel to its length. It is assumed Network Rail will maintain the breakwater and provide scour protection as required.

xi. Strengthening of the existing station building is likely feasible below platform level, but more challenging above platform level due to heritage constraints.

xii. There is no requirement to ensure the stability of the existing station building, except with respect to railway operational criteria and managing safety risk. At this stage, we have assumed that during extreme events (i.e. more onerous than 1 in 25-year events) the railway and platform will be closed, and that the areas adjacent to the station will unlikely have people present, reducing the risk of local damage to the structure resulting in hazards to people. This needs further consideration at the next stage.

### 5.4.2 Section ABC Low promenade at A to high promenade D with offshore breakwater

This solution is considered further as two parts:

- Offshore Breakwater;
- Low Promenade to High Promenade.

**Offshore breakwater**

As described in the Resilience Comparison Report (document reference number: 142630-ARP-REP-ECV-000023), a lower level, medium level and higher-level detached defence (offshore breakwater) has been considered further since feasibility stage.

We consider that only a medium-level offshore breakwater with toe protection along the existing foreshore structures was suitable to consider in option selection, because:

i. A lower-level breakwater – although reducing impact on views from the existing low-level walkway - would require additional structures at the seafront to further reduce overtopping. A locally nourished beach would likely not be feasible due to the required level and impacts on Dawlish Water.

ii. A higher-level breakwater – although reducing the need for toe protection structures – would likely have prohibitive costs and broader impacts.

Medium level breakwater

This option involves a building a detached structure with seaward and landward rock slopes to reduce wave energy reaching the frontage. This concept considers:

i. A crest level at +7.0mOD.

ii. Rock slopes at 1:3, with primary rock armour of 1.5m median nominal diameter (Dn50) and weight 6 – 10 tonnes weight grading. A primary armour layer thickness of 3m.

iii. A filter/core material consisting of quarry run and up to 4 tonne rock.

iv. A formation level of -4mOD, which likely requires excavation of the existing foreshore to a competent level.

v. A damage parameter of 2, which permits 0 to 5% structural damage during extreme events.

vi. The breakwater is located around 80m from the existing foreshore promenade. This offset reduces the extent of the breakwater (i.e. locating in relatively shallow water) whilst aiming to limit public access to the rock slopes at low tide.

This structure would require the partial demolition of Colonnade breakwater. The interface with the maintained length of Colonnade would require further consideration.

These outline characteristics were developed using rules of thumb and high-level engineering assessments suitable for option selection phase only.

The concept is illustrated in Figure 50 and Figure 51 below.

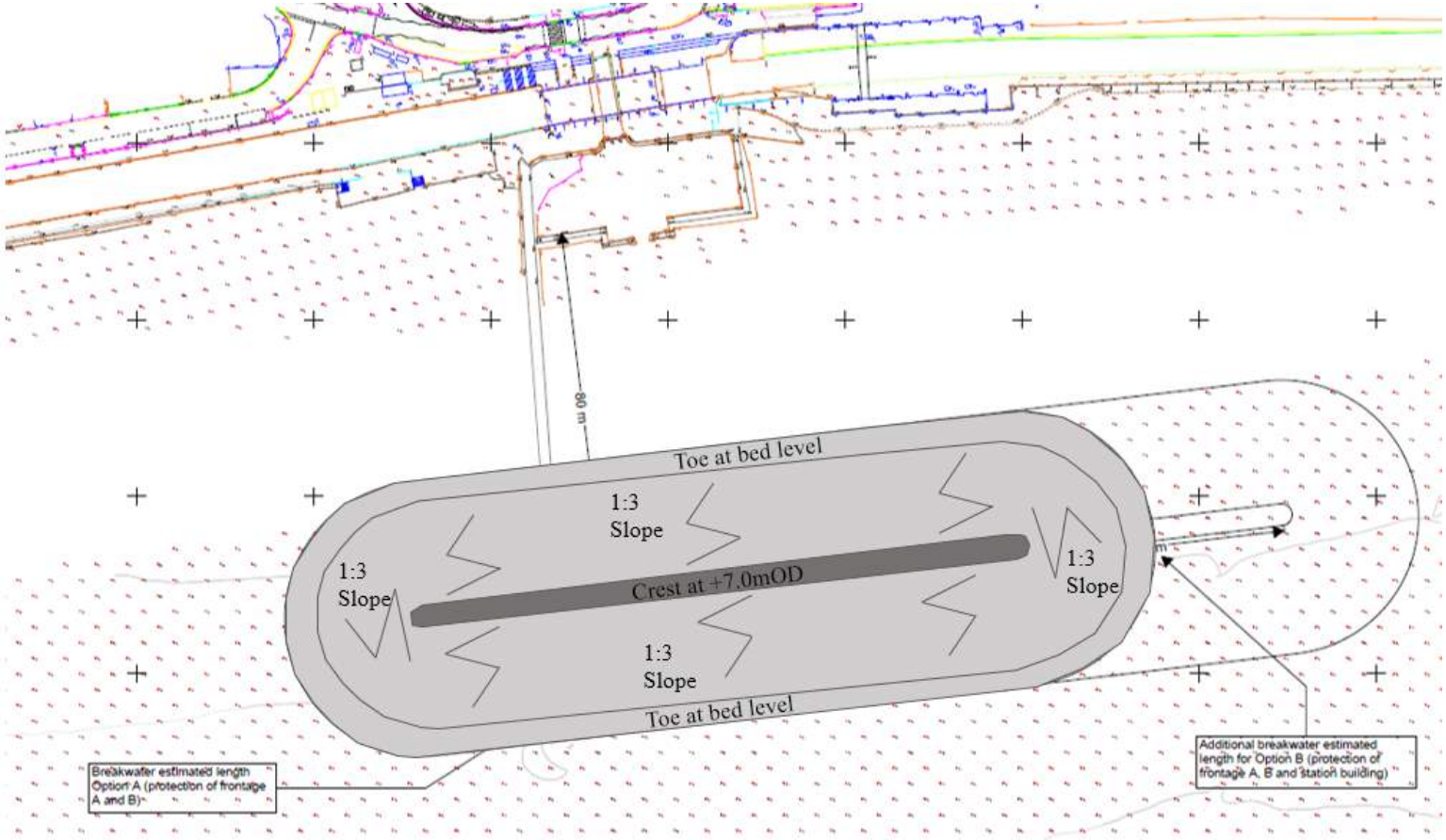



Figure 50 - Breakwater concept considered in option selection (plan)

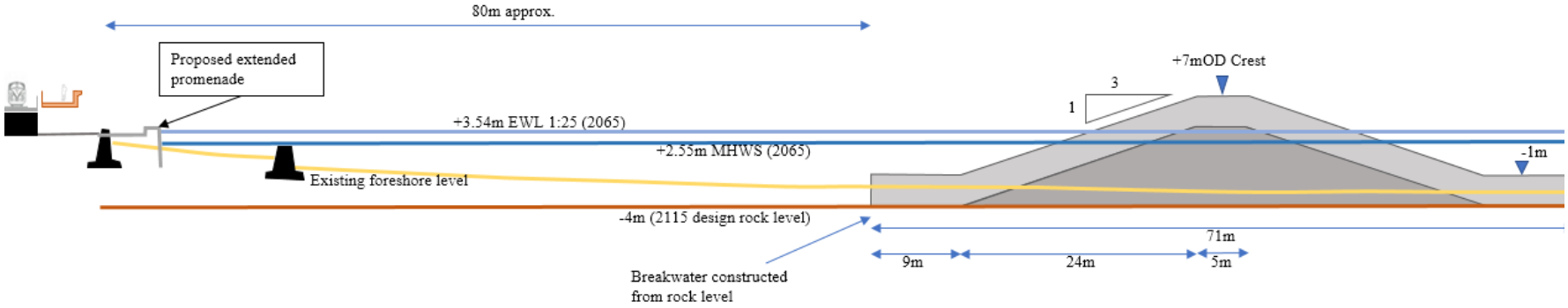



Figure 51 - Breakwater concept considered in option selection (section)

The breakwater size is primarily driven by the need to reduce both diffracted wave energy (around the breakwater) and transmitted wave energy (over and through the breakwater).

We considered two options for this breakwater:

1. Reducing the wave energy reaching the existing structures at sub-frontages A and B to suit railway operational criteria.
2. Additionally, reducing the wave energy reaching the existing structures at sub-frontage C, to reduce the risks associated with wave loads on the Station Building and potential impacts on railway operational criteria. Rather than a target wave climate at the station building, this option considered a similar reduction in wave energy to that provided at sub-frontages A and B in option a.

This is illustrated in Figure 52 below.

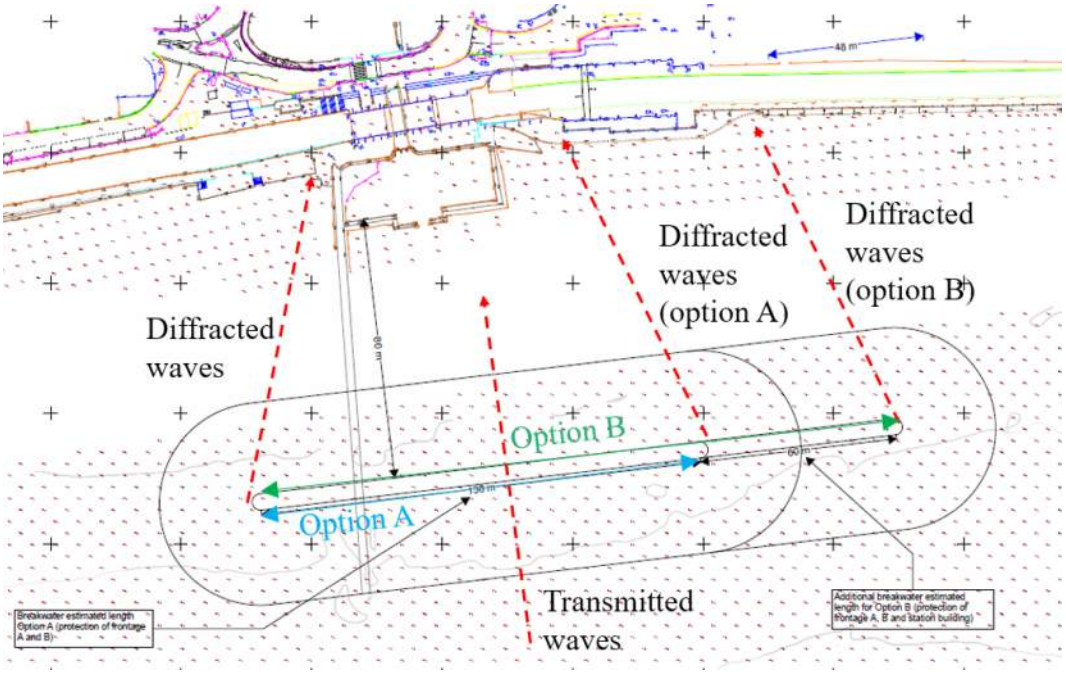



Figure 52 - Offshore breakwater and wave energy reaching ABC

A high-level assessment suitable to option selection stage only found the approximate lengths required for Options A and B to be 136m and 196m respectively. NB both options include for reducing the wave climate at the Marine Parade interface.

Considerations at existing structures

For sub-frontages A and B, the assessment was based on an approximation of overtopping of existing structures, considering railway operational criteria for the 2120 epoch. The overtopping assessment approximated existing structures as plain vertical walls and considered a range of foreshore levels between existing and the design low level of -4mOD. It should be noted that this is a complex, three-dimensional situation which requires physical modelling to accurately predict overtopping rates. Nonetheless, we consider the approach is suitable for

option selection stage. The assessment showed that the breakwater is required to reduce the nearshore wave heights by around half (e.g. from a significant wave height of 3.6m to one of 1.8m) to meet railway operational criteria. It should be noted that this concept assumes that existing structures would be strengthened or adapted to account for residual wave loading and foreshore levels up to the 2120 epoch. This is illustrated in Figure 53 and Figure 54 below. We note that, depending on the various promenade options, promenade structures could form the toe protection assumed.

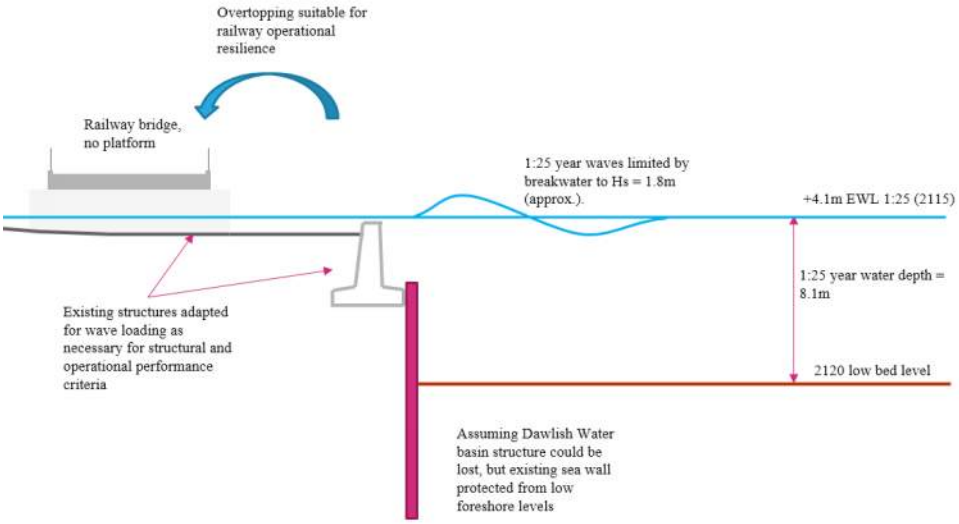



Figure 53 - Considerations at sub-frontage A for the Option 1

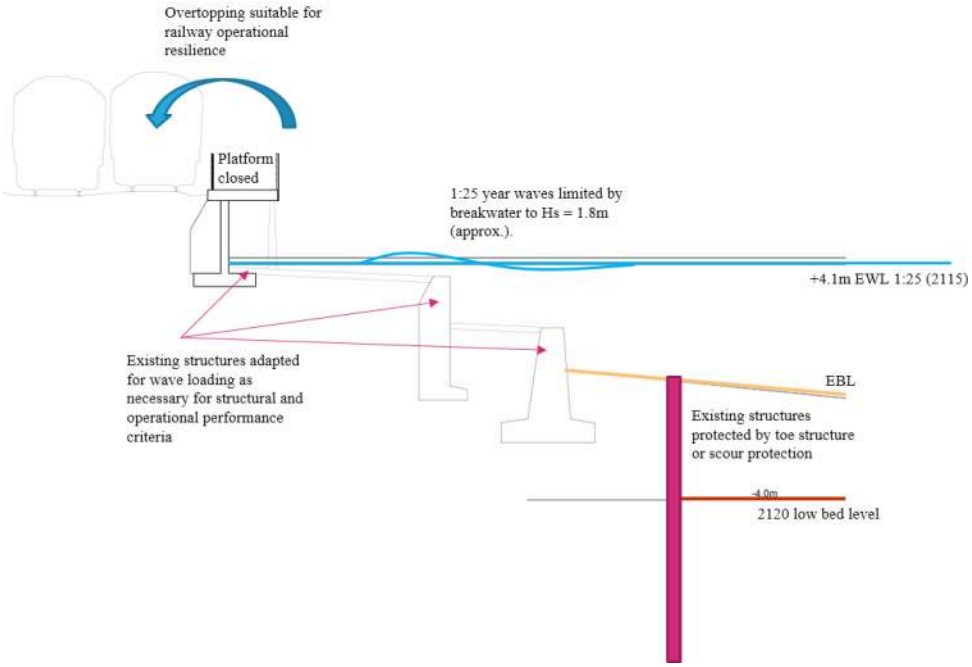



Figure 54 - Considerations at sub-frontage B for Option 1

For sub-frontage C, the breakwater design assumed that passenger and railway operational criteria is provided by the existing station building and platform canopy and that these are maintained over the design life. For both breakwater

options (longer and shorter) we consider that building resilience measures are required below platform level, suitable to the future wave loading and operational and structural design criteria. There is a risk that additional resilience measures are required above platform level, due to the risk of relatively deep water in front of the building in latter epochs. The longer breakwater option reduces this risk. This risk requires additional review and mitigation to be developed if this option is taken forward. We note heritage constraints on strengthening the building in this zone.

This is illustrated in Figure 55 below. Again, we note that, depending on the various promenade options, promenade structures could form the toe protection assumed and may also form part of the building resilience measures.

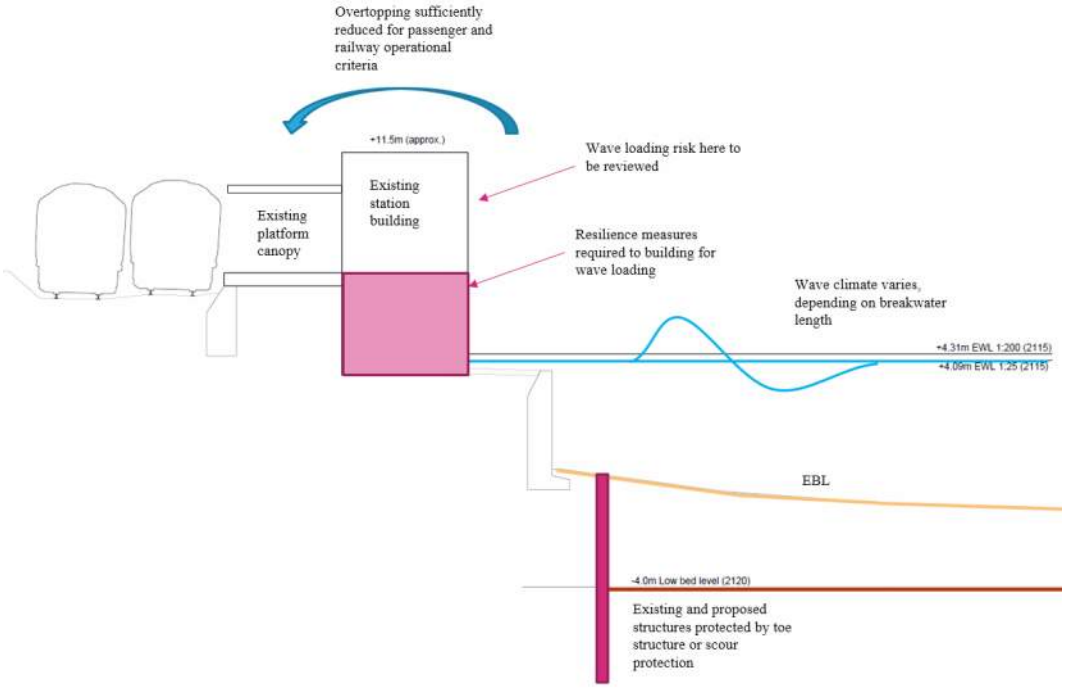



Figure 55 - Considerations at sub-frontage C for Option 1

An order of magnitude cost has been provided by BAM to help the option selection process. Refer to Appendix A for details.

| **Option** | **Construction Budget (excludes Risk, optimisation bias etc, see full list of assumptions)** |
|---|---|
| Breakwater to protect sections A&B | £19M |
| Breakwater to protect sections A, B&C | £24.5M |

Table 9 - Breakwater costs

## Low promenade to high promenade

For this solution the offshore breakwater provides protection from incoming waves sufficiently to reduce overtopping of existing structures. Accordingly, there will be no new defence required at or adjacent to the sea wall at sub-frontages A, B or C (except for the interface with section D), but additional measures are required as set-out below.

## Additional measures

Aside from the above-mentioned key elements of Option 1 two key considerations remain including the ramp configuration and scour protection.

### *Ramp configuration*

The transition from a low promenade in section ABC to a high-level Promenade in Section D is very problematic due to the significant level difference and resultant length of ramp required. The following sketches illustrate the options considered.

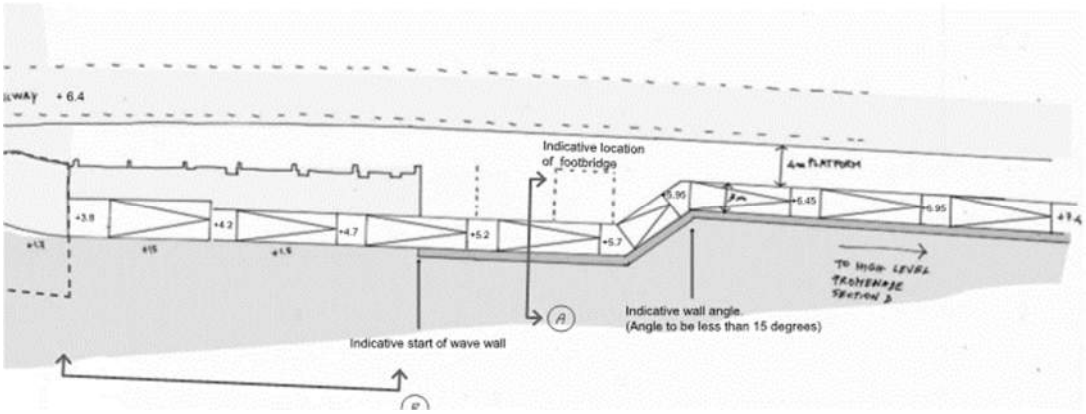



Figure 56 - Low Promenade to High Promenade - 1 in 20 ramp in front of station

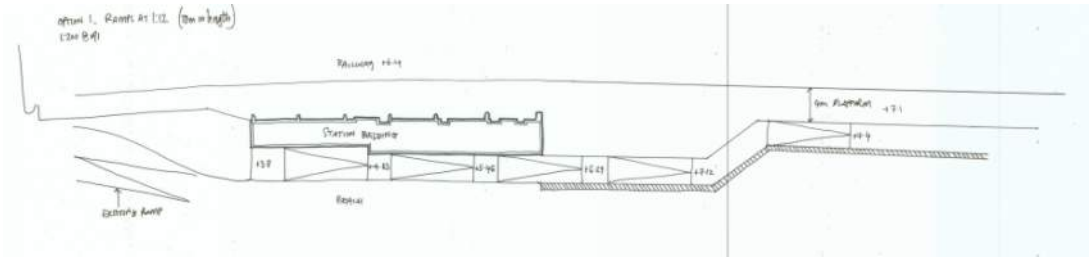


Figure 57 - Low Promenade to High Promenade - 1 in 12 ramp in front of Station (Sea wall at front)

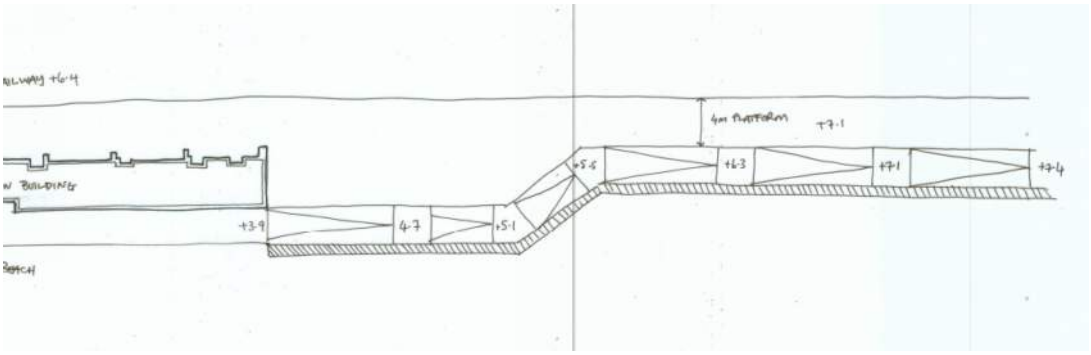


Figure 58 - Low Promenade to High Promenade - 1 in 12 ramp to north of station (Sea wall at front)

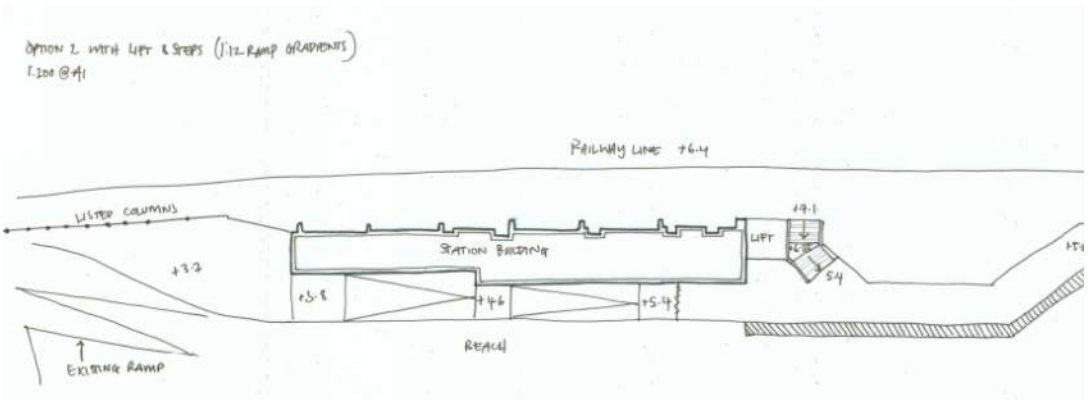



Figure 59 - Low Promenade to High Promenade - Lift to beach

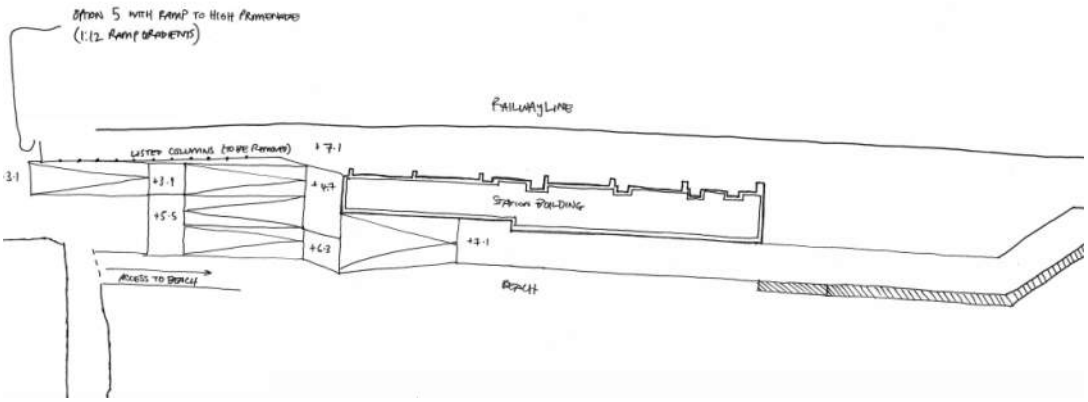



Figure 60 - Low Promenade to High Promenade - 1 in 12 ramp to south of Station

These options have the following challenges:

- They visually impose on the listed station building;
- Solutions which do not achieve the high promenade level at the northern extent require a sea wall at the front which will create a cavern like path with significant poor visual appeal;
- Lifts to beach level will be subject to significant inundation;
- Spatial constraints for ramps.

### *Scour protection*

Although the breakwater is likely to result in build-up of foreshore material in its lee under certain design conditions, at this stage it cannot be ruled out that the foreshore could reduce to design low bed level (-4mOD) considered for the remainder of the C2C frontage.

As such, existing structures will require the implementation of toe-protection or scour protection measures. At this stage we consider that adaptive scour protection would be required for part of the sub-frontage, and that for the remainder of the sub-frontage the new structures proposed for ramp access would be designed to accommodate the future bed level in a way that limits the impact on existing structures. See Figure 61 below.

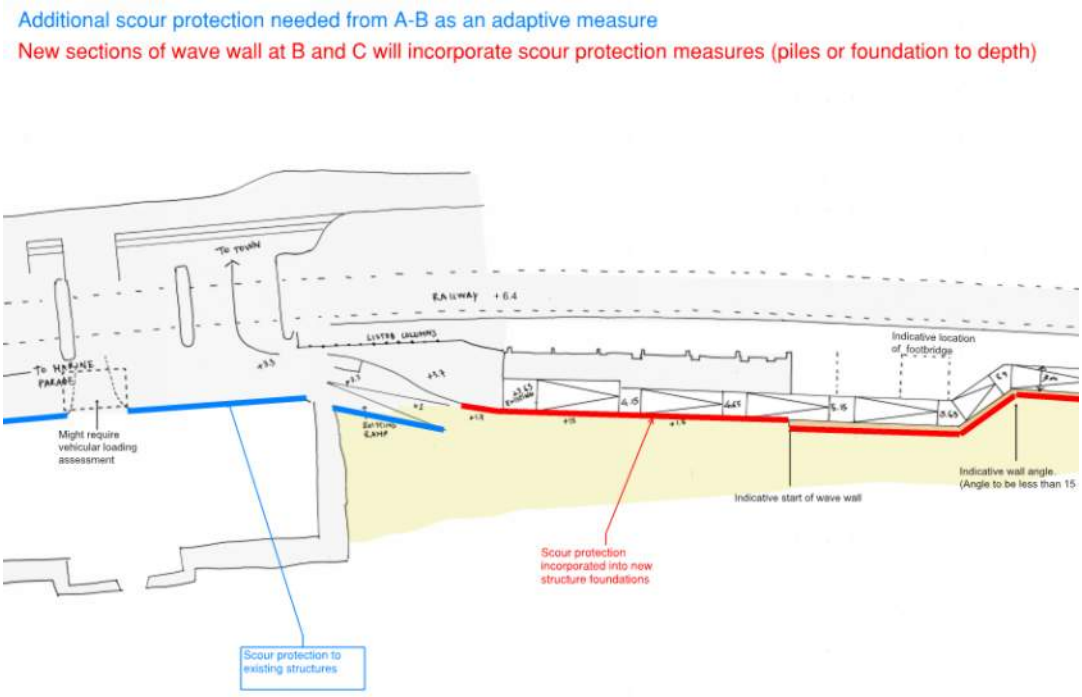



Figure 61 - Scour protection requirements for option 1

## Option 1 Summary

The following table is a summary of option 1

| Basic option description | Option name | Low promenade at A to high promenade D with off shore breakwater |
|---|---|---|
| Solution Description | Section A | Offshore breakwater<br>Nearshore scour protection to existing structures |
| | Section B | Offshore breakwater<br>Nearshore scour protection to existing structures |
| | Section C | Offshore breakwater<br>Ramp from high prom at D to low prom<br>Nearshore scour protection incorporated into new structures |
| Resilience Epoch | Section A | 2115 |
| | Section B | 2115 |
| | Section C | 2115 |
| Resilience | Rail resilience | Yes |
| | Passenger resilience | For sub-frontage C only |
| | Public resilience | No |
| Constructability issues | | - Jack up barge required for piling at Section C and D. Issues with draft and possible dredging required.<br>- Land based piling plant required for Section A and B scour protection. |
| Adjoining interfaces | | - Marine promenade interface no issues<br>- Interface with Section D will require a significant length of ramp at Section C |
| Dawlish flood risk | | - Potential issue with accretion/ siltation between Dawlish Water basin and offshore breakwater. May require maintenance. |
| Amenity | Section A | - Maintains existing |
| | Section B | - Maintains existing/ Ramp |
| | Section C | - Improves existing with higher level walkway (ramp up to D) |
| Cost | | High |
| Third Party | | - Heritage/ Visual Impact issue with ramp in front of station building<br>- Visual impact of offshore breakwater |
| Pros | | - Maintains existing appearance at Sections A and B<br>- Provides protection along entire length A-C |
| Cons | | - Extensive length and increase in level of ramp required<br>- Visual impact of offshore breakwater<br>- High cost of offshore breakwater<br>- Scour or toe protection structures required along sub-frontages A, B and C alongside potential strengthening for wave loading.<br>- Building resilience measures at sub-frontage C required that are likely challenging considering heritage constraints |

Table 10 - Summary of Option 1

### 5.4.3 Section ABC Low promenade at A to low promenade at D with revetment and future replacement of bridge at A

This solution is considered further as the following parts:

- Low promenade;
- Wall at Section B;
- Nearshore revetment at Dawlish Water basin;
- Resilience measures for station building.

**Low promenade**

The existing promenade at Section A is retained at the existing level without change. The promenade at Section B will be widened to compensate for a new wave wall along the line of the existing gas lamps. There will be an opportunity to provide public seating and other amenity enhancements. At sections A and B a new access ramp to the beach will be installed (refer to beach ramp gradients in section 5.1). Refer to Figure 62.

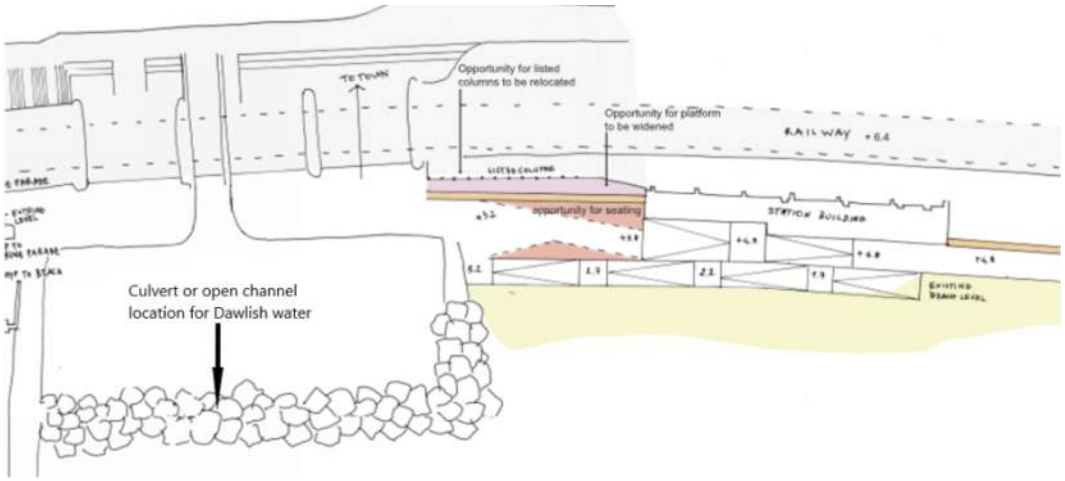



Figure 62 - General layout

**Wall at Section B**

At Section B a new wave wall will be required to provide resilience to the end of the platform as this area is not protected by the proposed revetment. It is envisaged this wall would be of a similar construction to that at Section D. The wall will be aligned with the existing gas lamps which will be removed and could potentially be relocated at a more protected location in the form of public lighting.

There is an option to extend a revetment solution to provide additional protection to section B, mitigating the need for a new sea wall (likely only in the medium term). The benefit of this could be assessed further following physical modelling.

**Resilience measures for station building**

As with the short breakwater in options 1 and 2, this configuration would potentially see relatively deep water and high wave heights in front of the existing Station Building.

Similarly, we consider that building resilience measures would be required below platform level, suitable to the future wave loading and operational and structural design criteria. There is a risk that additional resilience measures are required above platform level, due to the risk of relatively deep water in front of the building in latter epochs. This risk requires additional review and mitigation to be developed if this option is taken forward. We note heritage constraints on strengthening the building in this zone. We consider this a significant risk that promotes against the use of a low-level promenade in front of the building and thus this option.

**Nearshore revetment at Dawlish Water basin**

The area at Dawlish Water poses a significant challenge. The following key points should be considered:

- There is a need to maintain the existing access under the railway bridge (where headroom is currently limited) and provide a pedestrian link between Marine Parade and the promenade at DEF.
- The underbridge area currently provides some relief to wave impact as it allows energy to dissipate under the bridge. The effect of this would need to be assessed with physical modelling.
- Colonnade bridge is likely to be replaced within the next 50 years.
- The existing basin in front of Dawlish Water provides some protection (causing waves to break away from the rail bridge) but given its current state and potential for foreshore levels to reduce in front of it, works will be needed to enhance or maintain it if it is to be considered as part of the defence

Taking the above points into consideration, we have considered a solution that assumes that the Colonnade bridge will be replaced within the next 50 years and that its replacement structure will provide the necessary railway operational resilience (e.g. via a protective parapet). As such we have considered options for a revetment along the seawards edge of Dawlish Basin that would be required to provide the necessary railway operational resilience until 2065, and potentially contribute to the resilience solution thereafter.

To consider the effectiveness of a low-level revetment, we undertook a high-level overtopping assessment which effectively modelled the railway bridge as a vertical wall and assumed it was adjacent to the revetment, rather than around 27m offset. See Figure 63.

This indicated that, for a future low bed level of -3mOD, a revetment with a crest level of around +3.1mOD is potentially sufficiently reduce overtopping at the railway bridge to fit railway operational criteria. We note that this assessment does not accurately represent the complex defence arrangement and is not necessarily conservative. We estimate that the required crest level could be between +2.5mOD and +4.5mOD. Physical modelling is required to verify the required revetment crest level.

The revetment will have an impact on views from the underbridge area but is unlikely to have an impact as significant as the offshore breakwater option.

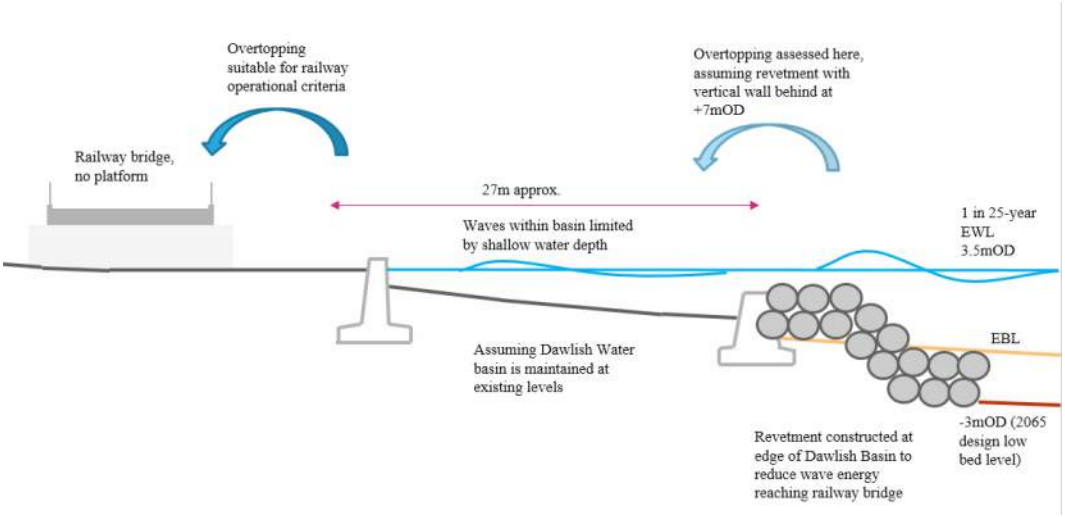



Figure 63 - Dawlish Water revetment

We applied a similar assessment methodology to the existing basin structure, for the 2065 epoch. This indicated that overtopping could be much higher than required for railway operational resilience if foreshore levels reduce in front of the basin structure. Furthermore, the future low bed level of -3mOD in front of the basin is likely to undermine existing structures. If foreshore levels were to be maintained near current levels it may be that reliance on the existing structures delivers the necessary resilience criteria, but wider consideration of beach management options has indicated that this is not preferred. As such, we have considered that a new structure would be required at this location.

A challenge with construction of a revetment along the edge of the basin is to suitably limit the impact of the revetment on flows from Dawlish Water. We have considered three potential options:

1. A culvert through the revetment.
2. A revetment with a low-crest section and wave wall within the basin.
3. A revetment with a low-crest section and small nearshore breakwater.

Dawlish water revetment options

An initial concept for these options is illustrated in Figure 64 to Figure 69 below. Each of these options requires further work to confirm their feasibility. Nonetheless, we consider that a feasible solution is likely and that this option should be considered further.

It should be noted that these sketches are outline initial sketches to illustrate the various concepts, further work is required to confirm all dimensions and other requirements.

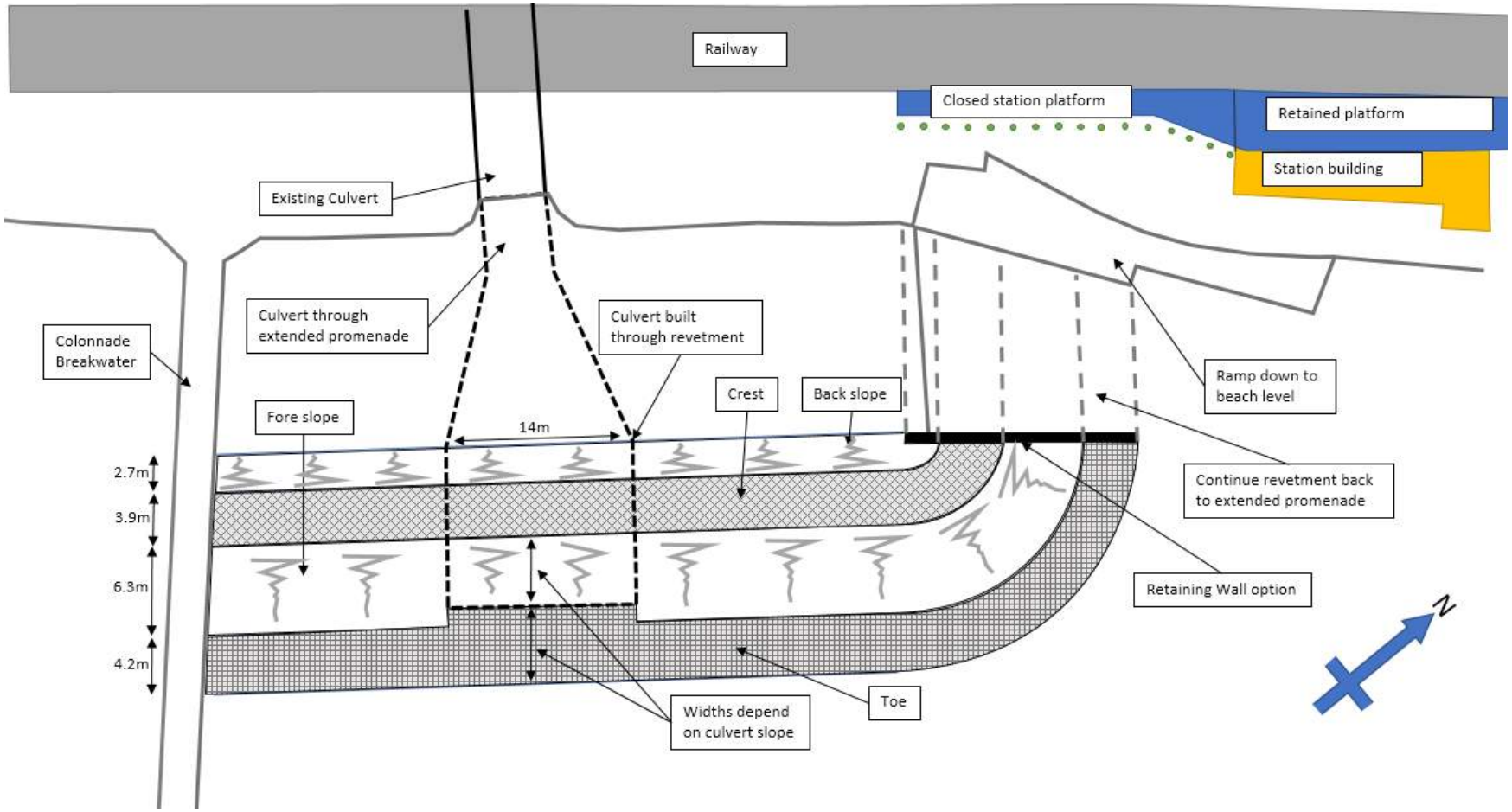



Figure 64 - Revetment Option A concept, plan

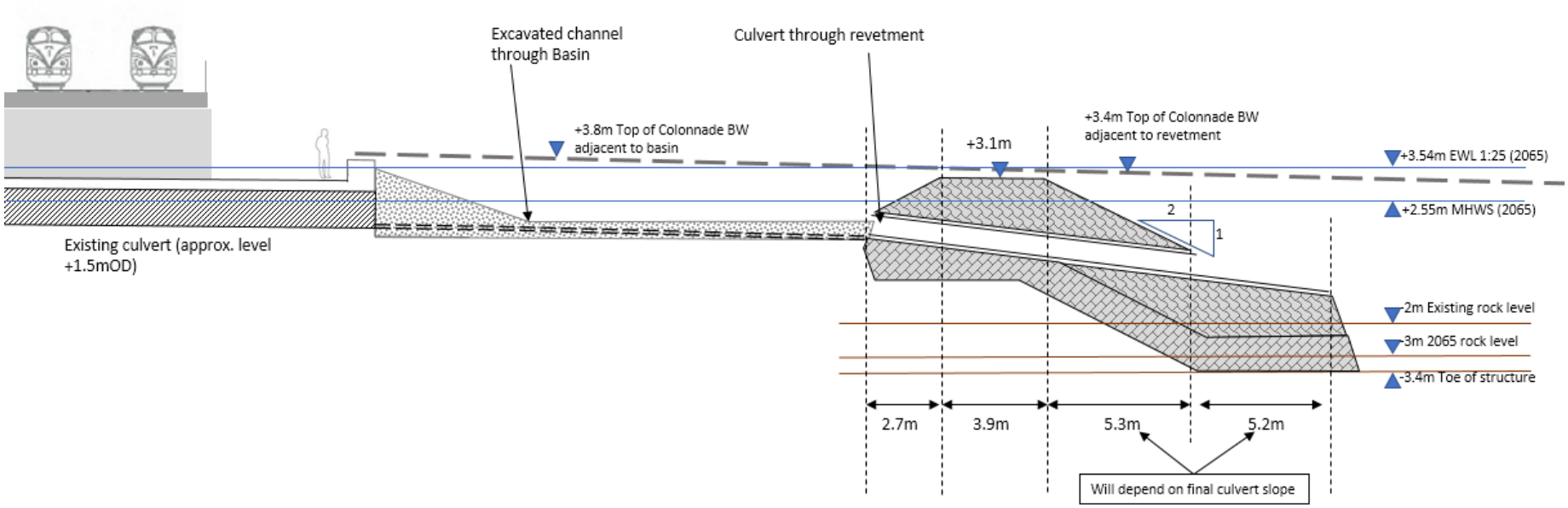



Figure 65 - Revetment option A concept, section

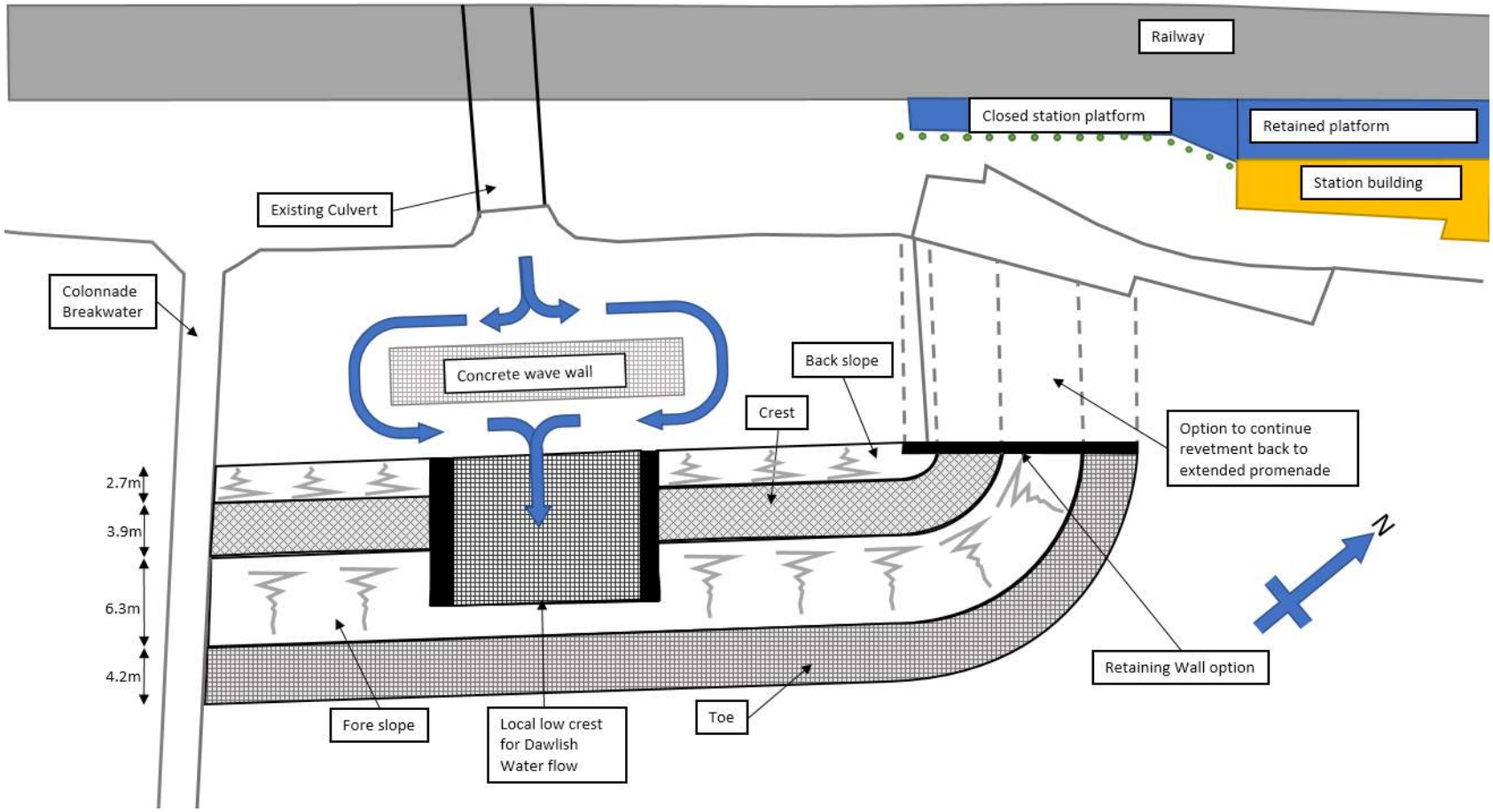



Figure 66 - Revetment Option B concept

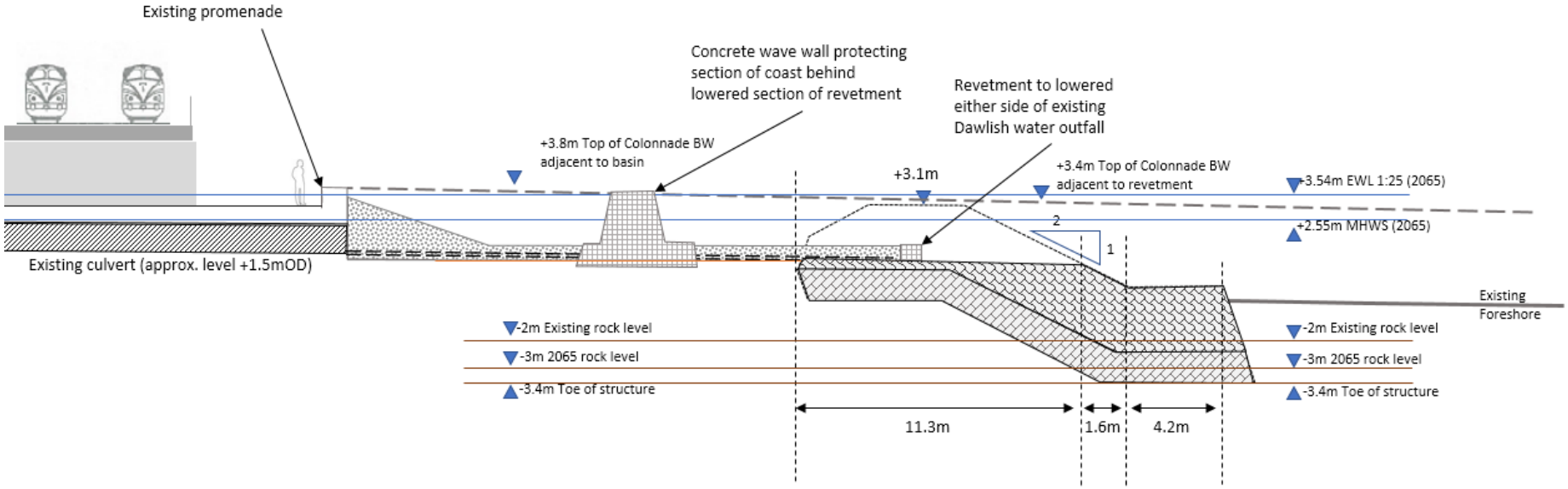



Figure 67 - Revetment Option B concept, section

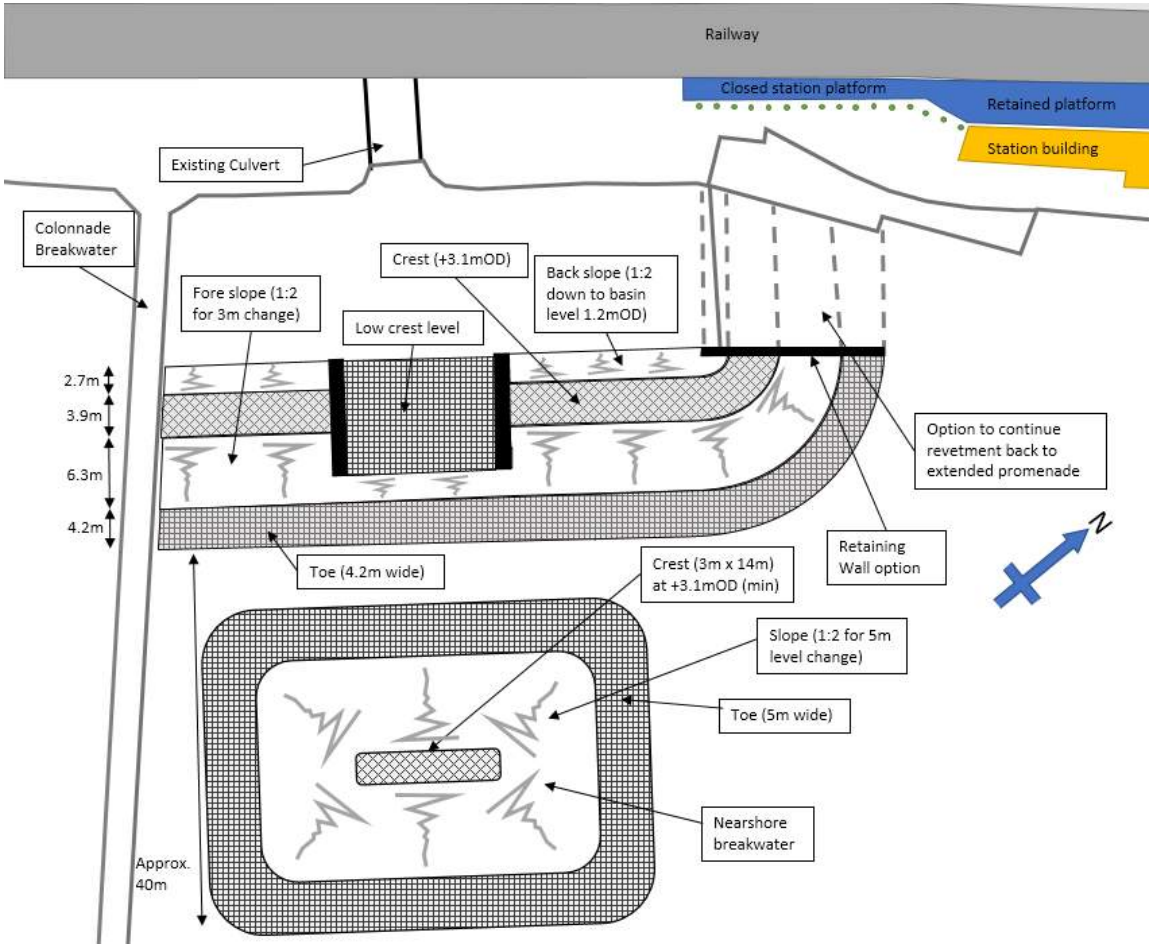



Figure 68 - Revetment Option C concept, plan

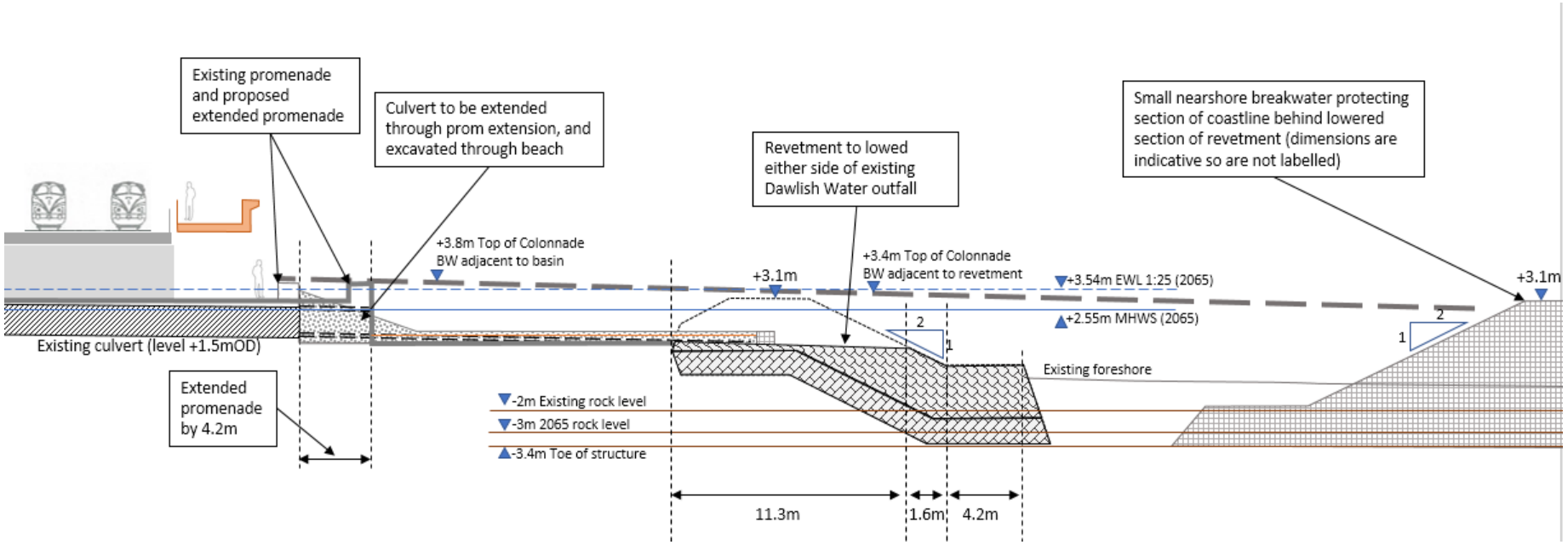



Figure 69 - Revetment Option C concept, section

## Additional measures

### *Scour protection*

As per previous options both new and existing structures will require the implementation of scour protection measures to meet the required design period. Refer to Figure 70 below.

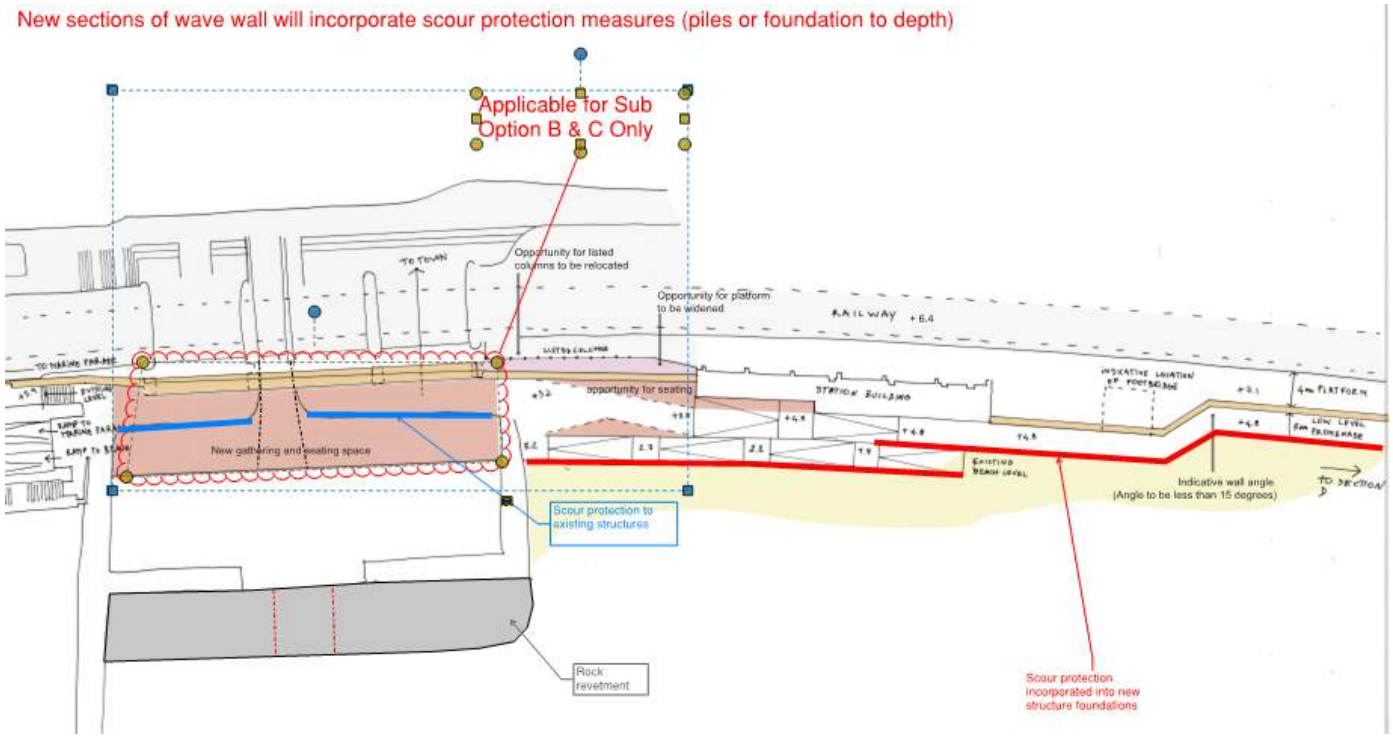



Figure 70 - Scour protection requirements

## Option 3 Summary

| Basic option description | Option name | Low promenade at A to low promenade at D with revetment and future replacement of bridge at A |
|---|---|---|
| Solution description | Section A | Nearshore revetment at Dawlish Basin |
| | Section B | New ramp to beach with scour protection<br>Extended lower promenade<br>Wave wall in front of listed columns |
| | Section C | New ramp to beach with scour protection<br>New ramp to lower level prom at D including scour protection measures |
| Resilience epoch | Section A | 2065 |
| | Section B | 2115 |
| | Section C | 2115 |
| Resilience | Rail resilience | Yes |
| | Passenger resilience | Sub-frontage C only |
| | Pedestrian resilience | No |
| Basic option description | Option name | Low promenade at A to low promenade at D with revetment and future replacement of bridge at A |
| Constructability issues | | - Jack up barge required for piling at Section B (scour protection), C and D. Issues with draft and possible dredging required.<br>- Land based piling plant required for Section A scour protection and wave wall at B. |
| Adjoining interfaces | | - Marine parade will require some additional measures to reduce wave overtopping<br>- Interface with Section D will require a minor length of ramp at Section C |
| Dawlish flood risk | | - Will require culvert (or similar) through revetment. Possible issue with siltation. May require maintenance. |
| Amenity | Section A | - Reduces existing as revetment taking up beach area and have a visual impact |
| | Section B | - Improves existing with wider promenade and improved beach access ramp |
| | Section C | - Improves existing with added protection from overtopping |
| Cost | | 2 |

| Basic option description | Option name | Low promenade at A to low promenade at D with revetment and future replacement of bridge at A |
|---|---|---|
| Third Party | | - Removal of listed columns/ gas lamps required<br>- Potential visual impact reducing views<br>- Heritage issue with ramp in front of station building to 4.8m OD |
| Pros | | - Landside elements at Section A maintain appearance<br>- Improved public space at Section B<br>- Improved access to beach and Section D<br>- Widened platform at Section B |
| Cons | | - Visual impact of revetment and reduced beach area<br>- Removal of listed columns<br>- Risk that necessary building resilience is challenging to achieve considering heritage constraints |

Table 11 - Summary of Option 3

### 5.4.4 Section ABC Low promenade at A to low promenade D with offshore breakwater

This solution is considered further as two parts:

1. Offshore breakwater;
2. Low promenade.

**Offshore breakwater**

The offshore breakwater solution would be similar to that described for Option 1.

**Low promenade**

The existing promenade would largely remain as existing but with the exception of a minor length of ramp between Section C and D and scour protection to the existing structures.

**Additional measures**

***Scour protection***

As described for Option 1 the existing structures will require the implementation of scour protection measures to meet the required design period as the breakwater does not completely remove this risk. In addition, the section of ramp adjacent to Section C will require scour protection. Refer to Figure 71 which show the requirements (assuming a ramp up to high level adjacent to Station).

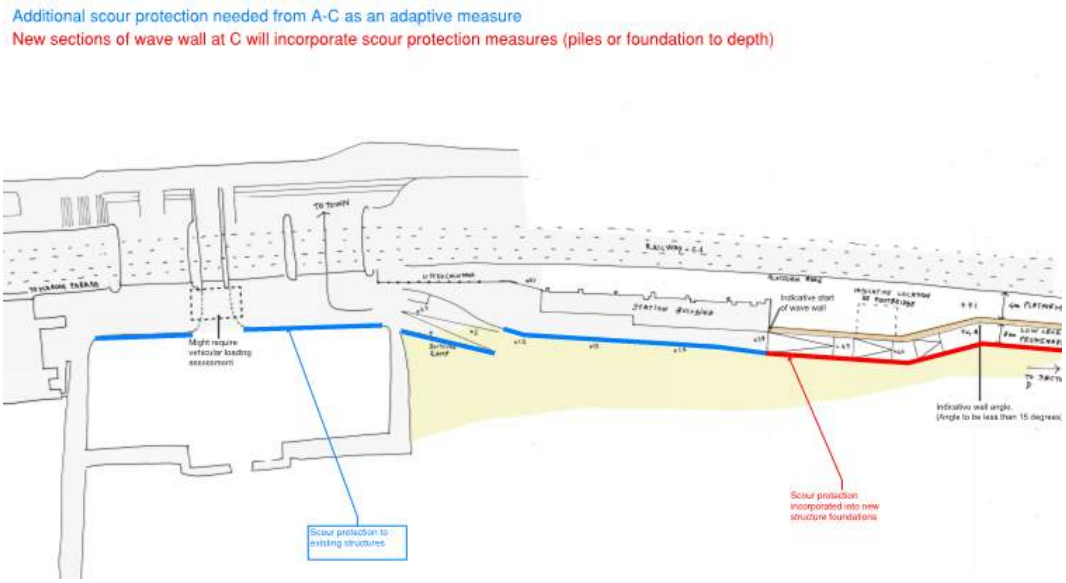



Figure 71 - Low promenade and scour protection

## Option 2 Summary

| Basic option description | Option name | Low promenade at A to low promenade D with off shore breakwater |
|---|---|---|
| Solution Description | Section A | Offshore breakwater<br>Nearshore scour protection to existing structures |
| | Section B | Offshore breakwater<br>Nearshore scour protection to existing structures |
| | Section C | Offshore breakwater<br>Nearshore scour protection incorporated into new structures |
| Resilience Epoch | Section A | 2115 |
| | Section B | 2115 |
| | Section C | 2115 |
| Resilience | Rail resilience | Yes |
| | Passenger resilience | For sub-frontage C only |
| | Public resilience | No |
| Constructability issues | | - Jack up barge required for piling at Section C and D. Issues with draft and possible dredging required.<br>- Land based piling plant required for Section A,B and C scour protection. |
| Adjoining interfaces | | - Marine promenade interface no issues<br>- Interface with Section D will require a minor length of ramp at Section C |
| Dawlish flood risk | | - Potential issue with accretion/ siltation between Dawlish Water basin and offshore breakwater. May require maintenance. |

| Basic option description | Option name | Low promenade at A to low promenade D with off shore breakwater |
|---|---|---|
| Amenity | Section A | - Maintains existing |
| | Section B | - Maintains existing |
| | Section C | - Maintains existing |
| Cost | | High |
| Third Party | | Visual impact of offshore breakwater |
| Pros | | - Maintains existing appearance at Sections A to C<br>- Provides protection along entire length A-C |
| Cons | | - Visual impact of offshore breakwater<br>- High cost of offshore breakwater<br>- Scour or toe protection structures required along sub-frontages A, B and C alongside potential strengthening for wave loading.<br>- Building resilience measures at sub-frontage C required that are likely challenging considering heritage constraints |

Table 12 - Summary of Option 2

### 5.4.5 Section ABC High promenade at A to high promenade at D with revetment, pedestrian footbridge and future replacement of bridge at A.

This solution is considered further as two parts:

- High promenade;
- Nearshore revetment at Dawlish Water.

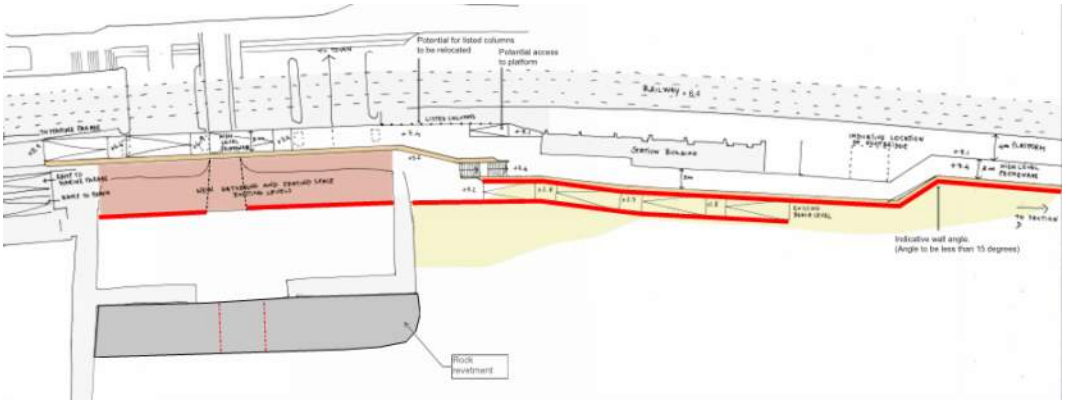


Figure 72 - Option 4 scour protection

## High promenade

The high promenade would connect a high promenade at Section D with the high promenade at Marine Parade. The solution will form a step free access between Colonnade and Marine Parade by way of a pedestrian walkway (further detail provided below). This has the benefit of not introducing another significant visually imposing ramp structure in close proximity to the Marine Parade ramp. A flight of steps would provide access from Colonnade to the north.

The construction of the new bridge would require a widening of the existing gateway area out into the existing basin i.e. and extension of the promenade seaward. New beach ramps would be provided north of the Dawlish water basin.

This option would clearly have a significant impact on the view of the station from the beach.

With the exception of the pedestrian walkway at Section A the high-level promenade is expected to be of a similar construction to that proposed in Section D although the physical modelling may allow for a lower crest level to be provided.

### *Colonnade pedestrian footbridge*

This option involves a pedestrian walkway or footbridge at Section A linking the upper promenade at Marine Parade and the high-level promenade from Section B onwards. This structure would be in the form of a 3-span bridge in front of the existing rail bridge. The purpose of the walkway would be to continue the upper promenade between Marine Parade and Section B whilst also protecting the railway line. This existing pedestrian access via the town gateway area under the rail bridge would be maintained with this option.

A typical cross section of the proposed pedestrian walkway is shown in Figure 73. The typical section was established based on the design waves loads arising from the feasibility design stage. Note that these loads did not take account of any reduction in wave loading from the presence of the rock revetment at the Dawlish Water basin.

As mentioned previously, physical modelling will be required in order to determine likely wave loads on the structure and to inform the outline design basis. It is recommended that the alignment and form of the bridge are reviewed once these loads are known.

The presence of the existing rail bridge pier foundation is a limiting factor for the footprint of the pedestrian walkway foundations. As shown in Figure 73. Due to the required clearance between the existing bridge structure foundation and the footings of the new pedestrian walkway, the deck position will need to be offset from the existing piers and will require a chamfer on the rail bridge side of the new piers.

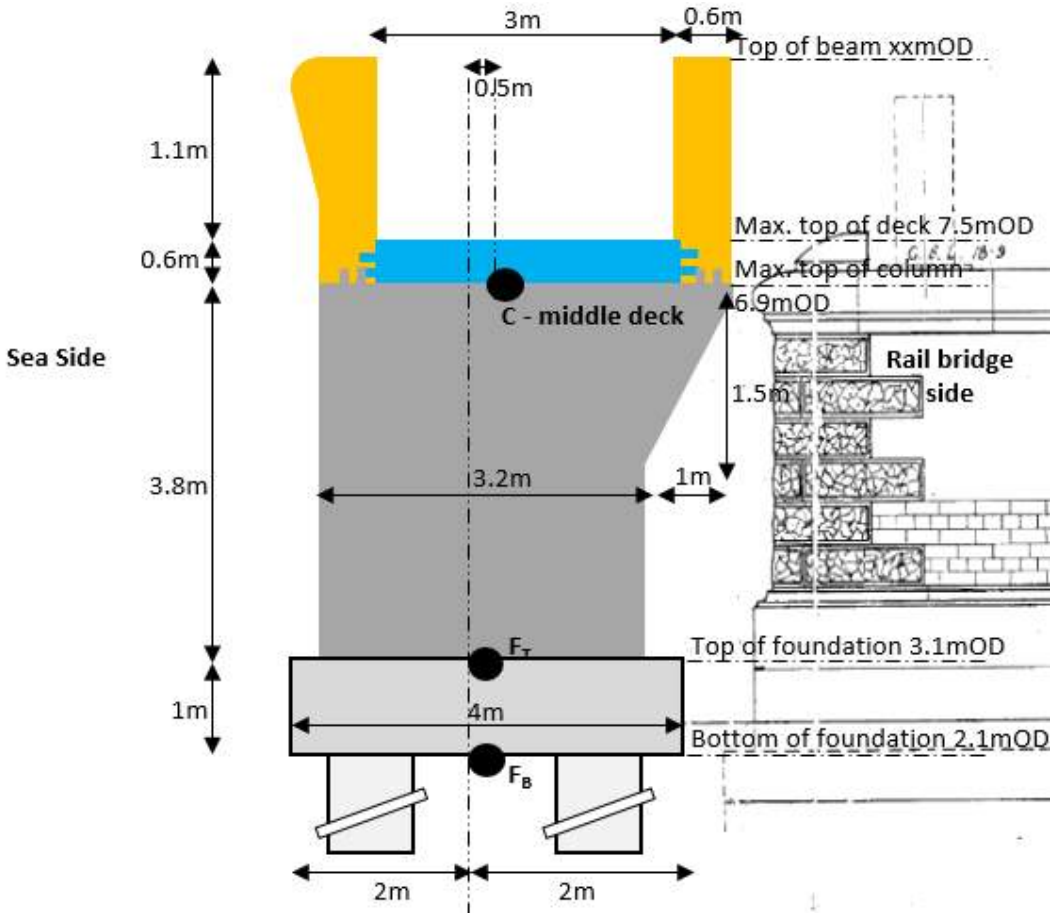



Figure 73 - Typical footbridge proposed cross section

The proposed pedestrian walkway will be a 3 spans continuous Reinforced Concrete (RC) deck with a RC fixed support to the piers. The fixed support will ensure deck stability against horizontal and uplift loads resulting from breaking waves.

As shown in Figure 74, the long section, chamfers may also be required to better spread the loads from the deck to the piers in the case of non-uniformly distributed wave loads on the spans of the pedestrian bridge.

The pedestrian walkway is located over the Dawlish Water area, as the ground conditions are expected to be weaker in this area the foundations will be piled. As there the jack up barge will not be able to gain access to this area, due to the existing rock revetment, a CFA pile solution will be the most likely option.

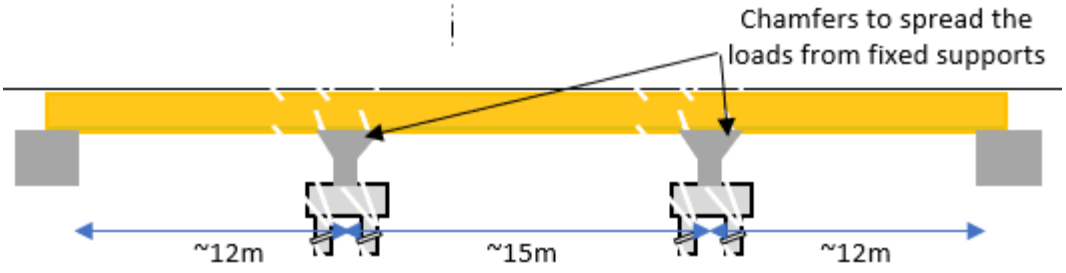



Figure 74 - Typical footbridge proposed long section

## Nearshore revetment at Dawlish Water

The pedestrian walkway at sub-frontage A was considered without the Dawlish Basin and nearshore revetment, as shown schematically in Figure 75.

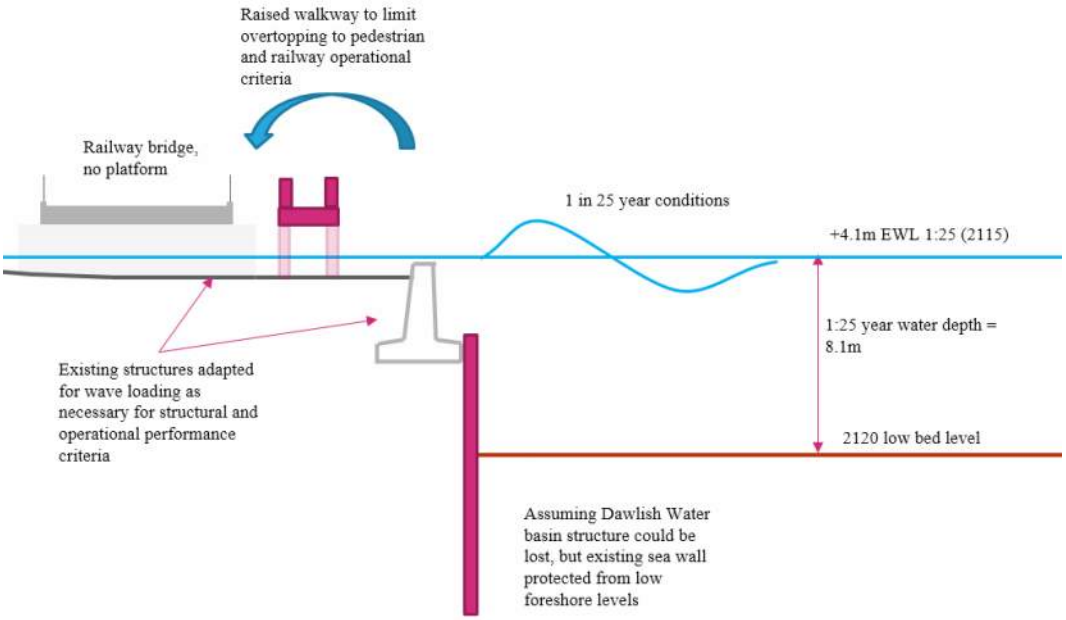



Figure 75 - Pedestrian walkway as defence

Given the likelihood of excessive wave loads for the design scenario it would be technically very challenging to provide a standalone pedestrian bridging structure designed to resist all wave forces at sub-frontage A up to 2115. It is therefore proposed that the Dawlish Water basin is protected by a rock revetment, as for Option 4.

## Additional measures

### *Scour protection*

As per previous options both new and existing structures will require the implementation of scour protection measures to meet the required design period. Refer to Figure 72.

## Option 4 Summary

| Basic option description | Option name | High promenade at A to high promenade at D with revetment, pedestrian walkway and future replacement of bridge at A |
|---|---|---|
| Solution description | Section A | Nearshore revetment at Dawlish Basin<br>Extended lower promenade<br>Pedestrian walkway seaward of rail bridge |
| | Section B | New ramp to beach with scour protection<br>New high promenade with wave wall<br>Steps from low prom to high prom. |
| | Section C | New ramp to beach with scour protection<br>New high promenade with wave wall including scour protection measures |
| Resilience epoch | Section A | 2065 |
| | Section B | 2115 |
| | Section C | 2115 |
| Resilience | Rail resilience | Yes |
| | Passenger resilience | Sub-frontage C only |
| | Pedestrian resilience | Yes |
| Constructability issues | | - Jack up barge required for piling at Section B (scour protection), C and D. Issues with draft and possible dredging required.<br>- Land based piling plant required for Section A scour protection and wave wall at B.<br>- Proximity of pedestrian walkway to existing rail bridge will impose spatial constraints (e.g. size of pile rig, practical separation between existing foundations and new piled foundations) |
| Adjoining interfaces | | - Marine promenade interface will require tie in with new MP levels<br>- Interface with Section D no issues |
| Dawlish flood risk | | - Will require culvert (or similar) through revetment. Possible issue with siltation. May require maintenance.<br>- Culvert extension required due to prom. extension |
| Amenity | Section A | - Improves existing with extension of promenade but revetment will reduce beach area and have a visual impact |
| | Section B | - Improves existing through with high prom. And improved beach access |
| | Section C | - Improves existing with added protection from overtopping but reduces access to the beach as no low level prom. |
| Cost | | 4 |
| 3RD Party | | - Removal of listed columns/ gas lamps required<br>- Potential visual impact reducing views<br>- Heritage issue with ramp in front of station building to 7.4m OD |

| Basic option description | Option name | High promenade at A to high promenade at D with revetment, pedestrian walkway and future replacement of bridge at A |
|---|---|---|
| Pros | | - Improved public space at Section A<br>- Improved access to upper level of Marine Promenade<br>- Improved public space at Section B<br>- Improved access to beach and Section D<br>- Additional platform access from pedestrian walkway |
| Cons | | - Visual impact of revetment and reduced beach area<br>- Increased area under rail bridge and pedestrian walkway<br>- Removal of listed columns<br>- Extension of Dawlish Water culvert and possible maintenance issues with revetment culvert |

Table 13 - Summary of Option 4

### 5.4.6 Section ABC / Marine Parade interface protection

It has been identified that the works proposed need to extend to tie in with the Marine parade solution to provide a continuous level of protection

The various protection methods that have been considered for the interface with section A are as follows:

- Option 1 - Rock revetment in the corner of the Marine Parade and the Dawlish Water basin. This would protect the town gateway area due to the wave direction.

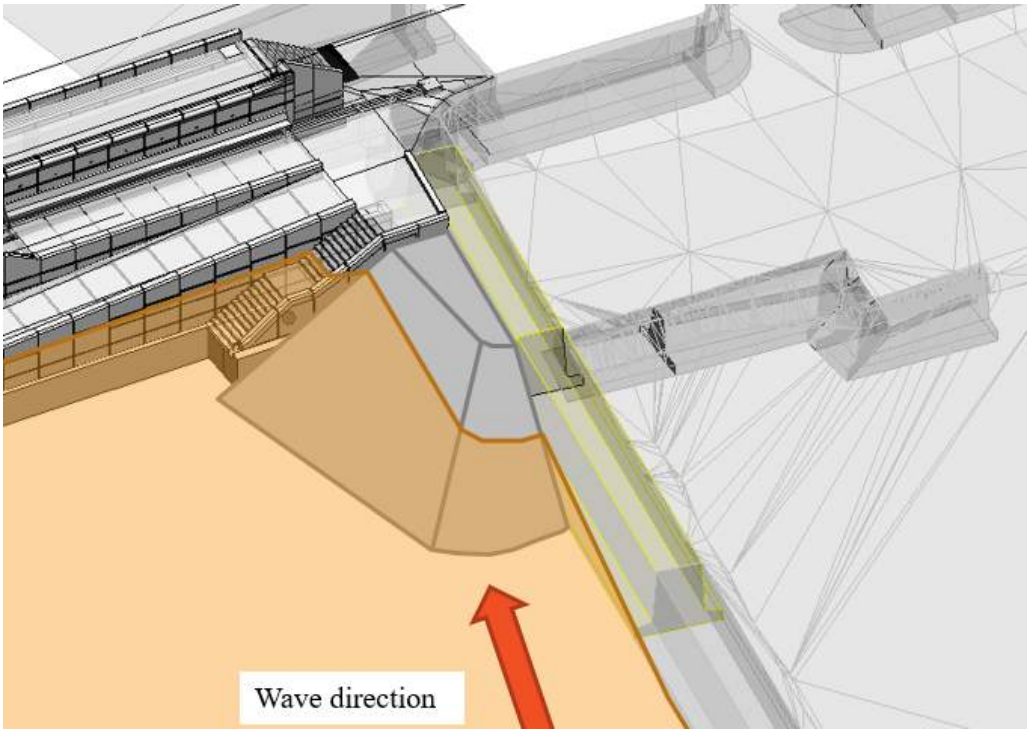



Figure 76 - Marine Parade interface - Option 1 – Rock revetment

- Option 2 - Beach nourishment with an increased breakwater height.

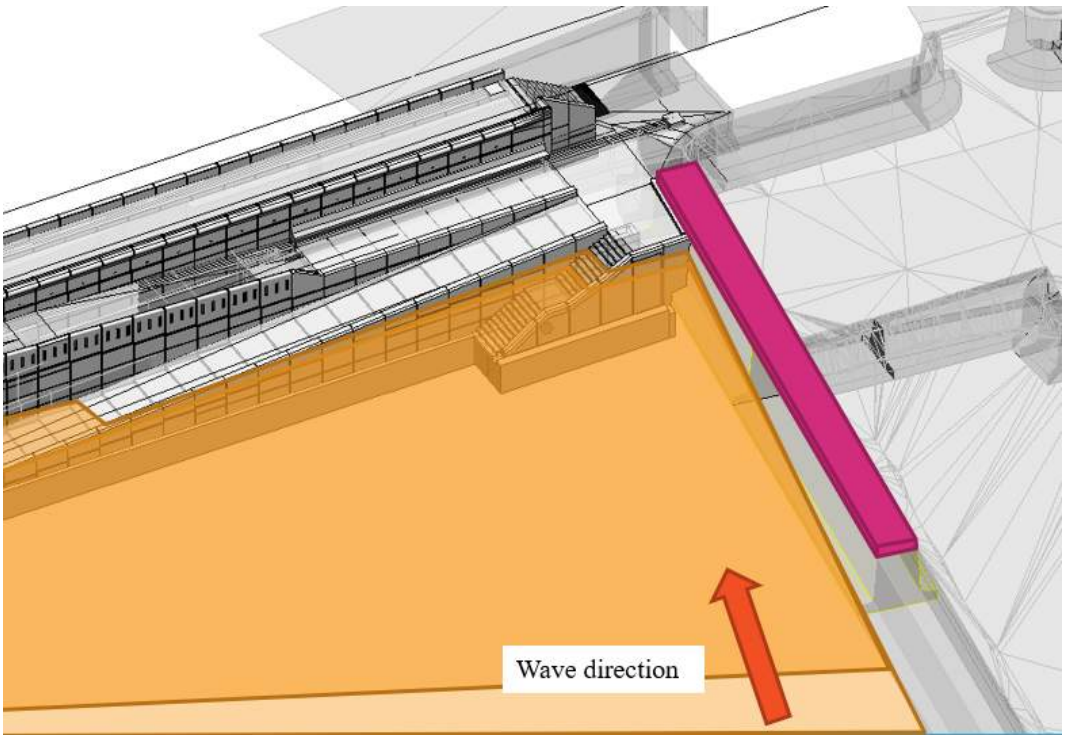



Figure 77 - Marine Parade interface - Option 2 – Beach nourishment

- Option 3 - Continuation of the Marine Parade wave wall in line with the stairs at the back of the promenade.

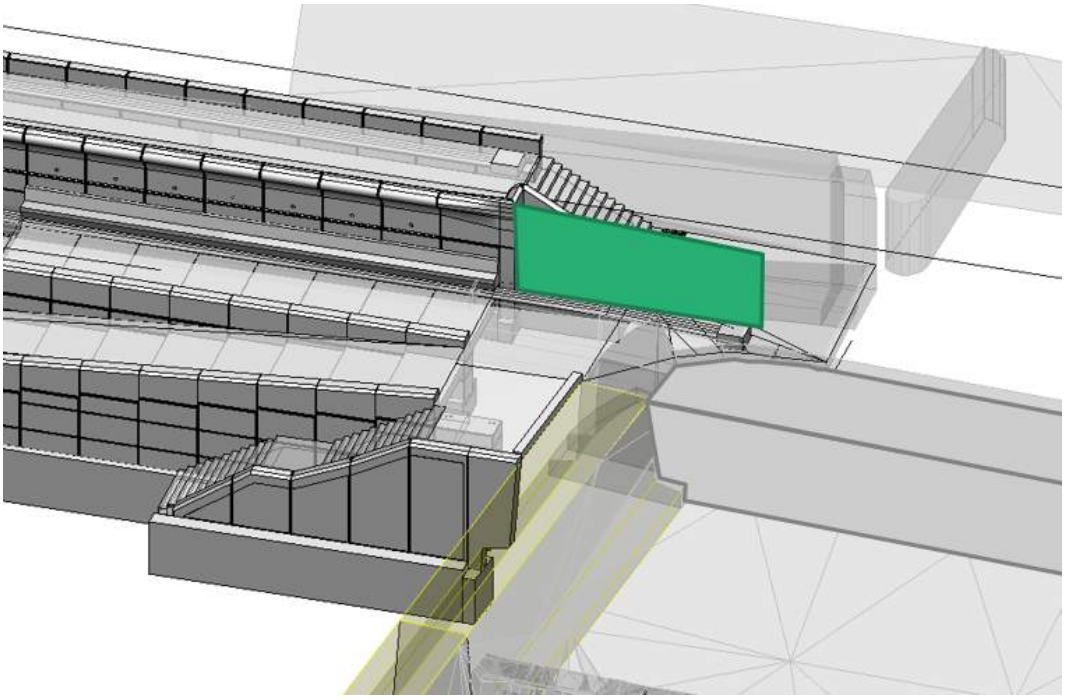


Figure 78 - Marine Parade interface - Option 3 – Wall continuation

- Option 4 - Wave wall element on the corner to protect the town gateway area from overtopping forces.

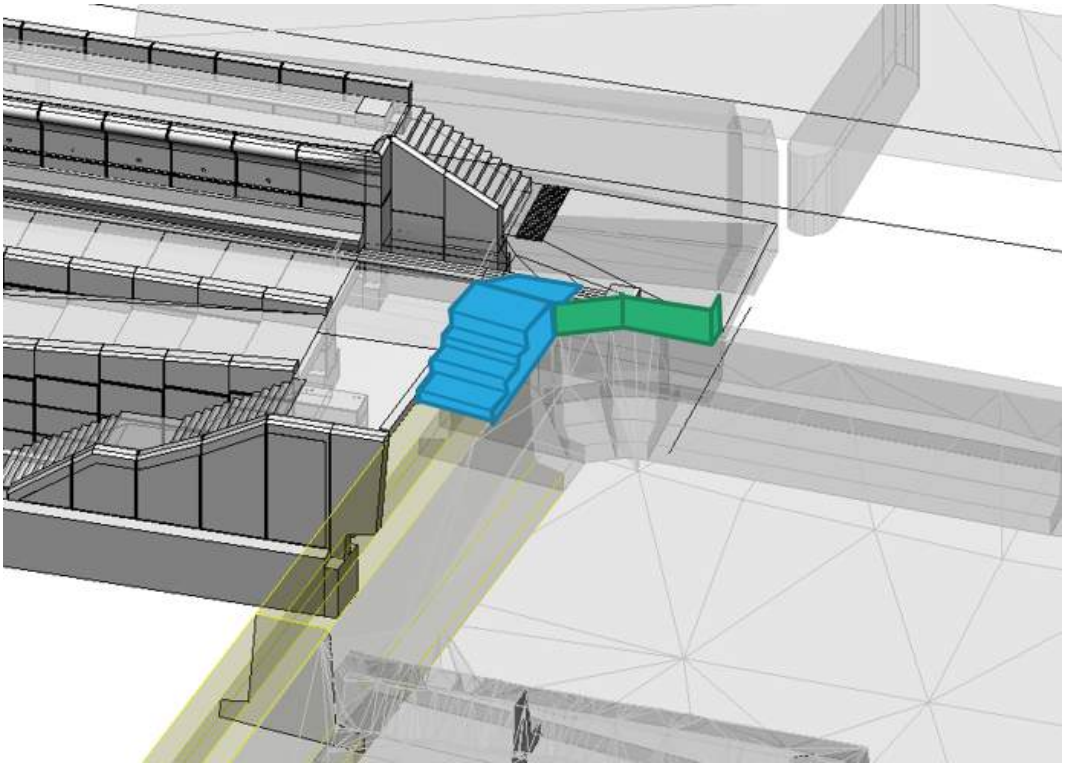


Figure 79 - Marine Parade interface - Option 4 – Wave wall

- Option 5 – Extension of proposed breakwater to protect this section of seafront.

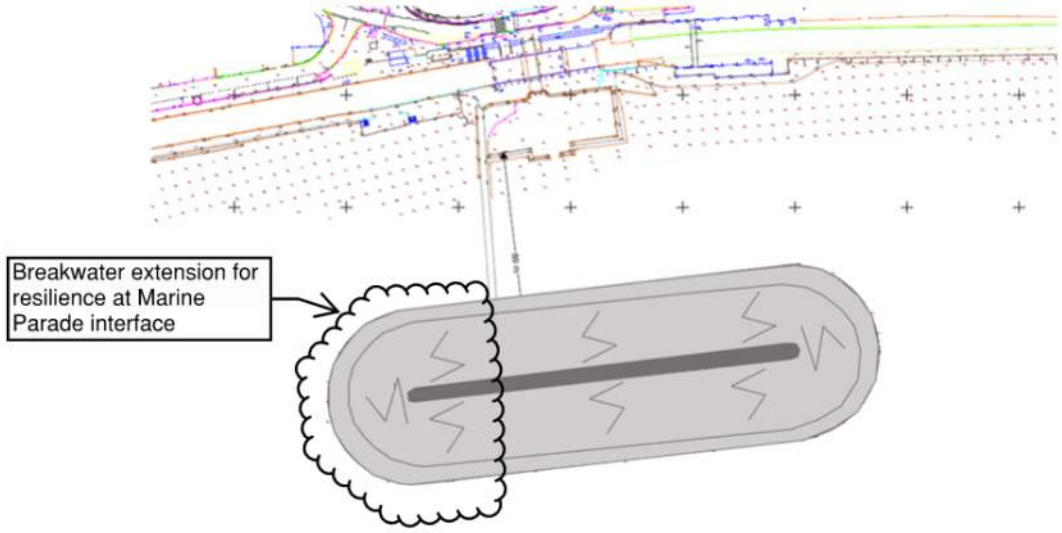



Figure 80 - Marine Parade interface - Option 5 - Extended breakwater

- Option 6 – Extension of the high-level sea wall with bullnose recurve.

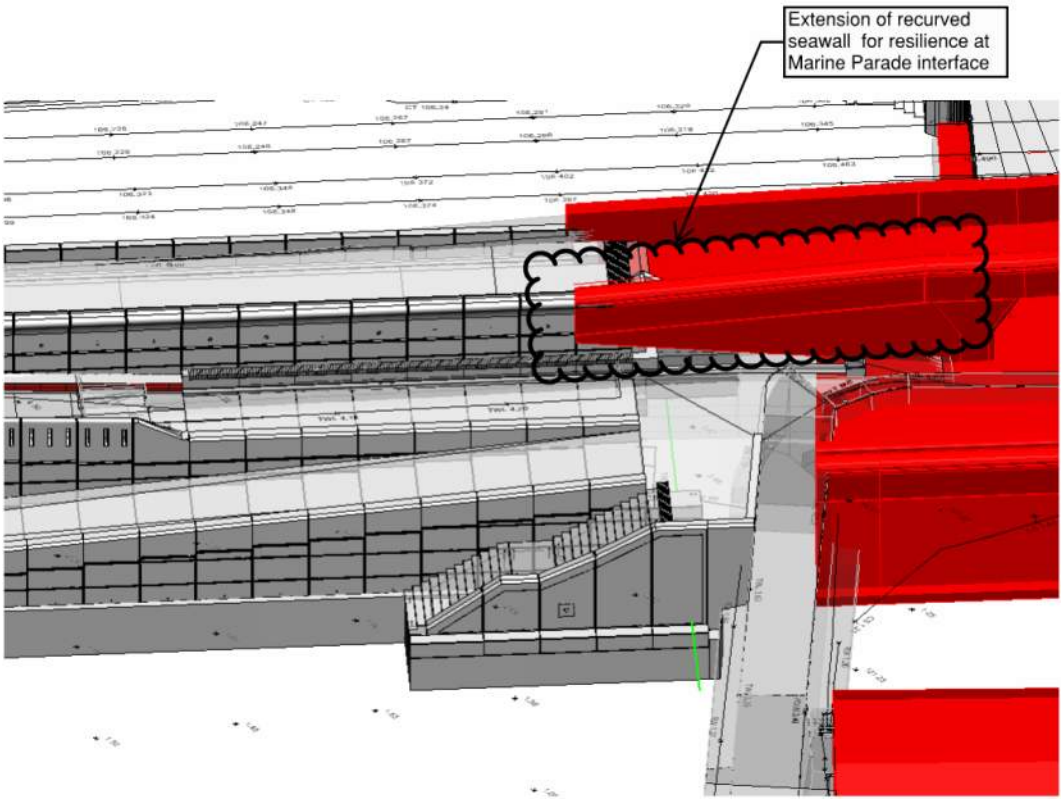



Figure 81 - Marine Parade interface - Option 6 - Extended recurved seawall

These options are summarised in Table 14 below.

| | **Option 1**<br>**Rock revetment** | **Option 2**<br>**Beach nourishment** | **Option 3**<br>**Wall continuation** | **Option 4**<br>**Wave wall** | **Option 5**<br>**Extension of new breakwater** | **Option 6**<br>**Extension of Seawall with recurve** |
|---|---|---|---|---|---|---|
| Likely to be able to provide full resilience | No | Yes | Yes | No | Yes | Yes |
| Advantages | Could be considered an extension of any proposed revetment the other side of the breakwater | Improved amenity value | Can be tied into high level promenade scheme | | Mobilisation cost small if considered as part of breakwater to Section A & B | Continuation of the resilience system along the high-level promenade |
| Disadvantages | Will not provide full resilience unless coupled with beach nourishment | Considerable management and maintenance cost to maintain beach level | Will require modification to end of Marine Parade works | Visual impact as will obscure sea views.<br>Will not provide full resilience unless coupled with beach nourishment | Cost | Review of interface required if bridge optimisation leads to the removal of the parapet. |
| Compatible with section ABC Option 1 (Low promenade at A to high promenade D with off shore breakwater) | Yes | Yes | No | Yes | Yes | No |
| Compatible with section ABC Option 2 (Low promenade at A to low promenade D with off shore breakwater) | Yes | Yes | No | Yes | Yes | No |

| | **Option 1**<br>**Rock revetment** | **Option 2**<br>**Beach nourishment** | **Option 3**<br>**Wall continuation** | **Option 4**<br>**Wave wall** | **Option 5**<br>**Extension of new breakwater** | **Option 6**<br>**Extension of Seawall with recurve** |
|---|---|---|---|---|---|---|
| Compatible with section ABC Option 3 (Low promenade at A to low promenade at D with Revetment and future replacement of bridge at A) | Yes | Yes | No | Yes | No | No |
| Compatible with section ABC Option 4 (High promenade at A to high promenade at D with Revetment, pedestrian walkway and future replacement of bridge at A.) | Yes | Yes | Yes | Yes | No | Yes |

Table 14 - Summary of options

The solution is largely dependent on the option chosen for Section ABC.

### 5.4.7 Section ABC Alternatives for low-level structure at Dawlish Basin in Options 3 and 4

The feasibility stage identified a rock revetment as potential option to consider at this location, this is considered in the option 3 and 4 review above. Network Rail have noted local perceptions that a rock revetment may be unsuitable at this location, principally on the grounds of public safety, and therefore requested that a number of other options are considered.

As such, we have reviewed the relative strengths and weaknesses of a rock revetment, vertical wall and concrete revetment as options for the low-level structure:

**Rock revetment**

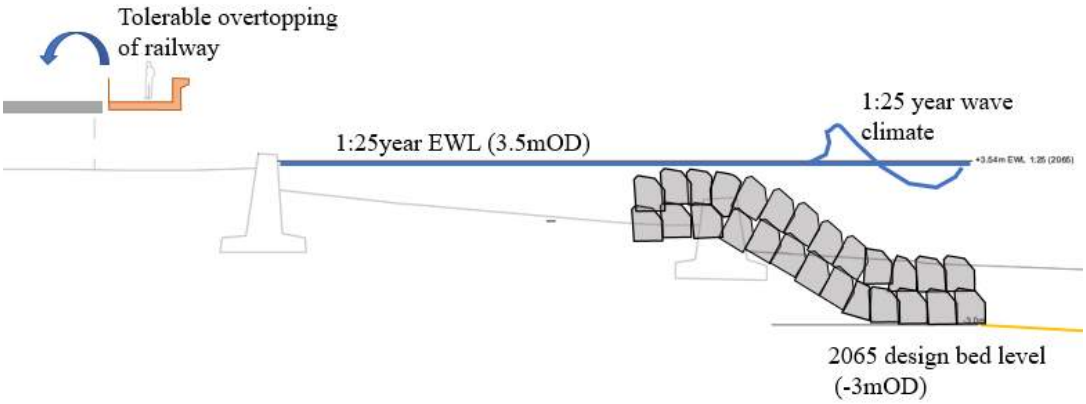



Figure 82 - Rock revetment concept at Dawlish Basin

A rock revetment, being a more energy-absorbing structure, is likely to perform well in limiting overtopping of the railway and the high-level pedestrian walkway. Our initial assessment has suggested that a revetment crest level around +3.1mOD is likely sufficient to meet the railway resilience criteria.

A rock revetment is likely to reflect less wave energy than other options, reducing the risk of foreshore lowering and scour in front of the structure. Foreshore lowering and scour can result in loss of intertidal area and onerous structural design conditions. This is of less concern in this location, due to the limited intertidal area and the relatively high rock strata which will limit foreshore lowering but should still be noted. It is assumed Network Rail will maintain the breakwater and provide scour protection as required.

The rock revetment would be accessible to the public and therefore there is a risk that people climb on the rocks and injure themselves. Furthermore, there are also risks that litter or debris accumulates in the rock. We understand there are some local perceptions that these risks are unacceptable and therefore rock is not preferred for foreshore structures. We note that there are opportunities to design the structures in a way the limits the likelihood of the public accessing them, which will reduce (but likely not eliminate) this risk.

If a culvert type solution is required to permit Dawlish Water flows through the structure (as opposed to a locally lower crest structure) this would be relatively difficult to achieve compared to a culvert through other structure options. This is because of the rock arrangements required for stability.

We consider that a rock revetment would have relatively moderate level of buildability, requiring construction in the intertidal zone but without the need for piling. The relatively high rock strata level means that ground improvement works for the revetment are not likely to be onerous.

**Vertical wall**

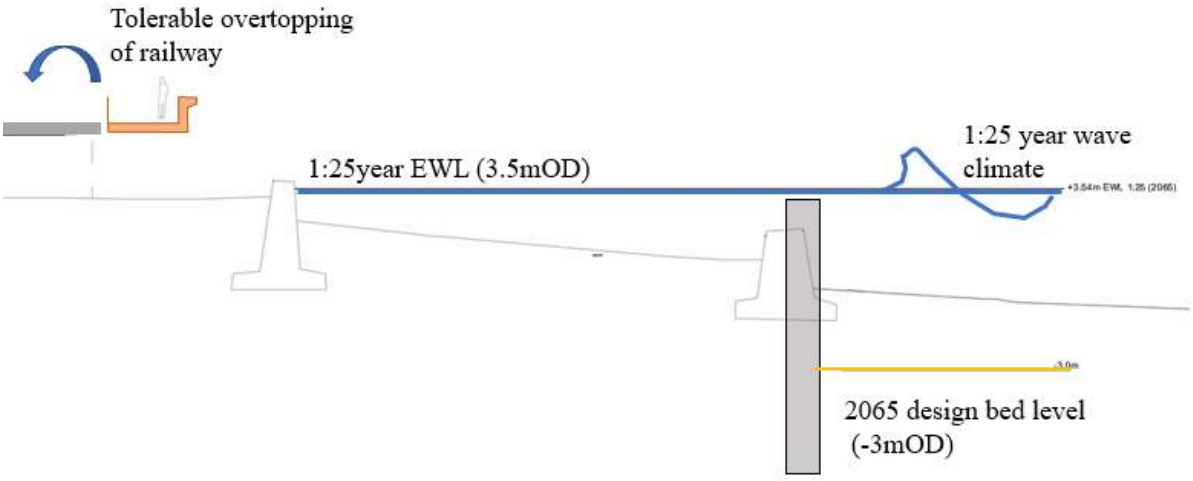



Figure 83 - Vertical wall concept at Dawlish Basin

A low crested vertical wall will have a significantly lower overtopping performance when compared with a rock revetment. The low crest, driven by the requirement to limit the impact on views, will mean little energy is reflected at design water levels, additionally minimal energy will be absorbed by the structure and thus higher overtopping will be expected. As such, a crest height higher than +3.1mOD may be required to meet the tolerable overtopping criteria. However, due to the high uncertainty inherent in the assessment undertaken and the approximately 25m offset from the railway, the tolerable overtopping criteria may be achievable with a lower crest level. This would need to be established with physical modelling.

The wall would create a change in levels which could require a pedestrian restraint system. This would, as a result of its location in the intertidal zone, be subject to frequent and sometimes high wave loading. This could require onerous design criteria and/or maintenance of the restraint structure. An alternative could be to limit access to the crest of the wall.

This option would remove the risks – real and perceived – associated with rock on the foreshore and would also be less likely to trap litter and debris.

A vertical wall, compared to a rock revetment, would encourage scour and lowering of the foreshore in front of the structure, reducing the size of the intertidal area.

A culvert type solution to meet the Dawlish Water requirements would likely be more easily achievable than with a rock revetment.

We consider that a vertical wall would likely have a moderate level of buildability. Piling would likely be required within the intertidal zone, but the same plant as used for the proposed sea wall at sub-frontage B could potentially be utilised.

## Concrete revetment

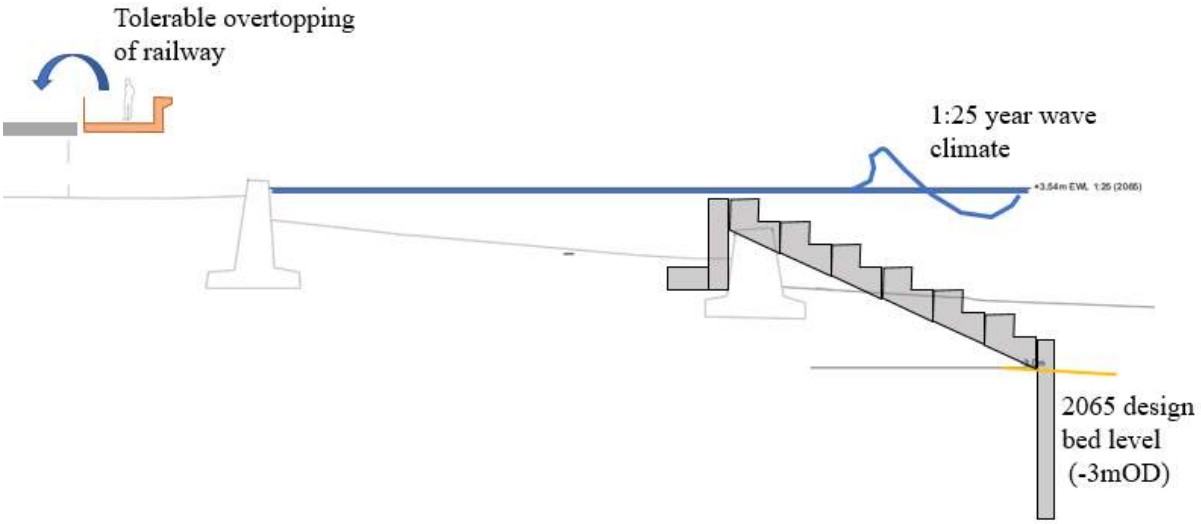



Figure 84 - Concrete revetment concept at Dawlish Basin

A concrete revetment, in particular one with incorporated energy dissipating aspects such as large steps, is likely to sit between the vertical wall and rock revetment in terms of overtopping performance.

The structure would, due to its form and location within the intertidal area, likely be subject to algae growth making it unsafe for pedestrian access or requiring frequent maintenance. The reflective nature of the structure would also lead to scour and foreshore lowering, reducing the size of the intertidal area it accessed.

The revetment would need to be constructed within the intertidal zone. This would pose some challenges, for example in preparation of the slope on which precast revetment units sit. A toe pile may be required to retain the revetment units, with the associated buildability challenges.

A culvert type solution to meet the Dawlish Water requirements would likely be more easily achievable than with a rock revetment but could post some challenges.

A similar performance, perhaps with improved buildability, could likely be achieved from a grouted rock revetment structure. Nonetheless, we do not consider that this offers significant advantages compared to a vertical wall.

**Summary and conclusion**

The relative performance of each option is summarised in Table 15 below. We have attributed a moderate relative cost rating to each option, the design concepts would need to be developed further to verify this.

| Criteria: | Overtopping performance | Public safety risk | Buildability | Cost |
|---|---|---|---|---|
| Rock revetment | Good | Moderate | Moderate | Moderate |
| Vertical wall | Moderate-poor | Good | Moderate | Moderate |
| Concrete revetment | Moderate | Moderate-poor | Moderate-poor | Moderate |

Table 15 - Relative performance of options for low level structure

We suggest that, to limit risks associated with stakeholders' objections to the use of rock structures in publicly accessible areas, a vertical wall option is considered further (i.e. in 3D wave modelling) to assess its overtopping performance. Allowance should be made to test a rock revetment as an alternative, with mitigation measures considered in design to limit safety risks.

### 5.4.8 Section ABC Chosen Option

The preferred option is a combination of the minimal approach and introduction of a new wave wall as described in Option 4. The section would tie-in to a high-level promenade in section D and carry on in this format through sections B and C. At section A there would be a new revetment at the end of the Dawlish Water basin which would offer protection to this section and reduce the wave energy reaching the promenade. A pedestrian walkway would span from the high promenade at section B to Marine Parade. This pedestrian walkway would offer protection to the viaduct and tracks beyond but could offer lower total resilience due to the partnership with the revetment.

Therefore, the preferred option is to include a revetment in front of section A where the basin currently ends. This would then remove a large percentage of the wave energy so that the waves that reach the pedestrian walkway would be much smaller in height with much less energy. This in turn reduces the wave loads being imparted on the pedestrian walkway structure and enables a lighter, less significant pedestrian walkway design to be introduced.

In the long term, the viaduct would be replaced once it reaches the end of its functional lifespan. When this is replaced the footbridge would also be replaced and would most likely be integrated into the new viaduct. The revetment would then be defunct and could effectively be removed. As a result, the new viaduct would need to be designed as if the revetment was not in place and offered no protection.

## 5.5 Proposed Station Footbridge

Refer to the Improving Station Accessibility report (document reference number: 142630-ARP-REP-EAR-000002) for details of the option selection process for determination of a lift bridge as the proposed solution for significant accessibility improvements at Dawlish Station.

### 5.5.1 Architectural Optioneering

Originally there were an array of options which were narrowed down to five primary options (Figure 85). Two of these were in line with the NR standard footbridge design with the rest being designed in line with the NR generic footbridge competition design. These designs included angled lift shafts enabling greater access and improved visibility from the platform.

These five options were then discussed and assessed against the following criteria: Comfort, legibility, permanence and identity in a workshop. Option 1 was discarded due to poor scoring in all for criteria. Option 5 was discarded as it also had poor scoring and was designed to allow for a shorter entrance route from the carpark however NR did not want an additional entrance.

Option 2 was kept despite poor scoring as it was the better NR standard bridge option. Option 3 & 4 were the best scored with option 3 requiring the least amount of beach encroachment. However, it did require an additional entrance. Option 4 had a medium beach encroachment impact and provided the best legibility. Refer to Figure 86 for scoring. NR also requested the review of a variation of option 3 with the staircase on the car park side spiralling around the lift shaft to the car park itself as it would remove the need for an additional entrance.

A second workshop was then held to look into the final three options in greater detail and the variation of option 3. This variation was discarded due to the level differences between platform and car park, increasing the length of the staircase. It was then decided that Option 4 would be the preferred option due to the angled lift shafts and the south-facing staircases which led towards the station building.

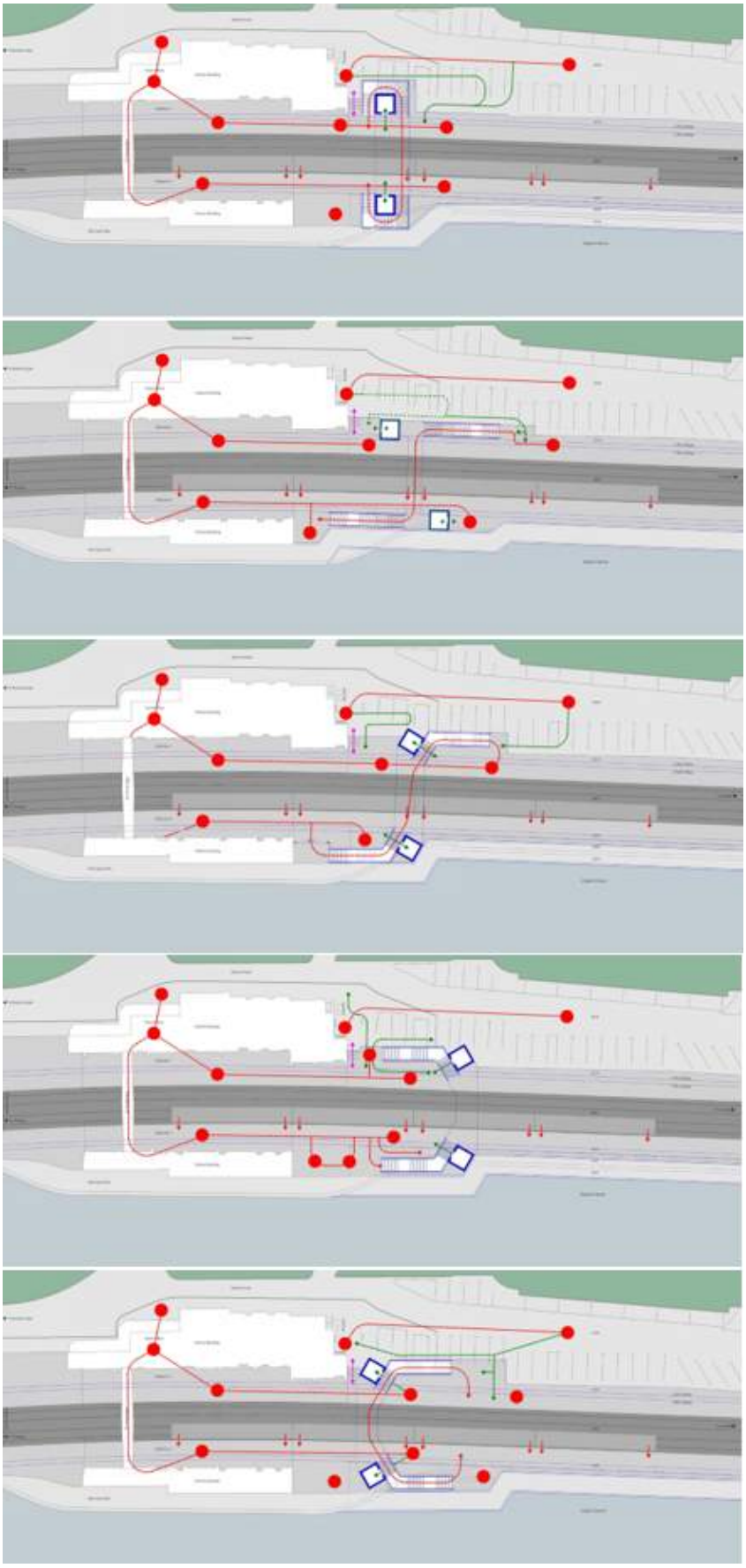


Figure 85 - Five high-level footbridge designs

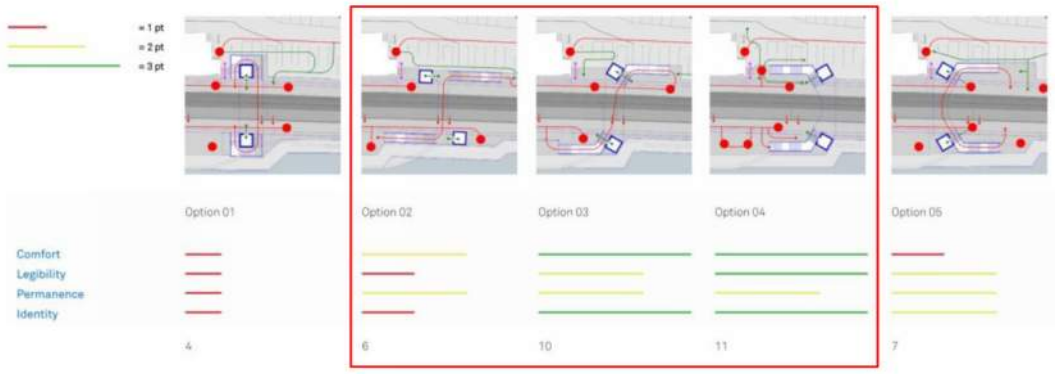



Figure 86 - Footbridge design ranking

## 5.5.2 Structural Optioneering

**Bridge deck material**

Three types of materials were considered for the bridge as part of the optioneering process. Painted carbon steel which was discarded due to the maintenance requirements and the increase tonnage required for sacrificial thickness. Both stainless steel and GRP were considered to have satisfactory structural capabilities for the environment, however immediate cost assessment of the two materials led to the choice of stainless steel.

The main advantages of stainless steel include:

- History of stainless steel used on seafront support the appropriateness of this choice.
    - Available steel grade appropriate given the marine environment (e.g. Utility Duplex Grade 1.4462)
    - Flat finish specification (e.g. bead blasted surface) available to minimise reflectivity and therefore glare.
- Maintenance free (120 years) if material selection and workmanship adequate
- European stainless steel is ~90% recycled content and is a recyclable material

It was also noted that it will be essential to talk to suppliers at early stage to maximise material use efficiency and reduce amount of welding required.

**Lift shaft material**

Both stainless steel and reinforced concrete were considered for the lift shaft material, however the marine condition led to choosing reinforced concrete which provides a better protection against wave loads and water ingress.

## Bridge canopy

Four options were considered for the bridge:

- Fully closed bridge, which was discounted due to the increased maintenance, increased loading capacity required leading to increased costs and bigger visual impact.
- Full open canopy, which was discounted for the same reasons as previously as well as a lack of protection against horizontal wave water.
- Stairs only canopy, which was discounted for the same reasons as previously as well as an unfinished look.
- No canopy, which is the chosen option.

The main advantages of this option are:

- Less maintenance.
- Lower load case.
- Cheaper.
- Better integration with listed building.

Additional aspects considered were that a protected route was available to able customers and staff while the time spent by disabled customers and other lifts users on the footbridge itself would not significant compared to the time spent to access the footbridge / on the platform (passengers therefore dressed for the weather). It was also considered that the station would be closed during major storms.

## Lift size

The chosen bridge layout has adjacent doors lift, where passengers enter and exits lifts at 90degree turn. To facilitate this turn for wheelchair users, and taking into account the touristic aspect of Dawlish leading to a high number of passengers carrying luggage or with a bike) it was judge appropriate to specify 16 person lift minimum.

A ped flow review based on data provided by the ORR (number of entries and exits) and Network Rail (number of passengers booking and/or using the barrow crossing) assessed the proposed lift capacity provision at Dawlish Railway Station. It assessed a 16 person lift on each platform should provide sufficient capacity to serve the predicted lift users at Dawlish Railway Station.

## Lift type

Lift shaft design had to take into account the following:

- use in salty, damp conditions
- the effects of seawater, wind, sun & sand
- a high level of reliability and safety for the users and maintenance staff, etc

Using these criteria, five lift options were assessed including:

- a traction lift, which was not suited to the damp atmosphere it would be exposed to.
- a direct centre acting hydraulic lift, which was vulnerable to inundation by sea water which would compromise its durability
- a direct side acting hydraulic lift, which was discarded due to the maintenance liability of the rams
- an indirect double acting hydraulic lift, which was suitable but was deemed unnecessarily capable, usually dealing with loads of 1600kg+ and,
- an indirect acting hydraulic 'rucksack' lift, which was chosen as the preferred option due to the ease of maintenance and suitability to the angled lift shafts with bi-planar entrances.

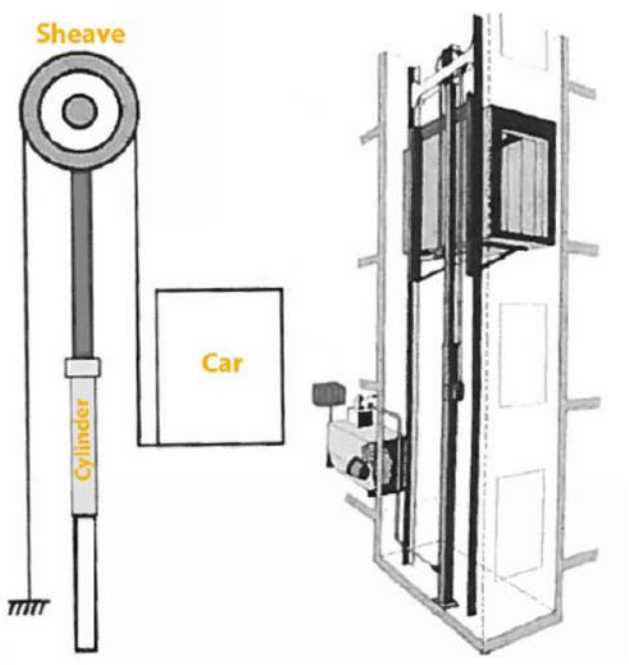



Figure 87 - Chosen lift option: indirect acting hydraulic 'rucksack' lift

## 5.6 Station and platform work

The works are largely driven by the platform gauging requirements and track alignment. Network Rail have commissioned a survey which was received in January 2020 (postdating the optioneering phase of this project). Optioneering of the platform works will be captured as part of the AiP process.

# 6 Constructability

Refer to the buildability report (document reference number: 142630-ARP-REP-EMG-000021) for detailed discussion on construction methodology.

# 7 Safe by Design

Throughout the design process various workshops have taken place to review project related hazards. All hazards from the workshops and those that are made apparent through design have been logged within the CDM Register/Project Hazard Log (142630-ARP-LOG-MPM-000002) along with the proposed mitigation measures.

A HAZID (hazard identification) workshop took place on 1st October 2019 in Arup's Bristol Office. The outcome of this meeting is summarised in the GRIP 3 HAZID Workshop 1 Summary Report (142630-ARP-REP-EMG-000019).

A hazard review meeting was also held on 11th December 2019 to review the risks already recorded against the design. All the mitigations already implemented were recorded and any other required mitigations were taken into account in the design development.

A second HAZID workshop was held by Network Rail with GWR on 8th January 2020. All hazards already in the CDM register were reviewed here and any additional hazards picked up were added to the CDM register.

# 8 Sustainability Considerations

## 8.1 Environmental

Please refer to the following document for environmental consideration:

- Preliminary Ecological Appraisal - 142630-ARP-REP-EEN-000009
- Environmental Water Framework Directive Assessment (WFD) - 142630-ARP-REP-EEN-000010
- Environmental HRA screening - 142630-ARP-REP-EEN-000011
- Carbon Assessment Options Report - 142630-ARP-REP-EEN-000012
- Phase 1 Habitat Survey Report - 142630-ARP-REP-EEN-000013
- Design Site Waste Management Plan - 142630-ARP-REP-EEN-000014
- Design Environmental Management Plan - 142630-ARP-REP-EEN-000015

## 8.2 People and community

During the construction phases large areas of the car parks and sections of the coastal footpath will be closed to the public. The impact of this needs to be considered, especially with regards to the disabled, elderly and children. The public need to be aware of these changes and be provided with information that helps them solve any issues they may encounter.

Whilst measures should be in place to reduce the impacts of the works, the priority will be the works programme. As a result, large changes to the programme or design will not be made in order to improve the public access.

# 9 Conclusions and Recommendations

The preferred option for all sections can be summarised as follows:

- Section A – A continuation of the promenade via a footbridge over the town gateway area, in line with the existing underbridge. There will also be a lower seawall within the existing Dawlish water basin and a rock revetment just offshore from this.
- Section B – This section of promenade will be high-level with a high-level wall between the footbridge at A and section C. There will also be a ramp down to beach level in front of the seawall here.
- Section C will also be a high-level promenade with seawall and will be at the same level as the floor line on the station building façade.
- Section D will consist of a high-level seawall and promenade and will form an extension to the rear of platform 2. As well as this it will create an area for the footing of a new station footbridge close to the station building
- Section E will widen from section D and will consist of a heritage area for the demolished coastguard's building whilst providing access to the coastguard's footbridge
- Section F will remain at high level at the rear of the promenade and will also include one set of stairs down to breakwater level, and another from this level down to the beach (in front of the seawall). This area will be similar to the Marine Parade interface and will form a link to extend the promenade into the next section of beach in the future.

The key risks for the preferred option are presented below in Table 16.

| Risk Issue | Description | Potential mitigation | Owner |
|---|---|---|---|
| **Consents** | | | |
| Listed building consent | From previous NR consultation, we are aware that HE prefer low level promenade | Discussions with HE emphasising protection to building and platforms | NR |
| Marine Works Licence | Process risk, especially if MMO deem that the project needs EIA or a dredging licence | Early consultation with MMO | NR |
| Planning (prior approval) | Potential stakeholder objections | Placemaking enhancements, assessment of impacts on Dawlish Water | Arup/NR |
| Consent packaging | Decision on whether above consents will include full frontage from east end of Marine Parade to section, or only part | Consultation and decision | NR |
| **Design** | | | |
| Design at section A &B | Preferred option for Dawlish basin not yet selected; subject to 3D testing | 3D hydraulic modelling | Arup/HR Wallingford |
| Design at sections B-F | Potential clash of piled wall with buried obstructions | Site investigation | NR/Arup |
| Design Approvals | | GRIP 3 sign off | NR |
| Design at section A | Crest level required for structure around Dawlish basin too high, alternative option required | 3D physical modelling testing | NR |
| **Construction** | | | |
| Impact on beach | Not yet clear how to construct works without major temporary impact on beach | Conduct workshop to review options | NR/Arup/contractor |
| Rail risks | Cranes and other operations close to railway | Conduct workshop to review options | NR/Arup/contractor |
| Weather risks | Construction works during worst weather seasons | Potential extended timing of works through summer season | NR |
| **Costs** | | | |
| Costs | Affordability of project | Cost estimate | NR/contractor |

Table 16 - Preferred option key risks