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Skerries Harbour Pier Wall Upgrade

Options Assessment Report

Fingal County Council

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1 Introduction

1.1 Scope of Work

ByrneLooby has been commissioned by the Fingal County Council (FCC), the Client, to investigate various remediation and replacement options for Skerries Harbour's sheet pile section.

The evaluation considers the Client's functional requirements, current legislative environment, cost, construction programme, and practical considerations to determine the most suitable option.

1.2 Overview

Skerries Harbour, established in the 18th century, uniquely blends historical and modern architectural elements. It incorporates an older masonry section and a newer sheet piled section added around 1968. The pier expands east-to-west from the unique Red Island, providing significant shelter from southerly waves for fishing and leisure craft. However, the current alignment of the harbour exposes fishing vessels moored to northerly waves.

The harbour hosts berthing facilities for small to medium-sized fishing crafts, extending protection to moored fishing and leisure crafts and the harbour road area. The northern slipway provides valuable access to deeper waters for the public and the Royal National Lifeboat Institution (RNLI). On the other hand, the southern slipway is largely utilised by the Skerries Sailing Club and the general public.

The original masonry pier has seen several renovations and extensions since its inception in the 18th century, including the significant addition of the sheet pile section in 1968. This section has contributed to the harbour's current layout, shown in Figure 1-1 and Figure 1-2 below, although it requires urgent attention due to substantial corrosion.

Skerries Harbour is a beacon of maritime history and function, serving the local fishing community and leisure enthusiasts. Its unique design and strategic location extending from Red Island make it a distinct and treasured area feature.

Figure 1-1: Skerries Harbour Aerial (eOcenic, 2023)

Figure 1-2: Skerries Harbour Pier Wall (eOcenic, 2023)

1.2.1 Site Description

Skerries Harbour is located on the east coast of Ireland, north of Dublin, as shown in Figure 1-3.

Figure 1-3: Skerries Harbour Location (Google Earth)

The harbour consists of a Pier and two slipways, as shown in the site layout below in Figure 1-4.

Figure 1-4: Skerries Harbour Site Layout

The water depths at lower tides within the leeward side of the pier wall are limited, with most craft berthed against the masonry section of the pier bottoming out on lower tides, as shown in Figure 1-5 below.

Figure 1-5: Boats Bottoming Out on Low Tide (Source http://surl.li/ibcix)

1.2.2 Masonry Pier

The masonry pier is approximately 70m in length and 5m in width, with a deck level of 3.1m ODM at the berthing face and 3.5m ODM at the masonry wall on the boundary of the northern side of the pier. The sea wall stands 2.5m above the pier deck. The seabed depths alongside this pier section are relatively shallow (MWP, 2022).

Figure 1-6: Masony Stone Pier

1.2.3 Sheet Pile Pier

The original masonry pier merges into a newer sheet piled structure, constructed in 1968 and oriented in a westerly direction. This pier section is approximately 60m long and 9m wide, with a deck level similar to the rest (3.1 to 3.3m ODM). The pier is backed by a reinforced concrete sea wall 3.4m above deck level. While the seabed levels fronting the berthing face on this section are deeper than the Masonry Pier section, at approximately -3.0m ODM, they are still relatively shallow regarding the required depths for the types of craft using the pier.

The sheet piled section of the pier is in poor condition, with some of the sheet pile out-pans corroded through, allowing the stone fill behind to escape. This section requires urgent remediation (MWP, 2022), as shown in Figure 1-7 below.

Figure 1-7: Photo of Sheet pile Corrosion

2 Functional Requirements

The Client has expressed the following functional requirements concerning the sheet pile pier wall remediation or replacement options assessment:

- Pier wall to provide safe berthing for fishing vessels and sailing boats.
- Allow for a maximum vessel size of 18m LOA.
- Access control to allow access for fishermen and authorised personnel only.
- The minimum design life of 50 years.
- No berthing on the seaward side.
- Maintain lighthouse and seawall along the seaward perimeter of the pier wall.
- Maintain the length of the pier wall as a minimum and investigate the potential for a 15m extension.
- Allow for mobile crane loading (TBC) and 30-ton diesel trucks.
- Remedial works on seaward should not impede or interfere with the RNLI channel navigability.

Once the preferred option has been selected, more defined functional requirements will be defined, including surcharge loadings, permitted operations, overtopping and downtime allowances.

3 Basis of Design – Options Assessment

The following has been determined based on the information available at this assessment stage. It is anticipated that additional studies and investigations will be undertaken once the preferred option has been selected.

3.1 Existing Sheet pile Section of Pier

Based on the Structural Assessment Report produced by (MWP, 2022), a typical cross-section indicating the principal elements of the pier structure is shown in Figure 3-1 and summarised below:

- A double wall consisting of Frodingham 3N sheet piles driven into the seabed to an elevation of circa -8.6 to -9m ODM.
- 62mm diameter steel solid bar tie rods at 2.85m c/c, providing tie-back support to the sheet piles at an elevation of circa +2.0m ODM.
- 2no. 225mm back-to-back whalings positioned at the rear face of the sheet pile wall to distribute the sheet pile forces to the tie rods.
- Stone fill between the sheet pile walls.
- Reinforced concrete capping beam encapsulating the top of the sheet piles around the full perimeter of the wall.
- Mooring bollards along the south face are cast into the RC capping beam and tied back via 4no. 22mm diameter bars connected to a 1050mm square x 400mm thick Deadman anchor.
- 175mm to 200mm thick mesh reinforced deck slab, supported on the stone fill material and resting on a corbel in the RC capping beam at each end.

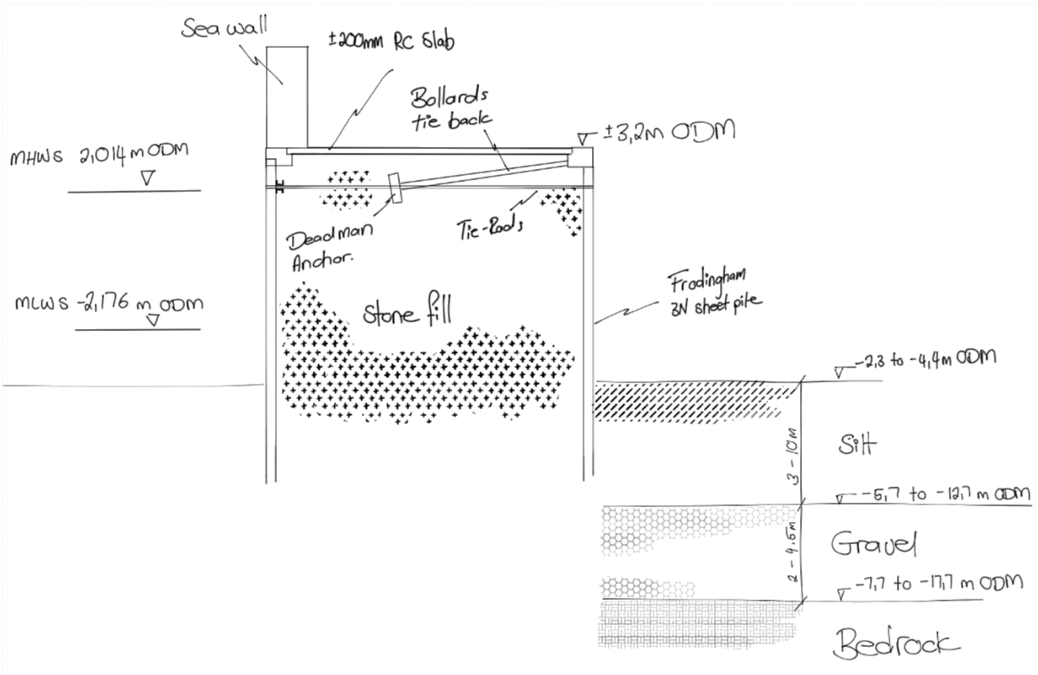

Figure 3-1: Typical Cross Section Through Existing Pier-Based MWP Report (MWP, 2022)

3.2 Design Life

The minimum design life of the remediation or replacement option should be 50 years.

3.3 Datums

3.3.1 Vertical Datum

The vertical datum is meter Ordnance Datum Malin (m ODM), where +0.00m ODM = +2.759m Chart Datum (CD) as per information provided by the Irish Marine Institute.

3.3.2 Horizontal Datum

Unless otherwise stated, all Easting and Northing coordinates will be provided to ITM. The relevant datum parameters are shown in Table 3-1 below.

Table 3-1: Horizontal Datum Parameters

Parameter	Details
Datum	European Terrestrial Reference System (ETRF89)
Projection	Irish Transverse Mercator (ITM)
Central Meridian	8° West
Linear Unit	Meter

3.4 General Levels

The topographical survey in Appendix A offers valuable data regarding the site elevation and contours. Table 3-2 below summarises the site information.

Table 3-2: General Site Levels

Item	Level (m ODM)	Variance (+/-mm)
Seabed (end of the pier)	-4.1	300
Seabed harbour side (interface of sheet pile & stone wall)	-2.3	150
Seabed harbour side (start of the pier)	-1.0	200
Deck level of the pier	+3.2	80
Top of the sea wall	+6.38	10

3.5 Wave Data

3.5.1 Offshore

Offshore measured wave data (significant wave height and mean direction) from a buoy, MD2, was obtained from the Irish Meteorological Service (Met éireann) from 23 February 2011 to 31 December 2022. The latitude and longitude coordinates of the buoy are -5.245° and 53.480°. The data was distributed into an occurrence table with directional and significant wave height bins to show what was measured at the buoy location (refer to Table 3-3 below).

The table indicates that the predominant wave direction measured at the buoy location is from the SSW to SSE sectors, and most waves with a significant wave height of less than 2m. This data can only be applied to Skerries Harbour through wave transformation modelling. The wave refraction and diffraction around the headland must be considered to properly understand the nearshore wave climate at the harbour.

Table 3-3: Occurrence table of measured offshore wave data at buoy MD2

		Directional bins (°TN)																TOTAL
		0	22.5	45	67.5	90	112.5	135	157.5	180	202.5	225	247.5	270	292.5	315	337.5	
H_s (m)		22.5	45	67.5	90	112.5	135	157.5	180	202.5	225	247.5	270	292.5	315	337.5	360	
0	0.5	0.5%	0.8%	1.0%	1.0%	1.1%	1.2%	1.9%	3.0%	1.7%	0.6%	0.3%	0.3%	0.3%	0.2%	0.2%	0.3%	14.4%
0.5	1	2.1%	1.9%	2.0%	1.9%	0.9%	0.7%	1.7%	7.3%	6.2%	2.3%	1.8%	1.5%	1.6%	1.6%	1.3%	1.5%	36.2%
1	1.5	1.0%	0.6%	0.7%	1.0%	0.4%	0.3%	0.6%	3.8%	5.2%	1.7%	1.4%	1.1%	1.2%	1.1%	0.8%	1.1%	21.9%
1.5	2	0.5%	0.3%	0.4%	0.5%	0.2%	0.1%	0.3%	2.3%	3.3%	1.0%	0.8%	0.7%	0.7%	0.5%	0.4%	0.5%	12.7%
2	2.5	0.2%	0.1%	0.1%	0.3%	0.1%	0.1%	0.2%	1.5%	2.6%	0.6%	0.5%	0.5%	0.3%	0.2%	0.2%	0.2%	7.7%
2.5	3	0.1%	0.1%	0.1%	0.2%	0.0%	0.0%	0.1%	0.9%	1.4%	0.3%	0.2%	0.1%	0.1%	0.1%	0.1%	0.1%	3.8%
3	3.5	0.1%	0.1%	0.1%	0.1%	0.0%	0.0%	0.1%	0.6%	0.7%	0.1%	0.1%	0.1%	0.0%	0.0%	0.0%	0.0%	2.1%
3.5	4	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%	0.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.7%
4	4.5	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.3%
4.5	5	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
5	5.5	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
5.5	6	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
6	6.5	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
6.5	7	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
TOTAL		4.5%	3.8%	4.4%	5.1%	2.8%	2.5%	4.9%	19.8%	21.6%	6.6%	5.1%	4.3%	4.1%	3.6%	3.1%	3.8%	100.0%

3.5.2 Nearshore

Nearshore extreme wave data at approximately 5.3km NNW of Skerries Harbour (lat long -6.131; 53.631) was obtained from the Irish Coastal Protection Strategy Study – Phase 3 – Northeast Coast completed by RPS for OPW (May 2011). The 1 in 100-year Annual Recurrence Interval (ARI) significant wave height from a direction within the N to NE sector was 3.8m, with a mean period of 6.9 seconds.

Refer extract from Appendix 4 of their report in Table 3-4 below. Only the N to NE sector wave directions were considered due to Skerries Harbour being relatively sheltered from the directions South of East.

Table 3-4: Extreme wave conditions at point -6.131, 53.631 (lat, long) (RPS, 2011)

Output Point 5 **-6.131002** **53.63104**

	Inshore Climate		
	Hm0	Tm	MWD
1in5	3.629	6.773	23.212
1in20	3.024	6.140	19.798
1in100	2.313	5.407	16.233
1in5	3.788	6.938	44.761
1in20	3.118	6.385	43.340
1in100	2.374	5.495	39.544
1in5	5.226	7.958	67.815
1in20	4.538	7.475	66.868
1in100	3.742	6.868	65.590
1in5	5.061	7.905	86.767
1in20	4.376	7.408	86.655
1in100	3.542	6.783	87.563
1in5	4.362	7.909	101.954
1in20	3.760	7.427	102.977
1in100	3.065	6.822	104.638
1in5	6.829	10.152	107.810
1in20	6.376	9.513	108.595
1in100	5.530	8.855	109.511
1in5	5.175	8.025	123.773
1in20	4.513	7.588	125.176
1in100	3.747	7.065	126.600

3.6 Water Levels

3.6.1 Tides

The tide levels relative to CD were estimated from NP201B, Vol 1B 2021 Admiralty Tide Tables (UK Hydrographic Office) using the secondary port adjustments available for Balbriggan and through correspondence with the Irish Marine Institute.

The tide levels relative to CD and ODM are summarised in Table 3-5 below.

Table 3-5: Tide Data for Skerries Harbour

Tide		Tide level (m CD)	Tide level (m ODM)
Highest Astronomical Tide	HAT	+4.90	+2.587
Mean High Water Springs	MHWS	+4.40	+2.014
Mean High Water Neaps	MHWN	+3.60	+1.205
Mean Low Water Neaps	MLWN	+1.50	-1.184
Mean Low Water Springs	MLWS	+0.70	-2.176
Lowest Astronomical Tide	LAT	-0.10	-2.859

3.6.2 Sea Level Rise (SLR) allowance

To effectively address the escalating concerns regarding rising sea levels, it is recommended to implement an allowance for a steady annual sea level rise (SLR) of 7.2mm/year. This approach is based on the projections outlined in the latest Intergovernmental Panel on Climate Change (IPCC AR6), which investigates various emission scenarios, including the high-emission scenario known as SSP5-8.5.

Based on this report, over the next 50 years, the projected sea level will increase by 360mm (7.2 mm/year x 50 years).

3.6.3 Storm Surge

Extreme water levels for the area near Skerries were extracted from the Irish Coastal Protection Strategy Study – Phase 3 – Northeast Coast completed by RPS for OPW and published in May 2011. The study provides extreme water levels for various annual exceedance probabilities (AEP) based on historic data for several points along the northeast coast of Ireland, considering storm surges and tidal levels. Point 13 is located just over a kilometre northeast of Skerries Harbour at a latitude and longitude of -6.09W, 53.59N, providing the closest available point. The extreme water levels are provided in m ODM, as shown in Table 3-6 below.

Note: an AEP of 1% is equivalent to a 1 in 100-year Annual Recurrence Interval (ARI).

Table 3-6: Extreme water levels near Skerries (RPS, 2011)

Annual Exceedance probability (AEP)	Elevation (m ODM)
5%	+3.07
2%	+3.20
1%	+3.30
0.5%	+3.40
0.1%	+3.63

3.6.4 Design Water Level

The design water level (DWL), based on a 50-year design life, was determined to summate the 1% AEP extreme water level and the anticipated sea level rise. These are presented in Table 3-7 below.

Table 3-7: Design Water Level

ARI (years)	Combination	Extreme Water Level (m ODM)	Sea Level Rise (m)	DWL (m ODM)
100	1:100-year ARI extreme water level + 50-year SLR	+3.30	+0.36	+3.66

3.7 Overtopping

A preliminary assessment of the required seawall height and wave-return wall design, using EurOtop II (2018), based on the limiting overtopping discharges defined in EurOtop II, as shown in Table 3-8 below, has been undertaken.

A mean limiting discharge of 20 l/s/m, applicable for "*significant damage or sinking of larger yachts*", was implemented. The wave conditions and water levels defined in Sections 3.5.2 and 3.6.4 were used as input to calculate the overtopping. It was assumed that the required seawall height wave-return wall is the same across all options for consistency.

Table 3-8: General limits for overtopping for property behind the defence (EurOtop II, 2018)

Hazard type and reason	Mean discharge q (l/s per m)	Max volume V_{max} (l per m)
Significant damage or sinking of larger yachts; H_{m0} > 5 m	>10	>5,000 – 30,000
Significant damage or sinking of larger yachts; H_{m0} = 3-5 m	>20	>5,000 – 30,000
Sinking small boats set 5-10 m from wall; H_{m0} = 3-5 m Damage to larger yachts	>5	>3,000-5,000
Safe for larger yachts; H_{m0} > 5 m	<5	<5,000
Safe for smaller boats set 5-10 m from wall; H_{m0} = 3-5 m	<1	<2,000
Building structure elements; H_{m0} = 1-3 m	≤1	<1,000
Damage to equipment set back 5-10m	≤1	<1,000

During the next stages of design, it will be imperative to use more accurate wave data to optimise the required seawall height and wave-return wall size based on the overtopping assessment for the preferred selected option (from the options assessment).

3.8 Loading

The anticipated maximum loading on the remediation or replaced wall section will be imposed by a mobile crane for vessel launching and retrieval and 30t diesel trucks to fuel fishing boats. These are also currently the largest loading considerations for the existing wall.

The future pier design will consider these loads covered under a uniform surcharge loading and point loads to be confirmed later in the design process. The crane loads (approximately 300kN) are anticipated to govern the sheet pile wall design since the load distribution will sit higher up the wall and directly load the tie rods.

A heavy-duty lifting slab to account for the mobile crane may be required and will be investigated and confirmed at the detailed design stage once the preferred option is selected.

3.9 Design Vessels

ByrneLooby, with input from FCC, has established a range of vessels and sizes based on the anticipated future use of the pier wall. The vessel characteristics are based on design codes AS 3962-2020 and PIANC 149 (Part 1).

The pier wall will be designed to accommodate predominantly inshore commercial and leisure fishing vessels of the size range shown in Table 3-9 below. The vessels' typical length, draft, beam and displacement are also shown in the table below.

Table 3-9: Design Vessel Characteristics

Length	Draft	Beam	Displacement

m	D_v (m)	B (m)	M_D (tonnes)
18.0	4.0	6.0	40
16.0	4.0	5.0	32
12.0	1.8	4.0	12
10.0	1.8	4.0	7
8.0	1.8	3.0	6

3.10 Corrosion Conditions

According to Section 4.4 of EN 1993-5, in areas where the structure is exposed to marine conditions, it is advised to consider a corrosion-induced loss of thickness of 0.02 mm per year. This recommendation applies to piles and sheet piles, whether immersed in freshwater or seawater.

In the case of piles and sheet piles used in seawater, a recommended value for the loss of thickness due to corrosion can be calculated using the following formula.

Corrosion loss = Corrosion rate (mm/year) x Design life (years)

Table 3-10 outlines the project-specific values of loss of thickness for relevant exposure times. These values are extracted from Table 4.2 from EN 1993-5 and will be utilised in designing the preferred option's steel elements, if applicable.

Table 3-10: Loss of Thickness

Required design working life	**5 years**	**25 years**	**50 years**
Sea water in a temperate climate in the zone of high attack (low water and splash zones)	0.55mm	1.9 mm	3.75 mm
Sea water in a temperate climate in the zone of permanent immersion or the intertidal zone	0.25 mm	0.9 mm	1.75 mm

The cathodic protection solution will be determined once the preferred option is selected.

4 Review of Existing Information

4.1 Survey Data

A topographic survey of the pier deck and seawall was conducted in 2012; see Figure 4-1 below. This contains considerable details which would be sufficient for the options assessment stage. However, the survey is more than 10 years old, and the location of services needs to be determined. Therefore, it is recommended that an up-to-date topographical survey be conducted.

This survey indicates the bed level adjacent to the sheet pile wall. However, a more detailed bathymetric survey is recommended before the detailed design of the preferred option is commenced.

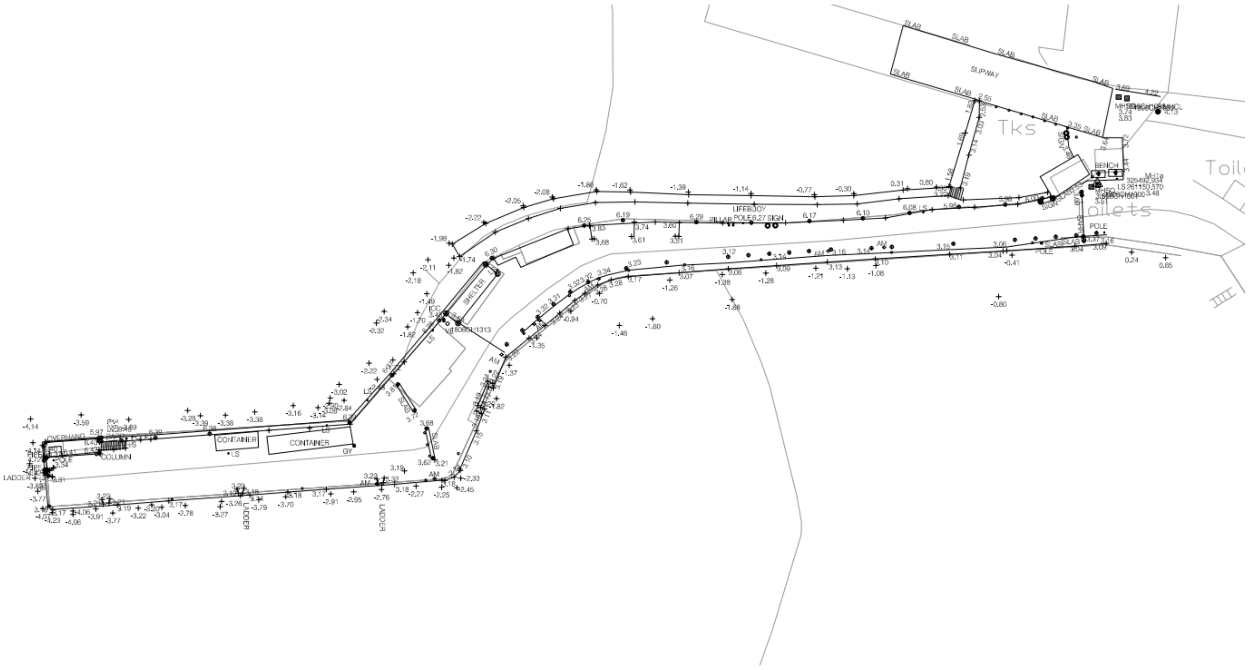

Figure 4-1: Skerries Harbour Survey (2012)

4.2 Geotechnical Characterisation of Soil and Site Conditions

4.2.1 Summary of Previous Site Investigations

During the 1960s, an initial site investigation (SI) was conducted to inform the sheet pile pier extension (ORRJE & CO AB, Matt T Wren, 1964). A plan indicating the borehole location is provided in Figure 4-2 below. The primary objective was determining the bedrock's depth and the overburdened material's engineering properties. The investigation concluded that bedrock sloped away sharply from the existing structure towards the West.

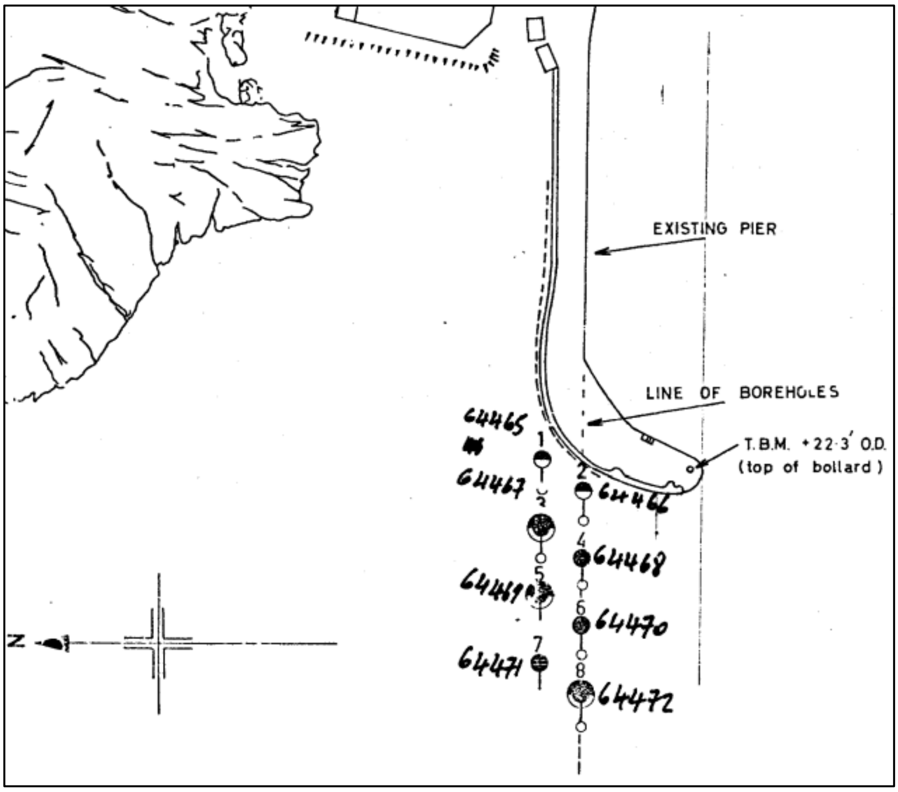

Figure 4-2: Skerries Site Investigation, 28 February 1966

No 4 to 8 indicate that bedrock was found to be overlain by gravel, with a thickness varying between 2.1m - 4.6m, which was not present in boreholes 1 to 4. A layer of clay/silt was found in boreholes 4 to 8 between approximately -3m and -9.1m OD. This layer is overlain by a stiff, gravelly, sandy silt/clay.

Based on the available SI data, Figure 4-3 indicates the envisaged geological long section along the current sheet pile section. It indicates that the bedrock steeply drops off as you progress along the length of the sheet pile section and should be considered for future extension plans and validated with additional SI.

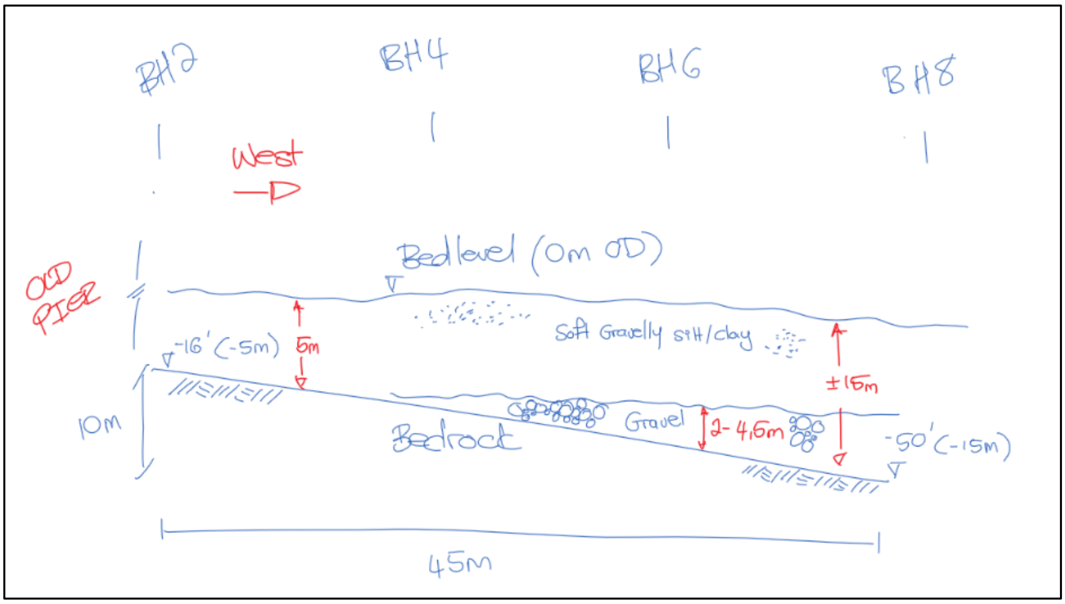

Figure 4-3: Envisaged Geological Long section based on 1960 SI

It is recommended that additional SI study, including boreholes, SPT's testing, and Sample and Core extraction for laboratory testing is recommended if the preferred option requires piling works.

4.3 Visual Inspection

Recent inspection surveys and reports (MWP, 2022), including the Royal Haskoning report from 2005, indicated significant corrosion damage in the upper section of the sheet piled wall. Some sections of the out-pan were completely corroded through, exposing the coarse rock infill.

In December 2021, Norfolk Marine Ltd. conducted a visual inspection and photographic record of the sheet piles, see Figure 4-5. Thickness measurements of the out-pans showed a remaining 6mm to 10mm in the upper zones, with even less thickness between the bed level and MLWS. Full section loss across the out-pan was observed in numerous locations, attributed to Microbial Induced Corrosion (MIC). MIC was more prominently observed along the south face of the pier. However, no significant signs of deterioration, settlement, or distress were observed during the visual inspections of the deck and capping (MWP, 2022).

The core hole investigation conducted in 2021 revealed that the deck slab was supported directly by rock infill material between the sheet piles, see Figure 4-4. There was no observed settlement of the fill material or horizontal wall displacement. The deck slab was also supported on the sheet pile capping beam corbel. Some localised voiding was observed within some holes but did not cause voiding under the deck slab. It was noted that the deck slab support disguises additional voiding.

Figure 4-4: Fill Material Core Hole 1 (Norfolk Marine Ltd, 2021)

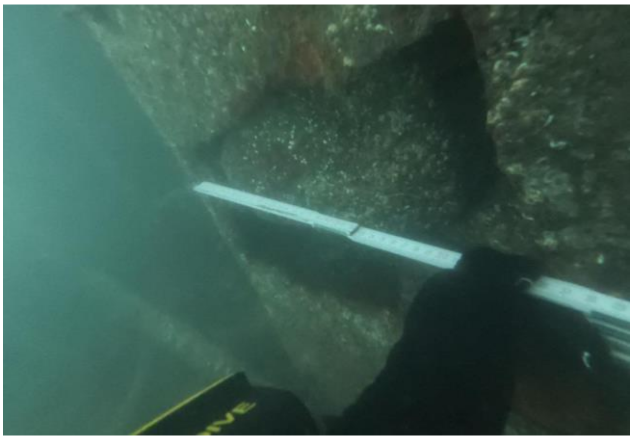

Figure 4-5: Hole at Outpan No.95 – Note large stone fill (Norfolk Marine Ltd, 2021)

5 Gap Analysis

Additional studies and investigations are potentially required during the next project stage. The confirmed list will depend on the preferred option selected.

1. **Geotechnical Investigation:** This investigation aims to evaluate the physical properties of the soil and rock upon which the sheet pile wall is built or will be built. It involves drilling boreholes, sampling, and conducting laboratory tests to determine soil classification, shear strength, compressibility, permeability, and potential reactivity. This information is essential for design decisions related to the construction or remediation of the new wall.
2. **Topographic Survey:** This survey provides a detailed and accurate representation of the site's physical features, including surface contours, location of services and utilities, and other physical entities that could influence the proposed work. This information will aid in avoiding potential conflicts during construction or remediation.
3. **Bathymetric Survey:** If the sheet pile wall is near or under a water body, a bathymetric survey is performed to map the depth and contours of the seabed. This survey is critical to understanding the underwater topography and defining the depth to which the sheet pile should extend.
4. **Hydrodynamic Modelling:** Using MIKE DHI software to simulate and predict water levels, wave actions, and currents in the nearby water body. These predictions are crucial to designing the new wall to withstand hydrodynamic forces and the effects of potential erosion, scour and sea level rise.
5. **Load Testing:** This process involves applying controlled loads to the existing pier to assess its structural integrity and safe working load. It helps to evaluate whether the pier can support the loads imposed during the remediation or replacement of the sheet pile wall.
6. **Durability and Corrosion Assessment:** Considering the accelerated corrosion at the site to date, assessing corrosive elements in the environment (like salt content in seawater) can provide an understanding of how these factors may affect the sheet pile wall over time.
7. **Risk Assessment:** This comprehensive assessment identifies potential risks in the project (both in the construction and operation phases), the probability of their occurrence, and their potential impact, and proposes mitigating measures.
8. **Archaeological Survey:** Considering the historic nature of the project, an archaeological survey may be necessary to avoid damaging any potential archaeological artefacts during construction.

6 Statutory Considerations

6.1 Planning Considerations

Planning on the Foreshore is a complex process with numerous potential considerations and requirements. The following section outlines various planning requirements, which we recommend are discussed with the FCC Planning Department to identify the most probable route based on the selected option.

Figure 6-1 below illustrates the potential planning routes that may be relevant for replacing the Skerries Harbour pier wall.

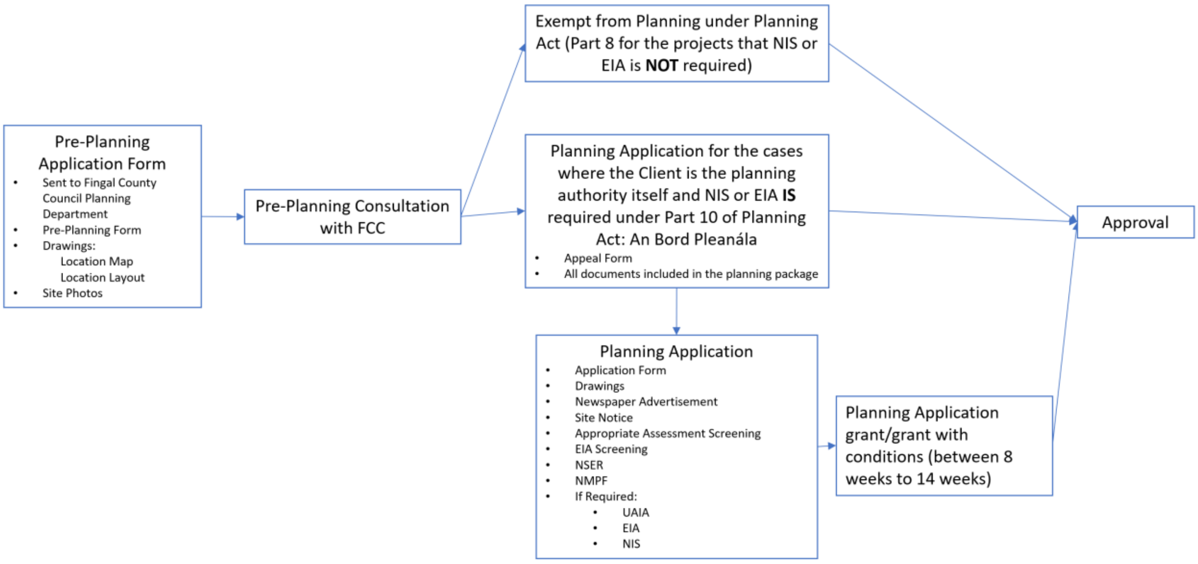

Figure 6-1: Planning Considerations

6.1.1 Part 8 of the Planning and Development Regulations

Where a Local Authority that is a planning authority proposes to carry out development, or development belonging to a class of development prescribed in Article 80 of the Planning and Development Regulations (PDR) 2001 to 2022, then it may do so per Part 8 which relates to requirements in respect of specified development by, on behalf of, or in partnership with Local Authorities.

Article 80 of the PDR describes the classes of development prescribed for Section 179 of the Planning and Development Act (PDA). The nature of this Project is not explicitly listed. Therefore, the Skerries Harbour improvements closest related to the description under sub-article 80 (1) (k), where it is stated that 'any development other than those specified in paragraphs (a) to (j), the estimated cost of which exceeds €126,000, not being development consisting of the laying underground of sewers, mains, pipes or other apparatus'.

Part 8 planning route cannot be followed where Stage 2 Appropriate Assessment (AA) or Environmental Impact Assessment (EIA) is required. The Local Authority must follow a Part 10 Application to An Bord Pleanála (the Board), as outlined below.

Given the proximity of Natura 2000 designated sites to the proposed development, it is anticipated that, as a minimum, undertake an Appropriate Assessment screening for the proposal (refer to Section 6.1.3). If required, a Natura Impact Statement may need to be prepared. If this is the case and Fingal County Council is the agency, it will be necessary to obtain planning approval from An Bord Pleanála.

On the other hand, part 8, Section 11 of the Planning and Development Act 2011 relates to the Strategic Infrastructure Development (SID) application procedures for An Bord Pleanála. These applications typically involve large-scale infrastructural developments of strategic economic or social importance to the State or a region.

The specific permission requirements for building a new pier at Skerries Harbour will depend on factors such as the scale of the project, its potential environmental impacts, and its potential effects on local heritage or conservation areas. If the project is considered strategically important, an application to An Bord Pleanála may be required. Otherwise, if it is considered a development of the local authority, Part 8 could potentially apply.

However, it is important to note that there are exceptions to this process. For example, a local authority may not have to go through the Part 8 process for emergency works or certain minor works under certain conditions. In the case of a new pier at Skerries Harbour, the application of Part 8 would depend on factors such as the scale and nature of the proposed development and the specific local circumstances. This is to be discussed with the Fingal Council Council's Planning Department.

Here is a general outline of how the process works:

- The local authority prepares a description of the proposed development, a plan of the site, and an assessment of any potential significant effects on the environment.
- The local authority puts this information on public display for at least four weeks and publishes a notice in a local newspaper. The notice invites submissions or observations on the proposed development, which must be submitted in writing within a specified time frame (generally four weeks from when the information is displayed).
- The local authority considers any submissions or observations received during this time before deciding whether to proceed with the proposed development.
- If the local authority decides to proceed, it is required to publish a notice of this decision.

6.1.2 Part 10 of the Planning and Development Regulations

Part 10 is a local authority's application to the Board to approve a proposed development to which section 175 of the PDA applies. Section 175 of the PDA refers to development where an EIA is required for Local Authority Developments.

The PDA identifies certain types and scales of development, generally based on thresholds of scale, for which an EIA is mandatory. Developments requiring an EIA are subject to Part X of the PDA and Part XI of the Act.

With respect to the Skerries Harbour, relevant criteria set out in Schedule 5, Part 2, include:

Section 10 (f): New or extended harbours and port installations, including fishing harbours, not included in Part 1 of this Schedule, where the area, or additional area, of water, enclosed would be 20 hectares or more, or which would involve the reclamation of 5 hectares or more of land, or which would involve the construction of additional piers exceeding 500 metres in length.

Section 12(b): Seawater marinas where the number of berths would exceed 300 and freshwater marinas where the number of berths would exceed 100.

Those conditions highlighted above are irrelevant to the Skerries Harbour improvements, as the proposal is for only the remediation of an existing harbour. Therefore, the Project is subject to Schedule 7 for the assessment of a sub-threshold development, as outlined in Section 15 of Schedule 5:

Any project listed in this Part that does not exceed a quantity, area or other limit specified in this Part in respect of the relevant class of development but which would be likely to have significant effects on the environment, having regard to the criteria set out in Schedule 7.

Schedule 7 of the PDR identifies the criteria for determining if a sub-threshold development (as identified in Schedule 5) will require an EIAR. This review is conducted as part of an Environmental Impact Assessment Screening Report.

When an EIA is required for development, the Local Authority applies to the Board for approval of the proposed development.

6.1.3 Appropriate Assessment

The requirements for Appropriate Assessment (AA) are outlined under the Habitats Directive (92/43/EEC) and the associated Birds Directive (2009/147/EC), which are transposed into Irish legislation by Part XAB of the 2000 Act and the Birds and Natural Habitats Regulations 2011. The legislative provisions for AA screening for planning applications are in Section 177U of the 2000 Act.

The intention of AA is to outline any possible impacts on identified Natura 2000 sites under the Habitats Directive. Natura 2000 is a network of important ecological sites. These are Special Areas of Conservation (SACs) designated under the Habitats Directive and Special Protection Areas (SPAs) designated under the Conservation of Wild Birds Directive (79/409/ECC) as codified by Directive 2009/147/EC.

Relevant to Skerries Harbour and the broader Fingal County Council, a new SPA (North-West Irish Sea cSPA 004236) was established in July 2023. The extent of the area is shown in the below figure:

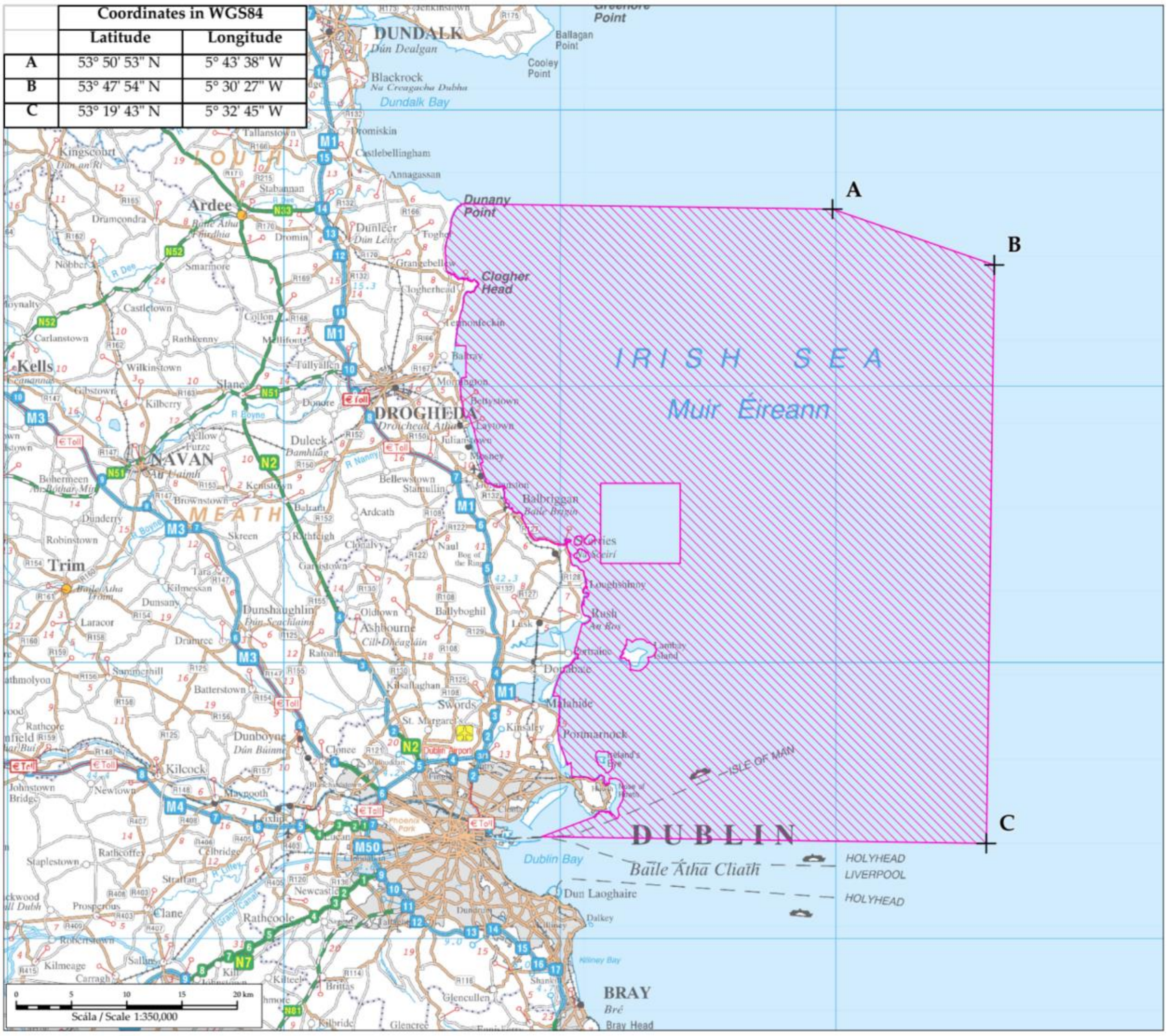

Figure 6-2: North-west Irish Sea SPAc (004236)

Articles 6(3) and 6(4) of the Habitats Directive set out the decision-making tests for plans and projects likely to have a significant effect on or to adversely affect the integrity of European Sites (Annex 1.1). Article 6(3) establishes the requirement for AA:

"Any plan or project not directly connected with or necessary to the management of the [European] site but likely to have a significant effect thereon, either individually or in combination with other plans or projects, shall be subjected to appropriate assessment of its implications for the site in view of the site's conservation objectives. In light of the conclusions of the assessment of the implications for the site and subject to the provisions of paragraph 4, the competent national authorities shall agree to the plan or project only after having ascertained that it will not adversely affect the integrity of the site concerned and, if appropriate, after having obtained the opinion of the general public."

Section 42 (1) of S.I. No. 477 of 2011, the European Communities (Birds and Natural Habitats) Regulations 2011 states:

"A screening for Appropriate Assessment of a plan or project for which an application for consent is received, or which a public authority wishes to undertake or adopt, and which is not directly connected with or necessary to the management of the site as a European Site, shall be carried out by the public authority to assess, in view of best scientific knowledge and view of the conservation objectives of the site, if that plan or project, individually or in combination with other plans or projects is likely to have a significant effect on the European site."

Where the screening process cannot exclude the possibility that a plan or project, individually or in combination with other plans or projects, could have a significant effect on a European site, there is a requirement under Article 42 (9) of these Regulations for the preparation of a Natura Impact Statement (NIS) to inform the AA process.

Where an AA is necessary, the Local Authority applies to the Board for approval of the proposed development.

At a minimum, it is recommended that an AA Screening be undertaken before submitting any planning applications.

6.1.4 Environmental Impact Assessments

The 2014 Environmental Impact Assessment (EIA) Directive (2014/52/EU) relates to assessing the effects of certain public and private projects on the environment. It applies to many projects listed in Annex I and II of the Directive. Article 4(2) and Annex II of the EIA Directive address projects that do not reach the thresholds established in Annex I and state that "Member States shall determine whether the project shall be made subject to an assessment". This is determined on a case-by-case examination or by thresholds or criteria set by the Member State. These requirements are transposed into Irish Law and included in the Planning and Development Regulations 2001(as amended).

EIA Screening is deciding whether a development requires an EIA, using a set of criteria in Schedule 5 of the Planning and Development Regulations 2001. The mandatory requirement for an EIA is generally based on the nature or scale of a proposed development. Where no mandatory requirement is concluded, screening advances to Sub-Threshold Development Assessment, where the Competent Authority evaluates whether the project is likely to significantly affect the environment concerning its scale, nature, location and context. This is established using a set of criteria outlined in Schedule 7 of the Planning and Development Regulations 2001.

To establish whether a proposed development requires an EIA (either mandatory or sub-threshold), a review against those mentioned above mandatory and sub-threshold criteria is required as part of a screening exercise endorsed by the Competent Authority.

Currently, the Project does not meet the thresholds set out in Schedule 5 for a mandatory EIAR and is unlikely to be considered to have significant environmental effects to warrant a sub-threshold EIA; however, this will need confirmation through an EIA Screening Report.

6.1.5 Foreshore Lease

A foreshore lease will be required to replace the new pier construction occupying an area of Foreshore (below the high water mark of ordinary tides).

Foreshore licenses and Marine Area Consents (MACs) are now reviewed and granted by the new state agency, Maritime Area Regulatory Authority (MARA), established in July 2023. MARA's functions are set out in the Maritime Area Planning Acts 2021 and 2022 and have a key role in the new streamlined consenting system for the maritime area. The requirements for a foreshore license or MAC are unclear at this stage; therefore, we have shown both application routes below. Since this is a new agency, the timelines to process and grant permissions are also unknown. Submitting a pre-application consultation request for a MAC and awaiting feedback on the appropriate route is recommended.

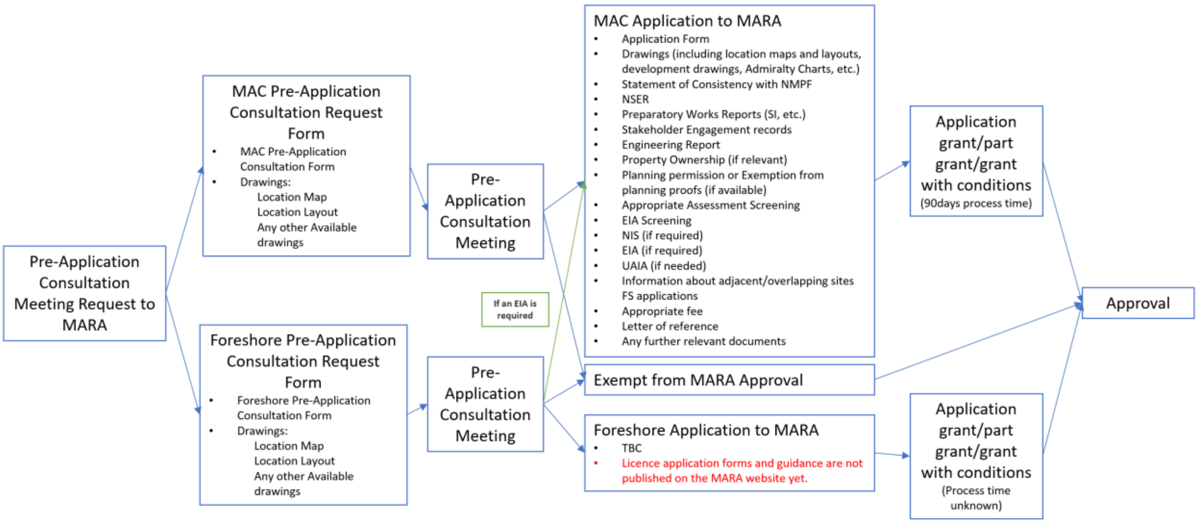

Figure 6-3: Foreshore Application Route

7 Stakeholder Engagement

Thorough and active stakeholder engagement is of utmost importance to any successful project. Recognising this, we have conducted a comprehensive stakeholder analysis, enabling us to identify and understand the diverse stakeholders involved in upgrading the Skerries Harbour pier wall. The findings of this analysis are visually represented in Figure 7-1.

Figure 7-1 presents our initial stakeholder analysis. We understand that the stakeholder landscape can evolve as the project progresses. Thus, we are committed to refining this analysis, maintaining transparent and regular communication with all stakeholders, and fostering collaboration and mutual respect. This ongoing dialogue will be pivotal in achieving the project's objectives and ensuring its success as the project progresses.

The stakeholders' importance and interest in the project were assessed by considering their direct or indirect involvement, influence, potential impact, and expressed or expected interest. Based on their interest level and importance, stakeholders were plotted in Figure 7-1, resulting in a visual representation that will guide our engagement strategy. This visual will be updated as the project progresses and information from stakeholders is available.

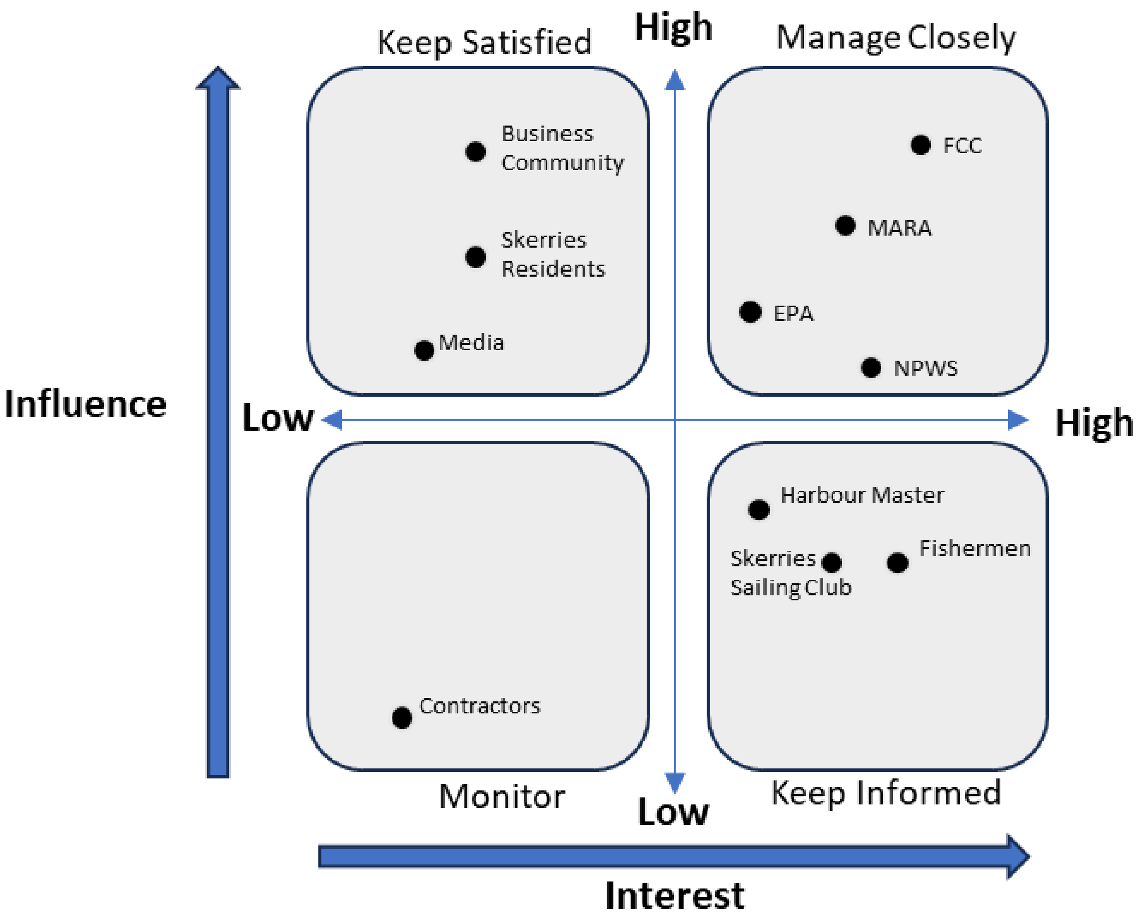

Figure 7-1: Skerries Harbour Stakeholder Analysis

Table 7-1 outlines the specific stakeholders involved, the objectives set for each engagement, and the outcomes achieved.

Table 7-1: Skerries Harbour Stakeholder Engagement History

Stakeholder	Importance	Interest	Rank
Fingal County Council	As the Client and decision-maker, their importance is high. They have the authority over the project budget and scope. Establish clear communication and ensure alignment on project scope and timelines.	High interest in ensuring the project is completed successfully, on time and within budget.	High
Regulatory Bodies (EPA, NPWS, MARA, Planning)	High importance. They enforce laws and regulations the project must comply with. Understand and ensure compliance with regulations. Discuss environmental and heritage concerns and incorporate their input where possible.	Moderate interest. Their primary concern is compliance with regulations rather than the project outcomes.	High
Residents of Skerries	High importance, as they are directly affected by construction activities and will benefit from the improved infrastructure. Inform about the project, address concerns, and manage expectations about construction activities.	High interest due to the potential impact on their daily lives and the local environment.	High
Business Community	High importance. The project could impact their operations temporarily but could benefit them in the long term.	High interest. Construction activities may disrupt their business, but the upgrade could attract more customers.	High
Harbour Users (Fishermen and Sailing Club)	High importance. They use the facilities and would be directly affected by the improvements. Understand their needs and concerns to ensure the upgraded pier wall serves their needs.	High interest, as the upgrade could affect their activities during construction and benefit them afterwards and therefore want to provide input.	High
Contractors / Subcontractors	Low importance at this stage. They execute the project and are responsible for its successful completion; however, their level of importance will increase as the preferred option is selected.	Low interest at this stage. The project provides them with business, and its success impacts their reputation.	Low
Design Consultants and Engineers	High importance. They design the upgrade and advise on technical matters.	High interest, as the project's success is directly tied to their work.	High
Media	Moderate importance. They provide necessary financial resources.	Moderate importance. They are interested in informing the public.	Medium

Tourists and Visitors	Low importance. They provide necessary financial resources. Manage expectations regarding access during construction.	Low interest, as they may not be directly affected by the construction but could benefit from the upgrades.	Low

Once the preferred option is selected, meetings will be held with each relevant stakeholder to obtain further information to advance the design aspects and programme to deliver the project.

8 Options Appraisal

8.1 Introduction

The following section evaluates the remedial and/or replacement works proposed for the sheet pile section of the Skerries Harbour upgrades. This appraisal aims to assess different options based on their feasibility, effectiveness, cost, and environmental impact, among other factors.

The Skerries Harbour is a vital infrastructure component in facilitating maritime activities in the region. However, due to the passage of time, natural wear and tear, and changing environmental conditions, the pier wall requires attention to ensure its structural integrity, safety, and functionality. In this appraisal, we identified several options, each addressing the specific needs and challenges of the Skerries pier wall. These options encompass a range of potential interventions, from minimal intervention) to more comprehensive approaches involving various construction techniques listed below:

- **Option 1 - Do Nothing**
- **Option 2a – Remediation (Steel Plates)**
- **Option 2b – Remediation (Concrete Façade)**
- **Option 3 – Gravity Block Wall**
- **Option 4a – Conventional Sheet Pile**
- **Option 4.1a – Conventional Sheet pile with a 15m extension at the head of the pier**
- **Option 4b – Encapsulation Sheet pile**
- **Option 4.1b - Encapsulation Sheet pile with a 15m extension at the head of the pier**
- **Option 4c – Sheet Pile and Rock Revetment**

Technical feasibility, cost-effectiveness and sustainability will be evaluated throughout the appraisal process. By carefully assessing each option, ByrneLooby aimed to determine the most suitable course of action to ensure the remediated Skerries Pier wall's long-term stability, resilience, and functionality.

Note that this Options Appraisal is a preliminary assessment and will serve as a basis for further discussions, studies, and consultations with relevant stakeholders. The ultimate decision regarding the chosen option will be based on a comprehensive analysis of all relevant information, including technical specifications, environmental assessments, financial considerations, and community feedback.

8.2 Option 1 – Do Nothing

The "Do Nothing" approach refers to the decision not to take any action to remediate the sheet pile wall. This approach would require heavily restrictive operational conditions to facilitate the use of the pier, such as:

1. The berthing of fishing vessels alongside the pier should be strictly limited to loading/unloading operations. Once these operations are completed, vessels should be relocated away from the pier.
2. Restricted vessel types: Limiting the types of vessels allowed to berth alongside the wall to those with a lower draft or lighter loads. This restriction aims to minimise the impact of larger, heavier vessels on the deteriorated structure and reduce the risk of further damage.
3. Load restrictions: Enforcing strict load limitations on the pier to prevent excessive weight from being placed on the wall. This could involve restricting the maximum weight of cargo, vehicles, and equipment that can be transported onto the pier.
4. Limited operational seasons: Introducing seasonal restrictions on the use of the pier to avoid periods of harsh weather conditions or high-water levels that could exacerbate the degradation of the wall. This may involve closing the pier during certain months or specific weather events (threshold to be determined with a mooring assessment).
5. Enhanced monitoring and surveillance: Implementing a comprehensive monitoring and surveillance system to monitor the condition of the wall continuously. This could include the installation of sensors, cameras, or other monitoring equipment at crucial points on the structure to accurately determine its position, elevation, and vertical alignment to detect any signs of movement, deterioration, or stress on the structure.

This passive approach ignores the existing challenges and does not address the detrimental effects of the environment on the wall's integrity or address the risk of structural failure, loss of life, and loss of revenue. The wall is left vulnerable to large-scale corrosion by choosing to do nothing, which can significantly compromise its strength over time.

Opting for this approach increases the risk of structural failure, and it is strongly recommended not to follow it.

By neglecting remediation, the wall will not achieve safe usage, posing a significant risk of collapse, especially during storms or adverse conditions in the coming years. Taking proactive measures to address the challenges and implement appropriate remediation methods is essential to ensure the wall's stability, safety, and functionality.

Also, considering that the section of the sheet pile wall is currently closed based on the recommendation of another consultant, remediation or replacement is recommended.

8.3 Option 2a – Remediation (Steel Plates)

8.3.1 Introduction

Option 2a proposes to strengthen the sheet piles by welding plates to the outer pans of the sheets, as detailed in Figure 8-1. This method provides limited improvements to the structural integrity and residual factors of safety, which may mitigate the potential for disproportionate failure. However, various engineering uncertainties present themselves when considering this solution, and accurate estimation of safe working capacity will remain uncertain. This option considers the strategic reinforcing of critical areas of the sheet pile pier. It aims to withstand the forces exerted by the marine environment and maintain the stability of the pier. The remediation process involves a fair amount of disturbance to the existing sheet pile sections and the surrounding pier structure, as all sheet piles will need to be cleaned and surfaces prepared for the welding of plates. Additionally, suitable remaining wall thickness would be needed to weld the plate to the in and out pans.

It should be noted that this option does not address potential corrosion issues, which may present a few meters below the seabed, which is an issue given the identified accelerated low-water corrosion issues.

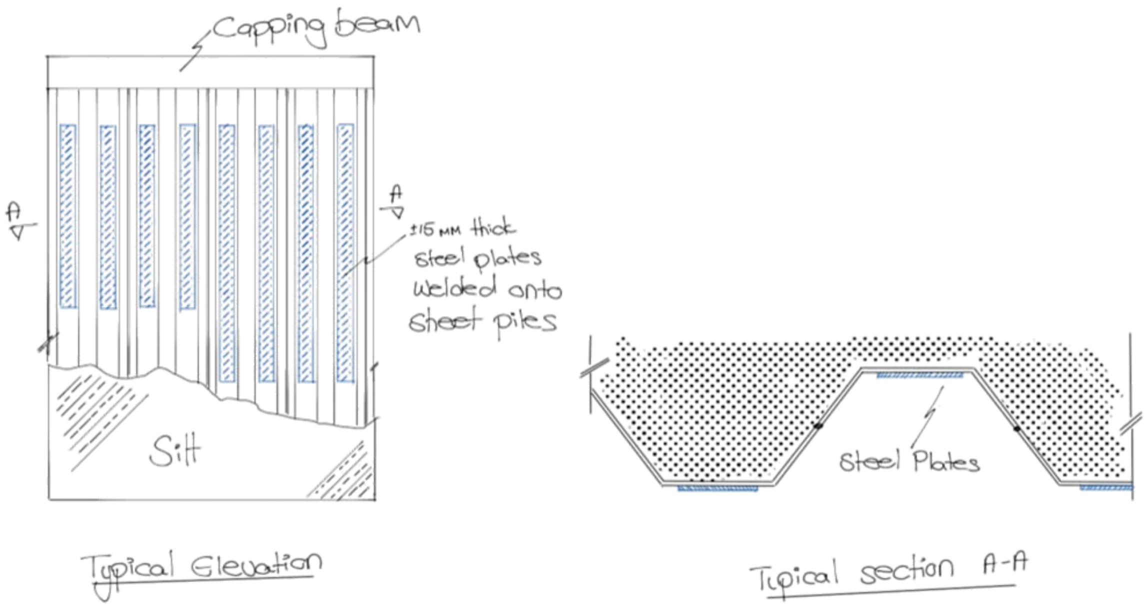

Figure 8-1: Sketch of Steel Plates Remediation

8.3.2 Performance

8.3.2.1 Design Life

Option 2a remediation option aims to achieve 1 to 5 years of design life extension, dependent on the frequency of maintenance/inspections, prompt repairs (if required), environmental conditions since installation and the successful management of the risks. Regular maintenance and inspections play a vital role in achieving 5-year remediation by enabling early detection of deterioration, damage, or structural weaknesses. This option will also require large-scale ultrasonic testing to give FCC a detailed map of the remaining section thicknesses to inform the maintenance plan. A well-structured maintenance program should include routine visual inspections to monitor the wall's condition, allowing for the identification of visible signs of corrosion, cracking, or deformation. Protection against corrosion is crucial to enhancing the durability of the steel plates. The selected steel to be welded to the sheet pile must be the same material composition as bi-metallic corrosion, accelerating corrosion with this repair. Furthermore, applying coatings or treatments after the weld is complete, such as epoxy or zinc-based coatings, onto the plates and, potentially, the surrounding sheet pile wall can provide additional protection against corrosion.

8.3.2.2 Structural Integrity

While a comprehensive maintenance and inspection program mitigates risks, it is important to acknowledge the marine environment's inherent challenges. Factors such as tidal variations, wave actions, and marine fouling exacerbate the potential for failure of the sheet pile structure. Moreover, the operational conditions of the wall influence its serviceability as the attached plates have a limited effect on increasing the loading capacity. Moreover, there is no possible way to understand the degree of 'strengthening' these plates provide. Therefore, fully understanding the load capacity of the structure is not possible. Therefore, load limitations would likely also need to be applied to compensate for the uncertainty. These operational restrictions must be determined during the next stages if this option is selected.

8.3.2.3 Overtopping

Overtopping allowances will remain the same due to the existing seawall. However, they may not be suitable according to current standards and recommendations.

8.3.3 Constructability

This construction takes into account several new considerations. These include the constraints of tidal conditions, potential unknowns regarding the steel's deterioration, the complexity of working with different steel types, the necessity of thorough steel preparation before welding, the challenges presented by vertical in-situ welds from a quality assurance/control perspective, the probable need for suspended access for reaching upper wall sections, and the likely necessity to remove the capping to fill and compact any voids properly.

It also encompasses two separate components: the reinforcement and restoration aspects. The reinforcement involves enhancing the structural integrity by welding additional plates to the outer pans of the sheet piles. This process must be carefully scheduled around tidal conditions to ensure safety and effectiveness. Furthermore, working with different steel types may present complexities, making the expertise and training of the welders crucial. Each steel area designated for welding must be meticulously cleaned and prepared, adding another layer to the process.

The repair process could involve vertical in-situ welds, which can be challenging from a quality assurance/control perspective. This necessitates rigorous inspection and monitoring protocols to ensure the quality and accuracy of the welds. Moreover, it is important to consider that unknown steel deterioration may pose unexpected challenges during the repair process, requiring flexibility and contingency planning.

The second aspect of the repair process is restoration, which addresses issues such as corrosion, damage, or voids by identifying and attending to specific areas within the sheet pile wall. These areas are to be thoroughly assessed to determine the extent of the repair needed. To reach the upper portions of the wall, it is likely that suspended access equipment will be required, requiring careful planning and heightened safety measures.

Patch repairs are then performed to restore the functionality and integrity of the pier. This can involve welding steel plates to the affected sections, addressing corrosion or damage, and filling voids with suitable backfill material. It is worth noting that to fill and compact the voids properly, it might be necessary to open the capping of the sheet piles.

By addressing these issues, the repair works aim to mitigate further deterioration, ensure the structural stability of the pier, and maintain the pier's safety. The installation process, while straightforward, will necessitate careful planning around tidal windows and potential disruptions, with a realistic and flexible project timeline being paramount. The duration of construction will depend on the extent of patch repairs required along the length of the pier wall and the availability of contractors.

8.3.4 Summary

The drawbacks of this approach outweigh its advantages. While installing steel plates can temporarily strengthen the sheet pile wall, it falls short of providing a long-term, sustainable remediation strategy.

One of the major concerns is the temporary nature of the steel plate remediation. While they temporarily enhance the load-carrying capacity and stability of the wall, they do not address the underlying causes of deterioration. Further attention and maintenance will be required, resulting in additional costs and disruptions to pier operations.

Moreover, the cost implications associated with this option should not be overlooked. Considering the relatively short serviceability life of 1-5 years, it becomes clear that this option does not provide the desired long-term durability as required by the functional requirements (50-year design life extension – refer to Section 2).

In conclusion, Option 2a is being screened out for further consideration in the options appraisal since it falls short of providing a long-term sustainable remediation strategy with high CAPEX and ongoing OPEX costs and maintenance required.

8.4 Option 2b – Remediation (Concrete Façade)

8.4.1 Introduction

This remediation option for a sheet pile pier involves the formulation of a concrete façade installed on the existing pier surface. The primary goal of this remediation process is to establish an impermeable layer around the current structure, serving as a protective barrier against detrimental environmental influences. By implementing a concrete façade, the remediated pier achieves increased corrosion resistance, effectively obstructing the infiltration of moisture and corrosive elements into the underlying sheet pile structure.

The structural façade will laterally restrain the pier, improve the sheet pile stiffness, and be reinforced and bonded to the existing sheet pile through shear lugs welded to the sheet pile. The façade will extend below the seabed level to where the additional stiffness is no longer required.

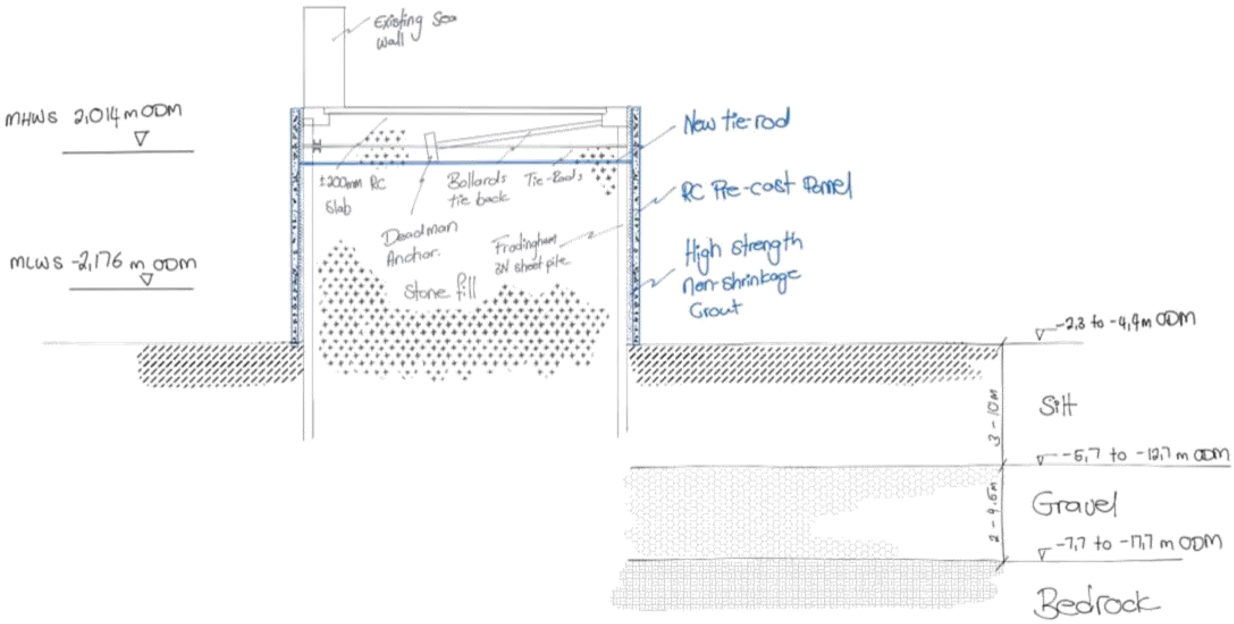

Figure 8-2: Sketch of Concrete Façade Remediation

8.4.2 Performance

8.4.2.1 Design Life

The design life of the remediated pier with a concrete façade can vary depending on the structural condition of the existing pier. Typically, the expected design life of the concrete façade option ranges between 10 to 15 years. Regular monitoring, maintenance, and timely interventions are essential to maximising the longevity of the concrete façade and ensuring its continued performance. The poor condition of the current sheet pile is a determining factor in the design life of the concrete façade as a remediation option.

It is crucial to implement a comprehensive maintenance/monitoring program to detect any excessive deflections, deformations, or movement of the structure during and after the installation of the concrete façade. Timely repairs and interventions are necessary to address any identified issues promptly. Neglecting proper maintenance and inspections can lead to accelerated deterioration.

During the following stage, a comprehensive analysis of the operational conditions should be conducted, including berthing and mooring forces, dynamic effects, and maintenance considerations. This analysis ensures that the design of the concrete façade and the overall remediated wall adequately addresses the operational requirements and remains serviceable throughout its intended design life.

8.4.2.2 Overtopping

Overtopping allowances will remain the same due to the existing seawall. However, they may not be suitable according to current standards and recommendations.

8.4.3 Constructability

The initial phase of implementing this construction option involves preparing the existing sheet pile elements. This preparation includes cleaning the surface to eliminate debris, marine growth, and loose materials. Repair or stabilisation measures may be necessary to establish a sturdy foundation for the concrete panels in cases of significant deterioration or damage. The concrete panels for the façade are typically precast off-site and can be customised in size, shape, and reinforcement, depending on the design specifications.

Once the concrete panels are ready, they are transported to the project site and lifted into position. This is typically done using heavy lifting equipment such as cranes or specialised lifting mechanisms. Careful coordination and precision are required during the lifting process to ensure the accurate and safe placement of the panels onto the existing wall. Once the panels are in position, they are fixed and connected to the sheet pile wall with anchor bolts, dowels, or welded connections. These connections provide stability and ensure that the panels remain securely attached to the existing pier, with an example depicted in Figure 8-3. To enhance the waterproofing and durability of the concrete façade, joints between the panels are sealed with specialised sealants or elastomeric compounds. Once the concrete panels are securely attached to the sheet pile wall, the next step involves filling the voids or gaps in the in-pans of the sheets with special non-shrink grout designed for underwater placement. The remaining steps include reinstating removed deck sections and installing a new coping beam structure. These steps aim to achieve an outcome similar to the right section depicted in Figure 8-3, which shows an example of the completed works performed in Castletownbere Co. Cork.

Figure 8-3: Concrete Panel being Installed (Left) and Finished panelling and Capping Beam (Right)

8.4.4 Cost

The estimated capital expenditure (CAPEX) for constructing the proposed option is based on this report's conceptual sketches, functional requirements, and assumptions. The CAPEX estimate was sufficiently detailed to have a confidence level of -+35% of the actual construction cost[1]. The estimated CAPEX for this option is **€1,127,000**.

This option will extend the asset's life by about 10 years, after which a more permanent solution will be needed. Regular monitoring of the pier's structural integrity will be needed to evaluate the success of the remediation works and identify if further intervention is needed.

Refer to Section 9 for more details on the cost estimate methodology and assumptions. A detailed breakdown of the cost estimate can be found in Appendix B.

8.4.5 Summary

A practical remediation option for the deteriorated sheet pile pier is to install a concrete façade. This impermeable layer protects against environmental factors, effectively extending the wall's service life and minimising the need for frequent repairs or replacements. However, this solution does not address the fact that the overall structure is temporarily closed. It is uncertain whether the existing sheet pile can sufficiently bear the additional dead load of the concrete on top of its existing load requirements.

Consequently, the design life of the concrete façade is heavily dependent on the structural condition of the existing sheet pile. It must be capable of withstanding the additional load brought about by the weight of the concrete panels, coupled with the significant environmental loading from winds and waves. Operational requirements and constructability issues also factor into the feasibility of this option.

One way to alleviate berthing loads on the overall structure is to affix an effective fendering system to the new concrete façade. This system would absorb the berthing forces exerted by vessels, further protecting the structure.

Given these numerous considerations, if funding is limited, installing a concrete façade on the sheet pile pier is being assessed as a potentially viable remediation solution. It should be noted that the structural integrity of the existing structure cannot be guaranteed at this stage. Therefore, this option would not be recommended.

[1] This estimate does not account for inflation or other variables that may affect the cost over time. Despite our best efforts to provide an accurate estimate, its precision cannot be guaranteed. The final cost may vary by more than 35% due to factors such as supply, procurement, construction methodology, and other related considerations. Please refer to Section 9 for further information on the assumptions made during the estimation process.

8.5 Option 3 – Gravity Block Wall

8.5.1 Introduction

Option 3 involves constructing a gravity block wall using precast unreinforced concrete blocks in front of the existing sheet pile wall. This type of wall relies on the self-weight of the blocks to resist lateral soil pressures, surcharges, and the forces generated by structures behind the wall. Refer to Figure 8-4 for a typical cross-section of a gravity block wall below.

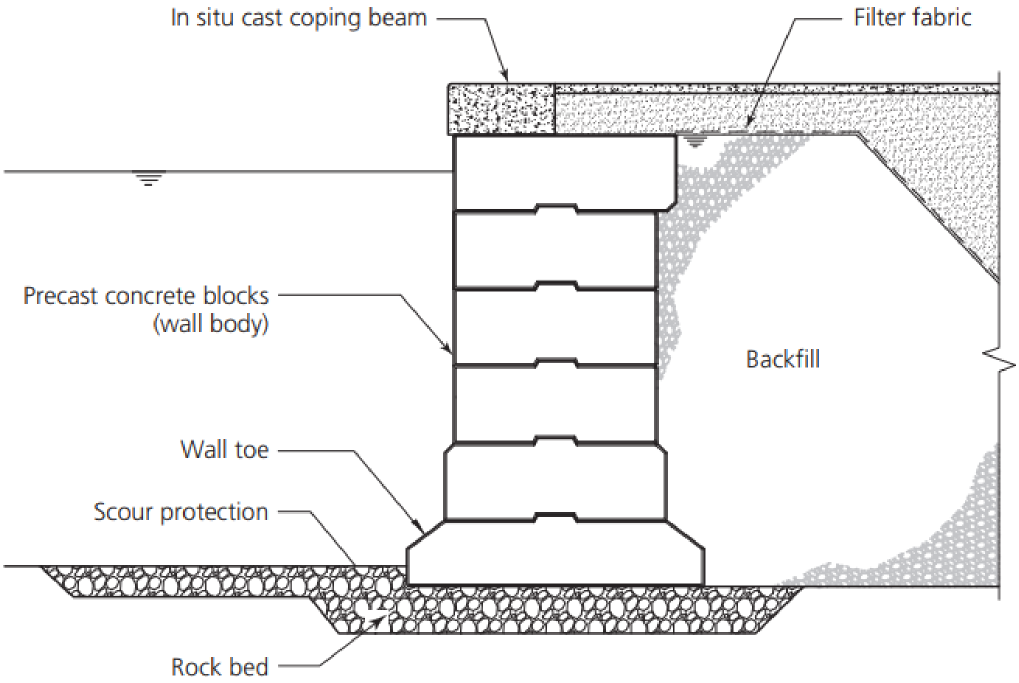

Figure 8-4: Typical cross-section of a gravity block wall (Ackhurst, 2020)

The key elements of a gravity block wall include the following:

- Quarry run backfill: The area behind the wall is filled with quarry run material. This backfill material type helps reduce lateral soil pressures.
- Separation layer (geotextile): A separation layer is typically installed between the backfill and the surrounding reclamation material. This layer helps prevent the migration of fine-grained soil particles into the backfill, ensuring its effectiveness in supporting the wall.
- Rock foundation with scour protection: A rock foundation is provided to support the gravity wall. A rock foundation is provided to uniformly distribute bearing pressures into the foundation layers. Scour protection measures, such as riprap or other erosion-resistant materials, may be incorporated to safeguard the foundation from undermining due to water flow, wave action, and vessel-induced scour.
- Capping beam: An in-situ cast capping beam is generally provided to close off the gravity wall block stack. The capping beam is reinforced and provides a structural element to distribute applied loads into the underlying block stack. Additionally, an in-situ cast

capping beam allows for equalising placing tolerances between the blocks in the block stack. These beams can be cast as a wave return wall to reduce overtopping water volumes, should this be required.

An advantage of the gravity block wall is its geometrical changes to account for seabed level variances. Blocks can be added or removed to maintain the desired wall height and stability. However, providing a uniform and level foundation bed for the wall is important. Achieving this may involve cut-and-fill operations to optimise material usage and establish appropriate founding levels.

8.5.2 Performance

8.5.2.1 Design Life

Gravity block walls for quay walls are designed to withstand external forces primarily through their self-weight, and as such, they often do not incorporate steel reinforcement. This benefits their design life, as it mitigates potential degradation caused by chloride penetration that can result in reinforcement corrosion. As a result, these walls demonstrate a high degree of durability, commonly exceeding a design life of 100 years, making them particularly appropriate for aggressive environments.

The lack of reinforcement in these structures also means that long-term maintenance requirements are typically lower, enhancing their suitability for prolonged service. However, where significant lateral load transfer or crack control is necessary, reinforcement may be included in the capping block elements. In such instances, durability can be further enhanced by utilising galvanised steel reinforcement, incorporating concrete admixtures, applying surface coatings, and using specially engineered concrete mixes tailored for marine environments.

An additional advantage of these walls is that the blocks are precast, which allows for stringent quality control measures during production. This process, performed under controlled and repetitive operations, yields consistently high-quality concrete blocks.

In summary, gravity block walls for pier walls, with their exceptional durability, low maintenance requirements, and high-quality construction, exhibit an anticipated design life of 100 years. The various enhancement measures, such as reinforced capping blocks and specialised concrete mix designs, coupled with strict production quality control, contribute to their ability to resist deterioration and withstand the test of time.

8.5.2.2 Overtopping

Considering this option proposes to build a new structure, the seawall will be designed to improve the overtopping performance. Since the existing structure will be buried behind the block wall, the new seawall will be shifted to the edge of the new structure.

Alternatively, the flat portion in front of the current seawall will reduce overtopping, forcing the wave to break and spill over the front face before hitting the seawall. This will need to be verified through physical modelling.

8.5.3 Constructability

Gravity block walls are relatively straightforward to construct due to their gravity structure and use of precast concrete blocks. The construction process involves laying the blocks on both the leeward and seaward sides of the pier on a rock bedding layer in a staggered pattern, creating a stable wall that relies on the self-weight of the blocks for stability.

Along the line of the steel sheet pile wall, the founding material is poor for placing gravity blocks. Therefore, approximately 3 to 10 meters of unsuitable foundation material may have to be removed and replaced with suitable material before placing the foundation blocks, as depicted in Figure 8-5. However, removing the silt with inadequate bearing capacity from the seabed risks undermining existing sheet pile walls if not managed properly. To mitigate this risk, the block work wall would be stepped out from the existing wall to create adequate passive material to ensure the temporary stability of the existing pier during construction. The alternative to reducing the footprint, i.e., to minimise the required buffer zone, would be to provide additional protective measures such as temporary sheet piling. However, implementing these mitigation measures adds significant complexity and cost to the project.

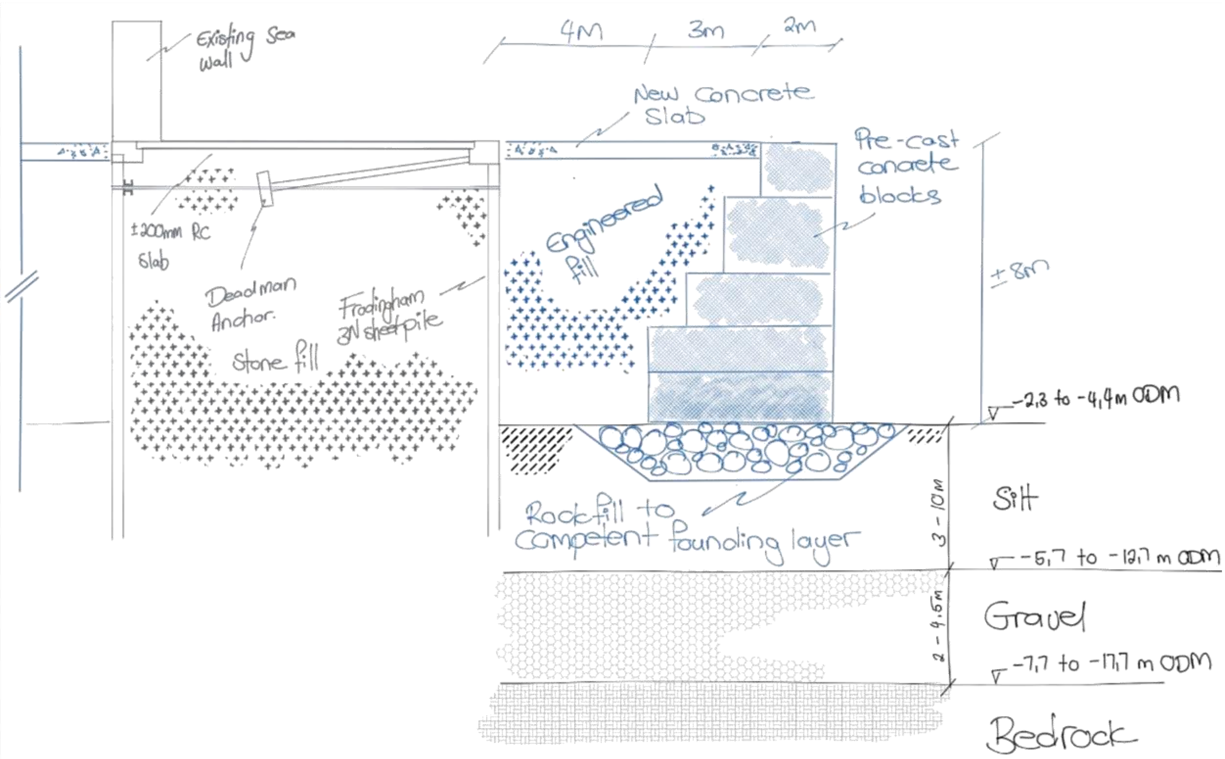

Figure 8-5: Sketch of Pre-cast Modular Concrete Block Gravity Wall

The unsuitable material identified for removal is assumed to be a mix of both contaminated and uncontaminated. Comprehensive testing is essential to accurately categorise this material, guiding the selection of the most appropriate disposal method. Disposing of the material will pose significant construction obstacles and programme delays. While uncontaminated materials can potentially be disposed of at sea, obtaining the necessary license for such an action can take more than 24 months. On the other hand, contaminated materials might be eligible for disposal at a local landfill, but this depends on their classification. A major challenge at the Skerries site will be drying the material before transportation by road. The town will also likely object to the many trucks needed to transport this material. Moreover, the drying process for the contaminated material will necessitate additional licenses and permits, especially for the discharge and treatment of excess water, leading to further complications and potential delays.

8.5.4 Summary

Constructing a gravity block wall may be a viable option to ensure a longer design life and lower maintenance. However, this should be balanced with the construction constraints and potential programme delays.

Key considerations include the amount of dredging required to achieve the desired ground conditions for wall installation. This process entails removing unsuitable material from the seabed, resulting in substantial costs, stringent statutory obligations, and inherent risks. This activity will be considered dredging; therefore, additional material sampling, including Waste Acceptance Criteria testing, would be required to classify contaminants. Disposal of the material will also require, most likely, both landside and offshore (dumping) disposal. A concern would be a suitable location to dry the contaminated material before transporting it to a licensed landfill and the volume of trucks required. These factors are difficult to capture in the high-level cost estimate but would be considered if preferred.

Considering the substantial cost implications and the need to comply with stringent statutory requirements associated with the dredging and material disposal necessary for the gravity block wall construction, it is evident that this option should be carefully considered.

It is not recommended to construct an extension to the pier with a gravity block wall, as the further you progress out, the deeper the layer of unsuitable material to be removed is, which will significantly increase costs and the complications associated with this option.

8.6 Option 4a – Conventional Sheet Pile

8.6.1 Introduction

Option 4a comprises a sheet pile wall driven on either side (seaside, lee side and end walls) of the existing pier at a 2-3-meter offset. A "sheet pile" is a retaining wall that consists of a continuous barrier made up of interlocking sheets, typically constructed from steel or other materials. It is commonly used in coastal areas of Ireland. In these areas, the piles are usually driven into soft sandy soil using a vibrating hammer.

The performance of sheet pile structures relies heavily on the geotechnical conditions at the site, particularly the ability to achieve sufficient embedment depths. Shallow bedrock conditions are not favourable for sheet piles since stiff or hard subsoil can negatively affect the driveability of the elements. Hard driving or pre-drilling could be utilised in these conditions; however would add significant cost to the methodology. Consequently, providing precise borehole information is crucial to ensure the adequate design of the piles.

Figure 8-6: Example of Sheet pile Pier Under Construction (source https://shorturl.at/azS27)

8.6.1 Performance

8.6.1.1 Design Life

A sheet pile wall is a common alternative to block walls for certain construction projects. Unlike block walls that rely on self-weight, sheet pile walls utilise interlocking steel or concrete sheets driven into the ground to create a continuous barrier. This design allows the wall to resist external forces such as soil or water pressure.

One advantage of sheet pile walls is their inherent strength and durability. Steel sheet piles will be coated to protect against corrosion, extending their service life in aggressive environments. The durability of sheet pile walls can be further enhanced by implementing appropriate design factors such as wall thickness, cathodic protection, tie-backs and anchor systems and adequate sheet pile material selection.

In addition to their strength, sheet pile walls offer versatility in design and installation. They can be customised to suit specific project requirements, including varying soil conditions and water depths.

Considering the above factors, a well-designed sheet pile wall can provide a long design life, typically lasting 50 years. The inherent strength of sheet piles, combined with proper material selection, corrosion protection, and quality control measures, contribute to their durability.

8.6.1.2 Overtopping

Due to this option requiring a new seawall, the required height of this seawall and any required additions, such as a wave return wall, were estimated by limiting the overtopping to the acceptable level defined in Section 3.7 of this report. The overtopping discharges were estimated by implementing EurOtop II (2018).

To ensure the overtopping discharge is less than the tolerable overtopping limit of 20 l/s/m during a 1 in 100-year ARI wave height (refer Section 3.5.2) at a 1 in 2-year ARI extreme water level (+3.1m ODM), the top of seawall needs to be minimum +7.1m ODM with a wave-return wall of 1.5m widths (seaward) is required. A 1 in 2-year DWL was chosen as it has a larger probability of coinciding with the 1 in 100-year wave than a DWL with a larger return period. Should the water level be higher than +3.1m ODM (for the same wave), extreme overtopping can be expected.

The required height of the seawall (and the deck) could be optimised, or at least confirmed with more confidence if adequate numerical modelling of metocean conditions is conducted to estimate the expected extreme wave heights at Skerries Harbour (as opposed to using wave heights from a point that is not sheltered like Skerries Harbour is). Therefore, numerical modelling is highly recommended to understand the wave climate at Skerries Harbour accurately.

8.6.2 Constructability

Constructing a new sheet pile wall adjacent to an existing pier, as proposed and shown in Figure 8-7, requires careful consideration of the construction sequence to ensure a smooth process and maintain structural integrity. If construction is preferred from the existing pier, load testing on the existing pier structure is required to ascertain its safe working load capacity. The outcomes of this testing will determine the construction feasibility, including whether the current pier can be utilised for the installation plant or if floating plant equipment is necessary. Practically, it would make better sense to construct the new wall from the seaside.

The sheet piles will be driven on either side (seaside, leeward side and end walls) of the existing pier at a 2-3-meter offset and embedment into the ground is crucial for stability. Once the sheet piles are in place, the existing pier will either remain or be safely demolished (cut and disposed of). Lateral stability is provided to the new sheet pile wall by installing tie-rods from the leeward side. Suitable backfill material is carefully placed behind the sheet piles to enhance structural stability, with compaction techniques ensuring the desired density to prevent settlement.

The final stage involves constructing the new sea wall, capping beams, and pier deck slab and integrating the existing sea wall into the structure. Integrating the new wall into the masonry wall will require partial demolition. Reinforcement and formwork are installed, followed by concrete pouring to create a durable pier deck slab. Capping beams are then constructed on top of the sheet piles, establishing a stable connection between the pier deck and the sheet pile wall.

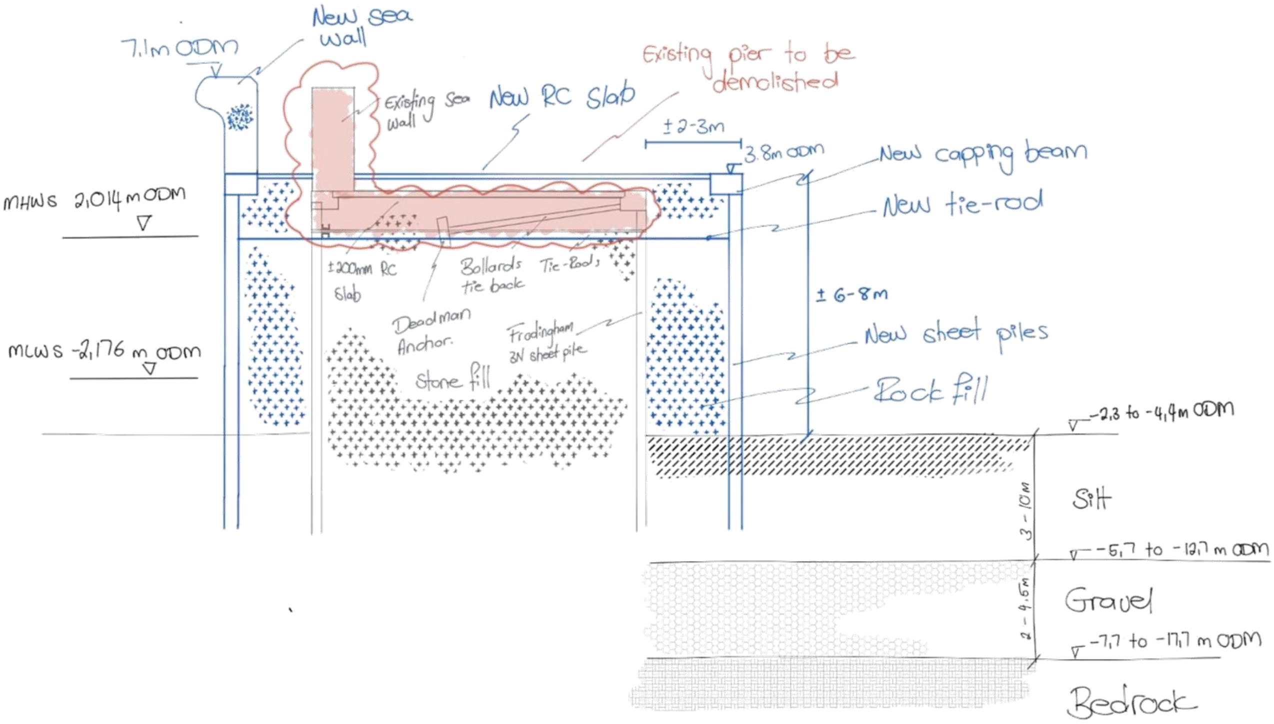

Figure 8-7: Sketch of Conventional Sheet Pile

8.6.3 Cost

The estimated capital expenditure (CAPEX) for constructing the proposed option is based on this report's conceptual sketches, functional requirements, and assumptions. The CAPEX estimate was sufficiently detailed to have a confidence level of -+35% of the actual construction cost[2]. The estimated CAPEX for this option is **€2,699,000**.

Additionally, the CAPEX required to extend the length of the pier by 15m was estimated to be **€3,185,000**. This works out to an additional **€486,000** for the extension or **€32,400 per meter.**

Although the operational and maintenance expenditure (OPEX) for this option was not explicitly determined, sheet pile walls typically require more maintenance in comparison to the other types of walls presented. The UK National Ports Council Port Structures Report recommends average maintenance costs as a percentage of gross current replacement cost. Steel sheet piling is recommended at 0.2% in the UK. This option will have a design life of 50 years but can safely be operated for longer if well-maintained.

[2] This estimate does not account for inflation or other variables that may affect the cost over time. Despite our best efforts to provide an accurate estimate, its precision cannot be guaranteed. The final cost may vary by more than 35% due to factors such as supply, procurement, construction methodology, and other related considerations. Please refer to Section 9 for further information on the assumptions made during the estimation process

Refer to section 9 for more details on the cost estimate methodology and assumptions. A detailed breakdown of the cost estimate can be found in 0.

8.6.4 Summary

Constructing a new sheet pile wall adjacent to an existing pier presents a viable option for this pier rehabilitation. The design life of the sheet pile wall is expected to be long-lasting, providing durability and stability to withstand coastal forces and environmental conditions. The construction sequence involves driving sheet piles, demolition of the existing pier, tie-rod installation, backfilling, and constructing capping beams and a pier deck slab, which is planned to ensure the structural integrity of the overall system.

In conclusion, constructing a new sheet pile wall adjacent to an existing pier is feasible for coastal protection and pier construction. However, further evaluation is required to assess cost implications, feasibility, and constructability challenges. These factors will be carefully analysed as part of the multi-criteria analysis later in Section 10 of this report.

8.7 Option 4b – Encapsulation Sheet pile

8.7.1 Introduction

Option 4b, as represented in Figure 8-8, is a variation of Option 4a, which involves constructing a new sheet pile wall adjacent to an existing pier. However, in Option 4b, an additional step is incorporated—including a concrete facade on the outer faces of the sheet piles. This variation aims to enhance the performance and longevity of the sheet pile structure by introducing an impermeable layer that provides numerous benefits.

By encasing the sheet pile structure with a concrete layer, the pier gains improved resistance to corrosion and degradation, effectively prolonging the wall's service life while reducing maintenance requirements.

The provided façade offers two primary benefits. Firstly, it enhances the aesthetic appearance of the wall by providing a clean, uniform, and smooth surface. This aesthetic improvement enhances the visual appeal and simplifies maintenance efforts. Secondly, the flat façade improves berthing capabilities by reducing the risk of vessels encountering snags or sustaining damage during docking or berthing operations. Furthermore, the flat façade permits mounting fenders, reducing/controlling berthing forces on the pier if necessary. This improvement enhances safety measures and operational efficiency, resulting in smoother maritime activities and minimising the potential for accidents or disruptions.

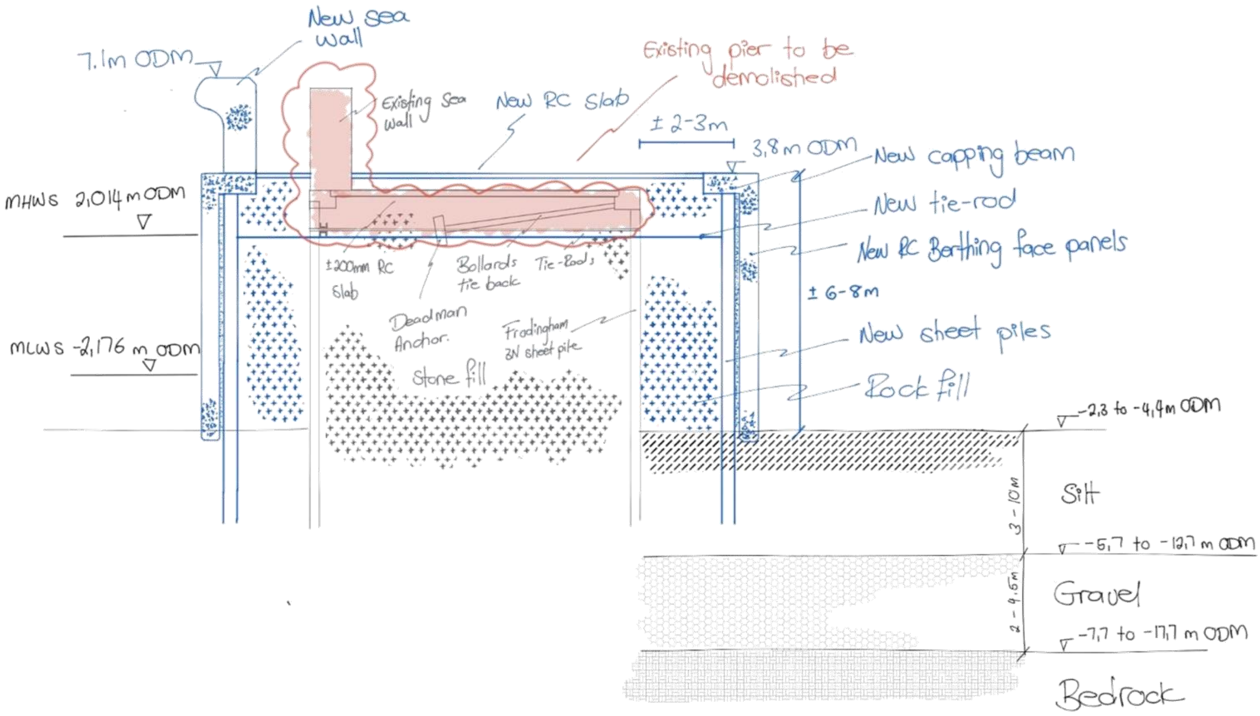

Figure 8-8: Sketch of Encapsulation Sheet Pile

8.7.2 Performance

8.7.2.1 Design Life

Compared to Option 4a, Option 4b with the concrete façade provides an enhanced resistance level to deterioration and degradation. The impermeable nature of the concrete barrier minimises the impact of external elements on the sheet pile structure, thereby preserving its integrity over an extended period and reducing maintenance requirements.

The design life of Option 4b is further augmented by the high durability of concrete. Concrete is known for its longevity and ability to withstand harsh conditions, making it an ideal material for coastal structures.

Option 4b provides long-term cost savings and operational efficiency. The extended design life and reduced maintenance requirements contribute to the overall sustainability of the solution. With the inclusion of the concrete facade, the structure will achieve a design life between 50-75 years with added redundancy to the design life, given that the façade can be seen as sacrificial. The structure will then be governed by internal corrosion of the elements (back face of the wall, tie rods, etc.).

8.7.2.2 Overtopping

This option requires a new seawall, and therefore, the required height of this seawall and any required additions, such as a wave return wall, will be similar to Option 4a above.

The seawall will also require a height of +7.1m ODM and a wave-return wall of 1.5m widths (seaward) to ensure the overtopping discharge is less than the tolerable overtopping limit of 20 l/s/m during a 1 in 100-year ARI wave height (refer Section 3.5.2) at a 1 in 2-year ARI extreme water level (+3.1m ODM).

8.7.3 Constructability

The installation process for Option 4b involves the installation of new sheet piles similar to the procedure outlined for Option 4a. The alignment and embedment of the sheet piles are crucial for ensuring the integrity and stability of the sheet pile wall. Once the sheet piles are properly positioned, anchored and backfilled, the construction of the concrete facade commences.

Concrete panels, precast off-site, are transported to the project site and lifted into place. After securely positioning the panels, they are fixed and connected to the sheet pile wall using practical methods such as anchor bolts, dowels, or welded connections. Specialised sealants or elastomeric compounds seal the joints between the panels, enhancing waterproofing and durability.

To further enhance the structural integrity and stability of the wall, the voids or gaps in the in-pans of the sheet piles are filled with non-shrinking grout. This filling process helps prevent potential movement or shrinkage that could compromise the connection and overall wall performance. Non-shrinking grout is specifically chosen to ensure a stable and durable connection.

However, the specific construction methodology for Option 4b cannot be definitively determined until load testing on the current pier structure is performed to verify the safe working load capacity of the pier. This testing is crucial in determining the feasibility and suitability of the construction approach.

8.7.4 Cost

The estimated capital expenditure (CAPEX) for constructing the proposed option is based on this report's conceptual sketches, functional requirements, and assumptions. The CAPEX estimate was sufficiently detailed to have a confidence level of -+35% of the actual construction cost[3]. The estimated CAPEX for this option is **€3,342,000**.

Additionally, the CAPEX required to extend the length of the pier by 15m was estimated to be **€3,874,000**. This works out to an additional **€532,000** for the extension or **€35,500 per meter**.

Although the operational and maintenance expenditure (OPEX) for this option was not explicitly determined, it is expected that minimal maintenance will be required during the 50-75-year design life. The sheet piles are well protected against corrosion and damage from external factors, which translates to a lower maintenance cost and extended design life.

[3] This estimate does not account for inflation or other variables that may affect the cost over time. Despite our best efforts to provide an accurate estimate, its precision cannot be guaranteed. The final cost may vary by more than 35% due to factors such as supply, procurement, construction methodology, and other related considerations. Please refer to Section 9 for further information on the assumptions made during the estimation process.

Refer to section 9 for more details on the cost estimate methodology and assumptions. A detailed breakdown of the cost estimate can be found in Appendix B.

8.7.5 Summary

Option 4b, involving the installation of a concrete facade on the sheet pile wall, presents significant advantages in terms of design life, cost, feasibility, and constructability. The concrete facade enhances the overall durability of the structure, providing effective protection against corrosion, physical damage, and weathering. With a projected design life of 50 years, this option ensures long-lasting performance and reduces the frequency of maintenance and repairs.

Regarding cost considerations, Option 4b may entail additional expenses compared to Option 4a due to the materials and labour required for the concrete facade. However, these costs can be justified by the extended service life and limited maintenance of the façade required. It is crucial to thoroughly evaluate the budgetary implications and balance them against improved durability and performance benefits.

In conclusion, Option 4b, which involves the installation of a concrete facade on the sheet pile wall, will be included as part of the multi-criteria analysis conducted subsequently in Section 10 of this report. Its advantages include extended design life, enhanced durability, potential long-term cost savings, feasibility, and constructability.

8.8 Option 4c – Sheet Pile and Rock Revetment

8.8.1 Introduction

Option 4c, illustrated in Figure 8-9, presents a comprehensive solution for replacing and protecting the current sheet piled section of the pier. Combining the advantages of conventional sheet piles and rock revetments, this approach aims to enhance the pier's structural integrity while providing improved wave dissipation and protection. This option involves installing sheet piles on the leeward side of the pier, following a 2-3-meter offset similar to Options 4a and 4b and adding a revetment on the seaward side of the pier.

It is anticipated that a minimum revetment slope of 1:2 will be required to provide a hydraulic stability slope, resulting in a 16m footprint, which may interfere with the RNLI channel.

Furthermore, stabilising the existing seawall will require a base acting as a crown wall. Considering the wave climate, the revetment installation will likely need to be designed to include a new large seawall (with a large base). Additionally, physical modelling may be required to validate forces on such an exposed crown wall under such considerable waves.

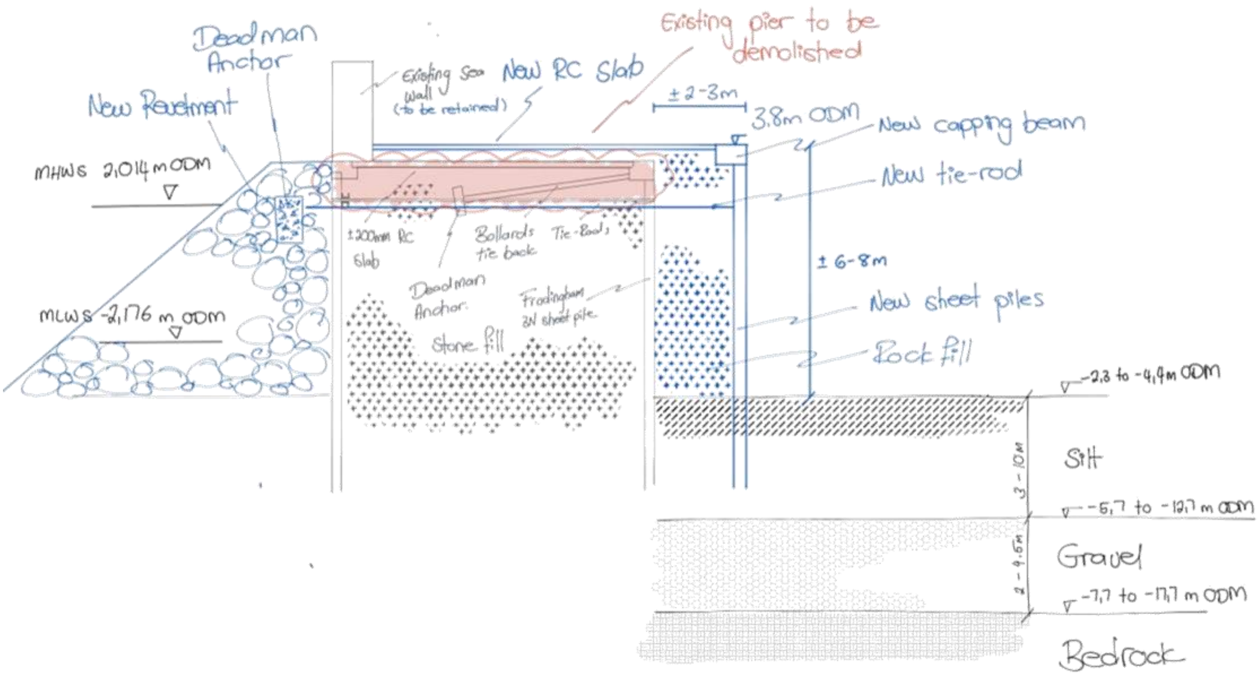

Figure 8-9: Sketch of Sheet pile and Rock Revetment

8.8.2 Performance

8.8.2.1 Design Life

This option has a similar design life to Option 4a. Both options are designed with an intended lifespan of 50 years. However, the crucial differentiating factor in ensuring the durability and longevity of Option 4c lies in properly installing the geotextile between the seaward sheet pile wall and fill for the revetment.

To maximise the durability of Option 4c, proper quality assurance and quality control measures should be implemented during the geotextile installation process. Regular inspections, adherence to industry standards and guidelines, and monitoring the performance of the geotextile fabric over time are essential to ensure its continued effectiveness and maintain the structure's design life.

8.8.2.2 Overtopping

This option will not require a new seawall and can be maintained. The revetment on the seaside of the pier will, however, influence the expected overtopping. Therefore, the expected overtopping discharges based on the wave and water level parameters stipulated in Section 3 were estimated using EurOtop II (2018) formulae for composite vertical walls.

The existing seawall height of +6.4m ODM (no wave-return wall) and a revetment with a crest height of +3.2m ODM will experience a tolerable overtopping limit of 20 l/s/m during a 1 in 100-year ARI wave height (refer Section 3.5.2) at a 1 in 2-year ARI extreme water level (+3.1m ODM). This is on the limit of the tolerable overtopping discharge limits and can be deemed acceptable for these conditions. However, the tolerable overtopping limits will be exceeded should a larger wave or higher extreme water level be experienced.

8.8.3 Constructability

The sheet pile installation in Option 4c follows a similar process to that of the other options, involving driving or vibrating the sheet piles into the ground along the leeward side of the pier with a 2-3-meter offset.

For the construction of the rock revetment, the necessary rock material will be sourced from a suitable quarry nearby or transported by barge, considering the option with the least impact on the area and cost implications. The rock material will be stockpiled in a suitable area nearby and utilised as needed during construction. The specific requirements of size, shape, and quality will be determined during the detailed design stage.

Before the revetment underlayers can be formed, the geotextile fabric must be installed along the seabed and lap up the vertical face of the pier, allowing the placement of the fill and underlayers on the fabric. The fill will then be placed on the geotextile and profiled to provide the desired slope, covered with a double layer of underlayer rock, with a double layer of primary armour rock as the final layer for the revetment. The primary armour rock, consisting of large, heavy, and durable stones, is carefully placed over the underlayer rocks to form a hydraulically stable slope capable of dissipating wave energy. It is anticipated that a floating rig will be required to place the larger rock and create the approximately 16m revetment base, significantly increasing project costs.

8.8.4 Cost

The estimated capital expenditure (CAPEX) for constructing the proposed option is based on this report's conceptual sketches, functional requirements, and assumptions. The CAPEX estimate was sufficiently detailed to have a confidence level of -+35% of the actual construction cost[4]. The estimated CAPEX for this option is **€2,423,000**.

Although the operational and maintenance expenditure (OPEX) for this option was not explicitly determined, sheet pile walls typically require more maintenance in comparison to the other types of walls presented. This option will have a design life of 50 years but can safely be operated for longer if well-maintained.

Refer to section 9 for more details on the cost estimate methodology and assumptions. A detailed breakdown of the cost estimate can be found in 0.

[4] This estimate does not account for inflation or other variables that may affect the cost over time. Despite our best efforts to provide an accurate estimate, its precision cannot be guaranteed. The final cost may vary by more than 35% due to factors such as supply, procurement, construction methodology, and other related considerations. Please refer to Section 9 for further information on the assumptions made during the estimation process.

8.8.5 Summary

Option 4c combines sheet pile installation with a rock revetment, which is being reconsidered as a viable option for further analysis. Although installing sheet piles and a rock revetment poses significant challenges and considerations due to the extensive resources required, including equipment, labour, and materials, the enhanced protection and resilience to the pier make it a compelling option to explore further.

While the construction process poses challenges and quality assurance risks, such as properly installing the geotextile fabric, dumping core rock and systematically placing secondary and primary layers of armour, this option offers the opportunity for a robust solution.

Option 4c, which involves the integration of a new sheet pile with the addition of a rock revetment, will be considered in the multi-criteria analysis conducted subsequently in Section 10 of this report.

9 Cost Comparison

The following general assumptions have been made throughout the assessment:

- The cost estimate is based on this report's conceptual sketches, functional requirements, and assumptions.
- No design development allowances have been made. Typically, assume 15% through to the IFC stage.
- The CAPEX estimate was sufficiently detailed to have a confidence level of -+35% of the actual construction cost.
- Dredging and replacement with suitable fill are assumed for the gravity block wall option.
- The cost estimates were done using 2023 construction rates. Rates were obtained from Spon's Civil Engineering and Highway Works Prices Book 2023 and other similar projects.
- The net construction cost includes a 30% provision for the contractor's P&Gs, site mobilisation, and temporary and miscellaneous works.
- The net construction cost includes a 5% provision for expenses associated with design, site investigations, permitting and supervision, H&S, etc.

Other specific assumptions are listed in the calculation sheets.

Studies such as site/ground investigations, bathymetric/geophysical surveys, hydrographic studies and, potentially, navigational assessments may be required to provide more detailed costings.

It is noted that large cost variations can occur due to construction methodology availability of material, plant, and resources. Some cost refinements are possible, considered part of a future study, preliminary/detailed design or value engineering stages.

A summary of the cost estimate for the various options is presented in Table 9-1. Refer to Appendix B for a detailed cost breakdown of each option.

Table 9-1: Cost Estimate Summary

Option		CAPEX
2b	Precast Concrete Façade - Remediation	€1,127,000
3	Gravity Block Wall	€4,850,000
4a	Conventional Sheet pile	€2,699,000
4.1a	Conventional Sheet pile + 15m Extension	€3,185,000
4b	Encapsulation Sheet pile	€3,342,000
4.1b	Encapsulation Sheet pile + 15m Extension	€3,874,000
4c	Conventional Sheet pile & Revetment	€2,423,000

10 Multi-Criteria Analysis

ByrneLooby has undertaken a high-level qualitative multi-criteria analysis (MCA) to score each remedial option against various selection criteria aligned with the Client's objectives and functional requirements. The analysis aimed to score different remedial options based on various selection criteria aligned with the Client's objectives. The criteria were divided into three main categories: performance, risk, and cost. The breakdown of the criteria within each category is presented below:

Performance

- Design Life: Assesses the structure's durability for its intended design life.
- Future Extensions: Consider how sensitive the wall option is to changes in wall length and how easily it can be extended.
- Aesthetics: Evaluate the wall option's visual appearance, including whether it impedes views and blends well with the surrounding environment.

Risk

- Regulatory Compliance: Considers how the design aligns with governing regulations and requirements related to planning and foreshore.
- Constructability: Assesses the implications of construction techniques on the chosen wall type, including factors such as ease of construction, flexibility in wall alignment changes, sensitivity to retained height, compatibility with in-situ geotechnical conditions, requirements for special transport vehicles or permits, and the need for large storage areas on-site.
- Construction Time: Considers the relative duration of the construction period.
- Data Collection Prerequisites: Evaluate the specific information required upfront for each option, such as bathymetric surveys, borehole surveys, loading requirements analysis, detailed topographic surveys, and wave characteristics analysis, to ensure comprehensive and reliable data is available for the detailed design stage.

Costs

- CAPEX: Scored based on relative capital expenditure associated with each option. (See Section 9 for more information)
- OPEX: Scored based on the relative operational cost associated with the options. The operational cost is determined qualitatively, accounting for monitoring, maintenance and other operational costs.

For each criterion, a score out of 10 was assigned to indicate the favourability or unfavorability of each wall option. A score of 0 indicated that the option was unfavourable (or bad) for that criterion, while a score of 10 indicated excellent performance. Refer to Table 10-1 below for the full evaluation scale.

Table 10-1: Evaluation Rating Scale

Rating	Score
Very Poor	0
Poor	2
Average	4
Good	6
Very Good	8
Excellent	10

Each criterion was assigned a percentage weighting to reflect its relative importance in decision-making. These prioritising aspects align closely with the Client's objectives for the wall option assessment. This weighting considered key factors such as construction methodology, durability, aesthetics, and cost.

This weighting system aimed to highlight the criteria that would substantially influence the selection of a remedial option. Criteria such as design life and construction cost were given higher weightings due to their critical importance in the decision-making process. Conversely, criteria with a lesser impact on the final decision, such as data collection prerequisites, were assigned lower weightings.

According to the MCA results, Option 4b – the Encapsulation Sheet Pile option, emerged as the preferred choice among the viable remedial options. The scores from Appendix C are summarised in Table 10-2.

Option 4b scored 78, demonstrating superior performance across the evaluated criteria. This option stood out primarily due to its longer design life than other options, which signals its durability over the intended lifespan. Furthermore, it had fewer operational considerations and a slightly more straightforward construction procedure than the other options. Despite similar risks associated with data, regulatory compliance, and timelines, the Encapsulation Sheet Pile option surpassed other alternatives in overall performance.

Table 10-2: Multi-Criteria Analysis Summary[5]

Option 2b Remediation (Concrete Façade)	Option 3 Gravity Block Wall	Option 4a Conventional Sheet Pile	Option 4b Encapsulation Sheet Pile	Option 4c Sheet Pile and Rock Revetment
64	63	71	**78**	66

[5] *Disclaimer: The scores provided in this Multi-Criteria Analysis (MCA) are subjective and based on expert judgment and experience. They serve as a qualitative assessment to guide the decision-making process. The scoring reflects the evaluators' interpretation of the available information and may be influenced by personal opinions and biases. It is important to note that these scores are not absolute measures but relative assessments within the defined criteria. The report aims to comprehensively evaluate the options based on the established criteria. However, it is acknowledged that there may be additional factors or criteria that were not explicitly considered in this analysis, which could influence the decision-making process.*

A comprehensive evaluation of all viable wall options, benchmarked against each criterion, is detailed in Appendix C.

11 Conclusions and Recommendations

We conducted an exhaustive options appraisal to rehabilitate the sheet pile pier at Skerries Harbour. Several options were discarded due to inapplicability, while others progressed to a multi-criteria analysis (MCA), where they were evaluated based on various client-agreed criteria. ByrneLooby has only considered the sheet pile structure, and the findings of this document do not consider the existing masonry structure and its condition.

Option 4b, the Encapsulation Sheet Pile option, emerged as the most promising due to its superior design life compared to other alternatives. This suggests its robustness and capacity to endure anticipated environmental conditions throughout the structure's lifespan. The extended design life guarantees lasting performance, thus decreasing the frequency of maintenance or replacement needs.

Regarding operational considerations, the Encapsulation Sheet Pile option exhibited fewer complications than other alternatives, suggesting fewer obstacles during operation and maintenance. This results in streamlined project execution and lowered operational costs.

The construction procedure for the Encapsulation Sheet Pile option also displays a slight advantage over other alternatives due to its simplicity. This aspect enhances the option's constructability, reduces construction time, and boosts the overall feasibility of the option.

Although the Encapsulation Sheet Pile option shares common risks with other alternatives concerning data availability, regulatory compliance, and timeline constraints, it still outperforms others based on evaluated criteria, thus making it the recommended choice for remediating the existing pier.

To ensure the successful implementation of Option 4b, we propose several recommendations:

Engage with Relevant Stakeholders: Establish open communication with all relevant stakeholders throughout the project. This involves seeking their feedback, addressing their concerns, and maintaining transparency. This approach will encourage stakeholder buy-in and create a supportive environment for project execution.

Collect Comprehensive Data: Conduct exhaustive data collection activities, including surveys (bathymetric and topographic), site investigation surveys (borehole, sampling), loading requirements analysis (crane loads, vessel and general operations), and numerical modelling (wave, wind, water levels and currents), at a minimum. These efforts will yield accurate and reliable data for the detailed design stage, crucial for making informed design decisions. Further details on recommended studies and data collection campaigns can be found in Section 5.

Conduct a Comprehensive Design: Conduct a preliminary stage followed by a detailed design to refine and optimise the preferred solution. This design approach should consider site-specific conditions and loading requirements to enhance the sheet pile wall's performance and structural integrity.

Implementing these recommendations will ensure that the selected option provides long-term durability, feasibility, operational efficiency, and constructability advantages, thereby offering an effective solution for rehabilitating the existing pier. Refer to the figures and Appendix D for 3-D indicative renderings of the recommended solution.

Figure 11-1: Proposed Encapsulation Sheet Pile

Figure 11-2: Proposed Encapsulation Sheet Pile

The evaluation has revealed that fishing vessels refrain from using the final 30 meters of Skerries pier wall during inclement weather. This avoidance can be attributed to the misalignment of the existing berth to the prevailing winds and waves. Before contemplating an expansion of the pier length, it's imperative to conduct in-depth numerical modelling assessments. These assessments will determine the ideal orientation and length for the berth, maximizing its utility. With the correct alignment, a 15m extension may free up 45m of usable berth during inclement weather conditions.

The potential for Skerries Harbour to transform into a pivotal crew transfer hub for the burgeoning offshore renewable sector is worth considering. Delving into potential partnerships with Offshore Renewable Energy (ORE) developers, notably the North Irish Sea Array (NISA), could be a strategic opportunity to co-finance a prospective extension.

Figure 11-3: Example of a CTV berth

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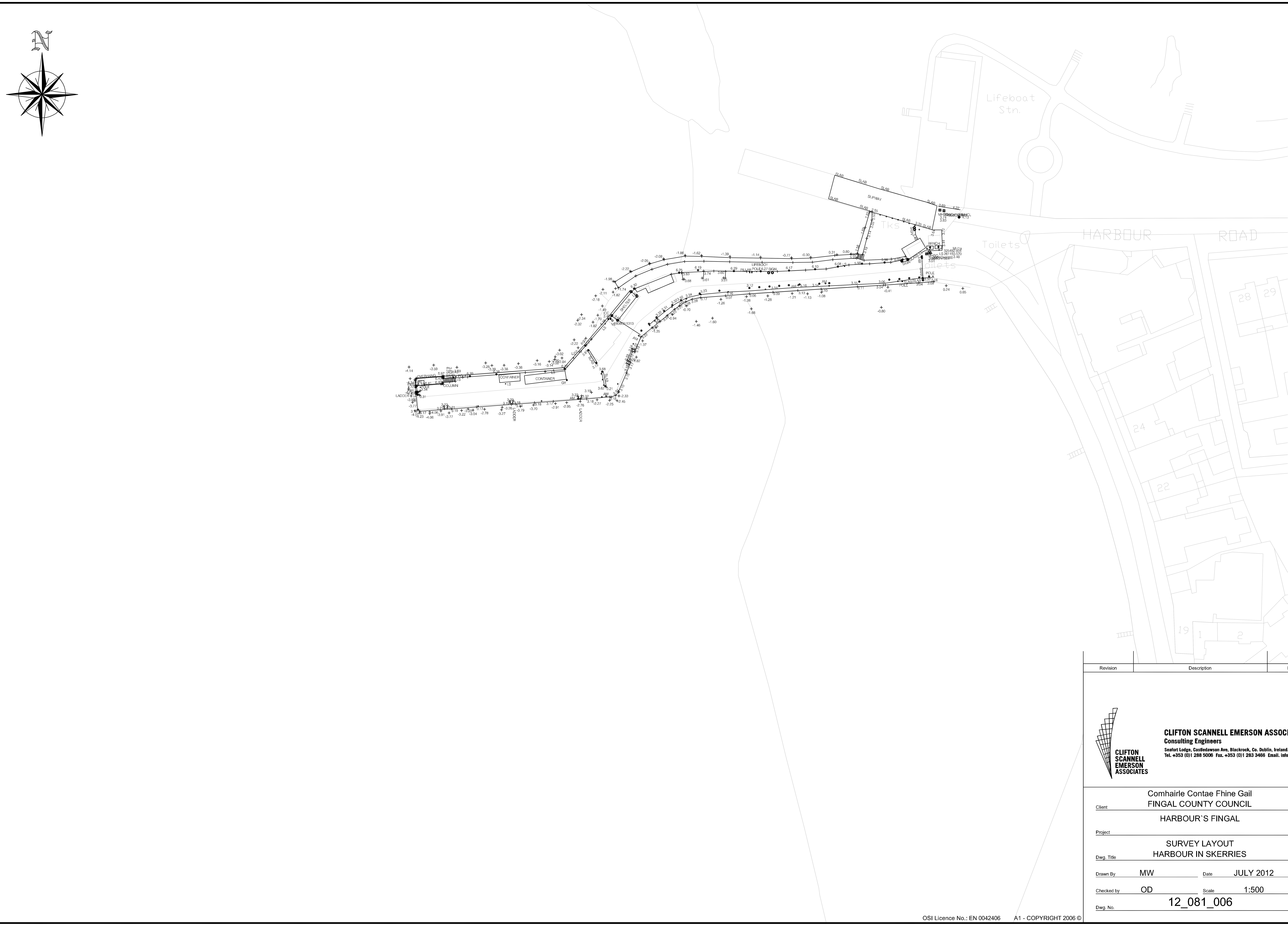
13 Appendices

Appendix A – Survey



Revision	Description	Date

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Project: HARBOUR`S FINGAL

Dwg. Title: SURVEY LAYOUT / HARBOUR IN SKERRIES

Drawn By: MW — Date: JULY 2012

Checked by: OD — Scale: 1:500

Dwg. No.: 12_081_006

Appendix B – Options Assessment Cost Breakdown

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Summary

Option	Type	Total
1b	Precast Concrete Façade	€1,127,000.00
3	Gravity Block Wall	€4,850,000.00
4a	Sheet Pile Option	€2,699,000.00
4b	Sheet Pile Option with Façade	€3,342,000.00
4c	Sheet Pile Revetment	€2,423,000.00
4.1a	Extended Sheet Pile Option	€3,185,000.00
4.1b	Extended Sheet Pile Option with Façade	€3,874,000.00

Option 2b
Precast Concrete Façade

Existing Pier Upgrade - Precast Concrete Façade					
Element	**Unit**	**Quantity**	**Rate**	**Cost**	**Notes**
Precast Units					
Concrete	m^3	321.60	€ 175.00	€ **56,280.00**	*assumed C50 *panels' width assumed to be 0.3m *panels height assumed to be 8m.
Reinforcement	t	50.50	€ 1,850.00	€ **93,425.00**	*assume 2% steel *Typical reinforcement rate is taken from Spon's book and previous tenders * rate includes supply, bending, fixing, etc.
Placement	m^3	321.60	€ 86.00	€ **27,657.60**	*assumed to be placement of piers with cross sectional area of exceeding $1m^2$
Formwork	m^2	2149.00	€ 84.00	€ **180,516.00**	*assumed that plane horizontal width is 0.4–1.22 m *formwork is calculated as perimeter*height
Tieback System					
Tie rods	nr	70	€ 2,500.00	€ **175,000.00**	*the distance between tie rods is 1.26m
Waling Beam	m	134	€ 513.00	€ **68,742.00**	*281X102 mm channel
Reinforced Concrete to anchoring Tie Rods					
Concrete	m^3	243	€ 175.00	€ **42,525.00**	*assumed C50 *two concrete blocks are assumed. *width and depth of concrete block is assumed to be 3m.
Reinforcement	t	19.10	€ 1,850.00	€ **35,335.00**	*assume 1% steel *Typical reinforcement rate is taken from Spon's book and previous tenders * rate includes supply, bending, fixing, etc.
Placement	m^3	243	€ 86.00	€ **20,898.00**	*assumed to be placement of a block with cross sectional area of exceeding $1m^2$
Formwork	m^2	198	€ 84.00	€ **16,632.00**	*assumed that plane horizontal width is 0.4–1.22 m *formwork is calculated as perimeter*height
Grouting between Sheet Piles and Precast Units					
Grouting with 50N grout	m^3	268	€ 180.00	€ **48,240.00**	*width of the area is assumed to be 0.25m.
Other					
Quay Furniture (ladders)	nr	5	€ 6,500.00	€ **32,500.00**	*5 ladder is assumed.
Quay Furniture (lifebuoys)	nr	2	€ 750.00	€ **1,500.00**	* estimate
Quay Furniture (bollards)	nr	5	€ 1,500.00	€ **7,500.00**	*Bollards are assumed to be 10t @ 12m
Quay Furniture (rings)	nr	15	€ 500.00	€ **7,500.00**	*Rings are assumed to be 5t @ 4m
Electrical Ducting	m	70	€ 150.00	€ **10,500.00**	*Taken from Spon's book
Water System	m	70	€ 138.00	€ **9,660.00**	*Taken from Spon's book
Additional/Provisional					
P&G, Temporary and Miscellaneous Work	%	30%		€ **251,000.00**	Based on total project cost
Design, Permitting, Tender, Health and Safety, and Construction administration	%	5%		€ **42,000.00**	Based on total project cost
Total Project Cost				€ **1,127,000.00**	Rounded to nearest €1000

Option 3
Gravity Block Wall

Existing Pier Upgrade - Gravity Wall					
Element	**Unit**	**Quantity**	**Rate**	**Cost**	**Notes**
Dredging					
Dredging of sediments and material other than rock, including handling and temporary storage as may be required.	m^3	3340	€ 21.00	**€ 70,140.00**	*the silty ground's depth vary from 5m to 15m through the 61m of the pier.
Dredging of unsuitable material other than rock, including handling and temporary storage as may be required.	m^3	3340	€ 30.00	**€ 100,200.00**	*assuming that 50% material are unsuitable.
Dumping at sea. Disposal of non-contaminated material to dump site.	m^3	3340	€ 21.00	**€ 70,140.00**	*the silty ground's depth vary from 5m to 15m through the 61m of the pier.
Disposal including drying to a licensed facility in sealed trucks - as per the contract documents	m^3	3340	€ 300.00	**€ 1,002,000.00**	*assuming that 50% material are unsuitable.
Precast Units					
Concrete	m^3	3021.00	€ 200.00	**€ 604,200.00**	*assumed C50 *Concrete blocks from width of 5m to 2m *Concrete blocks with a height of 1.5m.
Reinforcement	t	474.30	€ 1,850.00	**€ 877,455.00**	*assume 2% steel *Typical reinforcement rate is taken from Spon's book and previous tenders * rate includes supply, bending, fixing, etc.
Placement	m^3	3021.00	€ 86.00	**€ 259,806.00**	*assumed to be placement of piers with cross sectional area of exceeding $1m^2$
Formwork	m^2	569.00	€ 84.00	**€ 47,796.00**	*assumed that plane horizontal width is 0.4–1.22 m *formwork is calculated as perimeter*height
Specified Fill					
Replacement Fill Material	m^3	2276	€ 55.00	**€ 125,180.00**	*selected fill rate taking from Spon's Book
Rock Fill Between the Pre-Cast Concrete Blocks and Old Sheet Pile	m^3	3116	€ 55.00	**€ 171,380.00**	*selected fill rate taking from Spon's Book
Rock Fill Under the Pre-cast Concrete Blocks	m^3	1064	€ 100.00	**€ 106,400.00**	*Rock fill *area of fill 2*(8+6)/2 *rate taking from Spon's Book
Reinforced Slab					
Designed Concrete	m^3	159.60	€ 175.00	**€ 27,930.00**	*assumed RC40/50 *depth of the slab is assumed to be 0.3m. *the rate is directly taken from Spon's book.
Reinforcement	t	18.80	€ 1,850.00	**€ 34,780.00**	*assume 1.5% steel *Typical reinforcement rate is taken from Spon's book and previous tenders * rate includes supply, bending, fixing, etc.
Placement	m^3	159.60	€ 49.00	**€ 7,820.40**	*assumed to be placement of ground slabs with thickness of 300mm to 500mm.
Formwork	m^2	211.60	€ 84.00	**€ 17,774.40**	*assumed to be the plane horizontal formwork with width more than 1.22 m *slab depth is assumed to be 0.3m. *formwork is calculated as perimeter*height
Other					
Quay Furniture (ladders)	nr	5	€ 6,500.00	**€ 32,500.00**	*5 ladder is assumed.
Quay Furniture (lifebuoys)	nr	2	€ 750.00	**€ 1,500.00**	* estimate
Quay Furniture (bollards)	nr	5	€ 1,500.00	**€ 7,500.00**	*Bollards are assumed to be 10t @ 12m
Quay Furniture (rings)	nr	15	€ 500.00	**€ 7,500.00**	*Rings are assumed to be 5t @ 4m
Electrical Ducting	m	70	€ 150.00	**€ 10,500.00**	*Taken from Spon's book
Water System	m	70	€ 138.00	**€ 9,660.00**	*Taken from Spon's book
Additional/Provisional					
P&G, Temporary and Miscellaneous Work	%	30%		**€ 1,078,000.00**	Based on total project cost

Design, Permitting, Tender, Health and Safety, and Construction administration	%	5%		**€ 180,000.00**	Based on total project cost
Total Project Cost				**€ 4,850,000.00**	Rounded to nearest €1000

Option 4a
Conventional Sheet Pile

Existing Pier Upgrade - Sheet Pile Option with Façade					
Element	**Unit**	**Quantity**	**Rate**	**Cost**	**Notes**
Sheet piles					
Sheet Piles	m^2	2680	€ 262.00	€ **702,160.00**	* AZ 37 *Rates from Spon's Book * The total length of sheet piles is considered to be 20m. *Pile painting included
Driving Area	m^2	1608	€ 110.00	€ **176,880.00**	* The driving length is assumed to be 12m. * Rate from Spon's Book. * adjusted for difficult installation conditions
Tieback System					
Tie rods	nr	70	€ 2,500.00	€ **175,000.00**	*the distance between tie rods is 1.26m
Waling Beam	m	134	€ 513.00	€ **68,742.00**	*281X102 mm channel
Reinforced Concrete to anchoring Tie Rods					
Concrete	m^3	243	€ 175.00	€ **42,525.00**	*assumed C50 *two concrete blocks are assumed. *width and depth of concrete block is assumed to be 3m.
Reinforcement	t	19.10	€ 1,850.00	€ **35,335.00**	*assume 1% steel *Typical reinforcement rate is taken from Spon's book and previous tenders * rate includes supply, bending, fixing, etc.
Placement	m^3	243	€ 86.00	€ **20,898.00**	*assumed to be placement of a block with cross sectional area of exceeding $1m^2$
Formwork	m^2	198	€ 84.00	€ **16,632.00**	*assumed that plane horizontal width is 0.4–1.22 m *formwork is calculated as perimeter*height
Specified Fill					
Rock Fill Behind the Wall	m^3	5337	€ 55.00	€ **293,535.00**	*selected fill rate taking from Spon's Book
Rock Revetment	m^3	120	€ 100.00	€ **12,000.00**	*Rock fill *volume of fill 0.5*4*4*15m. *rate taking from Spon's Book
Capping Beam					
Designed Concrete	m^3	76.00	€ 175.00	€ **13,300.00**	*assumed RC40/50 *beam section is assumed to be 750mm*750mm. *the rate is directly taken from Spon's book.
Reinforcement	t	12.00	€ 1,850.00	€ **22,200.00**	*assume 2% steel *Typical reinforcement rate is taken from Spon's book and previous tenders * rate includes supply, bending, fixing, etc.
Placement	m^3	76.00	€ 107.00	€ **8,132.00**	*assumed to be placement of beams with cross-sectional area of 0.25 to 1 m^2
Formwork	m^2	203.00	€ 84.00	€ **17,052.00**	*assumed to be the plane horizontal formwork with width of 0.4–1.22 m *formwork is calculated as perimeter*height
Reinforced Slab					
Designed Concrete	m^3	292.50	€ 175.00	€ **51,187.50**	*assumed RC40/50 *length is assumed to be 65m instead of 61m to account for the curve in the section. *depth of the slab is assumed to be 0.3m. *the rate is directly taken from Spon's book.
Reinforcement	t	34.50	€ 1,850.00	€ **63,825.00**	*assume 1.5% steel *Typical reinforcement rate is taken from Spon's book and previous tenders * rate includes supply, bending, fixing, etc.
Placement	m^3	292.50	€ 49.00	€ **14,332.50**	*assumed to be placement of ground slabs with thickness of 300mm to 500mm.
Formwork	m^2	48.00	€ 84.00	€ **4,032.00**	*assumed to be the plane horizontal formwork with width more than 1.22 m *slab depth is assumed to be 0.3m. *formwork is calculated as perimeter*height
Demolition and Excavation Works					
Existing Seawall	m^3	104.40	€ 247.00	€ **25,786.80**	*width of the seawall is assumed to be 0.6m. *height of the seawall is assumed to be 3m. *the rate is directly taken from Spon's book.
Existing RC Slab	m^3	292.50	€ 109.00	€ **31,882.50**	*assumed to be excavation of reinforced concrete exposed at the commencing surface. * maximum depth is assumed to be 0.25-0.5m.
Topsoil	m^3	2925.00	€ 17.00	€ **49,725.00**	*amount of top soil to be removed is assumed to have 2-5m depth.

New Seawall					
Designed Concrete	m^3	104.40	€ 175.00	€ **18,270.00**	*assumed RC40/50 *width of the seawall is assumed to be 0.6m. *the rate is directly taken from Spon's book. *height of the seawall is assumed to be 3m.
Reinforcement	t	16.40	€ 1,850.00	€ **30,340.00**	*assume 2% steel *Typical reinforcement rate is taken from Spon's book and previous tenders * rate includes supply, bending, fixing, etc.
Placement	m^3	104.40	€ 62.00	€ **6,472.80**	*assumed to be placement of a wall with width of 300–500mm *width of the seawall is assumed to be 0.6m. *the rate is directly taken from Spon's book. *height of the seawall is assumed to be 3m.
Formwork	m^2	352.00	€ 84.00	€ **29,568.00**	*assumed that plane horizontal width is 0.4–1.22 m *formwork is calculated as perimeter*height
Other					
Quay Furniture (ladders)	nr	5	€ 6,500.00	€ **32,500.00**	*5 ladder is assumed.
Quay Furniture (lifebuoys)	nr	2	€ 750.00	€ **1,500.00**	* estimate
Quay Furniture (bollards)	nr	5	€ 1,500.00	€ **7,500.00**	*Bollards are assumed to be 10t @ 12m
Quay Furniture (rings)	nr	15	€ 500.00	€ **7,500.00**	*Rings are assumed to be 5t @ 4m
Electrical Ducting	m	70	€ 150.00	€ **10,500.00**	*Taken from Spon's book
Water System	m	70	€ 138.00	€ **9,660.00**	*Taken from Spon's book
Additional/Provisional					
P&G, Temporary and Miscellaneous Work	%	30%		€ **600,000.00**	Based on total project cost
Design, Permitting, Tender, Health and Safety, and Construction administration	%	5%		€ **100,000.00**	Based on total project cost
Total Project Cost				€ **2,699,000.00**	Rounded to the nearest €1000

Existing Pier Upgrade - Sheet Pile Option with Façade					
Element	**Unit**	**Quantity**	**Rate**	**Cost**	**Notes**
Sheet piles					
Sheet Piles	m^2	2680	€ 262.00	**€ 702,160.00**	* AZ 37 *Rates from Spon's Book * The total length of sheet piles is considered to be 20m. *Pile painting included
Driving Area	m^2	1608	€ 110.00	**€ 176,880.00**	* The driving length is assumed to be 12m. * Rate from Spon's Book. * adjusted for difficult installation conditions
Tieback System					
Tie rods	nr	70	€ 2,500.00	**€ 175,000.00**	*the distance between tie rods is 1.26m
Waling Beam	m	134	€ 513.00	**€ 68,742.00**	*281X102 mm channel
Reinforced Concrete to anchoring Tie Rods					
Concrete	m^3	243	€ 175.00	**€ 42,525.00**	*assumed C50 *two concrete blocks are assumed. *width and depth of concrete block is assumed to be 3m.
Reinforcement	t	19.10	€ 1,850.00	**€ 35,335.00**	*assume 1% steel *Typical reinforcement rate is taken from Spon's book and previous tenders * rate includes supply, bending, fixing, etc.
Placement	m^3	243	€ 86.00	**€ 20,898.00**	*assumed to be placement of a block with cross sectional area of exceeding $1m^2$
Formwork	m^2	198	€ 84.00	**€ 16,632.00**	*assumed that plane horizontal width is 0.4–1.22 m *formwork is calculated as perimeter*height
Specified Fill					
Rock Fill Behind the Wall	m^3	5337	€ 55.00	**€ 293,535.00**	*selected fill rate taking from Spon's Book
Rock Revetment	m^3	120	€ 100.00	**€ 12,000.00**	*Rock fill *volume of fill 0.5*4*4*15m. *rate taking from Spon's Book
Capping Beam					
Designed Concrete	m^3	76.00	€ 175.00	**€ 13,300.00**	*assumed RC40/50 *beam section is assumed to be 750mm*750mm. *the rate is directly taken from Spon's book.
Reinforcement	t	12.00	€ 1,850.00	**€ 22,200.00**	*assume 2% steel *Typical reinforcement rate is taken from Spon's book and previous tenders * rate includes supply, bending, fixing, etc.
Placement	m^3	76.00	€ 107.00	**€ 8,132.00**	*assumed to be placement of beams with cross-sectional area of 0.25 to 1 m^2
Formwork	m^2	203.00	€ 84.00	**€ 17,052.00**	*assumed to be the plane horizontal formwork with width of 0.4–1.22 m *formwork is calculated as perimeter*height
Reinforced Slab					
Designed Concrete	m^3	292.50	€ 175.00	**€ 51,187.50**	*assumed RC40/50 *length is assumed to be 65m instead of 61m to account for the curve in the section. *depth of the slab is assumed to be 0.3m. *the rate is directly taken from Spon's book.
Reinforcement	t	34.50	€ 1,850.00	**€ 63,825.00**	*assume 1.5% steel *Typical reinforcement rate is taken from Spon's book and previous tenders * rate includes supply, bending, fixing, etc.
Placement	m^3	292.50	€ 49.00	**€ 14,332.50**	*assumed to be placement of ground slabs with thickness of 300mm to 500mm.
Formwork	m^2	48.00	€ 84.00	**€ 4,032.00**	*assumed to be the plane horizontal formwork with width more than 1.22 m *slab depth is assumed to be 0.3m. *formwork is calculated as perimeter*height

Option 4b
Encapsulation Sheet Pile

Berthing Face Panel					
Designed Concrete	m^3	536.00	€ 175.00	€ **93,800.00**	*assumed RC40/50 *width of the berthing face is assumed to be 0.5m. *the rate is directly taken from Spon's book. *height of the berthing face is assumed to be 8m.
Reinforcement	t	84.20	€ 1,850.00	€ **155,770.00**	*assume 2% steel *Typical reinforcement rate is taken from Spon's book and previous tenders * rate includes supply, bending, fixing, etc.
Placement	m^3	536.00	€ 86.00	€ **46,096.00**	*assumed to be placement of a pier with cross sectional area exceeding $1m^2$
Formwork	m^2	2152.00	€ 84.00	€ **180,768.00**	*assumed that plane horizontal width is 0.4–1.22 m *formwork is calculated as perimeter*height
Demolition and Excavation Works					
Existing Seawall	m^3	104.40	€ 247.00	€ **25,786.80**	*width of the seawall is assumed to be 0.6m. *height of the seawall is assumed to be 3m. *the rate is directly taken from Spon's book.
Existing RC Slab	m^3	292.50	€ 109.00	€ **31,882.50**	*assumed to be excavation of reinforced concrete exposed at the commencing surface. * maximum depth is assumed to be 0.25-0.5m.
Topsoil	m^3	2925.00	€ 17.00	€ **49,725.00**	*amount of top soil to be removed is assumed to have 2-5m depth.
New Seawall					
Designed Concrete	m^3	104.40	€ 175.00	€ **18,270.00**	*assumed RC40/50 *width of the seawall is assumed to be 0.6m. *the rate is directly taken from Spon's book. *height of the seawall is assumed to be 3m.
Reinforcement	t	16.40	€ 1,850.00	€ **30,340.00**	*assume 2% steel *Typical reinforcement rate is taken from Spon's book and previous tenders * rate includes supply, bending, fixing, etc.
Placement	m^3	104.40	€ 62.00	€ **6,472.80**	*assumed to be placement of a wall with width of 300–500mm *width of the seawall is assumed to be 0.6m. *the rate is directly taken from Spon's book. *height of the seawall is assumed to be 3m.
Formwork	m^2	352.00	€ 84.00	€ **29,568.00**	*assumed that plane horizontal width is 0.4–1.22 m *formwork is calculated as perimeter*height
Other					
Quay Furniture (ladders)	nr	5	€ 6,500.00	€ **32,500.00**	*5 ladder is assumed.
Quay Furniture (lifebuoys)	nr	2	€ 750.00	€ **1,500.00**	* estimate
Quay Furniture (bollards)	nr	5	€ 1,500.00	€ **7,500.00**	*Bollards are assumed to be 10t @ 12m
Quay Furniture (rings)	nr	15	€ 500.00	€ **7,500.00**	*Rings are assumed to be 5t @ 4m
Electrical Ducting	m	70	€ 150.00	€ **10,500.00**	*Taken from Spon's book
Water System	m	70	€ 138.00	€ **9,660.00**	*Taken from Spon's book
Additional/Provisional					
P&G, Temporary and Miscellaneous Work	%	30%		€ **743,000.00**	Based on total project cost
Design, Permitting, Tender, Health and Safety, and Construction administration	%	5%		€ **124,000.00**	Based on total project cost
Total Project Cost				€ **3,342,000.00**	Rounded to the nearest €1000

Existing Pier Upgrade - Sheet Pile Option with Façade					
Element	**Unit**	**Quantity**	**Rate**	**Cost**	**Notes**
Sheet piles					
Sheet Piles	m^2	1520	€ 262.00	€ **398,240.00**	* AZ 37 *Rates from Spon's Book * The total length of sheet piles is considered to be 20m. *Pile painting included
Driving Area	m^2	912	€ 110.00	€ **100,320.00**	* The driving length is assumed to be 12m. * Rate from Spon's Book. * adjusted for difficult installation conditions
Tieback System					
Tie rods	nr	70	€ 2,500.00	€ **175,000.00**	*the distance between tie rods is 1.26m
Waling Beam	m	134	€ 513.00	€ **68,742.00**	*281X102 mm channel
Reinforced Concrete to anchoring Tie Rods					
Concrete	m^3	483	€ 175.00	€ **84,525.00**	*assumed C50 *two concrete blocks are assumed. *width and depth of concrete block is assumed to be 3m.
Reinforcement	t	38.00	€ 1,850.00	€ **70,300.00**	*assume 1% steel *Typical reinforcement rate is taken from Spon's book and previous tenders * rate includes supply, bending, fixing, etc.
Placement	m^3	483	€ 86.00	€ **41,538.00**	*assumed to be placement of a block with cross sectional area of exceeding $1m^2$
Formwork	m^2	446	€ 84.00	€ **37,464.00**	*assumed that plane horizontal width is 0.4–1.22 m *formwork is calculated as perimeter*height
Specified Fill					
Rock Fill Behind the Wall	m^3	5337	€ 55.00	€ **293,535.00**	*selected fill rate taking from Spon's Book
Rock Revetment	m^3	1800	€ 100.00	€ **180,000.00**	*Rock fill *volume of fill 0.5*4*4*15m. *rate taking from Spon's Book
Capping Beam					
Designed Concrete	m^3	76.00	€ 175.00	€ **13,300.00**	*assumed RC40/50 *beam section is assumed to be 750mm*750mm. *the rate is directly taken from Spon's book.
Reinforcement	t	12.00	€ 1,850.00	€ **22,200.00**	*assume 2% steel *Typical reinforcement rate is taken from Spon's book and previous tenders * rate includes supply, bending, fixing, etc.
Placement	m^3	76.00	€ 107.00	€ **8,132.00**	*assumed to be placement of beams with cross-sectional area of 0.25 to 1 m^2
Formwork	m^2	203.00	€ 84.00	€ **17,052.00**	*assumed to be the plane horizontal formwork with width of 0.4–1.22 m *formwork is calculated as perimeter*height
Reinforced Slab					
Designed Concrete	m^3	292.50	€ 175.00	€ **51,187.50**	*assumed RC40/50 *length is assumed to be 65m instead of 61m to account for the curve in the section. *depth of the slab is assumed to be 0.3m. *the rate is directly taken from Spon's book.
Reinforcement	t	34.50	€ 1,850.00	€ **63,825.00**	*assume 1.5% steel *Typical reinforcement rate is taken from Spon's book and previous tenders * rate includes supply, bending, fixing, etc.
Placement	m^3	292.50	€ 49.00	€ **14,332.50**	*assumed to be placement of ground slabs with thickness of 300mm to 500mm.
Formwork	m^2	48.00	€ 84.00	€ **4,032.00**	*assumed to be the plane horizontal formwork with width more than 1.22 m *slab depth is assumed to be 0.3m. *formwork is calculated as perimeter*height
Demolition and Excavation Works					
Existing RC Slab	m^3	292.50	€ 109.00	€ **31,882.50**	*assumed to be excavation of reinforced concrete exposed at the commencing surface. * maximum depth is assumed to be 0.25-0.5m.
Topsoil	m^3	2925.00	€ 17.00	€ **49,725.00**	*amount of top soil to be removed is assumed to have 2-5m depth.
Other					
Quay Furniture (ladders)	nr	5	€ 6,500.00	€ **32,500.00**	*5 ladder is assumed.
Quay Furniture (lifebuoys)	nr	2	€ 750.00	€ **1,500.00**	* estimate
Quay Furniture (bollards)	nr	5	€ 1,500.00	€ **7,500.00**	*Bollards are assumed to be 10t @ 12m
Quay Furniture (rings)	nr	15	€ 500.00	€ **7,500.00**	*Rings are assumed to be 5t @ 4m

Electrical Ducting	m	70	€ 150.00	**€ 10,500.00**	*Taken from Spon's book
Water System	m	70	€ 138.00	**€ 9,660.00**	*Taken from Spon's book
Additional/Provisional					
P&G, Temporary and Miscellaneous Work	%	30%		**€ 539,000.00**	Based on total project cost
Design, Permitting, Tender, Health and Safety, and Construction administration	%	5%		**€ 90,000.00**	Based on total project cost
Total Project Cost				**€ 2,423,000.00**	Rounded to the nearest €1000

Existing Pier Upgrade - Extended Sheet Pile Option with Façade					
Element	**Unit**	**Quantity**	**Rate**	**Cost**	**Notes**
Sheet piles					
Sheet Piles	m^2	3280	€ 262.00	**€ 859,360.00**	* AZ 37 *Rates from Spon's Book * The total length of sheet piles is considered to be 20m. *Pile painting included
Driving Area	m^2	1968	€ 110.00	**€ 216,480.00**	* The driving length is assumed to be 12m. * Rate from Spon's Book. * adjusted for difficult installation conditions
Tieback System					
Tie rods	nr	82	€ 2,500.00	**€ 205,000.00**	*the distance between tie rods is 1.26m
Waling Beam	m	164	€ 513.00	**€ 84,132.00**	*281X102 mm channel
Reinforced Concrete to anchoring Tie Rods					
Concrete	m^3	243	€ 175.00	**€ 42,525.00**	*assumed C50 *two concrete blocks are assumed. *width and depth of concrete block is assumed to be 3m.
Reinforcement	t	19.10	€ 1,850.00	**€ 35,335.00**	*assume 1% steel *Typical reinforcement rate is taken from Spon's book and previous tenders * rate includes supply, bending, fixing, etc.
Placement	m^3	243	€ 86.00	**€ 20,898.00**	*assumed to be placement of a block with cross sectional area of exceeding $1m^2$
Formwork	m^2	198	€ 84.00	**€ 16,632.00**	*assumed that plane horizontal width is 0.4–1.22 m *formwork is calculated as perimeter*height
Specified Fill					
Rock Fill Behind the Wall	m^3	6552	€ 55.00	**€ 360,360.00**	*selected fill rate taking from Spon's Book
Rock Revetment	m^3	120	€ 100.00	**€ 12,000.00**	*Rock fill *volume of fill 0.5*4*4*15m. *rate taking from Spon's Book
Capping Beam					
Designed Concrete	m^3	93.00	€ 175.00	**€ 16,275.00**	*assumed RC40/50 *beam section is assumed to be 750mm*750mm. *the rate is directly taken from Spon's book.
Reinforcement	t	14.70	€ 1,850.00	**€ 27,195.00**	*assume 2% steel *Typical reinforcement rate is taken from Spon's book and previous tenders * rate includes supply, bending, fixing, etc.
Placement	m^3	93.00	€ 107.00	**€ 9,951.00**	*assumed to be placement of beams with cross-sectional area of 0.25 to 1 m^2
Formwork	m^2	248.00	€ 84.00	**€ 20,832.00**	*assumed to be the plane horizontal formwork with width of 0.4–1.22 m *formwork is calculated as perimeter*height
Reinforced Slab					
Designed Concrete	m^3	360.00	€ 175.00	**€ 63,000.00**	*assumed RC40/50 *length is assumed to be 65m instead of 61m to account for the curve in the section. *depth of the slab is assumed to be 0.3m. *the rate is directly taken from Spon's book.
Reinforcement	t	42.40	€ 1,850.00	**€ 78,440.00**	*assume 1.5% steel *Typical reinforcement rate is taken from Spon's book and previous tenders * rate includes supply, bending, fixing, etc.
Placement	m^3	360.00	€ 49.00	**€ 17,640.00**	*assumed to be placement of ground slabs with thickness of 300mm to 500mm.
Formwork	m^2	48.00	€ 84.00	**€ 4,032.00**	*assumed to be the plane horizontal formwork with width more than 1.22 m *slab depth is assumed to be 0.3m. *formwork is calculated as perimeter*height
Demolition and Excavation Works					
Existing Seawall	m^3	104.40	€ 247.00	**€ 25,786.80**	*width of the seawall is assumed to be 0.6m. *height of the seawall is assumed to be 3m. *the rate is directly taken from Spon's book.
Existing RC Slab	m^3	292.50	€ 109.00	**€ 31,882.50**	*assumed to be excavation of reinforced concrete exposed at the commencing surface. * maximum depth is assumed to be 0.25-0.5m.
Topsoil	m^3	2925.00	€ 17.00	**€ 49,725.00**	*amount of top soil to be removed is assumed to have 2-5m depth.
New Seawall					

Designed Concrete	m^3	131.40	€ 175.00	**€ 22,995.00**	*assumed RC40/50 *width of the seawall is assumed to be 0.6m. *the rate is directly taken from Spon's book. *height of the seawall is assumed to be 3m.
Reinforcement	t	20.70	€ 1,143.00	**€ 23,660.10**	*assume 2% steel *Typical reinforcement rate is taken from Spon's book and previous tenders * rate includes supply, bending, fixing, etc.
Placement	m^3	131.40	€ 62.00	**€ 8,146.80**	*assumed to be placement of a wall with width of 300–500mm *width of the seawall is assumed to be 0.6m. *the rate is directly taken from Spon's book. *height of the seawall is assumed to be 3m.
Formwork	m^2	442.00	€ 84.00	**€ 37,128.00**	*assumed that plane horizontal width is 0.4–1.22 m *formwork is calculated as perimeter*height
Other					
Quay Furniture (ladders)	nr	5	€ 6,500.00	**€ 32,500.00**	*5 ladder is assumed.
Quay Furniture (lifebuoys)	nr	2	€ 750.00	**€ 1,500.00**	* estimate
Quay Furniture (bollards)	nr	5	€ 1,500.00	**€ 7,500.00**	*Bollards are assumed to be 10t @ 12m
Quay Furniture (rings)	nr	15	€ 500.00	**€ 7,500.00**	*Rings are assumed to be 5t @ 4m
Electrical Ducting	m	70	€ 150.00	**€ 10,500.00**	*Taken from Spon's book
Water System	m	70	€ 138.00	**€ 9,660.00**	*Taken from Spon's book
Additional/Provisional					
P&G, Temporary and Miscellaneous Work	%	30%		**€ 708,000.00**	Based on total project cost
Design, Permitting, Tender, Health and Safety, and Construction administration	%	5%		**€ 118,000.00**	Based on total project cost
Total Project Cost				**€ 3,185,000.00**	Rounded to the nearest €1000

**Option 4.1b
Extended Sheet Pile
Option with Façade**

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Existing Pier Upgrade - Extended Sheet Pile Option with Façade					
Element	**Unit**	**Quantity**	**Rate**	**Cost**	**Notes**
Sheet piles					
Sheet Piles	m^2	3280	€ 262.00	**€ 859,360.00**	* AZ 37 *Rates from Spon's Book * The total length of sheet piles is considered to be 20m. *Pile painting included
Driving Area	m^2	1968	€ 110.00	**€ 216,480.00**	* The driving length is assumed to be 12m. * Rate from Spon's Book. * adjusted for difficult installation conditions
Tieback System					
Tie rods	nr	82	€ 2,500.00	**€ 205,000.00**	*the distance between tie rods is 1.26m
Waling Beam	m	164	€ 513.00	**€ 84,132.00**	*281X102 mm channel
Reinforced Concrete to anchoring Tie Rods					
Concrete	m^3	243	€ 175.00	**€ 42,525.00**	*assumed C50 *two concrete blocks are assumed. *width and depth of concrete block is assumed to be 3m.
Reinforcement	t	19.10	€ 1,850.00	**€ 35,335.00**	*assume 1% steel *Typical reinforcement rate is taken from Spon's book and previous tenders * rate includes supply, bending, fixing, etc.
Placement	m^3	243	€ 86.00	**€ 20,898.00**	*assumed to be placement of a block with cross sectional area of exceeding $1m^2$
Formwork	m^2	198	€ 84.00	**€ 16,632.00**	*assumed that plane horizontal width is 0.4–1.22 m *formwork is calculated as perimeter*height
Specified Fill					
Rock Fill Behind the Wall	m^3	6552	€ 55.00	**€ 360,360.00**	*selected fill rate taking from Spon's Book
Rock Revetment	m^3	120	€ 100.00	**€ 12,000.00**	*Rock fill *volume of fill 0.5*4*4*15m. *rate taking from Spon's Book
Capping Beam					
Designed Concrete	m^3	93.00	€ 175.00	**€ 16,275.00**	*assumed RC40/50 *beam section is assumed to be 750mm*750mm. *the rate is directly taken from Spon's book.
Reinforcement	t	14.70	€ 1,850.00	**€ 27,195.00**	*assume 2% steel *Typical reinforcement rate is taken from Spon's book and previous tenders * rate includes supply, bending, fixing, etc.
Placement	m^3	93.00	€ 107.00	**€ 9,951.00**	*assumed to be placement of beams with cross-sectional area of 0.25 to 1 m^2
Formwork	m^2	248.00	€ 84.00	**€ 20,832.00**	*assumed to be the plane horizontal formwork with width of 0.4–1.22 m *formwork is calculated as perimeter*height
Reinforced Slab					
Designed Concrete	m^3	360.00	€ 175.00	**€ 63,000.00**	*assumed RC40/50 *length is assumed to be 65m instead of 61m to account for the curve in the section. *depth of the slab is assumed to be 0.3m. *the rate is directly taken from Spon's book.
Reinforcement	t	42.40	€ 1,850.00	**€ 78,440.00**	*assume 1.5% steel *Typical reinforcement rate is taken from Spon's book and previous tenders * rate includes supply, bending, fixing, etc.
Placement	m^3	360.00	€ 49.00	**€ 17,640.00**	*assumed to be placement of ground slabs with thickness of 300mm to 500mm.
Formwork	m^2	48.00	€ 84.00	**€ 4,032.00**	*assumed to be the plane horizontal formwork with width more than 1.22 m *slab depth is assumed to be 0.3m. *formwork is calculated as perimeter*height

Option 4.1b
Extended Sheet Pile
Option with Façade

Berthing Face Panel					
Designed Concrete	m^3	656.00	€ 175.00	**€ 114,800.00**	*assumed RC40/50 *width of the berthing face is assumed to be 0.5m. *the rate is directly taken from Spon's book. *height of the berthing face is assumed to be 8m.
Reinforcement	t	103.00	€ 1,143.00	**€ 117,729.00**	*assume 2% steel *Typical reinforcement rate is taken from Spon's book and previous tenders * rate includes supply, bending, fixing, etc.
Placement	m^3	656.00	€ 86.00	**€ 56,416.00**	*assumed to be placement of a pier with cross sectional area exceeding $1m^2$
Formwork	m^2	2632.00	€ 84.00	**€ 221,088.00**	*assumed that plane horizontal width is 0.4–1.22 m *formwork is calculated as perimeter*height
Demolition and Excavation Works					
Existing Seawall	m^3	104.40	€ 247.00	**€ 25,786.80**	*width of the seawall is assumed to be 0.6m. *height of the seawall is assumed to be 3m. *the rate is directly taken from Spon's book.
Existing RC Slab	m^3	292.50	€ 109.00	**€ 31,882.50**	*assumed to be excavation of reinforced concrete exposed at the commencing surface. * maximum depth is assumed to be 0.25-0.5m.
Topsoil	m^3	2925.00	€ 17.00	**€ 49,725.00**	*amount of top soil to be removed is assumed to have 2-5m depth.
New Seawall					
Designed Concrete	m^3	131.40	€ 175.00	**€ 22,995.00**	*assumed RC40/50 *width of the seawall is assumed to be 0.6m. *the rate is directly taken from Spon's book. *height of the seawall is assumed to be 3m.
Reinforcement	t	20.70	€ 1,143.00	**€ 23,660.10**	*assume 2% steel *Typical reinforcement rate is taken from Spon's book and previous tenders * rate includes supply, bending, fixing, etc.
Placement	m^3	131.40	€ 62.00	**€ 8,146.80**	*assumed to be placement of a wall with width of 300–500mm *width of the seawall is assumed to be 0.6m. *the rate is directly taken from Spon's book. *height of the seawall is assumed to be 3m.
Formwork	m^2	442.00	€ 84.00	**€ 37,128.00**	*assumed that plane horizontal width is 0.4–1.22 m *formwork is calculated as perimeter*height
Other					
Quay Furniture (ladders)	nr	5	€ 6,500.00	**€ 32,500.00**	*5 ladder is assumed.
Quay Furniture (lifebuoys)	nr	2	€ 750.00	**€ 1,500.00**	* estimate
Quay Furniture (bollards)	nr	5	€ 1,500.00	**€ 7,500.00**	*Bollards are assumed to be 10t @ 12m
Quay Furniture (rings)	nr	15	€ 500.00	**€ 7,500.00**	*Rings are assumed to be 5t @ 4m
Electrical Ducting	m	70	€ 150.00	**€ 10,500.00**	*Taken from Spon's book
Water System	m	70	€ 138.00	**€ 9,660.00**	*Taken from Spon's book
Additional/Provisional					
P&G, Temporary and Miscellaneous Work	%	30%		**€ 861,000.00**	Based on total project cost
Design, Permitting, Tender, Health and Safety, and Construction administration	%	5%		**€ 144,000.00**	Based on total project cost
Total Project Cost				**€ 3,874,000.00**	Rounded to the nearest €1000

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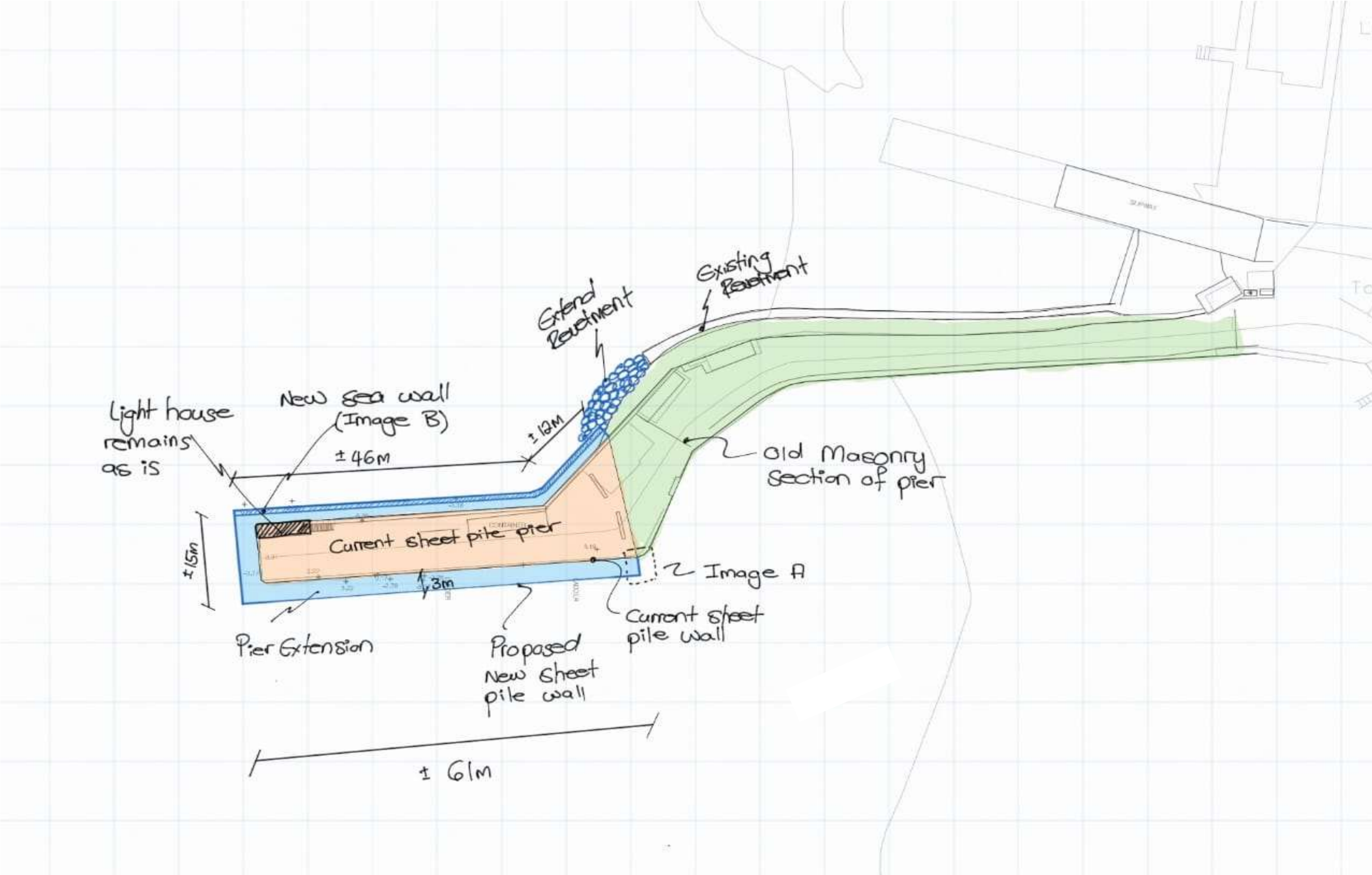


Appendix C – Multi-Criteria Analysis Table

Criteria	Weighting	Option 2b	Option 3	Option 4a	Option 4b	Option 4c
		Concrete Façade	Gravity Block Wall	Sheet Pile (Typical)	Sheet Pile (Encapsulation)	Sheet Pile + Revetment
Performance	**30%**					
Design Life	20%	4	10	6	8	6
Future Extensions	5%	2	8	10	8	8
Aesthetics	5%	6	8	8	10	8
Risk	**40%**					
Regulatory Compliance	15%	10	4	8	8	6
Constructability	15%	8	4	6	8	6
Data Requirements	5%	10	6	6	6	6
Construction Duration	5%	8	4	8	8	6
Costs	**30%**					
CAPEX	20%	6	4	8	6	8
OPEX	10%	4	10	6	10	6
Score	**100%**					
Weighted Option Score		64	63	71	78	66

Appendix D – Option 4b Graphic Illustrations

Skerries Pier, Redevelopment Works

Photomontage 1


Current View


Proposed View

Skerries Pier, Redevelopment Works

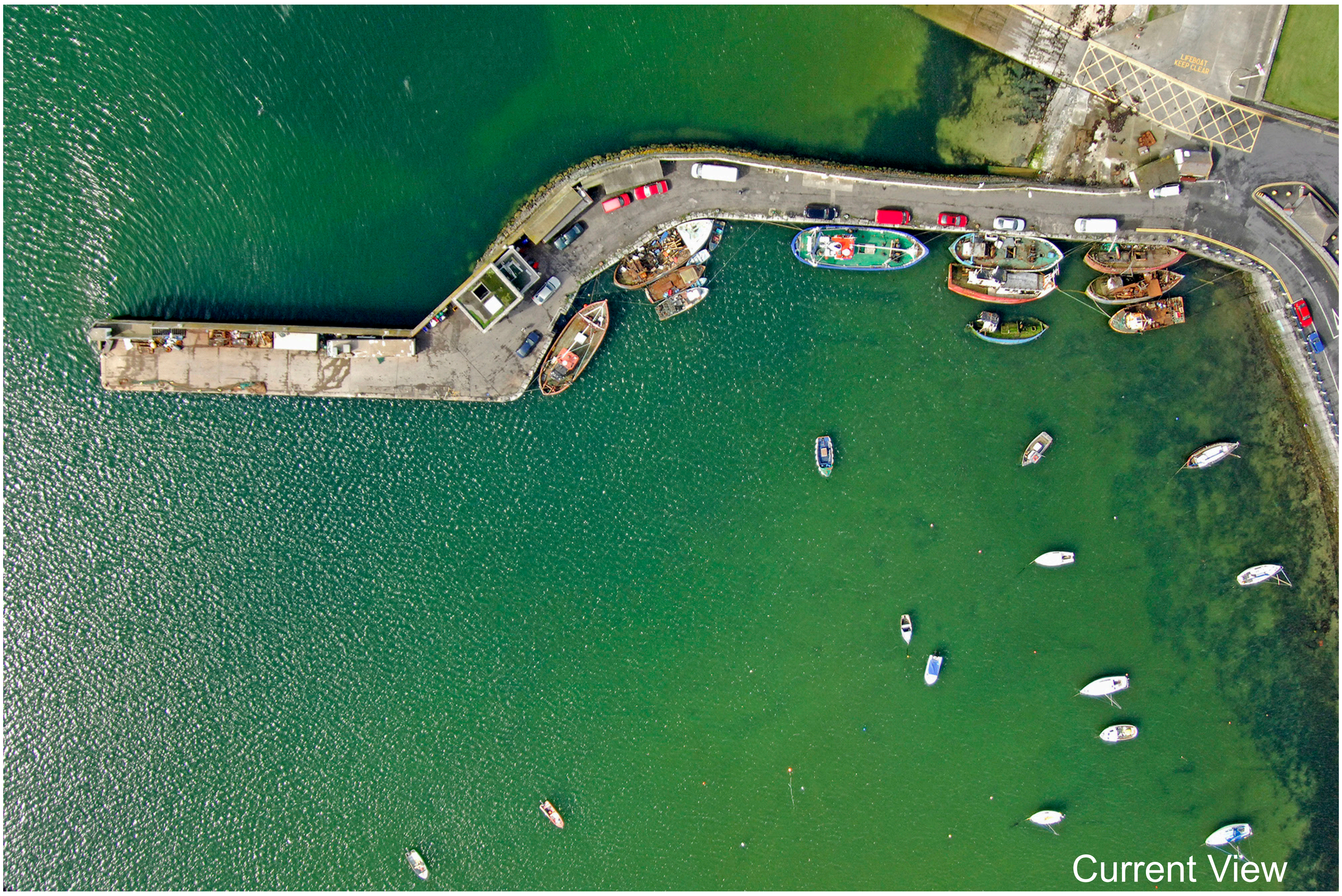
Photomontage 2

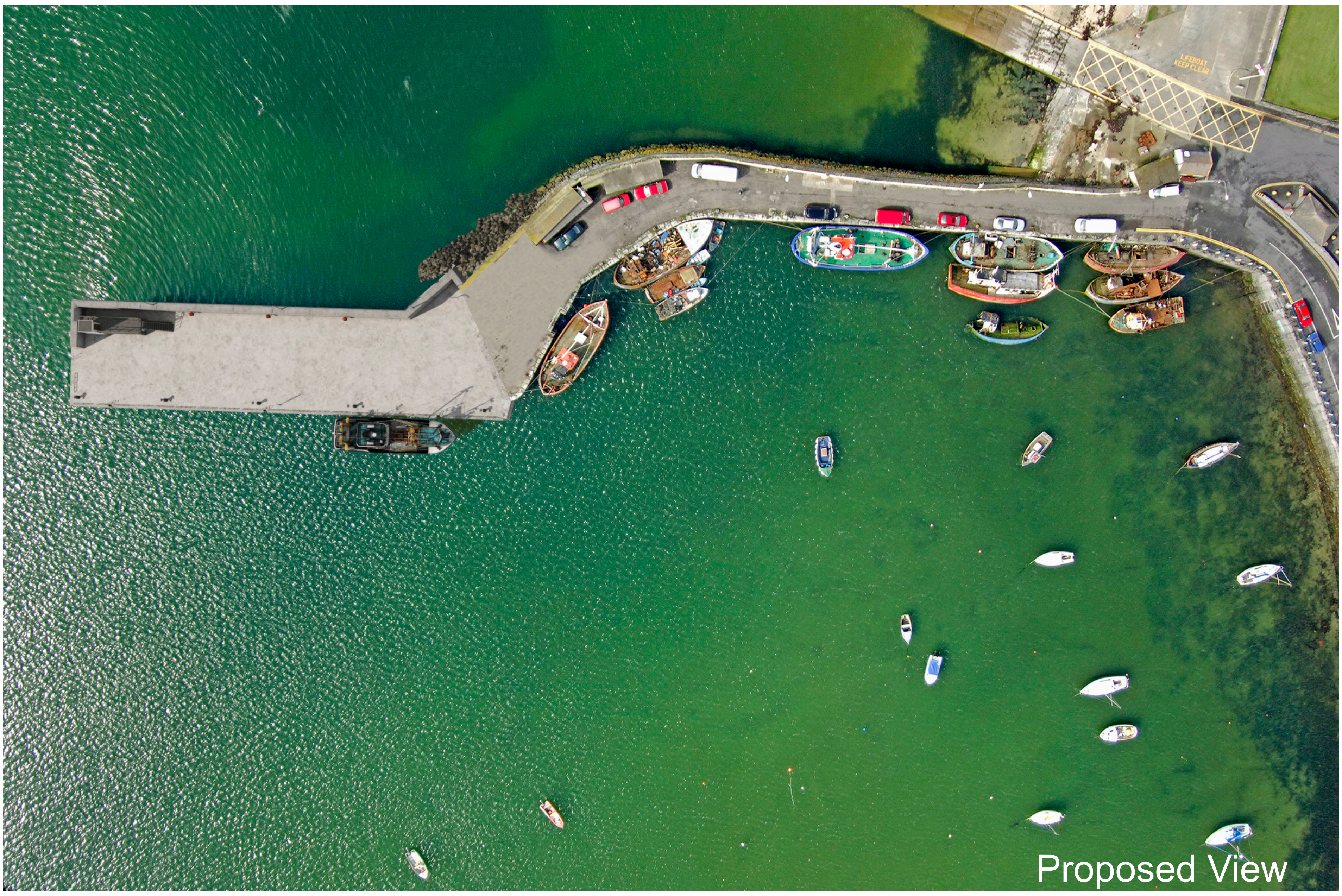
Skerries Pier, Redevelopment Works

Photomontage 3

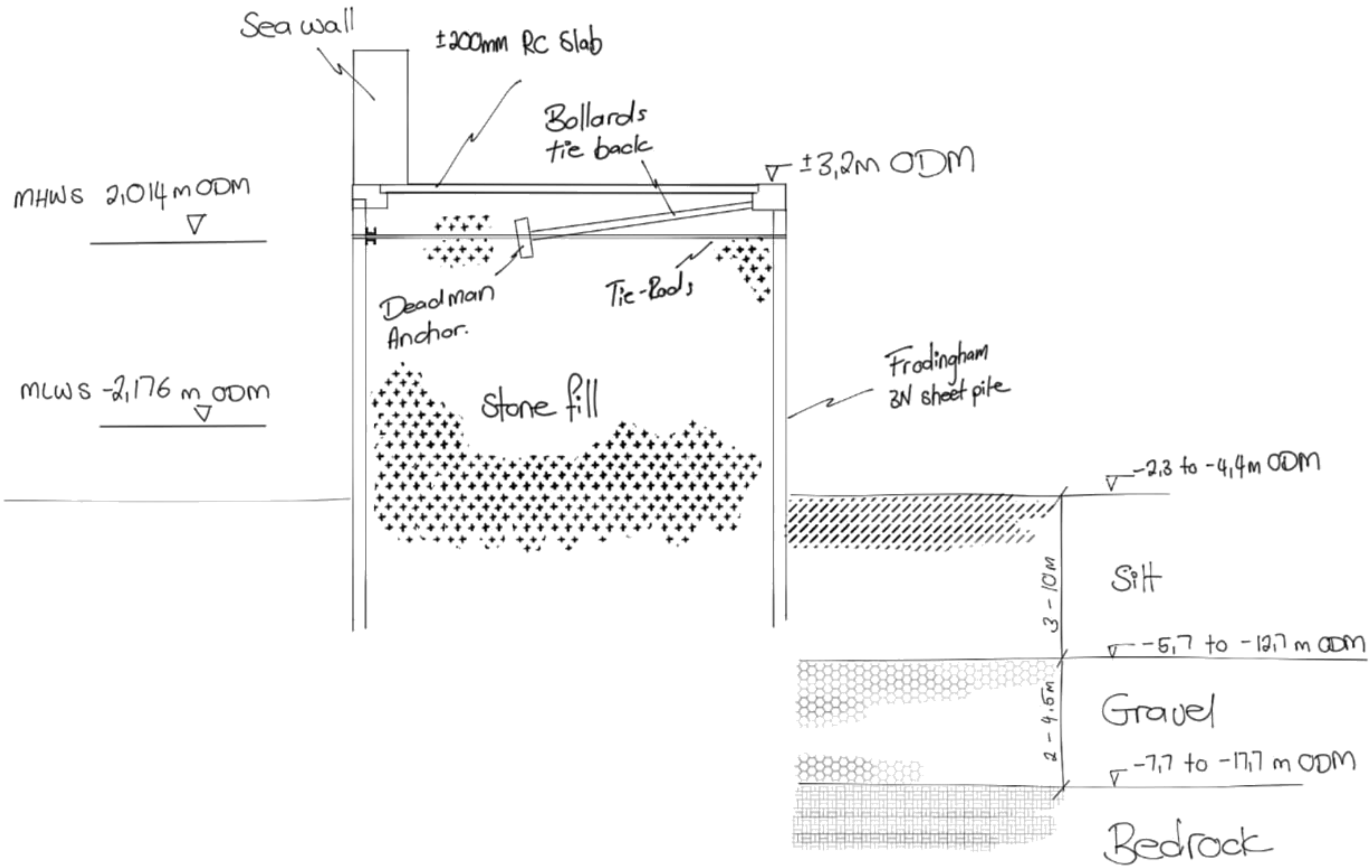
Skerries Pier, Redevelopment Works

Photomontage 4

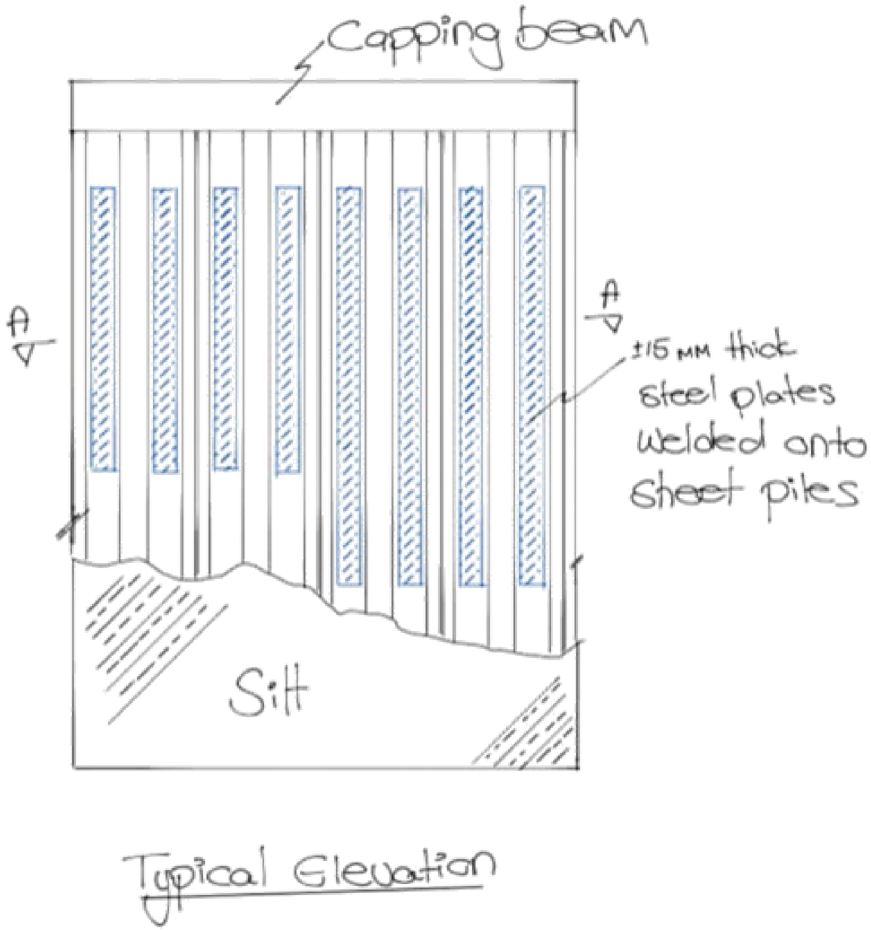


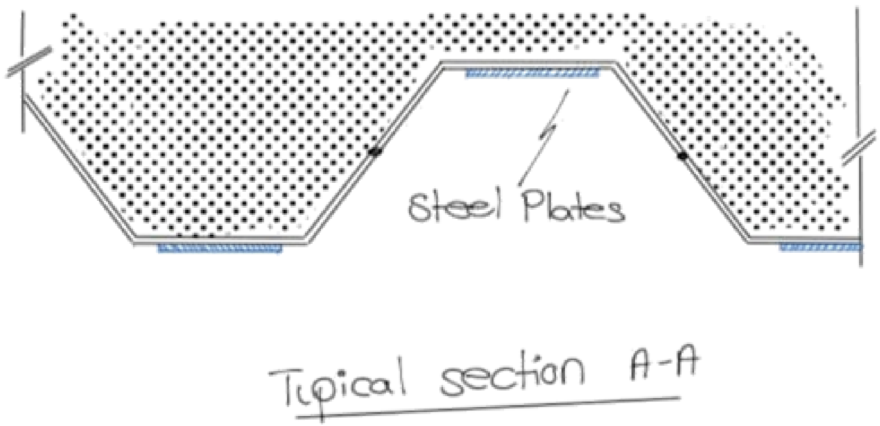


Appendix E – Sketches

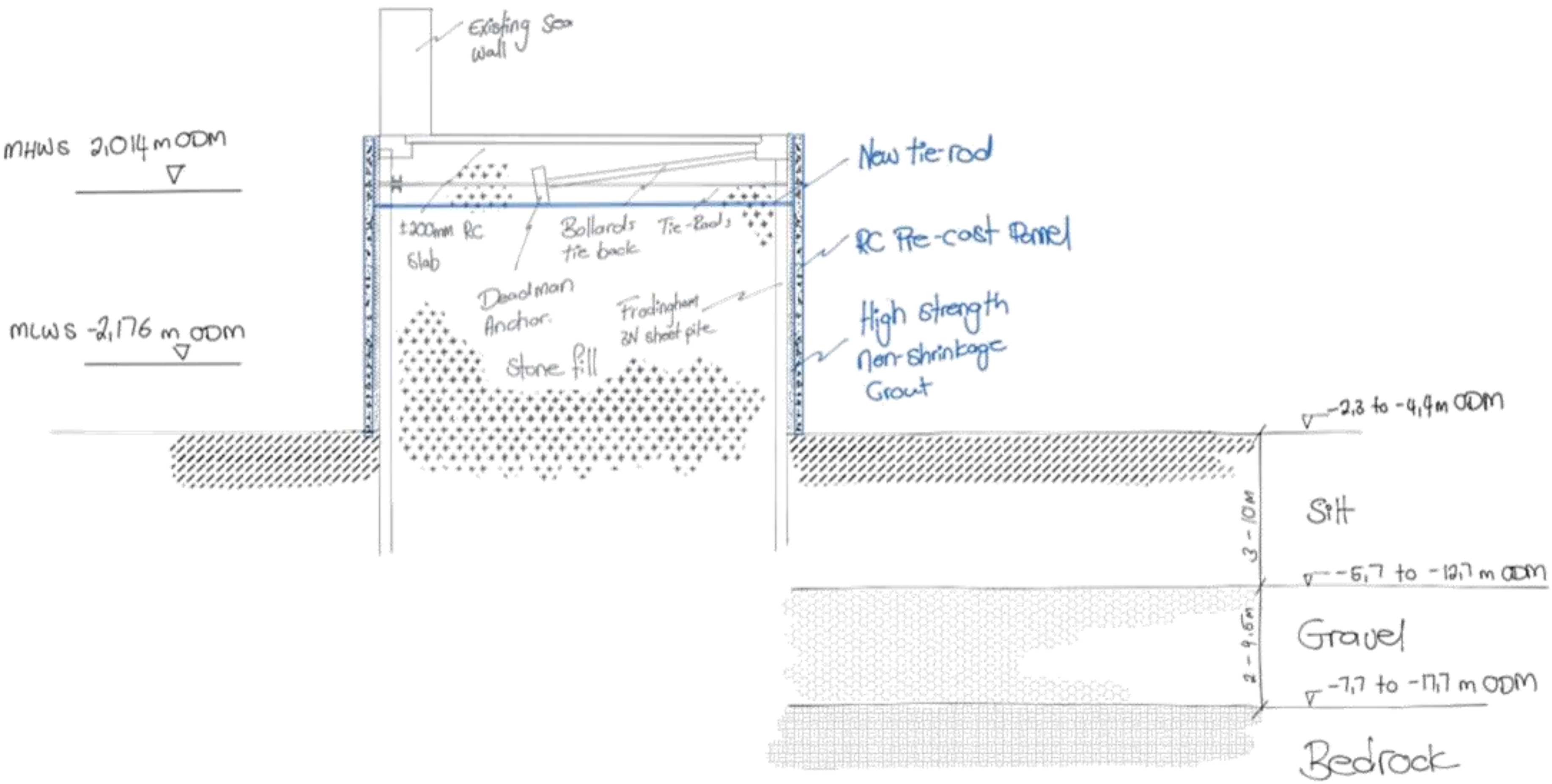


Status Quo: Section of Existing Pier

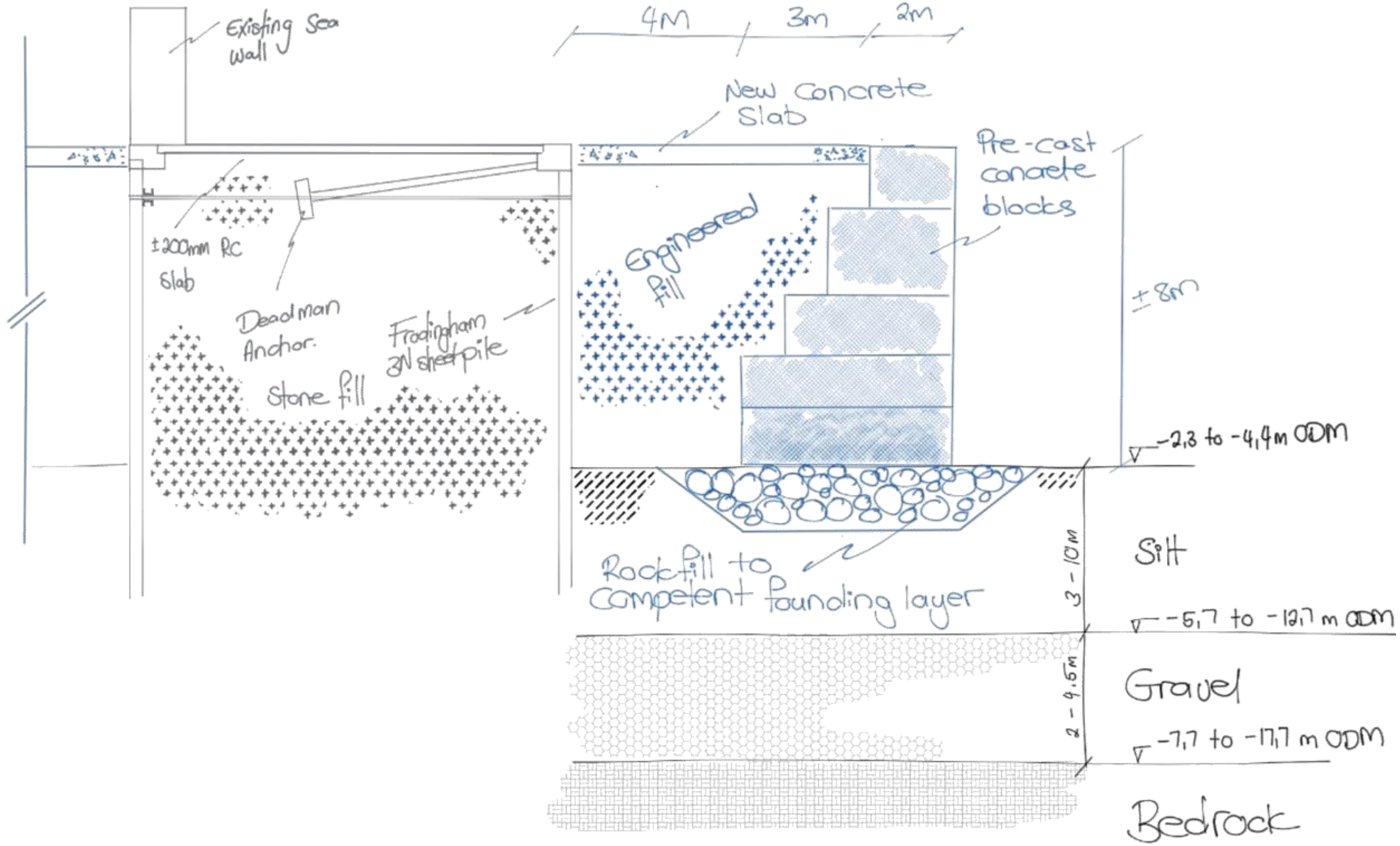




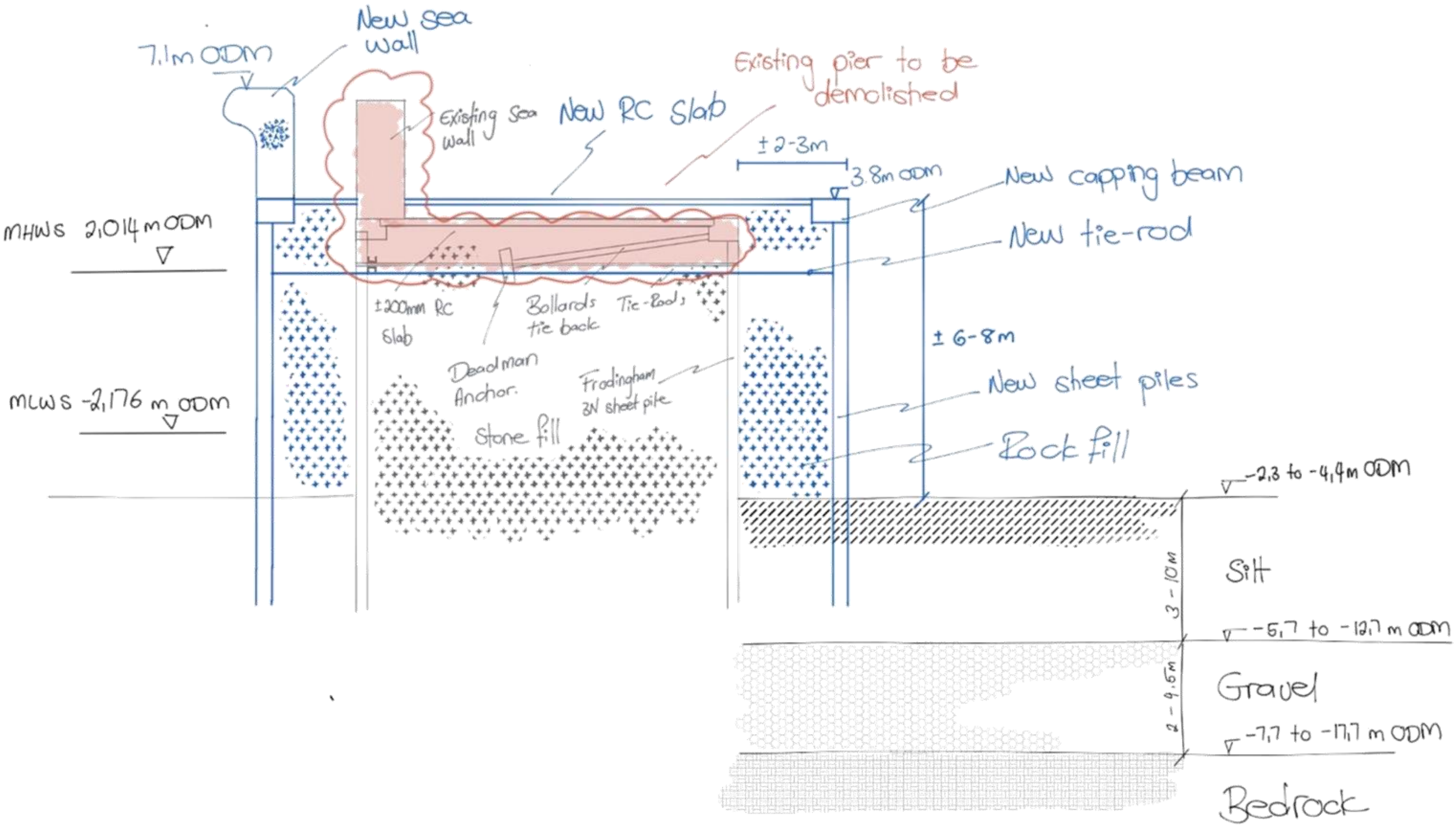
Option 2a: Remediation with Steel Plates



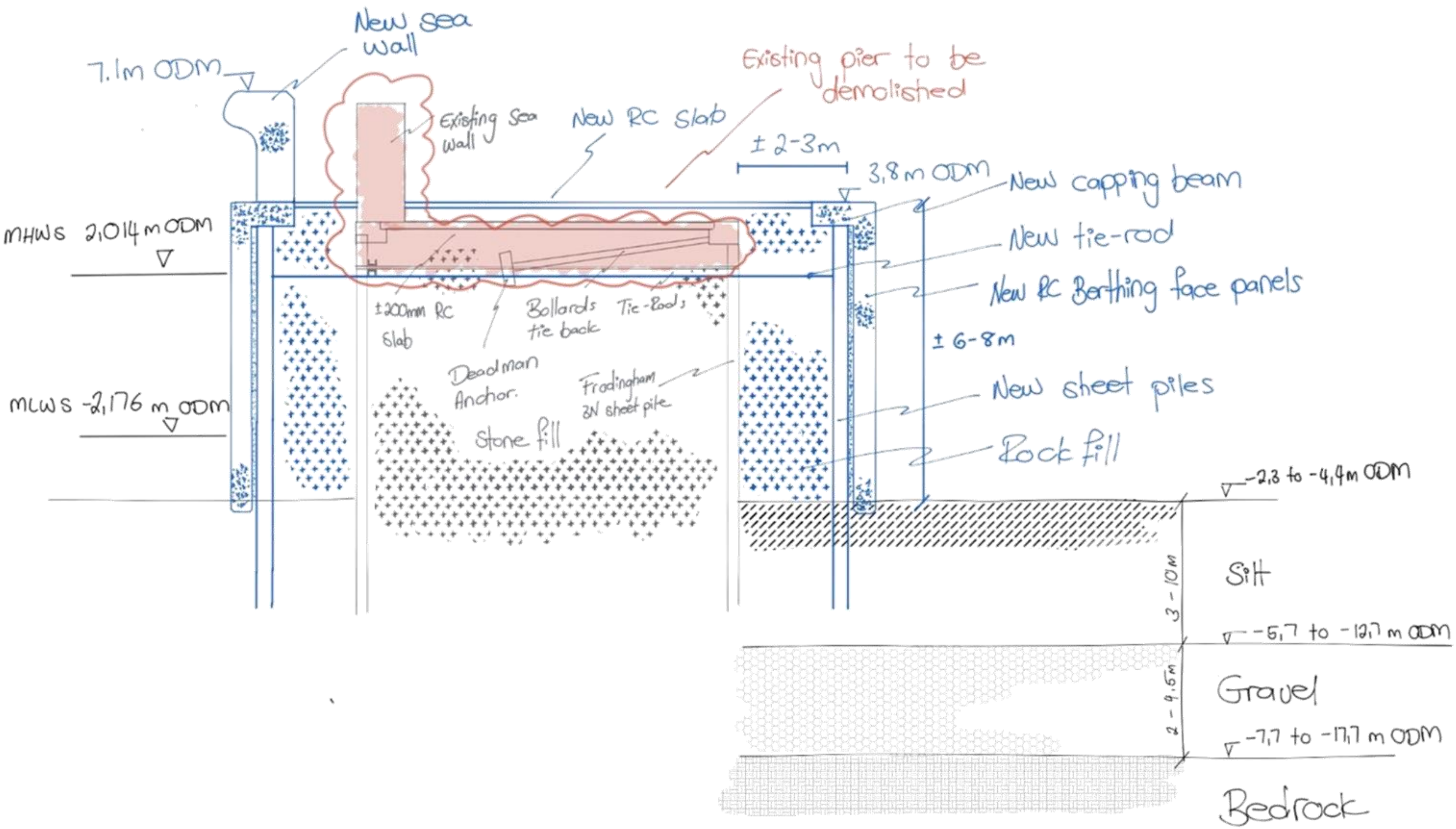
Option 2b: Remediation with Concrete Façade



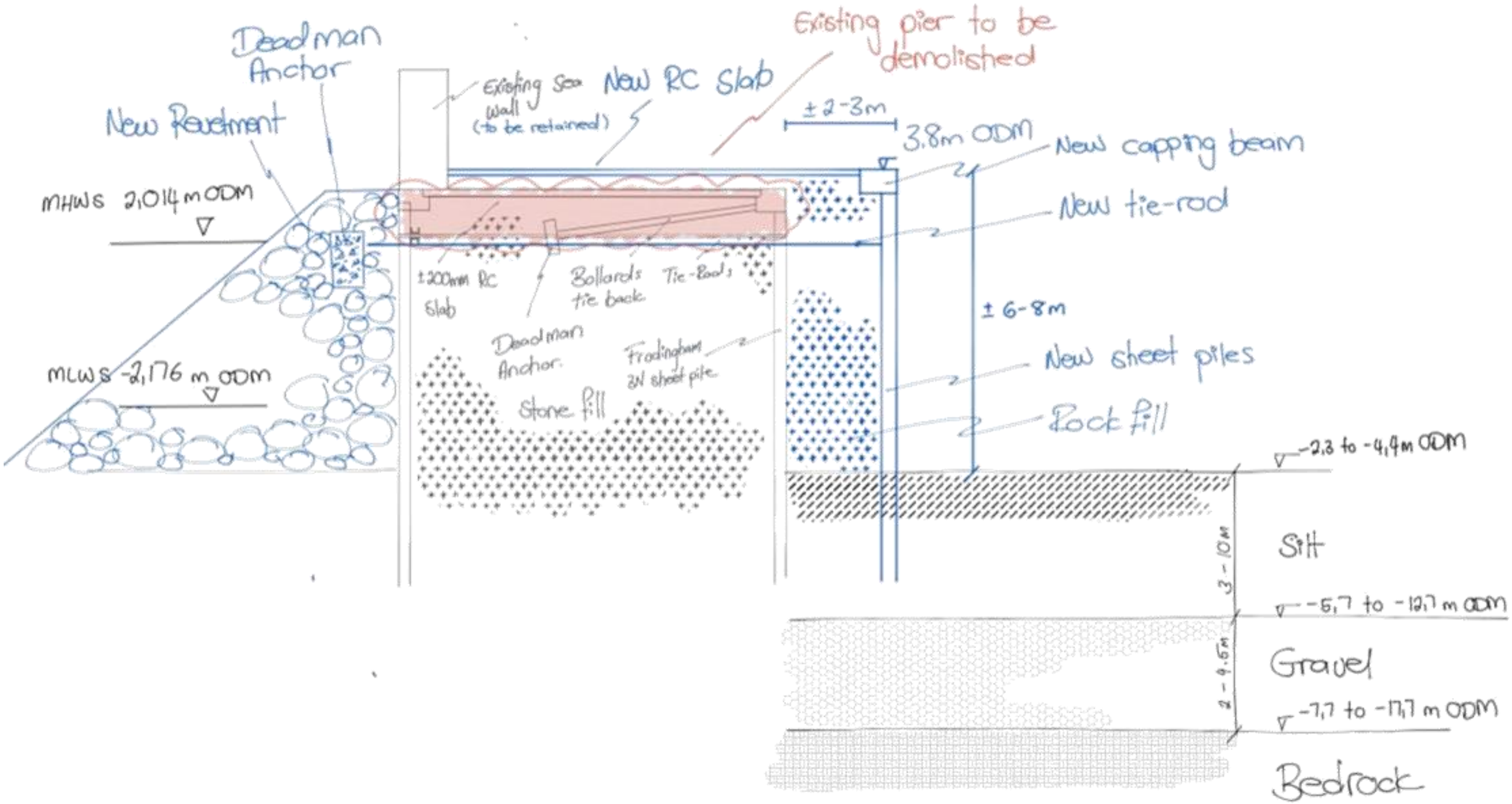
Option 3: Gravity Wall



Option 4a: Conventional Sheet Pile Wall



Option 4b: Encapsulation Sheet Pile



Option 4c: Sheet Pile and Rock Revetment

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