HR Wallingford
Working with water

Isles of Scilly - Design Services for Off Islands Coastal Erosion Defence and Dune Management

Climate Adaptation Scheme - Preliminary Design - Bryher

DKR6499-RT003-R02-00 December 2021

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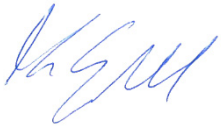		

Executive Summary

This document is a RIBA Stage 3 Design Engineering Report. This report presents the preliminary design for the interventions proposed at different beaches on Bryher Island to improve the coastal defences to protect the island and its infrastructure from the threat of climate change.

Seven beaches have previously been identified with sites under threat from climate change. HR Wallingford have reviewed the previous proposals at these sites and following a site visit to inspect the existing conditions at each of these beaches, have used wave modelling results from others and have applied our expertise on the impacts of climate change to propose design solutions to protect these beaches.

As appropriate the required water level and wave overtopping protection requirements at the critical sections of each beach have been determined and the sections of the beaches most vulnerable and in need of interventions have been identified and solutions proposed. The previous proposals made in the Outline Business Case (OBC) (Reference 2) were reviewed and these and alternative proposals for each beach have been assessed and recommendations made and preliminary designs developed. These recommendations have considered the critical sections at each beach, it is not intended to provide extensive protection measures around the entirety of the beaches. The recommendations have been developed considering the required technical requirements, the likely costs and construction form to make sure that they are appropriate for the Client's requirements and budget.

During the site visit each beach was assessed in its entirety and in some sites different sections of beach from those identified in the OBC were identified as requiring intervention, and this report sets out the proposed concepts at each site. The proposed protection measures are a combination of revetment and engineered embankments, such as the recommended revetment at Stinking Porth Beach (site 3) shown as Figure S.1 and will enhance the level of protection from wave inundation on Bryher. These recommendations will then be progressed to detailed design.

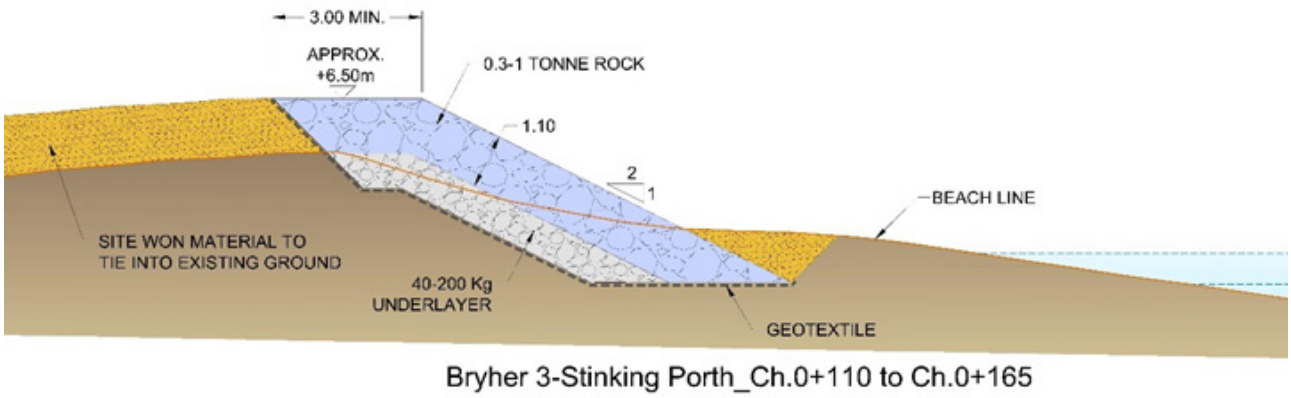

Figure S.1: Proposed revetment at Stinking Porth

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1. Introduction

The Isles of Scilly have received funding from the European Regional Development Fund and the Environment Agency to complete a range of climate change adaptation works in the Scilly Isles of St Agnes, Bryher and St Martins. These include interventions, such as coastal protection works, renourishment of existing beaches and dunes, upgrade or/and construction of new defences, aiming to reduce the impact of coastal erosion and wave overtopping exacerbated by future climate change scenarios.

The Isles of Scilly are one of the areas in Europe most vulnerable to the effects of climate change, sea level rise and consequent increased risk of inundation, overtopping and coastal erosion.

The council of the Isles of Scilly has commissioned HR Wallingford to undertake this work to evaluate the risk at the sites identified as being most vulnerable and develop designs for the coastal works proposed. The present report describes the approach to the identification, selection, appraisal and development of the schemes to detailed design for Bryher Island.

Conceptual options were suggested and were preliminary appraised as part of previous studies (JBA, 20). These will be qualitatively appraised together with suitable alternatives considered after the site inspection. The preferred schemes will then progress to detailed design.

The presented report is a RIBA Stage 3 Design Engineering Report. It includes design basis, option appraisal and selection of preferred option and development of the preferred option to a suitable level for Planning Application.

1.1. Abbreviations

AOD	Above ordnance datum
BMP	Beach management plan
GI	Ground investigation
OBC	Outline business case
RIBA	Royal Institute of British Architects
RFP	Request for Proposal
SPA	Special Protection Area
SSSI	Site of special scientific interest.

2. Scope

The scope of the works includes the following key elements for the sites on Bryher, as identified in the OBC (Ref. 2 in Table 3.1) and in the RFP (Ref. 1 in Table 3.1):

- Review of documents, data and information;
- Review of waves and water levels information;

- Site Visit, visual inspection of flood and coastal protection;
- Beach stability desk study;
- Option appraisal and evaluation, selection of preferred option;
- Scheme design RIBA Stage 3;
- Scheme Design RIBA Stage 4;
- Ground Investigation Specifications.

The sites on Bryher that were examined as part of this study are listed below with the locations of the sites shown in Figure 2.1. Note, Sites 4a, 6, 7, 8, 10 and 11 included in the plan were not included in the scope of work for this study:

- Site 1 - Great Porth/Par south of Great Carn
- Site 2/3b - Great Porth (Great Par) north of Great Carn
- Site 3 - Stinking Porth
- Site 4a - Great Popplestone
- Site 5 - Kitchen Porth
- Site 8b - The Quay
- Site 9 - Green Bay.

A more detailed plan of the Bryher sites, as well as identification of the some of the key features is included in Appendix A.

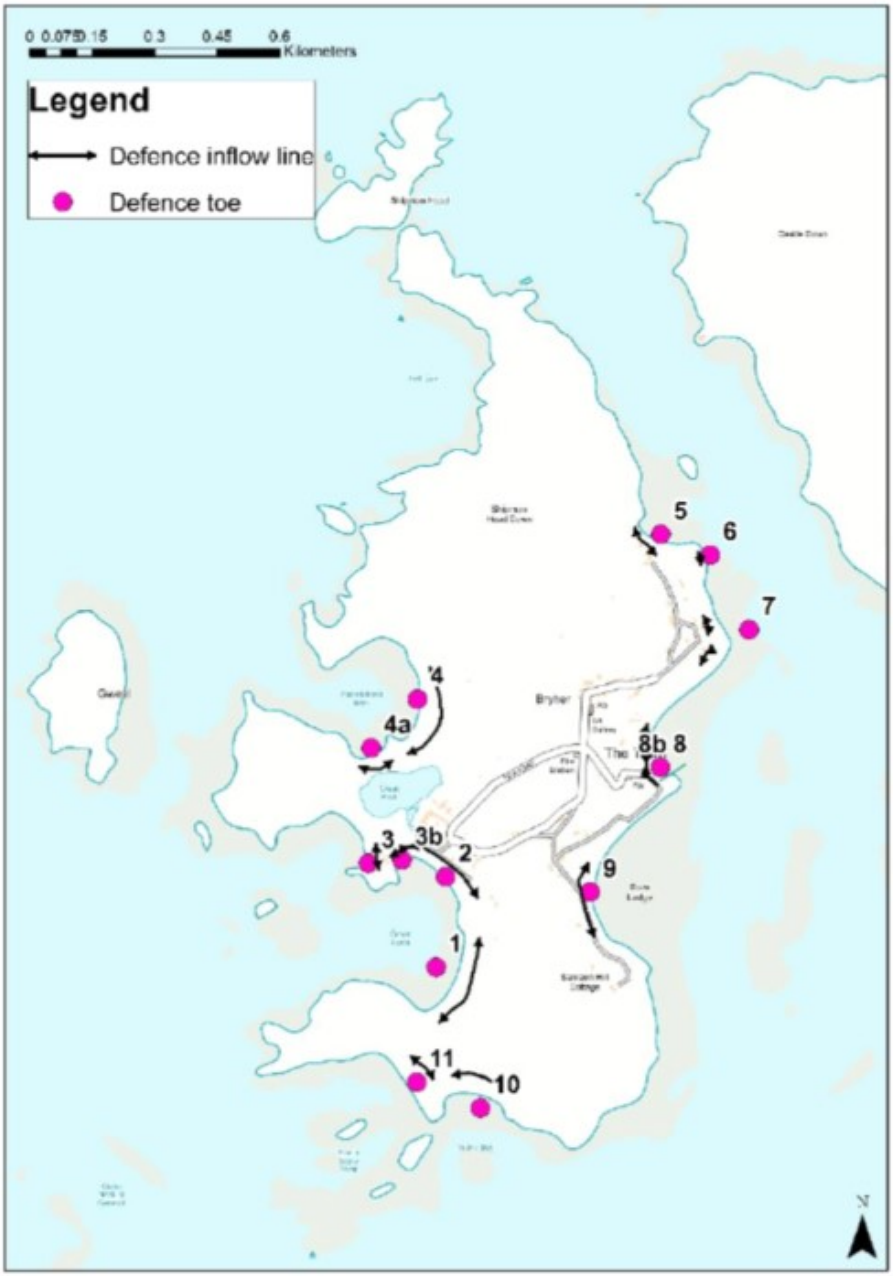

Figure 2.1: Location of sites

Source: Council of Isles of Scilly (OBC, 2020)

3. Reference documents

Data from the documents/sources described in Table 3.1 below, has been provided by the Council of the Isles of Scilly to be used for the purpose of the design.

Table 3.1: Reference used for the design

Reference Number	Document Title	Published	Provided by
1	Scope of Work- RFP- Annex B_Brief for Off-Island Coastal Defence Works_Final	2021	Council of the Isles of Scilly
2	Adaptive Scillies – Natural Dune Restoration & Flood Resilience – FCERM Outline Business Case	JBA, Arcadis, Council of the Isles of Scilly, April 2020	Council of Isles of Scilly
3	Isles of Scilly – Coastal Flood Modelling – Final Main Report	JBA, Environment Agency, February 2019(a)	Council of Isles of Scilly
4	Isles of Scilly – Coastal Flood Modelling- Model development Report	JBA, Environment Agency, February 2019(b)	
5	DKR6499_RT01-Site Visit Notes	HR Wallingford 2021	HR Wallingford
6	SMP2	2010	Council of the Isles of Scilly
7	SMP2 interim review	2016	Council of the Isles of Scilly

4. Holds

Some HOLDS exist at this preliminary design stage due to insufficient information. The preliminary design can be developed without these data, but these items will need to be addressed before investment decisions and prior to start of construction:

- Detailed Topographic survey (up to low water contour);
- Economic Appraisal, BoQ and detailed costing developed in the OBC;
- Ground Investigation Report.

5. Background

Bryher is the most westerly of the populated Scilly Isles and is directly exposed to the Atlantic Ocean. Much of the island is at an elevation safe from predicted flooding but several areas including to the north of Lower Town, near the main population centre, are currently at risk and with predicted climate change, further areas will be vulnerable as illustrated in Figure 5.1 and Figure 5.2, taken from modelling carried out by JBA for the Environmental Agency (Ref. 3 and Ref 4). In addition the freshwater pond known as Great Pool is at risk. This could impact the water supply on the island as well as important habitats for migrating birds.

The OBC (Ref. 2) in 2020 confirmed that; there was a need to continue working with natural processes while protecting, improving and sustaining the coastal and freshwater habitats. The OBC concluded that; this could be achieved by strengthening, improving elevation profiles, raising crest heights, addressing the causes of damage, improving public access and appreciation of the dunes and their coastal defence function. The proposed measures had the aim to manage flood risk (not resist coastal erosion). Where natural dunes exist, the protective measure do not seek to ‘hold the line’ against dune regression, instead they will enable the dunes, as repaired and restored eco-systems, to regress adaptively (as a ‘system’) in a manner that maximises environmental and habitat adaptation.

The recent site visit has identified that most of what was classed as dunes are better described as embankments and the rolling back and natural dynamic response of a dune system would not necessarily apply here. The enhancing of protection and increasing crest height of these embankments will need to be engineered rather than sand nourishment and planting. The proposed interventions do need to consider natural restoration to give the 'dunes' and their ecosystems the capacity to better withstand storms but strengthening their cores and reduce the loss of height following extreme storm events.

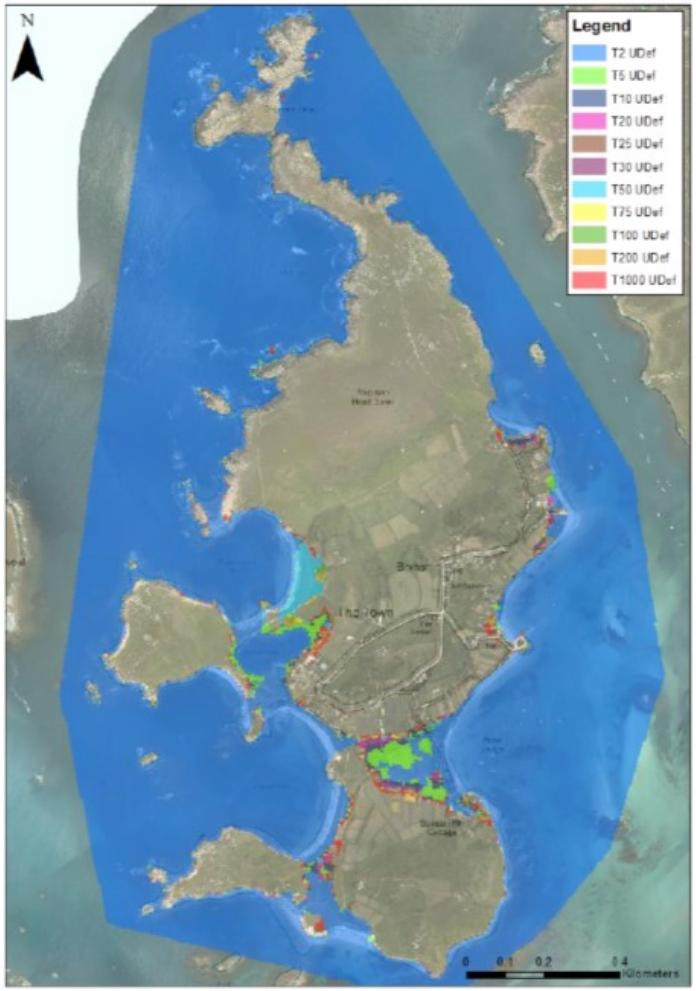

Figure 5.1: Undefended flood risk – Present day

Source: JBA (2019)

Figure 5.2: Undefended flood risk – Year 50

Source: JBA (2019)

Table 5.1 describes the preferred options as identified in the OBC (Ref.2) and also reported in the RFP (Ref. 1). In Section 9, where considered appropriate, alternative options are also discussed and then are appraised as part of the option appraisal in Section 10.

Table 5.1: OBC Preferred options

Option	Site	Protecting	Aim	Issue	Activity
1B	4a – Great Popplestone	Freshwater supply	Prevent saline intrusion by preventing overtopping waves	North of the bay sand dunes 2 m too low	Recharge & restore 90 m of dune inclusive of repositioning 50 m^3 of in-situ existing 'rock armour'
2B	3b – Great Porth [aka Great Par] north of Great Carn	Main road	Prevent overtopping waves damaging/blocking road	Dune crest 1 m below rest of beach frontage	80 m linear of dune nourishment and restoration along with negotiated changes to access and vehicular routes to enable the dune to recover and recess
3B	2 – Great Porth/Par south of Great Carn	Main road	Prevent overtopping waves damaging/blocking road	Low section of dune	20 m of damaged dune restoration with recharge
4B	8 – Green Bay	The Green	Prevent overtopping waves	Low section of dune	100 m of 'dune' restoration and nourishment with sand to raise dune height by 250 mm
5B	3 – Stinking Porth	Freshwater supply	Prevent saline intrusion by preventing overtopping waves	Low section of dune	Reduce overtop & breach risk at 20 m southern section with 20 m^3 of localised dune restoration
6B	5 – Kitchen Porth	Vulnerable properties	Prevent inundation	Low section of bank	Raise front edge and across 75 mm of informal pathway by 500 mm to provide protective embankment between dune area and properties
7B	8b – Quay	Quay access	Prevent erosion of road and quay	Eroded corners	Rock revetment protection works on Quay Beach

Source: From RFP – provided by Council of Isles of Scilly

6. Bryher site notes and observations

A site visit to the Isles of Scilly was conducted between 15th to the 17th of June 2021 to gain field information on the existing defences and the fronting beaches. This information has supported the identification, selection and development of the coastal works required. The findings of the site visit are discussed in DKR6499-RT001 (Ref. 5).

The site visit has provided information on the coastal environment and it has given a good appreciation of the boundaries with the designated sites and the condition of the present dune/banks. Also, it provided up to date information on which sections of defence had already been upgraded since 2019, and no longer require further intervention. During the site visit, alternative options were discussed with the Client and these were added to the project option appraisal together with the existing options indicated by the OBC.

The findings of the Site Visit are detailed in the Site Visit Notes (Ref. 5), the description of the alternative options below, see Section 9, includes the conclusions reached on site.

7. Design basis

7.1. Design life

The design life for the coastal scheme is 25 years.

7.2. Coordinate system

National Grid for plane coordinates.

7.3. Vertical datum

All levels are shown in m OD.

7.4. Data

7.4.1. Topographic and bathymetric data

The following topographic data was used:

- LiDAR downloaded from: https://environment.data.gov.uk/DefraDataDownload/?Mode=survey:
  - Digital Surface Model (DSM) - this LiDAR data type was chosen for consistency and better understanding when displaying data in Excel plots. Generally a DTM would be preferable but in this case, not available for all years of interest.
  - Years used: 2011, 2014, 2018 and 2020.

During the analysis of the LiDAR data, 'discrepancies' were apparent between surveys regarding elevation ('z' values). To address this issue, an additional elevation check was carried out using profile data from the Channel Coastal Observatory (CCO). The CCO data provided topographical coastline profiles using the same vertical datum (m ODN) as the LiDAR, therefore a local comparison could be made against the LiDAR datasets. This allowed an informed decision to be made regarding what was a 'realistic' elevation for a particular match of survey year. Following on from this, it was decided that the 2011 LiDAR (earliest year) values should be used as the baseline to adjust the other LiDAR survey to, thus making all the datasets nominally comparable. Hard point elevation values (roads surfaces, concrete slipways) were extracted from the same positions in all LiDAR datasets in order to work out an average difference (adjustment) between a baseline year and the other years of interest. The average adjustment values were applied to the 2014/18/20 datasets so these could be brought in line with the 2011 baseline LiDAR.

7.5. Water levels

7.5.1. Sea and tidal levels

Table 7.1: Tide tables

Level	Elevation (m CD) -	Elevation (m OD) -
MHWS	5.68	2.77
MHWN	4.35	1.44
MLWN	2.04	-0.87
MLWS	0.73	-2.18
LAT	0.09	-2.82

Source: HR Wallingford

7.5.2. Extreme water levels

Extreme sea levels were based on predictions published in the Environment Agency's Coastal Flood Boundaries report, Environment Agency (2018). These were updated to the present (2021) to account for likely rises on sea levels since 2017, the base date for these levels, University of Colorado (2021), and estimated changes in land levels since this date, Bradley *et. al.* (2008).

Site CFB Chainage	Extreme still water level for the year 2017 per AEP (mODK)										
	50%	20%	10%	5%	4%	3.33%	2%	1.33%	1%	0.5%	0.1%
ESL 0	3.51	3.59	3.64	3.69	3.71	3.72	3.75	3.78	3.80	3.84	3.95

Figure 7.1: Extreme sea level data

Source: JBA (2019)

7.6. Waves

The RFP did not require wave modelling and instructed the tenderers to extract the required input data from "The Isles of Scilly Coastal Flood Modelling" (JBA for the EA, 2019). A preliminary review of this document showed that the report did not provide suitable wave data for detailed design. More information on extreme waves and water levels data were required. The Client requested the data, in electronic copy, from the Environment Agency at the start of the project.

The EA provided a first set of data, which was considered insufficient. A further more extensive set of data was subsequently provided. This was reviewed and design wave conditions were extracted.

As instructed by the Client, HR Wallingford have utilised the data provided from the above mentioned study. HR Wallingford has duly reviewed the information provided and confirms that they appear reasonable. However, without access to the raw data, and repeating the full analysis, we note that HR Wallingford are unable to take responsibility for any existing data quality and quantity provided by others.

The data supplied to HR Wallingford from the JBA modelling study consists of a sub-set of 10,000 years' of modelled extreme conditions, which has been set-up for extreme overtopping conditions. This sub-set of data contains the combinations of wave and sea level parameters that give the largest overtopping rate, although not necessarily the largest wave heights. However, the method adopted to generate these data

was developed by HR Wallingford (see for example Gouldby et. al., 2017), and it is considered that a reliable estimate of the extreme wave heights at the site(s) could be determined from the data provided.

Two sets of data were provided:

- Defended
- Defended NPPF 2117.

Where NPFF stands for “National Planning Policy Framework”.

It is assumed that:

- “Defended” is the current day (2017) estimate of wave heights and overtopping rates with existing sea defences.
- “Defended NPPF 2117” is the 2117 estimate of wave heights and overtopping rates which includes a 10% increase in offshore wind speed and wave heights, though no adjustment seems to be made to the wave period to maintain the input wave steepness. Sea level rise from 2017 to 2117 is given as 1.037m. This seems to be consistent with guidance given for the higher central allowance for sea level rise as currently given in this link:

https://www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances#sea-level-allowances

The information for the relevant sites at Bryher were extracted from these datasets. As part of the present study, a SLR allowance has been included in the water level to update the data to present day water levels (@2021) and to calculate water levels in 2046 (25 years life).

7.6.1. Extreme wave heights and water levels

The design standard of protection for Bryher has been confirmed by the Client as a 1 in 45 year return period of flood event. Based on the review of the data as described above, and through interpolation between the 2017 and 2117 defended epochs, the following conditions have been selected for the design wave conditions and associated water levels at each of the sites considering the 25 year design life.

Table 7.2: Design waves and water levels

Site	Hs (m)	Tp (s)	Water Level
1	1.1	8.5	3.2
2	0.9	10.9	3.7
3b	0.7	10.0	3.9
3	1.2	10.2	3.8
4	0.8	10.4	3.4
5	1.5	11.3	3.6
8b	0.4	8.1	4.0
9	0.8	5.6	3.5

Source: HR Wallingford

7.7. Overtopping assessment

A wave overtopping study was carried out as part of the JBA (2019) study for the EA. This study provided as output the flood extent and recommendations for the increase in crest elevation required along the coastal

frontages. In addition, indications were given for flood alerts related to water levels and overtopping discharges.

As part of the present study, overtopping calculations are undertaken to assess the stability of the coastal/flood protection. No flood modelling is performed for the selected options, since this is outside the present scope of work.

The recommendations given in Ref. 2 and Ref.3, based on flood modelling, are considered as part of the assessment. Wave overtopping at the revetments is assessed using the empirical formulations reported in the EurOtop II (2016) manual.

7.8. Materials

7.8.1. Quarry rock properties

A quarry rock density of 2650kg/m^3 is assumed in the design of the rock revetment. This is the lower end of typical values for granite, so is a conservative value to use.

7.8.2. Concrete properties

A minimum concrete density of 2350kg/m^3 is assumed for concrete, for any flood or wave wall incorporated in the design.

7.8.3. Geotextile properties

The geotextiles to be used should be designed to meet the following criteria. Values will be assigned for the geotextiles and their use during the detailed design stage:

- A permeability criterion to ensure the geotextile is permeable enough to allow liquid to pass through relatively unhindered;
- A retention criterion to ensure the geotextile openings are small enough to prevent excessive migration of soil particles ("piping");
- An anti-clogging criterion to ensure the geotextile is porous enough so when soil particles become entrapped in or on the geotextile its permeability will not be adversely affected;
- A survivability criterion to ensure the geotextile survives installation; and,
- A durability criterion to ensure the geotextile is durable enough to withstand the effects of chemicals, UV light and abrasive conditions for the life of the project.

8. Design criteria

8.1.1. Dune/ridge recharge material

It is assumed that sand and recharge material to match existing ground can be locally sourced from the island.

8.2. Ultimate limit states

8.2.1. Rock armour

For stability, a return period event of 1:200 year (0.5% of occurrence per annum) is used for the preliminary design. The target damage level at this return period is selected as per the Rock Manual guidelines (CIRIA/CUR/CETMEF (2007)):

- Start of Damage: Sd = 2 – corresponds to “no damage” with approximately less than 5% armour rock displacement.

8.2.2. Overtopping

Guidance on methodologies and maximum allowable overtopping rates along the frontage will follow the recommendations in EurOtop II (2018), though consideration will also be given to acceptable flooding and acceptable damage following the conclusions and recommendations provided in Ref.2 and Ref. 3.

The crest level/configuration of the flood protection will be designed in such a way to limit mean wave overtopping and minimize risk of flooding and damage to the banks. Overtopping discharges obtained along the frontage will be reviewed considering the stability of the structures.

Based on extensive research on the resistance of grass covered slopes under overtopping events, EurOtop II (2018) provides the following suggestions:

- A good closed grass cover without open holes is very resilient to wave overtopping for wave heights H_{m0} < 3 m. Sometimes mean discharges of q ~ 100 l/s/m may not damage the rear slope;
- A badly maintained grass cover with open holes and a lot of moss may fail well below q < 5 l/s/m.

These limits are summarised in Table 8.1.

Table 8.1: Design return periods and the maximum allowable overtopping

Hazard type and reason	Mean discharge q (l/s per m)
Grass covered crest and landward slope; maintained and closed grass cover; Hm_0 = 1 – 3 m	5
Grass covered crest and landward slope; not maintained grass cover, open spots, moss, bare patches; Hm_0 = 0.5 – 3 m	0.1
Grass covered crest and landward slope; Hm_0 < 1 m	5-10

Source: EurOtop II (2018)

8.2.3. Geotextile sand containers

It is envisaged that geotextile tubes/containers, referred to a geocontainers in this report, will be used as part of the proposed material. Geotextile sand containers are a low cost, soft and reversible solution for a cost-effective shore protection, and have a history of more than 50 years in hydraulic and marine applications. Coastal structures built with geotextile sand containers are obtained by substituting rocks or concrete units with containers made of geotextile and filled with locally available sand.

The hydraulic processes affecting the stability of geotextile sand containers / structures will be assessed using Geosystems. Design rules and applications" by Bezuijen and Vastenburg and the work carried out by Oumeraci et al (2003, 2010) and Recio (2007).

8.3. Serviceability limit states

Sea defence overtopping conditions with a 1 in 1 year joint probability return period will be used as the serviceability limit state (SLS) design criterion. The sea defence will be designed in such a way that it will limit wave overtopping over the public footpath with a target maximum discharge not to exceed q = 1 l/s/m in order to not cause danger to pedestrians who are assumed to be aware of the weather conditions, see Figure 8.1 extract from EurOtop II (2018). The limit applicable for all the sites refers to $Hm_0 < 2m$.

No damage criteria are necessary for this serviceability limit state.

Hazard type and reason	Mean discharge q (l/s per m)	Max volume V_{max} (l per m)
People at structures with possible violent overtopping, mostly vertical structures	No access for any predicted overtopping	No access for any predicted overtopping
People at seawall / dike crest. Clear view of the sea.		
H_{m0} = 3 m	0.3	600
H_{m0} = 2 m	1	600
H_{m0} = 1 m	10-20	600
H_{m0} < 0.5 m	No limit	No limit
Cars on seawall / dike crest, or railway close behind crest		
H_{m0} = 3 m	<5	2000
H_{m0} = 2 m	10-20	2000
H_{m0} = 1 m	<75	2000
Highways and roads, fast traffic	Close before debris in spray becomes dangerous	Close before debris in spray becomes dangerous

Figure 8.1: Limits for overtopping for people and vehicles

Source: Extracted from EurOtop II (2018) Table 3.3

8.4. Code and standards

The design of the coastal works has been carried out in accordance with the codes, standards and guidance documents as listed below:

- British Standards, BS6349 suite, Maritime Structures;
- BS EN 1991-1-1:2002. Eurocode 1: Actions on structures - Part 1-1: General actions. BSI;
- BS EN 1997-1:2004 Eurocode 7: Geotechnical design - Part 1: General rules. BSI;
- BS EN 13383 Parts 1 and 2 European Armourstone Specification.

In addition to the standards above, the following international guides for good practice have also been adopted:

- CIRIA; CUR; CETMEF, (2007). The Rock Manual. The Use of Rock in Hydraulic Engineering; (2nd Edition), London;
- CIRIA, (2010). Beach management manual. (2nd Edition), London. PUB C685;
- CIRIA, (2020). Groynes in coastal engineering – Guide to design, monitoring and maintenance of narrow footprint groynes, London;
- EurOtop II (2018).

9. Description of options

9.1. Introduction

The Outlined Business Case (OBC, 2020) evaluated a number of conceptual options, including do nothing and do minimum. The preferred options identified as part of the OBC (Ref.2, 2020) are summarised in Table 3.1, and are as provided in the RFP (Ref. 1).

The site visit confirmed that some coastal features described as dunes in Table 5.1 were not sand dunes but often ridges or banks, not always of natural formation, and made of mixed material, as described below. The Client acknowledged that the word “dunes” had been used with a very broad meaning in the documentation provided.

The OBC (Ref. 2) did not make a differentiation between dunes and ridges / banks. However, a dune would respond dynamically to storms, reshape and reform. Ridges / banks are in many cases man made and engineered, therefore their response will be different from the response of a natural dune system and any reshaping may lead to failure. Below the word “dune”, used in the OBC, should be read therefore as “ridge / bank”.

In the sections that follow, the Preferred options presented in Table 5.1 are described in more detailed and alternative options, proposed as part of this study, and discussed with the Client on site, are also presented.

The preferred options are also the results of the Option Appraisal discussed in Section 10 and Section 11.

A layout showing the different sites and the sections reviewed and considered in this design are presented in Appendix A. The Construction (Design and Management) Regulations 2015 (CDM 2015) require that safety is a consideration throughout the design and construction process. It is the duty of the designer to consider, assess and mitigate the health, safety and welfare risks in both construction and operation of the proposed works. An initial assessment of the general risks at the sites is included in Appendix B. This assessment will be developed through the design.

9.2. Site No. 1 – Great Porth/Par south of Great Carn

Site No. 1 (Figure 2.1) corresponds to Option 3b in Table 5.1 which was noted incorrectly as Site No. 2. The site is south of the rocky outcrop know as Great Carn.

This pocket beach faces directly onto the Atlantic and is exposed to waves coming from deep water at the entrance to the bay. The beach comprises sand and cobbles from local igneous rock. The source of the rock / sand is the rock headland to the south, and there is a clear transition of angular to smooth cobbles along the beach towards the north. At the south the embankment is fronted by cobbles, but to the north it is more typical of a sand dune with a wider crest.

The crest of the beach at the south end is low and narrow and there is clear evidence of overtopping causing cobbles to washed over to the leeward side. The gaps / dips at the crest are discernible in Figure 9.1 below, which is further exacerbated by pedestrian access related erosion. The low points along the crest can also be identified in the longitudinal section shown in Figure 9.4. The narrow section of beach needs to be increased in width and some form of armour protection is required to prevent further leeward progression of the crest in the future.

The leeward side of the beach is a SSSI and so there is limited scope to push back on build up this area. Building out seaward of the coastal protection and keeping away from the rear side can raise the crest and reduce overtopping and further erosion of the leeward side.

Figure 9.1: Great Porth south showing a gap in the crest

Figure 9.2: Great Porth south showing narrower crest with lower leeward side

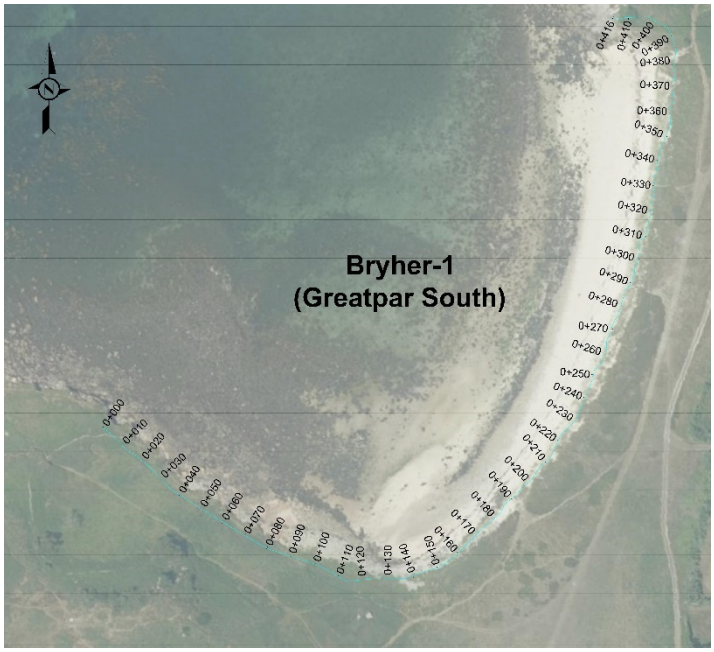

Figure 9.3: Chainages and crest line of Great Porth south

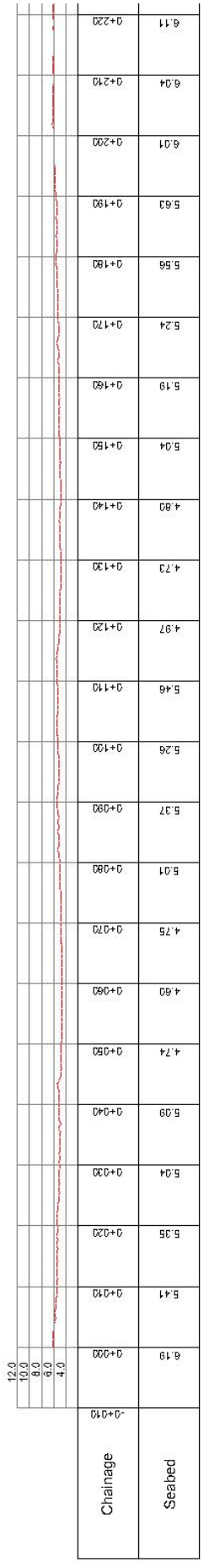

Figure 9.4: Great Porth south longitudinal section, Chainage 0 to 220m

9.2.1. Outline Business Case (OBC) preferred options

THE OBC proposed the following:

- Option 1: 20 m of damaged dune restoration with recharge.
- Option 2: 800m of hard protection at the southern end - rip rap.

9.2.2. Alternative preferred option

With limited scope to interfere or encroach into the SSSI, the following alternative is proposed. To prevent further leeward migration of the beach crest, an 80m armoured revetment will be constructed from chainage 130m to 210m, refer Figure 9.3. Rock stability and wave overtopping assessment was carried out using the extreme wave conditions and water levels summarised in Table 7.2. The size of the rock armour, was designed as described in Section 8.2.1. The slope of the main armour was 1V:3H and a rock grading of 0.3-1t was selected, as shown in Figure 9.5. Additionally, the wave overtopping was estimated using the method outlined in the EurOtop II. In order to satisfy the overtopping criteria (OT < 5l/s/m) reported in Section 8.2.2, the crest of the armour layer was set at +6.5m with a 3m wide crest.

The toe can be buried into the beach and the whole will be placed onto an underlayer with a geotextile barrier to separate it from the beach. Leeward of the crest the existing partial dune level can be matched up and planting and / or natural floral colonisation can follow.

The conceptual design is shown in Figure 9.5, and it is expected, that following installation, the natural beach material will accrete onto the seaward side of the revetement and provide some further initial resistance to wave attack.

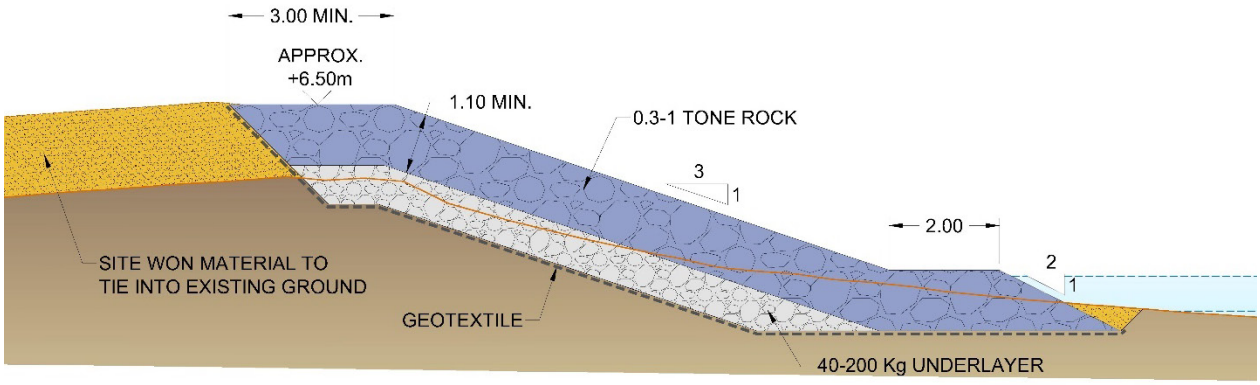

Figure 9.5: Typical proposed cross section for Great Porth south

Note, full extent of footprint to be indicated in the detailed design drawings. This preliminary design is to confirm the intervention concept.

9.2.3. Efficacy and advantages

- The proposed revetment is a robust solution that will provide resilience against extreme storm events.
- There should be minimal maintenance required as is a fixed hard structure.

- The seeding/planting of grasses behind the crest will help to quickly re-establish the habitat and will fix the topsoil/sand to protect the rear of the crest line from any erosion.

9.2.4. Constraints and disadvantages

- This revetment is a change to the appearance of the beach from the existing dune appearance. The proposed extents are however at the very south of the beach so tie into the existing rocky headland.
- The footprint of the raised embankment is quite large so the tie into existing levels behind the new crest needs to be carefully managed on site.
- Although it is anticipated that some rock can be sourced from the islands, there may be a requirement to import rock.
- The crest of the revetment cannot be used by pedestrians to access the beach. Pedestrian will use designated access points.

9.3. Site No. 2 & 3b – Great Porth [aka Great Par] north of Great Carn

To the north Great Porth beach (north of the boat house) there is an *ad hoc* embankment constructed from random larger armourstone interspersed with smaller rocks and earth (see Figure 9.6). It is assumed that this has been placed here by the local farmer as a first level of defence, but it is unsuitable as a coastal defence and needs to be replaced in its entirety. Nevertheless, it is feasible that the existing stone here could be re-used here or become available as armourstone for other upgrades / rebuilds.

The section is greater than the 80 m identified in the proposal and will require the design and construction of a new rock revetment with an impermeable core (as opposed to dune nourishment and restoration noted in the scope of works). There is a vehicle and boat access point, Figure 9.7, that will need consideration as it is evidently a lower part than the adjacent coastal protection crest levels. This will need to be incorporated into the rebuilt revetment with a suitable storm gate or similar demountable storm barrier.

Figure 9.6: Great Porth north showing *ad hoc* placement of rock and soil

Figure 9.7: Beach access point

9.3.1. Outline Business Case (OBC) preferred options

THE OBC proposed the following:

- Option 1: 80 m linear of dune nourishment and restoration along with negotiated changes to access and vehicular routes to enable the dune to recover and recess.
- Option 2: Section to be re-built using some of the local rocks from boat house north. Extend the revetment south to the boat house.

9.3.2. Alternative preferred option

The embankment as described is not a dune structure and cannot be re-built. The alternative option here requires a completely new structure built along the existing footprint. To protect the area behind the beach, and reduce overtopping discharges reaching the Great Pool, a new revetment with an impermeable core is required.

The extent of the proposed structure is shown in Figure 9.8, and the footprint will need to incorporate a boat ramp and / or access along its length. Rock stability and wave overtopping assessment was carried out using the extreme wave conditions and water levels summarised in Table 7.2. The size of the rock armour, was designed as described in Section 8.2.1. The slope of the main armour was 1V:2H and a rock grading of 0.3-1t was selected, as shown in Figure 9.8. Additionally, the wave overtopping was estimated using the method outlined in the EurOtop II. With a 3m wide crest at +6.0 m, the overtopping discharges will be reduced to satisfy the overtopping criteria (OT <5 l/s/m) reported in Section 8.2.2. Material is proposed to be placed on the rear of the rock crest to tie into existing ground levels. This material will provide some initial resistance to any overtopping discharges and will help the rear of the crest tie in to the area behind.

A demountable flood barrier is also recommended to protect the lower crest level of the boat ramp. This is to be a steel frame and stop log panels that can be easily erected by one person. There are several suppliers that offer this product with an example product shown in Figure 9.9. The frame will need to be fixed to the rock crest at both ends.

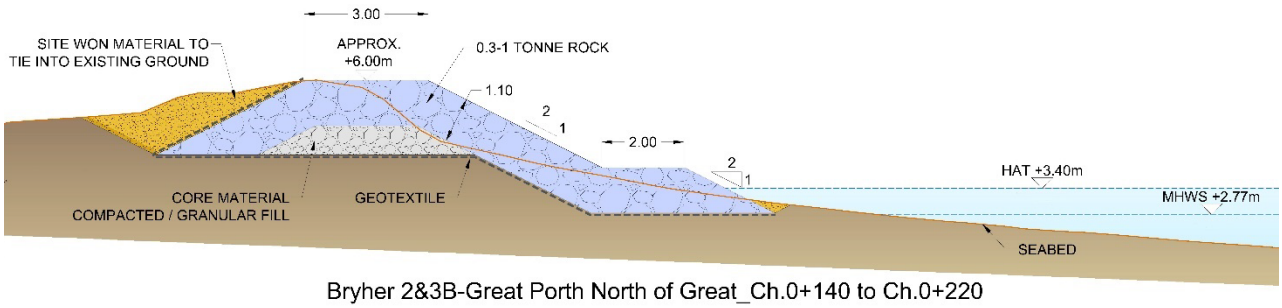

Figure 9.8: Typical cross section for Great Porth north

Figure 9.9: Demountable flood barrier example

Source: www.floodprotectionsolutions.co.uk

9.3.3. Efficacy and advantages

The solution is similar to that proposed for south of Great Carn so has similar advantages and disadvantages:

- The proposed revetment is a robust solution that will provide resilience against extreme storm events.
- There should be minimal maintenance required as is a fixed hard structure.
- The seeding/planting of grasses behind the crest will help to quickly re-establish the habitat and will fix the topsoil/sand to protect the rear of the crest line from any erosion.
- The demountable barrier will prove the additional protection for the fixed low point of the crest.

9.3.4. Constraints and disadvantages

- This revetment is a change to the appearance of the beach from the existing dune appearance. The proposed extents are however similar to the existing revetment at the north of the beach.
- The footprint of the raised embankment is quite large so the tie into existing levels behind the new crest needs to be carefully managed on site.

- Although it is anticipated that some rock can be sourced from the islands, there may be a requirement to import rock.
- The flood barrier relies on human intervention, so an appropriate warning system needs to be in place to ensure that the stop logs are inserted to provide the protection.
- The revetment cannot be used by pedestrians to access the beach.

9.4. Site No. 3 – Stinking Porth

There is a low section of Stinking Porth where overtopping has occurred and many cobbles and small boulders have been washed over the crest (see Figure 9.10). The beach is relatively narrow; especially when compared to other beaches on Bryher; and there is little resistance to sea-states that would likely result in overtopping discharges reaching the Great Pool.

To reduce overtopping, the crest needs to be increased above the present level of the crest of the beach, and a stable structure resistant to wave attack is required. This is a mixed cobble / sand embankment, but is not a dune structure and so beach recharge and / or natural accretion is neither viable nor likely.

Figure 9.10: Showing low crest and over washed cobbles at Stinking Porth

9.4.1. Outline Business Case (OBC) preferred options

THE OBC proposed the following:

- Option 1: Reduce overtop & breach risk at 20 m southern section with 20 m³ of localised dune restoration.
- Option 2: Increase elevation, built a revetment using geobags protected seaward by cobbles/natural material +planting; to the north of rock outcrop, low point with susceptibility to overtopping/flooding.

9.4.2. Alternative preferred option

This is a cobble / sand defence as opposed to a dune restoration as noted in the scope of work and the OBC. A new revetment with a higher crest level is required to ameliorate the overtopping. This would need to be along the section of Stinking Porth indicated in Figure 9.11, Chainages 110 to 165 where the existing crest levels are blow 5.5m.

The rear of the structure here needs to be increased in width and level to provide resistance to wave overtopping discharges. To enable this, a new revetment can be constructed using the existing beach as the base, as shown in Figure 9.12. Rock stability and wave overtopping assessment was carried out using the extreme wave conditions and water levels summarised in Table 7.2. The size of the rock armour, was designed as described in Section 8.2.1. The slope of the main armour was 1V:2H and a rock grading of 0.3-1t was selected, as shown in Figure 9.12. The rock armour and underlayer/geotextile will replace the top of the beach and provide a suitable structure to resist overtopping and maintain the required crest level. Additionally, the wave overtopping was estimated using the method outlined in the EurOtop II. In order to satisfy the overtopping criteria (OT < 5l/s/m) reported in Section 8.1.2, the crest of the armour layer was set at +6.5m. Using existing and reclaimed material, the leeward side of the structure can be bought up to +6.5 m to match the crest and also help re-establish the footpath behind.

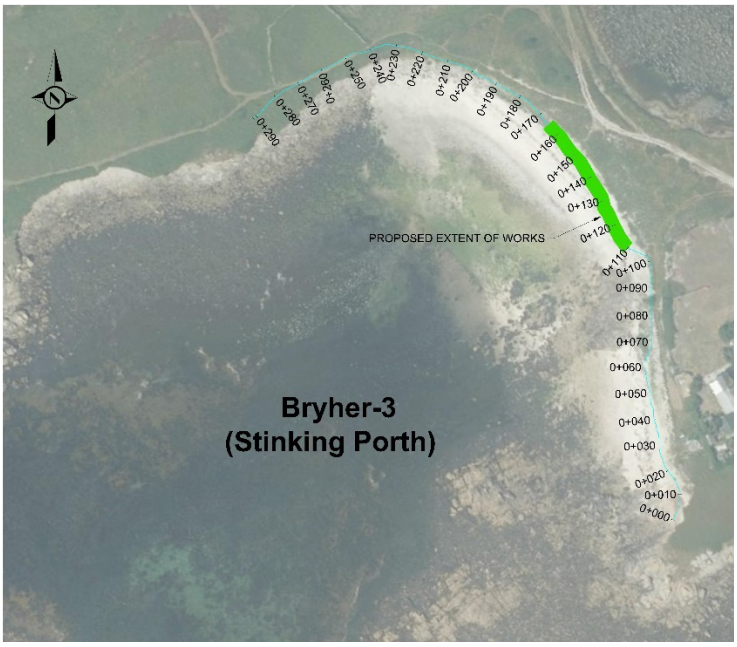

Figure 9.11: Chainage and crestline of Stinking Porth

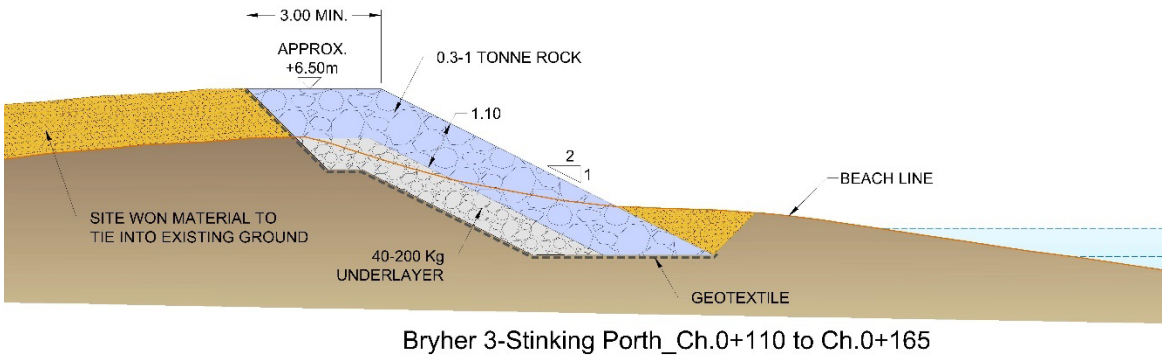

Figure 9.12: Typical proposed cross section for Stinking Porth

9.4.3. Efficacy and advantages

The solution is similar to those proposed for sites 1, 2B and 3 so has similar advantages and disadvantages:

- Protection for Great Pond with the section of beach with lowest crest being raised;
- The proposed revetment is a robust solution that will provide resilience against extreme storm events;
- There should be minimal maintenance required as is a fixed hard structure;
- The seeding/planting of grasses behind the crest will help to quickly re-establish the habitat and will fix the topsoil/sand to protect the rear of the crest line from any erosion.

9.4.4. Constraints and disadvantages

- This revetment is a change to the appearance of the beach from the existing dune appearance and wil be in the centre of the beach.
- The footprint of the proposed crest width is quite large so the tie into existing levels behind the new crest needs to be carefully managed on site.
- Although it is anticipated that some rock can be sourced from the islands, there may be a requirement to import rock.
- The revetment cannot be used by pedestrians to access the beach.

9.5. Site No. 4a – Great Popplestone

This pocket beach also faces directly onto the Atlantic and is exposed to waves coming from deep water at the entrance to the bay. The beach comprises sand and cobbles to the south and there is a more typical sand dune towards the north end of the beach. There is evidence that the larger rock armour to the rear of the masonry wall (at the southern end of Popplestone) was displaced by overtopping discharges during the 2014 storm event (see Figure 9.13), the beach is to the left in this photograph. The masonry wall is fronted by a rock revetment and has a wide flat crest (see Figure 9.14). The overall condition of the masonry wall is fair, and can be incorporated into an upgrade of the defence. The front face of the revetment does not show evidence of armour damage, but it is clear that the crest level is insufficient to control the overtopping discharges at this location. The displaced armourstone at the rear of the structure would have had no effect on reducing overtopping and / or preventing discharges from reaching the Great Pool. Reinstatement of any armourstone at the rear is unnecessary, and these rocks could more usefully be used on the seaward side.

Figure 9.13: Leeward side of the Great Popplestone revetment

Figure 9.14: Showing the crest and crown wall of the Great Popplestone rock revetment (Great Pool can be seen to the right hand side)

9.5.1. Outline Business Case (OBC) preferred options

THE OBC proposed the following:

- Option 1: Recharge & restore 90 m of dune inclusive of repositioning 50 m^3 of in-situ existing rock armour.
- Option 2: Rebuild wall with existing rock increasing crest elevation possibly through a masonry wall.

9.5.2. Alternative preferred option

The existing wall appears stable, from a visual inspection, though it should be assessed and verified prior construction, and the seaward armourstone is in a regular pattern with no obvious signs of damage / displacement due to wave activity. There is a nominally regular 0.5 m wide horizontal crest to the wall at a level of +5.5 m. The section of wall is approximately 100 m as shown in Figure 9.15, from Chainage 80 to 180m. Since the main objective here is to reduce overtopping discharges to protect Great Pond, raising the crest level will contribute to this. The wave overtopping along the existing wall was estimated using the method outlined in the EurOtop II. Results of the assessment showed that overtopping is already within the criteria set out in Section 8.2.2. However the on-site evidence shows that overtopping has occurred, most likely from long period waves. It is considered unlikely that overtopping could be completely eliminated here without a considerably larger (and potentially unacceptable) structure. However, the addition of a masonry block wall to the crest will raise the overall crest level and reduce the overtopping volumes. Since the

masonry wall is approximately 500 mm wide along the crest, then the addition of 600 mm in crest elevation of masonry here may be achievable if suitably keyed to the existing wall with stainless steel or similar dowels at 2 m centres.

Moreover, re-use of the displaced leeward armour on to the seaward side will provide additional voids / resistance (roughness) and contribute to a reduction in wave overtopping (recharged rock shown in Figure 9.16).

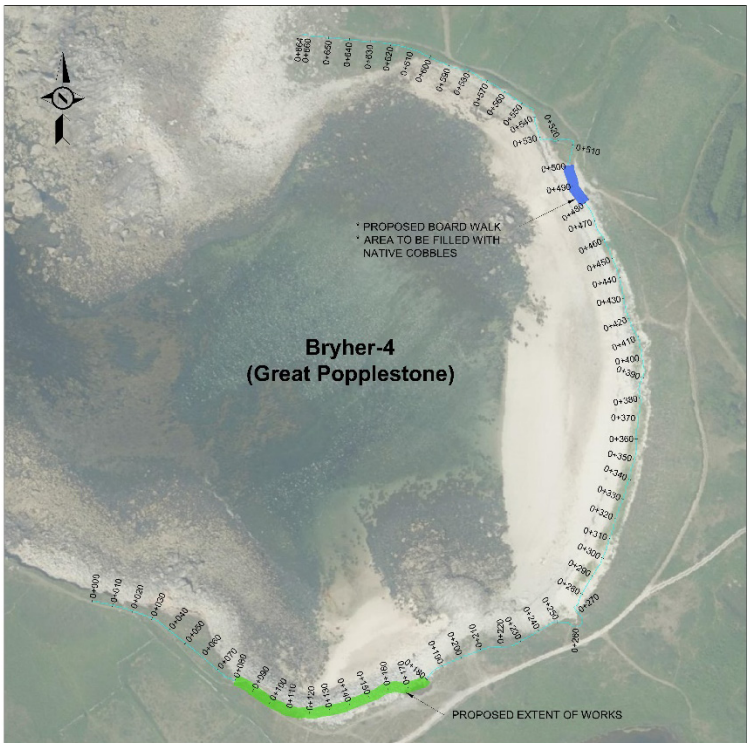

Figure 9.15: Chainage and crestline of Great Popplestone

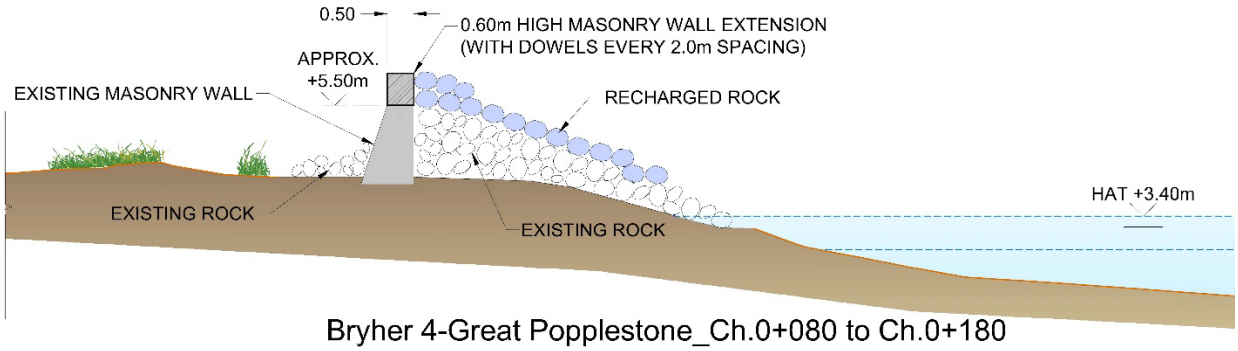

Figure 9.16: Typical proposed cross section for Great Popplestone

There is also an area in the north of the beach where some local erosion to the crest has occurred. This seems to be primarily due to people accessing the beach at this location. The crest in this area, Chainage 480 to 500 is not a concern to the protection of the island, but some soft measures to control access to the beach are recommended. This could include a potential board walk over this area to retain access to the beach with infill of locally sourced rocks and cobbles to help re-establish the beach crest. This measure is not to provide any coastal protection and so is not discussed further.

9.5.3. Efficacy and advantages

The proposed option has the advantage of making use of the existing protection and enhancing rather than providing new works that would require any demolition works:

- The increase in wall height can be done using bricks and mortar and does not require a concrete pour.
- The existing rocks behind the wall can be reused in front of this wall avoiding the need to import rock.

9.5.4. Constraints and disadvantages

- The main disadvantage of this proposed protection is that is make use of existing revetment and wall rather than building a new purpose built structure.
- The condition of the wall is not known. It appears to be in good condition but intrusive investigations should be done to confirm it is appropriate to extend.

9.6. Site No. 5 – Kitchen Porth

This small pocket beach is in the lee of the island but longer period waves form the Atlantic will diffract around the north of the island into this area. It is mainly a sand beach with some cobbles and the extreme south corner is vulnerable to wave activity. This wave activity leads to erosion of the Ram and embankment to the rear of the beach (as seen in Figure 9.17). There is clear erosion around the tree roots, which can be seen exposed, which in themselves make a contribution to the stability of the embankment. This area should have additional armourstone placed in front of the existing structure for approximately 25m up to the exit from the beach to the west.

Figure 9.17: Showing the exposed Ram on the embankment at the rear of Kitchen Porth

9.6.1. Outline Business Case (OBC) preferred options

THE OBC proposed the following:

- Option 1: Raise front edge and across 75 m of informal pathway by 500 mm to provide protective embankment between dune area and properties.
- Option 2: Southern section of bay (to be re-built) with local rocks and geobags to provide core.

9.6.2. Alternative preferred option

Wave attack directly onto the exposed embankment and Ram is a principal cause of the erosion seen in Figure 9.17. Protection for this length is required for approximately 25 m from the eastern corner of the beach up to the exit from the beach as shown in Figure 9.18 from Chainages 180 to 210. Rock stability assessment was carried out using the extreme wave conditions and water levels summarised in Table 7.2. The size of the rock armour, was designed as described in Section 8.2.1. The slope of the armourstone was 1V:2H and a rock grading of 0.3-1t was selected, as shown in Figure 9.19.

Using 0.3 to 1.0 tonne armourstone, either reclaimed from existing resources on the island or imported, should dissipate the wave energy and prevent direct attack on the Ram. The proposed section for the addition of the armourstone is shown in Figure 9.19. This structure does not include an impermeable layer,

and so some overtopping discharge is still expected to reach/percolate to the gardens of the leeward properties.

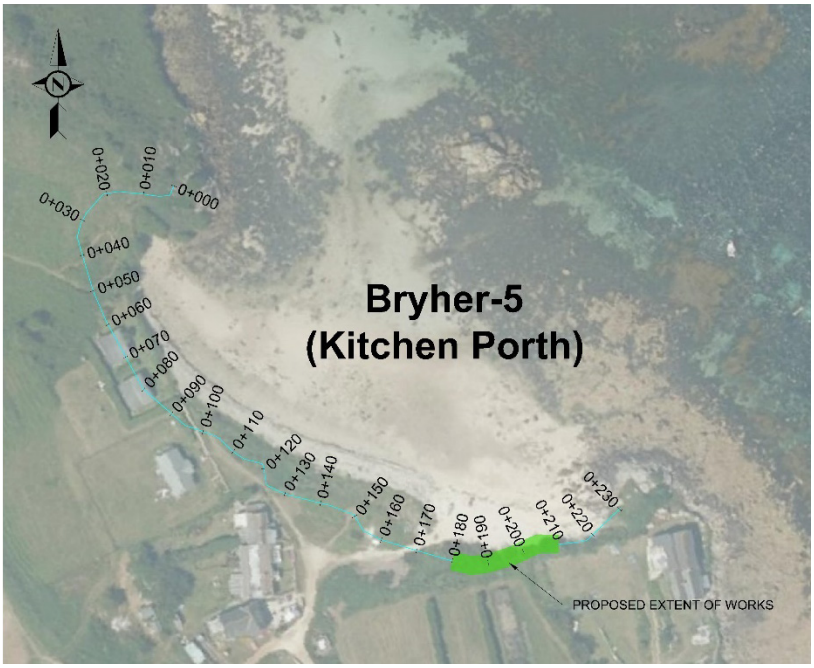

Figure 9.18: Chainage and crestline of Kitchen Porth

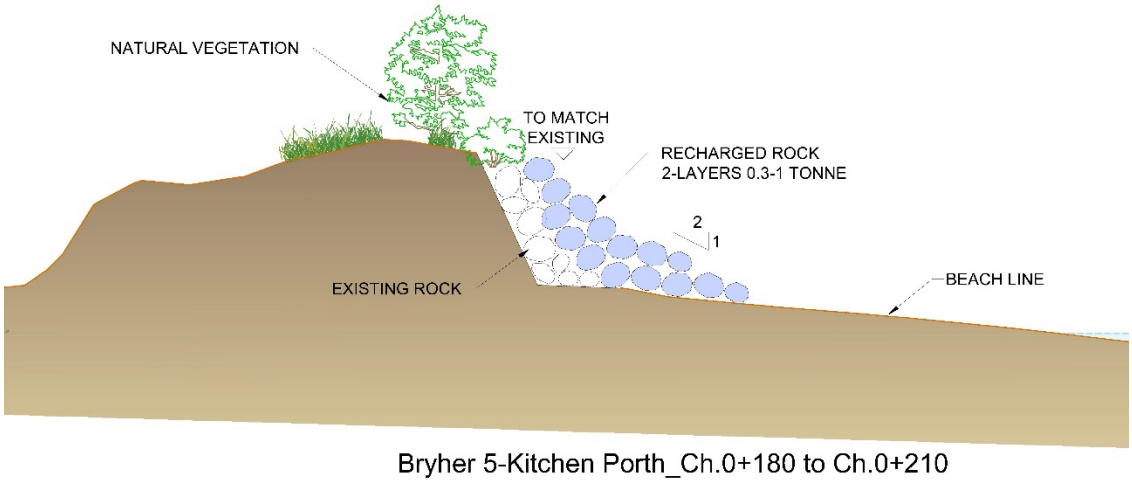

Figure 9.19: Typical proposed cross section for Kitchen Porth

9.6.3. Efficacy and advantages

- The proposed intervention is a short section of the beach only. It is a smaller intervention than proposed in the OBC.
- It may be possible to make use of existing rocks.

9.6.4. Constraints and disadvantages

- The proposed protection is not an impermeable barrier so overtopping discharges in extreme storms may cause some erosion of the Ram.
- The crest level is not to be increased, so some overtopping discharges may also encroach on the properties immediately behind.

9.7. Site No. 8b – Quay

The beach has a crenulated plan and there is clearly evidence of waves focussing into the area where the beach meets the quay. This results in some localised erosion at the point where the quay joins the coastal defence line, and this is exacerbated by pedestrians using this as a point of access / egress. Previous attempts to stabilise this area with some armour placement to protect this area are evident, but erosion and cut-back continue (see Figure 9.20). To prevent further erosion, a reduction in wave energy reaching this corner is required.

Figure 9.20: Showing erosion of the embankment adjacent to the Green Bay quay

9.7.1. Outline Business Case (OBC) preferred options

THE OBC proposed the following:

- Option 1: Rock revetment protection works on Quay Beach.
- Option 2: Include a small groyne to protect the corner of the beach.

9.7.2. Preferred option

For this location, the OBC Option 2 is recommended as the preferred option. Wave attack into the corner where the beach, dune and quay meet is eroding the dune at this corner. An armourstone groyne placed on the beach will attenuate waves approaching the shoreline and reduce direct wave activity. Placed at the end of the straight section of the existing quay, a 10 m long 0.3 to 1.0 tonne armourstone groyne is identified as appropriate, as shown in Figure 9.21, will achieve this. With a 1.3 m wide crest, level with the top of the existing quay at +4.25 m, a small groyne with 1:2 sides (see Figure 9.22) should provide the necessary wave attenuation. The structure may be overtopped but this is not the primary function of the groyne and is acceptable. Some beach changes may happen seaward of the groyne.

The structure can be founded on the existing beach, and requires only a shallow excavation to provide a suitable foundation. This would be expected to blend in with the natural beach contours relatively quickly.

Figure 9.21: Chainage and crestline of Quay beach and proposed groyne location

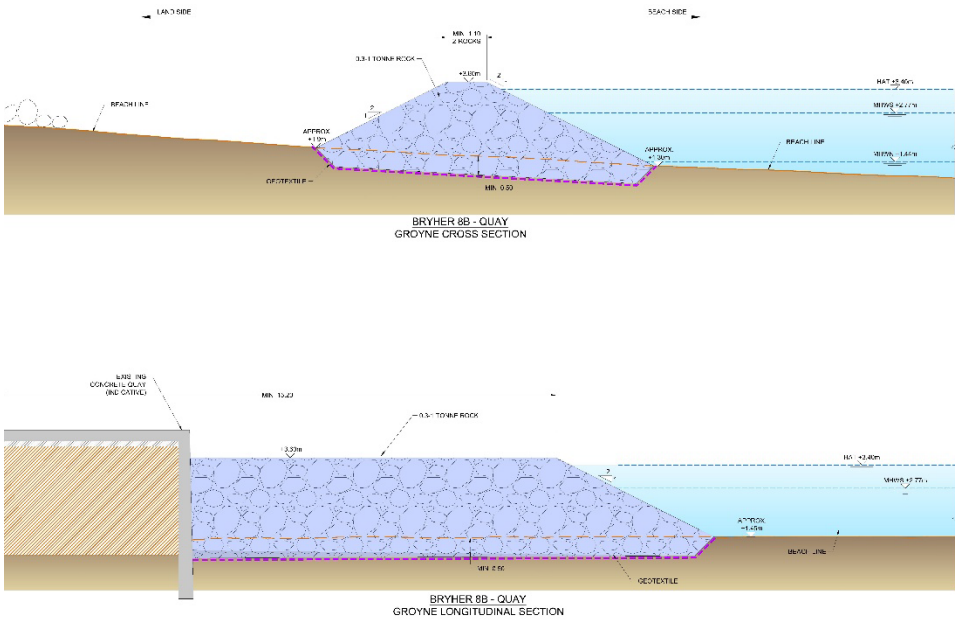

Figure 9.22: Cross and longitudinal section for the proposed quay groyne at Quay beach

9.7.3. Efficacy and advantages

- This small structure will protect the corner of the quay and will prevent further erosion that could potentially cause damage to the quay wall.

9.7.4. Constraints and disadvantages

- The groyne will likely require import of rock if locally sourced rocks can't be found.

9.8. Site No. 9 – Green Bay

Beach comprises sand and cobbles from local igneous rock. Cobbles range from angular to smooth and are the source material for the sand / cobble embankment. There is a gently sloping sand beach with mixed cobble with a well established vegetated crest as can be seen in Figure 9.23 and Figure 9.24. It is, however, thought likely that this is the area for biggest volume of overtopping that would flood the boatyard in the immediate vicinity. This is mostly likely due to a degree of permeability of the crest and the likely inundation of the area under combined surge and long period wave events. A resistant impermeable barrier at the crest should reduce the discharges reaching the boatyard. There is also anecdotal evidence of flooding onto the footpath from east of the boatyard at the very southern limit of the Green Bay frontage as waves come from the south and refract around the headland.

Figure 9.23: Showing the vegetated crest to the south of Green Bay

Figure 9.24: Showing the foreshore and vegetated crest to the south of Green Bay

9.8.1. Outline Business Case (OBC) preferred options

THE OBC proposed the following:

- Option 1: 100 m of 'dune' restoration and nourishment with sand to raise dune height by 250 mm.
- Option 2: Geobags at the southern end at the boat yard to the south of the boathouse (ramp) to raise level along the footpath.

9.8.2. Alternative preferred option

The whole embankment is stable and does not show any signs of damage and or erosion due to wave action. To the south of the bay towards Samson Hill the beach crest level is lower than around the boatyard area, this is where overtopping has previously been noted, and to help mitigate against future overtopping, impermeable geobags will be placed at the crest and then covered with natural reclaimed embankment material along a stretch of 70 m as shown in Figure 9.25 from Chainage 555 to 625.

Geobag stability and wave overtopping assessment was carried out using the extreme wave conditions and water levels summarised in Table 7.2. The size of the geobags, was designed according to the methods of Omeraci (2002), and the wave overtopping was estimated using the method outlined in Section 8.2.2.

Excavating the crest and placing geobags with a crest level at +5.0 m will provide an permanent barrier layer resistant to overtopping discharges. Reclaimed material will then be replaced around the geobags as shown in Figure 9.26, with minimum 0.3m cover to protect the geobags. With a 5 m wide crest as a minimum; contoured to blend into the immediate hinterland; the re-vegetated crest will provide an embankment with a natural appearance and the ability to reduce flooding onto the footpath and into the boatyard for future events.

Figure 9.25: Chainage and crestline of Green Bay

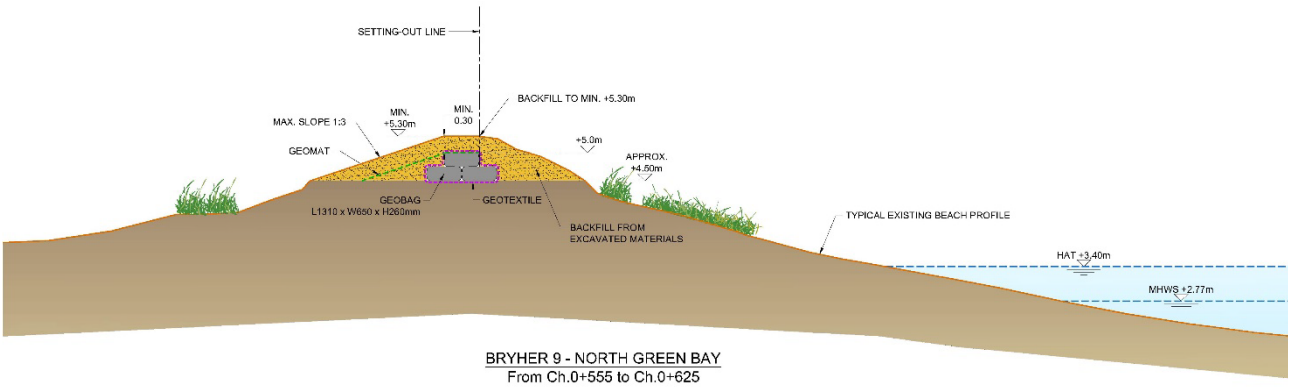

Figure 9.26: Typical proposed cross section for Green Bay

9.8.3. Efficacy and advantages

- The proposed solution is visually no different from the existing appearance of the beach.
- The geobags will provide an impermeable barrier to any run up and overtopping, protecting the boat yard behind.
- A vegetated embankment will provide additional erosion protection as well as replicating existing habitats.

9.8.4. Constraints and disadvantages

- The proposed section will require earthworks to bring up the crest. This material will need to be locally sourced to match existing materials.

10. Appraisal (criteria and evaluation- qualitative) – preferred option

10.1. Assessment criteria

A description of the option appraisal is given below.

The assessment criteria were developed taking into account the coastal environment where the project is located and the nature of the project. They reflect the appraisal carried out to date, itemising the issues and providing a basis for the evaluation.

The colour associated in the appraisal with each indicator or aspect of a criterion identifies the level of preference of the options. The preference is given considering the relevance and/or the impact of that item on the option. For example, an option that effectively manages coastal erosion and flood risk and provides an adequate level of protection would meet the requirements and therefore it will score highly; in this case a green colour will be associated to it. On the contrary, an option which would be not able to deliver an adequate protection over the life of the project, would not meet the requirement and it will score poorly; in

this case a red colour will be associated with it. When an indicator is relevant or has some impact on the option, but the consequence could be mitigated or the impact is moderate or they are acceptable, it will score moderately, and a yellow colour will be associated with it.

When an indicator or overall criterion is not applicable it will score 0 and indicated as NA.

The meaning of the colour associated with a preference is summarised below.

PR	Preferred	An option considered to provide an overall effective solution to the criteria being assessed.
A	Acceptable	An option considered to provide an acceptable solution to the criteria being assessed.
LP	Least preferred	An option which does not provide an acceptable solution to the criteria being assessed.
NA	Not Applicable	This criterion is not applicable for this option.

The identified criteria and relative indicators or aspects are described below:

Performance

- Option provides long term flood protection
- Option provides protection from long term coastal erosion
- Option supports the growth of vegetation and sand stabilization
- Negative impact along the adjacent frontages
- Positive impact along the adjacent frontages
- Option helps to prevent undermining of structures.

Monitoring and Maintenance

- Maintenance
- Monitoring.

Constructability

- Construction will occur near water - Tidal Restrictions
- Sourcing material
- Ease of access to site
- Ease of access to beach.

Impact on natural processes

- Allow supply of fresh material to the foreshore of adjacent frontages.

Impact on Environment

- Visual impact
- Amenity value / Access to beach
- Impact of construction (noise, dust etc)
- Potential impact on marine designations for construction as well as design solution
- Potential impact on land designations for construction as well as design solution
- Potential impact on Water Framework Directive (WFD) water body.

Schedule

- Construction Period Duration (Shortest preferred).

Costs

- Capital costs
- Maintenance costs.

The criteria have been assessed against each option and they are presented with their respective preference in Appendix D with an example illustrated in Figure 10.1 below.

Options and Option description	1	2	3	4
	Do Nothing	Do Minimum	Dune restoration	Rebuild the wall
Performance				
Option provides long term flood protection			A	PR
Option provides protection from long term coastal erosion			A	PR
Option supports the growth of vegetation and sand stabilization			PR	A
Negative impact along the adjacent frontages			A	A
Positive impact along the adjacent frontages			A	A
Option helps to prevent undermining of structures			A	PR
Monitoring and Maintenance				
Maintenance			PR	A
Monitoring			PR	A
Constructability				
Construction will occur near water - Tidal Restrictions			A	PR
Sourcing material			LP	PR
Ease of access to site			A	A
Ease of access to beach			A	A
Impact on natural processes				
Allow supply of fresh material to the foreshore of adjacent frontages			A	A
Impact on Environment				
Visual impact			A	LP
Amenity value / Access to beach			A	LP
Impact of construction (noise, dust etc)			A	A
Poptential impact on marine designations (during construction and once completed)			A	A
Potential impact on landside designations (during construction and once completed)			A	LP
Potential impact on WFD water body (during construction and once completed)			A	A
Schedule				
Construction Period Duration (Shortest preferred)			A	A
Costs				
Capital costs			A	PR
Maintenance costs			PR	A

Figure 10.1: Option appraisal matrix – Great Popplestone

- A score is then assigned to each preference as shown below:

LEGEND		
Preference		score
P	Preferred	3
A	Acceptable	2
LP	Least Preferred	1
NA	Not applicable	0

- The evaluation matrix calculates the subtotal score of the indicators/aspects per each criterion, given as a percentage.
- The subtotal per criterion show how well the options perform in the various criteria.
- The subtotals are calculated as the ratio between the total score for that criterion and the highest possible total score of the criterion. For example, the criterion “Performance” the highest possible

subtotal score is 12 and the subtotal achieved from scoring the indicators, for example for Great Popplestone Option 3 above, is 7, therefore 7/12 given as a % is 58.3%. See Figure 10.2.

- Using a similar approach to the above, the final score aims to show how well the options perform overall. The final score is calculated as the ratio between the sum of all the subtotal scores and the highest possible total score. To use the same example as above, for Option 3 it will be: (58.3+100+37.5+50+50+50+150)/700=70.8%.

Options and Option description	1	2	3	4
	Do Nothing	Do Minimum	Dune restoration	Rebuild the wall
Performance				
Option provides long term flood protection			1	2
Option provides protection from long term coastal erosion			1	2
Option supports the growth of vegetation and sand stabilization			2	1
Negative impact along the adjacent frontages			1	1
Positive impact along the adjacent frontages			1	1
Option helps to prenvent undermining of structures			1	2
Performance - Average score	**0.0%**	**0.0%**	**58.3%**	**75.0%**
Monitoring and Maintenance				
Maintenance			2	1
Monitoring			2	1
Monitoring and Maintenance - Average score	**0.0%**	**0.0%**	**100.0%**	**50.0%**
Constructability				
Construction will occur near water - Tidal Restrictions			1	2
Sourcing material			0	2
Ease of access to site			1	1
Ease of access to beach			1	1
Constructability- Average score	**NA**	**0.0%**	**37.5%**	**75.0%**
Impact on natural processes				
Allow supply of fresh material to the foreshore of adjacent frontages			1	1
Impact on natural processes - Average score	**0.0%**	**0.0%**	**50.0%**	**50.0%**
Impact on Environment				
Visual impact			1	0
Amenity value / Access to beach			1	0
Impact of construction (noise, dust etc)			1	1
Poptential impact on marine designations (during construction and once completed)			1	1
Potential impact on landside designations (during construction and once completed)			1	0
Potential impact on WFD water body (during construction and once completed)			1	1
Impact on Environment - Average score	**0.0%**	**0.0%**	**50.0%**	**25.0%**
Duration of works				
Construction Period Duration (Shortest preferred)			1	1
Duration of works - Average score	**NA**	**0.0%**	**50.0%**	**50.0%**
Costs				
Capital costs			1	2
Maintenance costs			2	1
Costs - Average score	**0.0%**	**0.0%**	**150.0%**	**150.0%**
TOTAL %SCORE	**0.0%**	**0.0%**	**70.8%**	**67.9%**

Figure 10.2: Option evaluation matrix from the appraisal shown in Figure 10.1 above

It is proposed that any option which does not meet the key indicator / aspect “Option provides long term flood protection” will not be shortlisted even if it has a high total score. However, the Do-nothing option will still be used for the economic appraisal. At this stage no weight has been applied to the preferences (green, yellow and red). Table 10.1 below gives a summary of the option appraisal and the shortlisted Options.

Note that alternative revetment solutions such as Tecco Cell matting or Elastocoast have been assessed and determined as not appropriate due to visual and environmental concerns. The protection solutions proposed are based around replenishment of material to the beaches and traditional rock revetment and engineering embankments with geobag cores.

Table 10.1: Summary of options

Location	Option		Description	Benefits delivered / Risks involved	Short list or rejection
1 - Greatpar South	1	Do Nothing	Appraised as part of OBC. This option is not re-appraised as part of the present study.		
	2	Do Minimum	Appraised as part of OBC. This option is not re-appraised as part of the present study.		
	3	Dune restoration	20 m of damaged dune restoration with recharge.	Sand recharge will provide additional material to allow some natural replenishment. The beach is not a traditional dune so recharge will not likely provide long term protection and will not protect southern end of the beach.	Rejection
	4	Hard protection	90m of hard protection at the southern end - rip rap.	The raised crest will limit overtopping and erosion at the south of the beach. This would be a change to the appearance of the beach, but as only at the top of the beach will not impact the amenity. Although it is anticipated that some rock can be sourced from the islands, there may be a requirement to import rock.	Preferred
2/3b – Great Porth [aka Great Par] north of Great Carn	1	Do Nothing	Appraised as part of OBC. This option is not re-appraised as part of the present study.		
	2	Do Minimum	Appraised as part of OBC. This option is not re-appraised as part of the present study.		
	3	Dune nourishment	80 m linear of dune nourishment and restoration along with negotiated changes to access and vehicular routes to enable the dune to recover and recess.	The nourishment and managed access should limit erosion by human action and will provide some protection against overtopping. As this is not a traditional dune, long term benefits of the restoration can't be assured and may require regular maintenance and recharge to maintain the level of protection.	Short list

Location	Option		Description	Benefits delivered / Risks involved	Short list or rejection
	4	Rebuild the wall	Section to be re-built using some of the local rocks from boat house north. Extend the revetment south to the boat house.	The raised crest will limit overtopping and erosion at the south of the beach. A demountable flood barrier can be incorporated into the crest at the boat ramp. This would be a change to the appearance of the beach, but as only at the top of the beach will not impact the amenity. This is a long term stability solution.	Short list/ Preferred
3 – Stinking Porth to the north of the outcrop	1	Do Nothing	Appraised as part of OBC. This option is not re-appraised as part of the present study.		
	2	Do Minimum	Appraised as part of OBC. This option is not re-appraised as part of the present study.		
	3	Dune restoration	Reduce overtop & breach risk at 20 m southern section with 20 m^3 of localised dune restoration.	Sand recharge will provide additional protection for the crest. The beach is not a traditional dune so recharge will not likely provide long term protection and may require recharge.	Short list
	4	Revetment	Crest elevation, built a revetment using geobags protected seaward by cobbles/natural material +planting; to the north of rock outcrop, low point with susceptibility to overtopping/flooding.	Hard protection will be a robust solution to provide long term protection to Great Pool and is proposed over the length of beach most vulnerable to wave overtopping. The footprint of the proposed raised embankment will need consideration for footpath access and for vegetating to encourage native plants and provide erosion protection.	Short list/ Preferred
4 – Great Popplestone	1	Do Nothing	Appraised as part of OBC. This option is not re-appraised as part of the present study.		
	2	Do Minimum	Appraised as part of OBC. This option is not re-appraised as part of the present study.		
	3	Dune restoration	Recharge & restore 90 m of dune inclusive of repositioning 50 m^3 of in-situ existing 'rock armour'.	This option utilises the existing rock on the face and leeward of the wall so no new rock is required. The risk of this option is that without increasing the crest height, the wall may continue to be overtopped and the rocks may be displaced.	Short list

Location	Option		Description	Benefits delivered / Risks involved	Short list or rejection
	4	Rebuild the wall	Southern end, rebuild wall with existing rock increasing crest elevation possibly through a masonry wall.	This option is similar to the rebuild option but by increasing the crest level, further protection against overtopping will be achieved. It is assumed that the existing wall can be built upon, as a full new wall will be too expensive to construct.	Short list/ Preferred
5 – Kitchen Porth	1	Do Nothing	Appraised as part of OBC. This option is not re-appraised as part of the present study.		
	2	Do Minimum	Appraised as part of OBC. This option is not re-appraised as part of the present study.		
	3	Raise front edge	Raise front edge and across 75 mm of informal pathway by 500 mm to provide protective embankment between dune area and properties.	This raised edge will provide added protection to the properties behind the crest. This footpath protection will not protect the Ram that is being eroded at the top of the beach (as can be seen by visible roots), which could undermine the footpath protection.	Short list
	4	Rebuild the wall	Southern section of bay(to be re-built) with local rocks and geobags to provide core.	A targeted rebuild of the extent of embankment most at risk will protect against further erosion and the rock will reduce overtopping. Reusing rocks will reduce need for import of any rock armour. Only a short section would be rebuilt so some of the front would still be at risk from overtopping, a full revetment is not proposed so the Ram may still get eroded by the wave run up, albeit at a slower rate.	Short list/ Preferred
8b – Quay	1	Do Nothing	Appraised as part of OBC. This option is not re-appraised as part of the present study.		
	2	Do Minimum	Appraised as part of OBC. This option is not re-appraised as part of the present study.		
	3	Revetment	Rock revetment protection works on Quay Beach.	A revetment will protect both the rear of the beach and the corner of the beach where it meets the quay. Presently only the corner of the beach is	Short list

Location	Option		Description	Benefits delivered / Risks involved	Short list or rejection
				showing signs of erosion and hence this wider protection may not be necessary.	
	4	Rock groyne	Small rock groyne to protect corner of quay for further erosion.	A small structure such as this will protect the corner of the quay from erosion and will be a small structure. The small groyne would not provide wider protection to the beach crest line, though this is not currently identified as being at risk.	Short list/ Preferred
9 - North Green Bay	1	Do Nothing	Appraised as part of OBC. This option is not re-appraised as part of the present study.		
	2	Do Minimum	Appraised as part of OBC. This option is not re-appraised as part of the present study.		
	3	Dune restoration	100 m of 'dune' restoration and nourishment with sand to raise dune height by 250 mm.	Raising the crest level would increase the level of protection and the sand can readily be sourced. Any replenishment is likely to be a temporary measure and further recharge is likely to be required over the design life.	Short list
	4	Revetment	Geobags at the southern end at the boat yard to the south of the boathouse(ramp) to raise level along the footpath.	Geobags will provide a solid and durable core to stabilise the embankment and the matting will provide protection whilst vegetation establishes. There will be more construction works required with this option as the ground will need to be prepared ahead of placement.	Short list/ Preferred

NOTE – Appraisal to be reviewed with further consideration of construction impact on marine and land designations.

11. Description of preliminary design of preferred options

11.1. Preferred options

Section 9 has described the proposed options for each site and included typical cross-sections, for all relevant sites on Bryher Island. The option appraisal evaluated the options, using the criteria described above and preferred options were selected as summarised in Section 10. The proposed cross sections for the solutions are included in Section 9.

12.BOQ and costs

Bills of Quantities and estimated costs will be included in the detailed design report.

13.Constructability

The proposed works have been selected considering constructability on Bryher. The following criteria were considered:

- Materials – locally available rock. However due to material property requirements some import of armour rock may be necessary.
- Rock may require import by barge, suitable landing sites at the beaches should be confirmed.
- Concrete – No options requiring large volumes of concrete have been included due to sourcing and environmental considerations.
- Geobags - are usually filled with dry sand. During filling, a constant supply of water is provide into the container to allow the sand to compact inside so the density of wet sand is increased. If sand material is not available, it is possible to fill geocontainers with graded local or imported rocks using high performance nets, which can be ecologically advantageous. The installation needs an experienced contractor, though manufactures will typically provide site training as needed.
- Plant – the requirement of large construction plant is not recommended due to accessibility and cost. All works proposed should be able to be completed be standard JCB type excavators or similar sized plant.
- Workforce – Although the proposed works are not complex, contractors with marine experience should undertake the works, but much of the workforce could be local manpower and equipment.

14.References

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Appendices

A. Drawings

6°21'40"W 6°21'20"W 6°21'0"W 6°20'40"W

87000 87250 87500 87750 88000 88250

15500 15250 15000 14750 14500

49°57'20"N 49°57'0"N

A SITE 1. Greatpar south lower section of defence line

E SITE 4. Great Popplestone wall showing recent repair

G SITE 5. Kitchen Porth eroded wall section

B SITE 2 & 3b. Great Porth section showing natural dune regeneration

F SITE 4. Great Popplestone north end section

H SITE 8. Quay eroded section

C SITE 2 & 3b. Great Porth section showing ad hoc rock placement

I SITE 9. Green Bay access erosion areas

D SITE 3. Stinking Porth lower section of defence line

J SITE 9. Green Bay view of lower section

DEFENCE ID

PHOTO LOCATION

Isles of Scilly – Design Services for Off Islands Coastal Erosion

Climate Adaptation Schemen -Preliminary Design - Bryher

SITE INVESTIGATIONS

0 0.1 0.2 KILOMETRES N

SCALE: 1:4,500 **PAPER SIZE:** A3 (42 x 29.7 cm)

GEODETIC INFORMATION

CRS: British National Grid
Projection: Transverse Mercator
Datum: OSGB 1936
False Easting: 400,000.0000
False Northing: -100,000.0000
Central Meridian: -2.0000
Scale Factor: 0.9996
Latitude Of Origin: 49.0000

PROJECT REF: DKR6499

DRAWING: DKR6499-004-01-DDE

DATE: 03/08/2021 **DRAWN:** DDE **CHECKED:** TAP

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Background Imagery from ArcGIS Pro. Service Layer Credits: Maxar, Microsoft.

BEACH CROSS SECTION PROFILE

CREST ELEVATION PROFILE

DEFENCE ID

Isles of Scilly – Design Services for Off Islands Coastal Erosion

Climate Adaptation Schemen -Preliminary Design - Bryher

PROFILE LOCATIONS

0 0.1 0.2 KILOMETRES

N

SCALE: 1:4,500 **PAPER SIZE:** A3 (42 x 29.7 cm)

GEODETIC INFORMATION

CRS: British National Grid
Projection: Transverse Mercator
Datum: OSGB 1936
False Easting: 400,000.0000
False Northing: -100,000.0000
Central Meridian: -2.0000
Scale Factor: 0.9996
Latitude Of Origin: 49.0000

PROJECT REF: DKR6499

DRAWING: DKR6499-002-01-DDE

DATE: 03/08/2021 **DRAWN:** DDE **CHECKED:** TAP

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6°21'40"W 6°21'20"W 6°21'0"W 6°20'40"W

87000 87250 87500 87750 88000 88250

15500 15250 15000 14750 14500

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J SITE 9. Green Bay view of lower section

DEFENCE ID

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Climate Adaptation Schemen -Preliminary Design - Bryher

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B. Health, Safety And Welfare Issues

B.1. Health, Safety and Welfare Issues

B.1.1. Construction - Construction (Design and Management Regulations)

Introduction

The Construction (Design and Management) Regulations 2015 (CDM 2015) require a designer to avoid foreseeable risks to those involved in construction and future use of the structure, and in doing so, they should eliminate hazards (so far as is reasonably practicable, taking into account other design considerations) and reduce and control risks associated with those hazards which remain. It is essential that, where required to do so, a principal designer and principal contractor are appointed to fulfil their respective duties under the CDM 2015. It is also essential to highlight and record the impacts of the works on health, safety and welfare which should feed into the Health and Safety File. Further details of the requirements of CDM 2015 can be found on:

http://www.hse.gov.uk/construction/cdm/2015/index.htm

HR Wallingford is a designer on this project under the CDM 2015. In this role we have given due consideration to the statutory duties contained in the CDM 2015 as summarised above. It is also essential that a competent principal designer and principal contractor are selected to undertake any construction work which may ultimately be undertaken.

We assume that the appointed principal designer will notify the client of their responsibilities under CDM 2015 and that the relevant enforcing authority is notified of the project in accordance with regulation 6 of the CDM 2015.

Key marine hazard sources

Coastal and maritime construction can be hazardous because of the hostile and sometimes unpredictable nature of the environment. Guidance documents by Simm & Cruickshank (1998) and Cork & Cruickshank (2005) have examined these issues for the coastal environment. The key sources of hazards are depicted in Figure B.1 below. They derive from:

- The (uncertain) marine environment – wind, waves, currents, water levels;
- The dynamic physical environment – impacts from the above including poor ground conditions;
- Third parties – lack of containment of the site.

The above items influence the works, the equipment, the operatives and third parties.

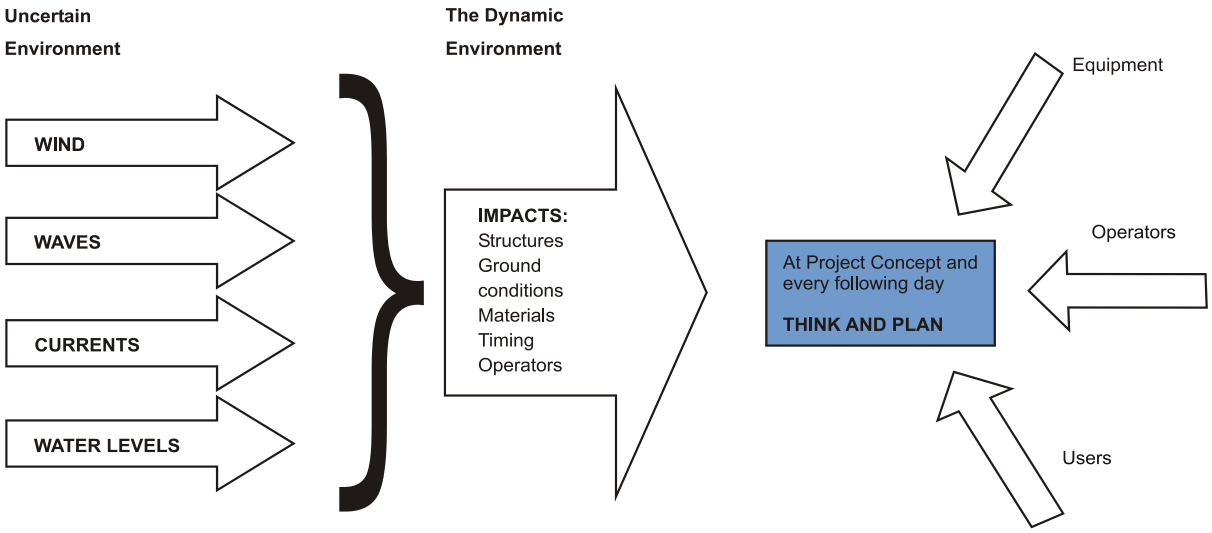

Figure B.1: Key marine hazards

Elimination of hazards

As a designer we have a duty to eliminate or reduce risks to the health and safety of any person in the preparation of that element of the design which we have undertaken for the project. Isles of Scilly - Design Services for Off Islands Coastal Erosion Defence and Dune Management".

In so doing we have assumed that a competent principal contractor will be employed who is experienced in the construction work proposed on this project and will use established good working practices for such engineering projects.

The feasibility design process has preliminarily identified risks and provided a preliminary response strategy; the risk assessment should be reviewed during the next phase of design:

Table B.1: Source of Risk

Source of Risk	Consequences	Risk Owner	Response Strategy
Availability of Surveys (Topographic, Geotechnical and Environmental)	Resulting in delay, costs and potential alteration to methods	Client	Undertake survey to inform Risk
Ground Conditions: beach levels can change following storms	Ground level for excavation and re- profiling operations could change during construction resulting in delays and costs	Contractor	Undertake subsequent surveys to inform risk Store plant securely outside beach area
Ground Condition (2): Uncertain ground conditions	Risk for plant and personnel. Resulting in delay, costs and potential alteration to methods. Additional geotechnical investigation required	Client/Contractor	Undertake survey to inform Risk (Client) Provide routes of safe access to plant and personnel (Contractor)

Source of Risk	Consequences	Risk Owner	Response Strategy
Beach level changes leading to need for modifications to excavation requirements	Increase cost and delay to programme	Contractor	Check latest site surveys have been incorporated into design. Check Design work
Weather/Tidal work	Increase cost and delay to programme	Contractor	Monitoring and Early planning of construction schedule
Work near water	Risk to equipment and personnel	Contractor	Monitoring and Early planning of construction schedule Store equipment safe away from intertidal area
Difficulties in the delivery of Material to the Islands	Increase cost and delay to programme	Client/Contractor	Identification and development of a schedule of construction which maximize construction during season with milder weather/sea conditions
Construction Access	Increase cost and delay to programme	Client/Contractor	Identification and development of potential temporary access and cost impact mitigated
Public Access during construction	Increase cost and delay to programme	Client/Contractor	Early identification of a construction schedule and consultation with main stakeholders
Storm / flood risk	Works commencement delayed	Client/Contractor	Early identification, and design / plan in place for addition works
Site Safety	Accident, harm, injury, death, works stopped, delay and litigation	Client/Contractor	Work to be undertaken by suitable, qualified and competent personnel. Adequate H&S procedure. Monitor that H&S procedures are correctly followed
Public Safety during Construction	Accident, harm, injury, death, works stopped, delay and litigation	Client/Contractor	Ensure an understanding of the Public use of the beach during construction. Put in place fencing, signage and exclusion zones. Use of banksmen and avoid busy season for construction if possible. Provide alternative routes where feasible
Possible presence of services and/or cables buried in the dunes/ridges	Danger to workforce and public. Increase in Costs and delay	Client/Contractor	Retrieve a detailed location map of any services located in/along the dunes/banks and in the area of work
Unexploded ordnance	Danger to workers and public	Client/Contractor	The risk is low on the three islands in question but desktop UXO search should be undertaken prior to construction works

Source: HR Wallingford

This design risk assessment only applies to the design work elements undertaken by HR Wallingford and has assumed that appropriate risk assessments will be undertaken for the detailed design and other parts of the construction works planned. We recommend that HR Wallingford (1998) and HR Wallingford (2004) be considered when assessing construction and public safety risk.

Health and safety file

We recommend that relevant information contained within this report is retained on the Health and Safety File as it sets out the overtopping rates allowed for in the design.

References

HR Wallingford (1998), Construction risk in coastal engineering, Thomas Telford, 2000.

R Wallingford (2004), Construction health and safety in coastal and maritime Engineering, Thomas Telford, 2004.

C. Option Appraisal and Evaluation

Site 1 Great Par - Appraisal

Score	Options and Option description	1	2	3	4
		Do Nothing	Do Minimum	Dune restoration	Hard protection
	Performance				
2	Option provides long term flood protection			A	PR
2	Option provides protection from long term coastal erosion			A	PR
2	Option supports the growth of vegetation and sand stabilization			PR	A
2	Negative impact along the adjacent frontages			A	A
2	Positive impact along the adjacent frontages			A	A
2	Option helps to prevent undermining of structures			A	PR
	Monitoring and Maintenance				
2	Maintenance			A	PR
2	Monitoring			PR	A
	Constructability				
2	Construction will occur near water - Tidal Restrictions			A	PR
2	Sourcing material			LP	PR
2	Ease of access to site			A	A
2	Ease of access to beach			A	A
	Impact on natural processes				
2	Allow supply of fresh material to the foreshore of adjacent frontages			A	A
	Impact on Environment				
2	Visual impact			PR	A
2	Amenity value / Access to beach			PR	A
2	Impact of construction (noise, dust etc)			A	A
2	Poptential impact on marine designations (during construction and once completed)			PR	A
2	Potential impact on landside designations (during construction and once completed)			A	LP
2	Potential impact on WFD water body (during construction and once completed)			A	A
	Schedule				
2	Construction Period Duration (Shortest preferred)			A	A
	Costs				
2	Capital costs			A	PR
2	Maintenance costs			A	PR

PR	Preferred
A	Acceptable
LP	Least preferred
N	No Applicable

PR	Preferred
A	Acceptable
LP	Least preferred
N	No Applicable

Site 1 Great Par - Evaluation

Options and Option description	1 Do Nothing	2 Do Minimum	3 Dune restoration	4 Hard protection
Performance				
Option provides long term flood protection			1	2
Option provides protection from long term coastal erosion			1	2
Option supports the growth of vegetation and sand stabilization			2	1
Negative impact along the adjacent frontages			1	1
Positive impact along the adjacent frontages			1	1
Option helps to prenvent undermining of structures			1	2
Performance - Average score	**0.0%**	**0.0%**	**58.3%**	**75.0%**
Monitoring and Maintenance				
Maintenance			1	2
Monitoring			2	1
Monitoring and Maintenance - Average score	**0.0%**	**0.0%**	**75.0%**	**75.0%**
Constructability				
Construction will occur near water - Tidal Restrictions			1	2
Sourcing material			0	2
Ease of access to site			1	1
Ease of access to beach			1	1
Constructability- Average score	**NA**	**0.0%**	**37.5%**	**75.0%**
Impact on natural processes				
Allow supply of fresh material to the foreshore of adjacent frontages			1	1
Impact on natural processes - Average score	**0.0%**	**0.0%**	**50.0%**	**50.0%**
Impact on Environment				
Visual impact			2	1
Amenity value / Access to beach			2	1
Impact of construction (noise, dust etc)			1	1
Poptential impact on marine designations (during construction and once completed)			2	1
Potential impact on landside designations (during construction and once completed)			1	0
Potential impact on WFD water body (during construction and once completed)			1	1
Impact on Environment - Average score	**0.0%**	**0.0%**	**75.0%**	**41.7%**
Duration of works				
Construction Period Duration (Shortest preferred)			1	1
Duration of works - Average score	**NA**	**0.0%**	**50.0%**	**50.0%**
Costs				
Capital costs			1	2
Maintenance costs			1	2
Costs - Average score	**0.0%**	**0.0%**	**100.0%**	**200.0%**
TOTAL %SCORE	**0.0%**	**0.0%**	**63.7%**	**81.0%**

Site 2/3b Great Porth - Appraisal

Score	Options and Option description	1	2	3	4
		Do Nothing	Do Minimum	Dune nourishment	Hard protection
	Performance				
2	Option provides long term flood protection			A	PR
2	Option provides protection from long term coastal erosion			A	PR
2	Option supports the growth of vegetation and sand stabilization			PR	A
2	Negative impact along the adjacent frontages			A	A
2	Positive impact along the adjacent frontages			A	A
2	Option helps to prevent undermining of structures			A	PR
	Monitoring and Maintenance				
2	Maintenance			A	PR
2	Monitoring			PR	A
	Constructability				
2	Construction will occur near water - Tidal Restrictions			A	PR
2	Sourcing material			LP	PR
2	Ease of access to site			A	A
2	Ease of access to beach			A	A
	Impact on natural processes				
2	Allow supply of fresh material to the foreshore of adjacent frontages			A	A
	Impact on Environment				
2	Visual impact			A	PR
2	Amenity value / Access to beach			A	PR
2	Impact of construction (noise, dust etc)			A	A
2	Poptential impact on marine designations (during construction and once completed)			PR	PR
2	Potential impact on landside designations (during construction and once completed)			PR	PR
2	Potential impact on WFD water body (during construction and once completed)			A	A
	Schedule				
2	Construction Period Duration (Shortest preferred)			A	A
	Costs				
2	Capital costs			A	PR
2	Maintenance costs			A	PR

PR	Preferred
A	Acceptable
LP	Least preferred
N	No Applicable

PR	Preferred
A	Acceptable
LP	Least preferred
N	No Applicable

Site 2/3b Great Porth - Evaluation

Options and Option description	1 Do Nothing	2 Do Minimum	3 Dune nourishment	4 Hard protection
Performance				
Option provides long term flood protection			1	2
Option provides protection from long term coastal erosion			1	2
Option supports the growth of vegetation and sand stabilization			2	1
Negative impact along the adjacent frontages			1	1
Positive impact along the adjacent frontages			1	1
Option helps to prenvent undermining of structures			1	2
Performance - Average score	**0.0%**	**0.0%**	**58.3%**	**75.0%**
Monitoring and Maintenance				
Maintenance			1	2
Monitoring			2	1
Monitoring and Maintenance - Average score	**0.0%**	**0.0%**	**75.0%**	**75.0%**
Constructability				
Construction will occur near water - Tidal Restrictions			1	2
Sourcing material			0	2
Ease of access to site			1	1
Ease of access to beach			1	1
Constructability- Average score	**NA**	**0.0%**	**37.5%**	**75.0%**
Impact on natural processes				
Allow supply of fresh material to the foreshore of adjacent frontages			1	1
Impact on natural processes - Average score	**0.0%**	**0.0%**	**50.0%**	**50.0%**
Impact on Environment				
Visual impact			1	2
Amenity value / Access to beach			1	2
Impact of construction (noise, dust etc)			1	1
Poptential impact on marine designations (during construction and once completed)			2	2
Potential impact on landside designations (during construction and once completed)			2	2
Potential impact on WFD water body (during construction and once completed)			1	1
Impact on Environment - Average score	**0.0%**	**0.0%**	**66.7%**	**83.3%**
Duration of works				
Construction Period Duration (Shortest preferred)			1	1
Duration of works - Average score	**NA**	**0.0%**	**50.0%**	**50.0%**
Costs				
Capital costs			1	2
Maintenance costs			1	2
Costs - Average score	**0.0%**	**0.0%**	**100.0%**	**200.0%**
TOTAL %SCORE	**0.0%**	**0.0%**	**62.5%**	**86.9%**

Site 3 Stinking Porth - Appraisal

Options and Option description	1	2	3	4
	Do Nothing	Do Minimum	Dune restoration	Revetment
Performance				
Option provides long term flood protection			A	PR
Option provides protection from long term coastal erosion			A	PR
Option supports the growth of vegetation and sand stabilization			PR	A
Negative impact along the adjacent frontages			A	A
Positive impact along the adjacent frontages			A	A
Option helps to prevent undermining of structures			A	PR
Monitoring and Maintenance				
Maintenance			A	PR
Monitoring			PR	A
Constructability				
Construction will occur near water - Tidal Restrictions			A	PR
Sourcing material			LP	PR
Ease of access to site			A	A
Ease of access to beach			A	A
Impact on natural processes				
Allow supply of fresh material to the foreshore of adjacent frontages			A	A
Impact on Environment				
Visual impact			A	A
Amenity value / Access to beach			A	A
Impact of construction (noise, dust etc)			A	LP
Poptential impact on marine designations (during construction and once completed)			A	A
Potential impact on landside designations (during construction and once completed)			PR	A
Potential impact on WFD water body (during construction and once completed)			A	A
Schedule				
Construction Period Duration (Shortest preferred)			A	A
Costs				
Capital costs			A	PR
Maintenance costs			A	PR

PR	Preferred
A	Acceptable
LP	Least preferred
N	No Applicable

PR	Preferred
A	Acceptable
LP	Least preferred
N	No Applicable

Site 3 Stinking Porth - Evaluation

Options and Option description	1 Do Nothing	2 Do Minimum	3 Dune restoration	4 Revetment
Performance				
Option provides long term flood protection			1	2
Option provides protection from long term coastal erosion			1	2
Option supports the growth of vegetation and sand stabilization			2	1
Negative impact along the adjacent frontages			1	1
Positive impact along the adjacent frontages			1	1
Option helps to prenvent undermining of structures			1	2
Performance - Average score	**0.0%**	**0.0%**	**58.3%**	**75.0%**
Monitoring and Maintenance				
Maintenance			1	2
Monitoring			2	1
Monitoring and Maintenance - Average score	**0.0%**	**0.0%**	**75.0%**	**75.0%**
Constructability				
Construction will occur near water - Tidal Restrictions			1	2
Sourcing material			0	2
Ease of access to site			1	1
Ease of access to beach			1	1
Constructability- Average score	**NA**	**0.0%**	**37.5%**	**75.0%**
Impact on natural processes				
Allow supply of fresh material to the foreshore of adjacent frontages			1	1
Impact on natural processes - Average score	**0.0%**	**0.0%**	**50.0%**	**50.0%**
Impact on Environment				
Visual impact			1	1
Amenity value / Access to beach			1	1
Impact of construction (noise, dust etc)			1	0
Poptential impact on marine designations (during construction and once completed)			1	1
Potential impact on landside designations (during construction and once completed)			2	1
Potential impact on WFD water body (during construction and once completed)			1	1
Impact on Environment - Average score	**0.0%**	**0.0%**	**58.3%**	**41.7%**
Duration of works				
Construction Period Duration (Shortest preferred)			1	1
Duration of works - Average score	**NA**	**0.0%**	**50.0%**	**50.0%**
Costs				
Capital costs			1	2
Maintenance costs			1	2
Costs - Average score	**0.0%**	**0.0%**	**100.0%**	**200.0%**
TOTAL %SCORE	**0.0%**	**0.0%**	**61.3%**	**81.0%**

Site 4 Great Pobblestone - Appraisal

Options and Option description	1	2	3	4
	Do Nothing	Do Minimum	Restoration	Rebuild the wall
Performance				
Option provides long term flood protection			A	PR
Option provides protection from long term coastal erosion			A	PR
Option supports the growth of vegetation and sand stabilization			PR	A
Negative impact along the adjacent frontages			A	A
Positive impact along the adjacent frontages			A	A
Option helps to prevent undermining of structures			A	PR
Monitoring and Maintenance				
Maintenance			A	PR
Monitoring			PR	A
Constructability				
Construction will occur near water - Tidal Restrictions			A	PR
Sourcing material			LP	PR
Ease of access to site			A	A
Ease of access to beach			A	A
Impact on natural processes				
Allow supply of fresh material to the foreshore of adjacent frontages			A	A
Impact on Environment				
Visual impact			A	LP
Amenity value / Access to beach			A	LP
Impact of construction (noise, dust etc)			A	A
Poptential impact on marine designations (during construction and once completed)			A	A
Potential impact on landside designations (during construction and once completed)			A	LP
Potential impact on WFD water body (during construction and once completed)			A	A
Schedule				
Construction Period Duration (Shortest preferred)			A	A
Costs				
Capital costs			A	PR
Maintenance costs			A	PR

PR	Preferred	PR	Preferred
A	Acceptable	A	Acceptable
LP	Least preferred	LP	Least preferred
N	No Applicable	N	No Applicable

Site 4 Great Pobblestone - Evaluation

Options and Option description	1 Do Nothing	2 Do Minimum	3 Restoration	4 Rebuild the wall
Performance				
Option provides long term flood protection			1	2
Option provides protection from long term coastal erosion			1	2
Option supports the growth of vegetation and sand stabilization			2	1
Negative impact along the adjacent frontages			1	1
Positive impact along the adjacent frontages			1	1
Option helps to prenvent undermining of structures			1	2
Performance - Average score	**0.0%**	**0.0%**	**58.3%**	**75.0%**
Monitoring and Maintenance				
Maintenance			1	2
Monitoring			2	1
Monitoring and Maintenance - Average score	**0.0%**	**0.0%**	**75.0%**	**75.0%**
Constructability				
Construction will occur near water - Tidal Restrictions			1	2
Sourcing material			0	2
Ease of access to site			1	1
Ease of access to beach			1	1
Constructability- Average score	**NA**	**0.0%**	**37.5%**	**75.0%**
Impact on natural processes				
Allow supply of fresh material to the foreshore of adjacent frontages			1	1
Impact on natural processes - Average score	**0.0%**	**0.0%**	**50.0%**	**50.0%**
Impact on Environment				
Visual impact			1	0
Amenity value / Access to beach			1	0
Impact of construction (noise, dust etc)			1	1
Poptential impact on marine designations (during construction and once completed)			1	1
Potential impact on landside designations (during construction and once completed)			1	0
Potential impact on WFD water body (during construction and once completed)			1	1
Impact on Environment - Average score	**0.0%**	**0.0%**	**50.0%**	**25.0%**
Duration of works				
Construction Period Duration (Shortest preferred)			1	1
Duration of works - Average score	**NA**	**0.0%**	**50.0%**	**50.0%**
Costs				
Capital costs			1	2
Maintenance costs			1	2
Costs - Average score	**0.0%**	**0.0%**	**100.0%**	**200.0%**
TOTAL %SCORE	**0.0%**	**0.0%**	**60.1%**	**78.6%**

Site 5 Kitchen Porth - Appraisal

Options and Option description	1	2	3	4
	Do Nothing	Do Minimum	Raise front edge of path	Rebuild the rock protection
Performance				
Option provides long term flood protection			A	PR
Option provides protection from long term coastal erosion			A	PR
Option supports the growth of vegetation and sand stabilization			A	A
Negative impact along the adjacent frontages			A	A
Positive impact along the adjacent frontages			A	A
Option helps to prevent undermining of structures			A	PR
Monitoring and Maintenance				
Maintenance			A	PR
Monitoring			A	PR
Constructability				
Construction will occur near water - Tidal Restrictions			A	A
Sourcing material			A	PR
Ease of access to site			A	PR
Ease of access to beach			A	PR
Impact on natural processes				
Allow supply of fresh material to the foreshore of adjacent frontages			A	PR
Impact on Environment				
Visual impact			PR	A
Amenity value / Access to beach			A	A
Impact of construction (noise, dust etc)			A	A
Poptential impact on marine designations (during construction and once completed)			A	PR
Potential impact on landside designations (during construction and once completed)			A	PR
Potential impact on WFD water body (during construction and once completed)			A	PR
Schedule				
Construction Period Duration (Shortest preferred)			A	PR
Costs				
Capital costs			A	PR
Maintenance costs			A	PR

PR	Preferred	PR	Preferred
A	Acceptable	A	Acceptable
LP	Least preferred	LP	Least preferred
N	No Applicable	N	No Applicable

Site 5 Kitchen Porth - Evaluation

Options and Option description	1 Do Nothing	2 Do Minimum	3 Raise front edge of path	4 Rebuild the rock protection
Performance				
Option provides long term flood protection			1	2
Option provides protection from long term coastal erosion			1	2
Option supports the growth of vegetation and sand stabilization			1	1
Negative impact along the adjacent frontages			1	1
Positive impact along the adjacent frontages			1	1
Option helps to prenvent undermining of structures			1	2
Performance - Average score	**0.0%**	**0.0%**	**50.0%**	**75.0%**
Monitoring and Maintenance				
Maintenance			1	2
Monitoring			1	2
Monitoring and Maintenance - Average score	**0.0%**	**0.0%**	**50.0%**	**100.0%**
Constructability				
Construction will occur near water - Tidal Restrictions			1	1
Sourcing material			1	2
Ease of access to site			1	2
Ease of access to beach			1	2
Constructability- Average score	**NA**	**0.0%**	**50.0%**	**87.5%**
Impact on natural processes				
Allow supply of fresh material to the foreshore of adjacent frontages			1	2
Impact on natural processes - Average score	**0.0%**	**0.0%**	**50.0%**	**100.0%**
Impact on Environment				
Visual impact			2	1
Amenity value / Access to beach			1	1
Impact of construction (noise, dust etc)			1	1
Poptential impact on marine designations (during construction and once completed)			1	2
Potential impact on landside designations (during construction and once completed)			1	2
Potential impact on WFD water body (during construction and once completed)			1	2
Impact on Environment - Average score	**0.0%**	**0.0%**	**58.3%**	**75.0%**
Duration of works				
Construction Period Duration (Shortest preferred)			1	2
Duration of works - Average score	**NA**	**0.0%**	**50.0%**	**100.0%**
Costs				
Capital costs			1	2
Maintenance costs			1	2
Costs - Average score	**0.0%**	**0.0%**	**100.0%**	**200.0%**
TOTAL %SCORE	**0.0%**	**0.0%**	**58.3%**	**105.4%**

Site 8b The Quay - Appraisal

Score	Options and Option description	1	2	3	4	5	6	7	8	9	10
		Do Nothing	Do Minimum	Revetment	Rock groyne						
	Performance										
2	Option provides long term flood protection			A	A						
2	Option provides protection from long term coastal erosion			A	PR						
2	Option supports the growth of vegetation and sand stabilization			A	A						
2	Negative impact along the adjacent frontages			A	A						
2	Positive impact along the adjacent frontages			A	PR						
2	Option helps to prevent undermining of structures			A	PR						
	Monitoring and Maintenance										
2	Maintenance			A	A						
2	Monitoring			A	A						
	Constructability										
2	Construction will occur near water - Tidal Restrictions			PR	A						
2	Sourcing material			A	A						
2	Ease of access to site			A	PR						
2	Ease of access to beach			A	PR						
	Impact on natural processes										
2	Allow supply of fresh material to the foreshore of adjacent frontages			A	PR						
	Impact on Environment										
2	Visual impact			A	A						
2	Amenity value / Access to beach			A	LP						
2	Impact of construction (noise, dust etc)			A	A						
2	Poptential impact on marine designations (during construction and once completed)			A	PR						
2	Potential impact on landside designations (during construction and once completed)			A	PR						
2	Potential impact on WFD water body (during construction and once completed)			A	PR						
	Schedule										
2	Construction Period Duration (Shortest preferred)			A	A						
	Costs										
2	Capital costs			A	A						
2	Maintenance costs			A	A						

PR	Preferred	PR	Preferred	2
A	Acceptable	A	Acceptable	1
LP	Least preferred	LP	Least preferred	0
N	No Applicable	N	No Applicable	

If option does not provide flood protection it is discarded

Site 8b The Quay - Evaluation

Options and Option description	1 Do Nothing	2 Do Minimum	3 Revetment	4 Rock groyne
Performance				
Option provides long term flood protection			1	1
Option provides protection from long term coastal erosion			1	2
Option supports the growth of vegetation and sand stabilization			1	1
Negative impact along the adjacent frontages			1	1
Positive impact along the adjacent frontages			1	2
Option helps to prenvent undermining of structures			1	2
Performance - Average score	**0.0%**	**0.0%**	**50.0%**	**75.0%**
Monitoring and Maintenance				
Maintenance			1	1
Monitoring			1	1
Monitoring and Maintenance - Average score	**0.0%**	**0.0%**	**50.0%**	**50.0%**
Constructability				
Construction will occur near water - Tidal Restrictions			2	1
Sourcing material			1	1
Ease of access to site			1	2
Ease of access to beach			1	2
Constructability- Average score	**NA**	**0.0%**	**62.5%**	**75.0%**
Impact on natural processes				
Allow supply of fresh material to the foreshore of adjacent frontages			1	2
Impact on natural processes - Average score	**0.0%**	**0.0%**	**50.0%**	**100.0%**
Impact on Environment				
Visual impact			1	1
Amenity value / Access to beach			1	0
Impact of construction (noise, dust etc)			1	1
Poptential impact on marine designations (during construction and once completed)			1	2
Potential impact on landside designations (during construction and once completed)			1	2
Potential impact on WFD water body (during construction and once completed)			1	2
Impact on Environment - Average score	**0.0%**	**0.0%**	**50.0%**	**66.7%**
Duration of works				
Construction Period Duration (Shortest preferred)			1	1
Duration of works - Average score	**NA**	**0.0%**	**50.0%**	**50.0%**
Costs				
Capital costs			1	1
Maintenance costs			1	1
Costs - Average score	**0.0%**	**0.0%**	**100.0%**	**100.0%**
TOTAL %SCORE	**0.0%**	**0.0%**	**58.9%**	**73.8%**

Site 9 Green Bay - Appraisal

Options and Option description	1	2	3	4
	Do Nothing	Do Minimum	Dune restoration	Geobags
Performance				
Option provides long term flood protection			A	PR
Option provides protection from long term coastal erosion			A	PR
Option supports the growth of vegetation and sand stabilization			PR	A
Negative impact along the adjacent frontages			A	A
Positive impact along the adjacent frontages			A	A
Option helps to prevent undermining of structures			A	PR
Monitoring and Maintenance				
Maintenance			PR	A
Monitoring			PR	A
Constructability				
Construction will occur near water - Tidal Restrictions			A	PR
Sourcing material			LP	PR
Ease of access to site			A	A
Ease of access to beach			A	A
Impact on natural processes				
Allow supply of fresh material to the foreshore of adjacent frontages			A	A
Impact on Environment				
Visual impact			PR	A
Amenity value / Access to beach			PR	A
Impact of construction (noise, dust etc)			PR	A
Poptential impact on marine designations (during construction and once completed)			PR	PR
Potential impact on landside designations (during construction and once completed)			PR	PR
Potential impact on WFD water body (during construction and once completed)			A	A
Schedule				
Construction Period Duration (Shortest preferred)			A	A
Costs				
Capital costs			A	PR
Maintenance costs			A	PR

PR	Preferred	PR	Preferred
A	Acceptable	A	Acceptable
LP	Least preferred	LP	Least preferred
N	No Applicable	N	No Applicable

Site 9 Green Bay - Evaluation

Options and Option description	1 Do Nothing	2 Do Minimum	3 Dune restoration	4 Geobags
Performance				
Option provides long term flood protection			1	2
Option provides protection from long term coastal erosion			1	2
Option supports the growth of vegetation and sand stabilization			2	1
Negative impact along the adjacent frontages			1	1
Positive impact along the adjacent frontages			1	1
Option helps to prenvent undermining of structures			1	2
Performance - Average score	**0.0%**	**0.0%**	**58.3%**	**75.0%**
Monitoring and Maintenance				
Maintenance			2	1
Monitoring			2	1
Monitoring and Maintenance - Average score	**0.0%**	**0.0%**	**100.0%**	**50.0%**
Constructability				
Construction will occur near water - Tidal Restrictions			1	2
Sourcing material			0	2
Ease of access to site			1	1
Ease of access to beach			1	1
Constructability- Average score	**NA**	**0.0%**	**37.5%**	**75.0%**
Impact on natural processes				
Allow supply of fresh material to the foreshore of adjacent frontages			1	1
Impact on natural processes - Average score	**0.0%**	**0.0%**	**50.0%**	**50.0%**
Impact on Environment				
Visual impact			2	1
Amenity value / Access to beach			2	1
Impact of construction (noise, dust etc)			2	1
Poptential impact on marine designations (during construction and once completed)			2	2
Potential impact on landside designations (during construction and once completed)			2	2
Potential impact on WFD water body (during construction and once completed)			1	1
Impact on Environment - Average score	**0.0%**	**0.0%**	**91.7%**	**66.7%**
Duration of works				
Construction Period Duration (Shortest preferred)			1	1
Duration of works - Average score	**NA**	**0.0%**	**50.0%**	**50.0%**
Costs				
Capital costs			1	2
Maintenance costs			1	2
Costs - Average score	**0.0%**	**0.0%**	**100.0%**	**200.0%**
TOTAL %SCORE	**0.0%**	**0.0%**	**69.6%**	**81.0%**

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