MOTT MACDONALD

Aberdeen North Beach Coastal Defence

Feasibility Report

31 March 2017

Aberdeen City Council

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Issue and Revision Record

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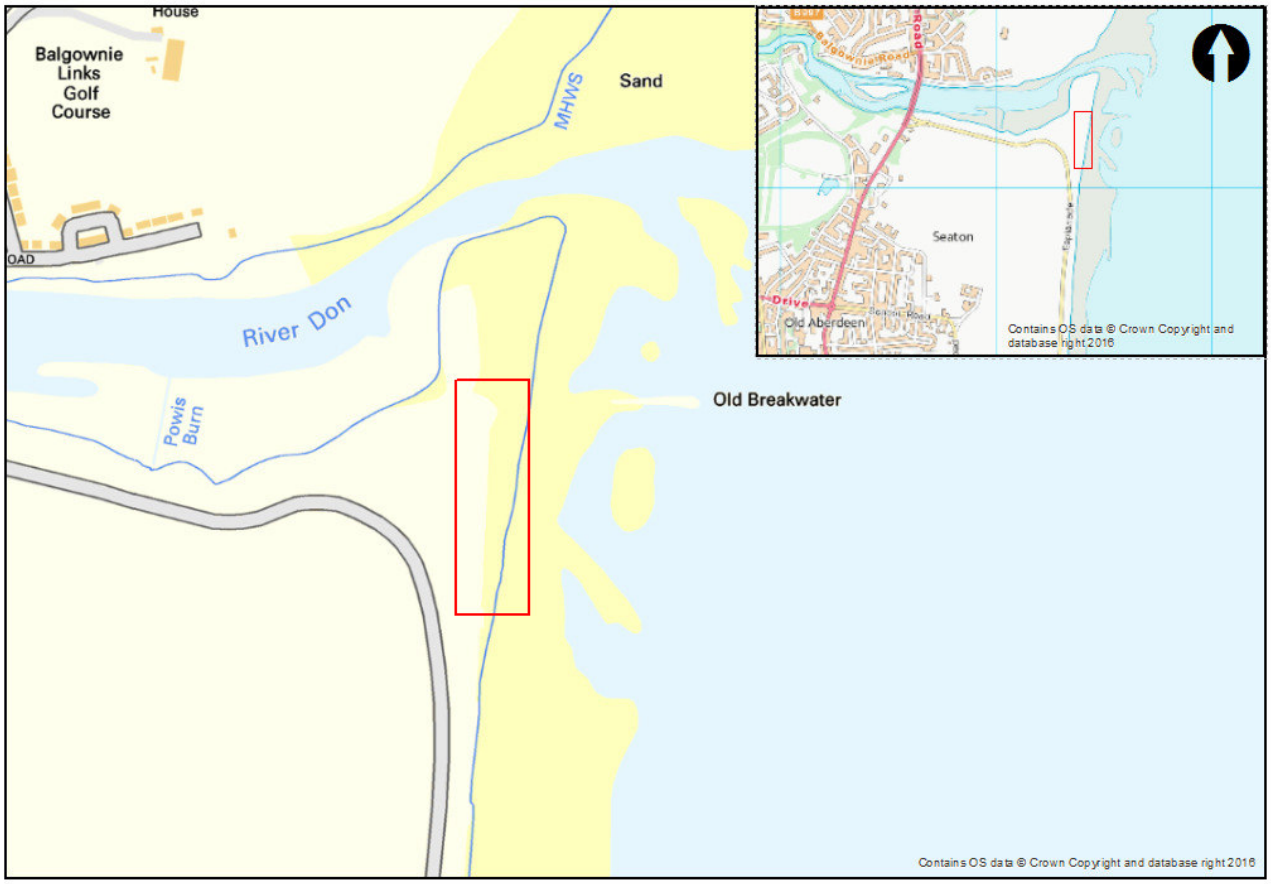
Contents

1 Introduction

1.1 Background and Scope

Aberdeen City Council (ACC) have commissioned Mott MacDonald Ltd (MML) to undertake an initial assessment of the condition of the coastal embankment and sea defences at North Beach to determine potential engineering solutions to managing ongoing embankment erosion and slope instability. The coastal embankment is located between the mouth of the River Don and Aberdeen Beach Esplanade, herein referred to as the site. The site location is shown in Figure 1.1.

Figure 1.1: Indicative Site Boundary



Source: Contains OS Data @ Crown Copyright 2016 Licence No. 100026791

Note : Coastal outline shown by OS map does not adequately represent the current coastal profile.

The objective of this Feasibility report is to summarise:

- Baseline condition of the coastal embankment and defences.
- Potential implications for the adjacent inland recreational area and beach.
- Recommendations for immediate actions that could be taken to slow the onset of erosion including indicative cost estimates.

- Recommendations for short, medium, and long-term solutions with indicative cross sections and indicative construction costs
- Advise of requirements for further work.

1.2 Sources of Information

The following sources of information summarised below have been used to compile this Feasibility report.

- MML North Beach Desk Study (Ref.1)
- ACC Tender Information (Ref.2)
- A guide to managing coastal erosion in beach/dune systems, SNH (Ref. 3)

2 Site Walkover Summary

A Site Walkover was completed by MML on 24th January 2017. The results of the walkover are included in Appendix A.

The site can essentially be divided into three sections. The southern 60m of the site has rock armour protection and the remainder of the site comprises failed gabion sea defences and is unprotected. No as-built records or design details have been provided for the existing constructed sea defences.

2.1 Rock Armour Area

The rock armour to the southern end of the site appears to be in good condition, with few apparent missing rocks, however, no comment can be made on the suitability of the rock armour sizing or construction. The rocks between two concrete toe walls have been partially buried. There appears to be minimal erosion to the crest of the slope above the rock armour, where a partially covered gabion revetment is visible.

2.2 Gabion Area & Northern Unprotected Area

Along the remainder of the site there is evidence of a failed gabion revetment, with collapsed, buried and burst gabions present, as well as a concrete toe beam. The coastal embankment in this area has been significantly eroded, with steep (>45 degree) and sub vertical / vertical slopes present along the 3 to 7m high embankment. This erosion has resulted in extensive deposition of embankment material on the beach. The embankment material comprises several distinct layers of made ground material of demolition / building waste, including bricks and granite blocks, overlying natural blown sand, (dune material). This deposition of material and the failed gabions indicates that much of the beach at the toe of the slopes is covered in debris.

There is a piled concrete beam at the northern end of the gabion area, with the bored piles and sheet piles exposed such that it is possible for people to pass underneath.

The northern end of the embankment faces north into the River Don Estuary and has no visible is-situ defences, however there was evidence of damaged gabion debris.

The crest of the embankment is visibly regressing, at an unknown rate, with clumps of grass and topsoil material fallen onto the beach. There are informal paths along the top of the embankment, some at the very edge of the failing crest.

3 Feasibility Options

3.1 Strategy

Continued regression of the coastal embankment may compromise the surrounding infrastructure and recreational land use. Based on the visual evidence, three main strategies for the management of coastal erosion, as is occurring at the site have been identified. These strategy scenarios are:

1. "Do Nothing" – adaptive management, observe and monitor the rate of erosion and the condition of the coast, possibly undertaking works in the future if necessary.
2. "Hold the line" – halt erosion using engineering solutions to maintain the current coastline profile.
3. "Retreat" – allow the erosion to continue, and move the affected infrastructure.

3.2 Design Considerations

The following points should be considered to determine which is the most appropriate strategy response to the identified coastal erosion:

- It is unknown if ACC currently have a management plan for the wider area along Aberdeen beach. A Shoreline Management Plan is an official strategy type document that can be used to determine the strategy for protection of the coastline in this area and what level of protection is required for the nearby infrastructure.
- The rate of erosion should be better understood to allow identification of infrastructure at immediate risk and inform how quickly a response to erosion is required. The rate of erosion could be determined by undertaking successive aerial point cloud laser surveys, and comparing current information with historical lidar, charts and aerial photography. Climate change and frequency of storm events should be accounted for to determine potential future erosion. It may be that the rate of erosion does not warrant remediation of the slopes, as the cost outweighs the benefit. This should be monitored to identify if this situation changes overtime.
- A monitoring and management programme could be established in the interim (0-5yrs) whilst the decision is made on the preferred option. This would allow ACC to better understand coastal processes and the effectiveness of the protection measures on site.
- If not already available, ACC may wish to commission a wave return survey / study to allow design of any remediation options for a specific design life.
- The effect of any works on the Local Nature Reserve and River Don estuary and upstream should be assessed to ensure that there is no detrimental impact.
- The environmental impact of potential solutions, in terms of construction impacts, potential habitat loss etc.

3.3 Potential Consequences of "Do Nothing"

The "Do Nothing" scenario looks at the implications if no remedial works were carried out. In this scenario it is likely that further erosion would take place, resulting in further collapse of the embankment and remaining gabions. There would also be continued deposition of debris on the beach/foreshore. Additionally, storm surge events may inundate the road should regression of the embankment continue.

The piled concrete beam to the northern end of the beach is considered unlikely to fail, however will continue to deteriorate as exposed to the elements.

3.4 "Hold the Line" Options

Potential options for remediation based on the "hold the line" strategy have been considered and are outlined in the following sections. Both soft (beach recharge) and hard (gabions, rock armour and concrete revetment) engineering solutions are included, with indicative cross sections of each option provided in Section 3.3.6.

Subject to more detailed consideration these solutions may be considered suitable for the failed gabions area and around the northern end of the embankment in the currently unprotected area, in the River Don estuary.

3.4.1 Short Term (5-20 years)

3.4.1.1 Beach Recharge

- Beach recharge (or nourishment) involves importing additional sediment, normally from marine sources, to increase the volume of an existing beach and raise beach levels, which reduces wave energy.
- Beach recharge performance is related to the local coastal processes, which may not always redistribute sediments evenly over the beach by alongshore and cross-shore transport and may be washed away entirely by a storm event.
- Suitable sediment would need to be sourced, dredging from the harbour or immediately offshore could provide the most cost effective solution.
- Fencing can be incorporated to stabilise and prevent movement of placed material.
- Ongoing monitoring and maintenance would be required, with the potential for multiple recharge top-ups.

3.4.1.2 Gabions

- Wire mesh baskets filled with cobbles or crushed rock, filled in-situ with locally available materials if possible. Coated or stainless steel mesh is used in coastal environments to resist corrosion.
- Flexible and porous solution, and can absorb some wave and wind energy, but should not be located in the wave breaking zone.
- Gabions placed as near/vertical wall, rather than a revetment as installed previously on site.
- Gabions need to be constructed on a suitable foundation i.e. a gabion mattress, with toe protection, and designed to withstand wave forces, and hydrostatic and soil pressure forces from the slope behind.
- Rock armour could be placed at the toe of the gabions to disperse wave energy and provide protection.
- Gabions can be formed at a steeper angle than the rock armour, but would then be more vulnerable to a frontal wave (a shallower slope allows for run out of velocity).
- Regrading of the existing slope would be required to tie the existing slope into the gabions.
- Gabions are less expensive than rock armour, but have a limited lifespan, potentially less than 10 years in a coastal environment.
- Monitoring of the condition of the gabions would be required and repair or replacement of any damaged gabions carried out on a regular basis after the initial period has passed.

3.4.2 Medium Term (21-50 year)

3.4.2.1 Beach Recharge

- As per section 3.2.1.1.
- Additional recharge of materials would likely be required on a regular basis to maintain beach levels for the lifetime of the solution.

3.4.2.2 Rock Armour Revetment

- As already employed at the southern end of the site.
- The rock amour protects by dissipating the energy of storm waves.
- Rock size is determined by the wave height and period for the design life and return period of the solution, with larger material required for bigger wave heights. Suitable rock might be expensive to source.
- Formed at a shallower angle than gabions (approximately 1V:2H), the angle of the slope will be determined on the rock size with the potential, for a more extensive footprint and earthworks.
- Regrading of the existing slope would be required to tie into the new rock armour slope.
- This option could be integrated with the existing concrete toe wall which is currently buried under the beach.
- Likely to be more economical to design for the long term lifespan and would adapt to changes in beach profile which makes it more resilient.
- Would require monitoring and maintenance.

3.4.3 Long Term (50+ years life span)

3.4.3.1 Beach Recharge

- As per section 3.2.1.1.
- Dependant on the beach material stability, additional recharge of materials may be required on a regular basis to maintain beach levels for the lifetime of the solution.

3.4.3.2 Rock Armour Revetment

- As per Section 3.2.2.3.
- Potentially more cost effective to design for the long term solution compared with medium term.

3.4.3.3 Concrete Revetment

- Similar solution to that employed along the Esplanade beachfront.
- Impermeable revetments are continuous sloping defence structures of concrete blockwork, or mass concrete, with toe protection.
- These revetments are built along the embankment/slope face and would require regrading of the existing slope.
- This option could be integrated with the existing concrete toe wall which is currently buried under the beach.
- Concrete revetments may be topped by a vertical or curved wave return wall to reduce overtopping where frequent wave action is likely.

- Maintenance would be required where individual blocks are plucked out by waves, as seen in other sections south of the site, and where gaps in the grout or bitumen used to seal the blocks.
- This type of design could reduce the level of the beach in front on the revetment due to reflection from the hard structure, which may result in greater exposure and damage to the structure.

3.4.4 Supplementary Works

The remediation options discussed should be considered in conjunction with supplementary protection works, including:

- Timber or rock groynes to interrupt beach drift northwards, as employed south of the site.
- Planting should be considered at the crest of the slope to increase resilience to erosion, comprising chestnut pails and marram grass with a green / grey scour protection mat to allow it to establish.
- Boardwalks at the crest of the slope, set further back than the current informal path to help manage people movement and allow planting to establish and prevent edge erosion. Installation of a boardwalk would encourage pedestrians onto a safe path away from the crest of the slope. Information signs to encourage people to keep away from the edge may also be useful.

3.4.5 Summary

The following table summarises the proposed options for each of the short, medium and long term lifespans with high level advantages (A) and disadvantages (D), as well as indicative construction costs.

Indicative construction costs have been based on a 200m length of remediation and based on costs provided in the Scottish Natural Heritage (SNH) - A guide to managing coastal erosion in beach/dune systems (Ref. 3)

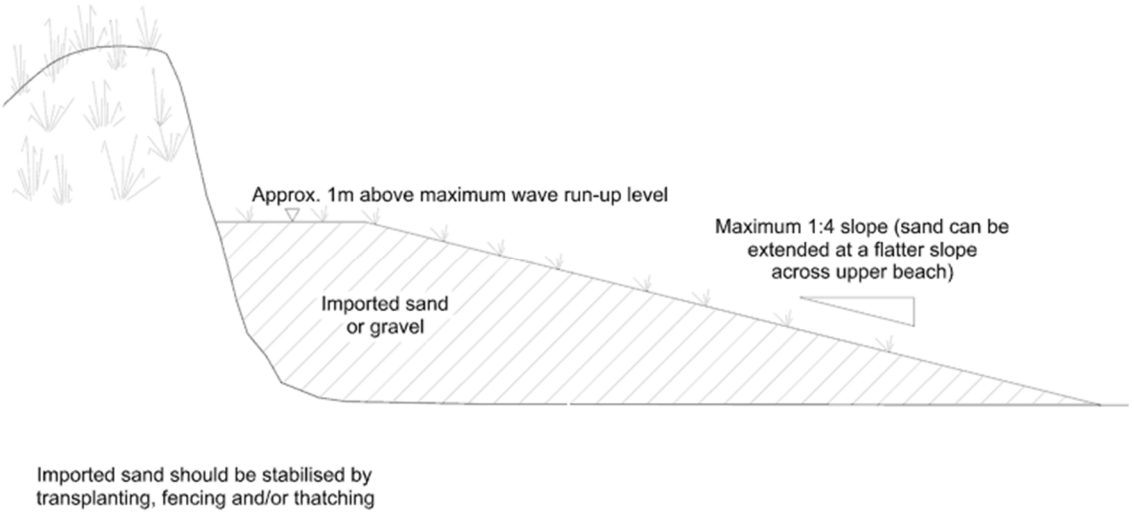
Table 1: Options Summary

Beach Recharge	Gabions	Rock Armour Revetment	Concrete Revetment
Estimated Costing £50K to 200K	*Estimated Costing £100K to 150K*	*Estimated Costing £200k to 600k*	*Estimated Costing £400k to 1M*
Short Term Options (5-20 yrs)			
• A: Potential for reuse of local dredging • A: Works with natural processes and more aesthetically pleasing • D: Recharge works likely to require annual recharge – additional works • D: Frequent ongoing monitoring and maintenance	• A: Engineering solution may last longer than beach recharge (if recharge not replenished). • D: Has already been implemented and failed at site • D: Frequent ongoing monitoring and maintenance • D: More vulnerable to frontal wave than rock armour • D: Significant landscape impact	N/A	N/A
Medium Term Options (21-50 yrs)			
• A: Potential for reuse of local dredging • A: Works with natural processes and more aesthetically pleasing • D: Recharge works likely to require annual recharge – additional works • D: Frequent ongoing monitoring and maintenance	N/A	• A: Engineering solution may last longer than beach recharge and gabions • A: Potential to integrate with existing concrete toe wall. • A: Could provide habitat. • D: More extensive earthworks than gabions • D: Significant landscape impact	N/A
Long Term Options (50+ yrs)			
• A: Potential for reuse of local dredging • A: Works with natural processes and more aesthetically pleasing • D: Recharge works likely to require annual recharge – additional works • D: Frequent ongoing monitoring and maintenance	N/A	• A: Potential to integrate with existing concrete toe wall. • A: More cost effective to extend to Long Term Solution • A: Could provide habitat. • D: Significant landscape impact	• A: Already employed along the Esplanade • A: Potential to integrate with existing concrete toe wall. • D: Ongoing Monitoring and Maintenance. • D: Potentially most costly option • D: Significant landscape impact • D: Risk of deteriorating the existing beach due to reflections from the hard structure

3.4.6 Indicative Cross Sections

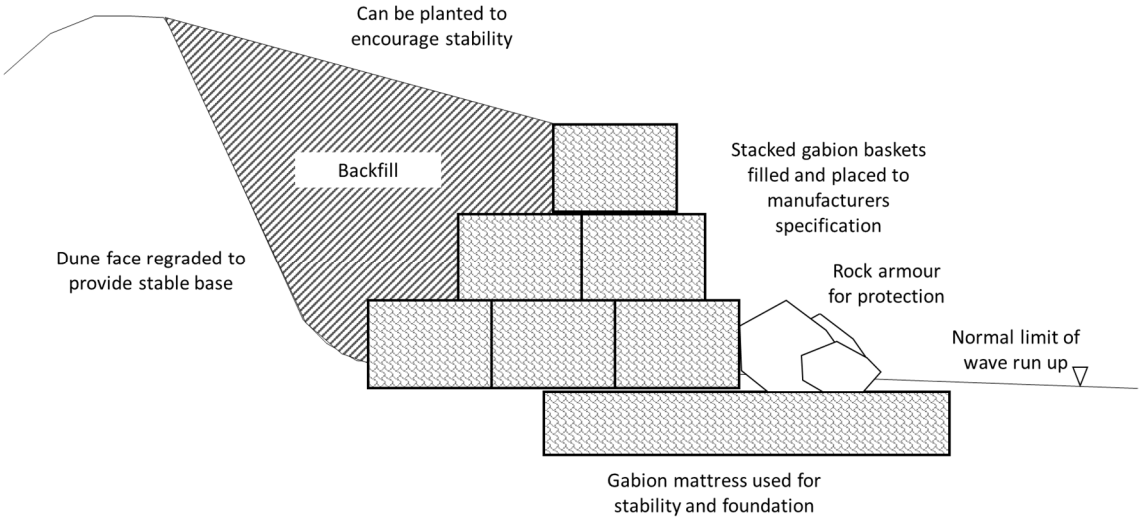
The following cross sections are indicative and are included to provide a representation of the options suggested in Section 3.2.

Figure 2: Beach Recharge



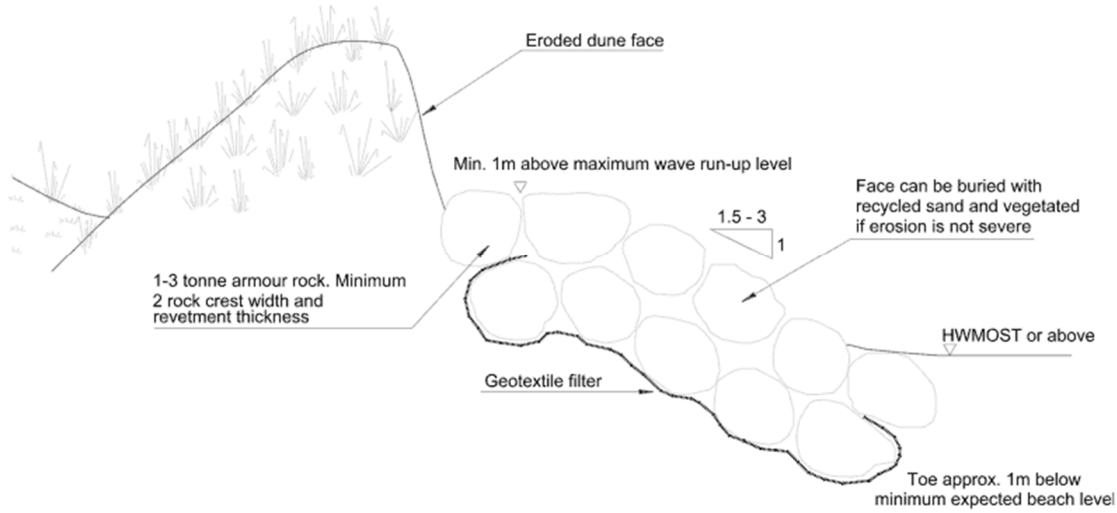
Source: Adapted from http://www.snh.org.uk/publications/on-line/heritagemanagement/erosion/appendix_1.7.shtml

Figure 3: Gabions



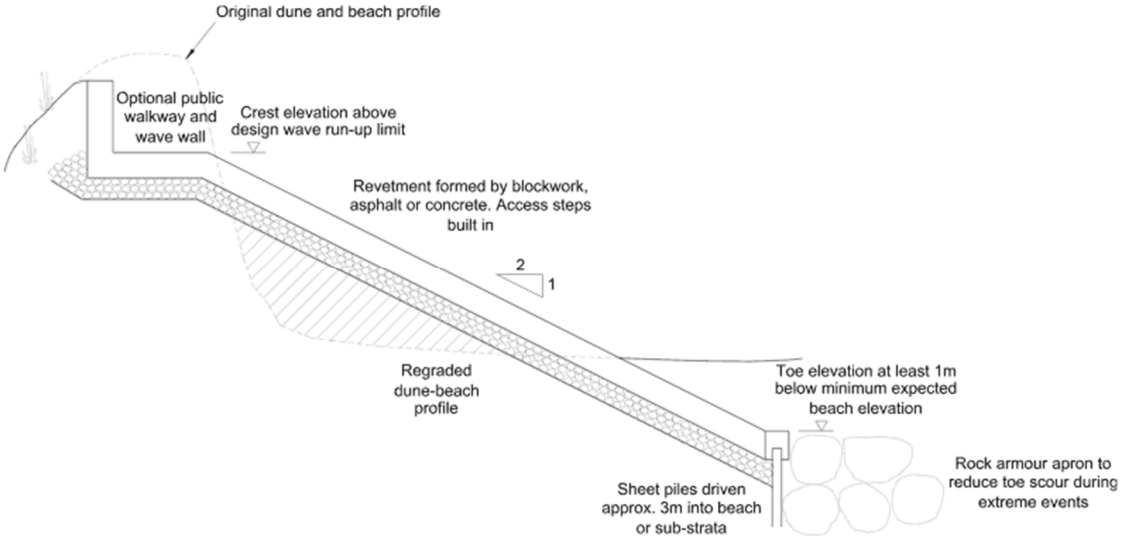
Source: Adapted from http://www.snh.org.uk/publications/on-line/heritagemanagement/erosion/appendix_1.8.shtml

Figure 4: Rock Armour Revetment



Source: Adapted from http://www.snh.org.uk/publications/on-line/heritagemanagement/erosion/appendix_1.14.shtml

Figure 5: Concrete Revetment



Source: http://www.snh.org.uk/publications/on-line/heritagemanagement/erosion/appendix_1.14.shtml

4 Conclusions

4.1 Site Condition

The site is currently experiencing erosion of the coastal embankment slopes and regression of the embankment crest. Previous gabion revetment sea defence measures have failed at the site.

Continued regression of the embankment may prove a threat to infrastructure inland and the recreational use of the site.

4.2 Further Work

There are three strategy scenarios to manage coastal erosion, these are:

- “Do Nothing”
- “Hold the line”
- “Retreat”

To determine the most appropriate reponse for the site further work should be undertaken. This may include:

- Production of, or consultation of, a Shoreline Management Plan.
- An erosion rate and coastal processes study.
- Establishment of a monitoring and management programme.
- The commissioning of a wave return survey / study to allow design of any remediation options for a specific design life.
- Environmental surveys to understand the potential risks to the implementation of options

Soft and hard engineering solutions to the “hold the line” strategy have been proposed; beach recharge, gabion, rock armour and concrete revetments, and potential construction costs have been presented. These options should be considered further.

To inform and protect the public who regularly access this area, ACC may wish to implement the following for safety purposes:

- Warning signs to inform public of the unstable coastal slopes.
- Some form of deterrent such as temporary wooden fencing be installed to prevent the public walking along the informal path running along the crest of the slope.
- Warning signs to inform public that the pilled concrete beam at the northern end of the site is a hazard and should not be climbed on or walked under for their own safety.

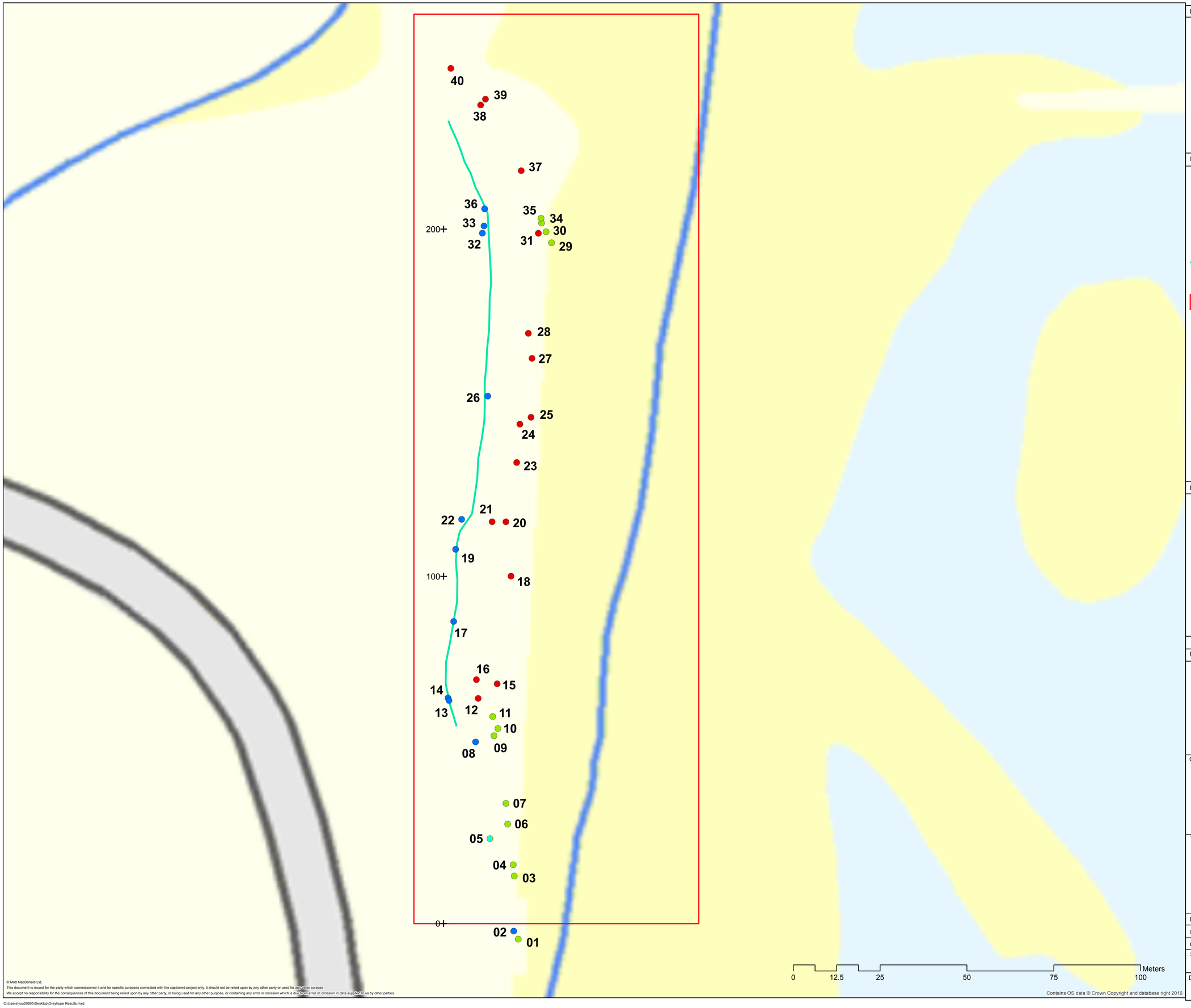
The cost of these measures is estimated to be around £5,000.

5 References

1. MML Desk Study, 378926 North Beach Phase I Desk Study, Rev B, Jan 2017
2. ACC, Tender Information 'Volume 2.3, Work Package 3 – Scoping Document, Aberdeen North Beach Coastal Defence' ref. 3097260/CS-ACE/2.3 Rev.T00, dated 7th October 2016
3. SNH, 'A guide to managing coastal erosion in beach/dune systems', dated October 2000. [online- http://www.snh.org.uk/publications/on-line/heritagemanagement/erosion/index.shtml]

A. Site Walkover Results

Figure A: Site Walkover Results



C:\Users\you59695\Desktop\Greyhope Results.mxd

Location Map

Key to Symbols

North Beach Site Walkover Points

- Current Instability
- Observation
- Structure
- Slope Crest Survey
- Chainage (m)
- Site Boundary

Reference Drawings

Rev	Date	Drawn	Description	Ch'k'd	App'd
A	17/02/2017	KY	Draft for Comment	SEY	AM

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Title

Aberdeen Coastal Embankments
North Beach
Site Walkover Results

Designed	K Young		Eng Check	S Eyers Young	
Drawn	K Young		Coordination	K Young	
GIS Check	J Irons		Approved	A Martin	

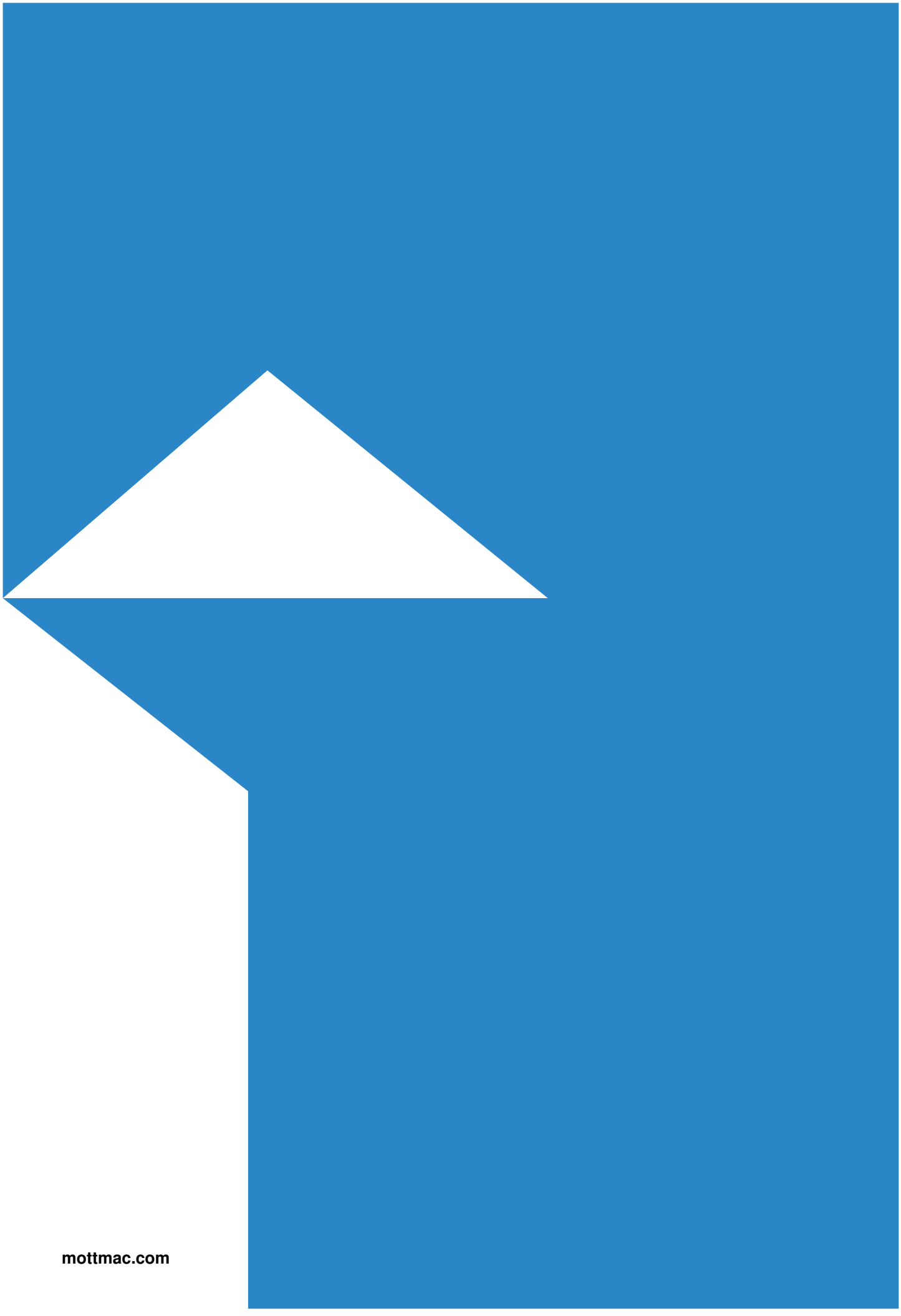
Scale at A1	Status	Rev	Security
1:500	DRA	A	STD

Drawing Number

378926-MMD-00-NB-GIS-001

Table A: Site Walkover Features

Number	Classification	Feature	Description	Comment
01	Structure	Sea wall and rock armour	Sea wall with rock armour either side, path down to beach to north	
02	Observation	Ch0	Start of site	
03	Structure	Concrete groyne / divider		
04	Structure	Rock armour	Grassy crest towards top of rock armour	
05	Structure	Rock armour	5m high slope with rock armour protection, 0.3m to >1m, two toe walls, lower toe wall almost entirely buried in sand	Rock armour covers gabions on slope
06	Structure	Gabions under rock armour		
07	Structure	Concrete groyne / divider	26 degrees slope on concrete	
08	Observation	View from crest	View of instability erosion Section 1	
09	Structure	Exposed piles	Exposed sheet piles to concrete divider	
10	Structure	Concrete groyne / divider exposed sheet piles	26 degrees slope on concrete, corroded sheet piles visible, 870mm high, concrete aggregate large rounded pebbles up to 20mm. 300mm wide	
11	Structure	Collapsed gabions	5 no. rows gabions coated double twist wire collapsed / buried, made ground behind, at least 2 distinct layers.	Sloping gabions failed by rotation / slumping by erosion?, filled with rough angular granite blocks 200 to 400mm.
12	Current Instability	Eroded Section 1	55m long section, 6.6m high slope at highest point	Exposed sheet piles at south end of section
13	Observation	View from crest		
14	Observation	View from crest	View north	
15	Current Instability	Eroded Section 1	Made ground visible, finer sand onto very large blocks (brick, granite), finer darker layer onto possible original sand dune. Partly covered by vegetation. Collapsed vegetation on slope	
16	Current Instability	Eroded Section 1	View north towards end of section	
17	Observation	View from crest	View south along coastal path	
18	Current Instability	Eroded Section 1	Stainless steel? square opening gabions collapsed / buried	
19	Observation	View from crest		
20	Current Instability	End of eroded Section 1/ start of Section 2	Section 2 extends to exposed discrete piles, 90m long section	
21	Current Instability	Eroded Section 2	Beacon above. View of made ground and gabions	
22	Observation	View from crest	View south	
23	Current Instability	Eroded Section 2		
24	Current Instability	Eroded Section 2	View of slope	
25	Current Instability	Eroded Section 2	3 to 5m high slope	
26	Observation	View from crest		
27	Current Instability	Eroded Section 2	Looking north towards end of section with exposed discrete piles	
28	Current Instability	Eroded Section 2	View of slope	
29	Structure	Concrete toe wall	Toe wall at end of concrete groyne / divider. Expected to extend to rock armour at other end of site, buried	010 bearing 300mm
30	Structure	Exposed sheet pile		
31	Current Instability	End of eroded Section 2 / start of Section 3	Toe wall and exposed discrete piles at concrete groyne / divider	
32	Observation	View from crest	View north	
33	Observation	View from crest	View of discrete piles end of eroded Section 2	
34	Structure	Exposed discrete piles	View north. Piles appear to be circular steel piles, with concrete visible to one side	Timber shuttering within concrete
35	Structure	Exposed discrete piles	View south	
36	Observation	View from crest	View of exposed discrete piles	
37	Current Instability	Eroded Section 3	View of made ground material being eroded out onto beach	
38	Current Instability	Eroded Section 3	View south and view north	
39	Current Instability	Eroded section 3	4 to 5m high slope	
40	Current Instability	End of eroded Section 3	Made ground material in slope (bricks, coping, metal), at entrance to River Don on corner	



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