Point Busaco Revetment
Detailed Design

Seashore Engineering Pty Ltd
December 2013

Report SE009-01-Rev1

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Document Control

Index	**Author**	**Date**	**Review**	**Date**	**Comment**
Rev0	G.McCormack	01.11.2013	M.Eliot	6.11.2013	Internal Review
Rev1	G.McCormack	02.12.2013	D.Lantry	21.11.2013	Client Review

1. Introduction

This report was commissioned by the Bunbury Port Authority and details the coastal engineering design basis for development of the Point Busaco revetment from a preliminary detailed (Damara WA 2011) to a detailed level as shown in Drawing DA 2296-2-1. This has included:

- Selection of rock types and minimum density parametres;
- Design of short groyne at the western end to 'hold' a beach at the toe of the revetment thereby reducing the risk of toe destabilisation;
- Estimates for the total volumes of excavation and fill required for construction based on a survey conducted on the 30th August 2013;
- Identifying set-out points for construction;
- Development of design drawings and technical specifications suitable for tendering and construction (Report SE009-02);
- Development of a monitoring and maintenance plan.

The rock revetment provides coastal protection to the Cristals lease area and has been designed to maintain pedestrian and emergency vehicle access along an existing access track. The revetment is 230m long west of the Point Busaco groyne and its armour layer is to be constructed from either granite or basalt rock with a minimum density of 2.6 tonnes per cubic metre.

A 50 year average recurrence interval design criteria has been selected, which implies a design working life of 25 years following to AS4997. It is recognised that this does not represent the length of time the revetment will last, as minor maintenance of rock armoured coastal protection structures can significantly extend the design life and alternatively inadequate maintenance can significantly reduce the design life. Furthermore, rock armour structures have a high residual capacity, such that they maintain a high level of functionality following minor damage.

1.1. PROJECT BACKGROUND

From 2003, the Bunbury Port Authority has identified ongoing erosion to the west of the Inner Harbour has increased the threat to the port access track adjacent to the Cristals site. In badly affected areas undermining has required track relocation. By 2011, the erosion had progressed to a degree where further relocation was considered impractical.

Bunbury Port Authority commissioned Damara WA (one of two companies forming Seashore Engineering) in late 2011, to undertake a preliminary detailed design for a 230m rock revetment (Point Busaco revetment) to provide erosion protection to the Cristals site, with the revetment designed to maintain the existing buffer currently used for access. The design consisted of a layout and cross-section and considered the following:

- Stability of rock armour under wave attack;
- A minimum trafficable width of four metres from the trees adjacent to the boundary fence plus an additional clearance of 1m;
- Overtopping levels and management of drainage;

- Practical construction limits for revetment toe construction in the southwest of Western Australia;
- Major pathways for adaptation of the revetment.
- Potential costs were derived for three alternative rock types (basalt, granite or lateritic ironstone) based on potential rock sources;

As part of design investigations, it was identified that the revetment is likely to transfer erosive pressure to the west where existing infrastructure towards the centre of Koombana Beach already has limited foreshore setback. Facilities potentially under threat include the Dolphin Discovery Centre, footpaths, roads, and car parks. The City of Bunbury, with the support of Bunbury Port Authority and the WA Department of Transport subsequently commissioned Seashore Engineering to investigate erosion occurring at Koombana Beach and determine an appropriate coastal management strategy that achieves optimal outcomes for both the short and long term (Seashore Engineering 2013).

The recommended coastal management strategy for Koombana Beach was to construct Point Busaco revetment and undertake ongoing renourishment works for the central and eastern parts of the beach, using material supplied from the Outer Harbour sand traps. It is recognised that how the City of Bunbury chooses to manage Koombana Beach will have implications on the vulnerability of the revetment to toe destabilisation, with the level of renourishment largely determining the amount of sand at the toe of the structure.

The Bunbury Port Authority has indicated they are willing to hold the construction of the revetment until the City of Bunbury has decided on its management strategy or the encroachment of erosion provides an immediate threat to infrastructure. It is recognised that this position may be challenged if erosion is sufficiently severe to warrant emergency works to protect infrastructure.

2. Design Refinement

2.1. SELECTION OF ROCK TYPE

The design is based on rock armour units with a minimum density of 2.6 tonnes per cubic metre allowing for the use of either granite or basalt rock. These rock types are typically preferred materials to provide longevity for coastal protection works, while they also provide appearance consistent with other existing rock structures.

Possible cost savings were identified in the preliminary design phase for the use of lateritic ironstone. This material will be considered for core rock only if it has a minimum density of 2.2 tonnes per cubic metre. As density of rock armour is a major design parameter along with the highly variable nature of lateritic ironstone availability (Damara WA 2011) and uncertainty of the timing of the works, no further consideration has been given to its use for rock armour.

2.2. ROCK REQUIREMENTS

The stable median armour size of 0.85 tonnes and appropriate size ranges previously calculated for a density of 2.6 tonnes per cubic metre has been used in the design (Damara WA 2011). Larger rock sizes are recommended for the toe, where a relative absence of rock interlocking reduces stability, requiring a median mass of approximately 1.5 times the stable armour size.

It is recognised that if basalt rock is used in the Works which typically has a density of 3.0 tonnes per cubic metre, extra stability will be provided. Basalt rock will generally result in a armour layer thickness reducing from 1.4m to 1.3m.

To allow for screening with a typical grizzly, the core rock size range has been adjusted to 0.15-0.5m, with the median diameter remaining at 0.3m.

2.3. EXCAVATION AND FILL VOLUMES

In situ material located along the beach and erosion scarp consists of dredge spoil including sand, silt and rock fragments. Excavation and fill volumes required for construction of the revetment have been estimated based on a survey of the foreshore carried out by Thomsons Surveying Consultants on the 30th August 2013 (Table 1).

Table 1: Excavation and Fill Volumes for the Revetment

Total Excavation	3,200m^3
Total Fill	600m^3

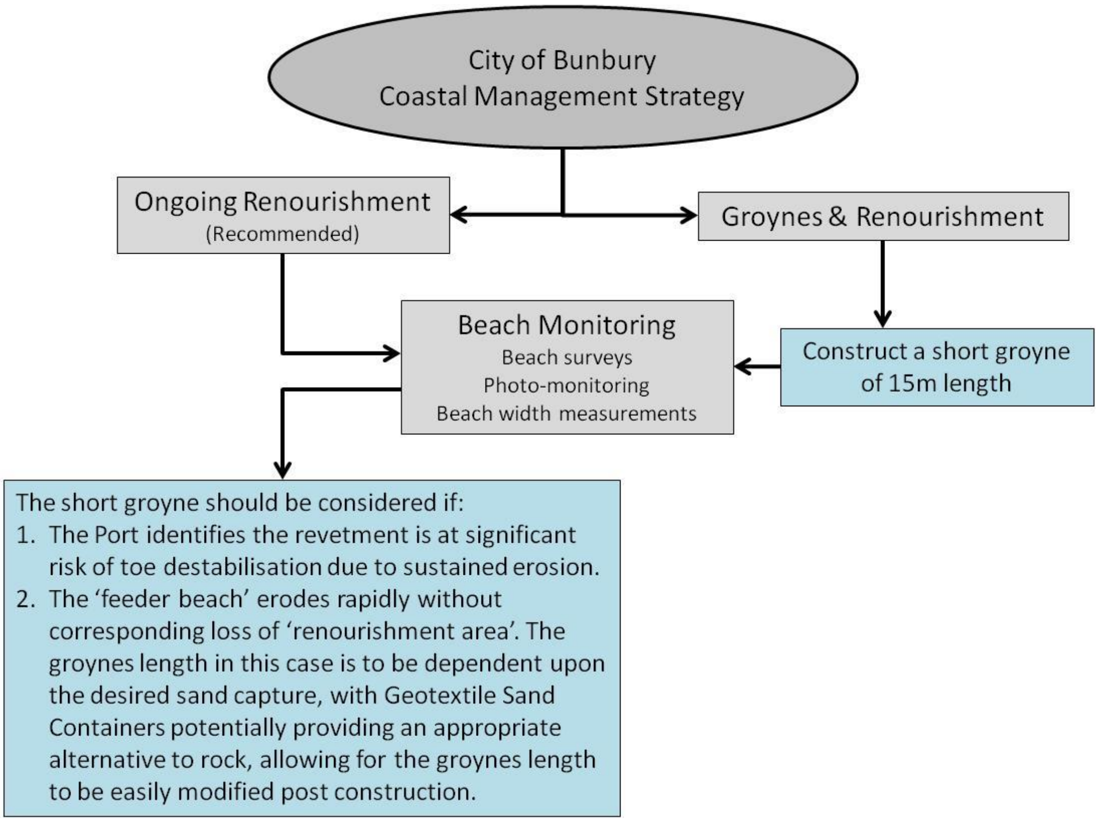
Any excavated material considered unsuitable for use as fill and for placement along the beach in front will need to be transported offsite and disposed of appropriately.

The revetment has been design to maintain a minimum trafficable width of four metres from the trees adjacent to the boundary fence plus an additional clearance of 1m to facilitate potential upgrading if required over extended structural life. Subsequently the majority of the 600m^3 of fill is required where the erosion scarp has encroached on the access track between chainages 60 and 140m. The fill required for this section should be sourced from suitable material excavated from adjacent areas, requiring stockpiling.

2.4. SHORT GROYNE DESIGN

Although toe rock is an considered an effective means of reducing the risk of toe undermining and it enables a degree of damage to occur without causing expensive repairs, toe undermining remains of significant concern due to the potential for ongoing westerly transport and scour during extreme events.

Following discussions with the Port as part of the *Bunbury Coastal Protection project*, a short groyne has been designed at the western extent of the Point Busaco revetment. The groyne design shown in Drawing DA-2296-2-2 is considered flexible in length with its construction provisional depending on how the City of Bunbury chooses to manage Koombana Beach (Figure 1).



The ongoing renourishment strategy includes the provision of a 'feeder beach', where additional renourishment is placed in front of the Point Busaco revetment to offset a portion of alongshore transport losses within the 'renourishment area' to the west (Seashore Engineering 2013). The 'feeder beach' has the additional benefit of mitigating the threat of toe undermining.

Figure 1: Framework for Construction of the Provision Short Groyne

Orientation: The groyne is orientated to 344°N, perpendicular to the face of the revetment.

Length: As the majority of alongshore sediment transport is expected to take place between the outermost breaking waves and the beach face (active transport zone), estimated between beach levels 1mAHD and -1mAHD , the groynes effective capture has been inferred by the proportion of this zone the groyne extends across this zone (Table 2).

Table 2: Groyne Effectiveness

Groyne Length (m)	Depth (mAHD)	Inferred Effective Capture	
10	0.0	50%	
15	-0.3	65%	← **Selected**
20	-0.4	70%	
25	-0.6	80%	
30	-0.7	85%	

Additional losses may be attributed to cross-shore transport (rips, erosion) and bypassing following 'saturation' of the groyne with sand.

The selected groyne length of 15m extending from the revetment face as shown in Drawing DA-2296-2-2 should apply if the City of Bunbury chooses to manage Koombana Beach with groynes and renourishment or the Bunbury Port identifies the revetment at significant risk to toe undermining. This suggests the groyne will be approximately 65% effective in capturing sediment transported west.

If the groyne is installed to control the rate of westward alongshore feed from the 'feeder beach', beach monitoring including surveys shall provide the basis for determining an appropriate groyne length. It is recognised that the use of Geotextile Sand Containers (GSCs) may be appropriate in this case, allowing the groyne's length to be readily modified post construction.

Toe Level: The groyne has a toe level of -1.0mAHD to accommodate the potential for scour and erosion. This level has also been defined for the revetment toe and is considered an achievable depth using 40-50 tonne excavators in the south west of Western Australia, with bunding (using excavated material) and local dewatering likely to be required.

Height: The groyne has a crest height of 2.0mAHD limiting sand transport over the groyne. This height sits approximately 0.5m above the estimated 100year water level (Damara WA 2011 limiting the risk of wave overtopping during extreme events.

Rock Sizes: The groyne has been designed using the stable median armour size (0.85 tonnes) for a two layered rock armoured coastal protection structure and a median core size of 0.3m. Rock sizes are consistent with the Point Busaco revetment.

3. Monitoring and Maintenance Plan

Maintenance of rock armoured coastal protection structures can significantly extend their structural life. It is recognised that the structural maintenance requirements will be strongly linked to the structural life-cycle, which follows the general sequence described by Table 3. The potential for the latter three mechanisms to be episodically active in the longer-term, and the reduction of structural capacity following damage suggests that an active program of monitoring and corresponding maintenance is required for the revetment and groyne.

Table 3: Revetment and Groyne Structural Life Cycle

Initial phase	Initially, structural stability is determined by a combination of interlocking between rock units and the self-weight of the armour units;
Early phase	During early storm events, areas of low-stability rock may be mobilised in the 'shakedown' period, reducing the degree of interlocking and causing an early phase of settlement;
Main phase	The structures typically changes slowly, with energetic wave conditions occasionally mobilising armour units, gradually reducing the effect of interlocking;
Episodic over life	Erosion may provide accelerated displacement to the armour layer, either through undermining or the increase in wave height that may propagate through deeper water;
Episodic over life	Secondary failure mechanisms, including undermining and overtopping may cause damage when conditions exceed a tolerable range;
Late phase	Tertiary failure mechanisms, such as rock fracture, settlement, intertidal voids and piping usually develop exponentially, such that they do not require maintenance until the latter phases of the structure life-cycle.

The primary aims of the monitoring and maintenance plan shown in Table 4 is to rapidly identify changes in structural integrity of the revetment and groyne and to monitor the beach levels at the toe of the revetment reducing the risk of toe destabilisation. The plan considers the four mechanisms considered most likely to cause damage to the revetment and utilises engineering inspections, simple beach monitoring techniques and general triggers to provide the basis for maintenance/management responses.

Table 4: Monitoring and Maintenance Program

Failure Mechanism	Description	Monitoring Techniques	Maintenance/Management Triggers[1]	Maintenance/Management Responses
Initial Shakedown	Early settlement of the structures is commonly developed during the first strong storm event experienced.	**Engineering inspection**[2] Following the first severe storm after construction.	Greater than 2% of armour units displaced.	Likely to consist of reworking armour units with the main cost associated with the mobilisation of a suitably sized excavator.
Armour unit mobilisation	Structures experiences reduced interlocking of armour units and a progressive increase exposure of core rock during storm events. Likely to provide the most consistent source of ongoing maintenance.	**Engineering inspection**[2] Every 1-3[3] years and following extreme events.	2-5% of armour units displaced.	Displaced units are to be reinstated. May require supply of additional rock amour from external sources.
Toe Undermining	Undermining of the structures toe may be caused temporarily by scour during severe storms, or in a more sustained fashion due to erosion, which includes seabed response to installation of the structure. Maintenance of the toe will be largely dependent upon the scour and erosion experienced over its structural life.	**Monitor beach levels at toe**[4] 3-6 monthly using photo-monitoring and visual inspections[6].	Sustained exposure of toe rocks due to erosion of the beach.	Management responses should be assessed according to the perceived severity of damage and sustained nature of the erosion. Responses may include: 1. Dumping/placement of additional toe rock; 2. Reinstate the armour face if it has been destabilised (loss of interlock/exposure of core rock); 3. Reinstate crest level; 4. Renourishment of the beach in front of the revetment; 5. Construction/extension of the small groyne.
		Engineering inspection[2] Every 1-3[3] years and following extreme events.	Destabilisation of the toe rock.	
Overtopping	Damage due to overtopping is highly episodic. The general crest level of +3.5mAHD for the revetment is anticipated to provide a high degree of protection. A higher risk of damage occurs at the eastern end where the crest level reduces to +2.5mAHD and for the groyne. It is recognised cement stabilised concrete and crushed limestone is recommended to manage drainage and restrict scour behind the revetment.	**Engineering inspection**[2] Following extreme events.	Minor damage including scour of crushed and cement stabilised limestone. Major damage including displacement of crest units and formation of drainage channels, often cutting back through the revetment[5].	Overtopping represents a relatively minor threat to structural performance and can be managed responsively according to the level of damage: 1. Reinstate crushed and cement stabilised limestone as required; 2. Reinstate crest units; 3. Earthworks to fill drainage channels. 4. Increase crest height at the western end of the revetment to 3.5mAHD and backfill the area behind.

[1]*Triggers are to be considered in conjunction with engineering judgement (e.g based on location and clustering of displaced units)*
[2] *Engineering inspections should evaluate the revetment and groynes condition utilising the US Army Corps of Engineers Repair, Evaluate, Maintain and Rehabilitate (USACE-REMR) technique (Oliver et al. 1998; USACE 2006)*
[3]*Depending on the magnitude of storm events experienced.*
[4]*Can be supplemented by beach monitoring undertaken along Koombana Beach by the City of Bunbury including surveys, beach width measurements and photo-monitoring.*
[5]*Major overtopping damage is not anticipated to occur due to the relatively low wave energy conditions.*
[6]*Photo-monitoring sites should be established along the revetment and groynes crest at regular intervals (approximately 50m) according to the recommended approach outlined in Department for Transports 'How to photo monitor beaches' (DoT 2012) to provide a consistent visual comparison.*

4. References

Damara WA. (2011) *Busaco Point Revetment: Preliminary Detailed Design.* Prepared for the Bunbury Port Authority*;*

Department of Transport (2012) *How to Photo Monitor Beaches,* Coastal Infrastructure, September 2012

Seashore Engineering. (2013) *Bunbury Coastal Protection: Part A – Koombana Beach Coastal Erosion and Design Report*. Prepared for the City of Bunbury.

Oliver J, Plotkin D, Lesnik J & Pirie D. (1998) *Condition and Performance Rating Procedures for Rubble Breakwaters and Jetties*. Technical Report REMR-OM-24, U.S. Army Construction Engineering Research Laboratory, Champaign, IL.

United States Army Corps of Engineers: USACE. (2006) *Coastal Engineering Manual*. EM 1110-2-1100.

Appendix A Potential Rock Sources

APPENDIX A.1 QUARRY INSPECTION

The Bunbury Port has identified a potential source of rock from the Greenbushes Mine Site where Hesketh Contracting has been allocated a section of land to process basalt rock (density of approximately 3.0 t/m^3) which is a waste product of the Lithium mining operations. The site is located approximately 80km southeast of the Bunbury Port.

To confirm the sites suitability for supply of the rock required for the Works, a site inspection was carried out on 4th September 2013. At the time of inspection there was approximately 1,000 tonnes of rock stockpiled meeting specification for core rock, however minimal quantities meeting rock armour specification were present. Discussions with Hesketh Contracting suggested in order to supply the required quantities of rock armour, sufficient notice before commencement of the Works (approximately 4-6 weeks) may be required to commence stockpiling of the required sizes.

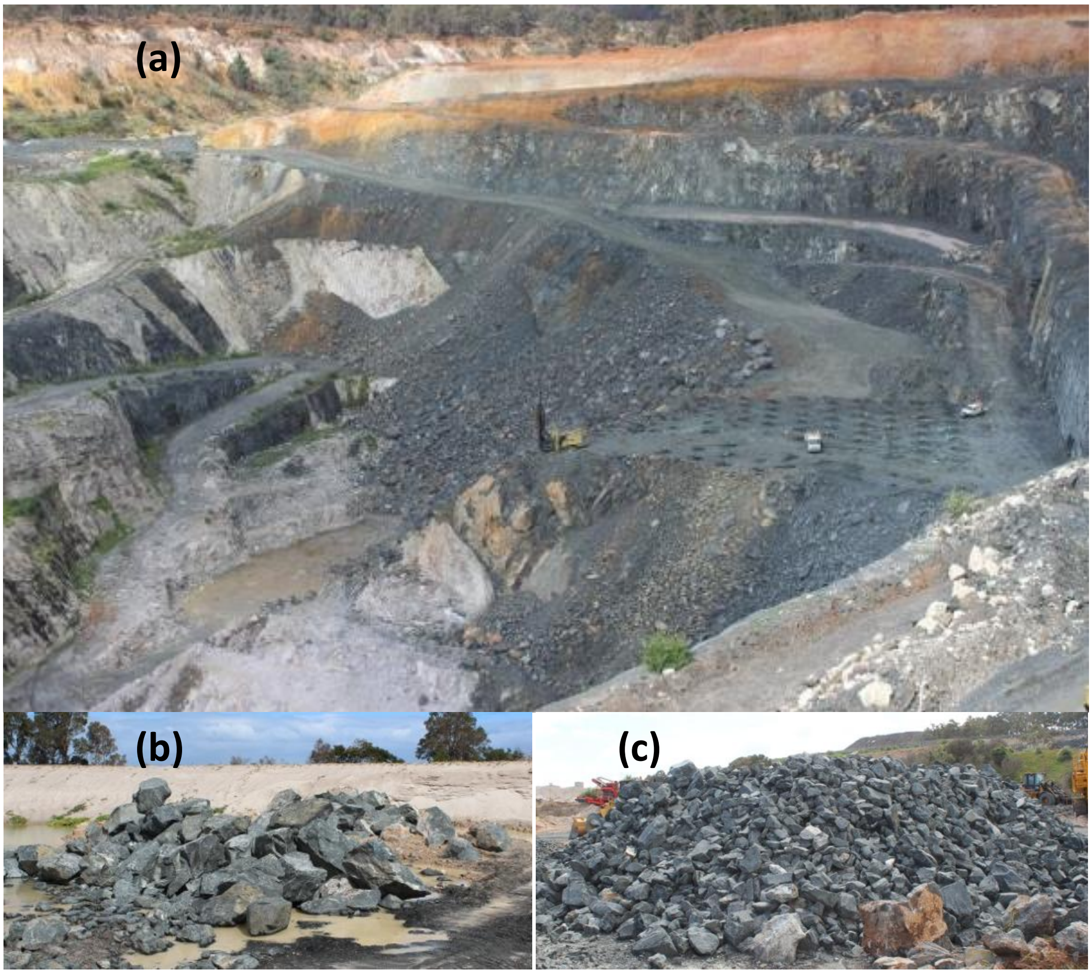


Figure A.1: Quarry Inspection Photos
(a) Mining Operations (b) Rock Armour Stockpile (c) Core Rock Stockpile

APPENDIX A.2 ALTERNATIVE ROCK SOURCES

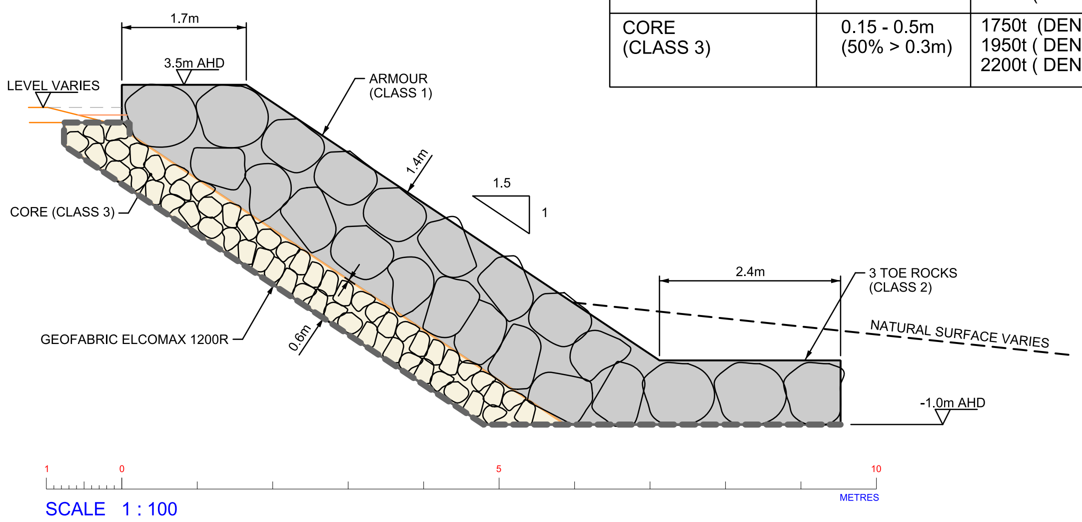
The state-owned Roelands quarry previously used to source Port development works potentially provides the nearest suitable quarry. Although the quarry is not presently operational, the Department of Transport is in the process of planning to evaluate the viability of re-establishing Roelands quarry to supply a range of local projects. Other quarries previously known to have supplied rock to recent coastal projects in the southwest are located at Gelorup (basalt) and Byford (granite).

Appendix B Drawings

Drawing No.	Title
DA-2296-2-1	POINT BUSACO REVETMENT - DETAILED DESIGN
DA-2296-2-2	PROVISIONAL GROYNE - DETAILED DESIGN

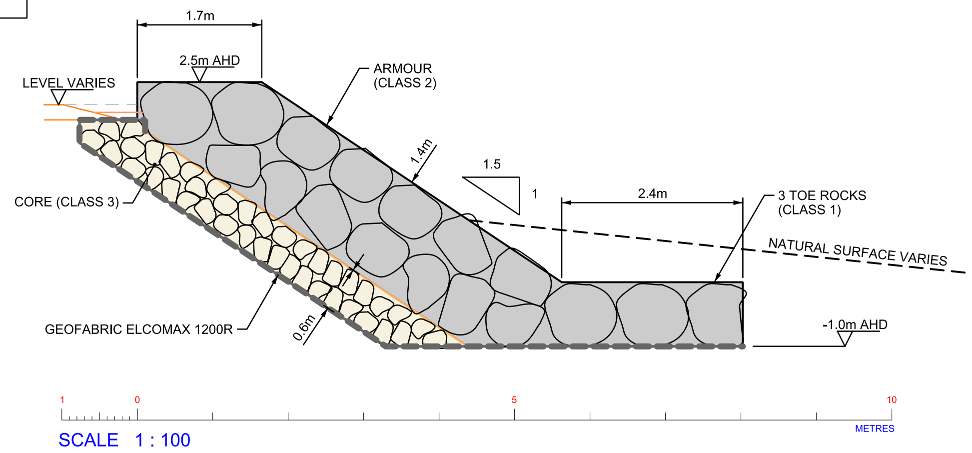
POINT	EASTING	NORTHING
1	34877.0	111841.8
2	34871.3	111830.6
3	34862.3	111821.3
4	34832.3	111801.0
5	34819.3	111794.5
6	34794.5	111784.9
7	34752.8	111770.8
8	34739.5	111768.9
9	34724.1	111766.0
10	34698.3	111759.4
11	34689.3	111738.1

ROCK TYPE	SIZE RANGE	ESTIMATED QUANTITIES
TOE (CLASS 1)	0.85 - 1.5t (50% > 1.25t)	750t (DENSITY 2.6t/m³) or 850t (DENSITY 3.0t/m³)
ARMOUR (CLASS 2)	0.4 - 1.2t (50% > 0.85t)	4150t (DENSITY 2.6t/m³) or 4550t (DENSITY 3.0t/m³)
CORE (CLASS 3)	0.15 - 0.5m (50% > 0.3m)	1750t (DENSITY 2.3t/m³) or 1950t (DENSITY 2.6t/m³) or 2200t (DENSITY 3.0t/m³)



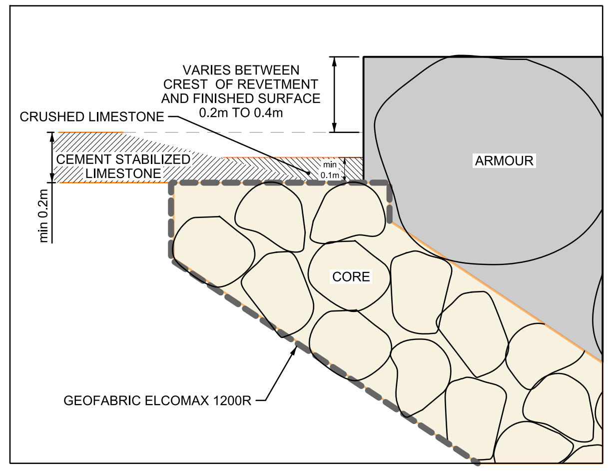
TYPICAL SECTION A

SCALE 1:100



TYPICAL SECTION B

SCALE 1:100



CREST DETAIL

NTS

REV	DATE	AMENDMENT	DRN	APP
C	09.04.14	DRAWING TRANSFORMED TO PERTH COASTAL GRID 94	SJM	
B	10.12.13	AMENDMENTS FROM ENGINEERING CHECK	CJL	
A	29.10.13	ISSUED FOR CLIENT REVIEW	JB	

ORIG SIZE A3 | ARCHIVE

NOTES
1. OVERLAP OF REQUIRED BETWEEN SHEETS OF GEOFABRIC IS 0.5m
2. AERIAL IMAGERY: BUNBURY TOWNSITE N0V 2010
3. EXCAVATED MATERIAL IS ANTICIPATED TO LARGELY CONSIST OF DREDGE SPOIL INCLUDING SAND, SILT AND ROCK FRAGMENTS

DATUM
VERTICAL AHD
HORIZONTAL PCG94

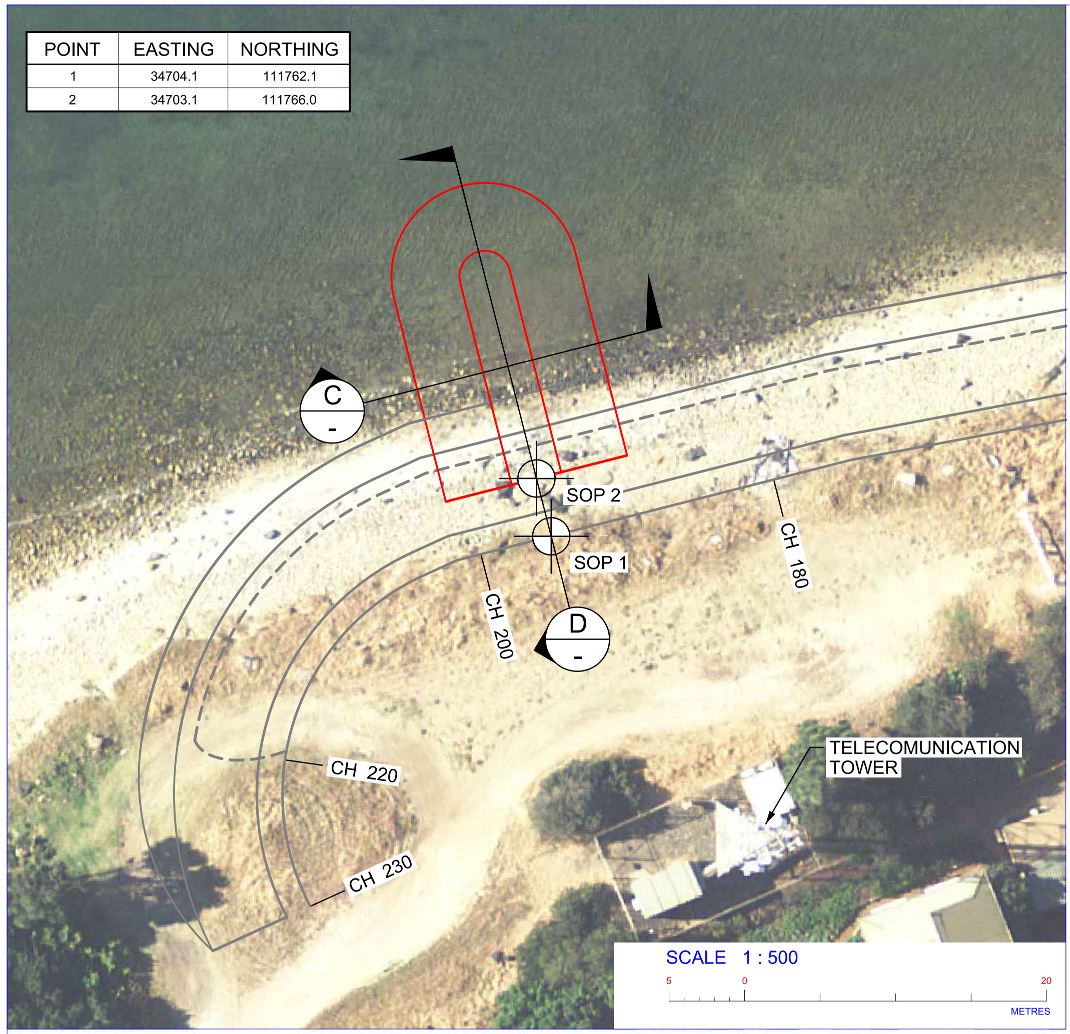
Seashore Engineering

BebbCart Marine, Cadastral & Topographic Mapping, Civil Drafting.

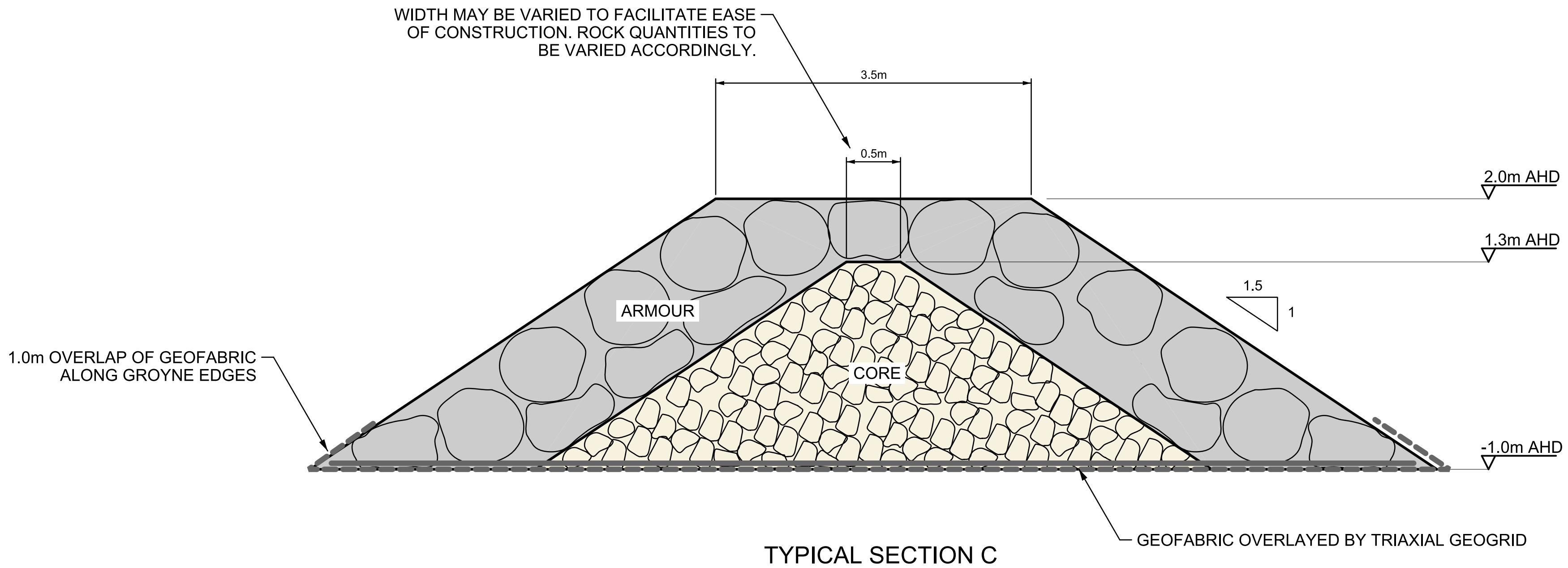
ENGINEER	G.McCORMACK	15.10.13
DRAWN	J.BARTLETT	15.10.13
DRAFTING CHECK	G.BEBBINGTON	26.11.13
ENGINEERING CHECK	S.BARR	26.11.13
APPROVED PROJECT MGR		

CLIENT BUNBURY PORT AUTHORITY
PROJECT POINT BUSACO REVETMENT
TITLE DETAILED DESIGN
DRAWING NUMBER DA-2296-2-1
REV C

POINT	EASTING	NORTHING
1	34704.1	111762.1
2	34703.1	111766.0



ROCK TYPE	SIZE RANGE	ESTIMATED QUANTITIES
ARMOUR	0.4 - 1.2t (50% > 0.85t)	430t (DENSITY 2.6t/m³) or 500t (DENSITY 3.0t/m³)
CORE	0.15 - 0.5m (50% > 0.3m)	190t (DENSITY 2.3t/m³) or 220t (DENSITY 2.6t/m³) or 250t (DENSITY 3.0t/m³)



TYPICAL SECTION C

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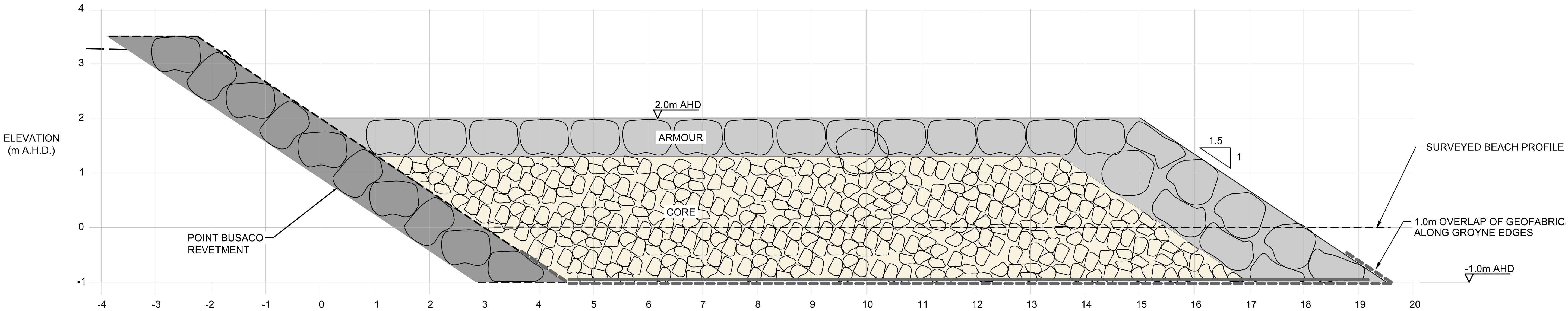

TYPICAL SECTION D

SCALE 1:75

SCALE 1 : 75

1 0 3

METRES

REV	DATE	AMENDMENT	DRN	APP
C	09.04.14	DRAWING TRANSFORMED TO PCG94, GEOFABRICS ADDED	SJM	
B	10.12.13	AMENDMENTS FROM ENGINEERING CHECK	CJL	
A	29.10.13	ISSUED FOR CLIENT REVIEW	JB	

ORIG SIZE A3 | ARCHIVE

NOTES

1. AERIAL IMAGERY; BUNBURY TOWNSITE NOVEMBER 2010

DATUM

VERTICAL AHD

HORIZONTAL PCG94

Seashore Engineering

BebbCart Marine, Cadastral & Topographic Mapping, Civil Drafting.

ENGINEER	G.McCORMACK	15.10.13
DRAWN	J.BARTLETT	15.10.13
DRAFTING CHECK	G.BEBBINGTON	
ENGINEERING CHECK	S.BARR	
APPROVED PROJECT MGR		

CLIENT BUNBURY PORT AUTHORITY

PROJECT POINT BUSACO REVETMENT

TITLE PROVISIONAL GROYNE DETAILED DESIGN

DRAWING NUMBER DA-2296-2-2

REV C