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ENGINEERS PLANNERS SURVEYORS ENVIRONMENTAL PROJECT MANAGEMENT

CLARKES BEACH DUNE RECONSTRUCTION

Summary of Geotechnical and Risk Assessment

for:

NSW Department of Planning, Industry and Environment – Crown Lands

3rd September 2021

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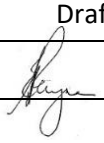
1	2/9/21			Bill Payne	
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STAGE 1 – DUNE ASSESSMENT and DESIGN OPTIONS

In October 2020, APP was engaged by the NSW Department of Planning Industry and Environment – Crown Lands (DPIE-Crown Lands) to provide geotechnical advice on the structural stability of the Beach Byron Bay café. APP were asked to review the 'risks of failure' associated with the eroding dune at Clarkes Beach in front of the Beach Byron Bay café, and to provide geotechnical advice on a range of coastal erosion management options under consideration. The brief was as follows:

1. *Undertake a slope stability assessment for the café and surrounding land.*
2. *Comment on whether assessment can be undertaken based on site inspection and desktop methods, or whether physical investigations are needed.*
3. *Consider the following scenarios:*
    a. *Existing situation for the café building*
    b. *Global stability with a Geobag wall at toe*
    c. *Any geotechnical constraints on the cross shore position of Geobags*
4. *Optional scenarios (if required):*
    a. *Global stability with a sand bund at the toe*
    b. *Any geotechnical constraints on the cross shore position of sand bund*

APP provided advice to DPIE-Crown Lands on the immediate risks to the café building. APP's advice also informed the consideration of a number of options for managing the risks at the site, and a preliminary design for coastal protection works and dune reconstruction. The design of the coastal protection works was prepared by James Carley, Principal Coastal Engineer, from the UNSW Water Research Laboratory (WRL), on behalf of DPIE-Crown Lands.

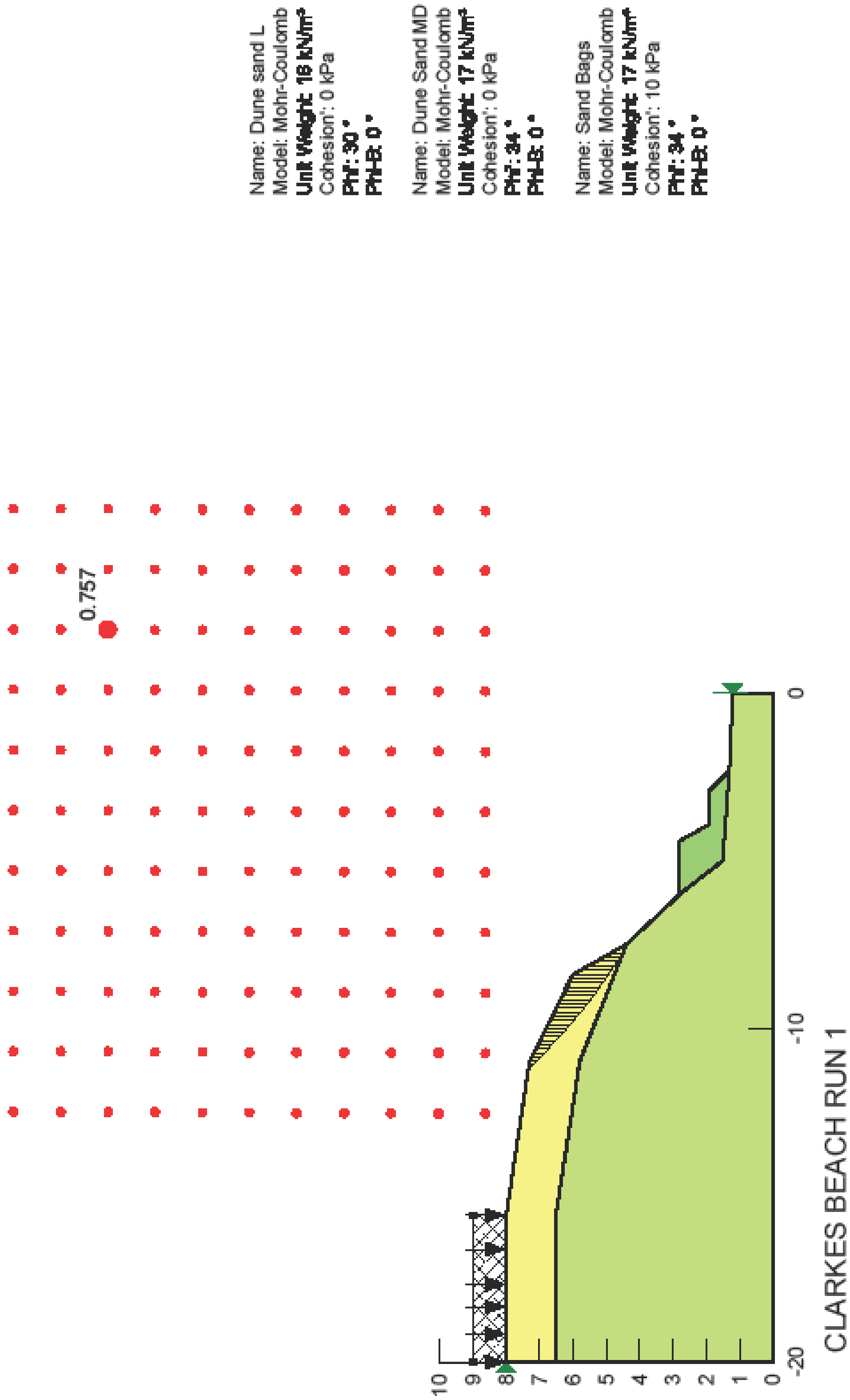
Treatment alternatives assessed by APP were:

- Toe protection only. As per Slip circle Run 1 overleaf.
- Rebuild dune without toe protection. As per Slip circle Run 4 over leaf.
- Re-build the dunes with toe protection. As per Slip circle Run 4A overleaf.

Backslope grades were investigated between 32 and 35 degrees based on observed backslopes from adjacent dunes measured in July 2020. Assumptions in soil profiles were:

Loose sand	ϕ = Internal angle of friction	= 30 degrees
	Υ = bulk density	= 16 kN/m^3
	C = soil cohesion	= 0 kPa
Medium dense sand	ϕ = 34 degrees	
	Υ = 17 kN/m^3	
	C = 0 kPa	
Sand Bags	ϕ = 34 degrees	
	Υ = 17 kN/m^3	
	C = 10 kPa	

Various piezometric water table levels were investigated. A summary of the key results and slip circle outputs is provided overleaf and in Table 1. Typical slip circle model geometry and soil properties are also provided over leaf.



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Model: Mohr-Coulomb
Unit Weight: 18 kN/m³
Cohesion': 0 kPa
Phi': 30 °
Phi-B: 0 °
Name: Dune Sand MD
Model: Mohr-Coulomb
Unit Weight: 17 kN/m³
Cohesion': 0 kPa
Phi': 34 °
Phi-B: 0 °
Name: Sand Bags
Model: Mohr-Coulomb
Unit Weight: 17 kN/m³
Cohesion': 10 kPa
Phi': 34 °
Phi-B: 0 °
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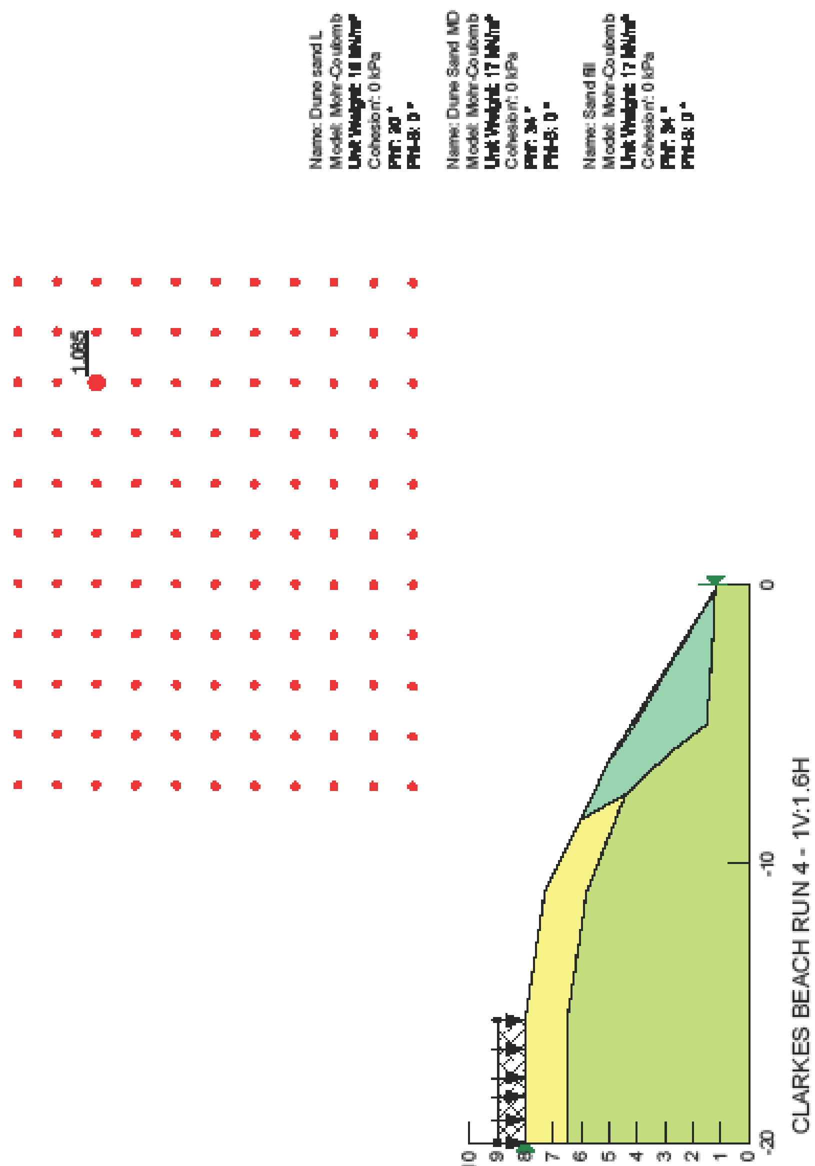
CLARKES BEACH RUN 1
-20
-10
0
10
9
8
7
6
5
4
3
2
1
0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Phi: 30 °
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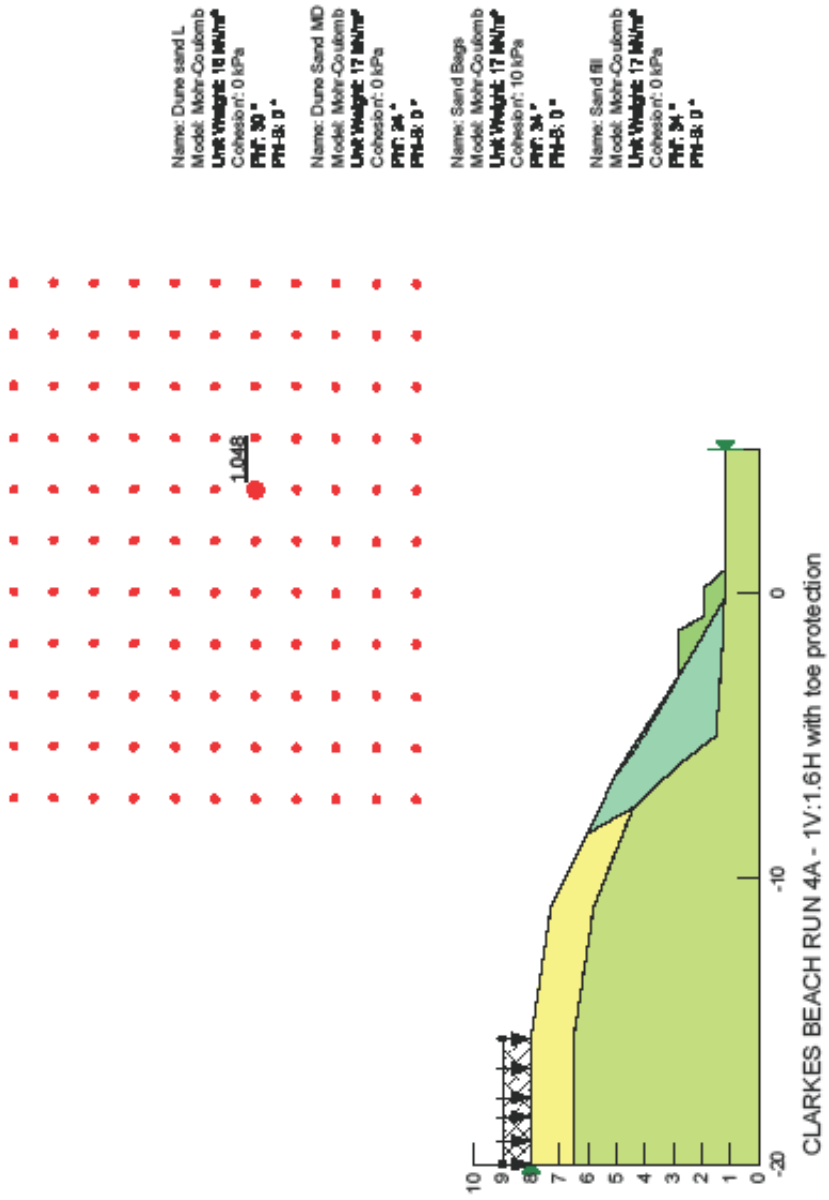
Name: Dune Sand MD
Model: Mohr-Coulomb
Unit Weight: 17 kN/m³
Cohesion: 0 kPa
Phi: 34 °
Phi-B: 0 °
Name: Sand fill
Model: Mohr-Coulomb
Unit Weight: 17 kN/m³
Cohesion: 0 kPa
Phi: 34 °
Phi-B: 0 °
1.085
CLARKES BEACH RUN 4 - 1V:1.6H
-20
-10
0
10
9
8
7
6
5
4
3
2
1
0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Unit Weight: 18 kN/m³
Cohesion: 0 kPa
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Psi-B: 0 °
Name: Dune Sand MD
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Unit Weight: 17 kN/m³
Cohesion: 0 kPa
Phi: 34 °
Psi-B: 0 °
Name: Sand Bags
Model: Mohr-Coulomb
Unit Weight: 17 kN/m³
Cohesion: 10 kPa
Phi: 34 °
Psi-B: 0 °
Name: Sand fill
Model: Mohr-Coulomb
Unit Weight: 17 kN/m³
Cohesion: 0 kPa
Phi: 34 °
Psi-B: 0 °
1048
CLARKES BEACH RUN 4A - 1V:1.6H with toe protection
10
9
8
7
6
5
4
3
2
1
0
-20
-10
0

The values in Table 1 are Factors of Safety against instability. Factors of Safety (FoS) can be defined by the amount a structure's ability to withstand a loading effect exceeds the effect of the load. Mathematically it is expressed as

$$\text{Factor of Safety} = \frac{\text{Capacity to resist load affect}}{\text{Load Affect}}$$

The value of the FoS to be adopted can vary with the depth of knowledge of underlying soil properties and the impact on infrastructure of failure. Where little information is available FoS values would exceed 2 for low risk impacts of failure and ideally be at 3 for high risk impacts. Where a high degree of knowledge exists of underlying soils ideal FoS are around 1.5. Lower FoS values between 1.2 – 1.3 can be adopted where the risk of failure can be managed. For this study a high degree of knowledge exists as to the underlying soils and their stability values as the densities can be assessed from eroded dunes and stable dune slopes can be measured from adjacent unaffected dunes. The study is informed by a detailed risk assessment which had been submitted and explained to the various Agencies for whom the reports were prepared.

In the following discussion *Local Stability* refers to slippage within the dune face between crest and toe whilst *Global Stability* refers to the entire dune collapsing from behind the dune crest to seaward of the dune toe. Lower values of local stability can be tolerated as the local slumping can be repaired and is not immediately injurious to assets. Global stability is more concerning as it can lead to a more catastrophic event.

The results in the table show that the steeply (> 40 degrees) eroded dunes in front of the Beach Café were "unstable" in July 2020 with FoS value of 0.7 whilst the unaffected Reflections dunes were relatively stable with a FoS of 1.16. The repair options show that in terms of stability the only acceptable option in terms of Factors of Safety were for a reconstructed dune with or without toe reinforcement set at no greater than a 32 degree back slope. The decision on toe reinforcement is more effected by scour events. Without the toe a stable dune can be quickly undermined by minor storm events and tides as witnessed between July and October 2020.

Location	July 2020		October 2020		Future **Local** Stability		Future **Global** Stability	
Beach Cafe	Local	Global	Local	Global	With toe	Without Toe	With toe	Without Toe
Untreated	0.7	N/A					1.26	
Reconstructed at 32 degrees					1.05	1.09	1.51	1.23
Reconstructed at 35 degrees					1.03	0.9	1.39	1.08
Reflections	1.16	N/A						

Table 1. Factors of Safety against Instability July 2020

APP concluded and advised DPIE-Crown Lands as follows

> *The preliminary analysis shows the July 2020 event created local instability within the dune resulting in its gradual recession via flattening of the upper portions to achieve stability and retreat of the toe with wave and tidal effects.*
>
> *The preliminary analysis shows acceptable levels of global stability are achieved for reseeded slopes of 32 degrees provided toe protection is included. Without toe protection the global FOS is marginal. Local stability values hover either side of unity for either protected or unprotected toes. This would be displayed as shallow ravelling of the front face. Revegetation would assist together with preventing human access.*
>
> *For steeper (35 degree) slopes reported global stability is not considered acceptable unless other stabilising measures are incorporated.*

STAGE 2 - CONSTRUCTION

A dune reconstruction design using 32 degree back slope, and accompanying sand-filled geobag toe protection was subsequently prepared by UNSW WRL.

APP was engaged by DPIE-Crown Lands to supervise the construction of the coastal protection works from an engineering and geotechnical perspective. As construction commenced, it became apparent that the fill above the geobag crest height could only be placed at loose density. This meant that a flatter backslope to the dune was required to maintain stability, and that the geobag toe protection would extend further into the active beach zone. Options were investigated by APP to minimise this distance and bring the toe protection closer to the dune crest. These two issues are mutually exclusive; one requiring a flatter slope, the other requiring a steeper slope. The design was refined to optimise results.

FOS results for the amended October study are summarised in the **Table 2** over leaf. The loose sand option was adopted as it was not possible to achieve medium density. To achieve medium density, heavy compaction equipment needed to work on the installed dune. This proved to be too difficult, dangerous and slow for the construction window and resources available. Hence the fill could only be dumped quickly from the excavator on site as loose fill. Accordingly, no compactive effort could be applied to the upper layers of the dune. Only the lower portion of dune behind the Geobags could be properly compacted.

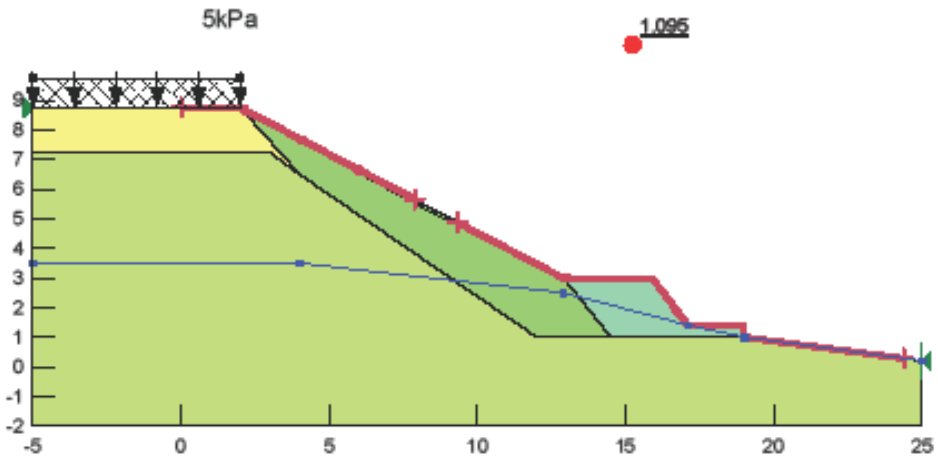
Hence the flatter slope of 28 degrees was adopted for the dune in front of the café as the factors of safety for steeper slopes for loose sand were considered too low. Consequently, the geobag toe protection could not be brought closer to the dune crest.

An example of the slip circle model used for this design refinement is also provided after the Slip Circle Results Table.

LOOSE SAND FILL						
	Batter 33°		Batter 30°		Batter 28°	
	Dry (Run 1)	Wet (Run 2)	Dry (Run 4)	Wet (Run 3)	Dry (Run 5)	Wet (Run 6)
	FOS		FOS		FOS	
Shallow surface	0.90	0.90	0.96	0.96	1.09	1.09
Extending behind crest	1.05	1.05	1.05	1.05	1.25	1.25
Batter above sand bags	1.06	1.06	1.07	1.07	1.38	1.32
Global	1.504	1.173	1.64	1.27	1.69	1.327
MEDIUM DENSE SAND FILL						
	Batter 33°		Batter 30°		Batter 28°	
	Dry (Run 11)	Wet (RUN 21)	Dry (Run 41)	Wet (Run 31)	Dry (Run 51)	Wet (Run 61)
	FOS		FOS		FOS	
Shallow surface	1.05	1.05	1.11	1.11	1.26	1.26
Extending behind crest	1.21	1.21	1.2	1.2	1.39	
Batter above sand bags	1.22	1.22	1.24	1.24	1.35	1.35
Global	1.623	1.233	1.697	1.267	1.75	1.32

Table 2. Factors of Safety against Instability Medium and Loose Sand Comparison October 2020

From the above results it can be seen that the FoS for a compacted (medium dense) sand dune at 32 degrees (highlighted in yellow), has similar FoS across the parameters investigated to that achieved by a 28 degree uncompacted dune (highlighted in blue). The medium dense sand at 28 degrees can be seen to generally outperform the 28 degree loose sand dune.



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Unit Weight: 18 kN/m³
Cohesion': 0 kPa
Phi': 30 °
Phi-B: 0 °
Piezometric Line: 1

Name: Medium dense Sand
Model: Mohr-Coulomb
Unit Weight: 17 kN/m³
Cohesion': 0 kPa
Phi': 34 °
Phi-B: 0 °
Piezometric Line: 1

Name: Sand Fill (Loose)
Model: Mohr-Coulomb
Unit Weight: 18 kN/m³
Cohesion': 0 kPa
Phi': 30 °
Phi-B: 0 °
Piezometric Line: 1

Name: Sand Bags
Model: Mohr-Coulomb
Unit Weight: 17 kN/m³
Cohesion': 10 kPa
Phi': 34 °
Phi-B: 0 °
Piezometric Line: 1

Clarkes Beach Remedial Works
Loose Sand Fill
Batter at 28 degrees (crest pushed back 1m back into cafe are 17m from surcharge to toe)
Elevated water table behind sand bags
Construction Run 6

Ardill Payne & PARTNERS

STAGE 3 – INTERVENING MAINTENANCE and FUTURE WORKS

3.1 Intervening Maintenance

In December 2020 large tidal events and minor storms over topped the geobag toe protection and removed sand from the toe of the dune above the geobags. This resulted in a back slope of between 41 and 50 degrees as described in sketch 1 overleaf. This slope range was consistent with the short-term stability values previously observed. An emergency response was initiated by DPIE-Crown Lands which involved reinstating the eroded toe of the dune with approximately 800 cubic metres of sand and placing an extra row of Geobags on top of the existing installation.

In June 2021 the crest of the dune required the installation of stormwater diversion and infiltration works and some 25 tonnes of sand to be installed to address scour from stormwater runoff from hard paving in front of the Beach Café. This stormwater driven repair was not associated with the beach erosion event.

As at July 2021 the dune and Geobag toe protection has not required any further maintenance.

3.2 Future Stability and Maintenance

In terms of asset risk allocation, the current arrangement is consistent with the risk profile of a medium (5 – 10 year) deployment for coastal protection works. Future maintenance requirements and stability will be reviewed within this deployment time frame. For a longer deployment period additional works to those described below may be required.

The Geobags are required to maintain the adopted Factors of Safety against instability. The governing FoS for Global Stability being 1.5. By reference to Table 1 this is only achieved with a toe protection system in place. Table 2 shows that for the options considered, the Global FoS achieved exceeded 1.5 for the permanent drained or dry case. Short term wet events have lower FoS but this is considered acceptable due to the event duration.

Furthermore, the Geobags are required to be maintained as toe protection elements to prevent undermining of the dune and subsequent steepening of backslope leading to destabilisation.

To maintain the adopted Factors of Safety the dune backslope is required to be kept at 28 degrees. In the short - medium term this may require supplementing the dune with additional sand. The maintenance frequency will be affected by the severity of beach scour events and the ability of the beach to be reinstated to pre-July 2020 profiles. Should the beach return to the pre July 2020 event then minimal maintenance will be required.

The amount and frequency of sand replenishment can be minimised by removing pedestrian access across the dunes and also by enhancing local stability with traditional primary dune “creeper” vegetation.

Published texts report that dune stability and maintenance is negatively impacted by pedestrian traffic, with beach goers using it to sunbake, view the beach and as an informal beach access. Serious consideration should be given to formalising pedestrian access points along the beach and providing

fencing to the top and bottom of the dunes to deter uncontrolled access and human activity along the dunes.

This has been used along many other beaches and allows low level revegetation to re-establish. Such vegetation greatly enhances local stability and short term global stability as well as providing a deterrent to pedestrian access and opportunities for local fauna to exist.

It is apparent from the adjoining Reflections site, where revegetation of the dunes has been partially completed, that the pedestrian damage can be greatly reduced by revegetation and that local backslopes can be maintained at steeper grades than 28 degrees.

In the short – medium term, minor repairs or reinstatement of the Geobags may be required in conjunction with sand nourishment to preserve toe protection of the dune against scour events.

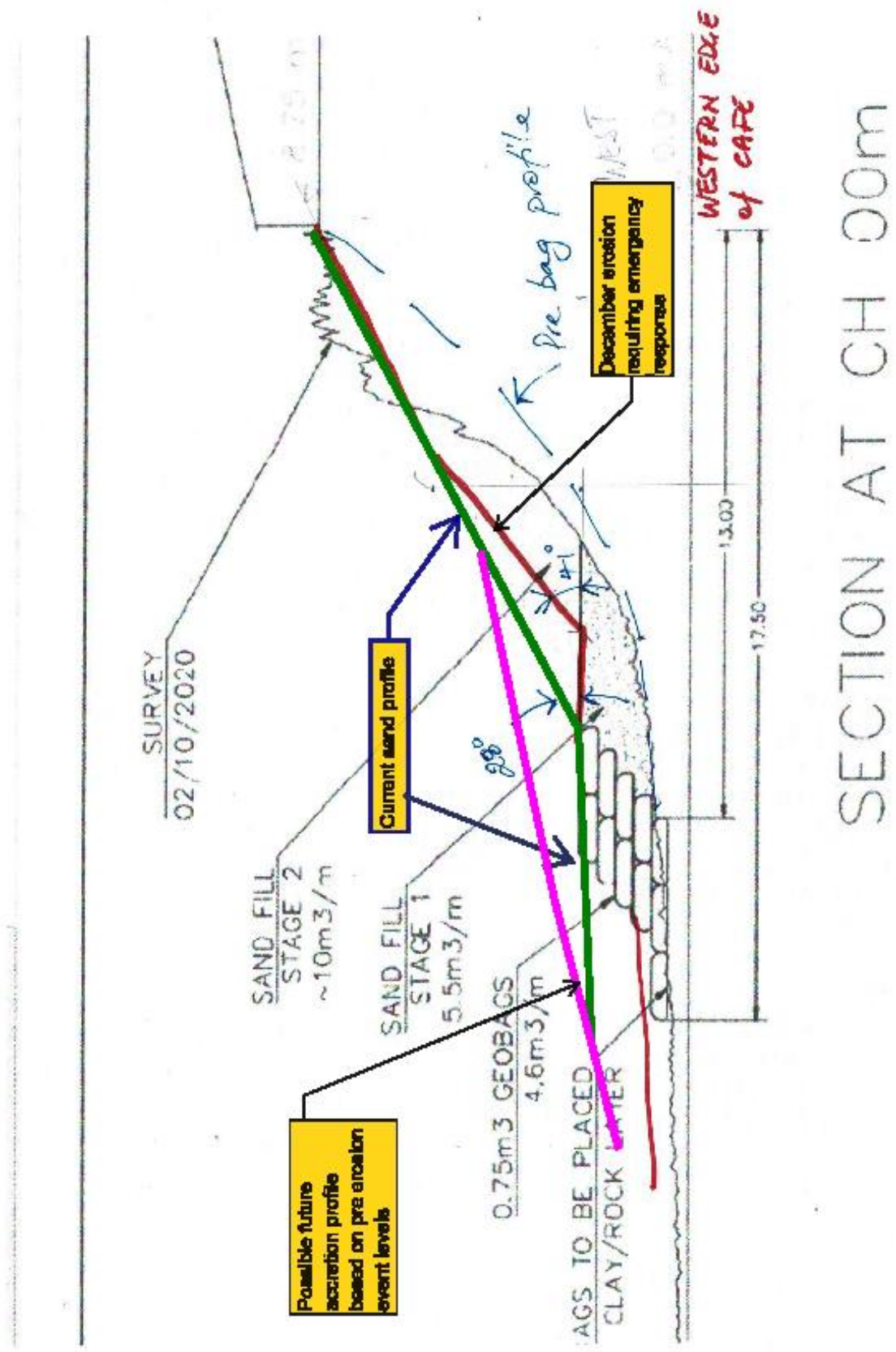
3.3 Key management and maintenance measures over the proposed five-year design life

- Revegetation works using similar plant species as deployed on the adjoining Reflections dunes
- Fencing of the subject works area
- Sand nourishment as required.
- Maintenance of the geobags and the structural integrity of the toe protection works

3.4 Time Frames and activation points

- Revegetation and fencing can start immediately
- Similarly, planning and design of formalised access points can be started now.
- Sand nourishment would be triggered by local backslopes exceeding 35 degrees. Table 1 indicates a FoS of 1.03 for the dune at 35 degrees with toe protection and this has been adopted as the trigger value. It is noted that the Reflections dune achieved a higher FoS for the same slope when sparsely vegetated.
- The sketch over leaf shows a local backslope at 41 degrees existed in the short term immediately prior to the December 2020 repair.
- The need to repair the Geobags would be assessed as part of a monitoring program. Repair is taken as replacing torn bags or reinstating dislodged bags. During the December 2020 event the Geobag work mainly involved placing an extra row of bags across the existing toe structure. Replacing torn or reinstating dislodged bags along the Reflections frontage was a relatively minor (1 day) exercise.

It is important to emphasise that these measures are for the short – medium term erosion event. Should a large, long term event occur then the current installation could be overtopped and destroyed. These measures are not meant to address that occurrence.



SKETCH 1: Various Dune Profiles recorded during 2020 Scour events