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Report

Geotechnical Assessment (Cliff Stability)

Witton Bluff, South Australia

30 OCTOBER 2009

Prepared for

City of Onkaparinga

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Introduction

1.1 General

URS Australia Pty Ltd (URS) has been engaged by the City of Onkaparinga (Council) to undertake an inspection of a length of coastal cliff between Christies Beach and Port Noarlunga, South Australia. The length of cliff runs to the west of the Esplanade from the intersection of Beach Road and the Esplanade in the north, to the Port Noarlunga boat ramp in the south. A location plan is shown in Figure 1.

1.2 Project Background

URS has previously undertaken cliff stability investigations and assessments along a significant portion of the coastline within the Onkaparinga Council area, these studies date back to 2001.

The Witton Bluff South to Port Noarlunga area was included in previous assessments and the length of cliff was previously identified by Golders (2001) and URS (2005 and 2007) as being within a 'high risk' area (References 1, 2 and 3).

In March 2006, URS re-inspected the area from Witton Bluff South to Port Noarlunga, part of a further assessment of cliff stability, and recommendations for slope risk reduction and remediation strategies were made.

An assessment of the stability of the cliff was also undertaken from the crest of the cliff as part of a wider cliff top erosion audit in 2007. This included the section from Christies Beach to Witton Bluff South.

In June 2009, URS reported on tension cracks evident at the crest of the slope previously remediated with a reinforced retaining wall (Reference 4).

A recent failure of the cliff face, to the north of the Port Noarlunga jetty, has led Council to commission URS to undertake a contemporary inspection of this of coastal cliff.

This report summarises the findings of a recent inspection and provides an outline of recommendations for mitigation measures.

1.3 Scope of Works

URS has been engaged to undertake an inspection of the cliff from both the crest and toe and an assessment of the principal geotechnical hazards and associated risks along with recommendations for risk mitigation measures.

The scope of works is outlined in the URS proposal entitled 'Geotechnical Assessment at Christies Beach (Witton Bluff)' dated 27th July 2009.

2 Site Description

2.1 General

The site is located to the west of the Esplanade at Christies Beach and Port Noarlunga and consists of the section of coastal cliff running from the south of Beach Road in the north to Saltfleet Street in the south; the total length of cliff is of the order of 1.15 km. The cliff ranges from less than 3 m in height at the northern and southern ends, and attains a maximum of height of approximately 25 m between Benny Avenue and Anderson Avenue, in the central part of the area inspected.

A parking lane exists between Beach Road and Short Street. There is no footpath or parking between Short Street and 40 m south of Dale Avenue. From this point south a shared use cycle and pedestrian footpath runs along the crest of the cliff, with sections of parallel car parking. Access to the beach to the north of the site, is on the Esplanade, near Beach Road via a short pedestrian footpath. Access to the beach to the south of the site, is on the Esplanade, near Saltfleet Street.

Vegetation cover on the cliff face and at the crest varies across the length and over the height of the section.

2.2 Geology

Reference to the 1:50,000 Geological Sheet for the area (Noarlunga, 6627-IV) indicates that the main geological unit present at the site is a quaternary clay of the Christies Beach Formation. Underlying the clay are mudstone and limestone layers of the Blanche Point Formation underlain by Tortachilla Limestone and North Maslin Sands.

2.3 Previous Studies

2.3.1 Detailed Cliff Stability Investigations Stage 2 Report (URS September 2005)

The southern section of the site, between Witton Bluff and the Port Noarlunga Boat ramp, was considered as part of the previous detailed cliff stability investigation undertaken by URS in 2005. The Stage 2 report consisted of a risk assessment and preliminary risk management strategy for Areas A to I (the southern section of the subject site being a part of Area A).

The cliffs were described as approximately 20 m high, consisting of aeolian sand over calcrete in the upper section, overlying clays and lower cemented sands and gravel units. The sands and gravel units are preferentially eroded creating overhangs that periodically collapse and are severally gullied and eroded by human and bird activity. Underlying these units is an upper soft limestone unit (heavily gullied and sloping at 1V:1H) and a lower, more competent limestone unit forming a platform which was eroded at the base of the slope by current wave action.

Within the tidal zone, wave action had created vertical faces in the limestone up to several metres high and also eroded the rock, resulting in the formation of caves. In a cave cut into the lower limestone unit, a continuous vertical defect with strike 350 degrees outcrops over at least 20 metres. This defect is a release surface in the roof that could potentially lead to collapse of the rock mass in the roof of the cave. Other overhangs in the limestone were also forming and may collapse. Also an overhang near the boat ramp was created due to the presence of steep dipping defects and could lead to the failure of a block from the rock mass.

2 Site Description

The main hazards identified for Area A, in 2005, are listed below. Note that this description covers only the southern section of the coastal cliff area considered as part of the subject site.

- Block / rock falls in the lower limestone cliffs at the shoreline as a result of wave undercutting.
- Erosion due to run off and foot traffic, and subsequent slumping/debris flow in the soil units.
- Slumps and rock falls in the steep upper calcrete and mid slope sand layers as a result of water erosion, foot traffic, coastal weathering and bird activity.

The causes of the limestone collapse hazard are natural and ongoing. The causes of the soil erosion and slumping hazard are partly natural and ongoing, but are exacerbated by human induced and preventable impacts.

The following risk treatments were considered to be feasible for Area A.

- Remove the two existing overhangs and cave in the limestone at beach level,
- Place fill and vegetate at the monument site,
- Monitor cracking in the road and install survey pins across the slope,
- Fence off the level area between walking track and base of vertical cliffs near Witton Bluff, and
- Check all fences and signs, and repair and augment as required.

2.3.2 Coastal Cliff Stability Study Concept Designs for Remedial Works to Areas A, C and E (URS Report, March 2006)

Further to the URS 2005 Stage 2 report, URS re-inspected Area A in 2006. The inspection confirmed details of the condition of the cliff and surrounds and of the nature and scope of the proposed remedial works to address the various forms of cliff instability that were present at the site. Note that this report covers only the southern section of the coastal cliff area considered as part of the subject site.

Geotechnical hazards affecting the cliff top were soil erosion and slumping, and calcrete rock falls or slides due to surface water runoff leading to failures in over-steep weak soils. Mitigation measures identified were maintenance of fencing and signage, installation of retaining walls adjacent to footpath areas undermined by erosion and placement of engineered fill buttresses where required and plantation of vegetation.

Geotechnical hazards affecting access paths down cliff face were soil erosion and slumping, and limestone rock falls due to surface water runoff leading to failures in over-steep weak soils and rock. Mitigation measures identified included checking all fences and signs, and repair and augmentation as required.

Geotechnical hazards affecting the cliff base were the continual undercutting of the lower and upper limestone units leading to the formation of caves. Mitigation measures are those described above and the removal of overhanging rocks by rock breaking the lower slopes and infilling of cliff undercut sections with rock revetments. In the area of an embayment, the long term mitigation measures recommended were to fill and cover the toe of the slope with rock armour. This was considered to be necessary to prevent significant further undercutting that may lead to large scale collapse of the limestone and overlying weaker strata.

2 Site Description

2.3.3 Cliff Top Erosion Audit (URS Report, June 2007)

In June 2007, a report detailed the results from a cliff top inspection in the subject area. The erosion audit detailed risk assessments, recommended risk treatments and cost estimates for the remediation of sections of the cliffs.

The main instability mechanisms identified for Christies Beach are listed below:

- Erosion by stormwater leading to gullying at crest of slopes,
- Soil slumping at the slope crest, and
- Over steepening at the crest leading to block falls/topples/slides of calcrete and soil.

The audit also included a risk evaluation and generic comment on risk treatment for the cliff faces in the area. The treatment areas are summarised below.

- Infilling of local gullies or slumps with granular material,
- Infill of sinkholes and tension cracks with bentonite pellets,
- Stormwater drainage control – where kerb and gutter are not present behind the cliff crest,
- Revegetation along cliff crest, and
- Fencing and signage.

The main instability mechanisms identified for Port Noarlunga were as detailed in the March 2006 URS report and erosion by stormwater leading to gullying at crest of slopes. Recommended treatment included infilling local gullies or slumps with granular material and stormwater drainage control.

2.3.4 Witton Bluff Upper Slope (URS report, June 2009)

In March 2009, URS were commissioned to provide remedial advice for tension cracks observed at the crest of a cliff previously remediated in 2003 with a reinforced retaining wall (Refer to Zone C on Figure 2). Tension cracks were also observed in the crest of the cliff during the 2007 URS Cliff Top Audit. Recommended remediation measures included local reinstatement of engineered fill, establishing vegetation and the placement of a growing medium covered by erosion protection matting.

2.4 Meeting with Council

URS met with Council representatives on site on 24th August 2009 and Council identified the following as being the key features.

- The assessment of actively forming caves and recent rock falls at the shore line in Zone J Figure 2. Refer to the attached Plate A for a photo of the cave in March 2006 and Plate D, Plate 37 and Plate 39 for a photograph of the same cliff face taken in September 2009.
- Council require an assessment of the cliff between Beach Road and Saltfleet Street for the risks of instability and recommendations for risk mitigation actions if appropriate. This includes potential consequences for crest infrastructure and effect on persons present at the base of the cliff.

2.5 Services

URS has obtained services plans via dial before you dig (DBYD). The services plans have been obtained and consulted to determine the presence or otherwise of services close to the crest of the coastal cliff that could be impacted by slumping and erosion at the crest.

The plans for this section of cliff indicate that there are no services present within the footpath or the west side (cliff side) of the Esplanade, all services are shown to either be located in the east of the Esplanade or in the eastern footpath.

3

Inspection of Cliff

3.1 General

A Senior Geological Engineer from URS undertook an inspection of the cliff from beach level and from crest level on 21st September and 24th September, 2009. The principal objective of the inspection was to record, or make an estimate of, all significant features including vegetation cover, main geological units present, slope angle and height, distance from crest of cliff to back of kerb, presence of historic failures and recent failures and other geotechnical hazards.

The main features recorded during the site inspection are noted on Figures 2 and 3 (Sheets 1 and 2 of the Site Observations). These features are referenced to a plate number; the plates are included in this report. Lengths of the cliff face with similar geotechnical features have been grouped into Zones (Zone A to Zone O). Refer to Figures 2 and 3 for the extent and description of features in each Zone. Refer to Table 3-1 for a listing of hazards observed in each cliff Zone. The description of each hazard is discussed in Section 4.1.

A general description of the observations made is provided in Section 3.2 and reference is also made to the appropriate plate number. The descriptions start at the north end of the coastal cliff and work to the south.

3.2 Site Observations

3.2.1 General Description

Access to the base of cliff in Zone A, west of the esplanade, was gained via a pedestrian access pathway. A view from the base of this path is shown in Plate B and Plate 2. This path extends from Beach Road to Anderson Avenue at the base of Zones A to I. Plate B is a general view of the typical 1V:1H slopes in Zone A to F, where slopes are either uniform in grade or are eroded into steep exposed soil upper slopes and shallow soil filled lower slopes. Typical geological profiles in Zones B to G are consistent with the regional geology described in Section 2.2 above. In these zones the cliffs are typically composed of thin aeolian (wind blown) brown sandy topsoil over a calcrete layer (Bakara Calcrete) of limited thickness (usually 1 m or less) that is often composed of hard rock at the top of the unit grading to calcrete rubble or calcareous soil at the base of the unit. This is underlain by the erodible mottled clays and sands of the Ngaltinga Clay.

Zone H, at Witton Bluff, marks a point in which the geotechnical features change from those observed in the northern zones to those observed in the southern zones. In Zones H to M, the upper geological units described above overlie weak limestone and sandstone units of the Port Willunga Formation, which are underlain by a significantly stronger and less erodible rock (the Blanche Point Formation) at the bases of the cliffs.

At Zone H a large amphitheatre has been eroded into the cliff face by wave action. Large scale erosion is no longer active due to the presence of rock armouring at the base of the slope. The rock revetment has led to a more stable slope and hazards to the public and road infrastructure have been reduced to small scale localized fretting and slumping of the steep slope.

South of Zone H, an old wave cut platform creates a stable base to most of the remaining Zones, with the exception of Zone J. Observation of geotechnical features in these zones are consistent with previous URS assessments, whereby all slopes are eroded by large erosion gullies, upper slopes and mid slopes are locally steep and undercut and lower slopes are shallow and stable. At the present sea level wave action erodes the old wave cut platform (Plates 40 and 41).

3 Inspection of Cliff

Zone J and Zone H are similar in geotechnical features, however Zone J is currently progressively eroding to the geometry of Zone I due to coastal wave action and subvertical and horizontal defects in the rock mass (Plate A, Plate D, Plate 36 and Plate 39). Note the distance between the cliff toe and road at the crest of the slope in Zone J is a similar distance to the road as within Zone H.

South of Zone J, the cliff zones extend to the edge of the footpath at shallow slopes (1V:1H), soils susceptible to erosion has necessitated remedial works in Zone L where gully erosion of soils led to the undercutting of the footpath along the Esplanade (Plate 46). Note that the erosion protection matting covering this area is damaged.

In Zone M, wave action has eroded parts of the lower cement covered slopes resulting in the undercutting of the '1954' stone retaining wall adjacent the boat ramp (Plate 47). Wave action is also fracturing the rock in the cliff adjacent the boat ramp (Plate 48).

Zone N is in the process of being remediated; to the north and south of the erosion protection matting small sections of the slope beneath water reticulation boxes are being eroded by water run off.

Table 3-1 Summary of Site Observations

Cliff Zone	Height (m)	Slope	Plate Number	Comment	Hazards
A	5 - 10	1V:1H *	2 & 3	Crest at fence line, patchy vegetation cover over soil slope.	None observed
B	10 - 15	1.7V:1H ^	4,5,6, & 7	Vegetated lower soil slopes; non vegetated, actively eroding steep soil upper slopes	CF, EM,
C	15	1V:1.5H #	8	Reinforced earth wall mid slope, vegetated lower and upper slope.	None observed
D	15	1.2V:1H ^	9,10 & 11	Vegetated lower soil slopes; non vegetated, actively eroding steep mid and upper soil slopes. Track.	CF, EM, EG
E	20	1V:1H *	12,13,14 &16	Crest at fence line, patchy vegetation cover over soil slope.	EG

** cliff has a uniform grade from crest to toe. ^ cliff has an upper steep slope and a lower shallow slope. # cliff has an upper shallow slope steep mid slope and shallow lower slope. ~ shallow upper slope and steep lower slope.*

Hazards are: CF crest slumping failures, EM erosion within the slope, EB erosion at base of cliff, and EG erosion gullies.

3 Inspection of Cliff

Table 3-2 Summary of Site Observations (continued)

Cliff Zone	Height (m)	Slope	Plate Number	Comment	Hazards
F	20	1V:1H ^	15,17,18 & 21	Vegetated lower slope. Vegetated mid soil slopes. Poorly vegetated, actively eroding steep upper soil slopes.	CF, M, EG
G	25 to 30	1V:1H *	20	Crest at fence line, vegetated cover over soil slope. Lower slope composed of low strength rock.	EG
H	25 to 30	1V:1H ^	22, 23, 24, 25, 26, 27, 28 & 29	Actively eroding steep soil upper slopes. Low strength mid slope and medium strength lower slope.	CF, EM, EG
I	25 to 30	1V:1H #	30, 31, 32,33, 34, 35, 36, 38 & 43	Actively eroding soil mid and upper slopes. Low strength mid slope, medium strength lower slope / wave cut platform. Wave erosion at slope toe.	CF, EM, EB, EG
J	20 to 25	1V:1H ~	44, 40, 39, 37	Poorly vegetated, actively eroding steep soil and rock slopes. Low strength mid slope and medium strength lower platform. Sub vertical joints and tension cracks in limestone. Wave erosion of slope toe leading to undercut and cave formation.	CF, EM, EB, EG
K	20 to 25	1V:1H *	41, 42 & 45	Actively eroding soil upper slopes. Low strength mid slope and medium strength lower platform. Wave erosion at slope toe.	CF, EM, EB, EG
L	<15	1V:1H *	46	Low strength mid slope and medium strength lower platform. Wave erosion at slope toe.	EM, EB, EG
M	<10	Irregular	47, 48	Actively eroding soil upper slope and Low strength mid slope to medium strength lower platform. Wave erosion at slope toe.	EM, EB, EG

** cliff has a uniform grade from crest to toe. ^ cliff has an upper steep slope and a lower shallow slope. # cliff has an upper shallow slope steep mid slope and shallow lower slope. ~ shallow upper slope and steep lower slope.*

Hazards are: CF crest slumping failures, EM erosion within the slope, EB erosion at base of clif, and EG erosion gullies.

3 Inspection of Cliff

Table 3-3 Summary of Site Observations (continued)

Zone	Height (m)	Slope	Plate Number	Comment	Hazards
N	<10	1V:1H *	49	Recently jute covered and vegetated slope, lower slope cement. Rock armour broken in north section.	EG, EM
O	<3	1V:1H *	50	Rock and cement armoured soil slope.	None observed

** cliff has a uniform grade from crest to toe. ^ cliff has an upper steep slope and a lower shallow slope. # cliff has an upper shallow slope steep mid slope and shallow lower slope. ~ shallow upper slope and steep lower slope.*

Hazards are: CF crest slumping failures, EM erosion within the slope, EB erosion at base of cliff, and EG erosion gullies.

4

Hazards and Risk Mitigation Measures

4.1 Principal Geotechnical Hazards and Instability Indicators

The observations made on site on 21st September and 24th September, 2009 indicated that there are a number of instability indicators and potential geotechnical hazards present over the length of cliff running adjacent the Esplanade, from south of Beach Road to Saltfleet Street. Given that the geometry and geology of this section of cliff is broadly similar along the full length inspected, the instability indicators and hazards have been grouped into four main types:

1. Erosion Gullies: (EG), caused by water flowing down soil slopes,
2. Backscars: (CF and EM), caused by gravity induced failure of soil and weak rock,
3. Erosion at base: (EB), caused by wave action, and
4. Erosion of entire slope: (EB + CF+ EM + EG), combined erosional forces acting upon the full height of the slope, leading to large scale slope instability.

Type 3, that is the formation of caves as shown in Plate A and Plate 38, is a slope stability hazard indicator that in the long term could lead to Type 4 hazards. Where Type 3 erosion leads to caves large enough for access by members of the public to risks are very high. Noting that if a public member is present in the cave during the initiation of a rock mass failure the public member may not have time to retreat safely from the cave. This is considered to be an unacceptable level of risk for the Council.

4.2 Risk Mitigation Measures

For each of the four types of hazard described above, recommendations for risk mitigation measures (if appropriate) are provided below. Implementation of the measures are described as either short term or long term – short term being either immediate (or within the next year) and long term being consideration or implementation of the actions over the next five years.

4.2.1 Erosion Gullies

The recent site inspection indicates that the erosion gullies evident across the length of cliff inspected are historic and that there does not appear to be any evidence of areas along the crest where run off would cause further large erosion gullies or excessive deterioration of those currently present on site. The presence of a kerb and gully system along the length of the crest will aid in managing any stormwater run off. Provided that the stormwater infrastructure continues to function effectively and does not adversely impact on the slope then the risk of failure associated with erosion gullies is considered to be low and it is not proposed that any remedial works are necessary at this time. Notwithstanding this, Council should continue to carry out routine inspections and ensure that the stormwater is managed appropriately so as not to affect the cliff. Inspections in the area should be more frequent after heavy rainfall or storm events.

4.2.2 Cliff Backscars

The presence of a number of older and more recent backscars is evident from slumping failures in the upper and mid slope soils of the cliffs (Plate 10, 17, 26, 27 and 28). Typically the backscars were formed in topsoil, calcrete and sand or clay in which overhanging material is created in the failure, which is at risk of further failure by toppling/fall mechanism. The trigger for these failures could have been stormwater run off or more likely erosion due to seaspray, wind and water action in the underlying soils. To undertake remedial works to each of these failures (thirteen recorded over the

length of cliff inspected) is not considered to be an appropriate treatment given that the level of risk to members of the public and crest infrastructure associated with these failures is considered to be relatively low.

Local infilling of the failed areas with a granular material is not recommended as a remedial action as this would not be effective unless the full height of cliff face was protected from erosion. This would be expensive and time consuming and would result in a change in landform along the coastal cliff environment. However, this should be considered as a long term slope stability remedial measure and may need to be implemented sooner should the routine inspections pick up any significant deterioration.

The following actions are recommended as short term measures.

1. Increase the number of warning danger signs at the toe of the cliff and upon the old wave cut platform between Short Street and Anderson Avenue – allow for another 3 to 4 signs.
2. Ensure that the fence is repaired at the base of Zone H (near Plate 25), at Witton Bluff look out (Plate 21) and surrounding the Monument (Plate 46).
3. Undertake regular inspections to assess if there has been any further deterioration in the condition of the cliff and backscars. Initially it is suggested that these be undertaken on an annual basis with more frequent, or one off inspections, carried out after heavy rainfall or storm events. Particular attention should be paid to Zones B, D, F, I, K and M where the backscars are above the lower public pathways. Should the long term measures need to be implemented then these would likely be the priority areas.

4.2.3 Erosion at Base of Cliff

This type of failure mechanism has occurred at the base of Zones I, J and K, L and M and appears to be both historic and contemporary and will continue to happen in the future unless erosion protection work is undertaken at the base. In sections where this is the most pronounced the undercutting has resulted in either vertical or overhanging lower sections of the cliff. Remediation would involve placement of rock armour at the base of the cliff, similar to what appears to have been implemented at two locations at the base of the platform, east of Anderson Avenue and the extensive rock armouring of Witton bluff between Beach Street and Anderson Avenue. Given the length of cliff affected, the volume of rock required then this would be part of a longer term remedial strategy for Zones I, K, L and M. In the short term, it is recommended that additional signs (say 4 to 5 signs) are placed along in the vertical cliff face of the platform, just above high tide to minimise public access to the area at the base of the cliff.

4.2.4 Undercutting of Entire Cliff Slope

In Zone J, erosion at the base of the cliff by wave action and the predominance of vertical defects striking parallel to the cliff face have resulted in a large embayment with a central cave leading to potential undermining the full height of the cliff slope. These hazards and associated risks are discussed further below.

4 Hazards and Risk Mitigation Measures

The presence of sub vertical joints and tension cracks in the mid slope section of this area is considered to be high risk. Public access to the crest and base of the cliff in this area is common and this high risk area needs to be addressed in the short term by forced removal of material from the mid slope, using a long reach excavator working on the beach. The forced removal of material from the mid slope of Zone J, will address some of the hazards associated with the presence of steep limestone cliff faces with sub vertical joints (block fall). However, a number of points need to be borne in mind when considering this treatment, these are outlined below.

- The material to be removed is likely to be of variable strength and may break from the cliff as a loose sand or in blocks of rock strength material. The contractor will need to exercise some caution and ensure that the no one has access to either the beach or the mid slope of the cliff at the time the work is carried out.
- Removing material from the mid slope to create a flatter slope will also result in the mid slope berm or platform being reduced in width - this has two consequences as outlined here.
    - The berm currently acts as a collection point for clay and sand material that fails in the upper part of the slope, after the berm is reduced in width, this material could reach beach level.
    - Reducing the width of the berm will create an additional hazard in that pedestrians could attempt to access this area by walking along a path of reduced width - consideration should be given to placing a physical barrier at the crest of the slope to prevent public access to this area.

Furthermore, in the short term, it is also recommended that the undercut area is fully backfilled to prevent access to the public. In addition a rock revetment is to be created by progressively dumping rock (at an oblique angle to the current slope) against the slope to a height greater than the old wave cut platform. It is noted that this backfilling operation must be undertaken by a method that ensures the current slope is not disturbed.

As a longer term strategy, consideration could be given to placing engineered fill against the full height of the natural slope above the embayment in Zone J, to prevent the progressive erosion of the slope through time to the east and impacting on Castleton Avenue Esplanade intersection.

5

Summary

URS undertook an inspection of a 1.1 to 1.2 km length of coastal cliff at the Esplanade, Christies Beach and Port Noarlunga. Previous inspections and studies have been undertaken in this section of cliff by URS, most recently in 2005 and 2007.

Generally the overall cliff height varies from <5 m to the order of 25 m to 30 m and the slope angle varies from around 1V:1H at to 1.7V:1H for most of the length of the cliff. Vertical and overhang sections were also noted where previous failures had occurred, in the base, middle and or crest of the slope.

The soil profile observed on the cliff face within Christies Beach typically consists of sandy topsoil over a thin layer of calcrete over clay and cemented sand, where the cemented sand unit is present over the lower half of the cliff face. A distinct gravel layer is present at some locations in the lower slope. This soil profile continues to the south in the Witton Bluff to Port Noarlunga, however the base of the slopes is composed of low and medium strength limestone rock. South of Anderson Avenue a rock or wave cut platform is present in this section of the cliff.

The results of the inspection identified a number of instability indicators and geotechnical hazards, which for convenience have been categorised as follows:

- Erosion gullies in soils.
- Backscars from slumping/toppling failures in soils.
- Erosion at base of cliff, leading to tensile wedge and intact rock failure.

The level of risk to infrastructure or members of the public from each of the above hazards has been assessed and it is considered that both short term and long term risk mitigation strategies or actions should be implemented. The actions recommended for each type of hazard are outlined in Table 5-1.

Table 5-1 Recommended Actions

Geotechnical Hazard/Instability Indicator	Short Term Action	Long Term Action
Erosion Gullies	Ensure stormwater run off is managed, routine inspections and one off /more frequent inspections after heavy rainfall/storm events	As short term at this stage
Backscars (erosion of soil at crest and mid slope)	Additional warning signs at base of cliff along the Christie Beach path to Anderson Avenue, carry out follow up geotechnical assessment area in one year for Zones B to H.	Where possible, at the crest or toe, selective backfill of backscar features with granular fill and erosion protection matting to the slope. Selective fencing at toe of slope zones where backscars have occurred.

5 Summary

Geotechnical Hazard/Instability Indicator	Short Term Action	Long Term Action
Erosion at base of cliff	Place warning signs immediately above the high tide mark In Zone J, forced removal of localised material where tension cracks and defects are present (mid slope area) and placement of erosion protection at base of cliff (rock armour revetment). Carry out follow up geotechnical assessment for Zones I to M in one year.	Placement of erosion protection at base of cliff (rock armour revetment) at selected areas where the wave platform is retreating back in close proximity to overlying soil profiles.

References

1. Coastal Cliff Stability Geotechnical Investigation, Golder Associate Pty Ltd. 01662002/01, dated May 2001.

2. Detailed Cliff Stability Investigations Stage 2 Report, Risk Assessment and Preliminary Risk Management Strategy for Site Areas A to I, URS Australia Pty Ltd., 42655715/Stage 2 Final Report, dated 13 September 2005.

3. Cliff Top Erosion Audit, URS Australia Pty Ltd, 42655715/Final Report, dated 12 June 2007.

4. Witton Bluff Upper Slope, Port Noarlunga, URS Australia Pty Ltd., 42655715/L001-a.doc dated 5 June 2009.

7

Limitations

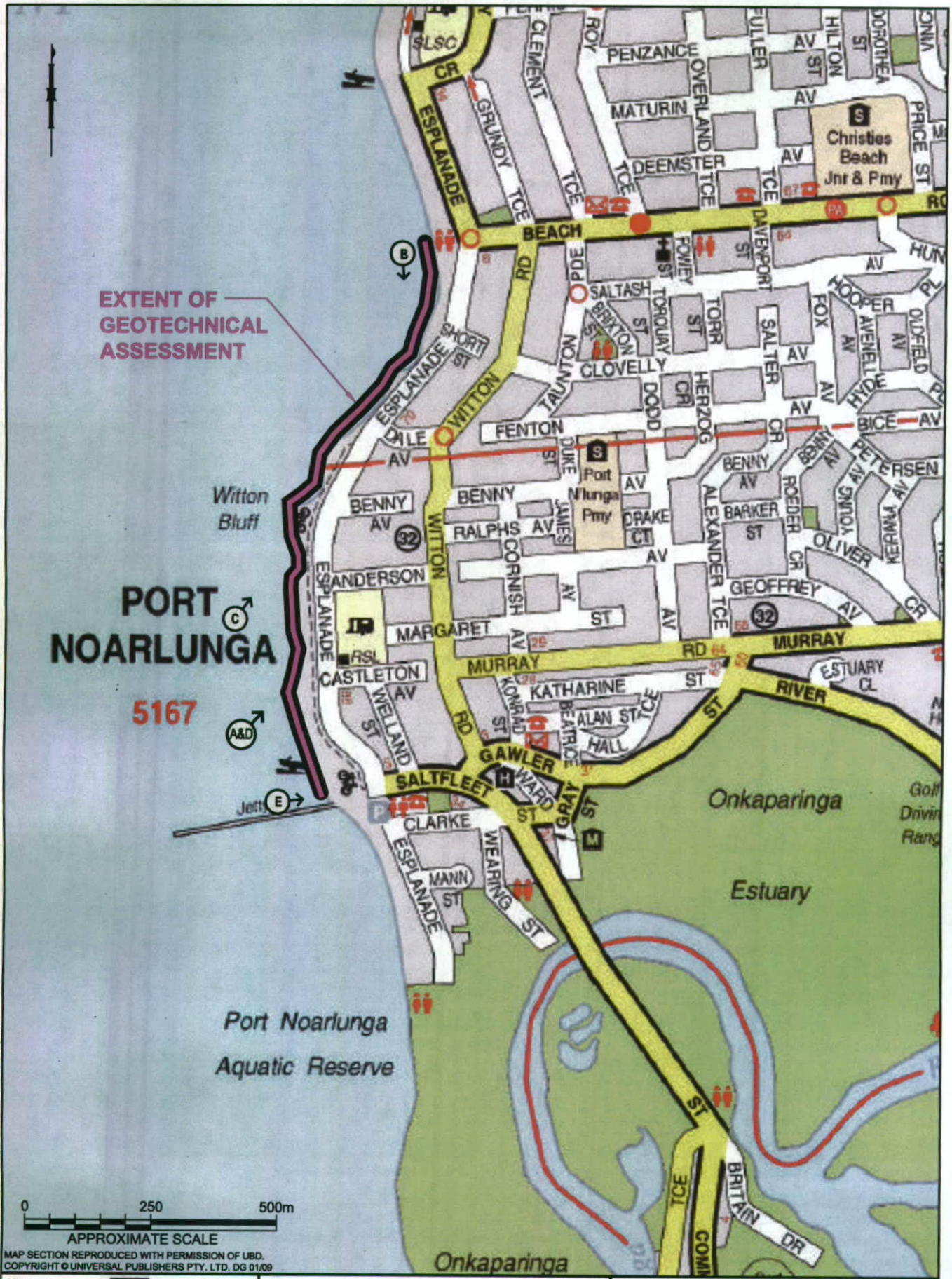
URS Australia Pty Ltd (URS) has prepared this report in accordance with the usual care and thoroughness of the consulting profession for the use of City of Onkaparinga and only those third parties who have been authorised in writing by URS to rely on the report. It is based on generally accepted practices and standards at the time it was prepared. No other warranty, expressed or implied, is made as to the professional advice included in this report. It is prepared in accordance with the scope of work and for the purpose outlined in the Proposal dated 27 July 2009.

The methodology adopted and sources of information used by URS are outlined in this report. URS has made no independent verification of this information beyond the agreed scope of works and URS assumes no responsibility for any inaccuracies or omissions. No indications were found during our investigations that information contained in this report as provided to URS was false.

This report was prepared between August and October and is based on the conditions encountered and information reviewed at the time of preparation. URS disclaims responsibility for any changes that may have occurred after this time.

This report should be read in full. No responsibility is accepted for use of any part of this report in any other context or for any other purpose or by third parties. This report does not purport to give legal advice. Legal advice can only be given by qualified legal practitioners.

Figures



Client: City of Onkaparinga / URS	Project: WITTON BLUFF GEOTECHNICAL ASSESSMENT		Title: SITE LOCATION PLAN & PLATES A TO E
	Drawn: RAO	Approved: JS	Date: OCT 2009
	Job No.: 42657366	File No.: 42657366-003-01	Figure: 1
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			Rev. A
			A4

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A3

CONCRETE STEPS TO BEACH

A. SOIL FILL OVER ENTIRE FACE OF CLIFF. CLIFF 5-10m HIGH, SLOPE 1V:1H, CREST AT FENCE LINE, MATTING COVER DEGRADED, PATCHY VEGETATION COVER.

FENCE POSTS WITH WIRE INFILL PANELS ALONG LENGTH OF CLIFF, TYPICALLY OFFSET 1-2m FROM KERB OF ESPLANADE. LAND BETWEEN FENCE AND CLIFF CREST GENERALLY WELL VEGETATED

B. SOIL FILL OVER LOWER PART OF CLIFF ONLY. CLIFF 15m HIGH AND NEAR VERTICAL. EROSION OF SOIL LEADING TO VERTICAL DEFECTS. TOPPLING SLUMPING FAILURE OF SOILS EVIDENT

MINOR EROSION GULLIES

LONGITUDINAL TENSION CRACK IN ROAD

D. SOIL FILL OVER LOWER PART OF CLIFF ONLY, 1.2V : 1H SLOPE (50°). CLIFF 15m HIGH

LONGITUDINAL TENSION CRACK IN ROAD

CLIFF TOP SOIL PROFILE IS AEOLIAN SOIL OVER CALCRETE OVER CLAYEY SOIL

NATURAL SOIL PLATEAU, NEAR VERTICAL SLOPES

OLD BACKSCAR

MINOR EROSION GULLIES

RUBBLE ACCESS TRACK AT BASE OF CLIFF, ROCK REVETMENT DOWN SLOPE TO SEA LEVEL. TRACK IS UNFENCED BUT HAS A WARNING SIGN FOR CLIFF INSTABILITY

C. REINFORCED EARTH WALL TO CLIFF FACE. SLOPE ABOVE REINFORCED EARTH WALL HAS 1V:1.5H SLOPE, CREST 2m FROM FENCE AND 3m FROM ROAD. MATTING COVER DEGRADED, PATCHY VEGETATION

GOAT TRACK

E. SOIL FILL OVER ENTIRE FACE OF CLIFF, CLIFF 20m HIGH, 1V:1H SLOPE

MINOR EROSION GULLIES

F. SOIL FILL OVER LOWER HALF OF CLIFF ONLY, SLOPE 1V:1H. SLOPE 20m HIGH, UPPER HALF OF CLIFF IS NEAR VERTICAL, ERODED BY STORMWATER AND PIGEONS, POSSIBLY SUBJECT TO ROCK BLOCK FALLS

LARGE EROSION GULLY

LOOKOUT FENCED, BUT FENCING WIRE BROKEN

LEGEND

- APPROXIMATE LOCATION OF PHOTOGRAPH AND PLATE NUMBER
- EROSION GULLIES
- BACKSCAR OF FAILURE
- SLOPE OF SIMILAR GEOTECHNICAL CHARACTERISTIC
- DISTANCE FROM CREST OF CLIFF TO ROAD
- DANGER SIGN
- INFORMATION SIGN FOR CLIFF INSTABILITY

0 100m

SCALE 1:2000

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Rev	By	Appd	Date	REVISION RECORD
A	JS	PWM	10/09	ISSUED FOR CLIENT REVIEW

Designed	JS
Drawn	RAO
Checked	JS
Approved	
Scales	1:2000

Client: City of Onkaparinga

Project Title: WITTON BLUFF GEOTECHNICAL ASSESSMENT

Drawing Title: SITE OBSERVATIONS SHEET 1 OF 2

Status: REVIEW

Datum:

Date: OCT 2009

CAD File Number: 42657366-001-01.dwg

Job Number: 42627366

Figure: 2

Rev: A

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A3

G. SOIL FILL OVER ENTIRE FACE OF CLIFF. SLOPE IS 25 - 30m HIGH, 1V:1H SLOPE, VEGETATED AND STABLE

H. SOIL FILL OVER LOWER QUARTER OF THE CLIFF ONLY. SLOPE 1V:1H, CLIFF 25 - 30m HEIGHT. SLOPE AREA HAVE A FENCE APPROX. 10m FROM TOE OF CLIFF

I. TOE OF SLOPE TAKEN TO BE THE OLD WAVE CUT PLATFORM. NO SOIL FILL IN SLOPE. TYPICAL CLIFF HEIGHT 30m 1V:1H SLOPE

J. TOE OF SLOPE TAKEN TO BE THE OLD WAVE CUT PLATFORM. NO SOIL FILL IN SLOPE. TYPICAL CLIFF HEIGHT 25 - 30m 1V:1.7H INCLINATION. ACTIVE CLIFF EROSION AT BASE OF SLOPE. AREA OF HIGHEST GEOTECHNICAL RISK

K. TOE OF SLOPE TAKEN TO BE THE OLD WAVE CUT PLATFORM. NO SOIL FILL IN SLOPE. NON VEGETATED SLOPE. TYPICAL CLIFF HEIGHT 20 - 25m 1V:1.7H INCLINATION

L. TOE OF SLOPE TAKEN TO BE THE OLD WAVE CUT PLATFORM. REMEDIATED SLOPE, 1V:1H, HEIGHT <15m. LOWER SLOPE HAS LARGE EROSION GULLIES

M. IRREGULAR SHAPED SLOPE, LOWER SLOPE TYPICAL SUBVERTICAL, HIGHLY ERODED SLOPE <10m HEIGHT. NO SOIL FILL ON SLOPE

N. RECENTLY COVERED SLOPE (JUTTE AND VEGETATION). HEIGHT <10m, SLOPE 1V:1H. RETAIN WALL AT TOE, FOOTPATH AND FENCE AT CREST

O. ROCK AND CEMENT SURFACE COVERD SLOPE, HEIGHT <3m, SLOPE 1V:1H. RETAIN WALL AT TOE, FOOTPATH AND FENCE AT CREST

HAIRLINE TENSION CRACKS

STORMWATER PIPE OUTLET

REVETTED SLOPES

LOCALIZED EROSION OF THE CEMENT COVERED WALL LEADING TO UNDERCUTTING OF THE UPPER REINFORCED WALL

SEVERAL GOAT TRACKS DOWN SLOPE FROM ESPLANADE TO PROMENADE, SLOPE MAXIMUM 5m HIGH, 1V:1H SLOPE, STABLE, 1.5m HIGH SLOPE. RETAINING WALL AT BASE

BOAT RAMP

HEAD 3m OFFSET FROM FENCE

RUBBLE ACCESS PATH. BELOW PATH COMPRISES ROCK ARMOUR.

MINOR EROSION GULLIES

LARGE EROSION GULLIES

OLD BACKSCARS

PERSISTENT SUBVERTICAL JOINT IN BLADE POINT FORMATION ROCK

OLD SEA LEVEL WAVE CUT PLATFORM AND CURRENT SEA LEVEL WAVE CUT PLATFORM. UPPER SLOPE HAS LOCALISED UNDERCUTTING OF RED CLAY SAND UNIT. MANY LARGE EROSION GULLIES.

RETAINING WALLS

RECENT SLOPE FAILURE. ONGOING ROCK MASS FRACTURING IN THIS ZONE. PUBLIC AT RISK TO SHORT TERM ROCK FALLS.

REMEDIATED SLOPE

LOOKOUT FENCED BUT FENCING WIRE BROKEN

ROCK ARMOUR COVERING SLOPE HAS BEEN DISTURBED IN RECENT EARTH WORKS. AREA PRONE TO EROSION AND WILL LEAD TO THE UNDERCUTTING OF THE ABOVE ROCK ARMOUR

TENSION CRACK IN SLOPE ADJACENT TO BOAT RAMP

LEGEND

- APPROXIMATE LOCATION OF PHOTOGRAPH AND PLATE NUMBER
- EROSION GULLIES
- BACKSCAR OF FAILURE
- SLOPE OF SIMILAR GEOTECHNICAL CHARACTERISTIC
- DISTANCE FROM CREST OF CLIFF TO ROAD
- DANGER SIGN
- INFORMATION SIGN FOR CLIFF INSTABILITY
- SUBVERTICAL JOINTS

0 100m

SCALE 1:2000

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Rev	By	Appd	Date	REVISION RECORD
A	JS	PWM	10/09	ISSUED FOR CLIENT REVIEW

Designed JS
Drawn RAO
Checked JS
Approved
Scales 1:2000

Client: City of Onkaparinga

Project Title: WITTON BLUFF GEOTECHNICAL ASSESSMENT

Drawing Title: SITE OBSERVATIONS SHEET 2 OF 2

Status: REVIEW

Datum

Date: OCT 2009

CAD File Number: 42657366-002-02

Job Number: 42657366

Figure: 3

Rev: A

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Plates

Plates

Plate A: View looking east at the slope, within the large embayment west of Castleton Avenue in March 2006. Refer to Plate D, Plate 37 and Plate 39 for a photograph of the same cliff face taken in September 2009.

Plate B: General view to the south at Zone A to Zone F (Beach Road to Dale Avenue).

Plates

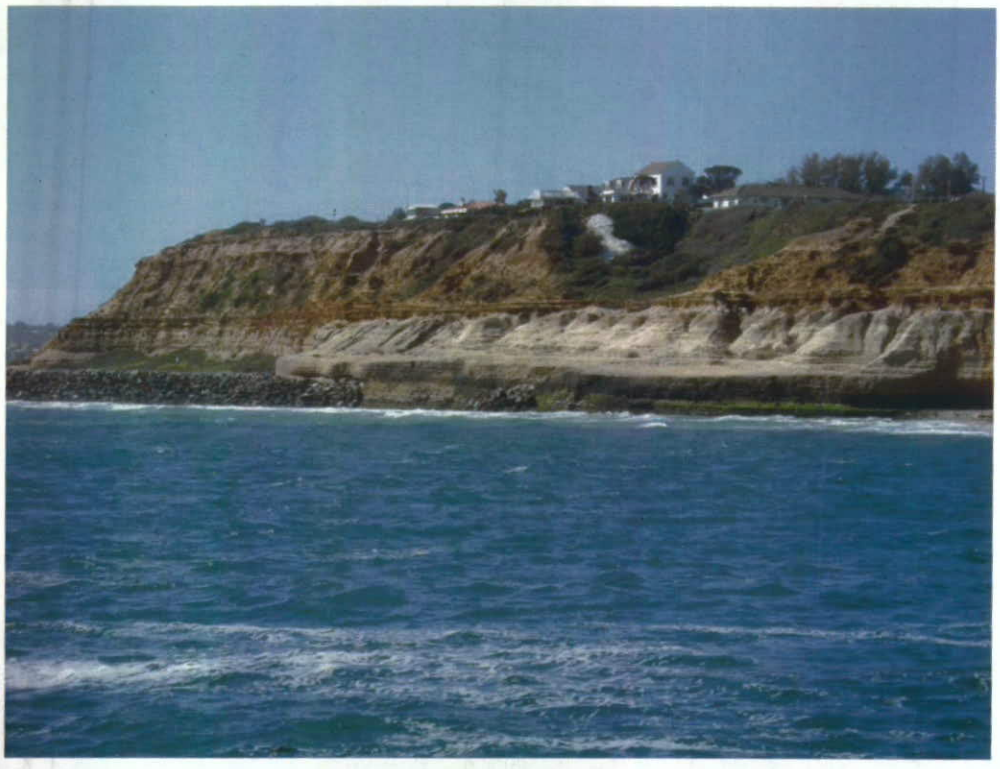

Plate C: General view to the east at Zone I to Zone K (Benny Road to Anderson Avenue).

Plate D: General view Zone I, J and K. Cave central to photograph.

Plates

Plate E: General view Zone K, L and M. Remediated slope central, boat ramp to the right.

Plate 1: View looking north at a natural soil plateau adjacent to the public toilets at the end of Beach Road, near vertical slopes of dessicated clay.

Plates

Plate 2: View looking south, from north end of the site, at Witton Bluff, along the pedestrian path.

Plate 3: General view of the slope, from the walking path, looking to south at a zone of 1V:1H (45°) slopes. Patchy vegetation with jute and enviromat covering the slope.

Plates

Plate 4: General view from the walking path, looking to south, at a zone with slopes 1V:1H (45°) to 2V:1H (60°). Zone has a danger sign 'Falling Rock' in the middle of the area adjacent to the walkway.

Plate 5: Localised crest erosion remediated in the past with a thin covering of concrete. Concrete partially intact due to erosion. Ongoing minor crest erosion.

Plates

Plate 6: Photo looking east, at the progressive disintegration of the cliff face, creating loose material which covers the vegetation at the base of the slope and the walkway.

Plates

Plate 7: General view of slope on the left and an enlarged photo of the weathering soils on the right. Water erodes gullies in sandy gravelly soils and the undermining of slopes by the dessication of discrete clay layers create potentially unstable subvertical cliffs.

Plates

Plate 8: View looking south, at the base of the reinforced earth retaining wall. Wall has limited vegetation and some areas where the jute is torn.

Plate 9: Southern end of retaining wall, cliff erosion is uneven, leading to shallow slopes at crest and undercut sections in the lower portion of the cliff face. No danger signs displayed.

Plates

Plate 10: Photo of an old slope crest failure. Failure was due a hard calcrete layer at the top of the slope, being undermined by soil erosion (2 m length by 1 m depth).

Plates

Plate 11: Photo looking south east at an unofficial beach access track with two hazards to the left of the track. Hazard one is subvertical sandy soils at the crest of the slope and Hazard two is the mass of red white sandy clay which is being undercut at the base of cliff by bird and water erosion activity.

Plates

Plate 12: General view from walkway looking south towards a cliff zone of typical 1V:1H (45°) vegetated slopes.

Plate 13: Water erosion has led to rill erosion of sandy soils (left photo) and of the edge of walkways (right photo).

Plates

Plate 14: Water erosion has led to rill erosion of sandy slopes (left photo) and of the edge of walkways (right photo).

Plate 15: View from north at Witton Bluff and gully eroded subvertical cliffs. No danger signs displayed.

Plates

Plate 16: Hairline longtitudinal tension cracks on the road

Plates

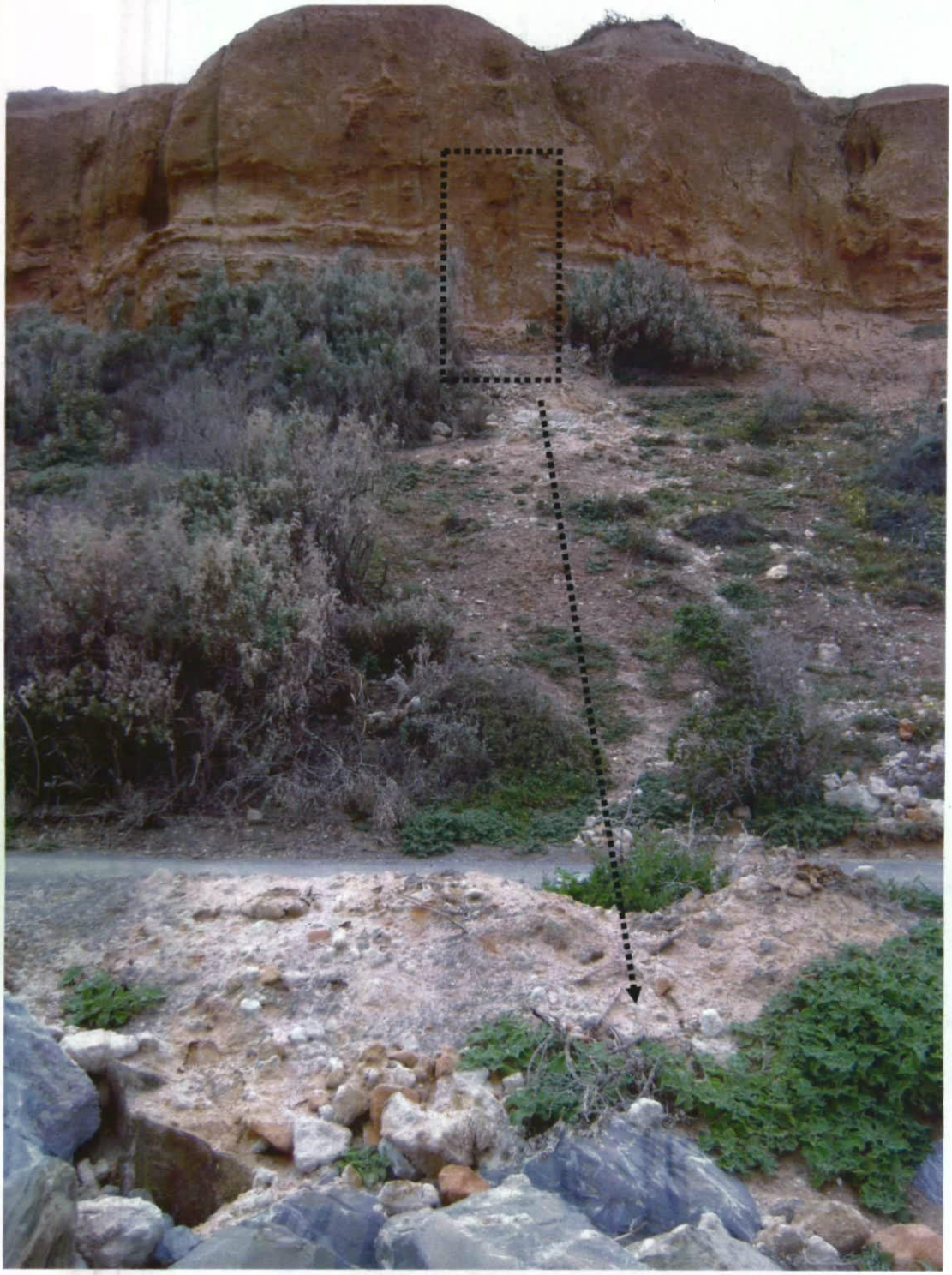

Plate 17: Recent toppling failure of sandy soils from the upper cliff face resulted in shrubs being destroyed and material transported down the slope over the walkway. Failure due to undercutting of cliff and subvertical tension cracks in vertical sandy slopes.

Plates

Plate 18: View looking east at Witton Bluff, minor rill erosion in the lower slopes and tension cracks in sandy soils and bird and water erosion leading to undercutting and of upper subvertical slopes.

Plates

Plate 19: View from north towards a cliff zone of typical 1V:1H (45°) sparsely vegetated slopes.

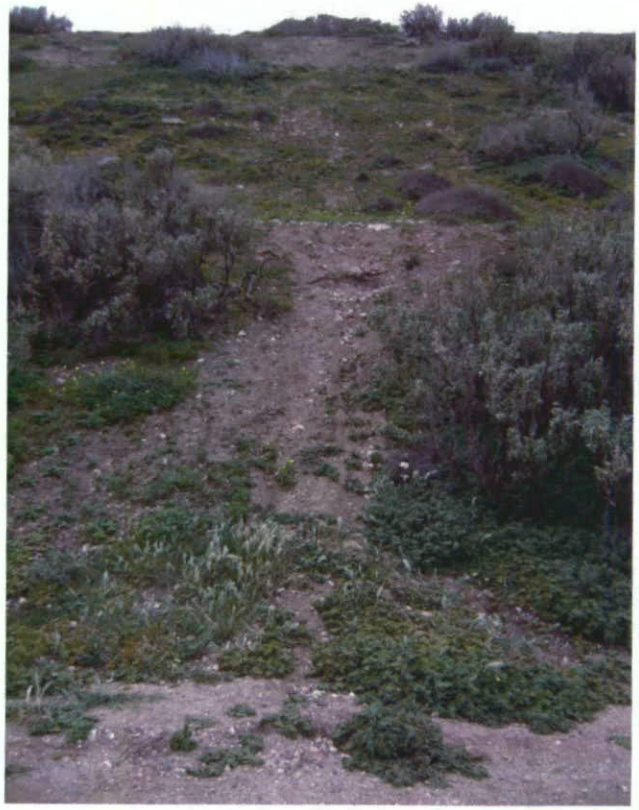

Plate 20:Photograph of typical minor signs of rill erosion within the cliff zone.

Plates

Plate 21: View looking north at broken wires in the lower section of the fence at Witton Bluff Look Out.

Plate 22: View looking north at the base of the slope. Note the fence and the small 120 x 200 x 300 mm low strength rocks on the walkway.

Plates

Plate 23: View looking east (towards Benny Avenue) at a typical slope covered with small rocks. Note the dominance of voids and undercut sections in all sections of the slope.

Plates

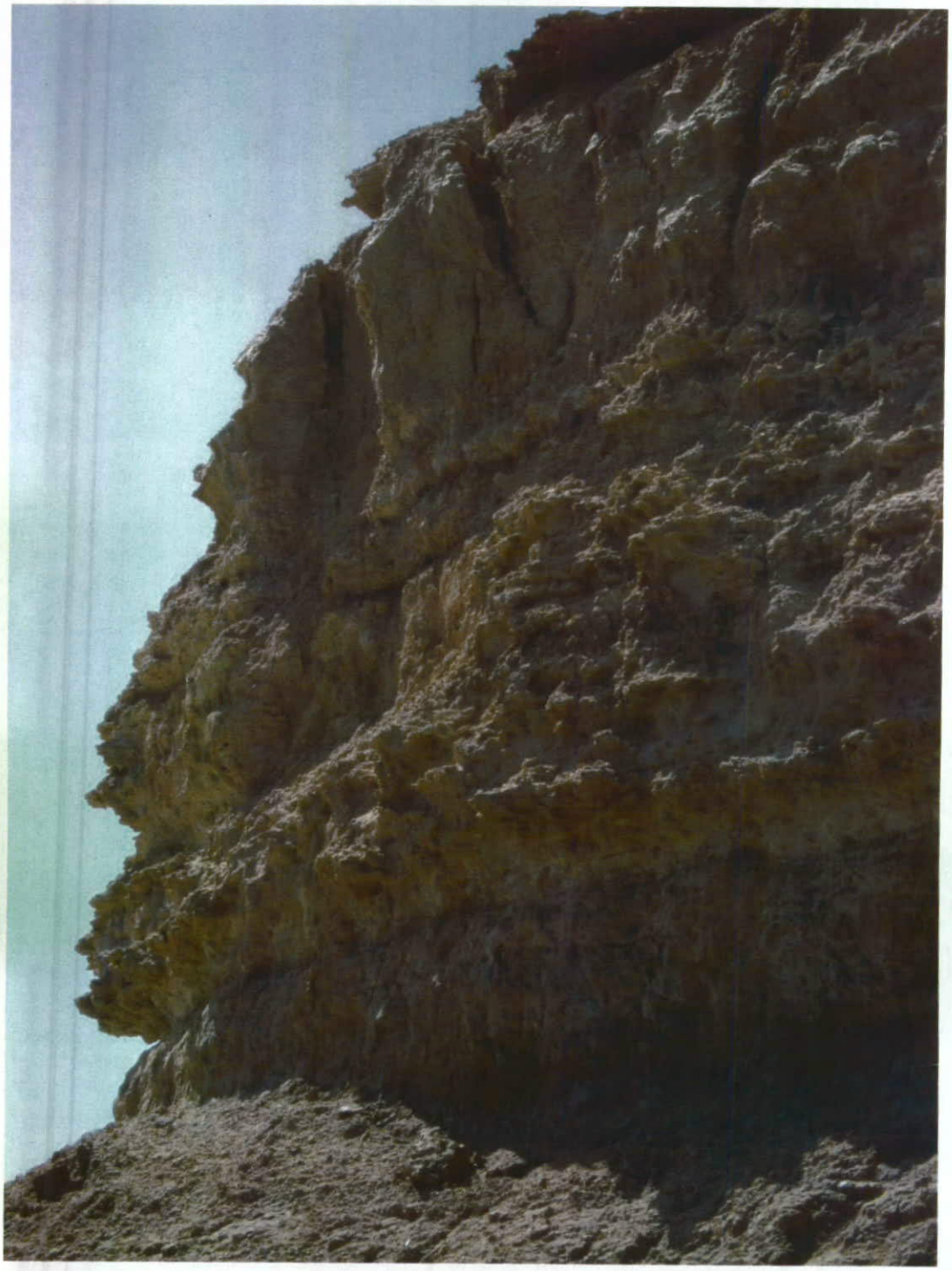

Plate 24: View looking north at the subvertical lower / middle cliff slopes at the headland east of Benny Avenue. Typical erosion of clay units resulting in vertical tension cracks and toppling failure (top of slope) and lower sand and gravel horizons eroded leading to undercutting of the cliff slope and eventual slope failure.

Plates

Plate 25: View looking north at the headland containing a lower slope (Plate 22) and mid slope clays of the Blanche Point Limestone (Plate 23) and an upper sandy slope (Ngaltinga Formation). Cliff zone of typical 1V:1H (45°) with predominantly non vegetated slopes.

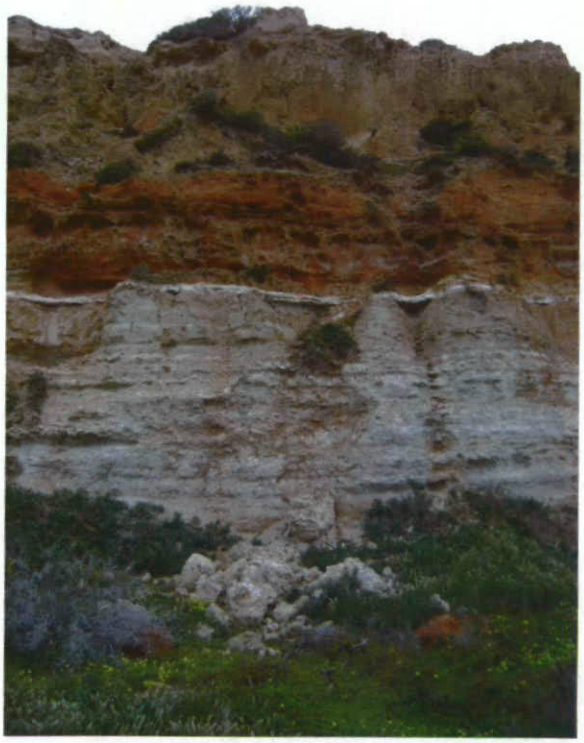

Plate 26: View looking east at a lower slope recent backscar and the material piled at the base of the slope. In the forefront of the photo, red boulders are old failures from the mid to upper slope.

Plates

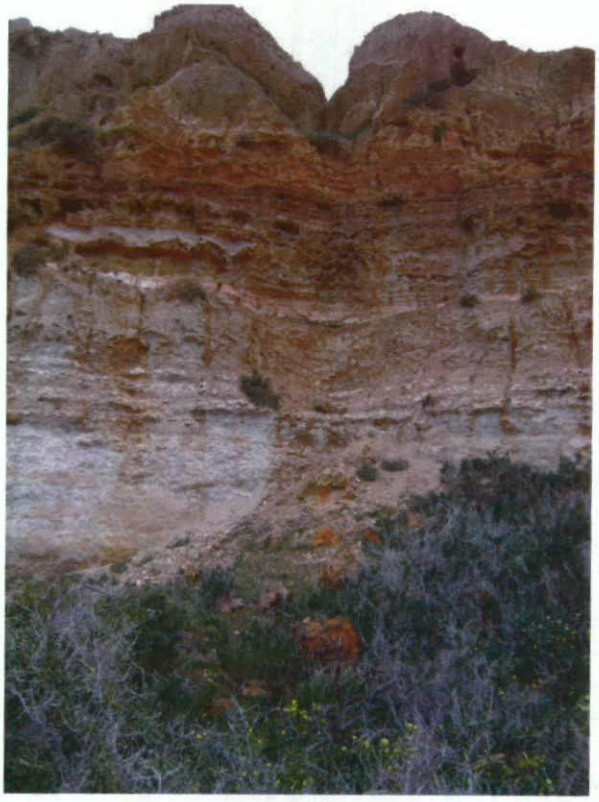

Plate 27: View looking east at an old back scar in the middle of the slope aligned beneath a large erosion gully (upper slope). Boulders from mid to upper slopes at base of cliff.

Plates

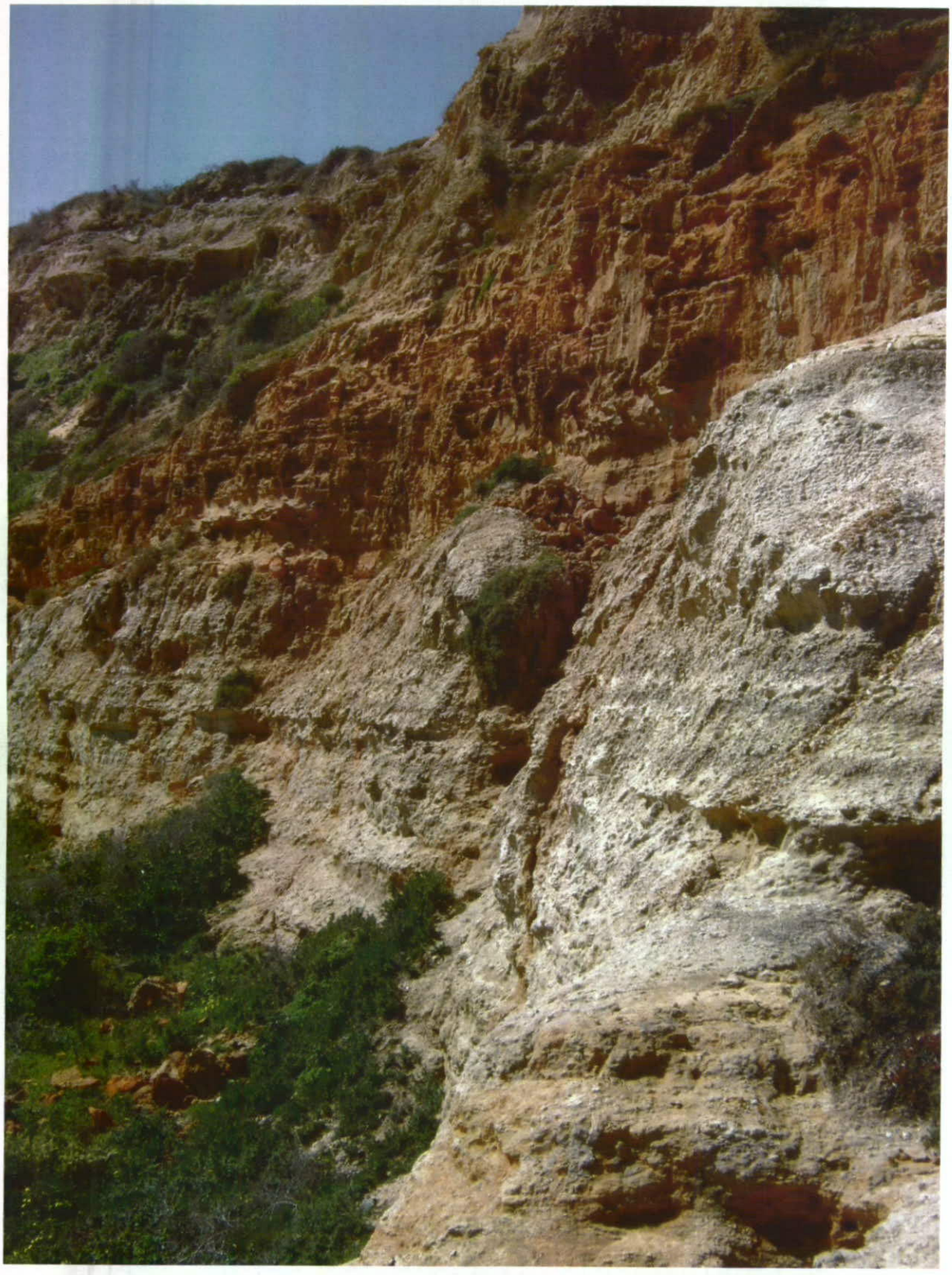

Plate 28: View looking north at recent backscars with mid slope red sandy soils and the overall irregular shape of the cliff due to the progressive atmospheric, bird and stormwater erosion.

Plates

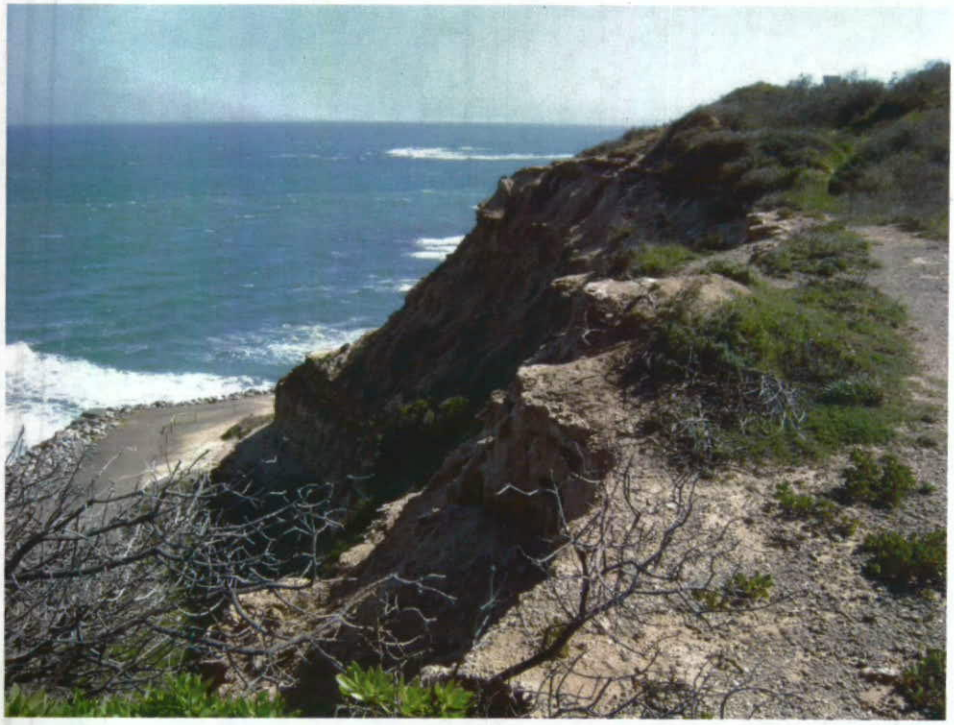

Plate 29: View looking north from the crest of the slope towards the headland off Benny Avenue.

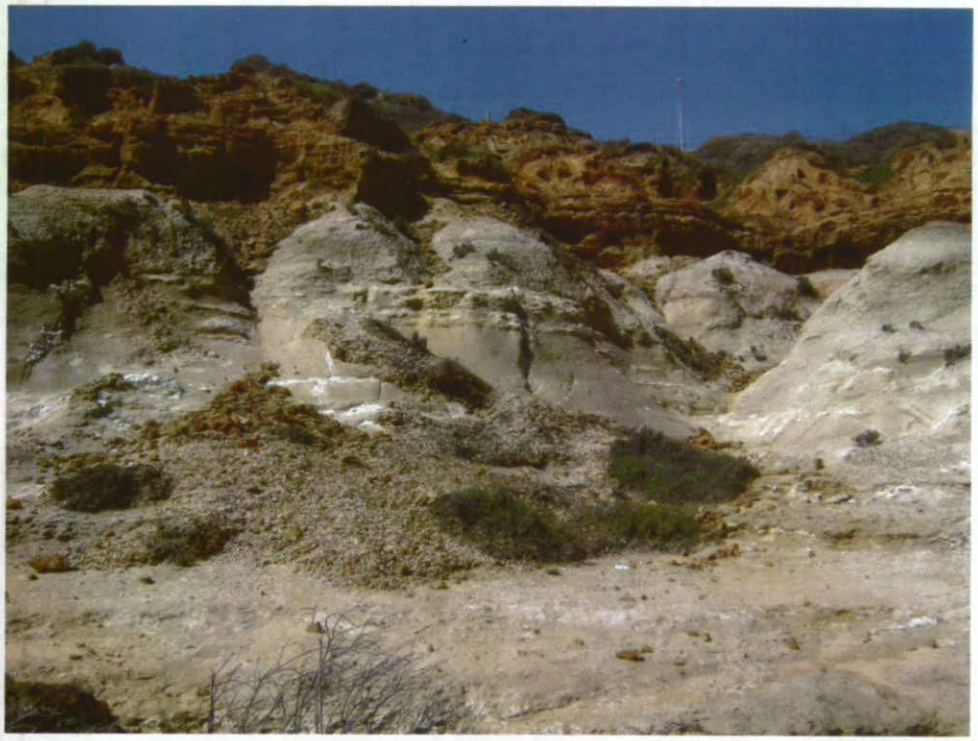

Plate 30: View looking east at the general cliff profile above the old wave cut platform that extends from Anderson Avenue to the Port Noarlunga Boat Ramp. Typical observations were the presence of small rocks from the sandy mid slopes onto lower rounded smooth slopes and old wave cut platform.

Plates

Plate 31: View looking north across an old backfilled backscar and white hydromulch and jute covered remediated slope. Upper slope is well vegetated.

Plate 32: Danger sign obscured by graffiti.

Plates

Plate 33: View looking south from the old wave cut platform down onto the present wavecut platform. Blue boulders have been placed within old caves as part of previous council hazard mitigation actions. Also large crack in platform has been sealed at the base with concrete. Large wedge still present.

Plates

Plate 34: Subvertical joints in the Blanche Point Formation siltstone / limestone, with white calcareous infill. Joints are regularly spaced at approx 0.5m and have a strike length of >20 m.

Plate 35: View looking south at the cliff containing regularly spaced subvertical joints in the siltstone / limestone that project into the cliff behind the site were a recent large scale slope failure has occurred.

Plates

Plate 36: View looking south down onto large boulders that have recently fallen onto the current wave cut platform. In the foreground, left of the silver folder, tension cracks in the rock align with subvertical joints observed in the area where the slope failed (refer to arrows). Note the persistence of these structures is greater than 20 m in length.

Plates

Plate 37: View looking north down onto the wave cut platform at the large slabs fallen. Man in the middle of the photos for scale. To the right of the man is an actively forming cave/undercut slope.

Plate 38: Close up of recent rocks fallen due to the forces of wave action which have undercut the cliff and have formed a cave. Cave depth is >5 m and >10 m in length. Rock failure due to horizontal defects and gravity, leading to tensile failure of the rock mass.

Plates

Plate 39: View looking north east showing recent failure backscar and undercut sections at the crest of the slope. Note the large >3 m tension cracks in the upper section of the overhanging slope.

Plates

Plate 40: View of shallow seated scalloping fracturing of the rock, above the moss covered tidal influenced wave cut platform. Cracks will lead to failure of the rock in the short term.

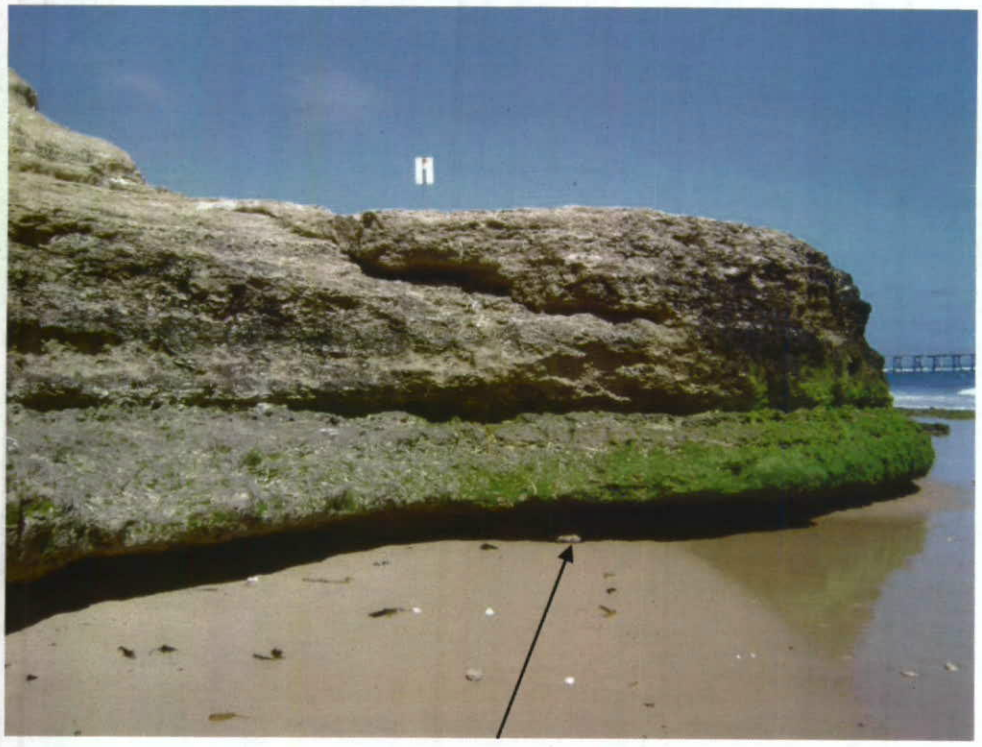

Plate 41: General view of the undercut in the slope due to wave action (approx. height 300 mm x 300 mm depth).

Plates

Plate 42: General view of the cliff from shoreline to cliff top (road), slope 30 m high, 1V:1.7H (30° inclination), where red sandy clay boulders (300 x 300 x 300 mm) fall down the slope, within large erosion gullies.

Plates

Plate 43: General view north at slopes 30 m high, 1V:1.7H (30° inclination), crest at edge of road.

Plate 44: General view south highlighting the proximity of the road to the crest of the cliff slope immediately above the coastal site of active cave formation and recent rock falls. Slope 30 m high, 1V:0.7H (55° inclination).

Plates

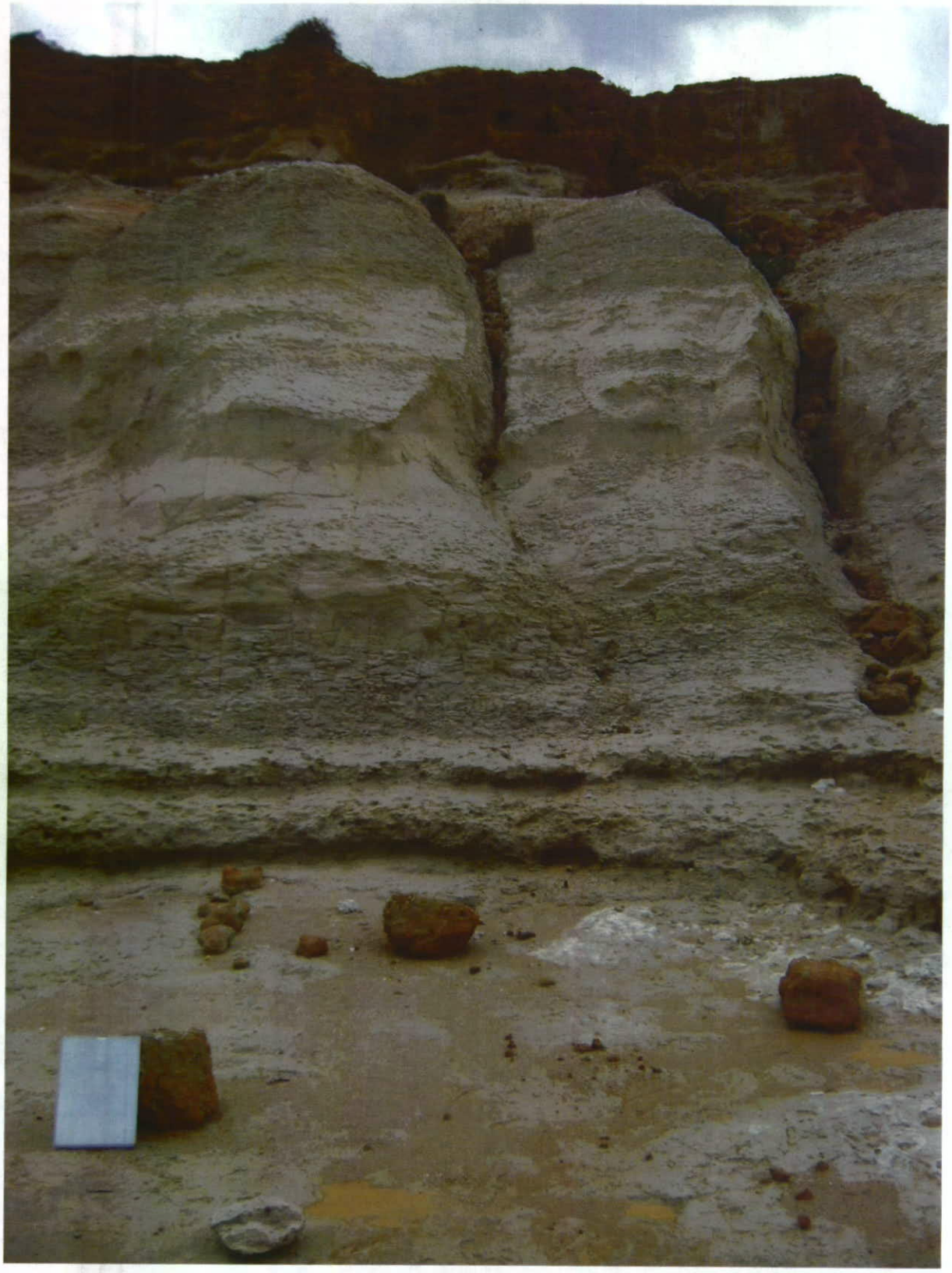

Plate 45: General view of the cliff above the platform in Zone K. Note the small 200 x 200 x 300 mm sandy clay boulders that have eroded and fallen down large erosion gullies from the steep upper slope.

Plates

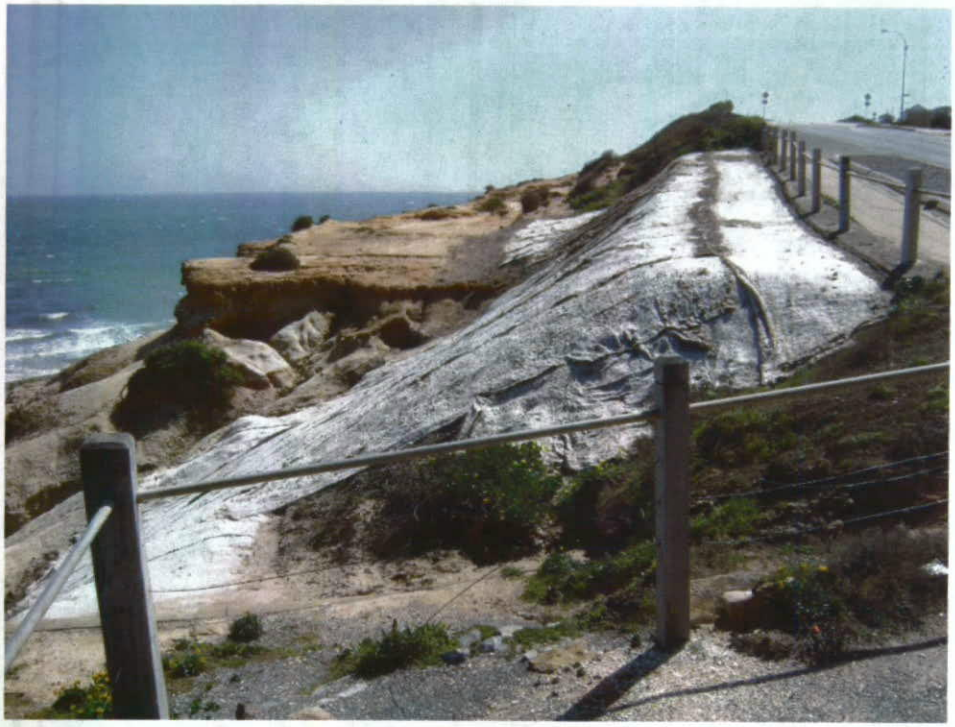

Plate 46: View looking north at the remediated slope north of the monument.

Plate 47: View looking north at the ongoing erosion leading to undercutting of the base of stone retaining wall (built in 1954).

Plates

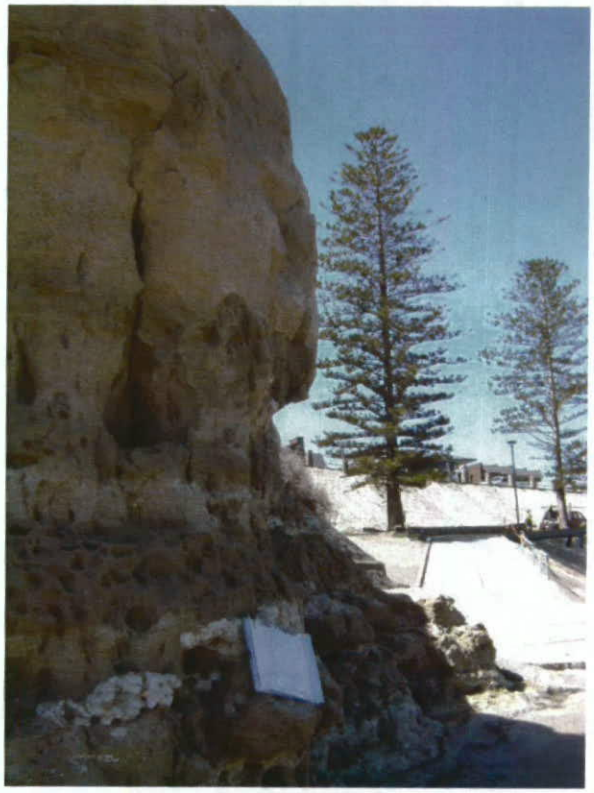

Plate 48: Adjacent to the boat ramp, high tide wave action is progressively undercutting the cliff. Cliff rock mass has vertical defects which in time may lead to the failure of wedges in the cliff upon the beach.

Plate 49: View looking north at Zone N where the remediated slope abuts a stone and cement rock armour of the slope. This armouring has been recently disturbed and through time will expose soils to erosion.

Plates

Plate 50: View looking north along Zone O and Zone N. To the left of the orange beacon, work was in progress placing the erosion protection matting and planting seedling in the slope.

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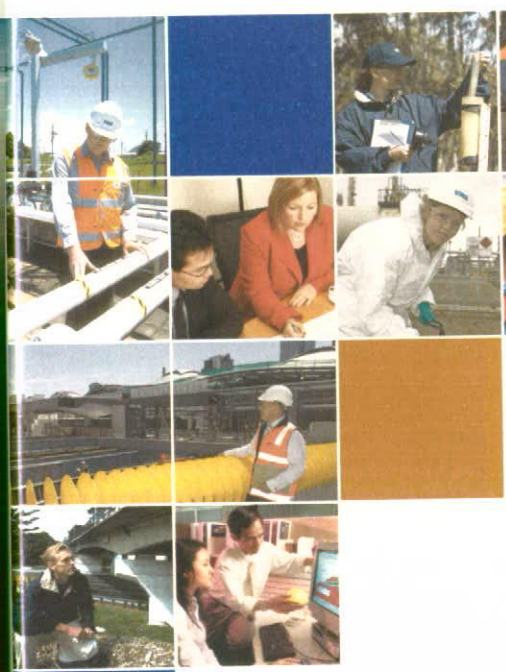
FINAL REPORT

Geotechnical Assessment (Cliff Stability)
Witton Bluff, South Australia



Prepared for

City of Onkaparinga

30 October 2009

42657366

URS