25 October 2019

LIMESTONE STABILTY ASSESSMENT

GRACETOWN, PREVELLY, GNARABUP, WESTERN AUSTRALIA

INSPECTION, RISK ASSESSMENT AND REMEDIATION DESIGN REPORT

Shire of Augusta Margaret River, Margaret River WA 6285

PER2019-0229AA Rev 1

PER2019-0229AA		
Date	Revision	Comments
18 October 2019	A	Draft Report
23 October 2019	0	Final including Monitoring Protocol as Appendix E
25 October 2019	1	Final incorporating comments from Shire of Augusta Margaret River

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Appendices

1 INTRODUCTION

On 22 August 2019 CMW Geosciences Pty Ltd (CMW) was commissioned by Shire of Augusta Margaret River by way of a signed contract and Purchase Order 124298 to carry out Contract RFQ 051909. This was a Limestone cliff stability assessment and design of remedial/mitigation works to manage rockfall or ground instability risk to people and property.

Details of the scope of work and methodology are documented our response to the RFQ 051909 dated 2 August 2019 (the Proposal) and provided (without costing) in Appendix A.

In summary the commission requires the consultant (CMW Geosciences) to provide the Shire of Augusta Margaret River (SAMR) with additional advice and information surrounding a study and recommendation made by Golder Associates in 2017 in relation Limestone Cliff Stability and to undertake the design of remediation/risk mitigation works at four specific locations. This report contains the review, assessment of current conditions and design of remediation/risk mitigation works. A cost estimate for the works is provided under separate correspondence.

As per our Proposal, CMW engaged Civil/Structural Consulting Pty Ltd to undertake a joint inspection with us and to undertake the structural and civil design of remediation/risk mitigation works, prepare drawings and specifications and provide cost estimates for the remedial works.

The joint inspection was made by Matthew Tutton, Senior Principal Engineering Geologist from CMW and Tim Moore, director of Civil/Structural Consulting Pty Ltd on Monday 19 August 2019.

A site visit was made by four personnel from the Shire of Augusta Margaret River accompanied by Matthew Tutton of CMW to visit the Prevelly and Gnarabup sites followed by a risk and options workshop at the Shire offices on Tuesday 20 August 2019, as per the Proposal. Subsequent site visits were made on 2 September 2019 to survey undercuts at Prevelly and Gnarabup and on 11 October to set out reference points for future surveys.

2 PROJECT BACKGROUND

A few studies have been undertaken for the Shire of Augusta Margaret River to quantify geotechnical risk to people and assets from coastal cliff stability and rockfalls and to inform the SAMR on geotechnical constraints prior to undertaking redevelopment works.

One of the most recent studies undertaken for SAMR was by Golder Associates and reported upon in May 2017. The title of the report is “Limestone Cliff Stability Assessment”. This was a comprehensive study of limestone cliff geology and stability and had particular focus on risk to people and SAMR assets at Gracetown, Prevelly, Gnarabup Headland and Grunters Beach.

Part of the scope of work for the current study was to review this report (refer Appendix A), address certain recommendations and re-assess conditions at six locations discussed in the report.

The six locations together with the SAMR’s current requirements are listed below:

Site ID: GC5 - 75 (Gracetown – cliffs south of stairs)

Provide details/analysis on whether to stabilise blocks or remove overhanging rocks, detailed methodology and indicative costing for preferred approach.

Site ID: GC6 - 15 (Gracetown – Southpoint lookout)

The Shire has removed the lookout at Southpoint that sat over the overhang and received engineering drawings to anchor the viewing platform back to the carpark. The consultant shall determine whether stabilisation carried out to date is sufficient, or whether further stabilisation of the stairs is also required and provide details how to proceed.

Site ID: GC6 - 60 (Southpoint carpark)

The consultant shall install monitoring equipment to the identified risk and prepare a monitoring protocol for Shire staff to monitor thereafter.

Site ID: PR4 - 30 (Surfers Point)

The Shire has removed the viewing platform in accordance with the recommendation. Provide an analysis as to the resultant risk of the overhang and response required (if any) and advise what is the best option to consider and details on how to proceed (i.e. removal of rock, reinforcement, a mix of these approaches, etc.) should the Shire wish to install the platform in the future.

Site ID: PR6 - 85 (Cliffs at Riflebutts Beach)

The limestone report refers to imminent rockfall risk in the next 1 – 10 years for this stretch of beach and recommends closing the beach by way of signage. Signage has been installed but people are still using the area. The consultant is required to:

- *Determine and detail a suitable method for removal of the identified hazard;*
- *Undertake and/or oversee removal of the hazard (provide indicative sub-contractor costings, if required).*
- *Identify a permanent exclusion zone at the base of the cliffs to discourage people from entering 'at risk' areas and recommend a method for excluding people from the area i.e. fencing or otherwise.*

Site ID: GN5 - 5 (Stairs leading to upper car park from White Elephant)

Overhang of up to 2.5 m developed beneath a caprock layer up to ~1 m thick. Stairs leading down to the White Elephant Café from the upper car park area are built directly on top of the overhang. The hazard at this location is largely associated with collapse of the overhang while recreational users are using the stairs. The consultant shall install monitoring equipment to the identified risk and prepare a monitoring protocol for the Shire to monitor thereafter.

Note the requirement at GN5-5 changed following the risk and options workshop undertaken with SAMR personnel on 20 August 2019. An outcome of the workshop was to proceed with underpinning. A provisional sum to undertake the design of the underpinning had been provided with the response to the RFQ.

3 PROVIDED INFORMATION

The following information was provided and has been relied upon in preparing this report.

- Golder Associates 2017; Limestone Cliff Stability Assessment - prepared for the Shire of Augusta Margaret River
- Baynes Geologic 2006; Surfers Point Redevelopment, Geotechnicval Constraints - prepared for the Shire of Augusta Margaret River
- Gordon Geological Consultants 2002; Huzza Beach, Gracetown Memorial Site and Huzza Beach Gracetown Stability of Steps - prepared for the Shire of Augusta Margaret River
- Gordon Geological Consultants 2005; Huzzas Cliff Inspection 2005 - prepared for the Shire of Augusta Margaret River

4 SITE INSPECTION AND RECOMMENDATIONS

The site inspection was undertaken on Monday 19 August 2019, jointly between Matthew Tutton of CMW and Tim Moore of Civil/Structural Engineering Pty Ltd.

Observation are described below and illustrated in Appendix B. Recommendations are also provided in this section of the report. Drawings of remedial/risk mitigation works are provided in Appendix C.

A risk assessment has also been undertaken for all locations and the details of this risk assessment are detailed in Appendix D. The method of calculating risk is in accordance with the Landslide Risk Management Guidelines AGS 2007 and tries to mirror the approach taken by Golder 2017, however with changing conditions the inputs are different. Definitions of the various terminology are reproduced in Appendix D for convenience. Note criteria for acceptable and tolerable risk needs to be determined by SAMR however guidance in AGS 2007 suggest the following limits for tolerable risk.

Tolerable Risk for Loss of Life

Risk	**Tolerable Annual Probability**
Individual Most at Risk	1.0×10^{-4}
Societal Risk	1.0×10^{-5}
Cumulative Individual Risk	No guidance provided

Cumulative Individual Risk is provided only for comparison purposes. All risk provided in Appendix D relate to the observed condition before any risk mitigation or remedial works are undertaken.

SAMR officers should review the assumptions presented in Appendix D used to calculate risk to see whether user numbers who may transit or use a beach, stairs etc., concur with their estimate of usage and exposure (time in the hazard area).

Columns coloured green in the risk assessment are those where remedial/risk mitigation works are recommended. Risks values highlighted in red exceed AGS 2007 values tabulated above and those highlighted in yellow are also considered high and require remedial/risk mitigation works.

4.1 Site ID: GC6 - 60 (Southpoint carpark)

Refer Slide 1 (Appendix B) for location details. Monitoring reference points as illustrated in Appendix E have been installed and a monitoring protocol prepared for the Shire.

It is noted that the embayment left by a former rockfall west of the GC6-60 has generally stabilised, with no retrogression noted since the Golder 2017 inspection and with a heathy growth of native vegetation. (refer Slide 2). Cracking noted by Golder in 2017 does not appear to have propagated further (refer Slide 3) indicating a period of relative stability.

The level of risk does not appear to have changed since 2017. A collapse of the block illustrated in Slide 4 would not immediately affect the car park. Debris would however likely reach the foreshore, as has been the case with previous rockfalls (refer Slide 4). Debris reaching the foreshore is the hazard that presents most risk to the public. However, this section of foreshore is not a beach but a wave-cut platform and does not need to be used to access the surf breaks. It is therefore sparsely used, and the signs erected on the beach recommended in the 2017 report further discourage people from traversing this part of the foreshore.

The probability of a collapse occurring whilst considered to be relatively high (once in ten years or 0.1 annualised probability) results in relatively small individual and societal risks (5.42×10^{-7} and 1.08×10^{-7} respectively - refer Appendix D). This largely due to the assumed small number of users of the foreshore, transiting the rocky limestone foreshore and their relative short time in the at risk area. This is not a beach where people for instance would sunbath and be present for a longer exposure time. As a result, it is recommended that this location be monitored and no recommendations are a this stage for physical remedial works as risk are relatively small.

4.2 Site ID: GC6 - 15 (Gracetown – Southpoint lookout)

Refer Slide 1 for location. The inspection reviewed the removal of the lookout at Southpoint, which was a recommendation of the 2017 Golder report. This has been undertaken. Whilst the hazard of an undercut block of limestone still exists (refer Slide 6) the risk to assets and people is substantially removed as the lookout is no longer present.

The current inspection focused on whether it was deemed probable that should the overhang collapse it would pull the stairs with it, thus putting people at risk. This risk was not assessed by Golder in 2017. Our August 2019 inspection did not identify a catastrophic risk of collapse from a single rockfall event. Instead it was considered the serviceability of the steps could be impacted. For instance twisting of the steps could occur, initiated by coastal erosion affecting individual supports without collapsing the structure. The potential for this to occur was particularly evident towards the bottom of the stairs (refer Slide7). This would not result in an immediate risk to people if the situation was monitored and corrective action taken to extend supporting stanchions affected by erosion or undercutting before or as soon as the issue is identified. Due to only loss of serviceability, we have assumed the risk to life would only be 1:50 should even quite a major twisting and warping of the stairs. This assumes a foundation collapse (resulting in the twisting and warping) occurs whilst people were on the structure. The resultant risk (refer Appendix D) is relatively small and no remedial works are recommended at present.

At this stage it is however recommended that the stairs be visually assessed by Shire personnel every 3 months or following storm events or any reports of erosion affecting Gracetown. If individual supporting stanchions get undercut by storm and wave activity or small-scale landsliding, the stairs should be immediately closed to the public until the undercut stanchions has been underpinned and the structure levelled, if subsidence occurred as a result of the loss of support.

4.3 Site ID: GC5 - 75 (Gracetown – cliffs south of stairs)

Refer Slide 1 for location. Two 5 m long sections of limestone outcrop approximately 10 m above the beach level are severely undercut. The limestone is part of the calcretised aeolianite (cemented dune sands) forming a weak caprock. Immediately underneath the caprock is a zone of roots where calcretised root casts are present (*rhizocretions*) and calcium carbonite has been leached from the surrounding limestone leaving a weakly cemented residual sand. This residual sand is the subject of wind erosion, which exposes the root casts and undercuts the caprock. This process is evident in Slide 8 and unusual overhanging shaped pieces of rock are left held only by the weak tensile strength of the rock. The projecting finger of rock approximately 1.5 m long seen in Slide 8 (left photograph) is an example. In the case of this finger of rock a crack is present, and collapse will occur in the near future.

The cracks observed in Slide 9 (left image) has not substantially changed much since the Golder 2017 inspection (right image) however this could change rapidly following a storm event.

The undercut, vuggy nature of the leached zone of roots and a *rhizocretion* forming a thin twisted column of limestone can be seen in Slide 10. The slope below the overhang is heavily vegetated and there is a chance of material hanging up on the slope once fallen from the overhang reducing the risk of debris impacting people exiting the Southpoint carpark stairs as they traverse the beach towards Huzza beach. Nonetheless some material could reach the beach.

Our risk assessment for people traversing the beach resulted in relatively small risks. However, because of the large number of people traversing this beach each year to access the popular surf breaks cumulative individual risks are relatively high (refer Appendix D) and risk mitigation works are recommended.

The option of building an elevated boardwalk to direct people away from the rockfall runout zone as they exit the Southpoint steps was considered. However, is also recognised that this is a popular

beach and children occasionally explore around the overhangs and undercuts and the very action of scrambling around the overhangs and undercuts could be a trigger for a rockfall. If this was to occur, they would likely be in the line of fire and thus be at risk. As such, it is recommended that physical works are undertaken to stabilise or remove the hazard.

The following options were considered in forming our recommendation to remove the overhang.

1) **Cover slope will rock mesh.** This would either a) require removal of vegetation to allow the mesh to be laid on the ground or b) require placement directly over vegetation. Option a) is considered environmentally damaging and geotechnically would exacerbate the issues of erosion and likely result in the development of new hazards. Option b) would create a trampoline – creating a new hazard for children and a trap for litter and debris. It might also allow children to explore underneath and still access the outcrops/undercuts
2) **Rock bolt and shotcrete undercut/outcrop**. This would require removal of vegetation to access the outcrop with plant and equipment. Furthermore, the materials forming the outcrop are considered to friable to bolt and excessive volumes of shotcrete would be required to underpin the outcrop. It would not be safe to erect a shutter and place mass concrete to underpin the undercut.
3) **Collapse/remove the undercut and overhanging rock pieces.** Possible techniques include:

a) *use of excavator and rock breaker* – discounted due to lack of vehicle access and amount of destruction to natural vegetation
b) *use of drill and blast.* Drilling would need to be by hand. However, blasting is not recommended due to the small volumes involved and the friable nature of the cliff adjacent to this feature that could be disturbed and weakened by blasting
c) *use of chemical blast using an expansion agent.* Drilling would need to be by hand. However the extreme vuggy nature of the limestone is question may not be suitable for expansion agents as the expansion agent may flow out of the drill hole. Where stronger less vuggy limestone is encountered it could be used, or a thicker paste used to prevent loss.
d) *Use of needle drilling and hand barring to remove rock on predetermined break lines.* This would require a detailed safe working methodology but could be undertaken safety and with minimum vegetation disturbance by accessing the undercuts from above and working behind a predetermined safety demarcation line set-out immediately prior to the commencing the works.

Slide 11 and 12 illustrate the difficult access and native vegetation surrounding this outcrop. Considering the above options, option 3d is considered the most appropriate method of collapsing removing the undercuts.

There are two undercuts to be collapsed. Each approximately 5 m long and averaging about 1 m deep and 0.5 m thick.

The following methodology is anticipated:

a) Erect barrier and place spotter so public do not enter work area or rockfall runout areas
b) Undertake pruning of vegetation between path and outcrop allow access (Slide 11)
c) Establish safe anchor points to secure personnel to prevent fall from edge (Slide 12)
d) Establish a survey line on the upper surface of outcrop showing extent of the undercut (Slides 11 and 12)
e) Establish a safe working zone that would not be impacted when collapse occurs
f) Establish key break lines to drill to predetermine the break point. Plan breakage to occur in small pieces rather than large wholesale collapses
g) Use pneumatic or large electric percussion drill to form break points.
h) Use driven expansion wedges (or similar), or possible use of chemical expansion grout, to prise open drill holes and promote cracking and subsequent collapse.

i) Once the upslope hazard has been collapsed, inspect debris to ensure it is secure and not likely to roll or be dislodged and become another hazard. If necessary, hand bar debris to base of slope.

Following removal of the rock overhang it is recommended that the area be inspected by a vegetation specialist to advise on planting or erosion protection works to help establish vegetation in the area formerly occupied by the overhang/undercut and to re-establish vegetation impacted during the removal works.

4.4 Site ID: PR4 - 30 (Surfers Point)

The Golder 2017 recommended removing a viewing platform immediately in front of a large overhang/undercut outcrop. This has been undertaken as can be seen by comparing the September 2017 Nearmap image (Slide 13) which shows the viewing platform to be present and the most recent August 2019 Nearmap image that shows the viewing platform removed and the current configuration.

An assessment of the undercut did not display significant change since 2017 with the maximum undercut measured at 3.5 m in the latest survey and the Golder Report reporting undercut up to 4 m. Towards the back of the undercut slot the height of the slot is only a few millimetres and it is possible some infilling with sand has occurred since 2017, possibly blown in, or a different location was recorded.

Slide 14 (Appendix B) shows the approximate plan extent of the undercut. Dimensions have been taken and these are shown on the drawing 190802-S2 presented in Appendix C. The undercut is slot like and comprises the erosion of a sandy layer of leached limestone largely through the action of the wind creating a slot beneath an overlying 0.5 to 1.5 m thick caprock layer (refer Slides 15 to 18)

The fact the bench and lower viewing platform have been removed results in the main risk now coming from people sitting on top of the outcrop (refer Slide15) during surf carnivals or at other times. It is understood security is in place during carnivals to prevent this, but occasionally it still occurs. Should the undercut slab of caprock collapse people sitting on the flat slab of rock would fall with the rock a metre or so but are unlikely to get crushed. Thus, these people are more likely to sustain a minor to moderate injury rather than a fatal injury. Their vulnerability is assessed to be 0.1. I.e. one person in 10 could be killed.

The following is considered a plausible remaining risk scenario:

- Likelihood total collapse every ten years $P_{(H)} = 0.1$
- Spatial probability $P_{(SH)} = 1$ (this because everyone on the overhang would be affected)
- Temporal probability 5 hours per year $P_{(TS)} = 5.7 \times 10^{-4}$ (this assumes this rock platform will rarely get used due to security at surf events etc.)
- Vulnerability $V_{(DT)} = 0.1$ (only 1 in 10 get killed in the event of a collapse)
- Number of visits each year by an individual N=2

It is also assumed that during a surf event 20 people could be present. The later results in a relatively high societal risk 1.14×10^{-4} (refer Appendix D for risk assessment). As such recommendation are made to remove the hazard or mitigate the risk.

The options are as follows:

1) Collapsing and remove the overhang
2) Support the overhang.

Option 1) would cause quite a lot of environmental damage and loss of amenity in the popular Surfers Point area and would but the existing lookout between the overhang and carpark at risk. The collapsed debris would need to be removed as it would present a hazard. Removal however would

expose the leached sandy layer that created the overhang in the first place to renewed wind erosion and as such a new overhang could occur in the future.

There are two options to support the overhang:

a) Columns partially supporting the overhang and
b) Full underpinning.

Option a) can only be executed by sending personnel under the overhang (which would require temporary support. This would be difficult due to restrict headroom and access. It would also not prevent ongoing wind erosion and further undercutting.

Option b) is the preferred option as most work can be done without having to work under the overhang and full underpinning not only supports the overhang from collapse but prevents future wind erosion.

As such the full underpinning option has been selected as the most effective risk mitigation option. The overhang/undercut would be underpinned with mass concrete and then the exposed concrete face concealed with architecture limestone blockwork in keeping with the many limestone walls around the Surfers Point facilities.

The length requiring underpinning is about 14 m long and is illustrated on Plates 17 and 18. It is estimated the total volume of concrete in the underpinning works will be is the order of 10 m^3.

The concrete used to underpin the undercut would need to be retained by a temporary shutter and would not look attractive once the shuttering has been removed and would be visible from the beach, the steps that descend from Surfers Point carpark to the beach and from the viewing platform (once reinstated). For this reason, during the options and risk workshop Shire officials requested the design incorporate for a facing of architectural limestone blocks similar to the walls and limestone artwork around the Surfers Point Carpark and facilities. An estimated 10 m^2 of architectural facing blockwork is required.

A design has been prepared to underpin the undercut and this is shown on Drawings 190802-S2 and 190802-S3 presented in Appendix C.

The following are considerations concerning the underpinning.

1) It is impractical and unsafe to send personnel under the overhang to dig out loose sand and compact the subgrade prior to placing concrete. Thus, some compression of the subgrade will occur if and when the load from the rock is transferred onto the underpinning concrete.
2) To reduce the degree of settlement it is recommended that vegetation and the uppermost and loosest surfical sand be removed using a long-handled rake/scraping tool and undertaken without people entering under the overhang. This will only be undertaken to the extent possible and is unlikely to involve removing more than about 100 mm of surfical material.
3) It is recognised that is the caprock was to collapse, some subsidence possibly in the order of 50 mm could occur due to compression of the very loose sand subgrade and residual voids not infilled with the underpin concrete.
4) In order to prevent the underpinning works from sliding and to provide a footing for the architectural blockwork and a key to anchor the lower edge of the concrete shutter, a concrete footing/key into the underlying sand, limestone rubble or limestone is proposed.
5) Temporary support (Acro props (possibly sacrificial) or similar) will need to be provided as required to facilitate this excavation which is anticipated to be hand-dug.
6) If limestone is present the requirement to excavate to form the key is negated (refer Drawing 190802-S3) although starter bars will still be required to be drilled into the limestone to form the key.
7) The shuttering will need to be tailored top and bottom in both elevation and plan to follow the profile of the undercut.

8) Cut-outs in the shuttering will be required to facilitate pumping of concrete in one continuous pour and to allow the use of a concrete compactor.

Following completion of the underpinning and the building of the architectural limestone blockwork, it is recommended a flora specialist is appointed to assess any requirements to reinstate vegetation removed and add new vegetation to improve the overall vegetation cover to minimise the impact of future wind erosion affecting adjacent natural features and restore or improve visual amenity

4.5 Site ID: PR6 - 85 (Cliffs at Riflebutts Beach)

Riflebutts beach is a popular section of beach where beach users regularly shelter from the wind at the base of cliff. Unfortunately sheltering at the base of the cliff puts beach users at risk from any material falling from the cliff.

The Golder 2017 limestone cliff stability report referred to imminent rockfall risk in the next 1 – 10 years for this stretch of beach and recommended closing the beach by way of signage. Signage has been installed. The Shire have advised us however that people are still using the area. At the time of our inspection on 19 August 2019, the sign erected warning people not to pass this point due to imminent rockfall risk had fallen over and was lying on the ground. By our later inspections it had re-erected. The sign is however incorrectly orientated and implies the point not to pass is the base of the cliff. The sign should be orientated s that it is evident that people should not traverse along the beach in a northerly direction any further that the point marked by the sign.

The beach can be seen in Slide 19. From the main photograph it is evident that at high tide waves lap up against the cliff. During storms, waves will crash against the cliff causing erosion. Even under normal weather events the waves will tend to remove evidence of small rockfall either by pulling the rock down into the wave break zone or by covering the fallen rocks with sand.

Several processes are occurring. The small cliff at the base of the slope is being undercut (refer Slide 23). Wind erosion is impacting the middle part and upper parts of the cliff/slope allowing more sandy horizons to be eroded and more resilient limestone horizons become undercut. From these undercut strata, blocks of limestone eventually topple and slide down to the beach running out onto the beach some 8 to 10 m. The block noted on Slide 21 and Slide 22 is an example. There is a block above the northern part of Riflebutts beach that is severely undercut and could topple and slide onto the beach (refer Slide 26). Slide 26 illustrates the mechanism and the potential run-out zone. With this degree of run-out it is not possible to simply isolate the upper part of the beach from the public. This because all of the beach at high tide and the majority of the beach at low tide would all within the impact/run-out zone.

As well as very large block which might fall with a frequency of between 1 and 10 years, there is much evidence of far more frequent but smaller events.

Slide 21 shows Nearmap imagery from August 2018 when some of the beach sand had eroded exposing many limestone boulders indicative of earlier rock falls. This image also clearly shows the ragged nature of the slope and the crest of the slope and the potential for small blocks to fall. The undercut cliff as illustrated in Slide 23 is particularly fragile and some rocks likely fall each time waves break against the cliffs.

The exposure of this beach to rockfall can be noted by a 400 mm boulder (refer Slide 24) that evidence suggests fell only minutes prior to the joint CMW/SAMR inspection on Tuesday 20 August 2019, carried out to discuss options.

Furthermore, there is much evidence of falling material. For instance, the scuff marks on the grey case-hardened faces of limestone blocks on the beach suggest another very recent fall had occurred (refer Slide 25).

Overall the risk levels remain similar for large rockfalls to those calculated by Golder in 2017. The risk level from smaller rockfalls might even be higher as indicated below:

The following is considered a plausible remaining risk scenario:

- Likelihood boulder falling once a day $P_{(H)}$ = 365
- Spatial probability $P_{(SH)}$ =6.25 x10^{-4}
  (impact zone 80 m by 5 m, boulder size 0.5 x 0.5 and area of person exposed to impact 1m^2)
- Temporal probability $P_{(TS)}$ = 3.43x10^{-4} (this assumes sunbathing conditions for 3 hrs per visit))
- Vulnerability $V_{(DT)}$ =0.8 (high likelihood of death if struck by rock)
- Number of visits each year N=10 (assume at individual might visit beach 10 times) i.e 30 hours in total

Another scenario for a walker /dog walker visiting the beach twice a week all year round is provided. The walker/dog walker has a similar exposure to the risk, because although these are visiting the beach far more frequently, there time in the risk zone is far shorter and walking rather than lying on the beach results in a reduced vulnerability.

The results of the two scenarios are presented in Appendix D. Both scenarios present risk higher than the thresholds for tolerable risk suggested in AGS 2017. As such risk mitigation work are recommended.

It is somewhat difficult to ascertain the extent to which the current signage (re-erected since 19 August 2019) might discourage sunbathers and dog walkers from using the beach and thus reduce the risks presented in Appendix D for this location. SAMR officers however report that the signs are generally ignored, and many people are still using the hazardous part of the beach.

It is thus necessary to investigate other methods to reduce the risk level.

Option include:

1) Additional signage only
2) Batter back slope to safe and stable angle
3) Cover slope in rockfall mesh
4) Fencing to present access to hazardous part of beach parallel to cliffs
5) Fencing to present access to hazardous part of beach perpendicular to cliffs

The option of additional signage only (Option1) was discussed in the risk and options workshop with SAMR. Shire officers noted that existing signage is currently being ignored by some people and people could become injured who could claim they had not seen the sign or could not read English or understand the graphics.

Option 2) is not practical or considered environmental acceptable as it would create a large scar, involve removal or existing vegetation. Furthermore, the cliff is subject to active coastal erosion and will continue to be undercut in the future with more material falling from the cliff onto the beach in the future.

Option 3) using rockfall fencing would be very difficult to execute. This is because the cliff is generally not steep enough to install using abseiling techniques and as the cliff is highly friable, installation may not be possible from a health and safety perspective. Furthermore, the size of some of the unstable blocks are too large for drape netting and thus a large number of rockbolts would be needed to secure the mesh and thus secure the unstable blocks. Safely installing these rockbolts is unlikely to be possible again from a health and safety perspective without first modifying the slope profile with the inherent disadvantages described for Option 2). Rockfall netting across such a large area would damage the visual amenity of the area.

Option 4) We considered during this study the option of a fence parallel to the toe of the cliff The general intention of this option is to allow people to still access beach whilst keeping them out of the rockfall impact zone. This unfortunately is not a practical solution as the fence would need to be 8-10 m from the toe of the cliff and this would put it in the wave zone. Thus, people would tend to walk on the beach between the fence and the cliff in the rockfall hazard zone. The fence would also

preclude access into the sea and present a hazard to people entering or leaving the water through the surf. The fence is also unlikely to survive winter storms.

These options were discussed during the site visit with officers of the Shire of Augusta Margaret River and it was decided that the only practical solution was to erect a substantial fence with *do not pass this point* signage across the full width of the beach. This is Option 5) as listed above. Where the fence interacts with the surf zone it would be at right angles and erected on a rock ledge to minimise any hazard to swimmers leaving the water.

Careful consideration was given to the location of the fence. If the fence was erected north of the rock ledge parts of the cliff outside of the fence would still pose a risk. However, there is a desire only to close the smallest possible part of the beach and keep public access to the rock ledge. To achieve both outcomes a dog-leg in the fence was proposed during the workshop with SAMR officers as illustrated on Slide 20.

It is proposed that four robust 125 mm diameter stainless steel post are socketed at least 750 mm into the granite and limestone ledge on and beneath the beach sand to form posts to erect the fence. These posts will be sufficiently substantial to resist winter storm waves, the western-most stanchion will be located as illustrated in Slide 27 close to the low water mark to discourage people walking around the end of it. Two or three stainless steel multi-strand wire tensioned with tamper-proof turnbuckles will form the barrier and signs similar to the existing signage (refer Slide 29) fastened onto each post above the height of winter breaking waves and wave run-up on the beach. Unfortunately, the fence also prevents the public from accessing a popular part of the beach but as illustrated in the risk scenarios and from the observed hazards, one of which occurred minutes before the combined CMW SAMR site inspection, the risks are significant and tangible.

The risk is so tangible the Shire may wish to erect an informative signboard where the path from Riflebutts Reserve meets the beach to illustrate the coastal process, the hazards and the reasons SAMR has taken steps to prevent public access. Such informative signs are used around the world to inform the public of hazards rather than simply present “do not signage” and can have an educational component.

The photograph from the rockfall from 20 August 2010, which clearly shows the freshness of the impact and the presence of dog footprints could be used, and photographs of the cliffs illustrating various unstable blocks that can be seen from the location of the sign board could be used. In additional some explanation of the geological and coastal processes at work could be included.

4.6 Site ID: GN5 - 5 (Stairs leading to upper car park from White Elephant)

The location of this hazard is indicated on Slide 28. A site visit was made with SAMR officers on Tuesday 20 August 2019, followed by the risk and options workshop at SAMRs offices. An outcome of this risk and options workshop was to prepare drawings for the underpinning of an overhang of up to 2.5 m developed beneath a caprock layer up to ~1 m thick upon which stairs leading down to the White Elephant Café from the upper car park area are built directly on top of the overhang.

The overhang may be getting progressively larger since the Golder 2017 inspection. The approximate extent of the undercut is shown on Slide 29. If the undercut was to topple forward there is a strong likelihood it could pull the stair with it, creating a significant risk for any users of the stairs. The site is exposed and the undercut (see Slide 29 (right-hand photograph) and wind erosion has caused the undercut in the first place and is undoubtedly increasing its size over each progressive winter. The cracks seen in Slide 30 could allow a small slab to drop but if this was to occur would not necessarily affect the stairs, but is a potential hazard during the execution of underpinning works and if underpinning is undertaken, temporary propping will be required for worker safety. Slide 31 and 32 shows the difficult access to the site to execute remedial works. It is however important that as much vegetation is preserved as possible not only for aesthetic and environmental reasons but because

the vegetation reduces the exposure to wind erosion which would rapidly become exacerbated once removed.

Individual and Societal risks using the assumptions illustrated in Appendix D yield results within the AGS suggested thresholds for tolerable risk. This is largely because of the relatively short transit time across the affected part of stairs and the relative low number of people who may be on the stairs at any one time. However, the stairs are well-frequented and this results in a relatively high Cumulative Individual Risk and as such remediation is recommended. Furthermore, the degree of undercutting will only increase with time. The undercut is exposed to wind erosion and thus the likelihood of a collapse will increase if no remedial works are undertaken and risk levels will thus increase. For this reason, remedial works have been considered.

The following options were considered:

Option 1) Collapse overhang

Option 2) Underpin overhang

Collapsing the overhang (Option 1) would result in the need to relocate and rebuild the stairs leading from the top car park to the White elephant café. It would also expose the leached limestone layer to further wind erosion and in time new undercutting would begin to occur.

Underpinning (Option 2) by contrast is considered a better option because it supports the stairs, repairs the hazard, prevents future wind erosion enlarging the existing overhang and can be executed with minimal environmental damage. It is also largely visually concealed by virtual of it being located below the path/stairs and shielded in the main by vegetation when viewed from the beach

Drawings showing the proposed underpinning works are provided in Appendix C (Drawings 190801-S1, 190802-S2 and 190802-S3). The extent of the underpinning is illustrated on Slide 34. It is 9 linear metres long. The average depth of underpinning will be 1.3 m, the mean thickness about 0.6 m with an estimated volume of 12 m^3 and shuttered face area of about 8 m^2. Unlike at Surfers Point, as long as vegetation is preserved, the concrete face will be largely screen by vegetation and for this reason we understand SAMR will not require the exposed concrete from the underpinning to be concealed behind architectural limestone blockwork.

The following are considerations concerning the underpinning.

1) It is impractical and unsafe to send personnel under the overhang to dig out loose sand and compact the subgrade prior to placing concrete. Thus, some compression of the subgrade will occur if the load from the rock is transferred onto the underpinning concrete.
2) To reduce the degree of settlement it is recommended that vegetation and the uppermost and loosest surficial sand be removed using a long-handled rake/scraping tool and undertaken without people entering under the overhang. This will only be undertaken to the extent possible and is unlikely to involve removing more than about 100 mm of surfical material.
3) It is recognised that if the caprock was to collapse, some subsidence possibly in the order of 50 mm could occur due to compression of the very loose sand subgrade and residual voids not infilled with the underpin concrete. Should this collapse occur this settlement may affect the serviceability of the stairs and repairs to level the affected part may be required. It is however unlikely that full collapse and compression of the sand will occur once underpinning has been undertaken since the mechanism of undercut enlargement will have been removed. and they would likely require re-building, however this
4) In order to prevent the underpinning works from sliding and to provide a footing for the architectural blockwork and a key to anchor the lower edge of the concrete shutter, a concrete footing/key into the underlying sand, limestone rubble or limestone is proposed.
5) Temporary support will need to be provided as required to facilitate this excavation which is anticipated to be hand dug. If limestone is present the requirement for an excavation is

negated (refer Drawing 190802-S3) although starter bars will still be required to be drilled into the limestone to form a key.

6) The shuttering will need to be tailored top and bottom in both elevation and plan to follow the profile of the undercut.
7) Cut-outs in the shuttering will be required to facilitate pumping of concrete in one continuous pour and to allow the use of a concrete compactor.

5 FUTURE MONITORING PROTOCOL

Part of the commission included the provision of monitoring reference points at some of the locations described in this report. These reference points are documented in Appendix E.

It also included for a protocol by which officers of SAMR can undertake routine monitoring themselves, recognising when erosion and potential instability is developing and documenting a set of procedures to increase monitoring frequency, obtain external specialised geotechnical advice or to implement immediate or staged closure to mitigate risks in the short term whilst remediation or other risk mitigation works are undertaken.

This monitoring protocol is also provided in Appendix E.

6 REFERENCES

AGS (2007), *Practice Note Guidelines for Landslide Risk Management 2007*. Australian Geomechanics, Vol 42, No 1, March 2007

7 CLOSURE

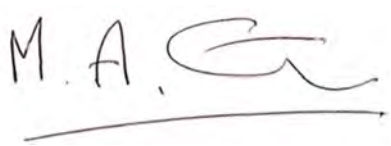
The findings contained within this report are the result of site observations, judgement of likelihood and impact of slope and cliff hazards and risk assessment conducted in accordance with normal practices and standards. To the best of our knowledge, they represent a reasonable interpretation of the general condition of the site. Conditions change with time and following severe weather events.

The information presented in this report therefore represents the condition observed and risk assessed at the time of the site inspection and from time to time additional surveys will be required to update observed conditions in accordance with the guidance provided in this report.

This report has been prepared for use by Shire of Augusta Margaret River in relation to managing coastal cliff stability risk at 6 discrete locations in accordance with generally accepted consulting practice. No other warranty, expressed or implied, is made as to the professional advice included in this report. Use of this report by parties other than Shire of Augusta Margaret River and their respective consultants and contractors is at their risk as it may not contain sufficient information for any other purposes.

For and on behalf of
CMW Geosciences Pty Ltd

Prepared By:



Matthew Tutton
Senior Principal Geotechnical Engineer

Reviewed By:

Craig Butterworth
Senior Principal Geotechnical Engineer

Distribution: 1 copy to Shire of Augusta Margaret River (electronic)
Original held by CMW Geosciences Pty Ltd

Appendix A

Scope of Work and Methodology

Proposed investigation scope and methodology

The Consultant will provide additional advice and information surrounding the original recommendations in the 2017 Cliff Stability Assessment provided with the RFQ and undertake design of remediation. To enable this we propose the following:

SITE INSPECTION

Senior CMW and CSC representatives will jointly undertake an inspection at the three Gracetown sites and the three Prevelly/Gnarabup sites to geologically appraise the current conditions, review previous recommendations and to take relevant measurements to facilitate analyses and/or design of remediation. During the inspection discussion and formulation of potential and preferred stabilisation options will occur. A subsequent site visit will be made to install survey monuments and photograph reference points to facilitate ongoing monitoring by the Shire staff

FORMULATION OF OPTIONS / DESIGN AND INDICATIVE COSTING

Words in italics are scope of work in the RfQ document

Site ID: GC5 - 75 (Gracetown – cliffs south of stairs)

Provide details/analysis on whether to stabilise blocks or remove overhanging rocks, detailed methodology and indicative costing for preferred approach. If removal of the hazard is recommended, the consultant is required to undertake and/or oversee removal of the hazard, or prepare a procedure and details for Shire staff to undertake removal of the hazard.

We have costed for recommending and designing the preferred option including a procedure for the Shire to monitor in the future. We have not costed for undertaking the physical works as this will require an independent contractor. Similarly, the cost of overseeing is not included in our lump sum but we provide an expected indication based on time and expenses

Site ID: GC6 - 15 (Gracetown – Southpoint lookout)

The Shire has removed the lookout at Southpoint that sat over the overhang and received engineering drawings to anchor the viewing platform back to the carpark. The consultant shall determine whether stabilisation carried out to date is sufficient, or whether further stabilisation of the stairs is also required, and provide details how to proceed. A methodology and costing shall be provided for the proposed approach.

We will evaluate whether work done is sufficient, review the engineering drawings and if further stabilisation is required design and provide details and provide indicative costs for execution.

Site ID: GC6 - 60 (Southpoint carpark)

The consultant shall install monitoring equipment to the identified risk, and prepare a monitoring protocol for Shire staff to monitor thereafter.

We shall inspect, update risk analysis if required, and install survey monuments or photo reference points to facilitate future monitoring by Shire Staff. We will prepare monitiroing protocol to be undertaken by Shire staff with an event tree to advise the Shire staff on when to increase monitoring period or actions to take in the event of significant change being noted or following adverse weather events.

Site ID: PR4 - 30 (Surfers Point)

The Shire has removed the viewing platform in accordance with the recommendation. Provide an analysis as to the resultant risk of the overhang and response required (if any) and advise what is the best option to consider and details on how to proceed (i.e. removal of rock, reinforcement, a mix of these approaches, etc.) should the Shire wish to install the platform in the future.

We will assess the current situation with respect to risk. We have priced for designing underpinning works assuming the Shire wants to reinstate the lookout. Even if the lookout is not reinstated underpinning would mitigate against collapse risk as we understand this undercut ledge is a well-used viewing platform during crowded surf events.

Site ID: PR6 - 85 (Cliffs at Riflebutts Beach)

The limestone report refers to imminent rockfall risk in the next 1 – 10 years for this stretch of beach and recommends closing the beach by way of signage. Signage has been installed but people are still using the area. The consultant is required to:

- *Determine and detail a suitable method for removal of the identified hazard;*
- *Undertake and/or oversee removal of the hazard (provide indicative sub-contractor costings, if required).*
- *Identify a permanent exclusion zone at the base of the cliffs to discourage people from entering 'at risk' areas and recommend a method for excluding people from the area i.e. fencing or otherwise.*

We are very familiar with this section of beach/cliff. Whilst we can design and cost remediation works, this is an area of active cliff erosion. Removal of high-risk blocks will be a short-term fix only and may result in environmental disturbance. We recommend and have costed for the following approach. We will assess the options (including rating options by cost, environmental and safety considerations (both in executing and to end users). We then present these options in a risk and options workshop with the Shire. We have costed for a 4-hour risk/options workshop with the Shire. During the workshop changes/improvement in risk will be discussed/documented alongside environmental and cost considerations.

Site ID: GN5 - 5 (Stairs leading to upper car park from White Elephant)

Overhang of up to 2.5 m developed beneath a caprock layer up to ~1 m thick. Stairs leading down to the White Elephant Café from the upper car park area are built directly on top of the overhang. The hazard at this location is largely associated with collapse of the overhang while recreational users are using the stairs. The consultant shall install monitoring equipment to the identified risk and prepare a monitoring protocol for the Shire to monitor thereafter.

We will install monitoring equipment and undertake analysis of the block stability. We have also allowed for the design of underpinning to support this overhang.

NB: Note, undertaking and/or overseeing removal of hazards is preferred, but is an optional requirement for quotation purposes.

We have allowed for the supply and installation of simply survey reference points and photograph reference points to assist with future monitoring. We have not allowed for undertaking the actual works to remove the hazards or to support overhanging blocks etc as these will require engagement of specialist contractors.

General monitoring protocol

The report recommends additional and on-going monitoring for all sites (in addition to the above sites). The consultant is required to provide a monitoring protocol for each site that can be implemented as required by Shire staff

In addition to providing advice and remedial option/designs for the sites (where required) we will prepare a monitoring protocol that can be implemented by Shire officers. This protocol will document key features to note and monitor, provide advice on frequency (fixed interval and following storm events etc.) and providing a flow chart that will give guidance on when action is required.

We have allowed for installation of survey monuments (e.g surveyors nails or pins grouted into the rock against which measures can be made and a number of small photo targets that are fixed and can be seen in subsequent inspection photographs in order to reference photographs for change. These survey monuments and targets will only be affixed to the main hazards in the six locations described above. The monitoring protocol will however apply to all locations described in the 2017 report.

Deliverables

We will provide a geotechnical interpretive report describing the inspections, risk analyses and documenting the rationale for recommendations together with the proposed monitoring regime.

Designs for remediation will be provided separately together with indicative costing for execution.

Appendix B

Site Observations and Photographs

Appendix B

Site Inspection 19 and 20 August 2019


GC6-60
GC6-15
Gracetown
Southpoint Carpark
GC5-75
4.22 m

No retrogression of embayment to west of GC6-60 since 2017 is apparent. Healthy establishment of native vegetation has occurred (see photo on right)

August 2019 inspection indicates little change from 2017

Fracture from Golder 2017 inspection

Photo from CMW August 2019 inspection little change noted from 2017

Photo from Golder 2017 inspection

Rockfall debris still present on wave cut platform similar to 2017

Warning signs in place on approaches to section of foreshore affected by rockfall

August 2019 – Undercut outcrop on which lookout formerly stood.

Following the recommendation of the 2017 report the lookout was removed.

Current (August 2019) inspection of stairs indicates the steps are not at imminent risk of catastrophic if rockfall was to occur below the steps but monitoring should still be undertaken to detect changing conditions and to maintain serviceability

Coastal erosion undercutting some of the supporting stanchions on the lower part of Southpoint carpark stairs.

Integrity of structure requires regular monitoring to detect and act upon changing conditions to maintain serviecabilty.

Fracture suggest collapse will occur in near future

Overhang comprises two sections each approximately 5 m long and with an average overhang of about 1 m. Thickness of overhang varies from 1+m to approximately 300 mm

Same fracture viewed from slightly different angles Left - August 2019 Right - 2017

GC5-75 Overhang above exit from Southpoint Carpark stairs

General nature of overhang which will require controlled collapse by needle drilling from above to define controlled breakaway line (approximately 10 metres (plan) require collapsing

GC5-75 Overhang above exit from Southpoint Carpark stairs

Access to GC5-75 is difficult from below. Pedestrian access will be required however to

a) survey overhang and establish points to needle drill and,
b) b) to fragment and bar down fallen rock that does not roll to base of slope

Access to top of overhang will be via footpath to South Point and will be pedestrian only. Some cutting of scrub between footpath and edge of overhang will be required. Anchor points for safety harness will need to be established and a line set out defining the overhang and no-go zone so no personnel stand or work in the no-go zone.


PR4-30 (in September 2017)

Lower lookout and bench removed since 2017

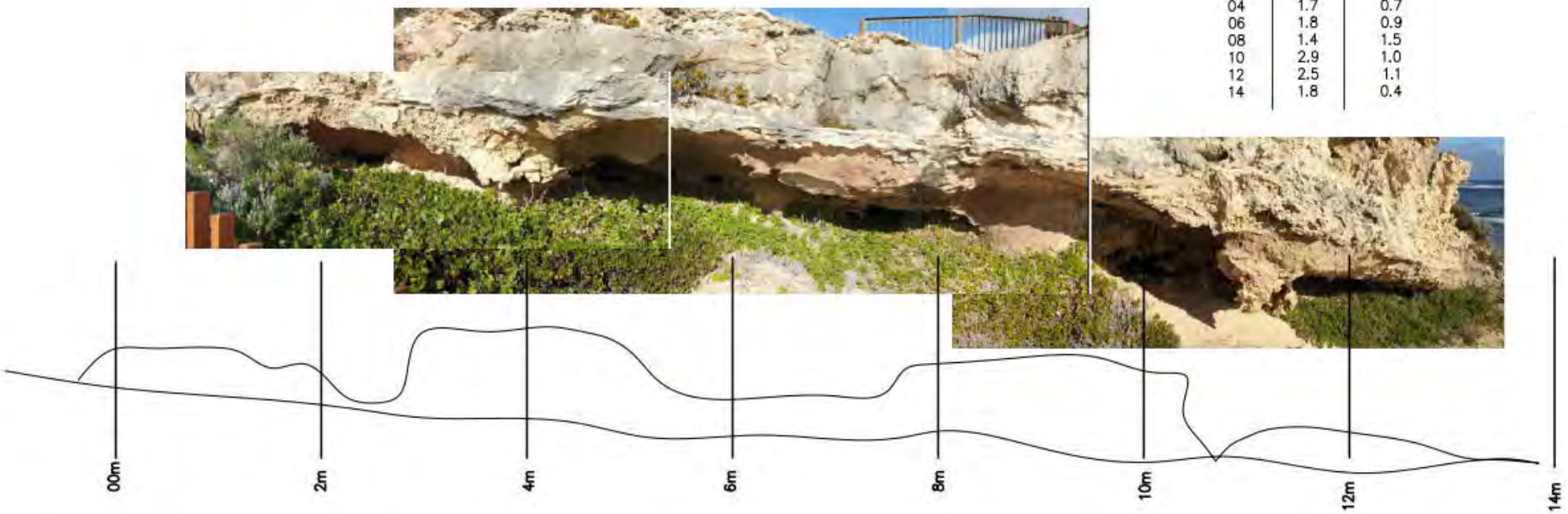
Approximate extent of undercut block caused by wind eroding out leached limestone/sand layer

Flat area above overhang used unofficially by spectators and cameramen during surf events

Undercut is a slot locally in excessive a 3 m deep.

Loose sand and vegetation will need to be carefully raked out prior to underpinning

CHAINAGE	WIDTH(m)	HEIGHT 1(m)
00	0.2	0.2
02	1.1	0.3
04	1.7	0.7
06	1.8	0.9
08	1.4	1.5
10	2.9	1.0
12	2.5	1.1
14	1.8	0.4



Overhang is approximately 14 m long, generally between 0.2 and 2.9 m wide (deep) (locally measured to be 3.5 m deep) with a height along outside face between 0.2 and 1.5 m tapering rapidly to a narrow slot a few centimetres high.

Approximate extent of underpinning with architecture limestone blockwork facing

Remnant of former lookout and bench platform


ROCKFALL HAZARD AREA
IMMINENT ROCKFALL
BEYOND THIS POINT
DO NOT GO PAST
THIS SIGN
DANGER

August 2019 Nearmap Imagery – showing proposed position of fence to restrict access

August 2018 Imagery

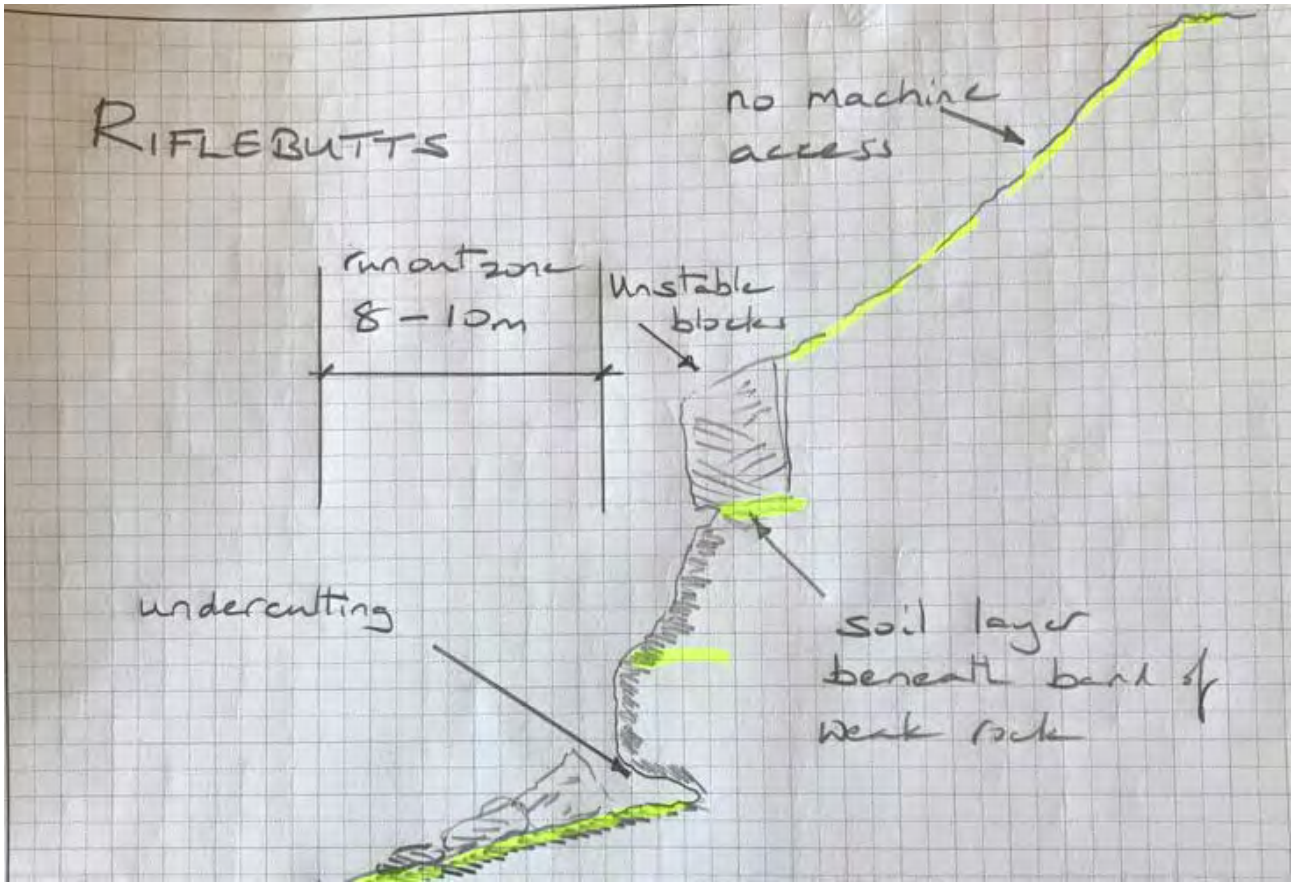
Although this rockfall was illustrated in the Baynes Geologic Report dated 2006 it serves to illustrate the large scale of rockfalls

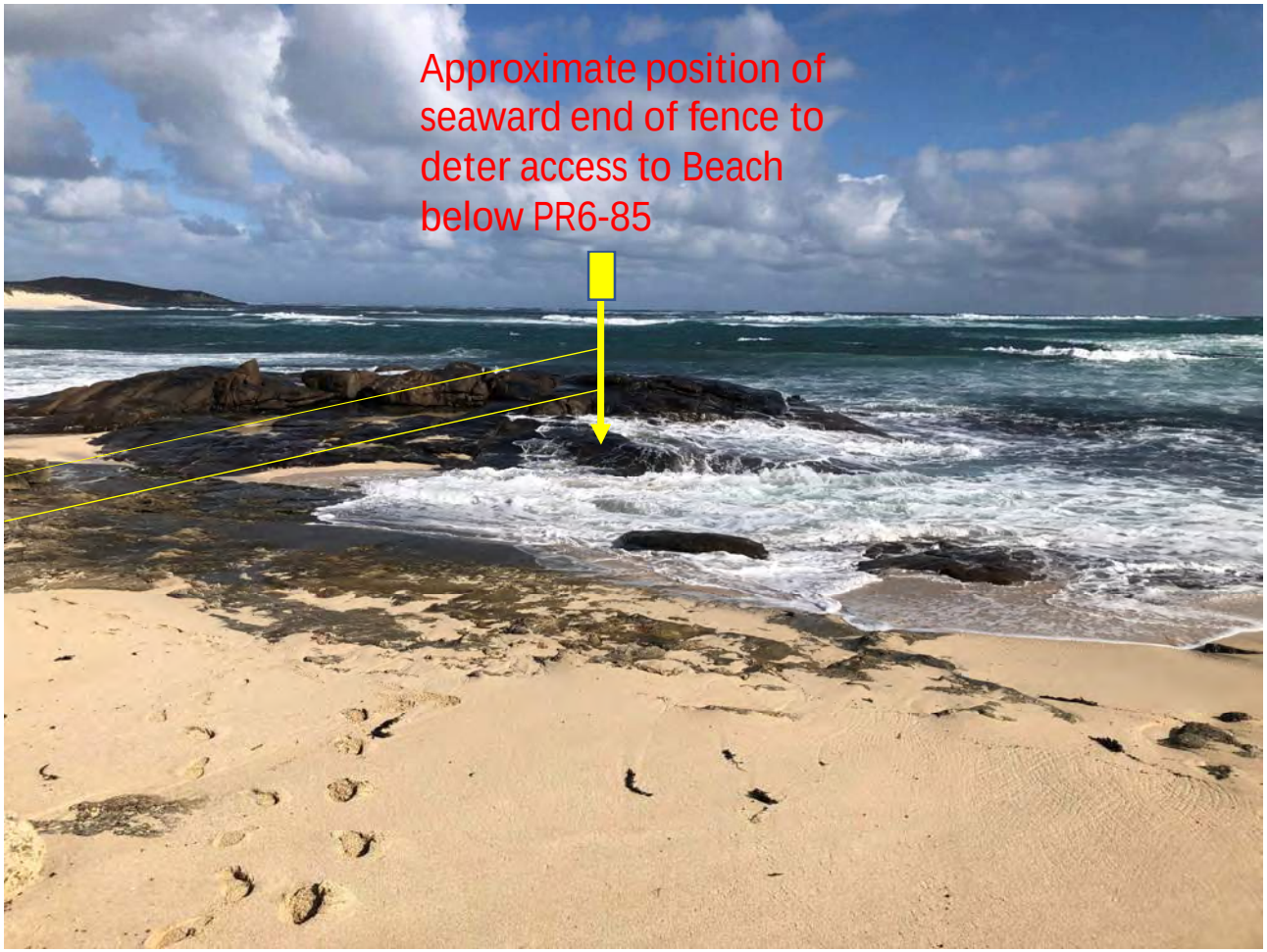
Undercutting of cliffs on normal tides/conditions likely to result in collapse of several cubic metres in near future. White rock indicate recent falls

Very fresh impact crater from boulder size rockfall that occur a very short time before a joint CMW/SAMR inspection of the cliffs on 20 August. It clearly occurred since the tide went out however cracking in sand marked X is very fresh

Highly leached and friable rock mass. Yellow colouration indicates materials has recently broken away from cliff

White scuff marks where cobbles and boulders have recently impacted a fallen block and ricocheted onto the beach

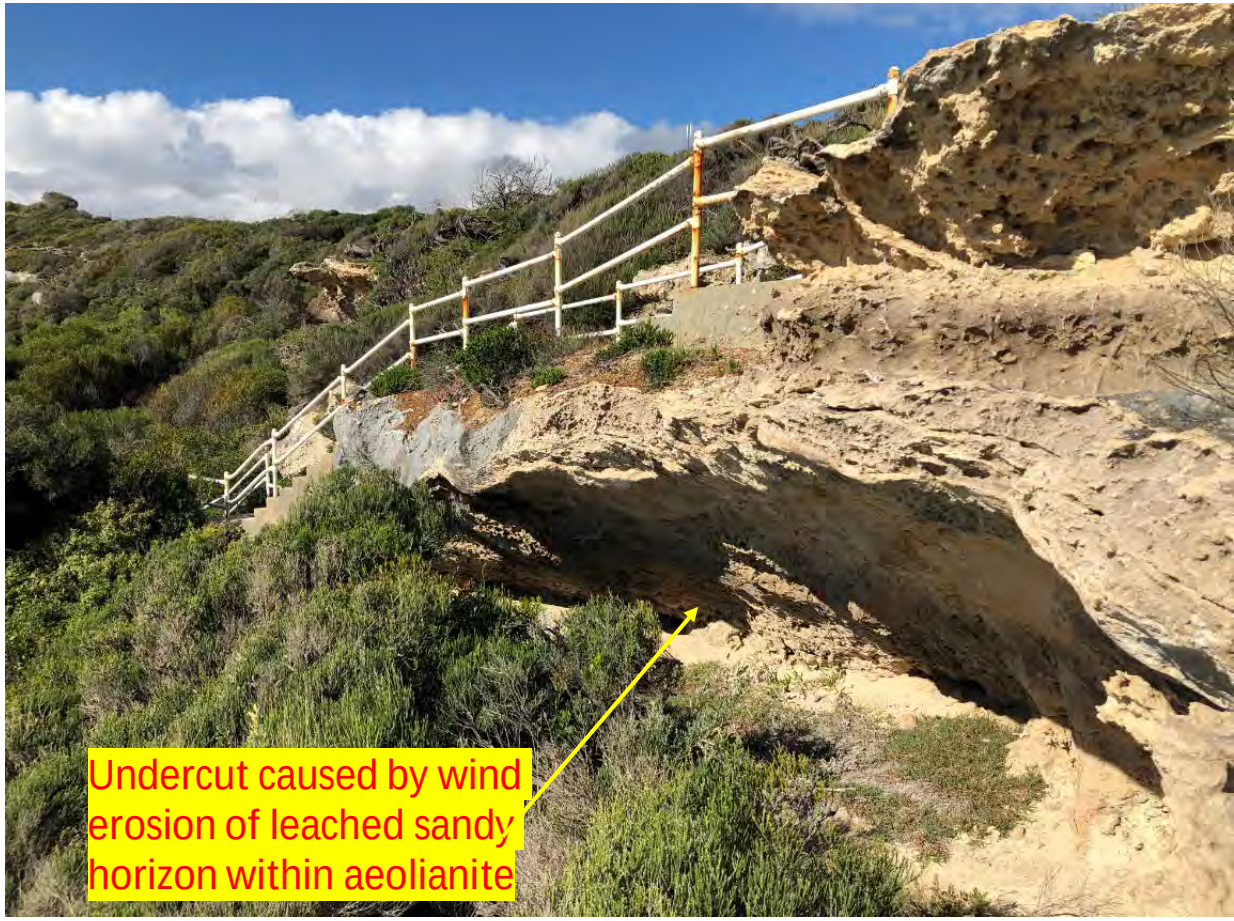

RIFLEBUTTS
no machine access
runout zone
8 – 10m
unstable blocks
undercutting
soil layer beneath band of weak rock



Proposed 2 or 3 strand fence extend to close to low- water with seaward fence installed on northern edge of granite ledge 3 other posts form the fence on the bench itself

Undercut to steps leading down from carpark to White Elephant Café highlighted in this August 2019 Nearmap Image


Approximate extent of undercut


Undercut caused by wind erosion of leached sandy horizon within aeolianite

Crack could allow a small slab to breakaway from overhang

Access to undercut is tight however vegetation clearance to facilitate underpinning should be keep to an absolute minimum and restricted to the narrow path immediately in front of the ourcrop

Dense vegetation is present in front of undercut which should be preserve. Only a narrow strip of vegetation to afford pedestrian access for the underpinning works should be undertaken

Loose mortar and render café end of stairs should be removed and repointed once any voids exposed have been infilled with mortar made good


Underpinning extends behind scrub to position shown by arrow
Approximate extent of proposed underpinning

Appendix C

Remedial Work Drawings (Draft) prepared by Civil/Structural Consulting Pty Ltd

GENERAL
1. INSTRUCTIONS ON DRAWINGS TAKE PRECEDENCE OVER THESE NOTES. ALL RELEVANT, LATEST SAA CODES AND AMENDMENTS MUST BE COMPLIED WITH.
2. STRUCTURAL DRAWINGS TO BE READ IN CONJUNCTION WITH REPORT.
3. ALL DIMENSIONS mm UON. DO NOT SCALE FROM DRAWINGS.
4. THIS CERTIFICATION IS LIMITED ONLY TO THOSE ITEMS SHOWN,
5. ALL WORK TO BE CARRIED OUT IN A SAFE MANNER. SAFETY OF WORKERS IS A VERY HIGH PRIORITY GIVEN THE POSSIBILITY OF INSTABILITY OF OVERHANGS.
6. THIS WORK IS LOCATED WITHIN 100m OF COAST, ENSURE SUITABLE CORROSION PROTECTION MEASURES ARE IMPLEMENTED.
7. CONTRACTOR/TENDERERS TO NOTE THAT LEVELS AND DIMENSIONS ARE APPROXIMATE ONLY. CONTRACTORS/TENDERERS ARE TO CHECK ALL DIMENSIONS AND LEVELS ONSITE PRIOR TO TENDERING AND PRIOR TO CARRYING OUT ANY CONSTRUCTION IN ORDER TO ASSESS ACTUAL DETAILS REQUIRED.
8. ALL FIXINGS ARE TO BE GRADE 316 STAINLESS STEEL UON.
9. CONTRACTOR IS TO ENSURE STRUCTURES ARE STABLE AT ALL TIMES, INCLUDING DURING CONSTRUCTION.
10. INSPECTIONS CARRIED OUT BY THE SUPERINTENDENT DO NOT ABSOLVE THE CONTRACTOR OF COMPLIANCE WITH THE DRAWINGS, SPECIFICATION AND SUITABLE LEVEL OF WORKMANSHIP. RESPONSIBILITY FOR COMPLIANCE RESTS WITH THE CONTRACTOR AT ALL TIMES.
11. CONTRACTOR IS TO ENSURE ALL PUBLIC AND PRIVATE PROPERTY AND SERVICES ARE PROTECTED. DAMAGE TO PUBLIC OR PRIVATE PROPERTY OR SERVICES, AS A RESULT OF THE WORKS, IS TO BE MADE GOOD AT THE EXPENSE OF THE CONTRACTOR.
12. SOIL, WATER MANAGEMENT AND SITE PROTECTION MEASURES ARE TO BE IMPLEMENTED SO AS TO PROTECT SURROUNDING AREAS FROM DAMAGE AND CONTAMINATION.
13. SPAN MEANS CENTRE OF SUPPORT TO CENTRE OF SUPPORT UNLESS OTHERWISE NOTED.

REINFORCEMENT
1. ALL REINFORCEMENT TO BE HOT DIP GALVANISED UON.
2. 'R' – PLAIN ROUND BARS, MIN YIELD STRENGTH OF 250MPa TO AS1302.
3. 'N' – HT HOT ROLLED DEFORMED BARS, MIN YIELD STRENGTH 400MPa TO AS1302
4. 'SL' AND 'L–TM' – STEEL FABRIC, MIN YIELD STRENGTH 450MPa TO AS1304.
5. CRANK SECONDARY REINFORCEMENT OVER PRIMARY BARS AS REQUIRED U.O.N. SLOPE MAXIMUM 1 IN 6.
6. PROVIDE RE–ENTRANT REINFORCEMENT AS PER DRAWINGS, 2N12 OR 1N16 OR L8–4TM, 1500 LONG, PLACED CENTRALLY IN SLAB AND TIED UNDER MESH.
7. MINIMUM LAPS – 'N' BARS – 40 DIAMETERS, FABRIC – ONE FULL MESH (TWO RODS) EACH SHEET U.O.N.
8. ALL REINFORCEMENT TO BE ADEQUATELY SUPPORTED ON APPROVED CHAIRS U.O.N.TO PROVIDE COVERS AS SHOWN.
9. ALL REINFORCEMENT TO BE FREE OF DIRT, GREASE, RUST AND MILL SCALE, CLEAN OR REPLACE AS NECESSARY.
10. REINFORCEMENT NOT TO BE BENT, CUT OR HEATED ON SITE WITHOUT ENGINEER'S PRIOR APPROVAL.

SITE PREPARATION/EARTHWORKS
1. SAFE WORKING METHODOLOGY IS TO BE DEVELOPED AND DOCUMENTED PRIOR TO CARRYING OUT WORK IN VICINITY OF OVERHANGS.
2. DO NOT ENTER UNDER OVERHANGS. USE LONG HANDLED EQUIPMENT TO RAKE OUT RUBBLE AND SAND.
3. WHERE NECESSARY PROVIDE A LOCALISED TEMPORARY PROPPING SYSTEM TO ALLOW WORK IN VICINITY OF OVERHANG(S).
4. WORKS ARE CARRIED OUT IN A FRAGILE COASTAL ENVIRONMENT, REGARD IS TO BE HAD FOR THIS AT ALL TIMES. ANY DAMAGE RESULTING FROM LACK OF REGARD BY THE CONTRACTOR IS TO BE MADE GOOD AT THE CONTRACTOR'S EXPENSE.
5. FOOTINGS ARE DESIGNED FOR AN ALLOWABLE BEARING PRESSURE OF 100kPa, ENGINEER TO BE ADVISED IF THIS APPEARS NOT ACHIEVABLE.
6. FORMWORK IS TO BE SET UP IN SUCH A WAY THAT VOIDS ARE FILLED WITH ONE CONTINUOUS, CONTIGUOUS POURREMOVE ALL VEGETATION, TOPSOIL, LOOSE SAND/RUBBLE AND ANY OTHER DELETERIOUS MATERIAL.
7. SUPERINTENDENT IS TO INSPECT SITE AFTER PREPARATION AND REINFORCEMENT SETUP, PRIOR TO PLACEMENT OF FORMWORK, MINIMUM 24 HOURS NOTICE TO BE PROVIDED.

CONCRETE
1. ALL CONCRETE TO COMPLY WITH AS3600.
2. USE ONLY ORDINARY PORTLAND (GP) CEMENT U.O.N., WITH NO ADDITIVES.
3. CONCRETE TO BE COMPACTED CORRECTLY USING AN APPROVED VIBRATOR, WHERE NOTED.
4. MINIMUM CONCRETE COVERS TO REINFORCEMENT: AS SHOWN OR 40mm.
5. DRY PACKED CONCRETE IS TO BE HIGH STRENGTH/LOW SHRINKAGE.
6. CONCRETE SHALL HAVE THE FOLLOWING PROPERTIES:

LOCATION	AGGREGATE	f'c (MPa)	CEMENTCONTENT kg/m3	MAX WATER/CEMENT RATIO	SLUMP
SLABS/FOOTINGS	20	25	250	0.65	80
CONCRETE FILL	20	20	250	0.65	100
DRY–PACK	5	40	–	–	–

CLIENT: Shire Augusta Margaret River

PROJECT: Limestone Cliff Assessment and Stabilisation

TITLE: NOTES

DRAWING NO: 190802–S1

DESIGN: T. Moore

APPROVED: Tim Moore

REVISION	DRAWN	DESCRIPTION
10/9/19	TM	DRAFT ISSUE

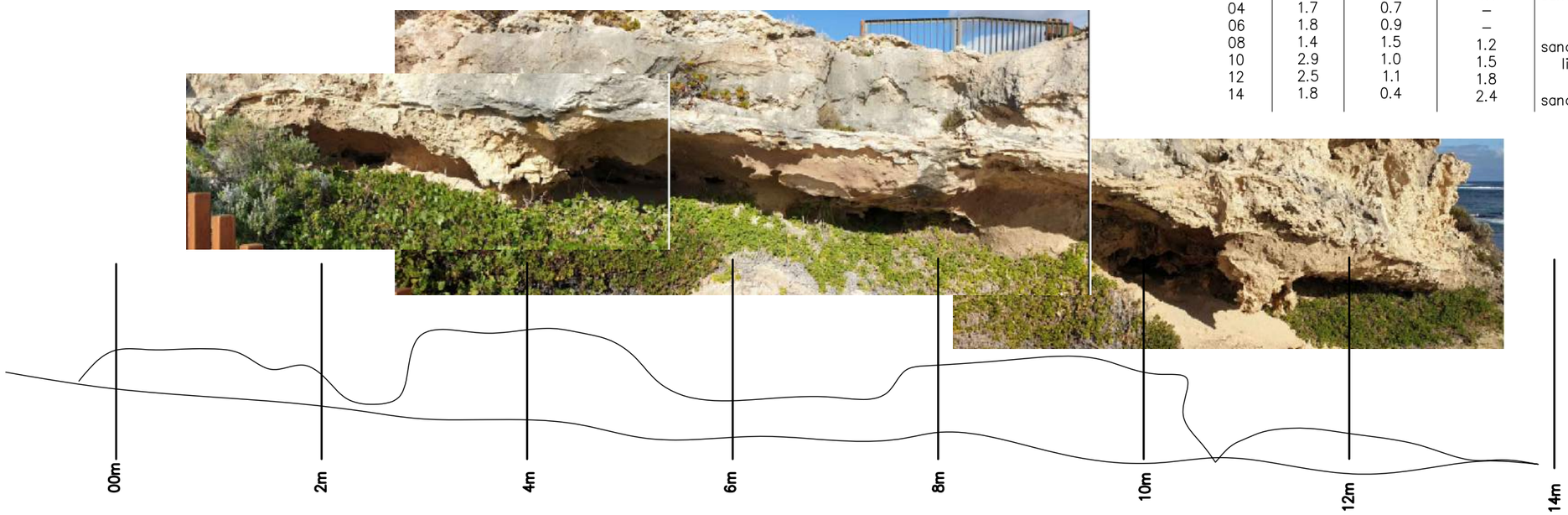
DATUM:

SCALE:

A3
1/4

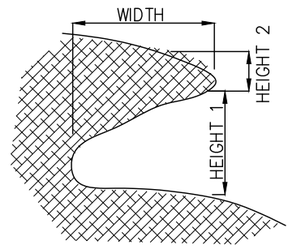
CIVIL/STRUCTURAL CONSULTING Pty Ltd
Civil, Structural and Environmental Engineers and Project Managers
41 Townview Tce
(P O Box 852)
MARGARET RIVER WA 6285
TEL: (08) 97572488
Mobile: 0419 969 010
E–mail: tim@cscmr.com.au

CHAINAGE	WIDTH(m)	HEIGHT 1(m)	HEIGHT 2(m)	SUBGRADE
00	0.2	0.2	1.1	sand
02	1.1	0.3	1.1	sand/limestone
04	1.7	0.7	–	sand
06	1.8	0.9	–	sand
08	1.4	1.5	1.2	sand/limestone
10	2.9	1.0	1.5	limestone
12	2.5	1.1	1.8	sand
14	1.8	0.4	2.4	sand/limestone



MAINBREAK SITE SCHEMATIC ELEVATION

Scale 1:50 (Approximate)



UNDERPINNING DIMENSIONS (APPX)

NTS

GNARABUP CAFE STAIRS SITE PLAN

NTS

APPROXIMATE PLAN OF UNDERPINNING

CHAINAGE	WIDTH(m)	HEIGHT 1(m)	HEIGHT 2(m)	SUBGRADE
00	0.8	0.8	–	sand
02	1.4	1.2	–	sand
04	2.3	1.4	0.9	sand
06	2.2	1.4	1.0	sand
08	1.8	1.5	1.0	sand
09	0.7	1.5	0.2	–

NOTES

1. All work to be carried out in a safe manner. Safety of workers is a very high priority given the possibility of instability of overhangs.
2. Safe working methodology is to be developed and documented prior to carrying out work in vicinity of overhangs. Do not enter under overhangs. Use long handled equipment to rake out rubble and sand.
3. 3. Where necessary provide a localised temporary propping system to allow work in vicinity of overhang(s).
4. To be read in conjunction with Drawings S1 and S3.
5. Photographs are representative only.
6. Scale and measurements are approximate only, contractors to measure onsite.
7. Remove vegetation and loose sand prior to setup.
8. Formwork is to be set up in such a way that voids are filled with one continuous, contiguous pour.

CLIENT: Shire Augusta Margaret River

PROJECT: Limestone Cliff Assessment and Stabilisation

TITLE: Structural Layout To Mainbreak and Gnarabup Cafe Stairs (Site ID: PR4–30 & Site GN5–5)

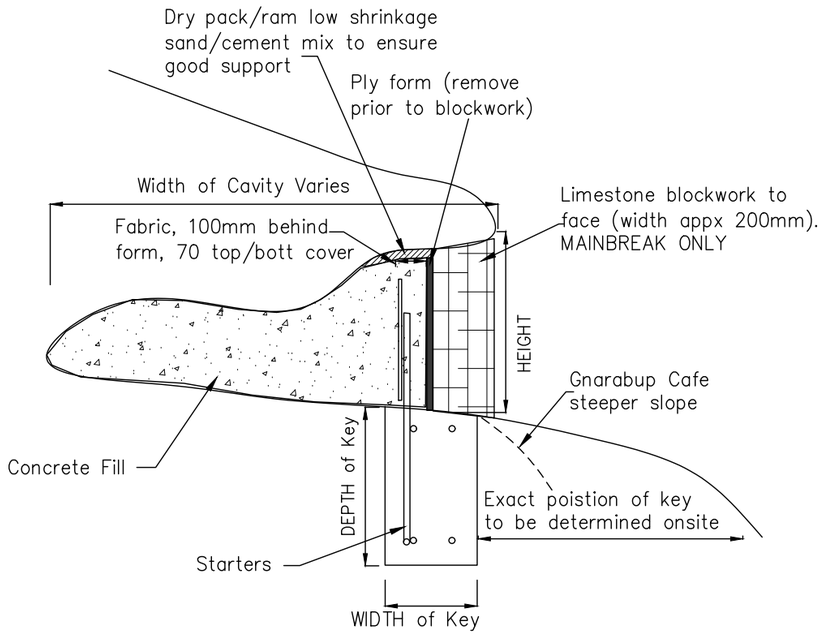
DRAWING NO: 190802–S2 | DESIGN: T. Moore

REVISION	DRAWN	DESCRIPTION
10/9/19	TM	DRAFT ISSUE

APPROVED:

DATUM: | SCALE: As Shown | A3 2/4

CIVIL/STRUCTURAL CONSULTING Pty Ltd
Civil, Structural and Environmental Engineers and Project Managers
41 Townview Tce
(P O Box 852)
MARGARET RIVER WA 6285
TEL: (08) 97572488
Mobile: 0419 969 010
E-mail: tim@cscmr.com.au



HEIGHT (m)	DEPTH (mm) (see NOTES)	WIDTH (mm)	STARTERS	REINFORCEMENT	FABRIC
0 to 0.5	300	200	N20–200	1/2N20	SL102
0.5 to 1	400	300	N24–200	1/2N24	SL102
1 to 1.5	500	300	N28–200	2/2N28	N12–200ew
1.5 to 2	500	400	N32–200	2/2N28	N16–200ew

NOTES
1. All work to be carried out in a safe manner. Safety of workers is a very high priority given the possibility of instability of overhangs.
2. Safe working methodology is to be developed and documented prior to carrying out work in vicinity of overhangs. Do not enter under overhangs. Use long handled equipment to rake out rubble and sand.
3. Where necessary provide a localised temporary propping system to allow work in vicinity of overhang(s).
4. To be read in conjunction with Drawings S1 and S2.
5. Position of key is determined by safety considerations.. Exact position to be determined onsite.
6. Key depths are nominal. Exact depths to be determined onsite.
7. Leave "tell–tale" gap at top of formwork to ensure voids are suitably filled.
8. Concrete: TOE 32MPa, 20–30 aggregate, 80 slump; FILL 32MPa, 20–30 aggregate, 100 slump.
9. Remove formwork after 7 days (prior to placing limestone blockwork).
10. Provide masonry ties to concrete face where blockwork is to be installed (at Mainbreak site).
11. Provide architectural limestone blockwork face to Mainbreak site.
12. DEPTHs shown for key are in sand/rubble.
13. Where key is in rock starters are to be drilled and epoxied 300mm, key depth reduced to zero.
14. All reinforcement to be hot dip galvanised (Bar–AS4680 Section 5, Fabric–AS4534).
15. STARTERS cog 200, extend 300
16. REINFORCEMENT 1/N# = 1 row 70 bottom/sides cover, 2/N# = 1 row bottom, 1 row top, 70 bottom/top/sides cover.

UNDERPINNING GENERAL DETAILS

Scale 1:20 (approximate)

CLIENT: Shire Augusta Margaret River

PROJECT: Limestone Cliff Assessment and Stabilisation

TITLE: Structural Details To Mainbreak and Gnarabup Cafe Stairs (Site ID: PR4–30 & Site GN5–5)

DRAWING NO: 190802–S3 | DESIGN: T. Moore

REVISION	DRAWN	DESCRIPTION
6/10/19	TM	DRAFT ISSUE

APPROVED:

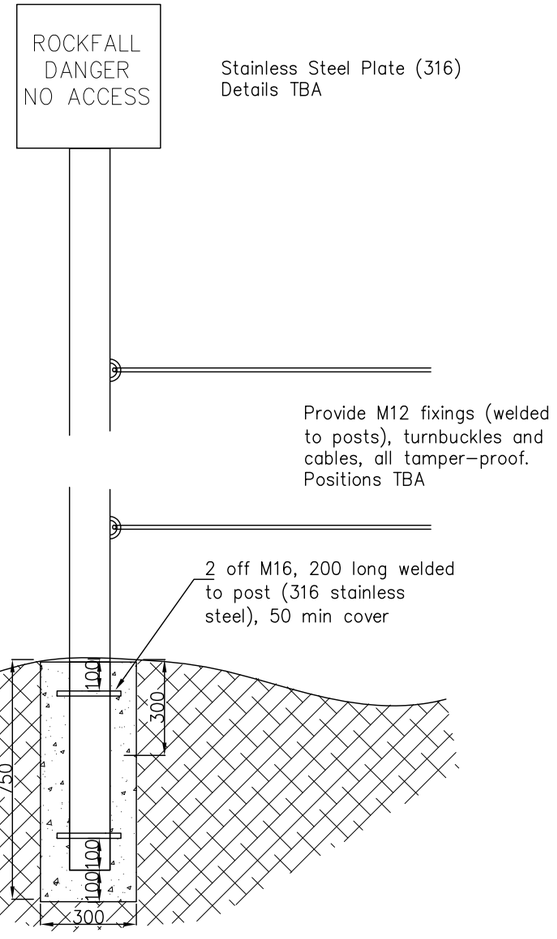
DATUM: AHD | SCALE: 1:20 | A3 3/4

CIVIL/STRUCTURAL CONSULTING Pty Ltd
Civil, Structural and Environmental Engineers and Project Managers
41 Townview Tce
(P O Box 852)
MARGARET RIVER WA 6285
TEL: (08) 97572488
Mobile: 0419 969 010
E–mail: tim@cscmr.com.au

PLAN LAYOUT
Scale 1:250 (approximate)

NOTES
1. All work to be carried out in a safe manner, given the possibly hazardous coastal area.
2. To be read in conjunction with Drawing S1.
3. Photographs are representative only.
4. Scale and measurements are approximate only, contractors to measure onsite.
5. All components to be stainless steel grade 316 UON.
6. CHS sections unpolished finish.
7. Posts are to be cored and grouted into rock base 750mm.
8. remove any vegetation and loose sand that may be present over rock base prior to setup.
9. Minimum dimensions of rock core and grout shown.

SIGNPOST AND ANCHOR DETAILS
Scale 1:20



CLIENT: Shire Augusta Margaret River	DRAWING NO: 190802–S4	APPROVED: Tim Moore
PROJECT: Limestone Cliff Assessment and Stabilisation	DESIGN: T. Moore	DATUM: 1:100 UON / SCALE: 1:250 UON / A3 4/4
TITLE: Site Plan and Structural Details To Riflebutts Beach (Site PR6–85)		

REVISION	DRAWN	DESCRIPTION
10/9/19	TM	DRAFT ISSUE

CIVIL/STRUCTURAL CONSULTING Pty Ltd
Civil, Structural and Environmental Engineers and Project Managers
41 Townview Tce
(P O Box 852)
MARGARET RIVER WA 6285
TEL: (08) 97572488
Mobile: 0419 969 010
E–mail: tim@cscmr.com.au

Appendix D
Risk Assessment

CMW Geosciences

SHIRE OF AUGUSTA MARGARET RIVER

LIMESTONE STABILITY ASSESSMENT

GRACETOWN, PREVELLEY, GNARABUP, WESTERN AUSTRALIA

DESIGNER:	LGL
CHECKED:	MAT
REVISION:	0
DATE:	18/10/2019
PROJECT:	PER2019-0229

Location	GRACETOWN, PREVELLY, GNARABUP - WESTERN AUSTRALIA						
Site ID	**GC6-60**	**GC6-15**	**GC5-75**	**PR4 - 30**	**PR6 - 85**		**GN - 5**
Location Description	**Southpoint carpark undercut**	**Southpoint carpark stairs**	**Cliifs south of stairs**	**Surfers Point**	**Cliffs at Riflebutts Beach**		**Stairs leading to upper carpark at White Elephant**
Main Hazard Type	**Rockfall onto foreshore**	**collpase of ground under stairs**	**undercuts collapsing onto beach**	**Collapse with spectators above**	**Rockfall impacting sunbathers**	**Rockfall impacting walker/dog walkers**	**Collapse underminning stairs**
Risk for Person Most at Risk	$R_{(DI)} = P_{(H)} * P_{(S:H)} * P_{(T:S)} * V_{(D:T)} * N$						
R_{DI}	**5.42E-07**	**7.91E-08**	**6.18E-06**	**1.14E-05**	**6.25E-04**	**1.13E-04**	**8.68E-06**
$P_{(H)}$	1.00E-01	2.00E-02	2.00E-01	1.00E-01	3.65E+02	3.65E+02	1.00E-01
$P_{(S:H)}$	1.14E-01	1.00E+00	6.25E-02	1.00E+00	6.25E-04	6.25E-04	2.50E-01
$P_{(T:S)}$	9.51E-06	1.90E-06	9.51E-06	5.70E-04	3.42E-04	9.51E-06	1.90E-06
$V_{(D:T)}$	0.50	0.02	0.50	0.10	0.80	0.50	0.50
N	10	104	104	2	10	104	365
Total Societal Risk	$R_{(SOC)} = IR_{(DI)} * N_{(SOC)}$						
$R_{(SOC)}$	**1.08E-07**	**3.81E-09**	**2.97E-07**	**1.14E-04**	**1.25E-04**	**2.17E-06**	**2.38E-07**
$IR_{(DI)}$	5.42E-08	7.61E-10	5.95E-08	5.70E-06	6.25E-05	1.09E-06	2.38E-08
$N_{(SOC)}$	2	5	5	20	2	2	10
Cumulative Individual Risk	$R_{(DI)} = IR_{(DI)} * T$						
$R_{(DI)}$	1.98E-04	2.78E-05	2.17E-03	2.28E-04	6.25E-02	1.58E-02	**2.08E-03**
T (total number of individuals visiting the site each year)	3650	36500	36500	40	1000	7300	87600
Total individual visitors per day in a year	10	100	100	ad hoc	seasonal	20	240
Notes	*P(H) assumes total collapse every ten years	*P(H) assumes major collapse every 50 years	*P(H) assumes major collapse every 5 years	*P(H) assumes total collapse every ten years	*P(H) assumes one boulder falling once a day		*P(H) assumes likelihood of undercut collapsing as a large single slab 1 in 10 years
	* P(S:H) assumes potentiall impact area of 90m2 and hazard area of 790 m2	* P(S:H) assumes everyone affected	* P(S:H) assumes potential impact area of 25m2 and hazard area of 400 m2	* P(S:H) assumes everyone on the overhang is affected	*P(S:H) assumes an impact zone 80x5m, boulder size 0.5x0.5m and area of person exposed to impact 1m2	*P(S:H) assumes an impact zone 80x5m, boulder size 0.5x0.5m and area of person exposed to impact 1m2	*P(S:H) assumes 25% of stairs would be impacted
	*P(T:S) 5 min in impact zone	*P(T:S) 1 min in affected zone zone (time on steps)	*P(T:S) 5 min in impact zone	*P(T:S) assumed 5 hours per year as mainly people don't jump the fence	*P(T:S) assumes sunbathing conditions, 3hrs per visit	*P(T:S) assumes walkers, 5 mins per visit	*P(T:S) assumes assumes stairs occupied for 60 seconds per person during daylight hours, with 10 people at one time and 240 people per day
	*V(DT) assumed 0.5 chance of getting killed if collapse occurs	*V(DT) assumed 1:50 chance of getting killed if collapse occurs (likely to affect only servieability)		*V(DT) assumed 1 in 10 get killed during collapse	*V(DT) assumes high likelihood of death if struck by rock	*V(DT) assumes lower likelihood of death if struck by rock when walking than sunbathing	*V(DT) assumes moderate likelihood of death if stairs to collapse due to undercut collapse
	N = average number of visits by indivudual most at risk/year	N = average number of visits by indivudual most at risk/year	N = average number of visits by indivudual most at risk/year	N = average number of visits by indivudual most at risk/year	N = average number of visits by indivudual most at risk/year	N = average number of visits by indivudual most at risk/year	N = average number of visits by indivudual most at risk/year
	*N(SOC) assumes 2 people present at one	*N(SOC) assumes 5 people present at one time	*N(SOC) assumes 5 people present at	*N(SOC) assumes 20 people present at one time	*N(SOC) assumes 2 people present at one time	*N(SOC) assumes 2 people present at one time	*N(SOC) assumes 10 people present at once
	*T assumesy 10 people per day, 365 days a year transit the hazard zone	*T assumes the stairs are used by 100 people per day, 365 days a year	*T assumes the stairs are used by 100 people per day, 365 days a year	*T assumes the rock ledge is only used twice a year by 20 people	*T assumes the beach is used by 1000 sunbathers (total) in summer months	*T assumes the beach is used by 20 walkers/dog walkers on average every day of the year	*T assumes the stairs are used by 30 people per hour, 8 hours a day, 365 days a year

Risk for Person Most at Risk, R(DI) = P(H) * P(S:H) * P(T:S) * V(D:T) * N

Risk Variable	Assumptions and Comment
$P_{(H)}$	PH describes the annual probability of a rockfall or slope collapse occurring of sufficient size to cause loss of life. This might vary from daily falls 365 to 1:10 year 0.1
$P_{(S:H)}$	PS:H describes the probability of spatial impact. The special impact area divided by the total hazard area provides the probability of spatial impact. The total hazard area is the area where is it reasonable to assume rockfall could impact if it occurs to where ground may be destabilised if slope collapse occurs.
$P_{(T:S)}$	PT:S describes the temporal spatial probability for recreational users, in other words, the probability that a person will be in the hazard zone at any given time of the year. There is a wide range of recreational users visiting the sections of coastline being analysed. Many users spend very little time in the rockfall or slope collapse hazard zones (e.g. dog walkers) while others are present for a more significant time (e.g. beachgoers, sport spectators for surf competitions).
$V_{(D:T)}$	VD:T describes the vulnerability of the individual. The chance of a fatality should the individual be struck by a falling, bouncing or rolling rock, or be standing on a collapsing ledge.
N	N describes the average number of times the person most at risk visits a location each year.

Total Societal Risk, $R_{(SOC)} = IR_{(DI)} * N_{SOC}$

Risk Variable	Assumptions and Comment
$IR_{(DI)}$	IRDI is the individual risk of death (IRDI) for each person who visits a site. This risk is the same as the R(DI) presented above except it does not account for repeat visits by the same person.
N_{SOC}	NSOC represents the potential number of people that could die in a single rockfall or collapse event.

Cumulative Individual Risk, $R_{(DI)} = IR_{(DI)} * N_{(SOC)}$

Risk Variable	Assumptions and Comment
$IR_{(DI)}$	IRDI is the individual risk of death (IRDI) for each person who visits a site.
T	The total number of individual visitors to a site each year.

Appendix E
Monitoring Protocol for Shire of Augusta Margaret River Staff

1 INTRODUCTION

This appendix includes a monitoring protocol requested by SAMR to provide guidance for their officers to note changing conditions that could present a risk to public safety with respect to rockfall or coastal cliff/slope instability.

It is suggested that the *May 2017 Limestone Cliff Stability Assessment* by Golder Associates and the October 2019 *Limestone Stability Assessment* by CMW Geosciences become reference documents. Ongoing observations carried out by Shire officers should be compared against observations and the risks described in these documents to assess if slope form is changing and whether or not the prevailing risk to public safety is changing. E.g. loss of a fence or sign could result in an increased risk to public safety.

This appendix is not intended to provide training in geotechnical engineering but instead provide a simple framework by which a Shire officer can review changes and be provided with guidance as to actions to implement.

2 HEALTH AND SAFETY

Shire officers are not trained landslide risk professionals and as such will not necessarily be able to fully evaluate personal risk when approaching potentially unstable outcrops and overhangs. For this reason, it will not be possible for them get as close to individual coastal features requiring assessment as would be the case with a trained geotechnical professional who can assess personal risk, for instance prior to passing beneath an overhang.

For this reason, the Shire officers should NOT engage in any of the following when carrying out inspections:

1) *Crawl or walk beneath overhangs*
2) *Stand on top of overhangs*
3) *Scramble or climb up cliff faces, or on slopes containing boulders or cobbles that could be dislodged*

In addition, it is expected that a detailed Job Safety Analysis is undertaken, all work is carried out with a spotter, risks are continually assessed, and work stopped if conditions change.

Appropriate PPE should be worn, comprising steel capped boots with sole with good grip, long trousers, long sleeve shirt, high visibility clothing, safety glasses and leather work gloves and hard hat when in rockfall zones.

Locations at the top of the overhang at GS5-75 are considered high risk to be surveyed by anyone other than geotechnical professional. These locations have been included as reference points for comparison purposes as and when SAMR next appoint a geotechnical professional who can make their own risk assessment prior to accessing this location. In the meanwhile any inspection undertaken by SAMR of GC5-75 should be undertaken entirely from the beach.

3 REFERENCE POINTS AND PHOTOS

At four of the six sites, reference points have been established comprising of a *surveyor's nail* with labelled tag (refer Appendix E Slide 3 for example). These are used either to indicate access points to a feature (as is the case for GC5-75) or mark the general locations where a reference photograph is to be taken. The nails are drilled into rock for permanency. It may however be necessary to move slightly away from the exact nail location for safety reasons, for instance to avoid being too close to a steep edge or so the observer is not standing on an uneven boulder.

The following Slides are intended as a set of reference photographs to be reproduced as close as possible following each successive future inspection to review whether changes can be detected.

Nearmap imagery is updated frequently and use of past and latest *Nearmap* imagery is recommended to illustrate change, especially where wave erosion, for instance at Riflebutts beach has a significant influence.

4 MONITORING FREQUENCY

A future monitoring frequency of every 6 months except for stairs leading to the beach (end of winter /end of summer) documented for all locations in the 2017 report is recommended with a geotechnical inspection and risk assessment carried out by a geotechnical professional with experience in landslide and slope risk assessments every 2 years. These monitoring and inspection frequencies may change following certain observations as documented in the *Action and Event Tree* provided below.

It is recommended that the monitoring frequency for beach stairs is three monthly or following a major storm event. This because of the risk of erosion undercutting supporting stanchion or erosion the coastal slope on which the stairs are founded and causing instability.

Special inspections would also be required following exceptional storm events or if reports of erosion or damage have been lodged.

5 ROCKFALL/SLOPE STABILITY CHECKLIST

A rockfall /slope stability checklist is provided below. This should be completed for each site to be inspected. Depending on how the questions are answered certain actions may be triggered. E.g. if a sign is missing arrangement for replacement is triggered.

6 ACTION AND EVENT TREE

An action and event tree is provided below. This tree navigates the Shire officer through a series of questions that need to be answered during the inspection. Depending on events (e.g. observation of changes to cliff (for instance. increased undercutting)) an action is trigger. E.g. if the event results in imminent risk to public safety the action is implement '*immediate measures to prevent public access'*.

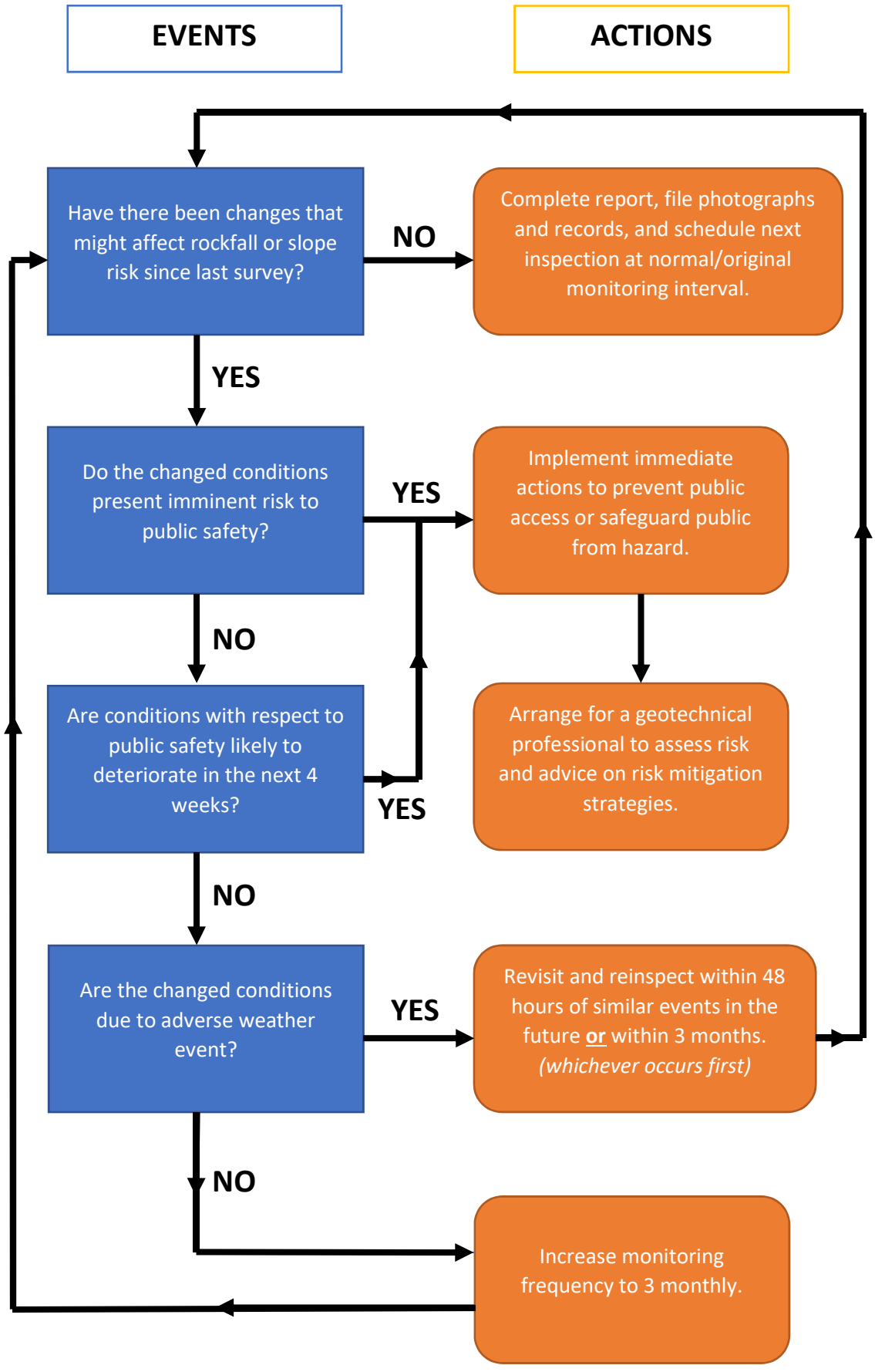
7 REPORTING

The following is envisaged as a reporting requirement following each inspection.

1) Photographs files by date and site location number.
2) A PowerPoint presentation (labelled with date of inspection) presenting the reference photograph or photograph from the last inspection against a photograph from the current inspection with any changes annotated.
3) A completed and dated rockfall checklist for each of the site inspected, including the name of the officer undertaking the inspection
4) A brief (generally single page) report for each location highlighting any actions required (informed by using the action and event tree).

	ROCKFALL/SLOPE STABILITY CHECKLIST **Date: Site Ref. No: Completed by:**	**YES**	**NO**
1.	Correct PPE available?	☐	☐
2.	Safe work method statements, JSA in place, approved and signed off?	☐	☐
3.	Previous survey available to reference in field?	☐	☐
4.	Peripheral assessment: Is site safe to approach for detailed assessment? ***Never walk/crawl under overhangs, stand on overhangs or climb/scramble up cliffs or slopes comprising cobbles and boulders. Keep away from steep edges.***	☐	☐
5.	Are permanent warning signs still in place? ***If NO, arrange for urgent replacement.***	☐	☐
6.	Are fences keeping public away from 'at risk areas' intact and in good state of repair? ***If NO, arrange for urgent repairs and temporary fencing in interim.***	☐	☐
7.	Has vegetation shielding rockface/slope from erosion been damaged? ***If YES, is replacement vegetation or other controls needed?***	☐	☐
8.	Has the incidence of rockfall or slope instability increased since last inspection? ***If YES, commission geotechnical professional to re-assess risk and advise on risk mitigation measures.***	☐	☐
9.	Has cliff/slope form or profile changed since last inspection? **Refer reference photographs for comparison and flow chart for actions needed.**	☐	☐

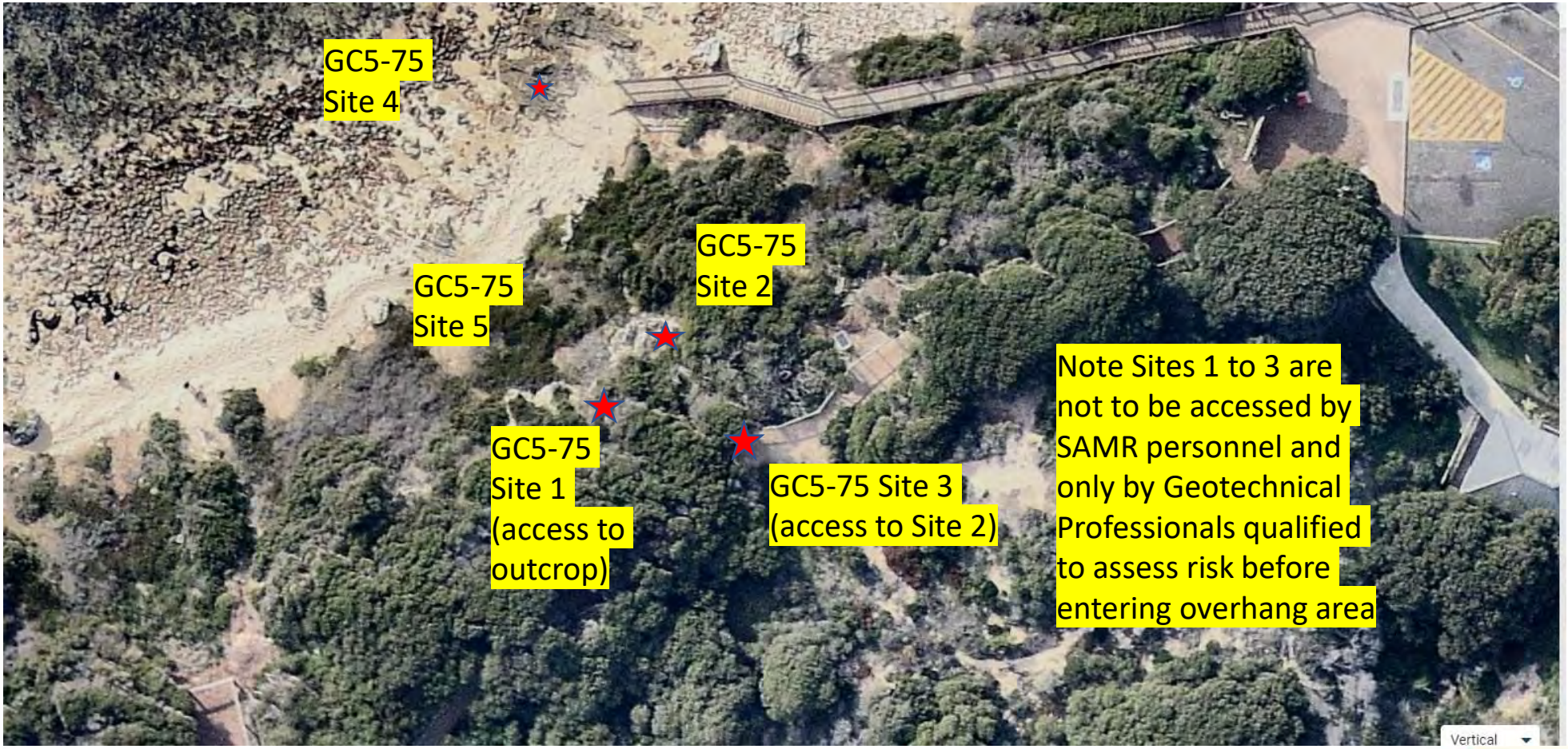
ACTION AND EVENT TREE FOR CHANGING ROCKFALL/SLOPE RISK



Appendix E

Reference Photographs (11 October 2019)


GC6-60
GC6-15
Gracetown
Southpoint Carpark
GC5-75
4.22 m


GC5-75
Site 4
GC5-75
Site 5
GC5-75
Site 2
GC5-75
Site 1
(access to
outcrop)
GC5-75 Site 3
(access to Site 2)
Note Sites 1 to 3 are not to be accessed by SAMR personnel and only by Geotechnical Professionals qualified to assess risk before entering overhang area
Vertical

Site 1 – Access outcrop from here to take photo on right

This site is not to be accessed by SAMR personnel and only a by Geotechnical Professional qualified to assess risk before entering overhang area

Use this location for future comparison

Site 3 – Access outcrop and Site 2 from here to take photo on right

This site must not be accessed by SAMR personnel and only by a Geotechnical Professional qualified to assess risk before entering overhang area

Use Site 2 (general proximity) to take reference photograph for comparison with this base photo. ***Exercise extreme care in this area and do not stand directly over marker point and do not stand on overhang or directly on steep edge***

Site 4 is located on this outcrop at base of stairs

Use Site 4 to take reference photograph of whole of outcrop for comparison. Note it is not considered safe to scrabble cliff to take direct measurements.

Site 5 is located on boulder close to base of slope and can be seen in Slide 2

Use Site 5 to take reference photograph of whole of outcrop for comparison. Note it is not considered safe to scramble the cliff to take direct measurements.


GC6-15 Site 1
GC6-15 Site 2
GC6-15 Site 4
GC6-15 Site 3

Reference photograph of stairs from outcrop showing erosion as at 11 October 2019

Site 1 is nail on this outcrop

Sites 2, 3 and 3 (GC6-15) are shown located on pegs like example.

Reference photograph of undercut outcrop for future reference

Reference photograph of erosion on west side of outcrop with stair in background for future reference


GC6-60 Site 1
GC6-60 Site 2

Reference Photograph from Site 1.
Note this slope comprises boulders in a sandy matrix and it is dangerous to scramble up and thus survey should be conducted from beach and carpark.

Reference Photograph (zoomed) from Site 1

Note this slope comprises boulders in a sandy matrix and is dangerous to scramble up and thus survey should be conducted from beach and carpark.

Reference Photograph (zoomed) from Site 1

Note this slope comprises boulders in a sandy matrix and is dangerous to scramble up and thus survey should be conducted from beach and carpark.

Reference Photograph from Site 1 looking east

Site 2 – GC6-60 at carpark level is the photo reference point looking in an easterly direction

Reference photographs taken from Site 2

Reference Photo taken from stairs as shown (there is no marker nail)

Reference Photo taken from stairs as shown (there is no marker nail)

View from rockfall sign. Look for and note new rocks and boulders on beach that have fallen since last survey

Check monthly for new imagery on *Nearmap* and compare with past imagery to note major changes or major rockfalls

Observe if undercutting is increasing or active. Undertake surveys following major storm events.

Look for and record fresh features like these. White indicate recent drop-outs (left photo) and impact marks (right photo)


Site 2 in wall (two nails)
Site 3 on flat rock slab
Site 2on flat rock close to change in direction of hand rail

Reference photo from near site 1

Survey nails at Site 2

Separation should be measured each survey. Separation (centre to centre) on 11 October 2019 was 101 mm and crack width at nails (6 mm) indicating 6 mm of subsidence to wall beneath stairs

Reference photograph taken from Site 2.

Surveyors nail mark Site 3

Reference photographs taken from Site 3