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GRACETOWN, PREVELLY, GNARABUP, GRUNTERS, WESTERN AUSTRALIA

LIMESTONE CLIFF RISK ASSESSMENT

Shire of Augusta Margaret River

Job No. PER2023-0291AB | Rev 1

Perth

Suite 1 | Level 3
29 Flynn Street
Wembley WA 6014
Australia

Ph: +61 8 6555 4920

www.cmwgeosciences.com

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Prepared by	Matthew Tutton, Senior Principal Geotechnical Engineer 
Reviewed by	James Field, Principal Engineering Geologist 

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Appendices

1.0 INTRODUCTION

On 13 February 2024 CMW Geosciences Pty Ltd (CMW) received a Letter of Award from the Shire of Augusta Margaret River (SAMR) and a signed contract to carry out Contract RFQ 112314 relating to a Review for Limestone Cliff Stability based on field monitoring.

Details of the scope of work and methodology are documented in CMW's response to the RFQ 112314 in a proposal to SAMR dated 30 November 2023 (ref. PER2023-0291AA_Rev0).

In summary, a number of coastal sites are the subject of ongoing stability monitoring. Further details of the project background are provided in Section 2.0 of this report.

This commission required the consultant (CMW) to undertake a monitoring audit of the following sites listed in the previous Limestone Cliff Assessment Report (March 2022):

- GC3-50,
- PR4-30,
- PR4-100,
- PR6-85 (Whole of Riflebutts Cliff Area),
- GN3-40/GN3-90 (area below Gnarabup Lookout,
- GR2-20 and
- GR3-1

A part of the scope of works also included a reinspection of almost all areas documented in the March 2022 report with a focus on monitoring.

As such, all sites except Wallcliffe have been reinspected. This is because Wallcliffe was only included in the March 2022 report (November 2021 inspection) for the purpose of giving specific advice relating to a tender for contractors to remove climbing bolts.

This report contains an assessment of the current conditions at various sites in Gracetown, Prevelly, Gnarabup and at Grunters, along with details of the prevailing risks or confirmation of no change in risk level since the last assessment.

This report also documents proposed new risk mitigation and preventative works. These works are recommended to either:

1) reduce the current level of risk or

2) address an issue (e. g erosion) that if left uncontrolled could result in future higher level of risk or the creation of a new hazard.

2.0 PROJECT BACKGROUND

Earlier 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.

These earlier studies include a recent study undertaken for SAMR by Golder Associates and reported upon in May 2017. The title of the report relating to the May 2017 study is "Limestone Cliff Stability Assessment".

This was a comprehensive study of limestone cliff geology and stability, and had a particular focus on relative risk to people and to SAMR assets in the context of sea level rise at Gracetown, Prevelly, Gnarabup Headland and Grunters Beach.

An additional study was undertaken by CMW in 2019, where six 'higher' risk locations identified in the Golder 2017 report were re-assessed and some remediation/risk mitigation works were advised.

In November 2021, CMW undertook a further Limestone Cliff Risk Assessment (report reference PER2021-0300AB, dated March 2022).

The November 2021 assessment is the last full assessment of all sites being monitored and therefore forms the point of reference against which change is noted herein.

At the time of the most recent inspection (March 2024), an audit was undertaken to see if recommendations made following the November 2021 had been enacted and whether they had been successful in mitigating risk or controlling erosion.

3.0 PROVIDED INFORMATION

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

- Golder Associates 2017; Limestone Cliff Stability Assessment - prepared for the Shire of Augusta Margaret River (reference 1666765-001-R-Rev0, dated May 2017)
- CMW Geosciences 2019; Limestone Stability Assessment – prepared for the Shire of Augusta Margaret River (reference PER2019-0229AA Rev1, dated 25 October 2019)
- CMW Geosciences 2022; Limestone Cliff Risk Assessment -prepared for the Shire of Augusta Margaret River (reference PER2021-0300AB Rev0, dated 22 March 2022)

4.0 SITE INSPECTION AND RECOMMENDATIONS

4.1 Preamble

4.1.1 Summary

The limestone cliff stability audit was undertaken in the field on 1 and 5 March 2024 by Matthew Tutton, Senior Principal Geotechnical Engineer & Engineering Geologist from CMW.

The observations are described below and are illustrated on Slides included in Appendix A.

Appendix A includes some photos comparing features observed in November 2021 with the same feature observed in March 2024.

Recommendations provided in this section of the report (Section 4) are also highlighted on the Slides in Appendix A (yellow text on grey background).

The quantitative risk assessment presented in the previous monitoring report (CMW Geosciences, ref. PER2021-0300AB Rev0, dated March 2022) has been updated and is included in Appendix B. For ease of reference, the recommendations made below (and in Appendix A) are also tabulated in the risk assessment.

In many cases there has been no change to the type or probability of occurrence and no change in visitor numbers or their exposure level, thus risk levels remain unchanged for many locations from the November 2021 assessment.

In other cases, recommendations are provided for risk reduction/remediation. These recommendations are discussed in the following sections of this report. A summary of the locations with mitigations recommended are presented below, with detailed descriptions provided in Sections 4.2 thru 4.27, and the appendices.

Table 1 – Summary of Hazard ID and Recommended Mitigation

Hazard ID	Recommended mitigation
GC3-50	Upgrade, extend and realign fence, install informative signage and install rockfall signage – future LiDAR/photogrammetry surveys
Southpoint carpark stairs	SAMR to monitor the situation regarding erosion of the beach and place riprap or other beach erosion control measures on an 'as and when required' basis. Stanchions to stairs be extended and secured to new footings if they become undercut.
GC5-75	Install brushwood to encourage vegetation growth and discourage informal path usage
GC6-15	Install additional brushwood to encourage vegetation growth and discourage informal path usage
GC6-50	Install rockfall hazard sign – Install brushwood to encourage vegetation growth and discourage informal path usage
PR3-165	Repair fence/close gap between fences at BBQ area/ install brushwood to stop informal path usage
PR4-30	Security recommended to prevent access during surf competitions
PR5-50	Install rockfall hazard sign (location as described in Section 4.14.2 of report)
PR4-100	Additional brushwood recommended to discourage access to top of ledges, fence maintenance, fence improvements (see Section 4.13.2 of report)
GN1-50	Reinstall damaged rockfall signage
GN5-5	Coastal erosion to be monitored by suitable specialist
GN3-40	Extend fence/rehabilitation/erosion control measures (refer Section 4.19.2 of report)
GN3-90	Extend fence/rehabilitation/erosion control measures (refer Section 4.19.2 of report)
GR2-20	Temporary fencing erected each summer (Nov to April). Install a permanent fence (as shown in Slide 53 -this report)

4.1.2 Risk Calculation Method

The method of calculating risk is principally in accordance with the Landslide Risk Management Guidelines AGS 2007. It tries to mirror the approach taken by Golder (2017); however with changing conditions some of the inputs are different.

Definitions of the various terminology are reproduced in Appendix C for convenience.

Note the criteria for acceptable and tolerable risk needs to be determined by SAMR; however guidance in AGS 2007 suggest the following limits for tolerable risk for existing slopes.

Table 2 – Tolerable Risk for Loss of Life (existing slopes)

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 but can be used to assess risk where many people are visiting a hazardous location. Appendix B relates to the observed conditions before any of the proposed future risk mitigation or remedial works – as outlined below - are undertaken. The only exceptions to this are as follows:

a) It is assumed that any damaged fencing will be promptly reinstated.

b) Measures that are recurring, such as the provision of temporary summer fencing, will continue to be erected.

c) Security at surf competitions will continue to be used to prevent access onto rock ledges and the coastal slopes at Surfer's Point.

SAMR officers should review the assumptions presented in Appendix B 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 where the Hazard ID is coloured **'green'** in the risk assessment are those where remedial/risk mitigation works beyond signage, brushwood and revegetation are recommended, to readily identify sites for which specific action is required.

Some of the cells in Appendix B have been coloured to draw attention to higher levels of risk:

- For the *Individual most at risk* and *Societal risk* any level of risk higher than $1x10^{-5}$ is highlighted as **'red'**, to demonstrate the greatest level of risk that requires addressing.
- Any risk greater than $1x10^{-6}$ but less than $1x10^{-5}$ is highlight as **'yellow'**, to demonstrate a significant level of risk that requires addressing.

These risk levels can be compared with the risk levels tabulated above for Tolerable Risk for Loss of Life.

The sub-section below discusses those locations where the assessed level of risk has changed.

The 'Site ID' originally used by Golder in their 2017 report continues to be used in this assessment. The letters GC, PR, GN and GR refer to Gracetown, Prevelly, Gnarabup and Grunters respectively.

As the Golder (2017) report extensively describes the hazard, and indeed the geology, geological and coastal processes that have shaped this coastline we have not re-described the hazard in detail or re-iterated the geology. If details are required reference should be made to the 2017 Golder report.

The Golder report also provides detailed maps regarding the locations of all the 'Site IDs'. Whilst these location plans are not reproduced in this report, an annotated aerial photograph is provided with each 'Site ID' in Appendix A so the reader than reference the location of the hazard in relation to local features on the beach or adjacent paths, lookouts etc.

Gracetown

4.2 Site ID: GC3-50

4.2.1 Observations

Hazard Site ID GC3-50 is Huzzas Cliff; the location of the 1996 Gracetown Tragedy, where 5 adults and 4 children were tragically killed by a cliff collapse.

Slide 1 (Appendix A) shows the location of GC3-50 and Slides 2 to 4 illustrate the hazards and March 2024 observations. Slides 4 to 6 present recommended risk mitigation works.

A drone was used during the March 2024 observations and three distinct hazards can be seen from the air. These are documented on Slides 2 and 3.

The risk assessment for Huzzas Cliff has been updated for each hazard separately and then the risk has been summarised.

In the context of risk assessment, it is assumed people do not access the area inside the fence (i.e. under the overhangs themselves). It is however noted that the existing fence is too close to the hazard to keep people out of the hazard zone should a major collapse occur. The problem is that there is not enough space to move the fence seaward by any substantial distance.

Risks have therefore been assessed based on the current fence position. Note that the fence is closer to the cliff at the eastern end of Huzzas Cliff.

The level of risk for the Individual Most at Risk ranges between **1.4×10^{-5}** and **2.9×10^{-6}** for the three separate hazards.

Logically, the individual most at risk would be exposed to all of these hazards and as such the individual risks can be summed resulting in a total risk to that person of **2.3×10^{-5}**. **This is the highest risk level of any of the limestone cliff sites inspected**.

Measures are needed to reduce the number of people visiting/transiting this area to reduce level of risk. This could be achieved through a strategically placed combined informative/warning/instruction sign.

4.2.2 Recommendations

Signage

The March 2022 report recommendation that 'Informative' signage be installed in positions similar to those indicated on Slide 6 remains. This has not been undertaken to date.

The informative signs need to be positioned such that the hazard at Huzzas Cliff can be seen from the sign, and that the sign is secured to rock and sufficiently high up the beach not to be washed away or damaged during stormy weather.

The signs should clearly explain (ideally through photographs and diagrams) the nature of the Huzzas Cliff hazards and present a clear message to discourage people from traversing in front Huzzas Beach, particularly at times when a high tide or large swell forces people up to and potentially inside the fence fronting the cliff and therefore well into the hazard zone.

The safer passage (with respect to rockfall risk) is along the waterline at low tide. The safest option is to avoid this part of the beach entirely and to use the path at the top of the cliff to access South Point.

In addition to the informative signs, it was also recommended in the March 2022 report that large "Rockfall Hazard Area" signs be installed at each end of GC3-50 to further warn the public against traversing the area.

CMW noted during the March 2024 inspection that this had not yet been undertaken. This recommendation remains current.

It is noted that the only warning signs at GC3-50 are postcard-sized signs (refer to inset photo on Slide 3). A person would need to already be in the hazard zone that extends outside the existing fence in order to read this sign.

Fencing

In the March 2022 report it was recommended that the existing fence fronting both SAMR and DBCA controlled parts of the cliff, which is damaged, be replaced with a more resilient fence similar to the one installed by SAMR at Riflebutts beach.

The damaged fence has since been repaired but remains on the same alignment and has not been upgraded.

In the March 2022 report it was also recommended that the fence be extended eastwards to prevent access to an area of recent coastal erosion. The proposed alignment of the extended fence is shown on Slide 5.

The recommendations shown on Slide 5 were developed during the onsite workshop on 17 January 2022 attended by representatives from SAMR, DBCA and CMW. These have not yet been enacted, but CMW understands from SAMR that these works are proceeding and are scheduled to be carried out.

Since our inspection of November 2021, informal tracks up and down the steep slope east of Huzzas Cliff have become more prominent. Erosion occurs each time they are traversed. These informal paths can be clearly seen in Slide 4.

The extension of the fence discussed above and the placement of brushwood across these informal paths would discourage foot traffic both down and up the slope and hopefully encourage vegetation to become re-established to help stabilise the coastal slope.

Safe ongoing monitoring

Huzzas Cliff is experiencing erosion by wind and rain, and by coastal erosion at the base.

DBCA have installed measurement pins to enable the rate of erosion (enlargement of the undercut) to be measured by way of a tape measure. This is occurring only at discrete locations along the lowermost undercut and is potentially putting the observer/surveyor in harm's way to take the measurement.

CMW recommends that detailed LIDAR and/or photogrammetry using a drone be considered for both SAMR and DBCA controlled portions of Huzzas Cliff instead.

Permanent surveyed reference points (away from the unstable areas) would be needed to allow each successive LIDAR/photogrammetry survey to be referenced to a common coordinate system and to enable comparison.

It is recommended that repeat surveys be undertaken every 2- or 3-years to enable erosion, development of undercuts and slots, ledge collapses, rockfalls etc., to be accurately documented.

It is noted that a drone survey would likely be centimetre to decimetre scale, and therefore potentially not be as accurate as measuring slot enlargement with a steel tape. However, it would enable the whole feature to be surveyed safely and for changes in cliff profile to be plotted and compared.

4.3 Site ID: GC4-60

4.3.1 Observations

Refer to Slide 7.

No significant change has been observed since the 2021 inspection.

The level of risk therefore remains unchanged.

4.4 Site ID: GC5-75

4.4.1 Observations

Refer to Slides 8 and 9.

The overhang discussed as a high-risk area following the 2017 and 2019 inspections was removed in 2020.

As such, the risk from this hazard was significantly reduced for the public walking on the beach and exiting the bottom of the Southpoint carpark stairs.

The November 2021 inspection indicated there was evidence of pedestrian traffic on the slope face causing erosion.

It was recommended at that time that brushwood be placed on this trafficked area to encourage vegetation growth and to discourage ascending or descending the steep and friable slope below this hazard.

This appears to have been done (refer to Slide 9).

4.4.2 Recommendations

It is recommended that further brushwood be placed to continue to discourage informal paths up and down the slope below GC5-75.

4.5 Southpoint Carpark Stairs

4.5.1 Observations

Refer to Slide 10.

Observations of minor ongoing coastal erosion have been made at this location.

4.5.2 Recommendations

It is recommended SAMR monitors the situation regarding erosion of the beach and places riprap or other beach erosion control measures on an ‘as and when required’ basis.

It is also recommended that stanchions to stairs be extended and secured to new footings if they become undercut.

In this context, the March 2024 inspection noted one supporting stanchion is being undercut and will soon require remediation (see Slide 10).

4.6 Site ID: GC6-15

4.6.1 Observations

Refer to Slide 11.

This hazard area was identified as a high priority area in the 2017 Golder report as a lookout attached to the Southpoint carpark stairs was founded on a potentially unstable block of limestone.

Since that time, the risk to the stairs has been significantly reduced as the lookout was removed and the stairs are set well back from the unstable block, such that they are unlikely to be adversely affected if the potentially unstable block was to fall.

As described in the March 2022 report, the most significant risk is now to beach users: specifically people traversing the rocky foreshore below the unstable block.

Site conditions have not changed since then and the risk level is also unchanged as such.

There is currently adequate signage on the beach below this hazard.

4.6.2 Recommendations

See Slide 12. It is recommended that additional brushwood be placed on unvegetated areas above the beach and below the hazard referred to on Slide 11 in order to discourage people scrambling up the slope.

This may otherwise cause erosion and increase the level of risk.

4.7 Site ID: GC6:50

4.7.1 Observations

Refer to Slides 8, 13 and 14.

This location was not included in the 2017 or 2019 assessments but it was included in the March 2022 report.

If a rockfall of the main hazard identified was to occur in this area, it is not expected to reach the beach in one piece due to the vegetation and other boulders breaking the fall, though it may break into smaller fragments.

There is evidence that this area is used as an informal pathway. Progressive use of this area as a pathway may lead to significant erosion and increase the risk of rockfall.

4.7.2 Recommendations

It is recommended that brushwood be placed to encourage stabilising vegetation growth and discourage informal paths up and down the slope below the carpark.

It is also recommended that a small ‘Rockfall Hazard Area’ sign be installed on the foreshore below the hazard.

4.8 Site ID: GC6-60

4.8.1 Observations

Refer to Slides 8 and 14 and 15.

The vegetation is largely unchanged from the November 2021 inspection and there has been negligible change to the rock mass fracture patterns around the main hazard.

The level of risk therefore remains unchanged.

4.9 Site ID: GC6-100

4.9.1 Observations

Refer to Slides 16 and 17.

Conditions do not appear to have changed significantly since November 2021 and therefore the level of risk remains unchanged.

Prevelly

4.10 Site ID: PR3-165

4.10.1 Observations

Refer to Slides 18, 19 and 20.

The hazard is the overhang breaking off, rolling down to beach level and impacting beach users (see Slide 19).

Conditions of the hazard do not appear to have changed significantly since November 2021 and therefore the level of risk remains unchanged.

However, erosion is noted at the bottom of the slope that has undermined the fence.

Whilst the erosion at beach level is not immediately undercutting the hazard, it does create an easier path for people to take short cuts up and down the coastal slope.

An informal path already leads down from a gap between two fences close the one of the picnic/barbecue shelters at Surfers Point (see Slide 20).

Erosion from these informal paths could increase the likelihood of this particular overhang collapsing or create new hazards.

4.10.2 Recommendations

It is recommended that the fence be repaired as soon as possible.

It is also recommended that the gap between the two fences at the picnic/barbecue area be closed off (see Slide 20) and brushwood be placed on the informal path to encourage stabilising vegetation growth and discourage use.

4.11 Site ID: PR4-30

4.11.1 Observations

Refer to Slides 18, 21, 22 and 23.

The risk in this area was initially reduced by 2019 due to the removal of the lookout and bench prior to this.

It is known that during past surf events, the rock ledge has been used by spectators and media personnel. The assessed level of risk is based on up to 5 people (at once) using the ledge as a spectator platform for up to two events each year each for a 5-hour period.

Risk levels have been reduced from the 2021 assessment based on signage and regrowth of vegetation likely being effective in reducing the number of people on and above the overhang.

The resultant risk is tolerable using the criteria set out in Section 4.1.2 of this report.

Nonetheless, it is still a high level of risk and as such these numbers should be reduced by using security during major events to prevent access onto this ledge.

4.11.2 Recommendations

It is understood that security is now used at such events to stop people from accessing the overhang and this includes media personnel.

This use of security to prevent people accessing the ledge during surf competitions should continue.

4.12 Site ID: PR4-40

4.12.1 Observations

Refer to Slides 18 and 24.

There is no significant change to this hazard since the November 2021 inspection.

There is a good stand-off distance between the hazard and the fence. The fence is in good condition. Signage is well placed and in good condition.

The level of risk therefore remains unchanged from the November 2021 assessment.

4.13 Site ID: PR4-100

4.13.1 Observations

Refer to Slides 25, 26 and 27.

A sign recommended in the March 2022 assessment report has been installed and brushwood has been placed to discourage informal access (see Slide 27).

However, there remains evidence of pedestrian traffic, including on the overhang itself (see Slide 26).

The risk levels remain the same as following the November 2021 assessment (refer to Appendix B).

4.13.2 Recommendations

To reduce the risk, it is recommended that further brushwood is used to reduce the traversing of informal paths and to encourage vegetation growth.

Fencing could also be improved (e.g. mesh panelling to prevent ducking under the single rail fence) to further reduce entry into this area from the southern picnic area at Surfer's Point (see Slide 27).

Note that there is some damage to the fence (broken strands etc.) down at beach level and maintenance is required to this fence to discourage people from entering the area between the fence and the rock ledge.

4.14 Site ID: PR5-50

4.14.1 Observations

Refer to Slides 25 and 28.

The level of risk remains unchanged from the November 2021 assessment.

4.14.2 Recommendations

It is recommended that a rockfall hazard sign be installed 5 m from the hazard at the edge of the cliff, at the location marked 'X' on Slide 28.

4.15 Site ID: PR5-150

4.15.1 Observations

Refer to Slides 25 and 29.

No significant change in conditions observed.

The level of risk therefore remains unchanged from the November 2021 assessment.

4.16 Site ID: PR6-85 and PR6-140

4.16.1 Observations

Refer to Slides 30 to 34.

This is the Riflebutts beach major hazard area and there continues to be evidence of ongoing rockfalls (see Slides 32 and 33).

The most recent major rockfall that occurred in August 2021 (see Slide 32) resulted in about 15 m^3 of limestone falling onto the beach and spilling out about 8 m across the beach from the cliff.

No significant volumes of additional material have fallen since this time.

Tension cracks in the cliff behind the rockfall (see Slide 32) are indicative that a future rockfall is imminent.

However, the substantial fence constructed in 2021 to discourage public access and extensive warning signs, including an informative sign panel (see Slide 31), appear to be significantly reducing the number of people accessing the risk zone.

The risk therefore remains unchanged from November 2021.

Gnarabup

4.17 Site ID: GN1-25

4.17.1 Observations

Refer to Slides 35 and 36.

It is noted that some small rocks are rolling down an erosion chute and reaching the beach but presenting negligible risk to beach users.

The main risk to beach users would be from a larger scale collapse of one of the overhanging ledges seen in Slide 36.

However, little change has occurred around these features since November 2021 and the level of risk remains unchanged (refer to Appendix B).

It is noted that a rockfall hazard sign recommended in the March 2022 assessment report has since been installed (see Slide 36).

4.18 Site ID: GN1-50

4.18.1 Observations

Refer to Slides 35 and 37.

The level of risk remains unchanged from the November 2021 assessment.

It is noted that a new “Rockfall Hazard Area” sign has been erected on the beach at the base of this hazard, though it is damaged (see Slide 37).

4.18.2 Recommendation

The damaged sign (see Slide 37) requires re-installation.

4.19 Site ID: GN3-40 and Site ID: GN3-90

4.19.1 Observations

Refer to Slides 38 to 42.

Hazard Site ID: GN3-40 is closely associated with Site ID: GN3-90. It is an undercut ledge at the western end of the Gnarabup Headland, west of and below the Gnarabup Headland Lookout. Examples of undercut ledges at this location are shown on Slide 42.

The whole area below the lookout in this area is heavily eroded due to people traversing along the ledges below the lookout.

Following the November 2021 assessment, a mesh fence was installed around the lookout to discourage people from ducking under and scrambling down the slope onto the hazardous ledges.

However, measures to discourage public access and to manage erosion do not currently appear to be successful as people are still accessing the Headland via this route. The access routes used are illustrated on Slides 39 and 40.

This has resulted in a heavily trafficked “informal” path that is used to gain access to the Gnarabup Headland or to walk south towards back beach. Foot traffic has caused deep erosion as illustrated in Slide 41 and is contributing to a general level of degeneration of vegetation west of the lookout.

Continuation of its use will ultimately prompt limestone features to collapse or new hazards to occur.

Measures are urgently needed to a) prevent further erosion and b) discourage public access that puts people in the risk zone but is also a major contributor to the erosion being experienced.

The level of risk for both Site ID: GN3-40 and Site ID: GN3-90 has not changed since the November 2021.

However, it is noted that there is significant potential for these risks to increase in the future in ongoing erosion is not controlled.

Formalising this path (e.g. steps and boardwalk) is a potential option to prevent further erosion from foot traffic occurring.

Rehabilitation of the vegetation will also help to mitigate the impacts of wind and rain erosion.

4.19.2 Recommendations

It is recommended that either the fence from the lookout down to the rock ledges be extended to prevent access occurring at the location shown in Slide 40 or that the current heavily trafficked informal path be formalised (steps and boardwalk towards Back Beach) to prevent foot erosion from enlarging the hazard zone.

In case of the former, brushwood and/or revegetation should also be installed to discourage informal pedestrian access and promote vegetation growth in area below the lookout.

It is recommended that the Shire seek advice on how to revegetate and rehabilitate the area affected by erosion west of the lookout and put in place a strategy to rehabilitate and maintain this area.

4.20 Site ID: GN3-100 (Gnarabup Beach Cave)

4.20.1 Observations

Refer to Slides 38 and 43.

No significant rockfalls were noted and the level of risk remains unchanged since the November 2021 assessment (refer Appendix B).

4.21 Site ID: GN5-5 (Stairs above White Elephant Beach Café)

4.21.1 Observations

Refer to Slides 38, 44 and 45.

These stairs were previously built upon a large overhang that was being progressively eroded with the overhang increasing in depth.

Remedial work was undertaken earlier in 2021 to underpin the overhang, thus preventing further weathering and erosion of the ground under the stairs, but also providing physical support to the stairs in doing so.

Vegetation disturbed during the installation of the shotcrete that underpins the former overhang has since re-established since the works were completed and since the November 2021 inspection.

The level of risk remains unchanged since the November 2021 assessment.

However, it should be noted that an area of coastal erosion is present some distance away, albeit not currently affecting the stability of the stairs nor the adjacent limestone cliff (see Slide 45).

4.21.2 Recommendations

It is recommended that the extent of erosion highlighted on Slide 45 is monitored by a suitable specialist.

If this erosion increases in extent, it is recommended that protective/remedial measures are put in place to prevent further erosion before it starts to undermine the stairs and adjacent cliff.

4.22 Site ID: GN5-30

4.22.1 Observations

Refer to Slides 38 and 46.

This hazard feature is a narrow ledge of overhanging rock. The feature does not appear to have changed since November 2021 and the level of risk therefore remains the same as that presented in the March 2022 assessment report.

The risk level is relatively low because the grassed area at the base of the slope below the overhang is not currently used by the café for customer seating. Should this lawned area be used for café seating in the future the level of risk would increase significantly, and consideration might need to be given to collapsing the overhanging ledge of rock as a precaution.

It was noted that the "Rockfall Hazard Area" sign recommended in the March 2022 assessment report has been installed on the lawned area below the hazard.

4.23 Site ID: GN5-100

4.23.1 Observations

Refer to Slides 38 and 47.

No rockfalls or changes to slope geometry were noted and level of risk is unchanged from that given in the March 2022 assessment report.

Grunters

4.24 Site ID: GR1-85

4.24.1 Observations

Refer to Slides 48 and 49.

The level of risk remains unchanged since the November 2021 assessment.

It was noted that a previously damaged fence fronting this hazard area has been repaired and a "Rockfall Hazard Area" signage has since been installed (see Slide 49) following recommendations for these in the March 2022 assessment report.

4.25 Site ID: GR2-10

4.25.1 Observations

Refer to Slides 48 and 50.

The level of risk remains unchanged since the November 2021 assessment.

The "Rockfall Hazard Area" sign recommended in the March 2022 assessment report has since been installed (see Slide 50)

4.26 Site ID: GR2-20

4.26.1 Observations

Refer Slides 48 and 51 to 54.

The level of risk has reduced since November 2021 due to the erection of a temporary summer fence as recommended in the March 2022 assessment report.

If a collapse were to occur, it is estimated that there is a 10% probability that debris would extend onto the beach beyond the temporary fence.

The level of risk presented in Appendix B assumes that the Shire will continue to erect a summer fence (November to April inclusive) at the position shown in Slide 54.

4.26.2 Recommendations

Continue to install the temporary summer fence (November to April inclusive).

Install a permanent fence at the position shown in Slide 53 to prevent people accessing the undercut and cave, and to prevent damage to the dune area below the hazard from the beach.

4.27 Site ID: GR3-1

4.27.1 Observations

Refer to Slides 55 and 56.

GR3-1 was a new location for the November 2021 assessment.

The risk level remains unchanged from the November 2021 assessment.

5.0 FUTURE MONITORING REQUIREMENTS

Risks can change. A major storm causing coastal erosion, heavy rain infiltrating tension cracks or a bushfire affecting coastal vegetation are all events that can result in a greater potential for rockfall.

It is recommended that Shire personnel inspect the sites described in this report following major storms, bushfire or following reports of changed conditions from the public. If there is evidence of greater erosion it is recommended that the Shire engage a geotechnical professional to assess the new risk level and make recommendations to mitigate or manage the risk as required.

Over and above undertaking inspections following such exceptional events, the following future monitoring regime as recommended in the March 2022 assessment report remains applicable:

- Inspection every year (during Spring) at the following locations is recommended:

  GC3-50, PR4-30, PR4-100, PR6-85 (Whole of Riflebutts Cliff area), GN3-40/GN3-90 (area below Gnarabup Lookout area), GR2-20 and GR3-1.

These are locations where the March 2024 level of risk is between **2.3×10^{-5}** and **1.5×10^{-6}**, as defined in Appendix B, and as per the definitions of colour-coding described in Section 4.1.2.

Every two years (during Spring) it is recommended all areas documented in this report are re-inspected.

As part of both the annual and biennial inspections a Quantitative Risk Assessment should be undertaken to assess if the risk levels have changed.

The inspection should also include observations of factors and events that might lead to an increased rockfall risk in the future, if not rectified.

Such observations and events might be factors such as coastal erosion leading to cliff undercutting, new informal pathways where people are accessing a hazard zone, perhaps as a short-cut, or increased erosion due to vegetation disturbance (e.g. from informal pathways, bushfire etc.).

6.0 REFERENCES

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

7.0 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 the Shire of Augusta Margaret River in relation to managing coastal cliff stability risk at a number of 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 / Engineering Geologist

Reviewed By:

James Field
Principal Engineering Geologist

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

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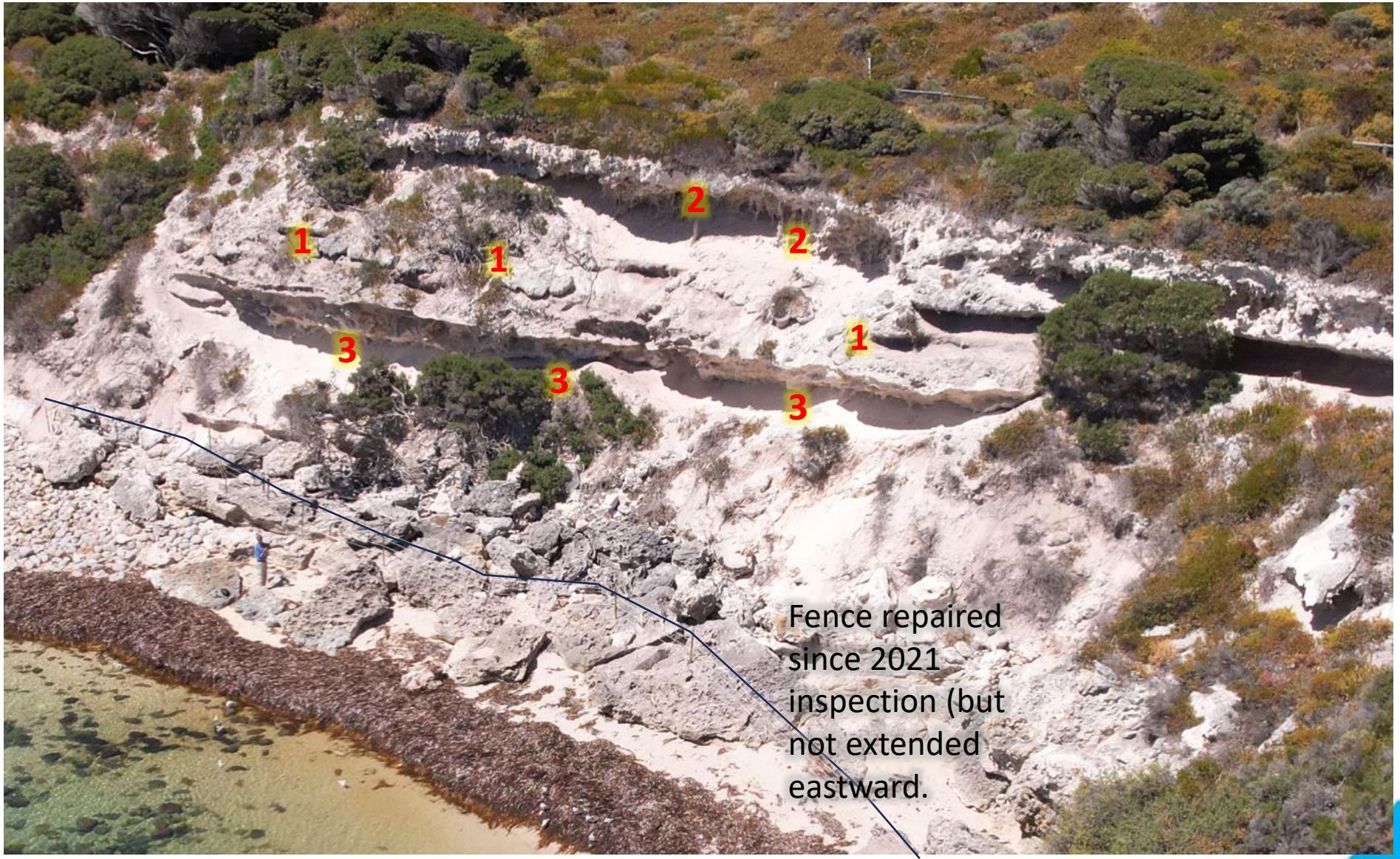
APPENDIX A
Site Observations and Photographs

Gracetown GC3-50 and GC4-60

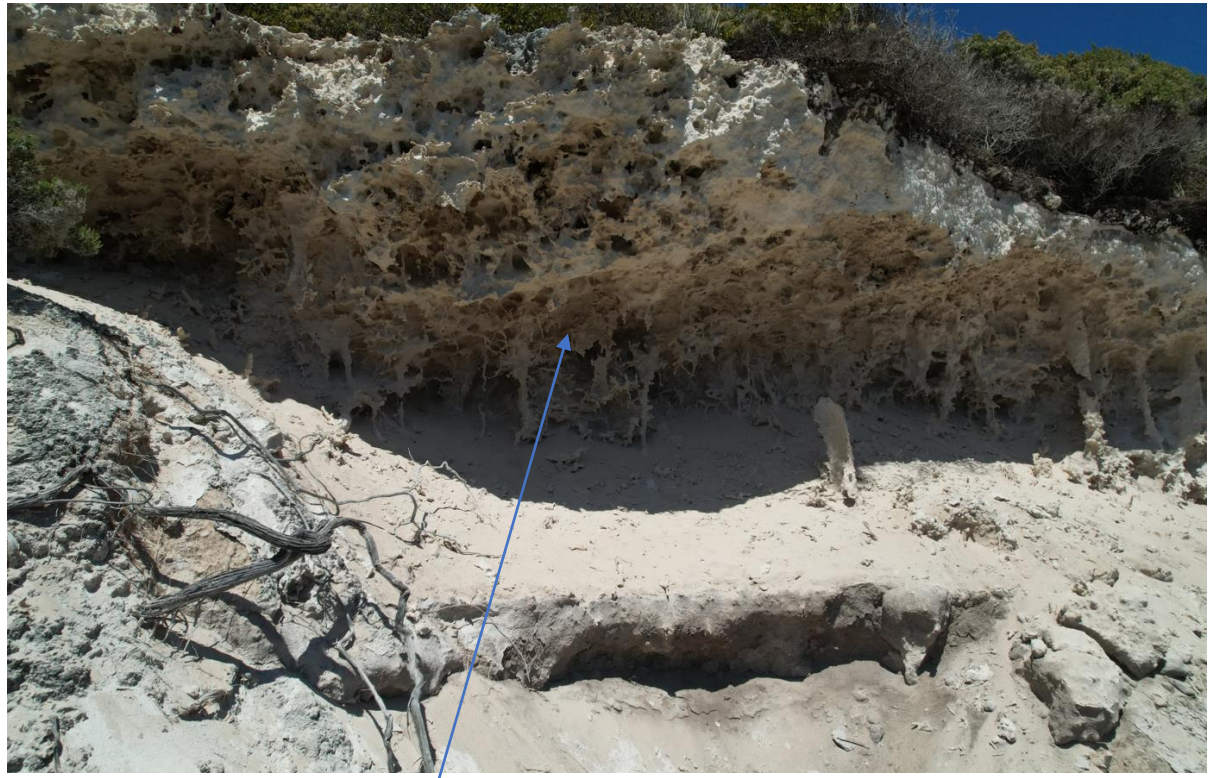


Hazards

1 - Slabs and boulders of rock could slide/roll off steep slope

2 - Slotting occuring in zone of roots could result in parts of ledge like overhang dropping off

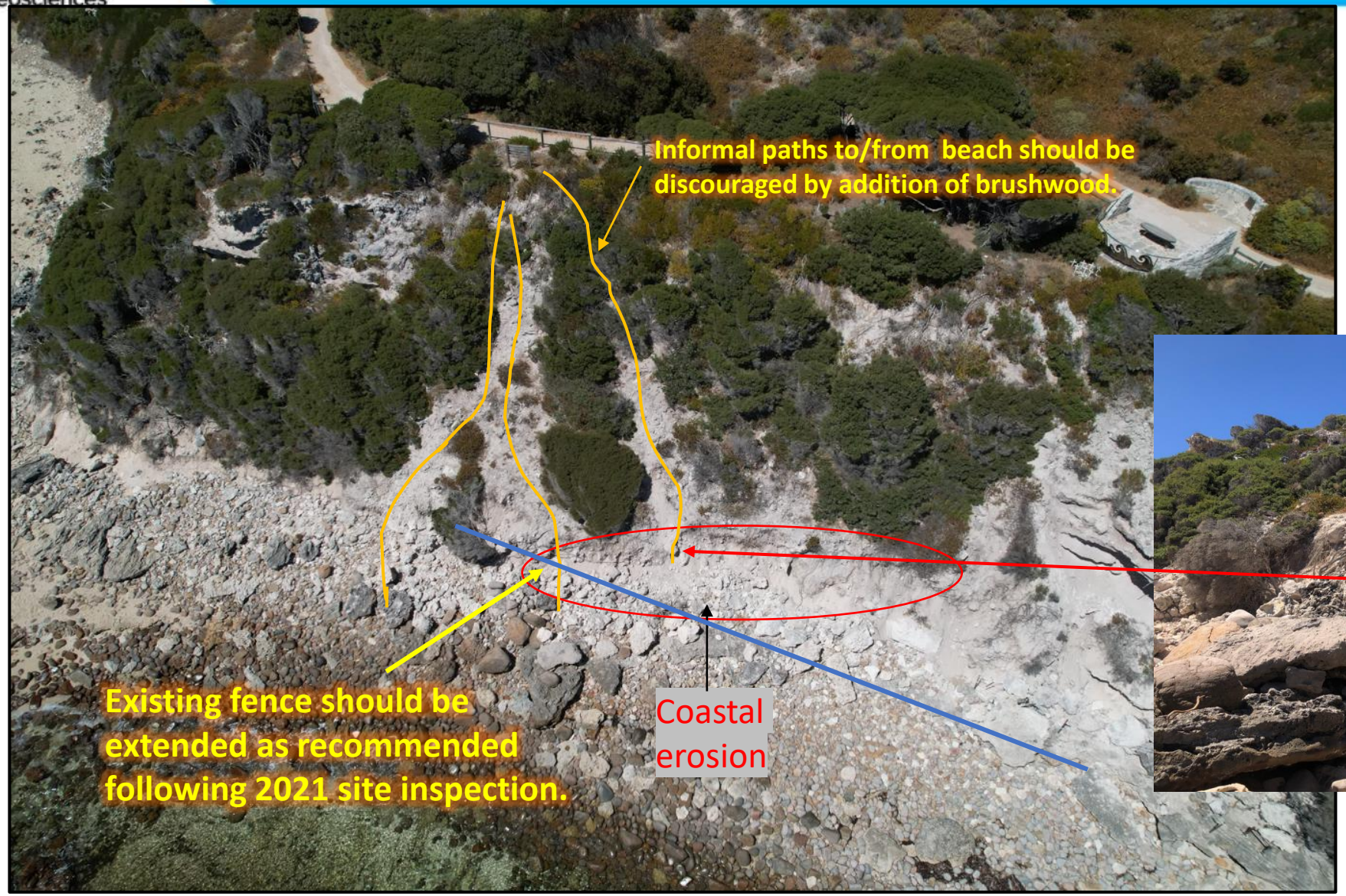
3 - Slotting lower in profile could ultimately result in large scale (whole of cliff) instability



Hazard 1 – Boulders and slabs with potential to roll and slide.

Signage at base of cliff.

Hazard 2 – Overhang experiencing active slotting with potential to locally collapse.


Informal paths to/from beach should be discouraged by addition of brushwood.
Existing fence should be extended as recommended following 2021 site inspection.
Coastal erosion


Upgraded fence recommended at Huzzas Beach, extended eastward to cover an additional area to the east of the present fence.
57.25 m
10.25 m
85°
4.41 m
75.9°
12.57 m
76.9°
6.36 m
79°
16.87 m
98.6°
Approx. extent of existing fence

Recommendation for future monitoring:

Detailed LiDAR survey using a drone be carried out at regular intervals (e.g. every 2 years) referenced to fixed reference points. Comparison between data set would enable the change in general erosion, loss of material through rockfall, coastal erosion etc to be quantified.

Gracetown GC4-60

Nov
2021

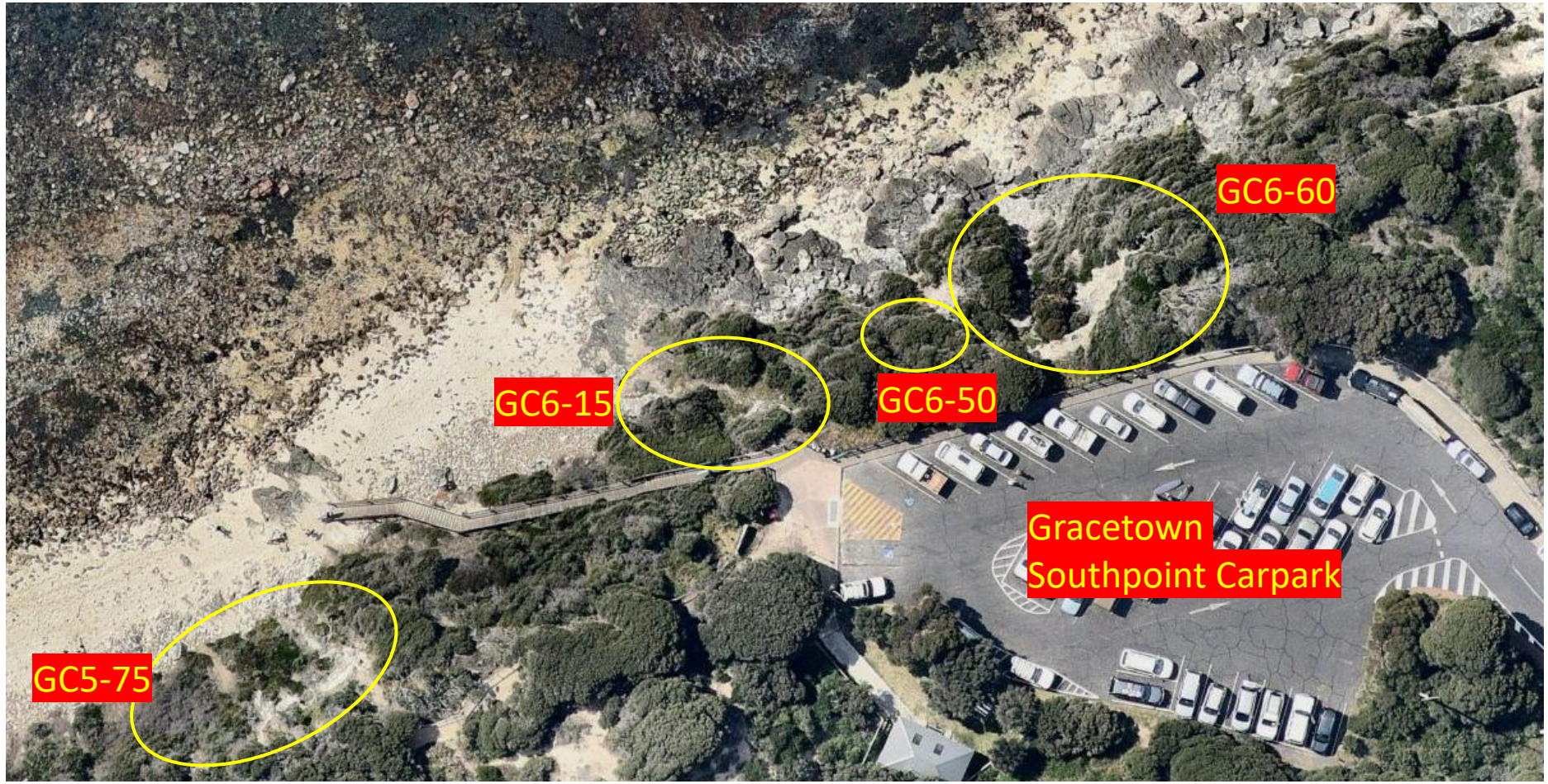
No significant changes to hazard or risk since 2021.

March
2024

Aerial view of overhangs at GC4-60.

Level of Risk to Individual Most at Risk (R_{DI}) remains the same as previous assessment – i.e March 2024 $R_{DI} = 6.1 \times 10^{-7}$.

Gracetown GC5-75, GC6-15, GC6-50 and GC6-60



Gracetown GC5-75

Remedial works (removal of overhang) occurred in May 2020. Subsequently the Level of Risk to Individual Most at Risk (R_{DI}) has reduced to 1.2×10^{-7} and has not change since 2021.
Following the 2021 site inspection it was recommended that brushwood was placed in the erosion chutes below GC5-75.
This was done and the remnants of the brushwood can be seen in left hand photo.

Recommendation
Additional brushwood is recommended to continue to encourage vegetation regrowth and discourage people climbing or descending the slope creating further erosion and putting themselves in the hazard area.

Gracetown (Southpoint Carpark) Stairs

Nov 2021

March 2024

Stanchion supporting lower part of stairs is being undercut and requires extending.

Minor coastal erosion has occurred since Nov 2021. This includes the undercutting shown above and stress to vegetation.

Recommendation

Place brushwood on parts of slope where vegetation has been impacted.

Monitor situation on beach, place riprap or other beach erosion control measures as and when required.

Extend stanchions to stairs if they become undercut – example of stanchion about to be undercut is illustrated above.

Gracetown GC6-15

Note: Since 2017 Golder inspection the lookout that sat on top of this potentially unstable block was removed. Existing steps to beach are a sufficient distance back not to be impacted by this hazard.

Level of Risk to Individual Most at Risk (R_{DI}) relates to a person traversing the rocky foreshore below the hazard rather than the steps above the hazard: R_{DI} =2.9 x 10^{-6}.
No change since 2021.
Note: Photos in this slide are similar to those in the March 2022 report but are actually March 2024 updates.

Recommendation

Place brushwood in this area to discourage use of informal path, prevent erosion and encourage re-establishment of vegetation.

Gracetown GC6-50

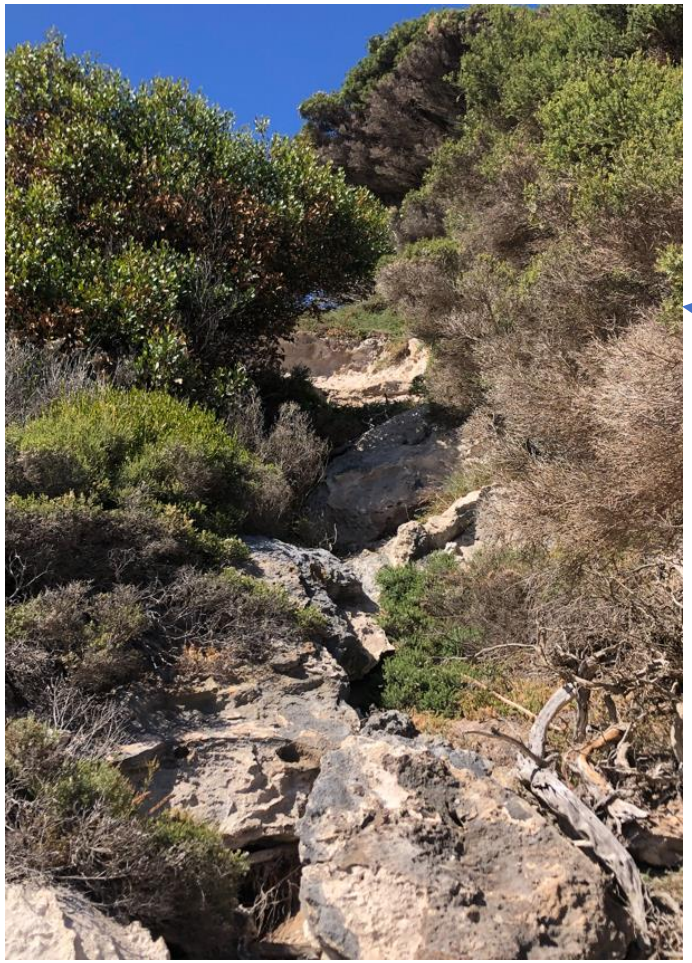
March 2024

Nov 2021

No change since identified as a new location in 2021.
If rockfall was to occur, it is not expected to reach the beach due to vegetation and other boulders breaking its fall.
If it topples, it is likely to fragment into small pieces.
Risk is assessed to be relatively low: R_{DI} =8.6 x10 $^{-7}$

Recommendations
Installation of a rockfall hazard sign. Additional brushwood is recommended to encourage vegetation regrowth and discourage people climbing or descending the slope.

Gracetown GC6-60



No apparent retrogression of embankment to west of GC6-60 since 2021.

March 2024

Nov 2021

Gracetown GC6-60

November 2021

March 2024

Negligible change to fracture pattern since November 2021.

Level of Risk to Individual Most at Risk (R_{DI}) Nov 2021 = 9.75×10^{-7}.

Gracetown GC6-100

Gracetown GC6-100

March 2024

November 2021

Negligible change noted between two inspection dates.

Level of Risk to Individual Most at Risk (R_{DI}) not changed since previous assessment – March 2024 risk level is $R_{DI} = 8 \times 10^{-7}$.

Prevelly PR3-165 and PR4-30

Prevelly PR3-165

Risk to Individual Most at Risk (R_{DI}) not changed since previous assessment in 2021. $R_{DI} = 1.5 \times 10^{-6}$.

Coastal erosion is occurring and there is an informal path (see next Slide) both with potential to increased level of risk if erosion continues.

Coastal erosion undercutting fence south of PR3-165.

Gap in fence south of picnic/barbecue shelter is used to access informal path down limestone slope with potential to cause erosion and increase risk at this location.

Recommendation

Carry out maintenance to fence to keep people off slope and away from limestone ledges - place brushwood across informal path and close gap in fence at picnic area.

Prevelly PR4-30

Prevelly PR4-30

Vegetation cover in front of rock ledge and protecting the ledge from wind erosion is similar to the previous (2021) inspection.

Main risk is to people sitting on top of this rock ledge if it was collapse – however signage and general healthy growth of vegetation suggests few people are accessing the rock ledge.

Prevelly PR4-30

Prevelly PR4-40

Risk to Individual Most at Risk (R_{DI}) has not changed since previous assessment (2021)
$R_{DI} = 1.2 \times 10^{-6}$.

No change from 2021 inspection.

Good stand-off distance between hazard and fence.

Fence in good condition.

Sign in good condition.

Prevelly PR4-100, PR5-50 & PR5-150

Hazard 1 -This overhang collapses whilst people are walking on it.
Note: Informal path traverses along the top of this overhang.

Hazard 2 – Boulder/block breaks away and rolls to beach.

Prevelly PR4-100

Evidence of pedestrian traffic continues, although there has been improved signage since Nov 2021 inspection.
Brushwood has also been placed.

Recommendation
Further placement of brushwood is recommended to further discourage access and minimise risk.
The fence in the photo above could include a mesh fence panel to stop people ducking under it.
Fence at beach level requires repair/maintenance.

Risk to Individual Most at Risk (R_{DI}) remains same as previous assessment: $R_{DI} = 4.8 \times 10^{-6}$

Path from picnic area to hazard less distinct as brushwood has been placed.

Prevelly PR5-50

March 2024

Nov 2021

Site conditions similar to 2021 assessment.

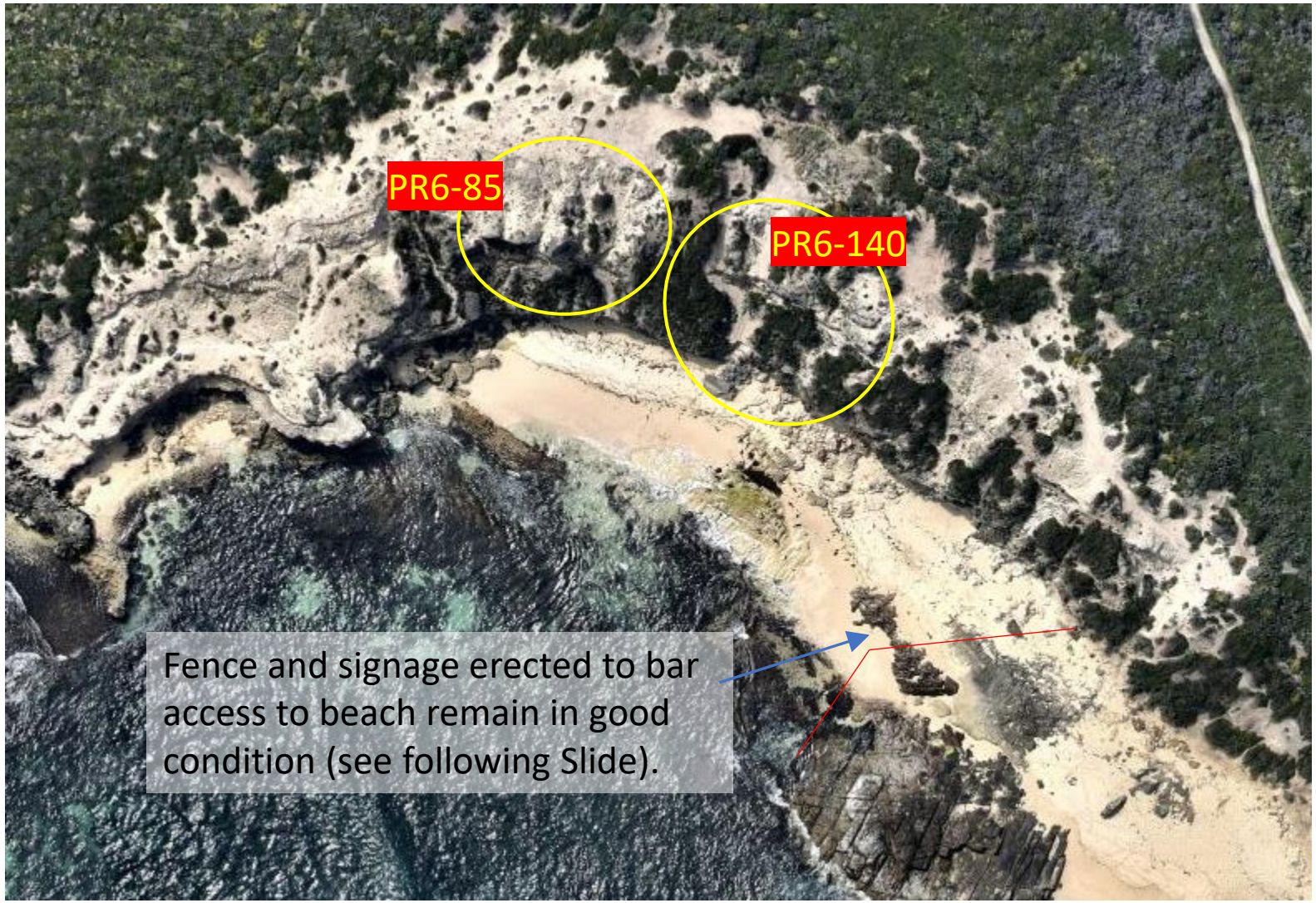
Risk to Individual Most at Risk (R_{DI}) has not changed since previous assessment (2017)
$R_{DI} = 1.8 \times 10^{-6}$

Recommendation
Install rockfall hazard sign 5 m from hazard at edge of cliff - at location marked 'X' above.
Note: This was previously recommended following the Nov 2021 inspection.

Prevelly PR5-150

Site conditions similar to previous assessment.
Risk to Individual Most at Risk (R_{DI}) has not changed since previous assessment (2021):
$R_{DI} = 1.5 \times 10^{-6}$

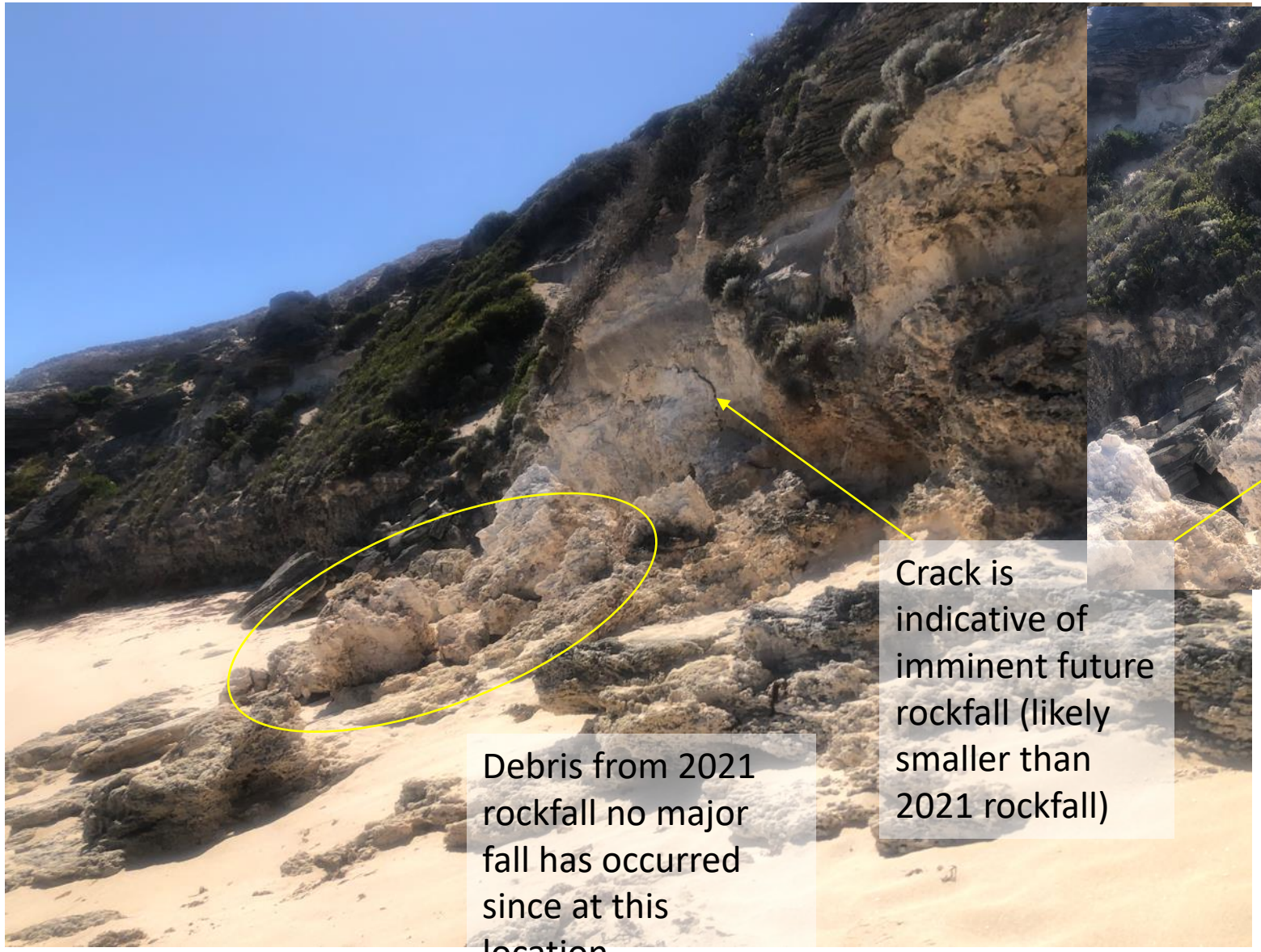
Prevelly PR6-85 & PR6-140 (Riflebutts Beach)



Prevelly PR6-85 & PR6-140

Fence and signage including informative sign in good condition.
Fence seems to be effective in discouraging access to section of beach below PR6-85 and PR6-140 – nobody was accessing beach at time of inspection.

Prevelly PR6-140



Risk to Individual Most at Risk (R_{DI}) assessed to be relatively low in this area but only due to people not accessing the beach due to the fence and signage.

No change in risk level from November 2021

$R_{DI} = 2.2 \times 10^{-6}$.

Prevelly PR6-85

Evidence of spalling of cliff – cliff is being actively undercut at this location and future rockfalls in this location are expected.

Prevelly PR6-85

Pinnacle of bedded aeolianite partially uncut. Evidence of wind erosion can be seen around this feature.

Gnarabup – GN1-25 & GN1-50

Gnarabup – GN1-25

Sign has been installed since Nov 2021 inspection.

Risk to Individual Most at Risk (R_{DI}) has not changed since previous assessment (2017):
$R_{DI} = 9.6 \times 10^{-8}$

Vegetation and shallow gradients in front of hazard reduce likelihood of rockfall reaching beach.

Some small rocks are reaching beach in vicinity of sign.

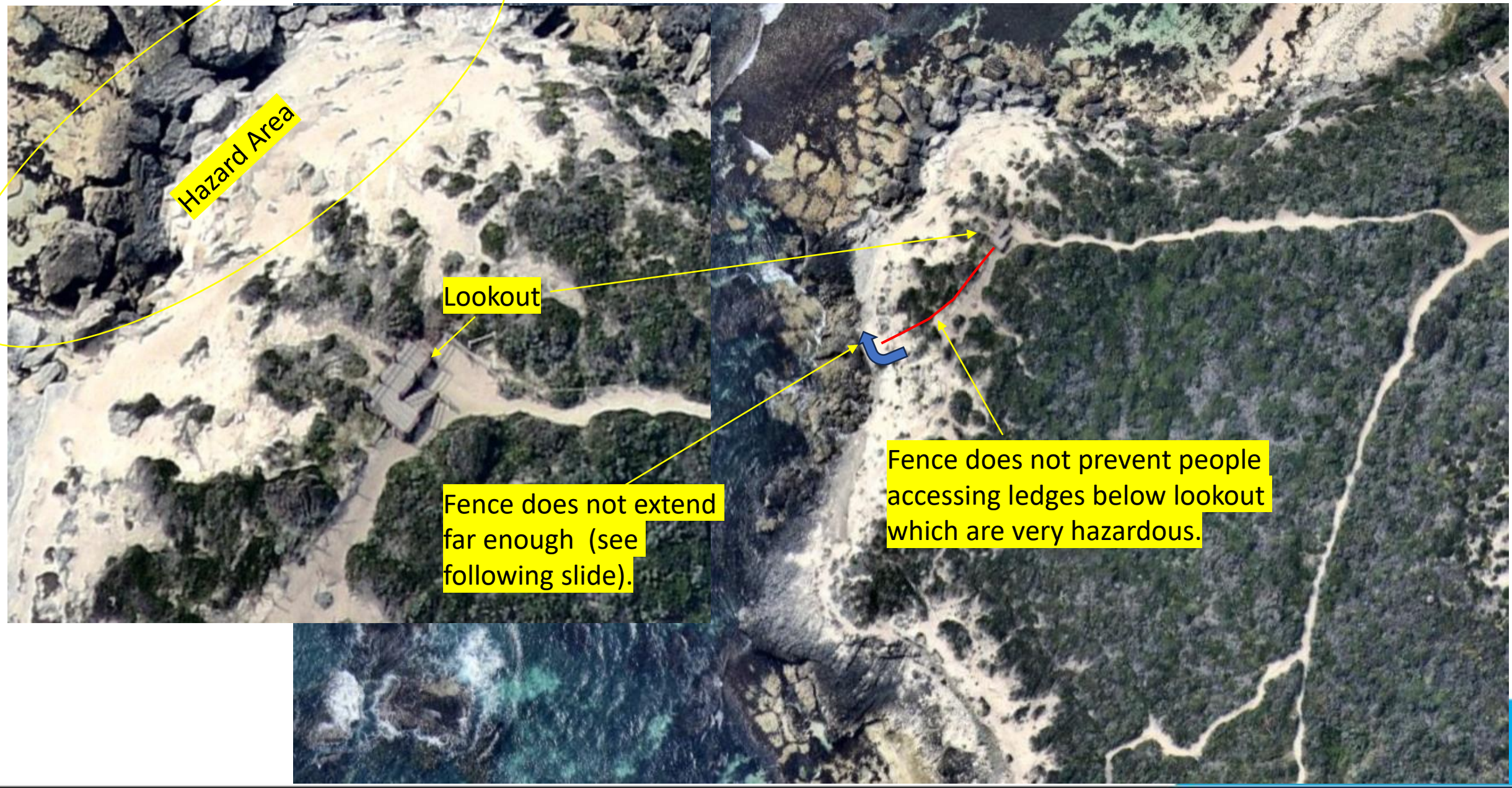
Gnarabup – GN1-50

Risk to Individual Most at Risk (R_{DI}) has not changed since previous assessment (2017): $R_{DI} = 2.0 \times 10^{-7}$.
New rockfall hazard risk was installed but has been damaged and requires re-installation.

Recommendation
Damaged sign requires re-installation.

Gnarabup – GN3-100, GN3-90, GN3-40, GN5-5, GN5-30 and GN5-100

Gnarabup – GN3-90 and GN3-40



Gnarabup – GN3-90 and GN3-40

People are accessing the lower bench (straight arrow) – this access leads to an undercut section. People are also accessing the upper bench (kinked arrow) resulting in access along the top of undercut ledges.

Right-hand photo is from Nov 2021.

Recommendation

Add brushwood and/or revegetate to discourage informal pedestrian access and promote vegetation growth in area below lookout.

The fence should be extended as a matter of urgency to prevent access.

Gnarabup – GN3-90 and GN3-40

Heavily trafficked informal path.

Recommendation

Either access should be restricted, or this path should be formalised (steps and boardwalk towards Back Beach) to prevent erosion from enlarging hazard zone.

Gnarabup – GN3-40 and GN3-90

GN3-40 example of undercut

Risk to Individual Most at Risk (R_{DI}) = 4.6 x 10^{-6} and 1.5 x 10^{-6} for GN3-40 and GN3-90 respectively. This is the same as Nov 2021**.**

It is noted however that ongoing erosion is likely to see these risk levels increase. Measures are **<u>urgently</u>** needed to **a) prevent further erosion and b) to discourage public access to the ledge below the lookout.**

People accessing this area cannot see if they are walking on an undercut ledge.

GN3-90 example of undercut

Gnarabup – GN3-100

The Gnarabup Beach Cave - The level of Risk to the Individual Most at Risk (R_{DI}) remains similar to 2017 at 8.3 x 10^{-7}

Gnarabup – GN5-5

Control/remedial measures put in place in 2021 to reduce weathering under the overhang and to underpin the stairs. Risk to the Individual Most at Risk assessed flowing these remedial works (March 2022 assessment report) to be 2.3 x10 $^{-7}$. This risk remains unchanged.

Gnarabup – GN5-5

Erosion of the soil slope below and in front of the white elephant stairs has been occuring due to storm wave attack.

Whilst this erosion is currently not affecting the stability of the stairs, it is possible further erosion could destabilise the slope and impact the stairs.

It is recommended that measures be taken to prevent further erosion at this location.

Gnarabup – GN5-30

This is the outcrop between the White Elephant Café and the steps up to the Gnarabup Headland car park.

The level of Risk to the Individual Most at Risk (R_{DI}) remains similar to the 2021 assessment.

$R_{DI} = 2.3 \times 10^{-7}$

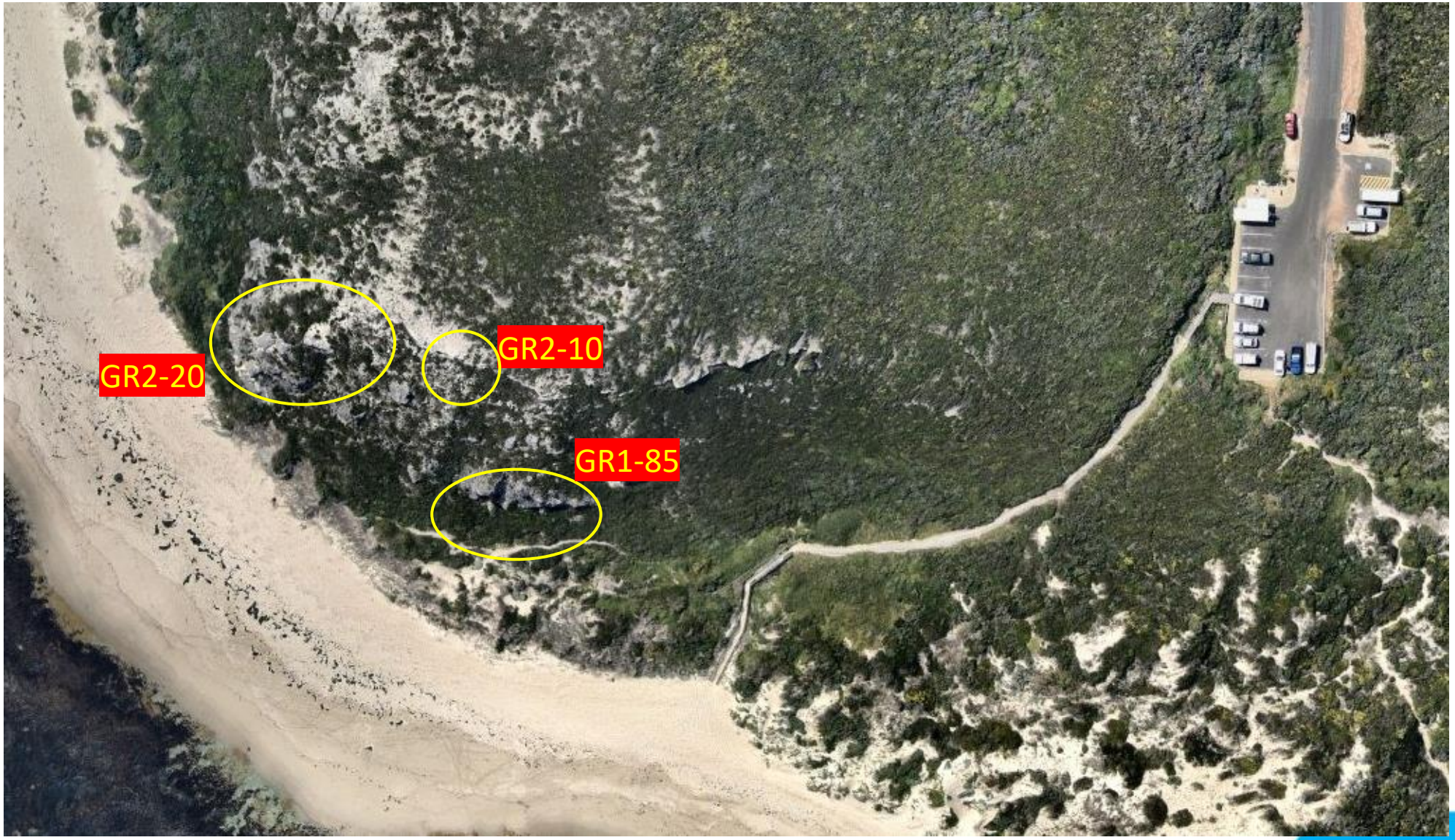
A Rockfall Hazard sign has been installed on the lawn area at base of this feature as requested following the 2021 inspection.

Note: There is currently minimal people traffic in this area and the grassed area below is not used by the Café for customers. **The level of risk would increase significantly if this area was used for seating.**

Gnarabup – GN5-100

The level of risk to the Individual Most at Risk (R_{DI}) remains the same as November 2021 R_{DI} = 7.6×10^{-7}

Grunters – GR2-20, GR2-10 & GR1-85



Grunters – GR1-85

The level of Risk to the Individual Most at Risk (R_{DI}) remains the same as the 2021 assessment.

$R_{DI} = 7.8 \times 10^{-8}$

Since 2021 inspection fence has been repaired and new sign installed.

Grunters – GR2-10

The level of Risk to the Individual Most at Risk (R_{DI}) remains the same as the 2021 assessment.

$R_{DI} = 1.3 \times 10^{-7}$

Rockfall hazard area sign on the beach recommended in March 2022 assessment report has been installed.

Grunters – GR2-20

The level of Risk to the Individual Most at Risk (R_{DI}) reduced since the November 2021 inspection assessment due to the provision of a summer fence.

$R_{DI} = 1.2 \times 10^{-6}$

This level of risk however assumes that a fence (see following slide) continues to be installed at least 6 m from dune/beach interface for the months of Nov to April inclusive to keep people away from high-risk zone.

Grunters – GR2-20

Temporary summer fence (Nov to April) to keep people away from the risk zone at the base of GR2-20.

This fence must be erected each summer.

A permanent fence should be installed along the base of the dune to prevent access to undercut, cave and prevent damage to dune area.

The temporary summer fence is still required because the hazard impact zone extends onto the beach.


GR2-20
47.12 m
4.57 m
19.3°
7.61 m
337.7°
8.16 m
340°
10.38 m
331.4°
9.33 m
326.2°
7.06 m
271.1°
This temporary fence was installed for the summer of 2022 and 2023.
Ongoing recommendation: Temporary fence to be erected between November and April (inclusive) each year.
Approx. extent of temporary summer fence 6 m off Feb 2022 vegetation line

Grunters – GR3-1

Grunters – GR3-1 (became new location at time of Nov 2021 inspection)

Approximately 3m overhang

Area approximately 10m wide with a 2.5m overhang.
Rockfall risk sign recommended in March 2022 inspection report has been installed.

The level of Risk to the Individual Most at Risk remain as previously assessed at (R_{DI}) = R_{DI} = 6.2 x 10^{-6}

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APPENDIX B
Risk Assessment

Location	Gracetown									
Hazard ID	**GC3-50 (Hazard 1)**	**GC3-50 (Hazard 2)**	**GC3-50 (Hazard 3)**	**GC3-50 (all hazards combined)**	**GC4-60**	**GC5-75**	**GC6-15**	**GC6-50**	**GC6-60**	**GC6-100**
Recommended mitigation	**Upgrade, extend and realign fence, install informative signage and install rockfall signage**	**Upgrade, extend and realign fence, install informative signage and install rockfall signage**	**Upgrade, extend and realign fence, install informative signage and install rockfall signage**	**Upgrade, extend and realign fence, install informative signage and install rockfall signage**				**Install rockfall hazard sign**		
Comments	Consider use of drone to monitor change with time	Consider use of drone to monitor change with time	Consider use of drone to monitor change with time	Consider use of drone to monitor change with time		Mitigation works conducted in 2020		New location		
Main Hazard Type Assessed	Boulder sliding off ledge	Upper ledge collapsing and fragments rolling to beach	Large Rockfall (cliff collapse)		Rockfall	Rockfall	Rockfall	Rockfall	Rockfall	Rockfall
Risk scenario	People traversing narrow beach in front of Shire part of GC3-50	People traversing narrow beach in front of Shire part of GC3-50	People traversing narrow beach in front of Shire part of GC3-50		People traversing beach in front of hazard	People exiting stairs onto beach	Lookout removed so risk is no longer to lookout/stairs but to people traversing beach	People traversing rocky foreshore	People traversing rocky foreshore	People traversing beach
R_{DI} or $R_{(L0L)}$ (without risk mitigation recomme	2.9E-06	5.7E-06	1.4E-05	2.3E-05	6.1E-07	1.2E-07	2.9E-06	8.6E-07	9.75E-07	8.0E-07
$P_{(H)}$	1.0E+00	5.0E-01	1.0E-01		1.0E-01	1.0E-02	6.7E-02	1.0E-01	1.00E-01	5.0E-02
$P_{(S:H)}$	1.0E-02	1.0E-01	5.0E-01		2.9E-02	5.5E-02	5.0E-01	1.0E-01	1.14E-01	7.4E-02
$P_{(T:S)}$	3.8E-05	1.5E-05	3.8E-05		2.9E-05	2.9E-05	1.1E-05	1.1E-05	1.14E-05	2.9E-05
$V_{(D:T)}$	0.5	0.5	0.5		0.5	0.5	0.5	0.5	0.5	0.5
N	15	15	15	15	15	15	15	15	15	15
R_{SOC}	1.9E-06	3.8E-06	9.6E-06	1.5E-05	4.1E-07	7.8E-08	1.90259E-06	5.70776E-07	6.50E-07	5.3E-07
IR_{DI} (individual risk per visit)	1.9E-07	3.8E-07	9.6E-07	1.5E-06	4.1E-08	7.8E-09	1.90259E-07	5.70776E-08	6.50E-08	5.3E-08
Total individual visitors at any one time	10	10	10		10	10	10	10	10	10
R_{CI}	1.90E-03	3.81E-03	9.59E-03	1.53E-05	4.08E-04	3.90E-04	9.51E-04	2.85E-04	3.25E-04	2.66E-04
N_T - total number of individuals visiting the site each year (assuming no repeat visits)	10001	10002	10000		10000	50000	5000	5000	5000	5000
Total individual visitors per day in a year	27	27	27		27	137	14	14	14	14
Risk Variable breakdown										
P_H										
Return Interval for Rockfall (once every ? Yrs)	1	2	10		10	100	15	10	10	20
$P_{S:H}$										
Length of Trajectory where people could be impacted (m) if rockfall is main hazard	12	12	12		10	10	20	10	12	12
Width of block (m)	0.5	5.0	18.0		4.0	5.0	4.0	1.5	15.0	10.0
Potential Impact area (m^2)	6	60	216		40	50	80	15	180	120
% of Trajectory where humans could be impacted that gets hit by rockfall or affected by collapse	50%	50%	70%		50%	50%	50%	20%	50%	50%
Assumed Spatial Impact Area (m^2)	3	30	151.2		20	25	20	3	90	60
Approximate general area in front of hazard a proportion of which will be in the impact area (m^2)	300	300	300		700	457	40	30	790	806
P_{TS}										
Minutes per year	525600	525600	525600		525600	525600	525600	525600	525600	525600
% significant rockfall in Rain	80%	80%	80%		80%	80%	80%	80%	80%	80%
% significant rockfall in Dry	20%	20%	20%		20%	20%	20%	20%	20%	20%
Time Spent in Rockfall Hazard Zone if raining (min)	20	20	20		5	5	5	5	5	5
Time spent in Rockfall Hazard Zone if dry (min)	20	20	20		55	55	10	10	10	55
Weighted Time exposed in rain (min)	16	16	16		4	4	4	4	4	4
Weighted Time exposed in dry (min)	4	4	4		11	11	2	2	2	11
Total Weighted Time exposed to Rockfall (min)	20	8	20		15	15	6	6	6	15

Location	Prevelly								
Hazard ID	**PR3-165**	**PR4-30**	**PR4-40**	**PR4-100 (hazard 1)**	**PR4-100 (Hazard 2)**	**PR5-50**	**PR5-150**	**PR6-85**	**PR6-140**
Recommended mitigation	**Repair fence/ install brushwood to stop informal path usage**	**Security recommended to prevent access during surf competititons**		**Additional brushwood recommended to discourage access to top of ledges**	**Additional brushwood recommended to discourage access to top of ledges**				
Comments								Access reduced due to fence	Access reduced due to fence
Main Hazard Type Assessed	Rockfall	Collapse	Rockfall	Collapse	Rockfall/collapse	Rockfall/Collapse	Rockfall/Collapse	Rockfall	Rockfall
Risk scenario	People traversing beach or sunbathing	People jumping fence to sit on top of rock ledge during surf competition	People traversing beach or sunbathing	People traversing overhang as it collapses	Collapsing overhang rolls down to beach	Collapsing overhang rolls down to beach	Collapsing overhang rolls down to beach	Dog walker/sunbathers impacted by large falling block	Dog walkers/sunbathers
R_{DI} or $R_{(L0L)}$ (without risk mitigation recomme	1.5E-06	2.9E-06	1.2E-06	3.1E-06	4.8E-06	1.8E-06	1.5E-06	6.1E-06	2.2E-06
$P_{(H)}$	1.0E-01	1.0E-01	5.0E-02	1.0E-01	1.0E-01	5.0E-02	5.0E-02	2.0E-01	2.0E-01
$P_{(S:H)}$	6.8E-02	1.0E+00	1.2E-01	1.0E+00	2.3E-01	1.7E-01	1.4E-01	1.5E-01	5.4E-02
$P_{(T:S)}$	2.9E-05	1.4E-04	2.9E-05	4.2E-06	2.9E-05	2.9E-05	2.9E-05	1.7E-05	1.7E-05
$V_{(D:T)}$	0.5	0.1	0.5	0.5	0.5	0.5	0.5	0.8	0.8
N	15	2	15	15	15	15	15	15	15
R_{SOC}	9.7E-07	7.1E-06	8.3E-07	4.2E-07	3.2E-06	1.2E-06	1.0E-06	1.6E-06	6.0E-07
IR_{DI} (individual risk per visit)	9.7E-08	1.4E-06	8.3E-08	2.1E-07	3.2E-07	1.2E-07	1.0E-07	4.0E-07	1.5E-07
Total individual visitors at any one time	10	5	10	2	10	10	10	4	4
R_{CI}	1.46E-03	7.13E-05	8.30E-04	1.05E-03	1.61E-03	2.97E-04	2.55E-04	8.08E-04	2.98E-04
N_T - total number of individuals visiting the site each year (assuming no repeat visits)	15000	50	10000	5000	5000	2500	2500	2000	2000
Total individual visitors per day in a year	41	0	27	14	14	7	7	5	5
Risk Variable breakdown									
P_H									
Return Interval for Rockfall (once every ? Yrs)	10	10	20	10	10	20	20	5	5
$P_{S:H}$									
Length of Trajectory where people could be impacted (m) if rockfall is main hazard	16	5	5	NA	2	NA	NA	12	16
Width of block (m)	3.0	6.0	2.0	NA	1.5	NA	NA	10.0	4.0
Potential Impact area (m^2)	48	30	10	NA	3	NA	NA	120	64
% of Trajectory where humans could be impacted that gets hit by rockfall or affected by collapse	75%	100%	100%	100%	60%	NA	NA	60%	60%
Assumed Spatial Impact Area (m^2)	36	30	10	5	1.8	10	10	72	38.4
Approximate general area in front of hazard a proportion of which will be in the impact area (m^2)	529	30	86	5	8	60	70	488	707
P_{TS}									
Minutes per year	525600	525600	525600	525600	525600	525600	525600	525600	525600
% significant rockfall in Rain	80%	80%	80%	80%	80%	80%	80%	80%	80%
% significant rockfall in Dry	20%	20%	20%	20%	20%	20%	20%	20%	20%
Time Spent in Rockfall Hazard Zone if raining (min)	5	25	5	2	5	5	5	5	5
Time spent in Rockfall Hazard Zone if dry (min)	55	275	55	3	55	55	55	25	25
Weighted Time exposed in rain (min)	4	20	4	2	4	4	4	4	4
Weighted Time exposed in dry (min)	11	55	11	1	11	11	11	5	5
Total Weighted Time exposed to Rockfall (min)	15	75	15	2	15	15	15	9	9

Location	Gnarabup							
Hazard ID	**GN1-25**	**GN1-50**	**GN3-40**	**GN3-90**	**GN3-100**	**GN5-5**	**GN5-30**	**GN5-100**
Recommended mitigation		**Reinstall rockfall signage**	**Extend fence/rehabilitation /erosion control measures**	**Extend fence/rehabilitation/ erosion control measures**				
Comments						Stairs underpinned in 2021		
Main Hazard Type Assessed	Rockfall	Rockfall	Collapse	Collapse	Collapse	Collapse	Rockfall	Rockfall
Risk scenario	Sunbathers	Sunbathers	Walking on ledge below lookout	Walking on ledge below lookout	Small rockfall collapse onto people visiting cave	Collapse of stairs	Collapse of ledge onto people below	Collapse of overhanging fragmenting and rolling to footpath
R_{DI} or $R_{(L0L)}$ (without risk mitigation recomme	9.6E-08	2.0E-07	4.6E-06	1.5E-06	8.3E-07	2.3E-07	2.6E-06	7.6E-07
$P_{(H)}$	5.0E-02	5.0E-02	1.0E-01	1.0E-01	1.0E+00	1.0E-02	2.0E-01	1.0E-01
$P_{(S:H)}$	9.0E-03	1.9E-02	2.1E-01	7.1E-02	9.1E-02	1.0E+00	1.5E-01	3.5E-02
$P_{(T:S)}$	2.9E-05	2.9E-05	2.9E-05	2.9E-05	3.0E-06	3.0E-06	2.9E-05	2.9E-05
$V_{(D:T)}$	0.5	0.5	0.5	0.5	0.2	0.5	0.5	0.5
N	15	15	15	15	15	15	6	15
R_{SOC}	6.4E-08	1.3E-07	3.1E-06	1.0E-06	5.5E-07	1.5E-07	4.3E-06	5.0E-07
IR_{DI} (individual risk per visit)	6.4E-09	1.3E-08	3.1E-07	1.0E-07	5.5E-08	1.5E-08	4.3E-07	5.0E-08
Total individual visitors at any one time	10	10	10	10	10	10	10	10
R_{CI}	6.42E-05	1.32E-04	7.64E-04	2.54E-04	5.53E-04	1.33E-03	8.56E-05	3.53E-03
N_T - total number of individuals visiting the site each year (assuming no repeat visits)	10000	10000	2500	2500	10000	87600	200	70000
Total individual visitors per day in a year	27	27	7	7	27	240	1	192
Risk Variable breakdown								
P_H								
Return Interval for Rockfall (once every ? Yrs)	20	20	10	10	1	100	5	10
$P_{S:H}$								
Length of Trajectory where people could be impacted (m) if rockfall is main hazard	10	10	NA	NA	6	NA	5	22
Width of block (m)	3.0	1.0	NA	NA	0.5	NA	3.0	4.0
Potential Impact area (m^2)	30	10	NA	NA	3	NA	15	88
% of Trajectory where humans could be impacted that gets hit by rockfall or affected by collapse	25%	80%	NA	NA	100%	NA	50%	25%
Assumed Spatial Impact Area (m^2)	7.5	8	15	15	3	10	7.5	22
Approximate general area in front of hazard a proportion of which will be in the impact area (m^2)	833	432	70	211	33	10	50	623
P_{TS}								
Minutes per year	525600	525600	525600	525600	525600	525600	525600	525600
% significant rockfall in Rain	80%	80%	80%	80%	80%	80%	80%	80%
% significant rockfall in Dry	20%	20%	20%	20%	20%	20%	20%	20%
Time Spent in Rockfall Hazard Zone if raining (min)	5	5	5	5	1	1	5	5
Time spent in Rockfall Hazard Zone if dry (min)	55	55	55	55	4	4	55	55
Weighted Time exposed in rain (min)	4	4	4	4	1	1	4	4
Weighted Time exposed in dry (min)	11	11	11	11	1	1	11	11
Total Weighted Time exposed to Rockfall (min)	15	15	15	15	2	2	15	15

Location	Grunters			
Hazard ID	**GR1-85**	**GR2-10**	**GR2-20**	**GR3-1**
Recommended mitigation			**Temporary fencing erected each summer (Nov to April) and new rockfall sign**	
Comments				New location following 2021 inspection
Main Hazard Type Assessed	Rockfall	Rockfall	Rockfall	Rockfall
Risk scenario	Collapse of overhang impacting beach users	Collapse of overhang impacting beach users	Collapse of overhang impacting beach users	
R_{DI} or $R_{(L0L)}$ (without risk mitigation recomme	7.8E-08	1.3E-07	1.2E-06	4.0E-06
$P_{(H)}$	1.0E-01	1.0E-01	1.0E-01	1.0E-01
$P_{(S:H)}$	3.6E-03	6.2E-03	5.8E-02	1.9E-01
$P_{(T:S)}$	2.9E-05	2.9E-05	2.9E-05	2.9E-05
$V_{(D:T)}$	0.5	0.5	0.5	0.5
N	15	15	15	15
R_{SOC}	5.2E-08	8.9E-08	8.2E-07	2.7E-06
IR_{DI} (individual risk per visit)	5.2E-09	8.9E-09	8.2E-08	2.7E-07
Total individual visitors at any one time	10	10	10	10
R_{CI}	5.17E-05	8.88E-05	8.23E-04	1.34E-04
N_T - total number of individuals visiting the site each year (assuming no repeat visits)	10000	10000	10000	500
Total individual visitors per day in a year	27	27	27	1
Risk Variable breakdown				
P_H				
Return Interval for Rockfall (once every ? Yrs)	10	10	10	10
$P_{S:H}$				
Length of Trajectory where people could be impacted (m) if rockfall is main hazard	11	16	25	5
Width of block (m)	4.0	1.0	15.0	5.0
Potential Impact area (m^2)	44	16	375	25
% of Trajectory where humans could be impacted that gets hit by rockfall or affected by collapse	5%	30%	10%	75%
Assumed Spatial Impact Area (m^2)	2.2	4.8	37.5	18.75
Approximate general area in front of hazard a proportion of which will be in the impact area (m^2)	607	771	650	100
P_{TS}				
Minutes per year	525600	525600	525600	525600
% significant rockfall in Rain	80%	80%	80%	80%
% significant rockfall in Dry	20%	20%	20%	20%
Time Spent in Rockfall Hazard Zone if raining (min)	5	5	5	5
Time spent in Rockfall Hazard Zone if dry (min)	55	55	55	55
Weighted Time exposed in rain (min)	4	4	4	4
Weighted Time exposed in dry (min)	11	11	11	11
Total Weighted Time exposed to Rockfall (min)	15	15	15	15

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APPENDIX C
Definitions

The definitions used within the risk assessment (Appendix B) follow the same format as the previous report conducted by Golder and are shown below.

Risk for individual most at risk, R_{DI} = P_H x $P_{S:H}$ x $P_{T:S}$ x $V_{D:T}$ x N

P_H – annual probability of rockfall or slope collapse occurring of sufficient size to cause loss of life

$P_{S:H}$ – the probability of spatial impact

$P_{T:S}$ - the temporal spatial probability for recreational users, the probability that a person will be in the hazard zone at any given time of the year

$V_{D:T}$ – the vulnerability of the individual

N – the average number of times the person most at risk visits a location each year

Total Societal Risk , R_{SOC} = R_{LOL} x N_{SOC}

R_{LOL} referred to as IR_{DI} in the Golder 2017 – individual risk of death for each person who visits a site

This risk is the same as R_{DI}, but does not account for repeat visits by the same person

N_{SOC} – potential number of people that could die in a single rockfall or collapse event

Cumulative Individual Risk, R_{CI} = R_{LOL} x N_T

N_T – total number of individual visitors to a site each year

- **Risk** – A measure of the probability and severity of an adverse effect to health, property or the environment.
- **Hazard** – A condition with the potential for causing an undesirable consequence (in this case, rockfall or ground collapse).
- **Hazard Zone** – An area within which the hazard may affect elements at risk if failure were to occur.
- **Elements at Risk** – Meaning the population, buildings and engineering works, economic activities, public services utilities, infrastructure and environmental features in the area potentially affected by the hazard.
- **Probability** – The likelihood of a specific outcome, measured by the ratio of specific outcomes to the total number of possible outcomes. Probability is expressed as a number between 0 and 1, with 0 indicating an impossible outcome and 1 indicating that an outcome is certain.
- **Frequency** – A measure of the likelihood expressed as the number of occurrences of an event in a given time.
- **Likelihood** – Used as a qualitative description of probability or frequency.
- **Temporal Probability** – The probability that the element at risk is in the area affected by the slope failure, at the time of the slope failure.
- **Vulnerability** – The degree of loss to a given element or set of elements within the area affected by the hazard. It is expressed on a scale of 0 (no loss) to 1 (total loss). For property, the loss will be the value of the damage relative to the value of the property; for persons, it will be the probability that a particular life (the element at risk) will be lost, given the person(s) is affected by the landslide.
- **Consequence** – The outcomes or potential outcomes arising from the occurrence of a landslide expressed qualitatively or quantitatively, in terms of loss, disadvantage or gain, damage, injury or loss of life.
- **Individual Risk** – The risk of fatality or injury to any identifiable individual who enters the hazard zone.
- **Societal Risk** – The risk of multiple fatalities or injuries in society as a whole: one where society would have to carry the burden of a slope failure causing a number of deaths, injuries, financial, environmental, and other losses.
- **Acceptable Risk** – A risk that, for the purposes of life or work, we are prepared to accept as it is with no regard to its management. Society does not generally consider expenditure in further reducing such risks justifiable.
- **Tolerable Risk** – A risk that society is willing to live with so as to secure certain net benefits in the confidence that it is being properly controlled, kept under review and further reduced as and when possible. In some situations risk may be tolerated because the individuals at risk cannot afford to reduce risk even though they recognise it is not properly controlled.

Figure – Risk Definitions - Golder Associates 2017; Limestone Cliff Stability Assessment - prepared for the Shire of Augusta Margaret River (reference 1666765-001-R-Rev0, dated May 2017)

Perth

Suite 1 | Level 3 29 Flynn Street
Wembley WA 6014
Australia

Ph: +61 8 6555 4920

admin@cmwgeo.com

www.cmwgeosciences.com