Geotechnical Assessment of Bat Caves

Mulga Downs Iron Ore Project

PSM5194-007R REV3 18 December 2024

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1. Introduction

The Mulga Downs Iron Ore Project (MDIOP, the Project) comprises two separate projects, the Mulga Downs Iron Ore Mine (MDIOM), and the Mulga Downs Hub and Rail Spur (Hub and Rail). The MDIOM is proposed to be developed by Hancock Prospecting Pty Ltd (HPPL) and the Hub and Rail is proposed to be developed by Roy Hill Infrastructure Pty Ltd (RHI).

This report presents the results of geotechnical assessments of 19 bat caves identified by others within the vicinity of the MDIOP. The primary objective of the assessments was to qualitatively assess geotechnical stability of the caves, with regards to the potential vibrations from blasting at nearby pits, or from vibrations induced by the mining hub and rail spur. We understand the primary concern would be loss of access to the cave for bats either from rockfall or collapse, or climatic changes within the cave making it no longer suitable for nocturnal roosting.

This report presents:

- Background
- Scope of work and available data
- Geotechnical observations and hazard observations for the specified caves
- Qualitative susceptibility assessment
- Recommendations for operational vibration limits
- Recommendations for additional controls.

The assessments were undertaken at the request of Samantha Mickan of JBS&G Australia (JBS&G), on behalf of HanRoy Iron Ore Projects Pty Ltd (HanRoy), the appointed lead of the HPPL Group's growth projects. The work was undertaken in accordance with our proposals dated 25 October 2023[(1)] and 19 December 2024[(2)].

A glossary of terms is provided at the end of this report.

2. Background, Objectives and Scope

2.1 Project Understanding

The MDIOP is located 230 km south of Port Hedland in the Pilbara region of Western Australia. The proposed development is situated in the northeast of the Hamersley Province along the Chichester Range. The MDIOM consists of a series of open pits and associated infrastructure, to support the production of up to 10 million tonnes of direct shipping ore per annum over an 18-year period. Production of iron ore will utilise drill and blast, load and haul mining methods, primarily above the groundwater table, but extending up to approximately 1 bench (12 m) below water table in some areas. The Hub and Rail will connect into the existing Roy Hill Railway for the transport of iron ore to Port Hedland. The study location and proposed action areas of the MDIOM and Hub and Rail are presented in Figure 1.

Several caves that have the potential to be utilised by bats (Category 4 caves) occur within or adjacent to the proposed Development Envelopes for the MDIOPs. As such, geotechnical assessments are required to evaluate the stability of the bat caves and surrounding rock mass, with specific regard to the potential impacts from blasting at nearby pits and operational vibration. Locations of the 19 caves which are subject to this assessment are shown on State and Commonwealth maps in Appendix A. Figure 2 shows the location of 19 caves on a geological map, which are situated at the northern extremities of the proposed Fridge Hill pit footprint. Details of the caves, including coordinates and site IDs, are presented in Section 3 of this report.

[(1)] PSM5194-001L Rev 4 – Mulga Downs Iron Ore Project – Proposal for Geotechnical Assessment of Caves. Dated 25 October 2023.

[(2)] PSM5194-008L – Mulga Downs Iron Ore Project – Proposal for Geotechnical Assessment of Caves. Dated 19 December 2023.

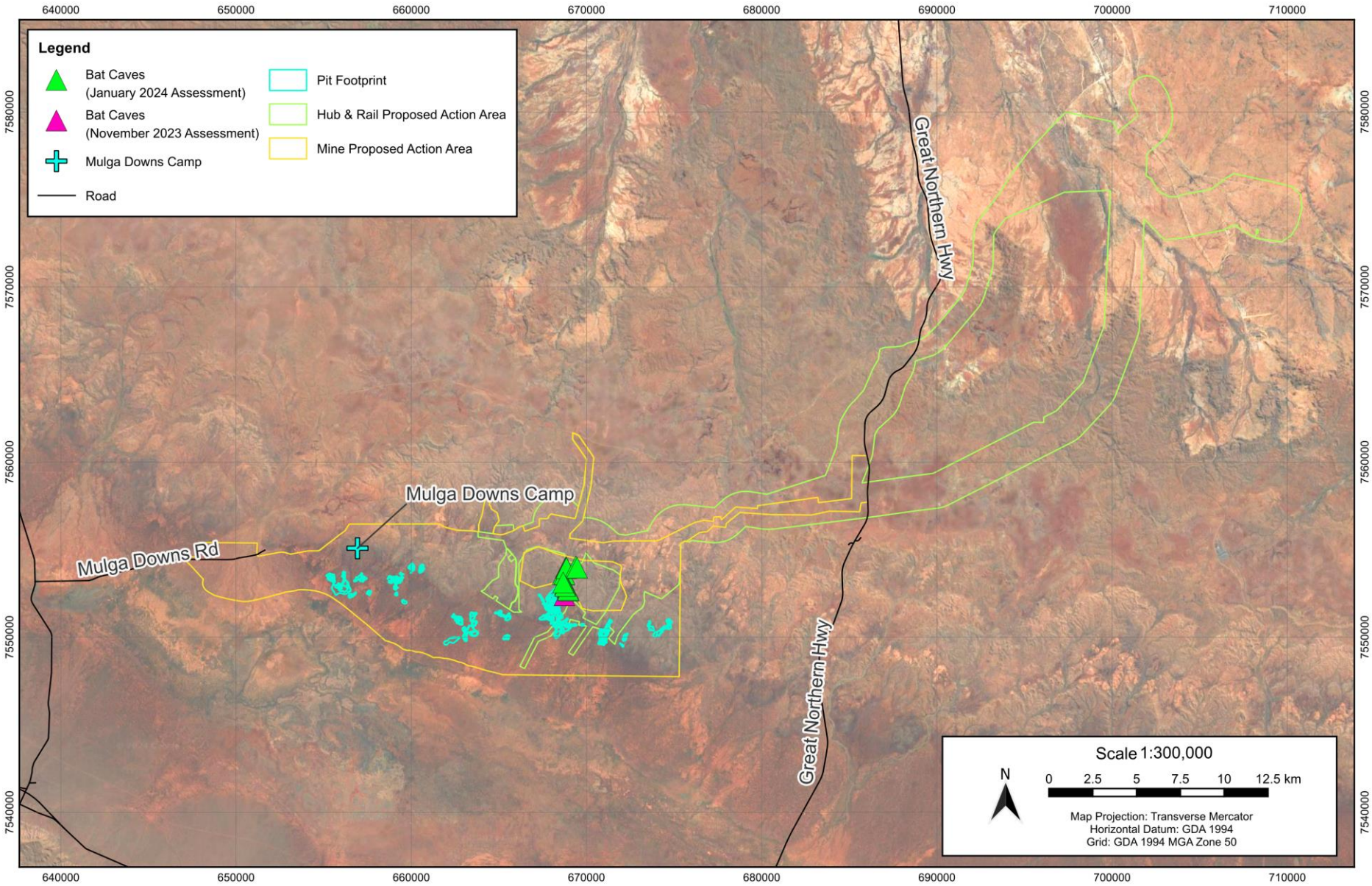


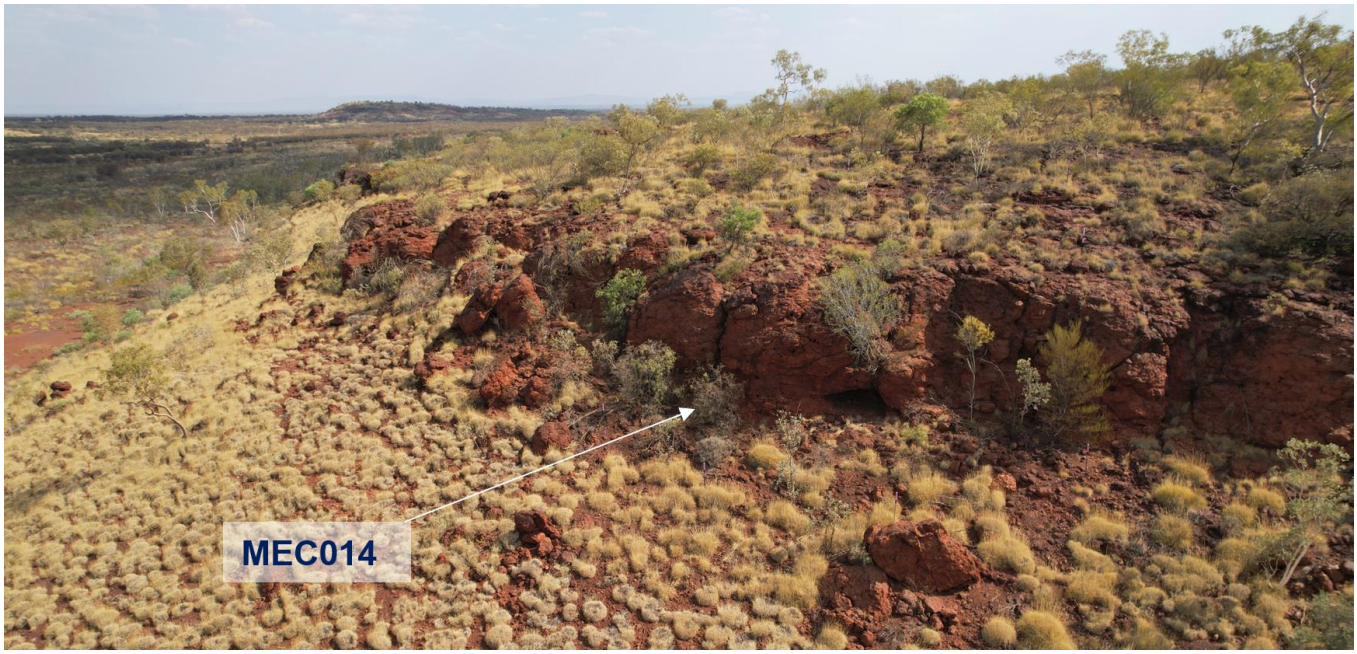
Figure 1: Overview of study location.

2.2 Geology and Geomorphology

The geology local to the cave locations is shown in Figure 2. The caves at Mulga Downs are hosted within the Marra Mamba Iron Formation, a basal member of the Hamersley Group. A distinctive characteristic of Proterozoic banded iron formation (BIF) units of the Hamersley Group is their extensive lateral continuity. These formations control the landscape development with the more resistant BIF units forming a range of hills with cuestas or mesa shapes and form the dominant topographic landforms such as the Chichester Range. Broad valleys are typically developed in association with shales and occasionally with dolomite subject to karst development.

The assessed caves are hosted within outcropping bedrock escarpments of the Marra Mamba Iron Formation, comprising BIF and interbedded chert. The flat-lying orientation of these lithologies at Mulga Downs results in cave profiles that are generally relatively low and wide. They are commonly highly weathered and hydrated, with pervasive overprinting of the original rock fabric. The exposed escarpments themselves are typically 10 to 15 m in height and overlie moderately sloping, vegetated talus slopes, Inset 1.

No regional-scale structures are known to intersect the caves in available mapping data published by the Geological Survey of Western Australia (Reference 1). Faulted intervals have been observed in cored boreholes elsewhere at Mulga Downs from previous work, indicating the potential for deposit scale geological structures.



Inset 1: Aerial view showing the location of MEC014 as an example of the escarpment and setting. The escarpment is approximately 6 m high.

2.3 Available Data

Data available for this study includes:

- Coordinates for the cave sites
- Topographic contours for the area of interest
- Expected pit footprint and proposed action areas for the mine as well as the hub & rail
- Regional 1:100,000 scale geological mapping available from the Geological Survey of Western Australia and 1:25,000 scale mapping from HPPL
- Excerpts of noise and vibration assessments undertaken by Lloyd George Acoustics (LGA), Reference 8.

2.4 Objectives and Scope of Work

The primary objectives of the study are:

1. Qualitatively assess the geotechnical stability of the specified caves, with specific regard to the potential impacts from:
    a. Blasting at nearby pits
    b. Operational vibration.
2. Recommend maximum blast vibration and operational vibration limits to be maintained at the boundary of the specified caves to reduce the likelihood of geotechnical instability.
3. Provide geotechnical information on the selected caves.
4. Provide indicative control options for each cave, based on the desktop study and geotechnical stability assessment outcomes.

The scope of work as outlined in our proposal comprised:

- A desktop study to review information on the location of the caves, planned pit designs, regional and local geology and geomorphology
- A site visit to carry out the engineering geological field assessments
- Geotechnical assessment and documentation of findings in a report.

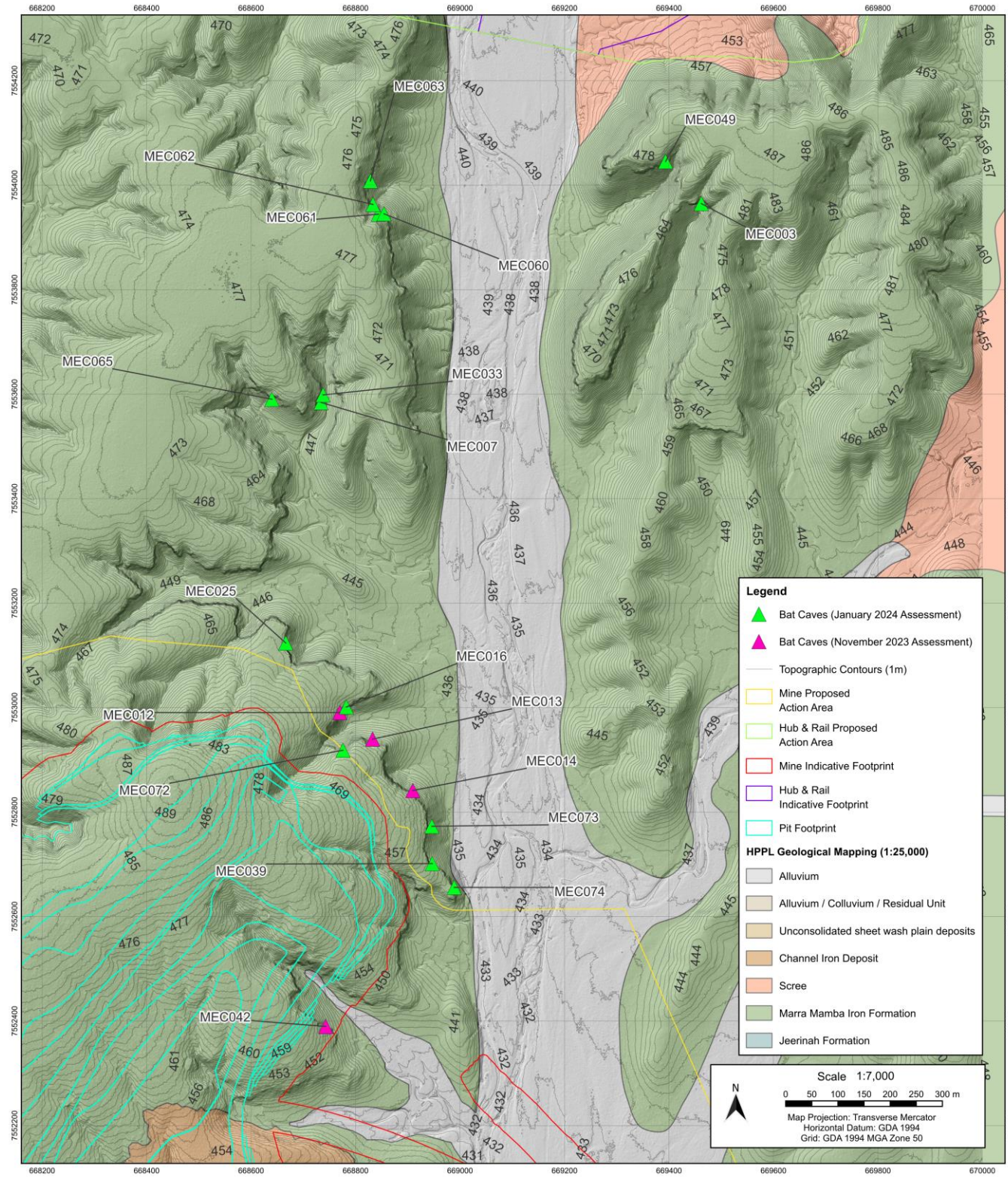


Figure 2: Mulga Downs Fridge Hill pit deposit showing design footprint, proposed action areas, bat cave locations, and mapped geology.

3. Engineering Geological Assessments

3.1 Introduction

The following sections describe the geotechnical condition of each cave as observed during the site visit including a brief description of each cave and the observed features that may be susceptible to instability. Details of the cave locations are summarised in Table 1 and the location of the caves relative to the planned final pit crests at Mulga Downs is presented in Figure 2. Summary sheets for each cave, including photos, schematic maps and Geological Strength Index (GSI) estimates are provided in Appendix B. The visual GSI and equivalent rock mass rating (RMR_{89}) for each cave is presented in Appendix C.

Table 1 – Summary of Cave Locations [1]

Cave ID	Easting (m)	Northing (m)	Approx. Elevation (m)	Distance to Nearest Infrastructure (km) [2]
MEC003	669462	7553965	463	1.32
MEC007	668734	7553584	461	0.62
MEC012	668770	7552990	451	0.15
MEC013	668833	7552940	450	0.12
MEC014	668910	7552841	448	0.10
MEC016 [3]	668782	7553001	450	0.16
MEC025	668666	7553123	448	0.16
MEC033	668738	7553598	457	0.64
MEC039	668947	7552701	456	0.09
MEC042	668743	7552389	450	0.03
MEC049	669394	7554045	470	1.35
MEC060	668854	7553945	474	1.00
MEC061	668844	7553944	471	1.00
MEC062	668833	7553963	461	1.01
MEC063	668829	7554008	460	1.05
MEC065	668640	7553590	456	0.62
MEC072	668776	7552918	458	0.07
MEC073	668946	7552773	459	0.11
MEC074	668989	7552656	444	0.11

(1) GDA94, MGA Zone 50 K.

(2) Horizontal distance to the nearest planned pit crest. The mining hub and rail spur is 1.65 km from the closest cave, and as such operational vibration from this source has not been considered in this assessment, as per Section 5.

(3) Updated coordinates are provided for MEC016, taken during January 2024 site visit.

3.2 Site Visits

The bat caves presented in this report were assessed across two separate site visits. The caves relevant to each site visit are presented in Table 2 with details of each site visit provided below:

- The first site visit was attended by Ronald Pollard of PSM (BSc Hons Geology) between 7 and 9 November 2023 and was undertaken concurrently with assessments for heritage rock shelters at Mulga Downs, the results of which are presented in a separate report [3]. Ronald was accompanied in the field by Robbie Thomas and Dionne Dugo of HanRoy, and Banjima Traditional Owner Dennis Long
- The second site visit was attended by Ronald Pollard between 8 and 11 January 2024 and was undertaken concurrently with assessments of two heritage rock shelters. Ronald was again accompanied in the field by Robbie Thomas of HanRoy.

[3] PSM5194-006R Rev1 DRAFT – Geotechnical Assessment of Heritage Rockshelters – Mulga Downs Iron Ore Project – Dated 30 January 2024.

Table 2 – Site Visit Summary

PSM Site Visit	Assessed Bat Caves			
7 to 9 November 2023	• MEC012	• MEC013	• MEC014	• MEC042
8 to 11 January 2024	• MEC003 • MEC033 • MEC061 • MEC072	• MEC007 • MEC039 • MEC062 • MEC073	• MEC016 • MEC049 • MEC063 • MEC074	• MEC025 • MEC060 • MEC065

Some of the assessed bat caves occur within the buffer zone of adjacent heritage sites. In these cases, the use of destructive methods in assessing rock strength was not permitted. As a result, estimates of intact rock strength at these caves are based on visual assessments and experience in similar rock mass conditions.

In most cases, access to the back or rear chambers of the caves was not attempted due to limited/tight entry and egress. As such, assessments were either not undertaken in these areas or were made from within the main chamber.

3.3 Bat Cave Observations

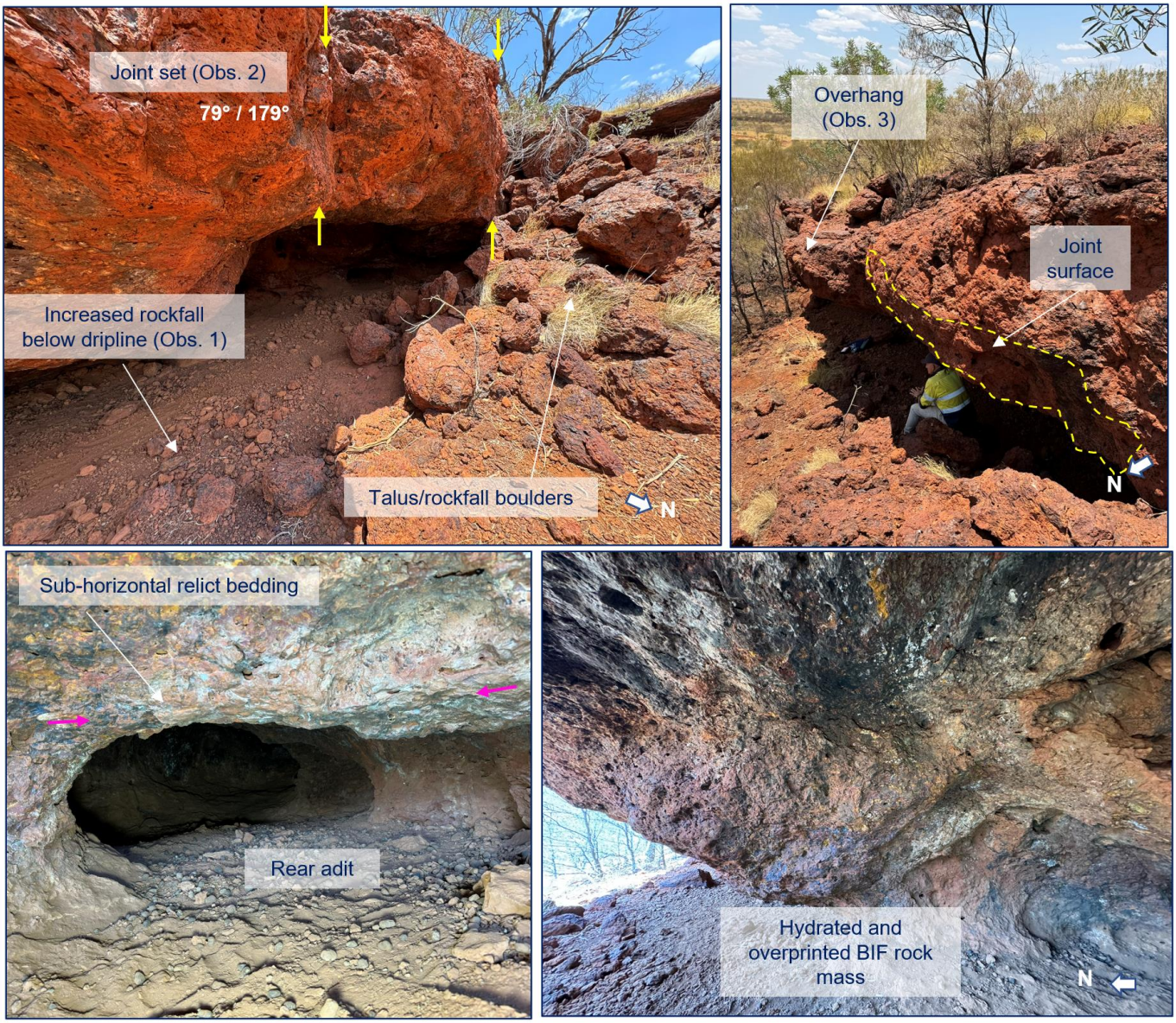
A summary of geotechnical conditions observed in the assessed bat caves at Mulga Downs is presented in Table B1, Appendix B. The following sections provide the site observations and descriptions made during the cave visits.

3.3.1 Cave MEC042

Cave MEC042 is a shallow overhang that occurs within an outcropping bedrock escarpment overlying a gentle to moderately sloping, vegetated talus slope. The cave entrance beneath the overhang is up to 10 m wide, but quickly tapers to form a cave with dimensions 4 m wide, 3.2 m deep, and up to 1.5 m high. The entrance faces north towards a southeast trending gully. The rock mass comprises high strength hydrated BIF with elongate vughs up to 50 mm oriented parallel to relict bedding, which is largely overprinted.

At the rear of the cave is a narrow natural adit approximately 5 m deep, 1.3 m wide and 0.6 m high. BIF bedding becomes developed at the entrance to the adit and was observed to be sub-horizontal. The flat roof profile of the adit indicates that it may have developed preferentially along bedding. Two parallel joints were observed at the cave entrance and appear to form a structural defect set (Obs. [Observation] 2, Inset 2). The joints dip steeply to the south, are undulating to irregular, rough, and iron stained. The joints do not persist for more than 2 m and were only observed at the cave entrance. The following observations were made:

- The joint set appears to control the western extent of the cave, evidenced by the planar sub-vertical shape of the dripline shown in Inset 2
- Rockfall debris appears to increase towards the cave entrance (Obs. 1, Inset 2). Most of the rockfall product observed on the ground does not appear to have detached from any specific identified structure
  - BIF blocks in front of the entrance have highly irregular surfaces, reflecting the degree of hydration and fabric overprinting in the rock mass
  - Measured blocks within the cave are 50 to 500 mm in size.
- No loose or hanging blocks were observed in the roof or cave walls.



Inset 2: **Engineering geological observations of cave MEC042.**
Top Left: Overview of the cave entrance viewed to the west showing vertical joint set and BIF boulders across the entrance. Note historical rockfall intensity increases towards the entrance. **Top Right:** Overview of cave entrance taken from western side of the cave. **Bottom Left:** Narrow adit at the rear of the cave**. Bottom Right:** Hydrated and vughy BIF rock mass.

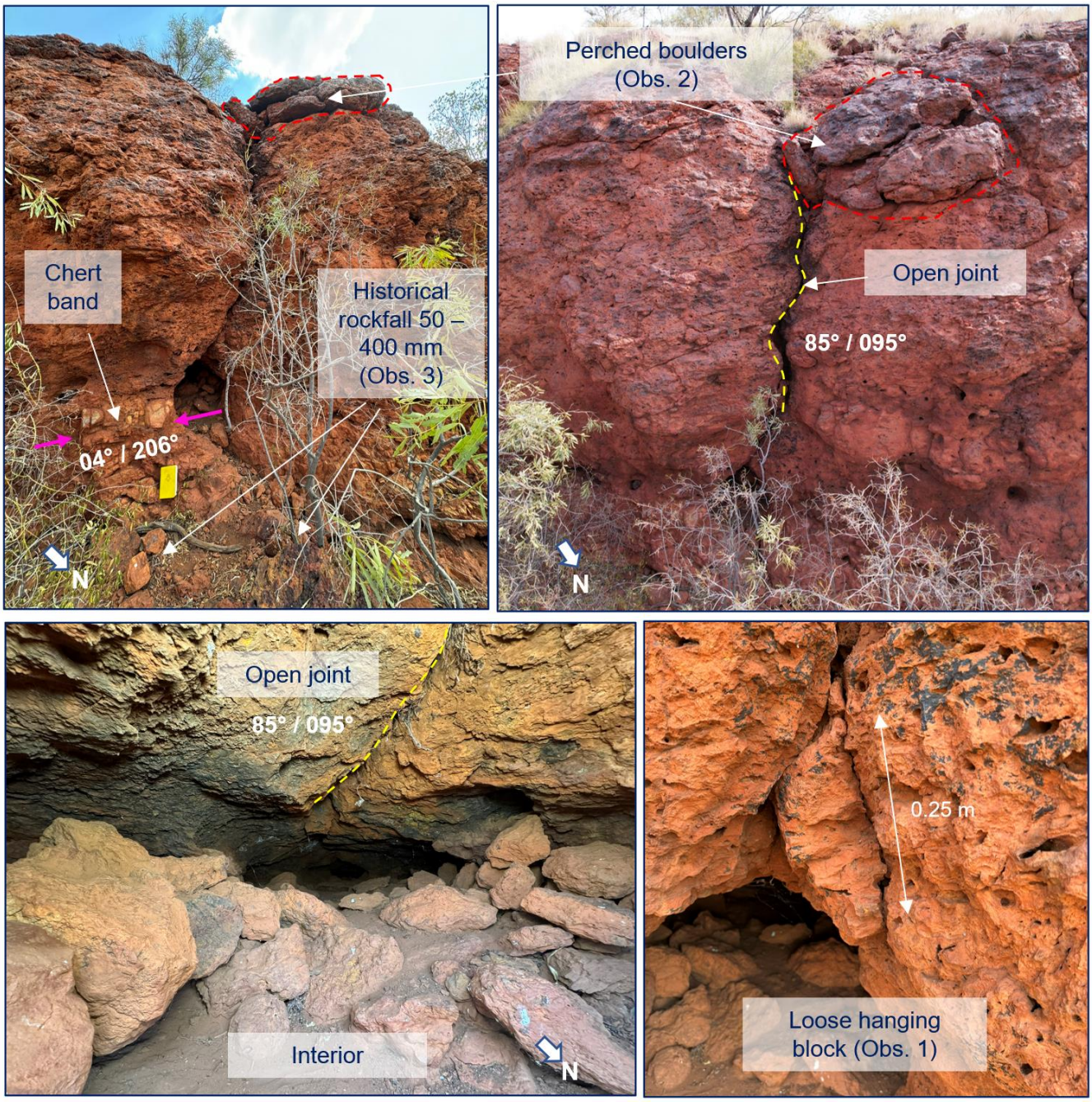
3.3.2 Cave MEC014

Cave MEC014 is a long and narrow cave situated at the bottom of a BIF escarpment. The cave entrance faces northeast and is situated above a moderately sloping, vegetated talus slope, which shallows towards a wide alluvial floodplain. The dimensions of the cave are 6 m deep, 0.8 m wide and 0.8 m high. The rock mass comprises medium to high strength, hydrated and vughy BIF. Bedding fabric has largely been overprinted, though bedding parallel vughs are developed throughout the rock mass. A discrete chert band at the base of the cave dips shallowly towards the southwest, Inset 3.

MEC014 appears to have formed along an open joint which persists along the cave roof for the first approximately 3 m beyond the entrance, Inset 3. The structure dips steeply to the east and is irregular, slightly rough to rough, and infilled with a veneer of iron oxide. Water seepage along the structure is indicated by black staining. Rootlets were observed growing within the joint. From the entrance, the joint appears to intersect the surface at the top of the bedrock escarpment 4 m above and is open throughout. The following observations were made:

- A 250 mm wide hanging BIF block was observed in the dripline of the cave and is bounded by an open fracture and the sub-vertical controlling joint (Obs. 1, Inset 3)

- Multiple perched and wedged boulders were observed at the top of the bedrock escarpment, approximately 4 m above the cave entrance (Obs. 2, Inset 3)
- Rockfall fragments ranging between 50 to 400 mm were observed on the floor immediately outside the cave entrance (Obs. 3, Inset 3)
  - The rockfall debris generally have a blocky shape, and some surfaces show evidence of detachment from bedding partings.
- A fresh BIF cobble was observed to be inserted into a large vugh in the outcrop. The HPPL and Banjima Traditional Owner representatives indicated that this was probably evidence of anthropogenic use of the cave. It is also possible that the unusually high amount of BIF rock debris just inside the cave was part of a walled niche.



Inset 3: **Engineering geological observations of cave MEC014.**
Top Left: Cave entrance viewed towards the southwest. **Top Right**: Aerial view of cave entrance showing the open joint and perched boulders**. Bottom Left**: Interior of the cave, showing detached or possibly relocated blocks, and the controlling joint persisting along the cave roof. **Bottom Right:** Hanging BIF block above the cave entrance. Hydrated vughy BIF rock mass with complete overprinting of bedding.

3.3.3 Cave MEC013

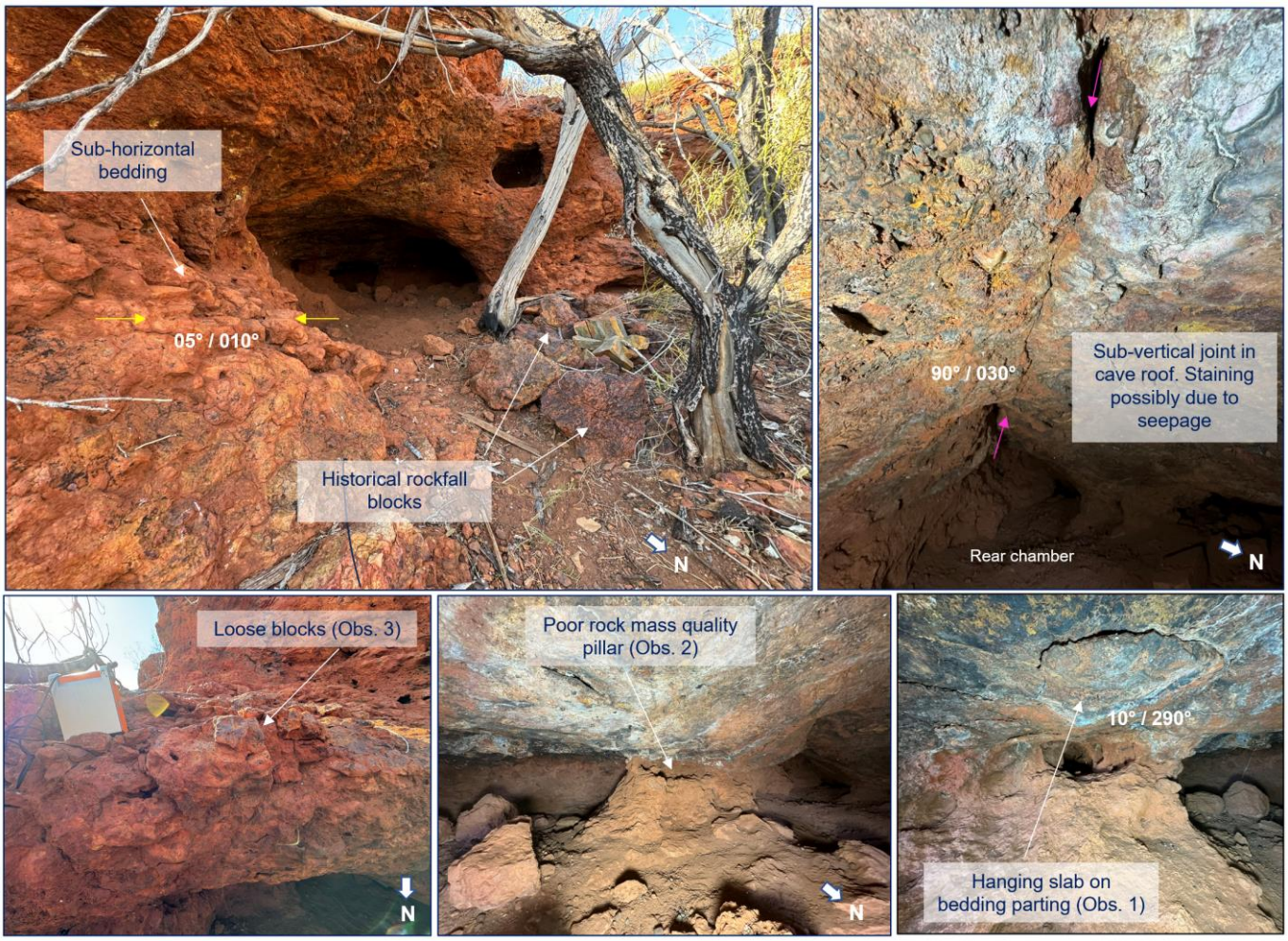
Cave MEC013 is a medium sized cave that is located at the base of a bedrock escarpment. The cave entrance faces north, measures 1.8 m wide by 1 m high, and is positioned at the top of a vegetated talus slope. The span of the cave widens towards the centre of the main chamber and the roof profile shallows forming a cavern that is 3.0 m wide, 3.1 m deep, and 0.7 m high. There is a second, long, narrow chamber in the southwest corner of the cave that measures 0.4 m wide and 2 m deep.

The rock mass comprises moderate to high strength, hydrated BIF and banded chert. Vughs up to 120 mm occur and are generally elongated in the direction of bedding. Deep vughs observed on the western escarpment adjacent to MEC013 have the potential to connect to the cave interior, though this was not able to be confirmed.

Bedding has been partially overprinted and is better preserved on the cave exterior where it is sub-horizontal, undulating and thickly laminated.

A single vertical joint that strikes 220° / 040° was observed in the roof of the rear chamber. The joint is open up to 6 mm and shows evidence of water seepage. At the time of the inspection the joint surface was moist, and the adjacent wall rock showed goethitic and other iron oxide staining, Inset 4. No other joint sets were observed. The following observations were made:

- Bedding does not form structurally significant partings in the cave wall rock mass; however, the cave roof profile has developed preferentially along sub horizontal bedding, Inset 4
- A loose hanging BIF slab on an open bedding parting was observed on the eastern side of the main chamber roof, (Obs. 1, Inset 4)
- A susceptible rock pillar of poor rock mass quality and inferred low rock strength, was observed on the eastern side of the rear chamber (Obs. 2, Inset 4)
- Past rockfall debris appears to be confined mostly to the cave entrance and the floor of the main chamber. The rockfall does not appear to be geologically recent, as debris are covered in a thick layer of dust and silt
- A cluster of loose 50 to 200 mm BIF fragments was observed in the dripline above the cave entrance (Obs. 3, Inset 4)
  - Given the small size of the blocks in this area (typically < 200 mm), any rockfall would not be expected to restrict access to the cave for either bats or personnel.
- No perched boulders were observed in the escarpments immediately above or adjacent to the cave.



Inset 4: **Engineering geological observations of cave MEC013.**
Top Left: Cave entrance viewed towards the southwest. **Top Right:** Sub-vertical joint intersecting the roof of the rear chamber. Note iron oxide staining on the roof proximal to the joint. **Bottom Left:** Loose blocks observed in the dripline above the cave entrance. **Bottom Middle:** Poor rock mass quality pillar located on the eastern side of the rear chamber. **Bottom Right:** Hanging slab in main chamber roof, on open bedding.

3.3.4 Cave MEC012

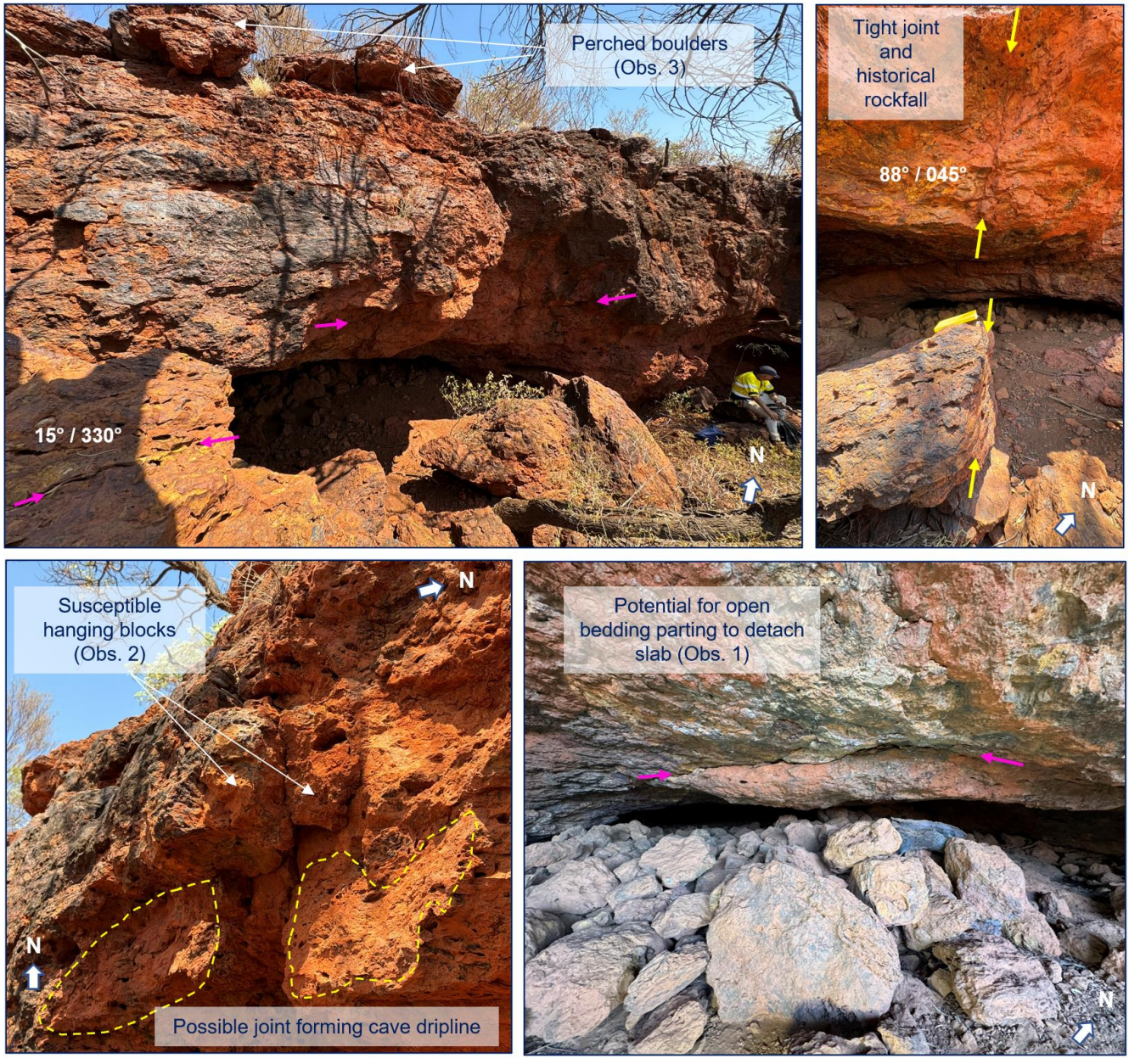
Cave MEC012 is a low, wide span located within a southeast facing bedrock escarpment. The cave is also a heritage site, and anthropogenic use is evidenced by stacked boulders and wood stacked amongst the rocks. The dimensions of the cave are 7.5 m wide, 3.5 m deep, and 1.5 m high. Beyond the main overhang is a shallow rear chamber that is 7 m deep and between 0.2 to 0.5 m high.

The rock mass at the cave comprises high strength hydrated BIF with elongate vughs up to 100 mm, oriented parallel to relict bedding that dips shallowly to the northwest. Some vughs are infilled with silt and gravels which are inferred to be residual rock fragments. The wide and shallow profile of the cave is a result of its development along bedding, Inset 5. Bedding is generally intact, with discontinuous partings (< 2 m) spaced at 0.1 to 0.3 m in the rear wall.

One steep northeast dipping joint set was identified at the cave site. It has a spacing of 3 to 4 m and is undulating, rough, and stained with iron and dark minerals. The joints appear to persist only around the cave entrance and main overhang, with observable lengths of less than 2 m. The joint structures terminate in the rock mass. Large planar surfaces occurring sub-parallel to the cave entrance are inferred to represent a second joint.

The following observations were made:

- A single bedding parting, open up to 5 mm, occurs in the roof between the main overhang and rear chamber. The parting bounds a large slab of BIF (Obs. 1, Inset 5) which may be susceptible to blasting induced vibrations
- Detachment from bedding appears to be a common rockfall mechanism in MEC012, with large tabular blocks up to 4 m wide observed on the cave floor
  - Some rockfall blocks show evidence of detachment from bedding and the steep northeast dipping joint set, Inset 5, which may act as a side release plane.
- Loose hanging blocks up to 0.35 m wide occur in the dripline immediately above the cave entrance (Obs. 2, Inset 5)
- Two perched boulders were observed at the top of the BIF escarpment and may be susceptible to mining induced vibrations (Obs. 3, Inset 5).



Inset 5: **Engineering geological observations of cave MEC012.**
Top Left: The cave entrance viewed to the north showing rock fall debris at entrance, sub-horizontal bedding, and perched boulders atop the escarpment. **Top Right:** Cave entrance showing sub-vertical joint set and release of a historical block from the cross-cutting joint. **Bottom Left**: Loose hanging blocks in cave dripline and inferred joint surfaces oriented sub-parallel to the strike of cave entrance. **Bottom Right:** Cave interior and open bedding parting above BIF slab.

3.3.5 Cave MEC074

Cave MEC074 is a small cave located at the base of a bedrock escarpment overlying a moderately steep, vegetated slope. The escarpment itself is approximately 5 m high and faces east overlooking an alluvial flood plain. The cave entrance is situated beneath a natural overhang that is 3.5 m wide, 1.7 m deep and 1.1 m high. Inside, the height of the overhang tapers down to approximately 0.4 m leading to a rear chamber that is 4.5 m deep and 3.5 m wide.

The rock mass at the cave comprises a thick chert band overlain by hydrated vughy BIF, Inset 6. The contact between the two rock types appears to be horizontal. The bat cave is hosted entirely within the chert band, which makes up the bottom approximately 2.5 m of the exposed escarpment. The chert is highly weathered and hydrated, with an estimated medium to high intact strength. The rock mass is blocky, with multiple intersecting joint sets and bedding partings, and is dilated and loose in some areas, Inset 6.

Bedding was observed to dip shallowly towards the northwest. Within the chert, partings are spaced between 50 and 300 mm, and have lengths of approximately 0.5 to 1.0 m. Bedding partings are typically undulating, rough, and iron stained.

Two joint sets were identified at the cave:

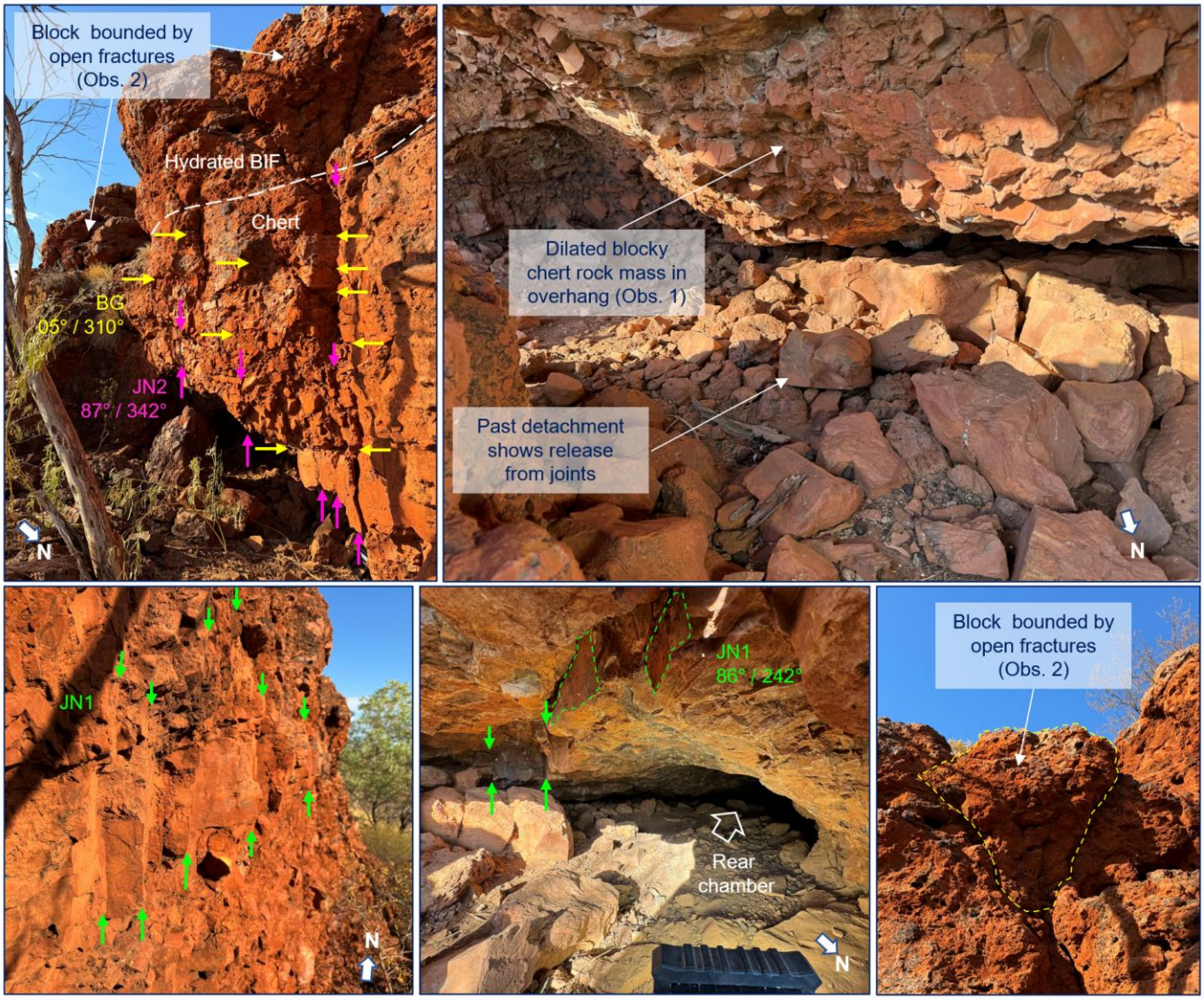
- Joint set 1 (JN1) strikes sub-parallel to the cave entrance and controls the dripline formation. It dips sub-vertically to steeply southwest and is typically planar to undulating. Joint set 1 is spaced between 100 and 300 mm with lengths ranging from 0.3 to 0.8 m. Surface conditions of joint set 1 are slightly rough to rough with an iron oxide veneer
- Joint set 2 (JN2) dips sub-vertically to steeply north-northwest. Joint set 2 has a typical spacing of 50 to 200 mm and is undulating, slightly rough to rough, and iron stained. It strikes obliquely into the escarpment, Inset 6, and has an observable length of 100 to 400 mm. Bridging defects connect some of these joints on the north side of the entrance, resulting in a 2.5 m long discontinuity that is open up to 2 mm. There is potential for additional, similar, defects in this orientation within the escarpment.

The chert appears to be less dilated in the rear chamber, with many of the observed joints at the front of the cave becoming tight towards the rear.

Past rockfall product at the cave is abundant below the overhang and dripline. Tabular blocks generally range between 50 and 400 mm in width, which is reflective of the defect spacing within the chert. Larger blocks (up to 1 m in width) appear to have detached from the hydrated BIF escarpment overlying the chert. The BIF blocks have irregular surfaces that do not show detachment from the observed structural sets. Approximately 20% of rockfall blocks at the cave entrance appear to be geologically recent, while rockfall debris within the rear chamber appears relatively old.

The following observations were made:

- Dilated, loose blocky chert rock mass was observed in some areas of the dripline and in the roof of the overhang (Obs. 1, Inset 6). There appears to be an increased potential for rockfall in these areas as evidenced by past detached blocks on the ground, Inset 6
- Hanging blocks bounded by non-systematic open fractures were identified in the BIF escarpment above the cave entrance (Obs. 2, Inset 6).



Inset 6: **Engineering geological observations of cave MEC074.**
Top Left: Cave entrance viewed towards the southwest, showing hanging blocks in dripline. **Top Right**: Interior of overhang showing past rockfall product and dilated chert rock mass in the cave roof. **Bottom Left**: Joint set 1 controlling dripline formation, viewed towards the north. **Bottom Middle:** Access point to rear chamber showing orientation of joint set 1 planes. **Bottom Right:** Susceptible hanging block above cave entrance bounded by open fractures.

3.3.6 Cave MEC065

Cave MEC065 is a large, wide-spanning cave located at the base of a bedrock escarpment approximately halfway up a moderately steep, vegetated talus slope. The escarpment itself is approximately 7 m high. The cave entrance faces southwest and is approximately 8 m wide and 2 m high. The cave can be divided into a main and rear chamber. The main chamber is 8 m wide, 5.7 m deep, and 1 m high. The rear chamber is distinguished by a drop in the roof profile and is up to 5.7 m deep and up to 0.4 m high. Due to the limited height of the rear chamber, it was not accessed and instead was assessed from the main chamber.

The rock mass comprises interbedded BIF and chert, is highly weathered, and appears to be medium to high strength. No field strength testing was undertaken at MEC065 as the HanRoy representative indicated the site had not received heritage clearance. The interbedded chert bands have a blocky appearance due to two sub-vertical joint sets. Bedding at the cave is undulating and was measured in the main chamber to dip shallowly to the northwest, Inset 7, becoming moderate on the western side of the main chamber. Bedding partings are spaced 0.2 to 0.5 m and are up to 8 m in length, longer than the span of the cave. Parting surfaces are slightly rough to rough, open 1 to 2 mm and iron stained. Partings become more dilated toward the cave entrance where they were observed to be open up to 5 mm. Residual hematitic silt was observed to infill dilated partings in places.

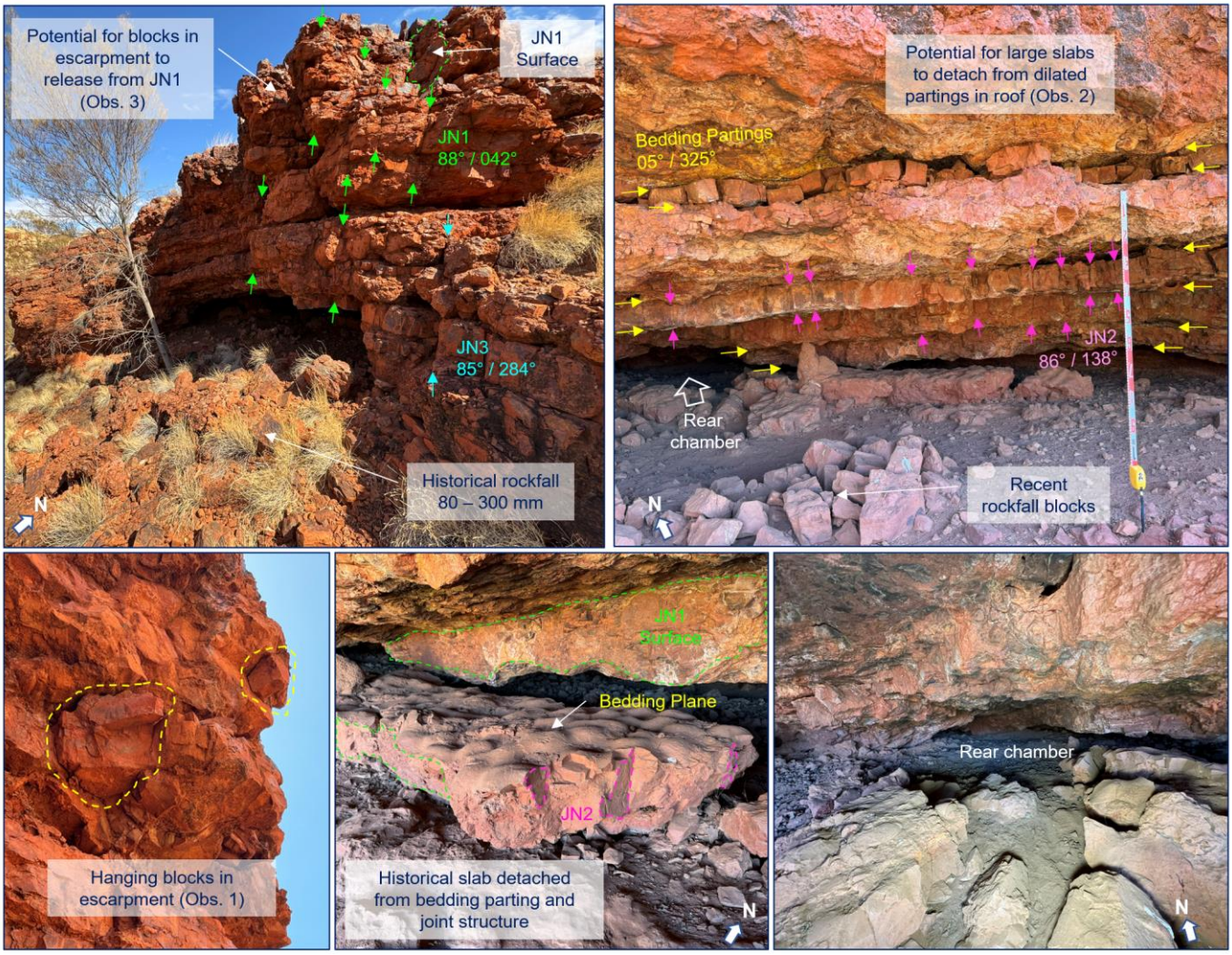
Three joint sets were identified at the cave and appear to be most evident in the interbedded chert bands. The following characteristics of each joint set were observed:

- Joint set 1 (JN1) is oriented parallel to the cave entrance and dips sub-vertically to steeply towards the northeast, Inset 7. It is spaced at 100 to 200 mm and is typically 0.5 to 1.0 m long. JN1 is planar to stepped, slightly rough to rough, and iron stained
- Joint set 2 (JN2) is a sub-vertical joint set that strikes perpendicular to the cave entrance, Inset 7. Joints along this orientation are 0.2 to 0.5 m long and are spaced between 50 and 150 mm. JN2 surface conditions are undulating and rough
- Joint set 3 (JN3) was only observed on the eastern side of the main chamber. It was measured to dip steeply towards the west, with a spacing between 1.0 and 1.5 m. JN3 is generally tight, rough and iron stained. Defect lengths up to 0.5 m were measured on the main chamber's east wall.

Only minor rockfall debris was observed in the rear chamber and it does not appear to be geologically recent. A higher amount of rockfall product was observed in the cave's main chamber. Blocky to tabular chert and BIF was observed throughout the floor of the main chamber and generally ranges between 80 and 300 mm in width. Most of the rockfall fragments in the main chamber are chert, suggesting a potentially higher rate of detachment from the blocky chert bands in the cave roof. At the back of the main chamber, a 2.5 m wide slab appears to have detached from structure in the cave roof, evidenced by an undulating bedding surface and vertical joint planes on the sides, Inset 7. At the cave entrance, approximately 40% of the rockfall debris is inferred to be geologically recent.

The following observations were made:

- Hanging blocks bounded by open joints or non-systematic fractures occur in the dripline above the cave entrance (Obs. 1, Inset 7)
- There is potential for large slabs of chert and hydrated BIF to detach from dilated bedding partings and joints in the main chamber roof (Obs. 2, Inset 7). This mechanism is evidenced by past rockfall product on the cave floor, Inset 7. These features appear relatively highly susceptible to vibration induced damage
- In the escarpment above the cave, there is potential for blocks to release from Joint set 1 (Obs. 3, Inset 7). This presents a rockfall hazard at the cave entrance.



Inset 7: **Engineering geological observations of cave MEC065.**
Top Left: Cave entrance viewed towards the northwest showing joint orientations and past rockfall product. **Top Right:** Cave entrance viewed towards the northeast showing slabs bounded by dilated bedding partings in the cave roof. **Bottom Left**: Susceptible hanging blocks in the escarpment above the entrance. **Bottom Middle:** Detached block in the cave's main chamber showing release from bedding and joint set 1. **Bottom Right**: Rear chamber viewed towards the north.

3.3.7 Cave MEC007

Cave MEC007 is a medium sized cave that is located at the base of a bedrock escarpment approximately midway up a moderately steep, vegetated talus and scree slope. The escarpment the cave is hosted in is approximately 5 to 6 m high. The cave entrance is 6 m wide and overlooks a north-south trending creek. The dimensions of the interior are 6 m wide, 10 m deep, and up to 1 m high.

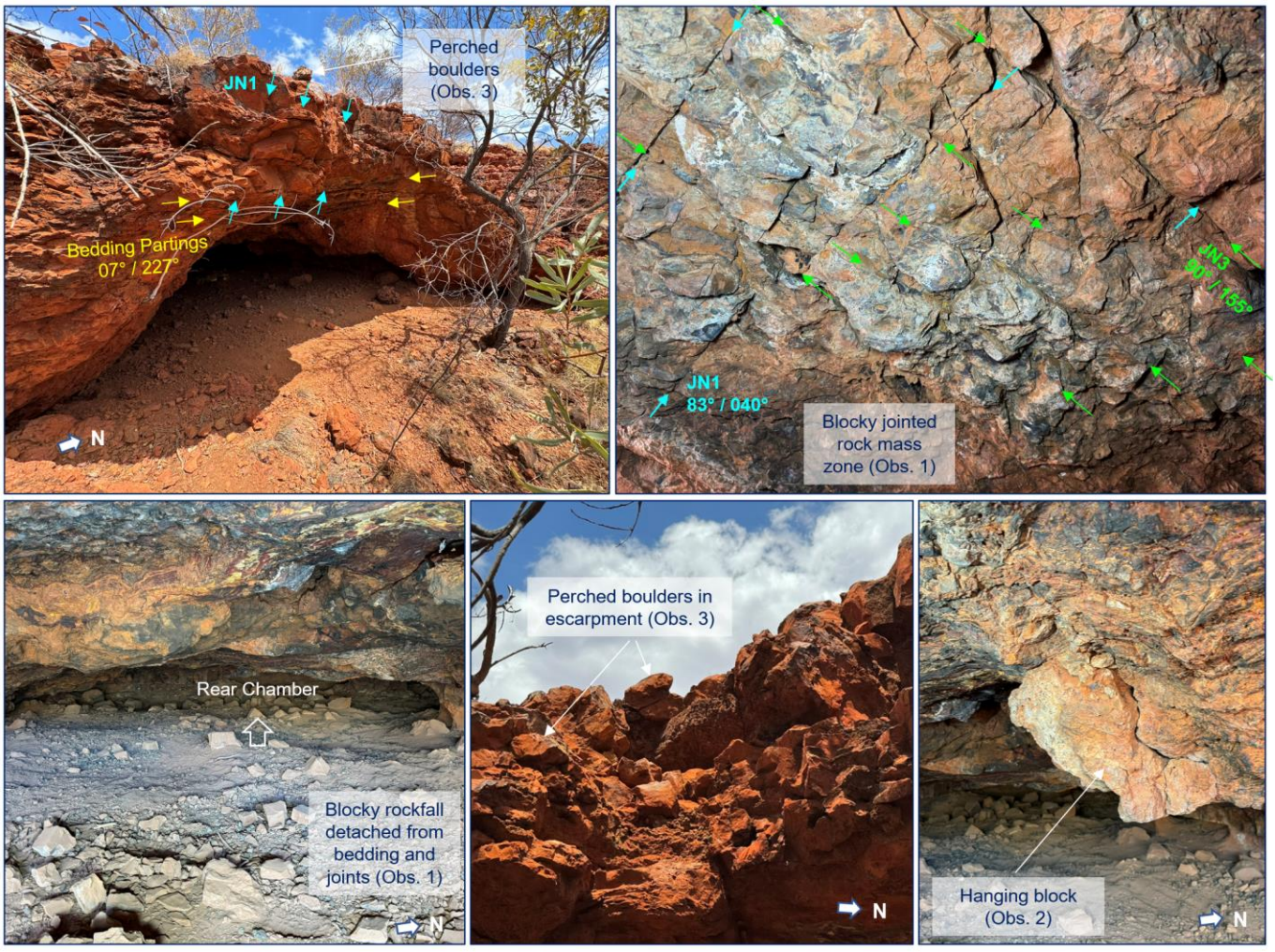
The rock mass at the cave comprises hydrated BIF and interbedded chert. The field estimated strength is medium to high. HanRoy indicated that MEC007 had not received heritage clearance, and as such, the strength estimate is based on assessments of outcrop outside of the heritage area. The rock mass is highly weathered and water seepage into the cave was evidenced by iron staining around the entrance, which obscures the bedding fabric in places. Where visible, bedding partings are undulating and spaced at 60 to 150 mm, with variable lengths between 0.5 and 2.5 m. Bedding is best developed in the cave roof and southern wall, where it was measured to dip shallowly towards the southwest. The cave appears preferentially developed along bedding, resulting in an arched shaped roof that tapers towards the rear of the cave.

Three joint sets were identified at the cave:

- Joint set 1 (JN1) dips steeply to the northeast. JN1 is typically undulating to irregular, with structure open less than 1 mm. Joints along this orientation are up to 4.5 m long and are spaced at 0.5 to 1.5 m. Surface conditions of JN1 are rough and iron stained. Water seepage along JN1 was observed at the back of the cave interior
- Joint set 2 (JN2) is a vertical joint set that strikes east-northeast, and is irregular, rough and iron stained. Defect lengths range between 1 and 2 m and are spaced at 0.5 to 1.0 m
- Joint set 3 (JN3) is a northeast striking joint set that is oriented sub-vertically, and is undulating, rough, and iron stained. Unlike JN1 and JN2, which were observed throughout the cave, JN3 is only developed in the central part of the cave roof. The joints are between 0.5 and 0.8 m in length and are spaced between 100 and 200 mm. They are typically tight and have an iron oxide stain on the surface.

At the back of the cave interior, many of the joints become tight. Rockfall debris, both inside and outside the cave, mostly appears to have detached from bedding surfaces and/or joints. Approximately 10% of the rockfall at the cave appears geologically recent. The following observations were made.

- A zone of blocky, jointed rock mass was observed in the roof of the cave interior (Obs. 1, Inset 8). The area is limited to where joint set 3 is visible, resulting in multiple intersecting sub-vertical joint sets, Inset 8)
- Two hanging blocks bounded by open fractures were observed on the interior of the cave (Obs.2, Inset 8)
- Multiple perched boulders are situated in the escarpment above the cave entrance (Obs. 3, Inset 8).



Inset 8: **Engineering geological observations of cave MEC007.**
Top Left: Cave entrance viewed towards the northwest. **Top Right:** Area of blocky, jointed rock mass, showing intersections of joint set 1 and joint set 3. **Bottom Left**: Rear chamber viewed towards the west, showing past rockfall debris on the cave floor. **Bottom Middle**: Perched boulders in the escarpment above the cave entrance. **Bottom Right:** Identified hanging block in the cave roof bounded by open fractures.

3.3.8 Cave MEC033

Cave MEC033 is hosted within a bedrock escarpment located approximately halfway up a vegetated talus slope. It is situated above a north-south trending creek line. The cave entrance faces southwest and comprises an overhang that is 4.5 m wide, 1.8 m deep and 1.3 m high. The interior of the cave has dimensions 2.5 m wide, 5.6 m deep, and 1 m high. The rock mass at the cave comprises highly weathered, hydrated BIF, with elongate vughs oriented parallel to well-developed bedding. As the site had not received heritage clearance at the time of assessment, intact strength was estimated from nearby outcrop and was assessed to be high strength. A thick, blocky chert band forms the lower third of the cave entrance, Inset 9.

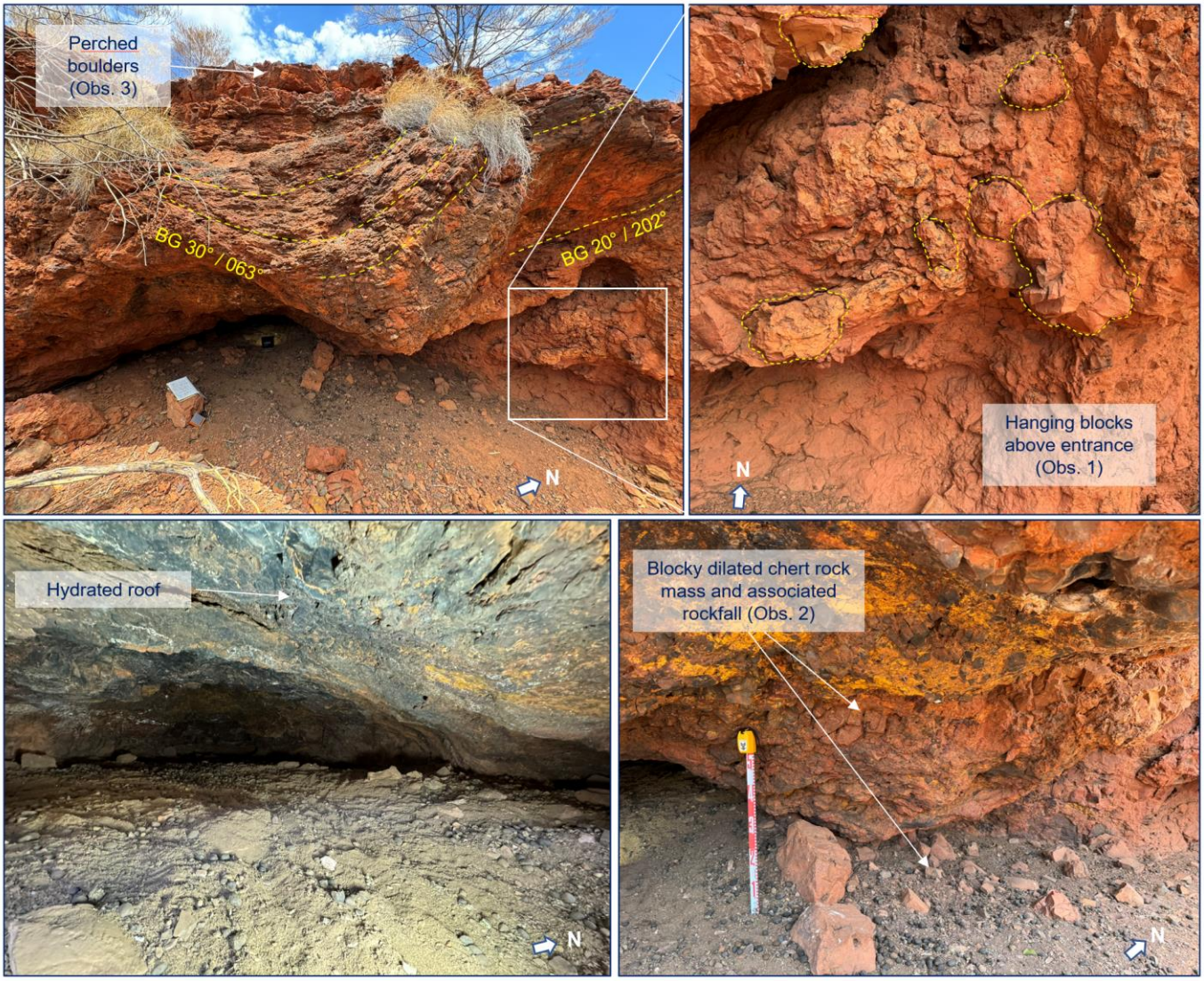
Bedding generally has a shallow dip and is partially overprinted by hydration of the rock mass. The dip direction of bedding is variable due to the degree of undulation, with the dip becoming moderate in some highly folded areas, as observed at the cave entrance (Inset 9). Partings are spaced 50 to 150 mm and are generally more persistent in the overhang and exterior with lengths between 0.8 and 1.2 m. Bedding partings are typically open less than 1 mm and exhibit iron staining. The cave roof is formed along bedding.

No structurally significant joint sets were observed at MEC033, though some open non-systematic fractures were observed around the exterior and overhang. These fractures are shown on the schematic plan presented in Appendix A. Some joints were observed in the chert band, which makes up the lower part of the overhang, though they do not appear to be structurally important. Inside, the defects within the chert appear to become tight.

At the cave entrance BIF rockfall debris is generally blocky and ranges between 50 and 300 mm in width. Most have irregular surfaces, suggesting detachment by breaking of the hydrated rock mass, rather than from systematic structural sets, though a few blocks appear to have detached from bedding. The more geologically recent rockfall appears to be concentrated below the dripline. Minimal rockfall product was observed inside the cave, none of which appears geologically recent.

The following observations were made:

- Loose hanging blocks were identified in the overhang (Obs. 1, Inset 9)
- Blocky dilated chert rock mass was observed in the lower part of the overhang, with detached blocky to tabular chert fragments observed on the floor below (Obs. 2, Inset 9)
- Perched boulders were identified in the escarpment above the overhang (Obs. 3, Inset 9). These boulders have the potential to fall down the escarpment and over the dripline.



Inset 9: **Engineering geological observations of cave MEC033.**
Top Left: Cave entrance viewed towards the west, showing variable bedding orientation and perched boulders in the escarpment above the entrance. **Top Right:** Loose hanging blocks identified around the entrance. **Bottom Left**: Cave interior viewed towards the east showing stained roof as a result of water seepage into the cave. **Bottom Right:** Area of blocky, dilated chert rock mass at the cave entrance, and associated rockfall debris below.

3.3.9 Cave MEC073

Cave MEC073 is located at the base of an east-facing bedrock escarpment. The escarpment is approximately 5 m high and overlooks a moderately steep, vegetated talus slope. The cave entrance is located beneath a natural overhang that is 4 m wide, 1.7 m deep, and 1 m high. The overhang narrows and tapers down towards the east, leading to a main chamber that is 6 m deep, up to 1.5 m wide and 0.5 m high. The rock mass at the cave comprises medium to high strength, hydrated chert and interbedded BIF. The cave itself is hosted within a chert-dominant rock mass which makes up the lower half of the exposed escarpment. The upper half of the escarpment comprises a BIF-dominant rock mass, Inset 10.

The cherty rock mass that hosts the cave is high strength and highly weathered. Bedding is developed with partings spaced at 50 to 300 mm and between 0.5 and 1.0 m long. Partings are undulating, slightly rough to rough, and have an iron oxide stain or veneer on dilated surfaces. Bedding was measured at the back of the overhang to dip shallowly to the east. Bedding is still developed on the cave interior but appears to become overprinted deeper into the cave's main chamber. In the BIF-dominant escarpment above the cave, the hydrated rock mass largely overprints any bedding fabric.

Two joint sets were observed at the cave and are confined to the chert dominant rock mass:

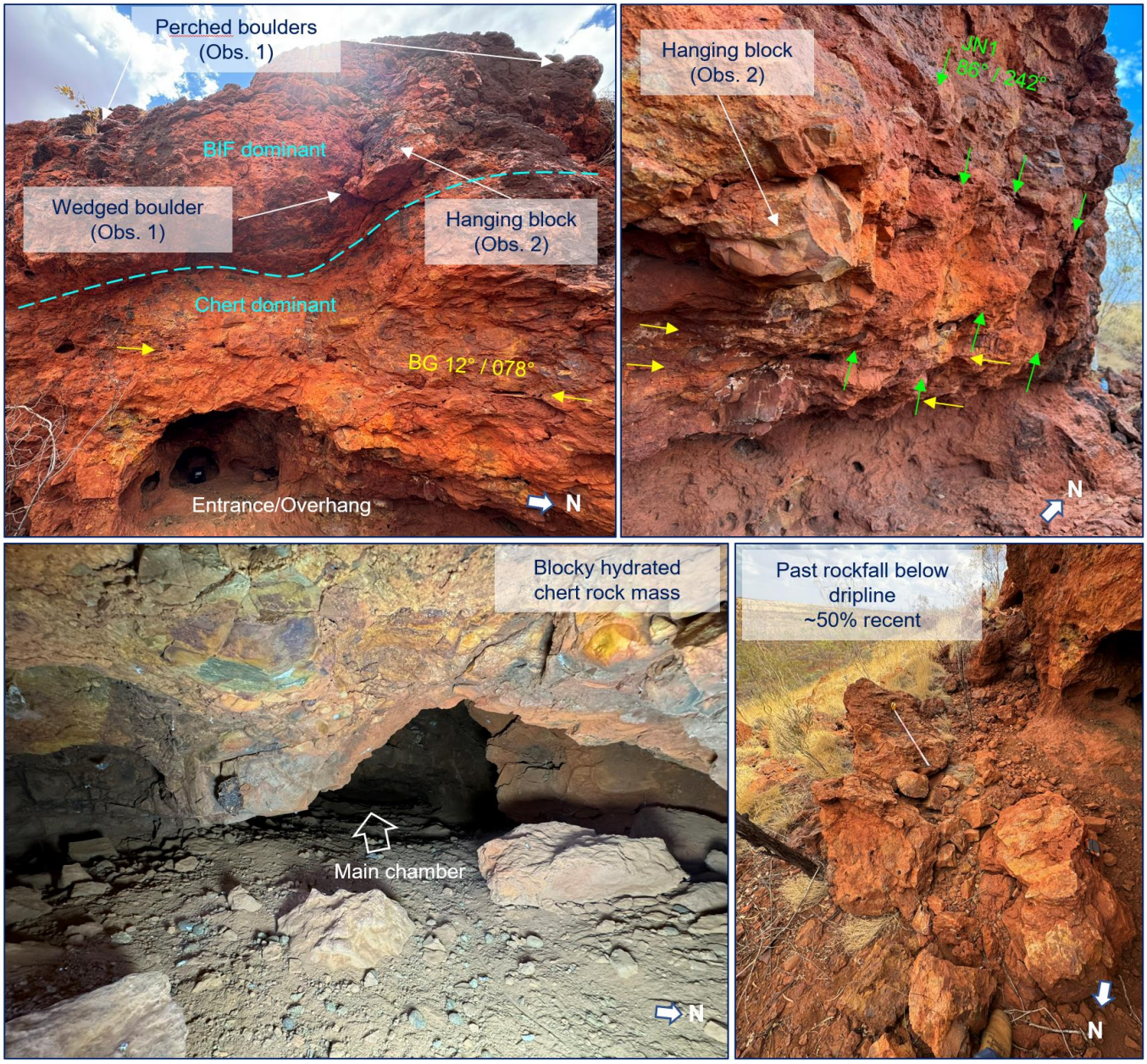
- Joint set 1 (JN1) is oriented sub-parallel to the escarpment, Inset 10. JN1 dips steeply to the southwest and is spaced at approximately 0.1 m, is 0.4 to 0.7 m long
- Joint set 2 (JN2) dips steeply to the southeast. It is spaced between 100 to 200 mm and is typically 0.1 to 0.3 m long. Shorter, tight joints were also observed along this orientation.

Both joint sets are tight, and surface conditions are undulating and rough. Past rockfall is concentrated below the dripline of the cave, Inset 10. The rockfall product comprises both chert and BIF, with approximately half appearing to be geologically recent. The chert debris have a blocky shape and show detachment from structure, whereas hydrated BIF blocks have more irregular surfaces. Rockfall observed within the cave's main chamber was mostly covered by dust and silt, indicating that it is not geologically recent.

The following observations were made:

- Wedged and perched boulders were identified in the escarpment above the cave entrance (Obs. 1, Inset 10)
- Loose hanging blocks bounded by open fractures were also identified in the escarpment, both above and adjacent to the cave entrance (Obs. 2, Inset 10).

Based on the orientations of bedding and the observed joint sets, it is kinematically possible for blocks to detach from the cave roof and overhang, however, no specific susceptible blocks were observed, given that the defects are typically tight.



Inset 10: **Engineering geological observations of cave MEC073.**
Top Left: Cave entrance and overlying escarpment viewed towards the west, showing susceptible features and contact between chert and BIF. **Top Right:** Northern side of escarpment adjacent to cave entrance, showing orientations of joint set 1 and bedding. **Bottom Left:** Cave interior viewed towards the west, showing access point to main chamber and blocky hydrated chert in the cave roof. **Bottom Right**: Past rockfall blocks immediately outside the cave entrance, viewed towards the south.

3.3.10 Cave MEC039

Cave MEC039 is a medium sized cave located at the base of an exposed bedrock escarpment. The escarpment itself is approximately 6 m high and is located near the top of a moderately sloping, vegetated talus slope. The lower third of the outcropping escarpment comprises chert, which is overlain by BIF, Inset 11. Both rock types are highly weathered and hydrated. The cave appears to have preferentially developed along the contact between the chert and the BIF. The cave floor slopes upward, meaning the cave's interior chamber is almost entirely hosted within the BIF, Inset 11.

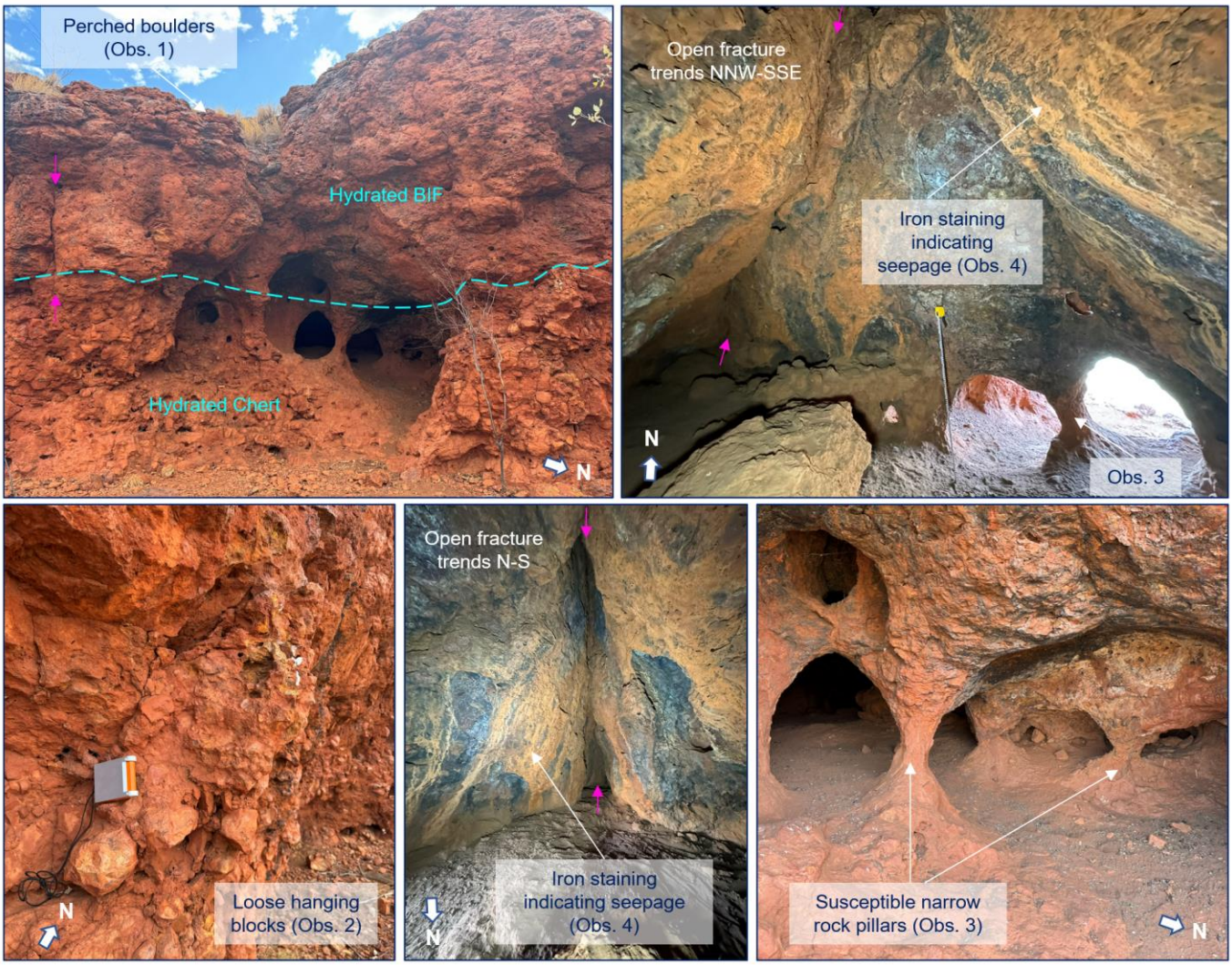
The cave entrance is approximately 2.1 m wide, 1.1 m high and is situated beneath a natural overhang in the escarpment, Inset 11. Two circular shaped entry points into the cave are separated by a narrow rock pillar, and lead to an interior chamber with dimensions of 4.5 m wide, 5.7 m deep and 1.8 m high. On the southern side of the chamber, a narrow natural adit extends 2.1 m to the south.

The chert rock mass, which makes up the lower half of the cave entrance, Inset 11, is blocky and loose in places. The blockiness within the chert is a product of multiple intersecting joint sets. These joints within the chert are not considered to present a significant stability concern on the scale of the cave, due to the relatively short defect lengths. In the overlying BIF, bedding has been overprinted but can be distinguished by elongate bedding-parallel vughs. Where rock fabrics are preserved, bedding partings were observed to have a spacing of 0.4 to 0.7 m and lengths of 0.5 to 1.5 m.

Open fractures occur within the BIF rock mass and are shown on the schematic plan presented in Appendix A. The fractures do not appear to form systematic joint sets. The main north to north-northwest striking fracture inside the cave is interpreted to have formed due to slumping of the bedrock escarpment. The cave appears to have then developed by preferential weathering along this fracture. Connectivity to the surface is inferred along this fracture due to considerable iron staining, suggesting surface water seepage into the cave, Inset 11. Bedding partings are not developed inside the cave and fabric is overprinted, Inset 11.

The following observations were made:

- Boulders perched on the edge of the escarpment above the cave entrance (Obs. 1, Inset 11)
- Multiple hanging blocks bounded by non-systematic, dilated fractures in the cave dripline (Obs. 2, Inset 11)
- Narrow rock pillars located at the entrance to the interior chamber may be susceptible to damage or collapse from blast induced vibrations (Obs. 3, Inset 11). The pillars occur at the interface between the chert and overlying BIF
- Seepage into the cave was observed to occur along the north to north-northwest trending fracture inside the cave, evidenced by considerable iron staining (Obs. 4, Inset 11).



Inset 11: **Engineering geological observations of cave MEC039.**
Top Left: Cave entrance viewed towards the west-southwest showing perched boulders in the escarpment above and boundary between hydrated BIF and hydrated chert. **Top Right:** Interior of the cave looking north towards the entrance. **Bottom Left:** Loose hanging blocks within chert located on the cave exterior. **Bottom Middle**: Cave interior viewed towards the south showing cave-controlling fracture, and iron staining. **Bottom Right:** Susceptible narrow rock pillars located at the entrance to the main chamber.

3.3.11 Cave MEC016 (MIB-MD13-043)

Cave MEC016 (heritage ID MIB-MD13-043) has been identified as both a bat cave and heritage rock shelter. MEC016 is a large, multi-chambered cave located within an outcropping BIF escarpment. The cave is situated on the northern flank of a north-east draining gully, above a vegetated talus slope. The cave entrance faces southeast and is 6 m wide and up to 2.8 m high. The interior dimensions of the cave are as follows:

- A main central chamber that measures 6 m wide, 7.6 m deep, and up to 1.2 m high. A skylight 0.8m wide occurs in the roof of the central chamber
  - On the eastern side of the main chamber, the roof profile drops to 0.7 m high and the cave extends a further 4.5 m to the east.
- Three natural adits that that spur from the main chamber, all of which are 5 to 6 m deep, 1.8 to 2.2 m wide, and less than 0.8 m high, with roof profiles that taper towards the rear.

The rock mass comprises partially hydrated, vughy BIF and chert that dips shallowly towards the southeast. The roof profile is undulating and sub-horizontal, suggesting the cave developed along BIF bedding planes. The floor level of the cave and the escarpment below comprises a thick boudinaged chert band. Bedding partings are spaced at 150 to 300 mm, though are not continuous across the cave.

Parting spacing increases to 0.5 m towards the top of the escarpment where bedding becomes largely overprinted. Observed parting lengths are typically between 2 and 4 m.

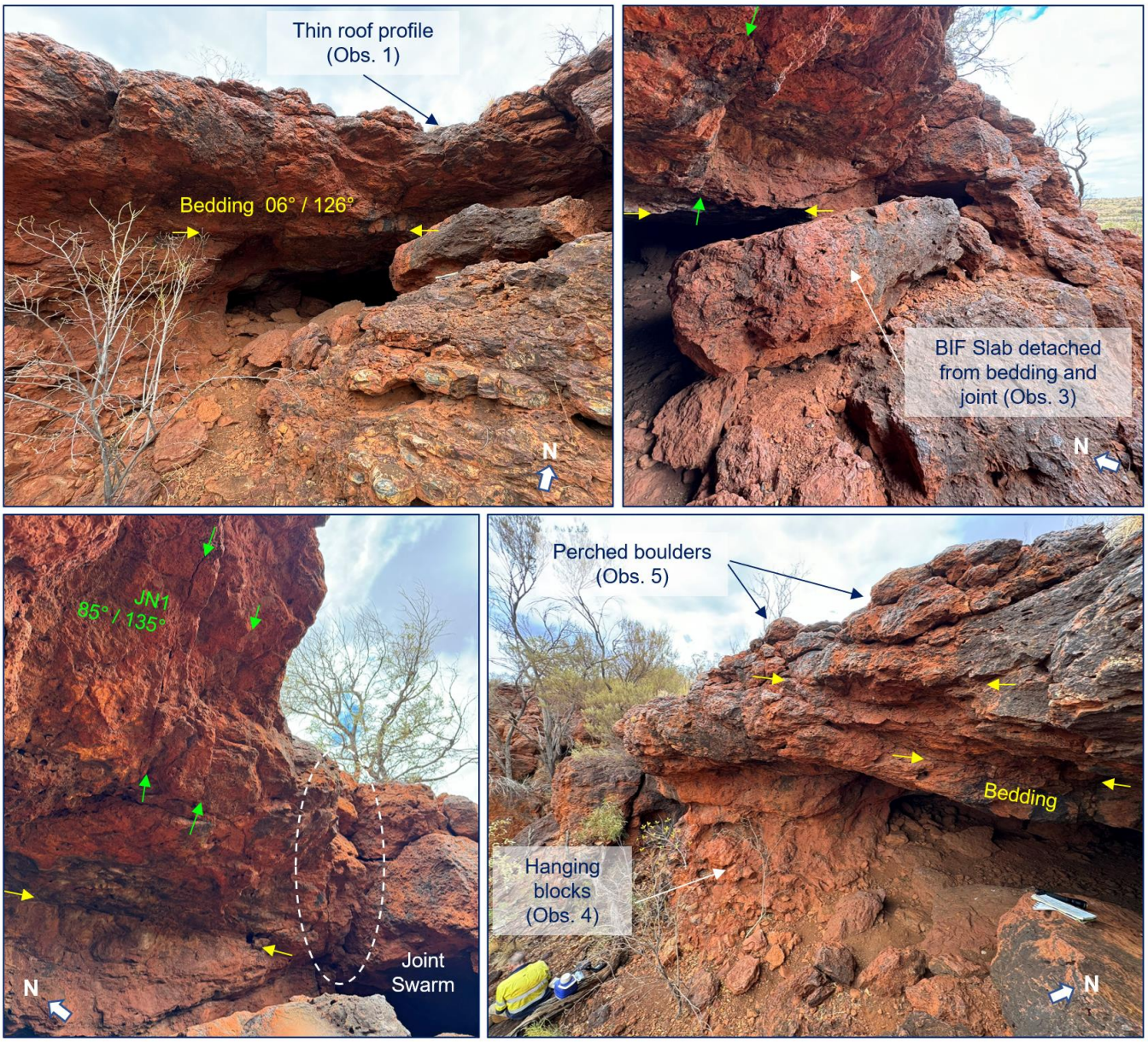
A sub-vertical joint swarm was observed on the eastern side of the cave entrance, Inset 12. The joints dip steeply to the northeast. No other joint sets were observed to be parallel to the joint swarm. Three joint sets were identified and have the following characteristics:

- Joint set 1 (JN1) dips steeply to the southeast. It has a spacing of 0.4 to 1.0 m at the entrance. The spacing increases into the cave where it is spaced at approximately 3 m. Defect lengths are highly variable and range between 1.5 and 5.0 m. The joints are undulating and slightly rough to rough. They are typically open less than 1 mm and have an iron oxide veneer. A single joint along this orientation in the main chamber roof is open up to 3 mm and infilled with silt and a veneer of iron oxide. Evidence of water seepage into the cave was observed along this structure, Inset 13.
- Joint set 2 (JN2) dips steeply to the east-northeast. Only two joints were observed along this orientation in the roof of the main chamber, indicating a spacing of 1.2 m and lengths between 3.0 and 4.5 m. The two joints are irregular and rough. They are open less than 1 mm and have an iron oxide veneer on dilated surfaces.
- Joint set 3 (JN3) dips steeply to the northeast. Only two joints were observed, on the western side of the main chamber, indicating a spacing of 0.7 m and lengths of approximately 1 m. The joints are open less than 1 mm and are irregular, rough, and iron stained.

Due to the spacing and lengths relative to the size of the cave, the three joint sets were not observed to intersect each other. Rockfall debris observed inside the cave does not appear geologically recent, with most blocks covered or buried by dust. A large slab at the entrance shows detachment form bedding and joints in the overhang, Inset 12. Approximately 30% of rockfall at the entrance appears to be geologically recent.

The following susceptible features were observed:

- A thin roof profile (measured 1 to 2 m thick above the entrance) in combination with the cave's wide span increases the susceptibility to collapse (Obs. 1, Inset 12)
- A pillar of poorer rock mass is situated at the back of the main chamber, and may be susceptible to cracking (Obs. 2, Inset 13)
- There is potential for blocks to detach from bedding partings in the cave roof or overhang where crosscut by a sub-vertical joint set (Obs. 3, Inset 12). This mechanism is evidenced by past tabular rockfall below the entrance
- Loose hanging blocks were identified in the escarpment around the entrance (Obs. 4, Inset 12). No hanging blocks were identified on the interior
- Perched boulders situated in the escarpment above the cave have the potential to fall across the entrance (Obs. 5, Inset 12).



Inset 12: **Engineering geological observations of cave MEC016 (MIB-MD13-043) exterior.**
Top Left: Cave entrance viewed towards the north. **Top Right:** Large BIF slab detached from bedding parting and joints in the overhang. **Bottom Left**: Eastern side of the cave entrance showing joint set 1 orientation in the overhang, and joint swarm location. **Bottom Right:** Cave entrance viewed towards the west showing perched boulders in the escarpment above entrance, and sub-horizontal bedding orientation.

Inset 13: **Engineering geological observations of cave MEC016 (MIB-MD13-043) interior.**
Top Left: Cave interior viewed towards the northwest showing access point to the western rear adit and the natural skylight developed in the cave roof. **Top Right**: Interior viewed towards the south showing cave entrance and access point to southwest adit. **Bottom Left:** Joint set 1 intersecting the interior roof, and access point to eastern rear adit. **Bottom Right:** Cave interior viewed towards the south showing a large slab detached from bedding in the cave roof.

3.3.12 Cave MEC063

MEC063 is a medium sized cave that is hosted within a bedrock escarpment. It is located approximately two-thirds of the way up a moderate to steep, vegetated talus slope and overlooks and alluvial flood plain. The cave entrance faces east-southeast and is 6.3 m wide and 1.9 m high. The interior of the cave has dimensions of 10.8 m wide, 7.8 m deep, and up to 1.2 m high. The escarpment to the east appears to have detached along a significant defect, resulting in a gap between the escarpment edge and cave dripline, Inset 14.

The rock mass at the cave comprises highly weathered, interbedded BIF and chert. Water seepage into the cave was evidenced by black and white staining on the cave roof. As the site had not received heritage clearance, the intact rock strength was visually estimated to be high.

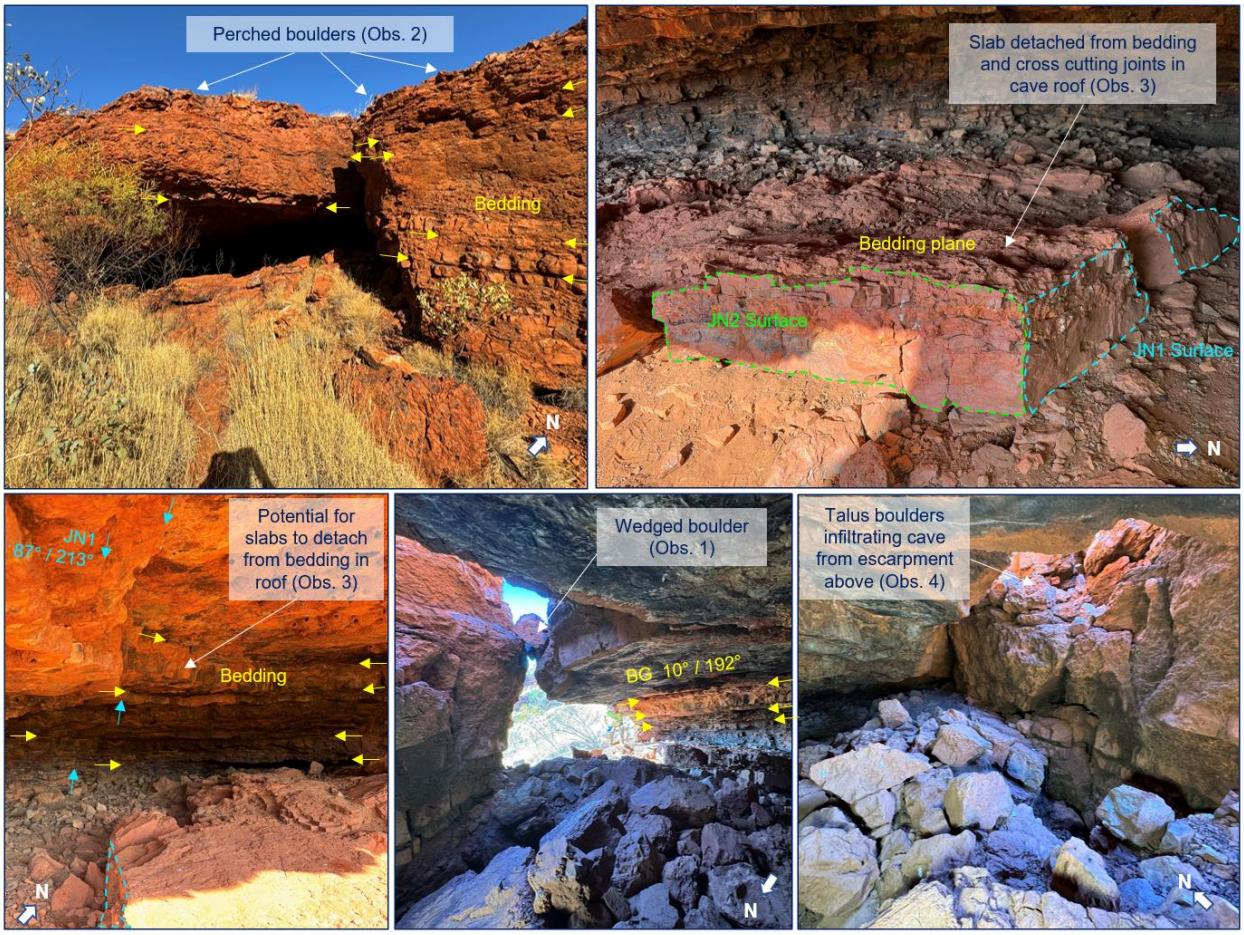
Bedding is well developed, undulating and strongly controls cave development. Bedding was measured in the centre of the cave to dip shallowly to the south. Partings are spaced between 80 and 300 mm. Some partings persist longer than the span of the cave, though most are between 5 and 10 m in length and are open less than 1 mm. Surface conditions of bedding partings are undulating and slightly rough, though smooth bedding planes were observed in places, possibly due to preferential weathering and water inflow along dilated partings.

Two pervasive joint sets were identified at the cave throughout the exterior and interior:

- Joint set 1 (JN1) is oriented sub-vertically and strikes northeast-southwest. Defects along this orientation are typically short (0.3 to 0.8 m), but some JN1 structures were observed up to 5 m in length. The joint set has a spacing of 0.2 to 0.5 m and is tight. Surface conditions are undulating and rough
- Joint set 2 (JN2) dips steeply to the northwest, sub-parallel to the bedrock escarpment. Surfaces are planar to undulating and range between 0.3 and 1.0 m in length. Some exposed JN2 surfaces where past blocks have detached are up to 2.5 m long. Defects are open less than 1 mm and have an iron oxide stain.

Rockfall debris occurs throughout the interior floor and approximately half of the observable blocks appear to be geologically recent. Most blocks have a tabular to platy shape and appear to have detached from bedding and/or joints in the cave roof. The largest detached block inside the cave is 3 m wide, however, most blocks are 0.1 to 0.5 m wide. The following observations were made:

- Wedged boulders were observed on the eastern side of the cave, in the gap between the cave dripline and eastern escarpment (Obs. 1, Inset 14)
- Perched boulders are situated atop the escarpment above the cave entrance (Obs. 2, Inset 14)
- There is potential for large slabs of hydrated BIF and chert to detach from dilated bedding partings and joints in the cave roof (Obs. 3, Inset 14)
- Talus boulders form the escarpment above the cave were observed to have fallen through the gap between the cave dripline and eastern escarpment edge (Obs. 4, Inset 14).



Inset 14: **Engineering geological observations of cave MEC063.**
Top Left: Cave entrance viewed towards the northwest, showing bedding partings in the surrounding escarpment and locations of boulders perched on the escarpment edge. **Top Right:** Detached block inside the cave showing detachment from bedding and vertical joint planes. **Bottom Left:** Cave interior viewed to the northwest showing dilated bedding partings and joint set 1 orientation. **Bottom Middle:** Cave interior viewed towards the southeast, showing wedged boulders in the gap between the cave dripline and adjacent escarpment. **Bottom Right:** Talus originating from the gap on the eastern side of the cave, note drop in floor profile.

3.3.13 Cave MEC062

Cave MEC062 is a medium sized cave located at the base of a 6 m high bedrock escarpment. The escarpment is situated approximately two-thirds up slope. The cave entrance faces north-northeast and overlooks a moderately steep, vegetated talus slope. The cave comprises a single chamber that is 6.1 m wide, 6.7 m deep and 1.5 m high.

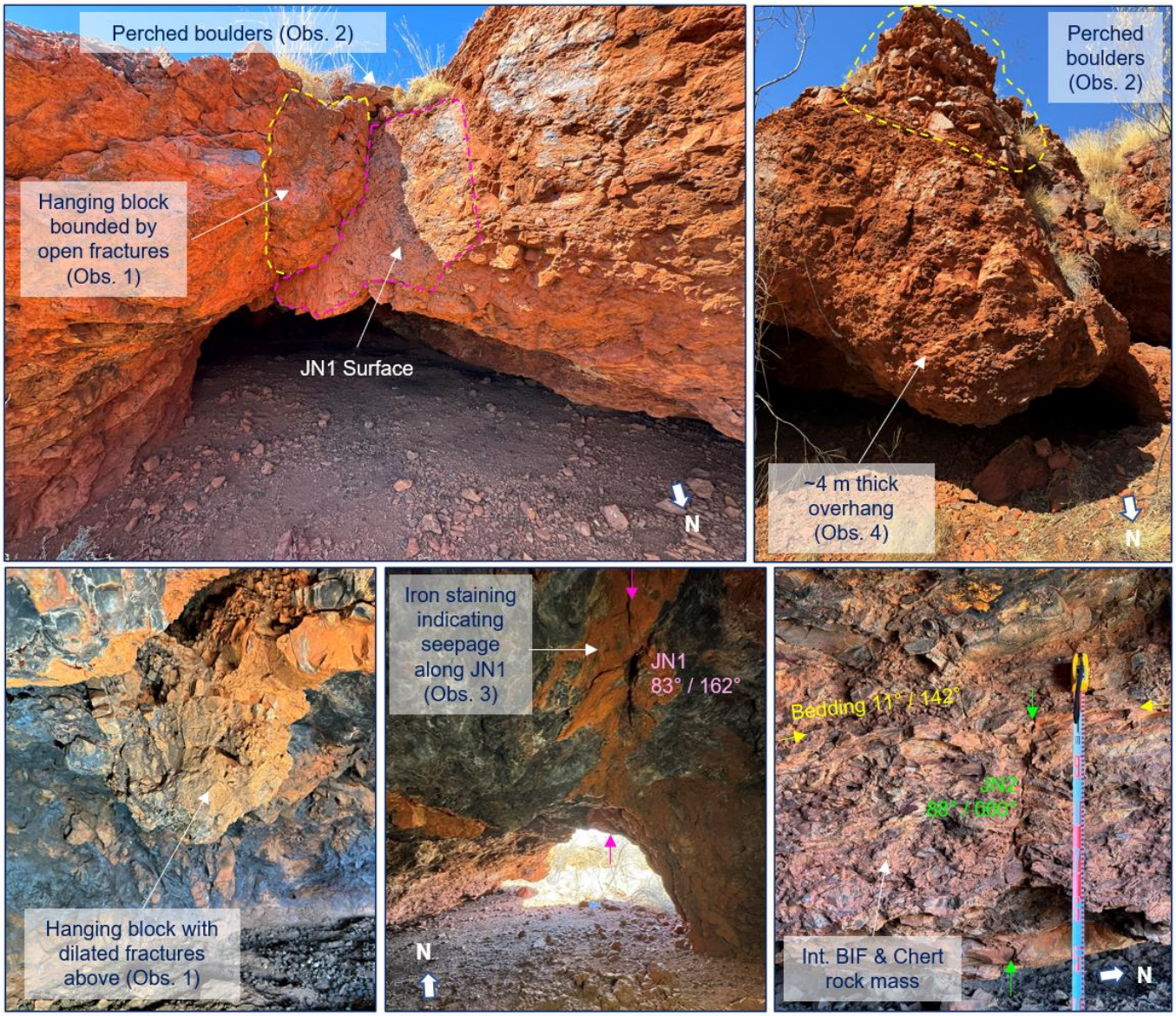
The rock mass at the cave comprises highly weathered, hydrated, interbedded BIF and chert. Intact strength was estimated visually, as the site has not received heritage clearance, and was inferred to be high. Hydration has overprinted bedding in parts of the cave, particularly on the cave roof and southern wall. Where visible, bedding is sub-horizontal and is highly undulose. The dip direction of bedding is variable due to the degree of undulation, with the dip becoming moderate to steep in some highly folded areas at the rear of the cave. Partings were observed to have a 100 to 400 mm spacing at the front of the main chamber. The partings are between 0.5 and 1.5 m in length and are either tight or open less than 1 mm. Bedding becomes overprinted at the back of the main chamber, with no significant partings observed.

Two joint sets were identified at the cave. Joint set 1 (JN1) dips steeply to the south-southeast and is 0.6 to 2.8 m long. The second joint set (JN2) dips sub-vertically to the northeast and is 1.0 to 2.5 m long. Both joint sets have irregular and rough surface conditions and are typically tight with an iron stain infill. The joint sets are spaced variable between 1 and 3 m apart. A large open fracture in the cave roof appears to initiate along JN1 in at the cave entrance, and then rotates to join a folded bedding parting towards the rear of the cave, Inset 15.

Rockfall debris in the cave varies from 50 to 150 mm wide, with larger blocks up to 700 mm wide observed in front of the dripline. Most of the rockfall does not appear to be geologically recent. The rocks are blocky in shape and most do not appear to have detached from an observed structural set.

The following observations were made:

- Hanging blocks were observed on the cave exterior and interior (Obs. 1, Inset 15). A large hanging block situated immediately above the entrance is bounded by joint set 1 and other open fractures, Inset 15
- Multiple perched boulders up to 0.6 m in width were observed on the escarpment above the cave entrance (Obs. 2, Inset 15)
- Water seepage into the cave was inferred along a dilated fracture in the cave roof, which is partially aligned along joint set 1 (Obs. 3, Inset 15). Seepage was evidenced by iron staining of the wall rock either side of the fracture, Inset 15
- The overhanging escarpment on the western side of the cave entrance is up to 4 m thick. Due to the orientation of joint set 2, there is potential for the substantial overhang to detach from the sub-vertical structure (Obs. 4, Inset 15).



Inset 15: **Engineering geological observations of cave MEC062.**
Top Left: Cave entrance viewed towards the southwest, showing susceptible features and joint set 1 surface. **Top Right:** Perched blocks in the escarpment and thick overhang profile. **Bottom Left:** Example of hanging block in the cave roof bounded by open fractures. **Bottom Middle:** Cave interior viewed towards the north, showing orientation of joint set 1 and iron staining along structure indicating seepage. **Bottom Right:** Front of the main chamber showing highly undulating interbedded rock mass, and the orientations of bedding and joint set 2.

3.3.14 Cave MEC061

Cave MEC61 is a small cave located at the base of a bedrock escarpment overlooking a moderately steep, vegetated talus slope. The escarpment itself is approximately 4 m high and faces northeast. The cave entrance is hosted within a shallow, natural overhang and is 5.1 m wide, 1.7 m deep and 0.5 m high. A 0.3 m high chamber occurs at the back of the overhang and was observed to extend up to 3 m deep and 4 m wide. The rear chamber was not accessed due to the limited height.

The rock mass at the cave comprises hydrated interbedded BIF and chert. The rock mass is highly weathered and has a medium to high intact strength. In some areas along the dripline, the rock mass appears blocky due to the closely spaced jointing and bedding partings, Inset 16. A thinly laminated siliceous shale band was observed above the cave entrance, Inset 16. The band is approximately 100 mm thick and appears to have been preferentially weathered.

Bedding is well developed and is undulating with 1.5 to 3.5 m long partings that are open less than 1 mm. Some dilated partings around the entrance are open up to 4 mm. Partings are spaced variable between 0.15 and 0.4 m. Surfaces are typically slightly rough to rough and are iron stained. Bedding is partially overprinted by hydration in some areas of the escarpment. Bedding was measured to dip shallowly to the southeast. Within the siliceous shale band, laminations are spaced at approximately 10 mm, though they are not laterally persistent.

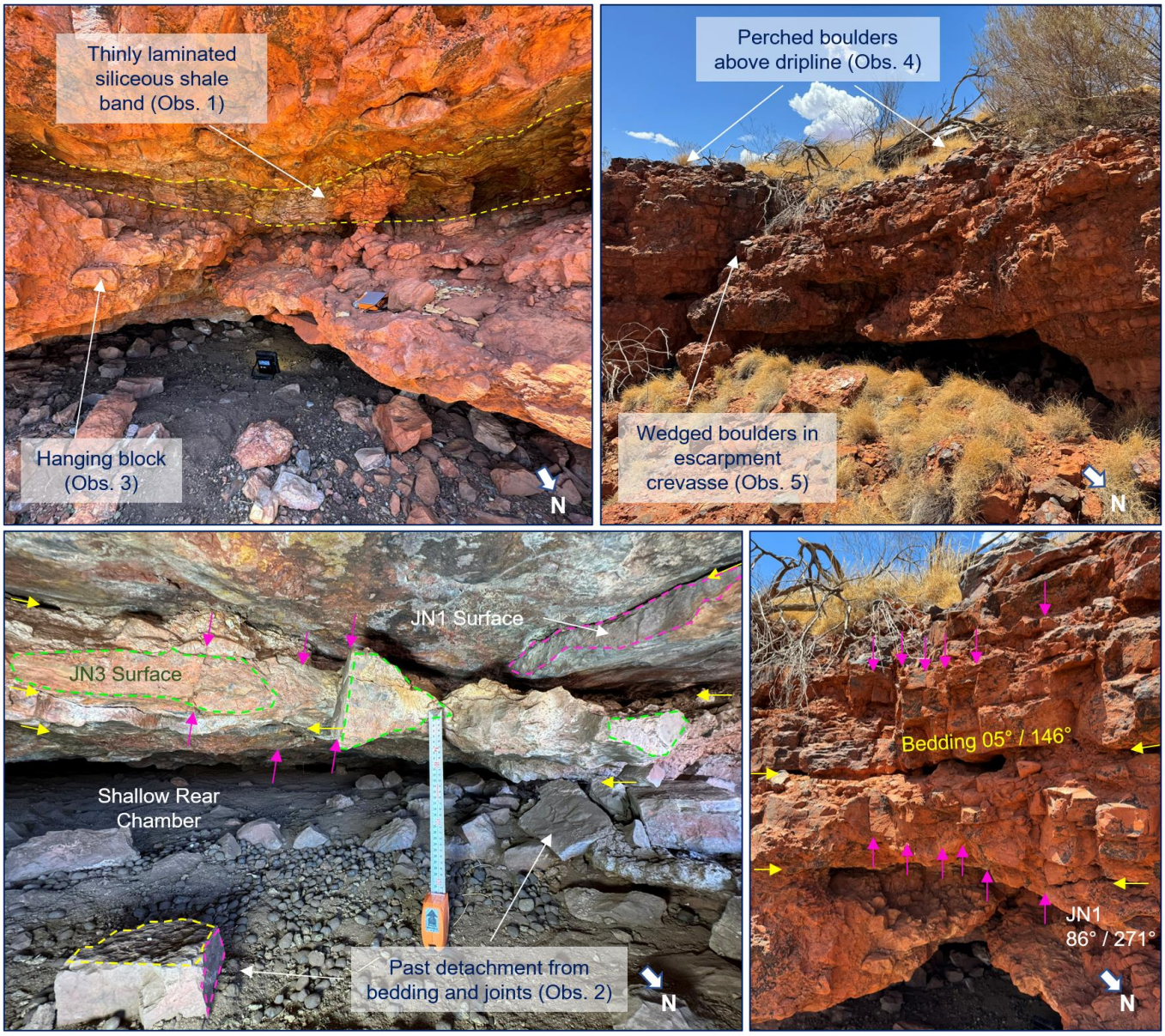
Two major joint sets were identified:

- Joint set 1 (JN1) strikes into the cave and dips steeply to the west. The joint set has a spacing of 50 to 100 mm and is open over lengths of 0.2 to 0.5 m
- Joint set 2 (JN2) also strikes into the cave, and dips steeply to the southeast. The joint set has a spacing of 50 to 300 mm and is open over lengths of 0.2 to 0.5 m
- Joint set 3 (JN3) strikes sub-parallel to the cave entrance and was measured to dip steeply to the northeast. The joint set is spaced between 100 and 200 mm and has an observable length of up to 1 m.

All joint sets identified were typically undulating and rough, with an iron oxide veneer on visible surfaces. Rockfall debris at the cave generally ranges between 50 to 300 mm in width. Most blocks have a blocky to tabular shape and show evidence of detachment from structure, Inset 16. Larger blocks up to 1 m in width appeared to have fallen down slope from the escarpment. Less rockfall debris was observed inside the cave's interior, with none appearing to be geologically recently.

The following observations were made:

- The siliceous shale band dips obliquely into the escarpment. The band is inferred to pass over the rear chamber roof and may be susceptible to block detachment (Obs. 1, Inset 16). Observed preferential weathering of the siliceous shale band also has the potential to undermine the overlying escarpment
- There is potential for blocks in the escarpment and cave roof to detach from bedding where crosscut by vertical joints (Obs. 2, Inset 16). A 150 mm thick chert band located at the access point to the rear chamber appears to be susceptible to this mechanism, Inset 16
- Hanging blocks bounded by open defects were observed in areas of the cave roof and dripline (Obs. 3, Inset 16)
- Perched boulders occur at the top of the escarpment in which the cave is situated (Obs. 4, Inset 16)
- Wedged boulders were observed in a crevasse on the southern side of the cave entrance (Obs. 5, Inset 16).



Inset 16: **Engineering geological observations of cave MEC061.**
Top Left: Cave entrance viewed towards the southwest, showing a weathered shale band and hanging blocks in the overhang. **Top Right:** Overview of cave setting showing perched and wedged boulders in the escarpment above the entrance. **Bottom Left:** Cave interior showing developed bedding partings in the cave roof, and past rock detachment from structure. **Bottom Right:** Bedding partings and joint set 1 observed in the dripline above the entrance.

3.3.15 Cave MEC060

Cave MEC060 is a medium sized cave located at the base of bedrock escarpment. The escarpment itself is approximately 6 m high and appears to be displaced. Cracks and deep crevasses were observed either side of the escarpment, suggesting it has at least partially detached or slumped. The cave faces northeast and overlies a moderately steep vegetated talus slope, approximately 11 m west of cave MEC061. The rock mass at the cave comprises highly weathered, medium to high strength, hydrated, interbedded BIF and chert. The rock mass appears blocky due to multiple intersecting joint sets and bedding partings, Inset 17.

Bedding is well developed with partings commonly observed on the upper and lower contacts of interbedded chert bands, Inset 17. Bedding dips shallowly to the southwest and is undulating. Partings are typically 1 to 4 m in length and are spaced between 70 and 300 mm. They are open up to 1 mm with surfaces that are rough and iron stained.

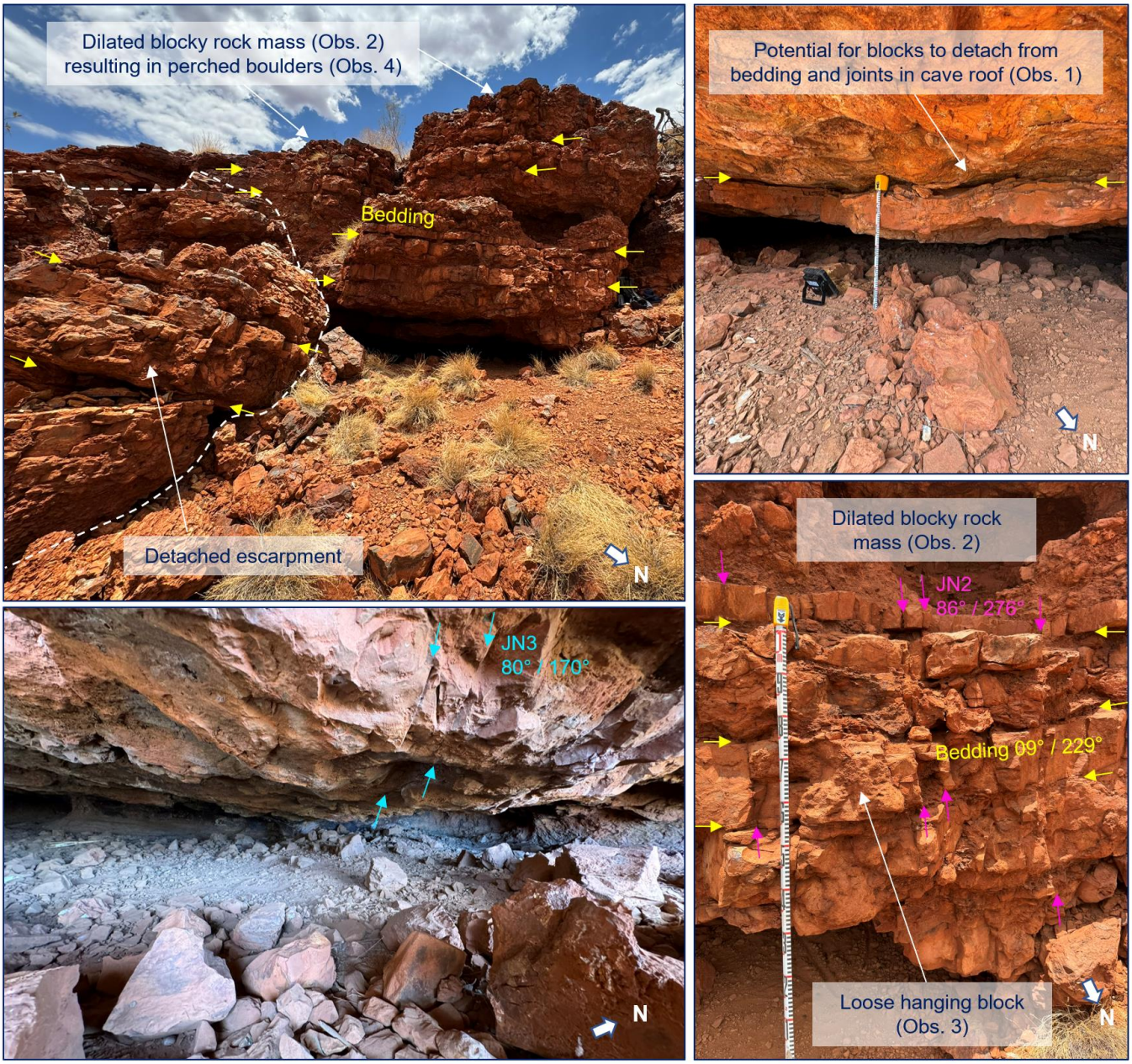
Three joint sets were identified:

- Joint set 1 (JN1) strikes obliquely to the cave entrance, dipping steeply to the south-southwest. JN1 has an observable length of 0.2 to 0.9 m and a spacing of 100 to 200 mm, Inset 17. JN1 is typically tight to open less than 1 mm, with surfaces that are undulating and rough
- Joint set 2 (JN2) dips steeply to the west. It has relatively short defect lengths between 150 and 500 mm. JN2 is most prominent in the escarpment and areas around the entrance where it was observed to have a spacing of 100 to 300 mm. Surfaces are undulating, rough, and have an iron oxide veneer
- Joint set 3 (JN3) strikes parallel to the escarpment and was only observed on the eastern side of the cave. The joint set could not be measured directly due the height of the escarpment but was observed in one area of the cave interior to dip steeply to the south, Inset 17.

Past rockfall product is concentrated around the entrance and below the cave dripline where approximately 40 to 50% of observed blocks appear to be geologically recent. The blocks appear to be sourced from the loose dilated rock mass in the escarpment above the cave, Inset 17. Blocks are typically 50 to 250 mm in width. On the cave interior, some slabs up to 800 mm wide appear to have detached from bedding and joints in the cave roof, though none appear to be geologically recent. A slab of hydrated BIF was observed to be hanging from the cave roof at the cave's western entrance, and is dilated up to 80 mm, Inset 17.

The following observations were made:

- There is potential for slabs of hydrated BIF and chert to detach from bedding and/or joints in the cave roof (Obs. 2, Inset 17)
- The rock mass in the escarpment is loose and dilated in parts (Obs. 2, Inset 17). This is a potential source for future rockfall as evidenced by past rockfall product on the cave exterior
- Hanging blocks bounded by dilated bedding partings and joints were observed in the dripline above the cave entrance (Obs. 3, Inset 17)
- Perched boulders were observed along the top of the escarpment in which the cave is hosted (Obs. 4, Inset 17). Some tabular boulders appear to have become detached due to continual weathering of the dilated blocky rock mass.



Inset 17: **Engineering geological observations of cave MEC060.**
Top Left: Cave entrance viewed towards the southwest showing dilated blocky rock mass that makes up the escarpment, and location of perched boulders. **Top Right:** Cave interior viewed towards the southwest showing BIF slab bounded by dilated bedding parting in the cave roof. **Bottom Left:** Cave interior viewed towards the west showing orientation of joint set 3 and past rockfall debris. **Bottom Right:** Close up of dilated blocky rock mass showing orientations of bedding and joint set 2.

3.3.16 Cave MEC072

Cave MEC072 is a small, narrow cave located near the top of a moderately steep, vegetated talus slope. The cave entrance faces north-northwest and is 1 m wide and 0.6 m high. The cave narrows to form an interior that is 0.6 m wide, 5.5 m deep, and approximately 0.4 m high. The cave interior was not accessed and was assessed from the entrance.

The rock mass at the cave comprises hydrated, highly weathered BIF. The intact strength is high to very high. Bedding is developed and elongate vughs were observed on the cave exterior oriented parallel to bedding. Bedding dips shallowly to the southeast with partings that are undulating and up to 0.5 m long. The partings are spaced at 60 to 200 mm and have surfaces that are slightly rough to rough. They are tight to open less than 1 mm. Bedding appears to become overprinted deeper into the cave. No structurally significant joint sets were identified.

Past rockfall was observed inside the cave though does not appear to be geologically recent. At the cave entrance, rockfall blocks are irregular suggesting detachment from the hydrated rock mass. Some tabular shaped fragments were observed at the entrance suggesting detachment from bedding, Inset 18. Rockfall product is generally between 50 and 100 mm wide, with some larger fragments beyond the entrance up to 300 mm wide.

The following observations were made:

- Perched boulders are situated above the cave entrance (Obs. 1, Inset 18)
- There is potential for blocks to detach from bedding where partings are developed around the entrance, Obs. 2, Inset 18. If blocks detach they do not appear likely to restrict access to the cave for bats.

Inset 18: **Engineering geological observations of cave MEC072.**
Left: Cave entrance viewed towards the southeast showing perched boulders above the escarpment. **Top Right:** Bedding partings observed inside the cave entrance. **Bottom Right:** Cave interior viewed towards the south.

3.3.17 Cave MEC049

Cave MEC049 is a small cave located at the base of an outcropping bedrock escarpment approximately two-thirds of the way up a steep, vegetated talus slope. The cave is situated on the western slope of a south-west draining gully. The escarpment itself is approximately 4 m high and comprises partially hydrated interbedded chert and BIF. The cave is approximately 1.5 m wide, 2.8 m deep, and 0.8 m high. The rock mass is highly weathered and typically has a high to very high intact strength. In some areas around the entrance the rock appears to be medium strength. The rock mass is generally blocky and dilated as a result of multiple sub-vertical joint sets and dilated bedding partings.

Bedding is well developed with partings 2 to 6 m long observed throughout the cave and surrounding escarpment. Partings are typically undulating and oriented sub-horizontally. They are open up to 4 mm in places but typically have an aperture of approximately 1 mm with an iron veneer infill. Partings are spaced at 100 to 300 mm and have rough surfaces.

Three joint sets were observed:

- Joint set 1 (JN1) dips steeply to the northwest and has an observable length of 1 to 3 m. The set is spaced at 100 to 200 mm and has surface conditions that are undulating and smooth to rough. Generally, the joint set is tight or open less than 1 mm. Joint set 1 was only observed in the escarpment and around the entrance of the cave
- Joint set 2 (JN2) dips steeply to the west-southwest. Joints along this orientation are relatively short with lengths between 0.1 and 0.4 m. The joint set was observed to often terminate on bedding planes. JN2 has a spacing of 40 to 120 mm and is typically undulating, slightly rough, and iron stained
- Joint set 3 (JN3) dips steeply to the southwest and is generally spaced between 0.1 and 0.3 m. The joint set was observed throughout the cave site but has a greater persistence on the cave interior. Two large open structures along this orientation were observed at the back of the interior chamber, Inset 19, forming roof profiles up to 2 m high. These structures are interpreted to be joint swarms, as evidenced by a decrease in JN3 spacing. At the back of the main chamber, JN3 is up to 3 m long and spacing decreases to 50 mm, Inset 19.

Rockfall inside the cave is typically blocky to tabular in shape with a size range between 50 to 250 mm wide. The rockfall inside the cave does not appear to be geologically recent. Abundant rockfall debris was observed below the dripline and appears to have detached from the loose blocky rock mass in the escarpment. Blocks up to 500 mm wide were observed, though most are between 50 and 80 mm in width. Most blocks show evidence of detachment from geological structure.

The following observations were made:

- A dilated joint swarm along joint set 3 orientation was interpreted to control cave development at the back of the interior chamber (Obs. 1, Inset 19)
- Loose, dilated, blocky rock mass was observed in the escarpment above and adjacent to the cave, and also in areas around the cave entrance (Obs.2, Inset 19)
- Perched boulders situated atop the escarpment (Obs. 3, Inset 19).

Inset 19: **Engineering geological observations of cave MEC049.**
Top Left: Cave entrance viewed towards the north showing dilated blocky rock mass comprising the escarpment, and dilated bedding partings. **Top Right:** Escarpment above the cave entrance showing joint set 1 orientation and perched boulders situated on the escarpment edge. **Bottom Left:** Cave interior viewed towards the south showing joint set 2 orientation and dilated blocky rock mass in roof. **Bottom Middle:** Back of cave interior viewed towards the west, showing joint set 3 orientation and associated high roof profile. **Bottom Right:** Cave interior viewed from the entrance showing dilated joint set 2 structures and detached tabular block.

3.3.18 Cave MEC003

Cave MEC003 is located at the base of a bedrock escarpment approximately halfway up a moderately steep, vegetated talus slope. The cave entrance faces south-southeast, located above a south-southwest draining creek. The main chamber of the cave is 5.2 m wide, 4 m deep, and 0.7 m high. A rear chamber 1.8 m wide, 4.8 m deep, and 0.6 m high is located at the back of the main chamber. The rock mass at the site comprises interbedded hydrated BIF and chert. The rock is dilated and loose in areas around the entrance, and in the escarpment above the cave, Inset 20. The intact strength is high to very high. A laminated siliceous shale band was observed on the roof the main chamber and was assessed to have a low to medium intact strength.

Bedding at the cave is well developed and forms partings with lengths between 1 and 10 m long. The partings are spaced between 80 and 200 mm, and are open up to 2 mm. Surface conditions of bedding partings are generally undulating and smooth to rough. Smooth surfaces were observed to be confined to the interbedded chert bands. Bedding was measured above the entrance to dip shallowly to the west.

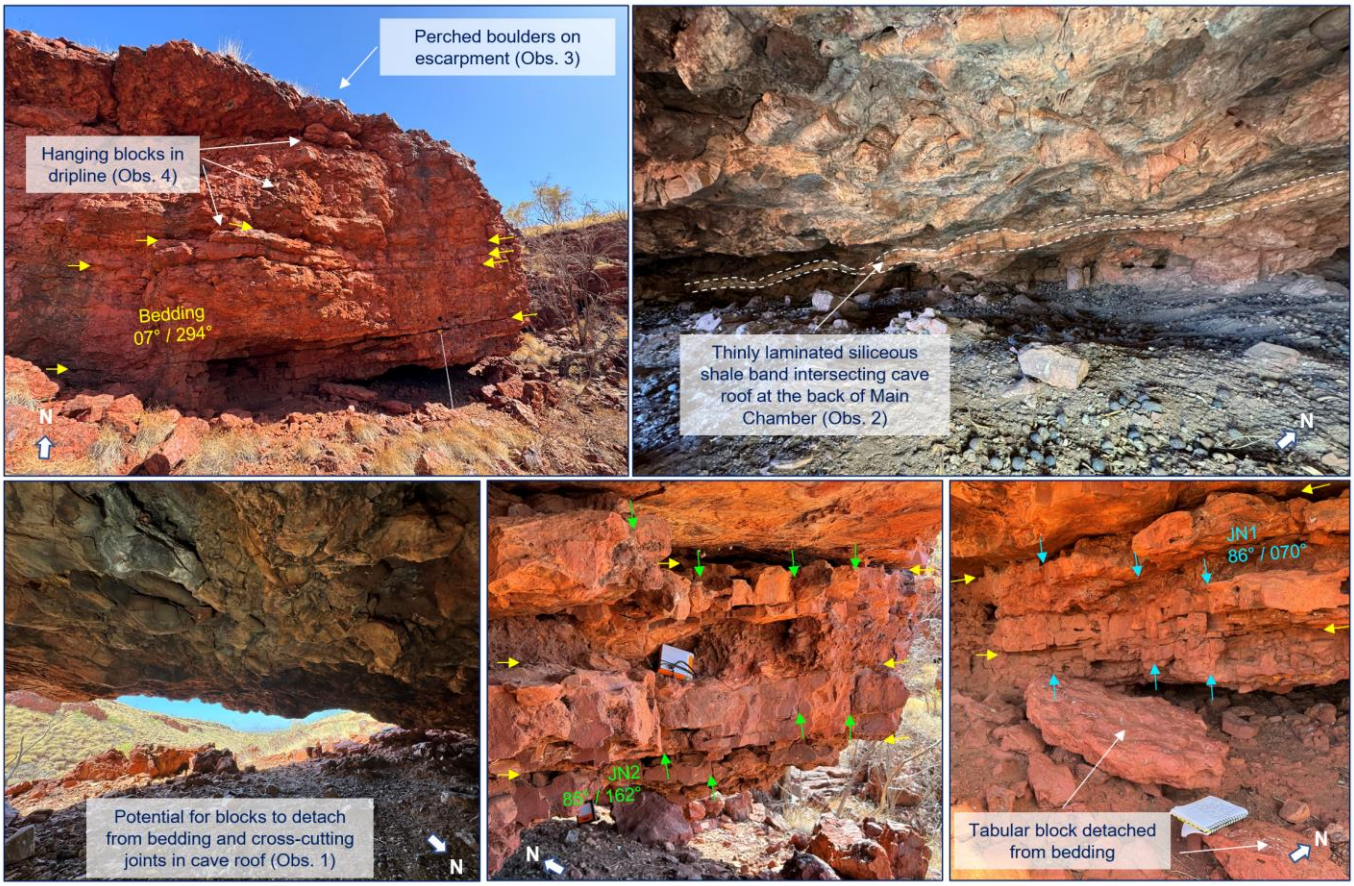
Three joint sets were observed at the cave:

- Joint set 1 (JN1) dips steeply to the east-northeast. It has a length of 0.3 to 0.5 m and is spaced between 50 and 150 mm. Joints along this orientation are typically tight to open less than 1 mm. Surface conditions are undulating and slightly rough
- Joint set 2 (JN2) controls dripline formation on the southern side of the escarpment. It dips steeply to the south-southeast and has defect lengths between 0.4 and 0.8 m. The joints are typically undulating and are spaced between 100 and 200 mm. Joints are dilated up to 1 mm and have surfaces that are rough and iron stained
- Joint set 3 (JN3) dips steeply to the southeast and was observed to be tight. JN3 is typically 0.5 to 1.5 m long and spaced at 100 to 400 mm. Surface conditions are undulating and rough.

Most of the observed rockfall debris was concentrated below the dripline and main chamber. Approximately 50% of the blocks around the cave entrance appear to be geologically recent rockfall product. Blocks have a wide range of sizes between 40 mm and 1.2 m wide. Most slabs show evidence of detachment from bedding and joints that are developed in the cave roof. Blocks bounded by open joints in the roof of the main chamber may be susceptible to detachment, Inset 20.

The following observations were made:

- There is potential for blocks of rock to detach from bedding partings and joints in the cave roof, evidenced by past rockfall debris throughout the main chamber and below the dripline (Obs. 1, Inset 20)
- A thinly laminated siliceous shale band was observed to intersect the roof of the main chamber (Obs. 2, Inset 20). Although the laminations are intact, blocks below the shale band may be susceptible to detachment from the lower strength band
- Loose hanging blocks up to 0.8 m wide were observed on the southern side the escarpment (Obs. 3, Inset 20). The hanging blocks are bounded by dilated joints or non-systematic fractures
- Perched boulders situated in the escarpment above the cave have the potential to fall across the entrance (Obs. 4, Inset 20).



Inset 20: **Engineering geological observations of cave MEC003.**
Top Left: Cave entrance viewed towards the north showing dilated bedding partings and susceptible features in the overlying escarpment. **Top Right:** Cave interior viewed towards the northwest showing siliceous shale band intersecting the roof of the main chamber. **Bottom Left:** Cave interior viewed towards the south showing susceptible hanging blocks in the cave roof. **Bottom Middle:** Cave entrance viewed towards east showing joint set 2 orientation and bedding partings, compass for scale. **Bottom Right:** Eastern side of cave entrance showing past detached blocks and orientations of joint set 1.

3.3.19 Cave MEC025

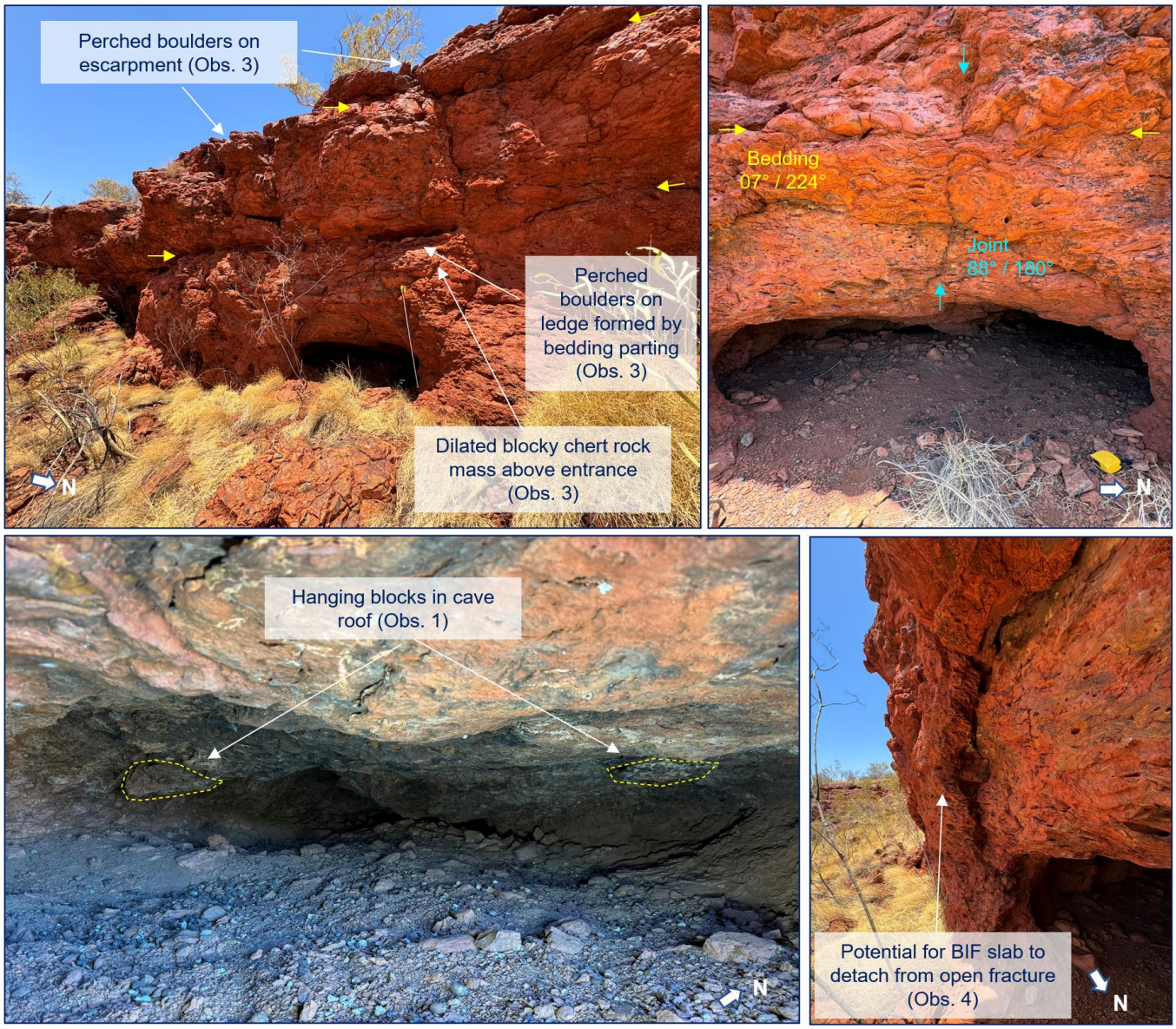
Cave MEC025 is a small cave located at the base of a bedrock escarpment overlooking a moderately steep, vegetated talus slope. The escarpment itself is 5 m high and is situated near the top of the slope. The cave entrance is 2.1 m wide and 6 m high. Inside, the cave is 1.7 m deep, 5.5 m wide, and 0.5 m high. Rock mass at the cave comprises interbedded hydrated BIF and chert. The cave is hosted within the hydrated BIF which makes up the lower part of the exposed escarpment, Inset 21, with blocky chert bands observed in the escarpment above the cave. The rock mass is high strength, with elongate vughs oriented parallel to BIF bedding.

Bedding dips shallowly to the southwest and does not form structurally significant partings at the cave level, however, partings do persist in the rock above the cave along the contacts of interbedded chert bands, Inset 21. Above the cave, partings are 1 to 6 m long and spaced between 200 and 400 mm. Although partings do not persist within BIF at the cave level, the cave still appears to have developed along relict bedding evidenced by the wide span of the cave and sub-horizontal, undulating roof profile, Inset 21.

A single joint set was observed at the cave. The joints are oriented sub-vertically and strike east-west. Only two open joints were observed along this orientation, indicating a spacing of approximately 2 m and lengths up to 1.7 m. The surface conditions of the joints are irregular and rough. It is possible that joint set 1 is related to the defects producing the blockiness within interbedded chert bands above the cave.

The following observations were made:

- Hanging blocks bounded by open fractures were observed in the cave roof (Obs. 1, Inset 21)
- Blocky chert bands occur in the escarpment above the cave entrance (Obs. 2, Inset 21) and have the potential to release blocks from the escarpment
- Perched boulders were observed along the top of the escarpment above the cave entrance (Obs. 3, Inset 21)
- A large BIF slab is bounded by an open fracture on the southern side of the cave entrance (Obs. 4, Inset 21).



Inset 21: **Engineering geological observations of cave MEC025.**
Top Left: Cave entrance viewed towards the southwest, showing bedding partings and perched boulders in the escarpment above the cave. **Top Right:** Cave entrance viewed towards the west, showing orientation of bedding partings and vertical joint structure. **Bottom Left:** Cave interior viewed towards the northwest showing susceptible hanging blocks in the cave roof. **Bottom Right:** Slab bounded by open fracture above the cave entrance.

4. Qualitative Susceptibility Assessment

To assist in assessing appropriate blasting limits for the caves, each site has been assigned a qualitative susceptibility rating, based on the observations undertaken during the site visit.

The assessed caves have been rated based on the condition of key geotechnical features observed in the cave and/or escarpment around the cave entrance. The key features are:

1. Identified specific potential rockfall hazard sources.
2. Open/dilated defects.
3. Structural controls on cave formation or stability (e.g. major joints, bedding).
4. Interpreted potential for significant roof collapse events, including observations of:
    a. Wide spans
    b. Flat roof profiles
    c. Persistent sub-horizontal bedding partings
    d. Separating or detached arches
    e. Highly jointed and dilated rock mass.

Wall collapse was not considered separately as most caves form an arch-like structure with distinct walls being relatively uncommon. As such, no specific cases of high potential of wall collapse without associated roof collapse were observed. Examples of these features are presented in Inset 22. Of the 19 caves assessed:

- Specific potential rockfall sources were observed in 16 caves
- Open defects were observed in 17 caves
- Significant structural controls such as major joints, faults or strong bedding fabrics were observed in 15 caves
- Four of the caves were interpreted to have significant potential for roof collapse.

Based on these observations, the caves were assigned a qualitative susceptibility rating of low, medium, or high as follows:

- Low – no specific rockfall hazards, and/or no open defects identified. Low potential for roof collapse:
    - MEC014
    - MEC042
    - MEC072
    - MEC073.
- Medium – specific rockfall hazards identified. Open defects and/or structural controls observed. Medium potential for roof collapse:
    - MEC007
    - MEC012
    - MEC013
    - MEC016
    - MEC025
    - MEC033
    - MEC039
    - MEC049
    - MEC060
    - MEC062
    - MEC074.

- High – specific rockfall hazards identified. Open defects and/or structural controls observed. High potential for significant roof collapse:
  - MEC003
  - MEC061
  - MEC063
  - MEC065.

Inset 22: **Examples of susceptible features observed at Mulga Downs cave sites. A)** Cave formed on structure (bedding). **B)** Hanging blocks bounded by open defects. **C)** Perched boulders. **D)** Sub-vertical open joints intersecting the cave roof.

In addition to the condition of the caves, susceptibility will also be related to induced vibrations that are governed by factors such as:

1. The distance from blasting activity.
2. The frequency and magnitude of blasting.
3. Topographic or geological amplification effects.

These factors should be revisited as the open cut is developed and vibration and other geotechnical monitoring data becomes available. This additional operational data may allow vibration limits to be adjusted to optimise blasting practices without causing unwanted damage to the caves.

PSM understands that the planned hub and rail spur will be constructed 1.65 km from the closest bat cave included in this assessment, as such, no specific requirements relating to this infrastructure are considered necessary at this time.

5. Vibration Limits

5.1 Literature Review

Little public information is available regarding the impact of mining activities on nearby caves and rock shelters in the Pilbara, and PSM is not aware of any published vibration limits or guidelines specifically for caves or rock formations.

Australian Standard AS2187.2 (Reference 2) presents guidelines for peak particle velocities (PPV) that could be expected to cause cosmetic damage to man-made structures. These guidelines indicate that cosmetic damage may result from PPVs of:

- Greater than or equal to 15 mm/s for unreinforced structures
- Greater than or equal to 50 mm/s for reinforced structures.

The definition used for ‘cosmetic damage’ in Reference 2 includes growth of cracks in mortar joints. From this, it is reasonable to infer that dilation of defects in natural rock structures could result from similar levels of PPV, which in turn will result in an accelerated rate of rockfall above natural baseline conditions.

Caves in analogous geological environments elsewhere include those in hydrated iron formations near open cut iron ore mines in Brazil. Although no vibration limits are provided, the Brazilian Government requires a 'specific technical study' before blasting can be undertaken within 250 m of a cave, Reference 3. No technical justification is provided for this requirement; however, a study reported by Barbosa et al. (2019) (Reference 4) reported that rockfall (0.1 m^3 block) has occurred when blasting was conducted as far as 230 m from one such cave. The same cave collapsed during a blast at 32 m distance; however, PPVs are not reported and the damage leading up to collapse was likely cumulative over several years of progressively closer blasts.

Brandi et al. (2019) (Reference 5) reported no significant dilation of defects (< 0.2 mm) resulting from blasting as close as 75 m from an iron ore cave in Brazil, despite charges of up to 300 kg per delay, which could be expected to produce PPVs at the cave of approximately 30 to 110 mm/s.

A review of rockfall resulting from earthquake shaking in the United States of America provides an indication of the lower bound of PPV that may cause damage to natural rock formations. Jibson and Harp (2016) (Reference 6) report landslide and rockfall mapping undertaken after six earthquakes in the United States. Their mapping indicated mass movements resulting from peak ground velocities as low as 10 mm/s, as reported by the United States Geological Survey, although the outer limit was more commonly between 50 and 100 mm/s.

The rockfall events occurring at apparently very low PPVs may be the result of local topographic amplification. These effects are relevant to the topographic setting at Mulga Downs, where caves are often positioned on steep escarpments facing away from the blasting location.

5.2 Recommendations

Of the 19 bat caves included in this study, 21% are assessed as low susceptibility, 58% medium susceptibility and 21% high susceptibility. Two sets of PPV thresholds are recommended to the assessed bat caves to reduce the likelihood of significant damage above the natural background level of degradation, including:

- Dilation of defects connecting to the surface, which may result in changes to air flow and climatic conditions within the cave
- Rockfall in or around the caves resulting in reduced access for fauna.

Based on the literature review and PSM's experience at other Pilbara mine sites, the initial recommended vibration limits for each bat cave are presented in Table 3. In summary, the recommended limits are:

- 75 mm/s is recommended for low to medium susceptibility bat caves. This value is:
  - 50% above the threshold for cosmetic damage to reinforced man-made structures, Reference 2. PSM consider this to be appropriate where minor rockfall not impacting cave access is acceptable
  - The approximate median PPV causing some rockfall due to earthquakes in the events studied in Reference 6, noting that earthquakes are likely to be lower frequency and longer duration than blasts, and that earthquake induced rockfall is likely to have occurred from the most susceptible features in each event.
- 25 mm/s is recommended for high susceptibility bat caves at Mulga Downs. This value is:
  - Slightly above the limit of cosmetic damage in unreinforced man-made structures. PSM consider this to be appropriate where minor rockfall not impacting cave access is acceptable
  - Below the inferred PPV of blasting reported in Reference 5, which caused no rockfall or significant dilation of the "most fragile" defects within an iron ore cave.

These limits are intended to represent the maximum allowable peak particle velocity as measured at the cave site.

Table 3 – Recommended Vibration Limits for Bat Caves at Mulga Downs

Cave ID	Qualitative Susceptibility Rating	Recommended Vibration Limits (mm/s)
MEC014	Low (No specific rockfall hazards, and/or no open defects identified. Low potential for roof collapse)	75
MEC042		
MEC072		
MEC073		
MEC007	Medium (Specific rockfall hazards identified. Open defects and/or structural controls observed. Medium potential for roof collapse)	
MEC012		
MEC013		
MEC016 (MIB-MD13-043)		
MEC025		
MEC033		
MEC039		
MEC049		
MEC060		
MEC062		
MEC074		
MEC003	High (Specific rockfall hazards identified. Open defects and/or structural controls observed. High potential for significant roof collapse)	25
MEC061		
MEC063		
MEC065		

It should be noted that this recommended PPV does not take into account any potential impact of vibrations on bat behaviour or direct physical impacts on the bats themselves. In applying these limits, it should be noted that the impact of cumulative rock mass damage over a period of regular blasting is difficult to assess, and once blasting is within 500 m of the cave site, continued geotechnical monitoring should be undertaken to assess the impact of the mining operations on the rock mass. This should include:

- PPV monitoring at the cave sites. Positioning of the monitoring equipment will be vital in acquiring reliable data as there can be local topographic and geological amplification effects across relatively short distances. Ideally the instruments should be installed at the cave entrance
- Geotechnical monitoring of significant defects or susceptible features, which may include:
  - 2D or 3D crack-meters installed across defects
  - Tilt-meters installed on susceptible features or escarpments
  - Regular geotechnical inspections and photography, either on foot or by drone. Initially, at six months, or in the event of the recommended vibration limits being exceeded.

As more data is collected it may be beneficial to reassess the adopted vibration limits to optimise operational processes without causing unintentional damage to the sites.

5.3 Comparison with Predicted Vibration Levels

The recommendations presented in Section 5.2 have been compared to predicted vibration levels provided by HanRoy in excerpts from an airblast and vibration prediction study undertaken by others, Reference 8. The study applied the ground vibration equation presented in Reference 2 to estimate maximum instantaneous charge (MIC), i.e., the maximum allowable charge per borehole per delay in kilograms, for a range of rock mass and blast confinement conditions. The constants adopted by Reference 8 are presented in Table 4.

PSM understands that the "Free Face – Average Rock" constants are adopted directly from AS2187.2 (Reference 2, while those for "Free Face – Hard/Highly Structured Rock" and "Heavily Confined" conditions have been adopted from previous work undertaken by the acoustics consultant[4]. These ground condition categories are not defined further in Reference 8, but are understood to be considered upper and lower bound estimates.

Table 4 – Site Constants Adopted by Reference 8

Ground Conditions	Constant 'K_g'	Constant 'B'
Free Face – Hard/Highly Structured Rock	500	-1.6
Free Face – Average Rock	1140	-1.6
Heavily Confined	5000	-1.6

PSM understands that the maximum MIC planned for use at Mulga Downs is approximately 530 kg, Reference 8. For comparison, the provided blasting constants have been used to calculate the maximum allowable MIC for blasting at the closest part of the proposed pit footprint to each cave site without exceeding the recommended vibration limits. The results are presented in Table 5 with maximum MICs below 530 kg highlighted in red. The results indicate that:

- In Free Face – Average Rock conditions, seven sites could be expected to exceed recommended vibration limits if the maximum MIC of 530 kg is implemented at the closest pit crest
- For the closest site to blasting activities (ME042), which is 30 m from the nearest pit crest, the MIC estimates to limit vibrations to 75 mm/s range from 5 kg to 84 kg
- At all highly susceptibility sites, MICs of 530 kg are not expected to result in exceedance of the recommended PPV of 25 mm/s.

Table 5 – Estimated Maximum MIC for Closest Planned Blasting Location to Each Cave Site

Site ID	Recommended PPV Limit (mm/s)	Distance from Pit (m)	Maximum Charge per Borehole per Delay (kg) for Rock Mass and Blast Conditions		
			Free Face – Hard/Highly Structured Rock	Free Face – Average Rock	Heavily Confined
MEC007	75	620	35884	12808	2018
MEC012		150	2100	750	118
MEC013		120	1344	480	76
MEC014		100	933	333	52
MEC016		160	2390	853	134
MEC025		160	2390	853	134
MEC033		640	38236	13648	2150
MEC039		90	756	270	43
MEC042		30	84	30	5
MEC049		1350	170130	60724	9567
MEC060		1000	93350	33319	5249
MEC062		1010	95226	33989	5355
MEC072		70	457	163	26
MEC073		110	1130	403	64
MEC074		110	1130	403	64
MEC003	25	1320	162653	58056	9147
MEC061		1000	93350	33319	5249
MEC063		1050	102918	36734	5788
MEC065		620	35884	12808	2018

(1) Red cells indicate predicted vibration limits exceedances if the maximum planned MIC of 530 kg is implemented.

[4] Conference call between Duncan Noble of PSM and Matt Moyle of LGA. 6 November 2024.

These estimates are based on the preliminary blasting constants provided in Reference 8 and should be updated once site specific blasting constants (K_g and B values) are derived by the blasting contractor. Until that time, PSM recommend adopting conservative blasting practices, combined with careful monitoring to ensure that the recommended vibration limits are not exceeded.

6. Summary

Engineering geological assessments have been carried out at 19 bat caves at Mulga Downs. Susceptible features observed at each of the sites are summarised in Table B1 and in the cave summary sheets provided in Appendix B. The hazards identified from the inspections and our geotechnical advice for minimising risk to people whilst working at the cave sites are reproduced below.

The assessed caves at Mulga Downs typically have a wide span and low roof profile, with preferential development along bedding structure in the rock mass.

Susceptible features observed across the Project range from zones of loose rock on cave walls and blocks of rock defined by structure in the cave roof, through to clusters of boulders and rockfall hazards along the escarpments. Four of the 19 assessed caves were qualitatively assessed as high susceptibility sites.

Blasting practices should take into account the specific features identified at each location along with the distance from the pit, local topographic and geological features, and site-specific K and B constants, which should be formulated by the blasting contractor from site specific vibration monitoring data. The actual vibration levels impacting each cave will depend on parameters including the maximum instantaneous charge, delay times, and direction of blast propagation. Factors such as these will need to be adjusted by the blasting contractor to limit vibrations to the recommended levels.

PSM recommend adopting a PPV limit of ≤ 75 mm/s for low to medium susceptibility sites, and ≤ 25 mm/s for high susceptibility sites, as measured at the cave site, to reduce the likelihood of significant damage above the natural background level of degradation that may result in changes to climatic conditions within the cave, or reduced access for fauna. This limit may be revised following assessment of initial monitoring data recorded during blasting, which should include vibration monitoring at the cave sites, and geotechnical monitoring of selected susceptible features. Given the distance of the hub and rail from the assessed caves, no specific requirements relating to this infrastructure are considered necessary at this time.

The geotechnical hazards in and around the caves should be considered by all personnel working in and around these sites. The following list provides some factors to consider when accessing these and other cave sites:

1. PPE should include hard hats and steel capped boots for rockfall and trip hazard protection for both walking to the cave entrance and working inside the caves.
2. All personnel inside the cave should have a head lamp or torch to help watch and monitor stability conditions.
3. Anyone accessing the caves should make an assessment at the time of entry as to the current geotechnical conditions and if there are any new or increased hazards to safe access, particularly following any blasting or heavy rainfall. Where changes are observed to the features noted in this report or new features are observed, a new geotechnical assessment should be sought before further work is undertaken within the caves. Observed changes may include:
    a. Dilation of defects in and around the cave or new defects/cracks in the rock mass
    b. Movement of rock or fresh rock fall debris in and around the caves and along the escarpments
    c. New water seepages or increased flow from fractures in the rock, or significant recent rainfall.
4. Areas of loose rock or hanging blocks observed in this assessment should be located in the field before approaching or entering the caves and should be visually monitored and avoided where possible. Summary sheets including schematic maps and photos are provided in Appendix B to assist in locating these hazards in the field.
5. Areas of increased risk identified in this report or observed in the field, such as below escarpments with loose rock or perched boulders, should be avoided or moved through quickly to minimise time spent in hazardous areas. It is worth noting that rockfall risk is sometimes lower inside the cave entrance than under the escarpment outside the cave.

6. Work should not be undertaken in the caves or along the escarpments during blasts or heavy rainfall.

Walking under the escarpment slopes and working inside the caves will involve an element of risk due to the occurrence of the hazards observed in the field assessment and recorded in this report. There is also the chance that other hazards are present that were not observed during this assessment, or new hazards form over time in response to stress changes in the rock mass. Part of the risk management plan should include communicating the risk to all people accessing the caves, and informing them of their personal responsibility to:

- Watch and monitor the hazards recorded during this assessment, and
- Look out for any additional hazards not currently recorded.

7. Closing

We trust this report meets your immediate requirements. Please do not hesitate to contact the undersigned if you have any questions.

Yours Sincerely

RONALD POLLARD
ENGINEERING GEOLOGIST

DUNCAN NOBLE
ASSOCIATE ENGINEERING GEOLOGIST

MARK EGGERS
CHIEF ENGINEERING GEOLOGIST

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Glossary

Glossary	
Alteration	Involves the modification and replacement of the original minerals in a rock with a new suite of minerals with different chemistry.
Bedding parting	A parting lineation is a sedimentary structure commonly found on the surface of parallel-laminated sandstones or siltstones.
BIF	Banded Iron Formation: A distinctive type of rock often found in primordial sedimentary rocks.
Boudinage	Structures that occur in deformed rocks that have undergone extension, also known as ‘pinch and swell’ structures.
Cangarised BIF	Hydrated banded iron formation that exhibits features termed vughs, which appear similar to volcanic vesicles or air-bubbles. Bedding will generally be overprinted, and the rock is normally highly oxidised with a distinct orange colour
Cuesta	A physiogeographic feature that has a steep cliff or escarpment on one side, and a gentle slope on the other.
Defect	A plane/discontinuity of weakness in a rock, over which there is no tensile strength
Dilation	An aperture between the blocks on either side of a defect or fracture
Dip	The acute angle that a rock surface makes with a horizontal plane.
Dip Direction	The bearing the Dip is declined in.
Escarpment	A transition zone between different physiogeographic provinces that involves an elevation differential, characterized by a cliff or steep slope.
Fault	A discontinuity surface with evidence of displacement.
Fault Gouge	Fine material formed by mechanical breakdown of rock within a fault
Hydrated Zone	A secondary mineralised zone formed by surface weathered processes.
Joint	A discrete discontinuity surface without evidence of displacement.
Mesa	A flat topped mountain or hill
Mineralisation	The hydrothermal deposition of economically important metals in the formation of ore bodies or "lodes".
Massive Rock	Rock mass with no significant structural or textural features such as bedding or joints
Regional Structure	A geological structure such as a fault or dyke that is persistent on a scale of kilometres to tens of kilometres

Glossary	
RMR_{89}	'Rock Mass Rating'. A geomechanical classification system developed by Bieniawski (1989)
Shear	A discrete discontinuity surface with evidence of displacement.
Skylight	A natural opening to the surface
Strike	Is the direction of the line formed by the intersection of a rock surface with a horizontal plane.
Talus	A collection of broken rock fragments at the base of crags, mountain cliffs, volcanoes or valley shoulders that has accumulated through periodic rockfall from adjacent cliff faces. Landforms associated with these materials are often called talus deposits.
UCS	Unconfined compressive strength: The maximum axial compressive strength that a material can withstand under unconfined conditions.
Vein	A mineral filling of a fracture or other crack within a rock in a sheet-like or tabular shape.
Vughs	Small cavities within the rock mass formed as a result of a reduction in volume through mineral alteration processes.
Waviness	Is the measurement of the more widely spaced component of surface texture associated with structural defects or bedding.

Brisbane

Level 6, 500 Queen Street
Brisbane QLD 4000
+61 7 3220 8300

Sydney

G3-56 Delhi Road
North Ryde NSW 2113
+61 2 9812 5000

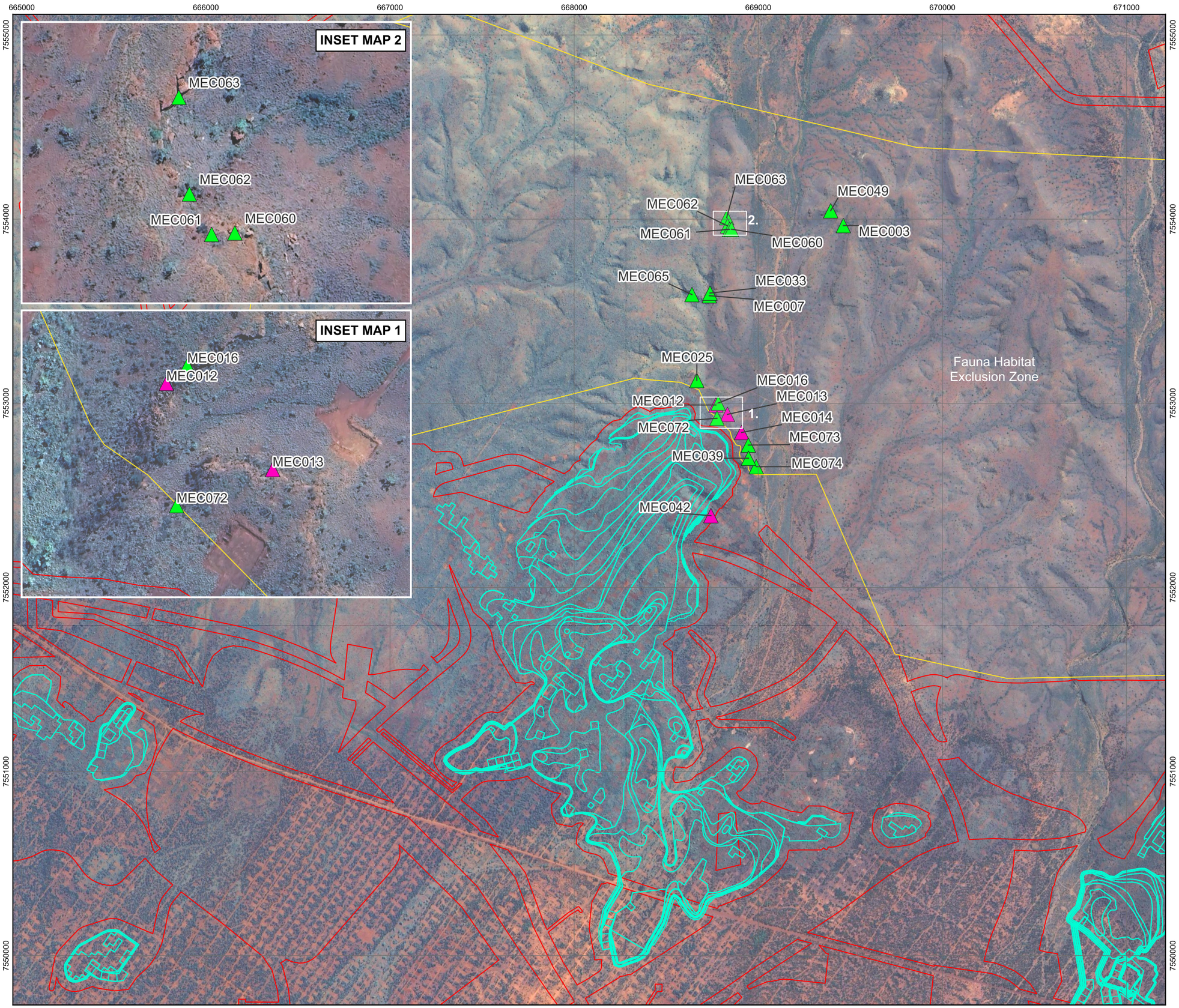
Melbourne

Office 16
Level 4, 60 Moorabool Street
Geelong VIC 3220
+61 3 7068 5699

Perth

Level 3 22 Delhi Street
West Perth WA 6005
+61 8 9462 8400

Appendix A
State and Commonwealth Maps



Legend

- Bat Caves (January 2024 Assessment)
- Bat Caves (November 2023 Assessment)
- Development Envelope/ Proposed Action Area
- Mine Indicative Footprint
- Pit Footprint

Scale 1:20,000

N

0 0.2 0.4 0.6 0.8 1 km

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 50

P S M	Created By: RP	Revision: A
	Date: 25 Sep 2024	Paper Size: A3

Hanroy Iron Ore Projects Ltd
Mulga Downs Iron Ore Projects
Geotechnical Asssessment of Bat Caves

STATE MINE
BAT CAVE LOCATIONS

PSM5194	Figure A1

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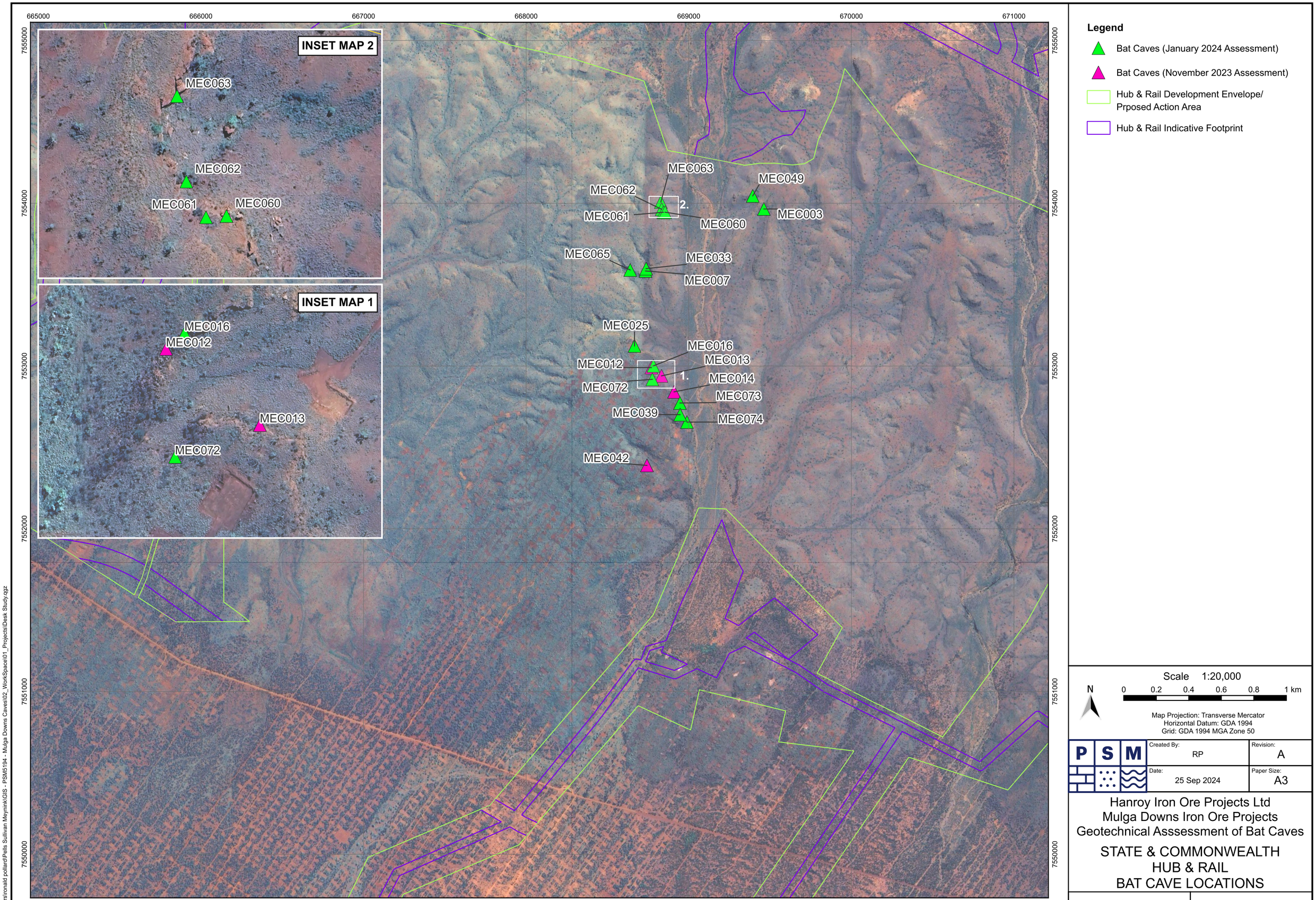

Legend

- Bat Caves (January 2024 Assessment)
- Bat Caves (November 2023 Assessment)
- Hub & Rail Development Envelope/ Prposed Action Area
- Hub & Rail Indicative Footprint

Scale 1:20,000

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0 0.2 0.4 0.6 0.8 1 km

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 50

P S M	Created By: RP	Revision: A
	Date: 25 Sep 2024	Paper Size: A3

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Mulga Downs Iron Ore Projects
Geotechnical Asssessment of Bat Caves

STATE & COMMONWEALTH HUB & RAIL BAT CAVE LOCATIONS

PSM5194 | Figure A2

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7555000 7554000 7553000 7552000 7551000 7550000

INSET MAP 2

MEC063
MEC062
MEC061
MEC060

INSET MAP 1

MEC016
MEC012
MEC013
MEC072

MEC063
MEC062
MEC061
MEC060
MEC049
MEC003
2.
MEC065
MEC033
MEC007
MEC025
MEC016
MEC012
MEC013
1.
MEC014
MEC072
MEC073
MEC039
MEC074
MEC042

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Legend

- Bat Caves (January 2024 Assessment)
- Bat Caves (November 2023 Assessment)
- Development Envelope/ Proposed Action Area
- Mine Indicative Footprint
- Pit Footprint

Scale 1:20,000

N

0 0.2 0.4 0.6 0.8 1 km

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 50

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	Date: 25 Sep 2024	Paper Size: A3

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Geotechnical Asssessment of Bat Caves

COMMONWEALTH MINE BAT CAVE LOCATIONS

PSM5194 | Figure A3

Appendix B
Table B1 and Cave Summary Sheets

Table B1 – Summary of Geotechnical Conditions at Assessed Bat Caves at Mulga Downs

Cave ID	Approximate Dimensions	Estimated GSI Range and Typical RMR_{89}	Rock Mass Description	Observed Susceptible Features	Recommendations for Personnel Working in or Around the Cave
MEC042	Entrance/Overhang – 10 m wide, 2.5 m deep Main Cave – 4 m wide, 3.2 m deep, 1.5 m high Rear Adit – 5 m deep, 1.3 m wide, 0.6 m high	GSI All Areas 68 – 78 RMR_{89} All Areas: 78	The rock mass comprises high strength hydrated BIF with elongate vughs up to 50 mm oriented parallel to relict bedding, which is largely overprinted. BIF bedding becomes developed at the entrance to the rear adit and was observed to be sub-horizontal. Two parallel joints were observed at the cave entrance and appear to form a structural set. The joints dip steeply to the south, are undulating to irregular, rough, and iron stained. The joints do not persist greater than 2 m and were only observed at the cave entrance.	1. Increased rockfall potential below the dripline of the cave, evidenced by historical blocks on the cave floor. 2. Sub-vertical open joints intersecting the cave roof. 3. Increased potential for roof collapse due to the wide, flat span.	• Check for or dilation of joints at the cave entrance, and for sub-horizontal partings which may indicate opening of relict bedding planes • Avoid standing or sitting below the dripline of the cave • Check for fresh rock fall debris around the cave entrance before approaching.
MEC014	Cave – 6 m deep, 0.8 m wide, 0.8 m high	GSI All Areas 65 – 75 RMR_{89} All Areas: 75	The rock mass comprises medium to high strength hydrated and vughy BIF. Original bedding fabrics have largely been overprinted, though bedding parallel vughs are developed throughout the rock mass. A discrete chert band occurs at the base of the cave. Bedding was measured from the exposed chert band and dips shallowly towards the southwest. The cave has formed along an open joint which persists along the cave roof for the first ~3 m beyond the entrance. The structure dips steeply to the east and is irregular, slightly rough to rough, and infilled with a veneer of iron oxide. Water seepage along the structure is indicated by black staining and plant rootlets growing within the joint	1. A 250 mm hanging block in the dripline immediately above the cave entrance. Bounded by a sub-vertical joint and open fracture. 2. Perched and wedged boulders at the top of the bedrock escarpment, approximately 4 m above the cave entrance. 3. Increased rockfall potential at the cave entrance, with historical 50 to 400 mm fragments of BIF, some of which have detached from bedding.	• Limit time spent at the cave entrance, immediately below the escarpment due to the perched boulders atop the escarpment • Check for movement or dilation of the controlling joint in the escarpment and within the cave roof before approaching • Avoid standing or working below or leaning on the loose boulder in the dripline of the cave.
MEC013	Entrance – 1.8m wide, 1 m high Main chamber – 3.0 m wide, 3.1 m deep, and 0.7 m high. Rear chamber –0.4 m wide and 2 m deep.	GSI Exterior 70 – 80 Interior 67 – 77 RMR_{89} Exterior: 80 Interior: 77	The rock mass comprises moderate to high strength, hydrated BIF and banded chert. Vughs up to 120 mm are generally elongated in the direction of bedding. Bedding has been partially overprinted and is better preserved on the cave exterior where it is sub-horizontal, undulating and thickly laminated. Bedding does not form structurally significant partings in the cave walls. The cave roof profile, however, has developed preferentially along sub horizontal bedding. A single vertical joint that strikes 220° was observed in the roof of the rear chamber. The joint is open up to 6 mm and shows evidence of water seepage. At the time of the inspection the joint surface was moist, and the adjacent wall rock showed goethitic and other iron oxide staining	1. A hanging BIF slab bounded by an open bedding parting was observed on the eastern side of the main chamber roof. 2. A rock pillar of poor rock mass quality (low intact strength inferred) identified on the eastern side of the rear chamber. 3. A cluster of loose 50 to 200 mm fragments was observed in the dripline directly above the cave entrance.	• Check for movement or dilation of defects, or fresh rock fall before approaching the cave • Limit time spent below the hanging slab in the main chamber or avoid if possible • Check for signs of fretting of the susceptible rock pillar and/or further erosion at the base • Avoid standing or leaning on the area of loose BIF fragments above the cave entrance. Do not stand in the cave entrance, move past the entrance zone when accessing the cave.
MEC012	Main Overhang - 7.5 m wide, 3.5 m deep, 1.5 m high. Rear Chamber –7 m deep, 4 m wide, 0.2 to 0.5 m high	GSI All Areas 63 – 73 RMR_{89} All Areas: 73	The rock mass at the cave comprises high strength hydrated BIF with elongate vughs up to 100 mm oriented parallel to relict bedding, which dips shallowly to the northwest. Some vughs are infilled with silt and gravels which are inferred to be residual rock fragments. One steep northeast dipping joint set was identified at the cave site. It has a spacing of 3 to 4 m and is undulating, rough, and stained with iron and dark minerals. The joints appear to persist only around the cave entrance and main overhang, with observable lengths < 2 m.	1. Large BIF slabs bounded by dilated bedding partings in the cave roof, cross-cut by the northeast dipping joint set in places. 2. Loose hanging blocks up to 0.35 mm wide in the dripline above the cave entrance. 3. Two perched boulders at the top of the escarpment	• Check for movement or of hanging blocks and perched boulders above the entrance before approaching the cave. Avoid standing and sitting in this area • Check for dilation of the bedding parting or detachment of the BIF slab in the cave roof at the back of the main overhang.
MEC074	Entrance/Overhang – 3.5 m wide, 1.7 m deep and 1.1 m high. Rear Chamber – 3.5 m wide, 4.5 m deep, 0.4 m high	GSI Entrance/Overhang 55 – 65 Rear Chamber 65 – 75 RMR_{89} Entrance/Overhang 65	The rock mass at the cave comprises a thick chert band overlain by hydrated vughy BIF. The bat cave is hosted entirely within the chert band which approximately makes up the bottom half of the exposed escarpment. The chert rock mass is highly weathered and hydrated, with an apparent medium to high intact strength. The chert is dilated and loose in some areas. Bedding was observed to dip sub-horizontally towards the northwest. Within the chert, partings are spaced between 50 to 300 mm, and have lengths of approximately 0.5 to 1.0 m. Two joint sets were identified: Joint set 1 (JN1) strikes sub-parallel to the cave entrance and controls dripline formation. It dips sub-vertically towards the southwest, and is typically planar to undulating. Joint set 1 is spaced between 100 and 300 mm with lengths ranging from 0.3 to 0.8 m.	1. Dilated, loose blocky chert rock mass was observed in some areas of the dripline and in the roof of the overhang. There is an increased potential for rockfall in these areas as evidenced by past detached blocks on the ground. 2. Hanging blocks bounded by non-systematic open fractures were identified in the BIF escarpment above the cave entrance.	• Limit time spent immediately below identified hanging blocks bounded by open fractures in the escarpment above the entrance • Avoid leaning on the area of dilated loose chert in the overhang when accessing the cave, or sitting directly underneath it • Check for fresh rockfall debris around the cave entrance and overhang when approaching the cave.

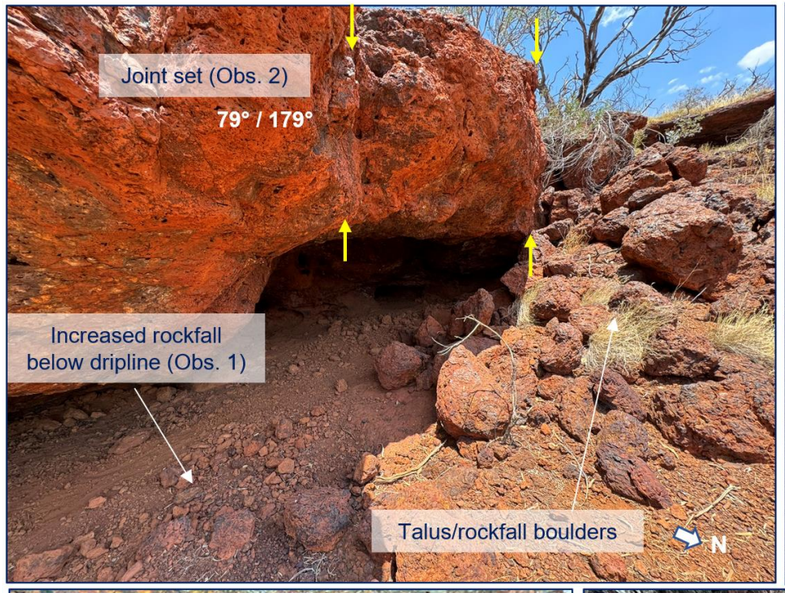
Cave ID	Approximate Dimensions	Estimated GSI Range and Typical RMR_{89}	Rock Mass Description	Observed Susceptible Features	Recommendations for Personnel Working in or Around the Cave
		Rear Chamber 75	Joint set 2 (JN2) has a typical spacing of 50 to 200 mm and strikes obliquely into the escarpment. It has an observable length of 100 to 400 mm. A single defect along this orientation on the north side of the entrance appears to bridge through the rock mass along multiple JN2 structures, resulting in a 2.5 m long defect that is open up to 2 mm.		
MEC065	Main Chamber – 8 m wide, 5.7 m deep, and 1 m high. Rear Chamber – 5.7 m deep and up to 0.4 m high.	GSI Exterior and Main Chamber 52 – 65 Rear Chamber 59 – 69 RMR_{89} Exterior and Main Chamber 65 Rear Chamber 69	The rock mass comprises interbedded BIF and blocky chert. The rock mass is highly weathered and appears to be medium to high strength. Bedding at the cave is undulating and was measured in the main chamber to dip shallowly to the northwest. Bedding partings are spaced 0.2 to 0.5 m and are up to 8 m in length (greater than the span of the cave). Partings surfaces are slightly rough to rough, open 1 to 2 mm and iron stained. Partings become more dilated toward the cave entrance where they were observed to be open up to 5 mm. Residual hematitic silt was observed to infill dilated partings in places. Joint set 1 (JN1) is oriented parallel to the cave entrance and dips sub-vertically towards the northeast, Inset 7. It is spaced at 100 to 200 mm and is typically 0.5 to 1.0 m long. JN1 is planar to stepped, slightly rough to rough, and iron stained. Joint set 2 (JN2) is a sub-vertical joint set that strikes perpendicular to the cave entrance, Inset 7. JN2 is 0.2 to 0.5 m long and spaced between 50 to 150 mm. Joint set 3 (JN3) was only observed on the eastern side of the main chamber. It was measured to dip steeply towards the west, with a spacing between 1.0 to 1.5 m. Defect lengths up to 0.5 m were measured on the main chamber's east wall.	1. Hanging blocks bounded by open joints or non-systematic fractures occur in the dripline above the cave entrance 2. There is significant potential for large slabs of chert and hydrated BIF to detach from dilated bedding partings and joints in the main chamber roof. This mechanism is evidenced by past detachment on the cave floor. 3. In the escarpment above the cave, there is potential for blocks to release from Joint set 1. This presents a rockfall hazard at the cave entrance.	• Limit time spent immediately outside the cave entrance due to hanging blocks in the escarpment and the potential for blocks above to detach from joint set 1 • Before entering the cave, check for fresh rockfall debris and for movement or further dilation of the open bedding partings in main chamber roof • No standing or sitting below the area of dilated chert slabs in the main chamber roof. Move quickly past these areas if necessary.
MEC007	Cave – 6 m wide, 10 m deep, and up to 1 m high.	GSI Exterior and Front 62 – 72 Obs. 1 Zone 59 – 69 Rear 65 – 75 RMR_{89} Exterior and Front 72 Obs. 1 Zone 69 Rear 75	The rock mass at the cave comprises hydrated BIF and interbedded chert. It is highly weathered and has a medium to high intact strength. Water seepage into the cave was evidenced by iron staining around the entrance, which overprints original bedding fabrics in parts of the cave. Where visible, bedding partings are undulose and spaced at 60 to 150 mm, with variable lengths between 0.5 and 2.5 m. Bedding is best developed in the cave roof and southern wall, where it was measured to dip shallowly towards the southwest. Three joint sets were identified at the cave JN1 dips steeply to the northeast. Joint set 1 is typically undulating to irregular and open less than 1 mm. Joints along this orientation are up to 4.5 m long and are spaced at 0.5 to 1.5 m. Seepage along JN1 was observed at the back of the cave. JN2 is vertical joint set that strikes east northeast, and is irregular, rough and iron stained. Defect lengths range between 1 and 2 m and are spaced at 0.5 to 1.0 m. JN3 is a northeast striking joint set that is oriented sub-vertically, and is undulating, rough, and iron stained. JN3 is only developed in the central part of the cave roof. The joints are between 0.5 and 0.8 m in length and are spaced 100 to 200mm.	1. A blocky jointed rock mass zone was observed in the roof of the cave interior. The area is limited to where joint set 3 is visible, resulting in multiple intersecting sub-vertical joint sets that produce a 'blocky' BIF rock mass. 2. Hanging blocks bounded by open fractures. 3. Multiple perched boulders are situated in the escarpment above the cave entrance.	• Assess the area for any hanging blocks that may have detached from the cave roof, or for any perched boulders that have dropped from the escarpment above the entrance • Check for dilation or water seepage in the joint structures, particularly in the 'blocky' rock mass zone • Limit time spent below the dripline and identified hanging blocks.
MEC033	Overhang – 4.5 m wide, 1.8 m deep and 1.3 m high. Interior 2.5 m wide, 5.6 m deep, and 1 m high.	GSI Exterior and Overhang 70 – 80 Interior 64 – 74 RMR_{89} Exterior and Overhang 80 Interior 74	The rock mass at the cave comprises highly weathered, hydrated BIF, with elongate vughs oriented parallel to well-developed bedding. A thick blocky chert band forms the lower third of the cave entrance. Bedding generally has a shallow dip and is partially overprinted due to hydration of the rock mass. The dip direction of bedding is variable due to the degree of undulation, with the dip becoming moderate in some highly folded areas, as observed at the cave entrance. Partings are spaced 50 to 150 mm and are generally more persistent in the overhang and exterior with lengths between 0.8 and 1.2 m. Bedding partings are typically open less than 1 mm and exhibit iron staining. No structurally significant joint sets were observed at MEC033, though some open non-systematic fractures were observed around the exterior and overhang.	1. Loose hanging blocks were identified in the overhang. 2. Blocky dilated chert rock mass was observed in the lower part of the overhang, with detached blocky to tabular chert fragments evident on the floor below. 3. Perched boulders were identified in the escarpment above the overhang. These boulders have the potential to rill down the escarpment and over the dripline.	• Before approaching the cave, assess the top of the escarpment for perched boulders that may be at risk of falling • Check the area beneath the overhang for fresh rockfall • Check for water seepage in the cave roof.
MEC073	Entrance/Overhang – 4m wide, 1.7 m deep, and 1 m high. Main Chamber – 1.5 m wide, 6 m deep, and 0.5 m high.	GSI Entrance/Overhang 58 – 68 Main Chamber 66 – 76 RMR_{89} Entrance/Overhang 68 Main Chamber 76	The rock mass at the cave comprises hydrated chert and interbedded BIF. The chert dominant rock mass that hosts the cave is high strength and highly weathered. Bedding is developed in the chert with partings spaces at 50 to 300 mm and between 0.5 and 1.0 m long. Partings are undulating, slightly rough to rough, and have an iron oxide stain to veneer on dilated surfaces. Bedding was measured at the back of the overhang to dip shallowly to the east. Bedding appears to become overprinted in the cave's main chamber. Two joint sets were observed at the cave and are confined to the chert dominant rock mass. JN1 is oriented sub-parallel to the escarpment. It dips steeply to the southwest and is spaced at approximately 0.1 m, and 0.4 to 0.7 m long. JN2 dips steeply to the southeast. It is spaced between 100 to 200 mm and is typically 0.1 to 0.3 m long. Both of the joint sets are tight, and surface conditions of are undulating and rough.	1. Wedged and perched boulders were identified in the escarpment above the cave entrance 2. Loose hanging blocks bounded by open fractures were also identified in the escarpment, both above and adjacent to the cave entrance	• Limit time spent at against the rock face below any identified hanging or wedged boulders • Assess the area for any perched blocks that may have fallen from the escarpment above • Check for dilation of fractures bounding hanging blocks or any new cracks that may have formed in the escarpment and cave roof.

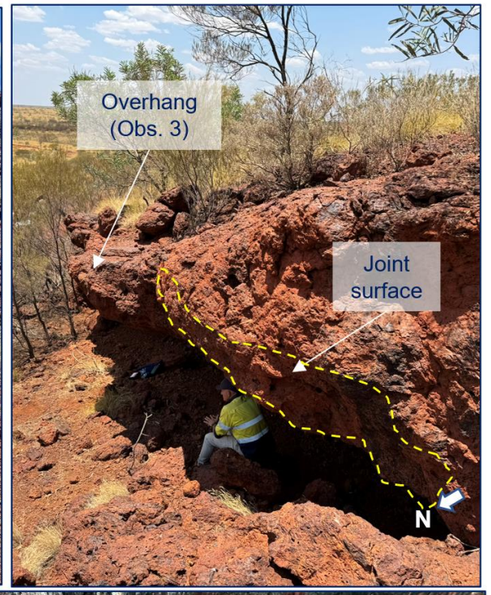
Cave ID	Approximate Dimensions	Estimated GSI Range and Typical RMR_{89}	Rock Mass Description	Observed Susceptible Features	Recommendations for Personnel Working in or Around the Cave
MEC039	Entrance/Overhang – 2.1 m wide and 1.1 m high Interior Chamber – 4.5 m wide, 5.7 m deep and 1.8 m high.	GSI Entrance/Overhang 67 – 77 Main Chamber 70 – 80 Exterior (chert band) 58 – 68 RMR_{89} Entrance/Overhang 77 Main Chamber 80 Exterior (chert band) 68	The lower third of the outcropping escarpment comprises chert, which is overlain by BIF comprising the upper two-thirds of the escarpment. Both rock types are highly weathered and hydrated. The cave appears to have preferentially developed along the contact between the chert and the BIF. Due to the upward sloping floor into the cave, the cave's interior chamber is almost entirely hosted within the BIF overlying the chert. The chert rock mass which makes up the lower half of the cave entrance is blocky and loose in places. The blockiness within the chert is a product of multiple intersecting joints. These joints within the chert are considered to not be significant on the scale of the cave due to the relatively short defect lengths. In the overlying BIF, original bedding has been overprinted but can be distinguished by elongate bedding parallel vughs. Where original rock fabrics are preserved, bedding partings were observed to have a spacing of 0.4 to 0.7 m and lengths of 0.5 to 1.5 m. None of the fractures observed appear to be systematic joints. The main north to north-northwest striking fracture inside the cave is interpreted to have formed due to slumping of the bedrock escarpment. Bedding partings are not developed inside the cave and are completely overprinted.	1. Boulders are perched on the edge of the escarpment above the cave entrance 2. Multiple hanging blocks bounded by non-systematic, dilated fractures occur in the cave dripline 3. Narrow rock pillars located at the entrance to the interior chamber may be susceptible to cracking and collapse from blast induced vibrations. The pillars occur at the interface between the chert and overlying BIF. 4. Seepage into the cave was observed to occur along the north to north-northwest trending fracture inside the cave, evidenced by considerable iron staining.	• Check for fresh rock fall debris around the cave entrance before approaching • Limit time spent immediately below identified hanging blocks bounded by open fractures in the escarpment above the entrance • Check for signs of fretting or cracking within the susceptible rock pillars • Check for dilation or water seepage in the north to north-northwest trending fracture inside the cave before accessing.
MEC016 (MIB-MD13-043)	Main Chamber – 6 m wide, 7.6 m deep, and up to 1.2 m high. • A skylight 0.8m wide occurs in the roof of the central chamber • Eastern main chamber –4.5 m deep and 0.7 m. Three natural adits: • Southwest adit 5.5 m deep • Western rear adit 5 m deep • Eastern rear adit 6 m deep The adits are 1.8 to 2.2 m wide, and all less than 0.8 m high	GSI Exterior, Main Chamber and Southwest Adit 63 – 73 Western and Eastern Rear Adits 68 – 78 RMR_{89} Exterior, Main Chamber and Southwest Adit 73 Western and Eastern Rear Adits 78	The rock mass comprises partially hydrated, vughy BIF and chert that dips shallowly towards the southeast. The roof profile is undulating and sub-horizontal, suggesting the cave developed along BIF bedding planes. Bedding partings are spaced at 150 to 300 mm, though are not continuous across the cave. Parting spacings increase to 0.5 m towards the top of the escarpment where bedding becomes largely overprinted. Observed parting lengths are typically between 2 and 4 m. Three joint sets were identified and have the following characteristics: Joint set 1 (JN1) dips steeply to the southeast. It has a spacing of 0.4 to 1.0 m at the entrance. The spacing increases into the cave where it is spaced at approximately 3 m. Defect lengths are highly variable and range between 1.5 and 5.0 m. A single joint along this orientation in the main chamber roof is open up to 3 mm and infilled with silt and a veneer of iron oxide Joint set 2 (JN2) dips steeply to the east northeast. Only two joints were observed along this orientation in the roof of the main chamber, indicating a spacing of 1.2 m and lengths between 3.0 and 4.5 m. Joint set 3 (JN3) dips steeply to the northeast. Only two joints were observed on the western side of the main chamber, indicating a spacing of 0.7 m and lengths of approximately 1 m.	1. A thin roof profile (measured 1 to 2 m thick above the entrance) in combination with the cave's wide span increases the susceptibility to collapse 2. A pillar of poorer quality rock quality is situated at the back of the main chamber, and may be susceptible to cracking 3. There is potential for blocks to detach from bedding partings in the cave roof or overhang where cross cut by a sub-vertical joint set. This mechanism is evidenced by past tabular rockfall below the entrance. 4. Loose hanging blocks were identified in the escarpment around the entrance. No hanging blocks were identified on the interior. 5. Perched boulders are situated in the escarpment above the cave have the potential to fall.	• Assess the area for any blocks that may have detached from the overhang at the entrance • Check for dilation and water seepage in structures within the entrance overhand and inside the main chamber. Also check for any new fractures that may have formed • Limit time spent immediately below the dripline where perched boulders are at risk of falling, or loose hanging blocks have been identified • Check for signs of fretting or cracking within the susceptible rock pillar.
MEC063	Main Chamber – 10.8 m wide, 7.8 m deep, and up to 1.2 m high.	GSI Exterior 63 – 73 Interior 58 – 68 RMR_{89} Exterior 73 Interior 68	The rock mass at the cave comprises high strength, highly weathered interbedded BIF and chert. Bedding is well developed, undulating and strongly controls cave development. Bedding was measured in the centre of the cave to dip shallowly to the south. Partings are spaced between 80 and 300 mm. Some partings persist greater than the span of the cave, though most are between 5 and 10 m in length and are open less than 1 mm. Two pervasive joint sets were identified at the cave throughout the exterior and interior. Joint set 1 (JN1) is oriented sub-vertically and strikes northeast-southwest. Defects along this orientation are typically 0.3 to 0.8 m long but some JN1 structures were observed up to 5 m in length. The joint set has a spacing of 0.2 to 0.5 m and is tight. Joint set 2 (JN2) dips steeply to the northwest, sub-parallel to the bedrock escarpment. Surfaces are planar to undulating and range between 0.3 and 1.0 m in length. Some exposed JN2 surfaces where past blocks have detached are up to 2.5 m long.	1. Wedged boulders were observed on the eastern side of the cave, in the gap between the cave dripline and escarpment 2. Perched boulders are situated atop the escarpment above the cave entrance 3. There is potential for large slabs of hydrated BIF and chert to detach from dilated bedding partings and joints in the cave roof 4. Talus boulders form the escarpment above the cave were observed to infiltrate the gap between the cave dripline and eastern escarpment edge	• Avoid spending time spent below the gap between the eastern escarpment and cave dripline, where wedged boulders and talus from the above escarpment present multiple potential rockfall sources • Watch footing below identified Obs. 1 areas due to a drop in the floor profile • Before entering the cave, check for fresh rockfall debris and for movement or further dilation of the open bedding partings in the cave roof • No standing or sitting below dilated the area of dilated rock mass in the cave roof (Obs. 3). Move quickly past these areas if necessary.
MEC062	Main Chamber – 6.1 m wide, 6.7 m deep, 1.5 m high	GSI Exterior and Front of Main Chamber 60 – 70 Rear of Main Chamber 65 – 75 RMR_{89}	The rock mass at the cave comprises hydrated, interbedded BIF and chert. The rock mass is highly weathered. Intact strength was estimated to be high. Hydration has overprinted bedding in parts of the cave, particularly on the cave roof and southern wall. Where visible, bedding is sub-horizontal and is highly undulose. The dip direction of bedding is variable due to the degree of undulation, with the dip becoming moderate to steep in some highly folded areas at the rear of the cave. Structurally significant partings were observed to have a 100 to 400 mm spacing at the front of the main chamber. The partings are between 0.5 and 1.5 m in length and are either tight or open less than 1 mm.	1. Hanging blocks were observed on the cave exterior and interior. A large hanging block situated immediately above the entrance is bounded by joint set 1 and open fractures 2. Multiple perched boulders up to 0.6 m in width were observed on the escarpment above the cave entrance 3. Water seepage into the cave was observed along a dilated fracture in the cave roof, which is	• Before approaching the cave, assess the area for any fresh rockfall and loose blocks that may have formed in the escarpment • Avoid standing or sitting below identified hanging blocks in the cave dripline and interior. When accessing the cave, move past the large block above the entrance quickly.

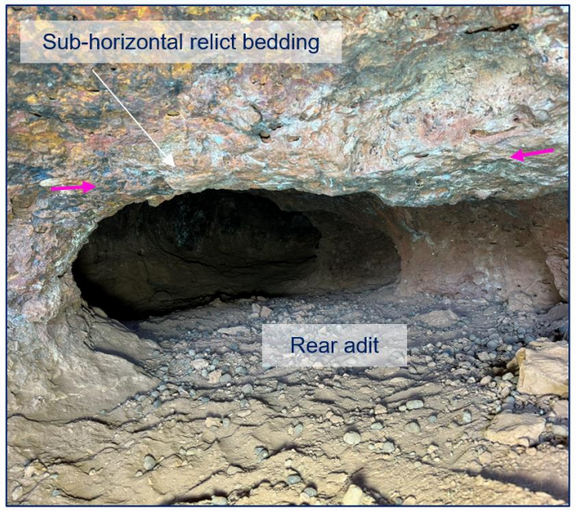
Cave ID	Approximate Dimensions	Estimated GSI Range and Typical RMR_{89}	Rock Mass Description	Observed Susceptible Features	Recommendations for Personnel Working in or Around the Cave
		Exterior and Front of Main Chamber 70 Rear of Main Chamber 75	Two joint sets were identified at the cave. Joint set 1 (JN1) dips steeply to the south-southeast and is 0.6 to 2.8 m long. The second joint set (JN2) dips sub-vertically to the northeast and is 1.0 to 2.5 m long. Both joint sets have irregular and rough surface conditions, and are typically tight with an iron stain infill. The joint sets are spaced variable between 1 and 3 m apart. A large open fracture in the cave roof appears to initiate along JN1 in at the cave entrance, and then rotates along folded bedding towards the rear of the cave.	partially aligned along joint set 1. Seepage was evidenced by iron staining of the wall rock either side of the fracture 4. The overhanging escarpment on the western side of the cave entrance is up to 4 m thick. Due to the orientation of joint set 2, there is potential for the substantial overhang to detach from the sub-vertical structure	• Check for dilation of joint fractures inside the cave and for the formation of any new cracks in the substantial overhang on the western side of the entrance.
MEC061	Overhang – 5.4 m wide, 1.7 m deep, 0.6 m high Rear Chamber – 4 m wide, 3 m deep, 0.3 m high (approximate)	GSI Exterior 51 – 61 Interior 58 – 68 RMR_{89} Exterior 61 Interior 68	The rock mass comprises hydrated interbedded BIF and chert. The rock mass is highly weathered and has a medium to high intact strength. A thinly laminated siliceous shale band was observed above the cave entrance. The band is approximately 100 mm thick and appears to have been preferentially weathered. Bedding is well developed and is undulating with 1.5 to 3.5 m long partings that are open less than 1 mm. Some dilated partings around the entrance are open up to 4 mm. Partings are spaced variable between 0.15 and 0.4 m. Surfaces are typically slightly rough to rough and are iron stained. Bedding is partially overprinted in some areas of the escarpment due to hydration of the rock mass. Bedding was measured to dip shallowly to the southeast. Within the siliceous shale band, laminations are spaced at approximately 10 mm, though are not laterally persistent. Three major joint sets were identified: JN1 strikes into the cave and dips steeply to the west. The joint set has a spacing of 50 to 100 mm and is open over lengths of 0.2 to 0.5 m. JN2 also strikes into the cave, and dips steeply to the southeast. The joint set has a spacing of 50 to 300 mm and is open over lengths of 0.2 to 0.5 m JN3 strikes sub-parallel to the cave entrance and was measured to dip steeply to the northeast. The joint set is spaced between 100 and 200 mm and has an observable length of up to 1 m.	1. The siliceous shale band dips obliquely into the escarpment. Although not directly observed, there is potential for the shale band to intersect the rear chamber roof and for blocks to detach from the laminated band if it passes close enough to the cave roof. Observed preferential weathering of the siliceous shale band also has the potential to undermine the overlying escarpment. 2. There is potential for blocks in the escarpment and cave roof to detach from bedding where cross cut by vertical joints. A 150 mm thick dilated chert band located at the access point to the rear chamber appears to be susceptible mechanism 3. Hanging blocks bounded by open defects were observed in areas of the cave roof and dripline 4. Perched boulders occur at the top of the escarpment in which the cave is situated 5. Wedged boulders were observed in a crevasse on the southern side of the cave entrance	• Assess the area for any hanging blocks that may have detached from the cave roof, or for any perched boulders that have dropped from the escarpment above the entrance. • Check for dilation of defects in the escarpment and cave roof before accessing the cave. • Avoid spending time below the 150 mm thick dilated chert band just beyond the cave entrance. Check for further dilation or seepage along the dilated bedding partings and do not access if observed. • Limit time spent immediately below the dripline where perched boulders are susceptible to falling, or loose hanging blocks have been identified.
MEC060	Main Chamber – 7.7 m wide, 8.3 m deep, 0.7 m high	GSI Exterior 50 – 60 Interior 58 – 68 RMR_{89} Exterior 60 Interior 68	The rock mass at the cave comprises hydrated interbedded BIF and chert. The rock mass is highly weathered and has a medium to high intact strength. The rock mass appears blocky due to multiple intersecting joint sets and bedding partings. Bedding is well developed with partings were commonly observed on the upper and lower contacts of interbedded chert bands. Bedding dips shallowly to the southwest and is undulating. Partings are typically 1 to 4 m in length and are spaced between 70 and 300 mm. Three joint sets were identified: JN1 strikes obliquely to the cave entrance, dipping steeply to the south-southwest. JN1 has an observable length of 0.2 to 0.9 m and a spacing of 100 to 200 mm, Inset 17. JN2 dips steeply to the west. It has relatively short defect lengths between 150 and 500 mm. JN2 is best preserved in the escarpment and areas around the entrance where it was observed to have a spacing of 100 to 300 mm. JN3 strikes parallel to the escarpment and was only observed on the eastern side of the cave. JN3 dips steeply to the south,	1. There is potential for slabs of hydrated BIF and chert to detach from bedding and/or joints in the cave roof 2. The rock mass in the escarpment is loose and dilated in parts. This a potential source for future rockfall as evidenced in past rockfall product on the cave exterior. 3. Hanging blocks bounded by dilated bedding partings and joints were observed in the dripline above the cave entrance 4. Perched boulders were observed along the top of the escarpment in which the cave is hosted. Some tabular boulders appear to have become perched due to continual weathering of the dilated blocky rock mass.	• Assess the identified hanging blocks and the BIF slab at the entrance for dilation of bedding partings and joint structures that bound the them. • Before approaching the cave, assess the top of the escarpment for perched boulders that may be at risk of falling. Check the area below the dripline for fresh rockfall. • Limit time spent at the escarpment face where loose dilated rock mass has been identified. Avoid leaning or sitting below these areas.
MEC072	Entrance – 1 m wide, 0.6 m high Interior – 0.6 m wide, 5.5 m deep, 0.4 m high	GSI Exterior 67 – 77 Entrance 63 – 73 Interior 67 – 77 RMR_{89} Exterior 77 Entrance 73 Interior 77	The rock mas at the cave comprises hydrated, highly weathered BIF. The intact strength is high to very high. Bedding is developed and elongate vughs were observed on the exterior oriented parallel to bedding. Bedding dips shallowly to the southeast with partings that are undulating and up to 0.5 m long. The partings are spaced at 60 to 200 mm and have surfaces that are slightly rough to trough. They are tight to open less than 1 mm. Bedding appears to become overprinted deeper into the cave. No structurally significant joint sets were identified.	1. Perched boulders are situated above the cave entrance 2. There is potential for blocks to detach from bedding where partings are developed around the entrance. If blocks detach they are likely not going to restrict access for bats in to the cave	• Before accessing the cave, assess the perched blocks above the entrance that have the potential to fall and check for any fresh rockfall and on the ground.
MEC049	Interior – 1.5m wide, 2.8 m deep, and 0.8 m high (up to 2 m high at rear)	GSI Exterior 50 – 60 Interior 56 – 66	The rock mass comprises partially hydrated interbedded chert and BIF. It is highly weathered and typically has a high to very high intact strength. In some areas around the entrance, medium strength was observed. The rock mass is generally blocky and dilated.	1. A dilated joint swarm along joint set 3 orientation was observed to control cave development at the back of the interior chamber.	• Before accessing the cave, assess the perched blocks above the entrance that have the potential to fall and check for any fresh rockfall and on the ground.

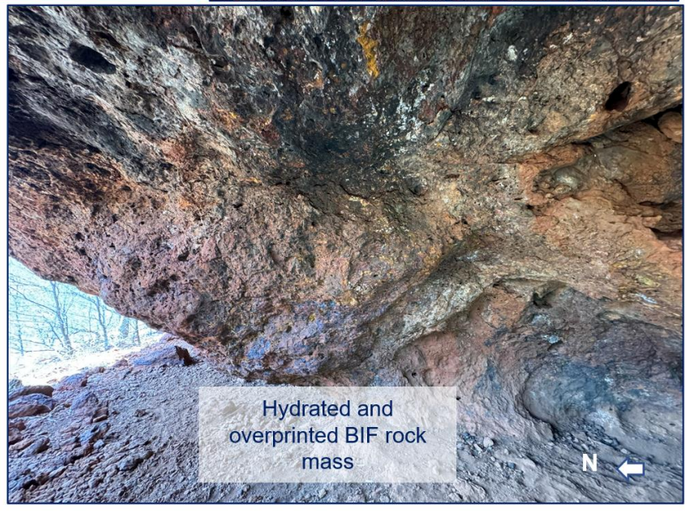
Cave ID	Approximate Dimensions	Estimated GSI Range and Typical RMR_{89}	Rock Mass Description	Observed Susceptible Features	Recommendations for Personnel Working in or Around the Cave
		RMR_{89} Exterior 60 Interior 66	Bedding is well developed with partings 2 to 6 m long observed throughout the cave and surrounding escarpment. Partings are typically undulating and oriented sub-horizontally. They are open up to 4 mm in places but typically have an aperture of approximately 1 mm with an iron veneer infill. Partings are spaced at 100 to 300 mm and have rough surfaces. Three joint sets were observed: JN1 dips steeply to the northwest and has an observable length of 1 to 3 m. The set is spaced at 100 to 200. JN1 was only observed in the escarpment and around the entrance of the cave. JN2 dips steeply to the west-southwest. Joints along this orientation are relatively short with lengths between 0.1 and 0.4 m. JN2 has a spacing of 40 to 120 mm. JN3 dips steeply to the southwest and is generally spaced between 0.1 and 0.3 m. Two large open structures along this orientation occur at the back of the interior chamber resulting roof profiles up to 2 m high. At the back of the main chamber, JN3 is up to 3 m long and spaced at 50 mm proximal to the joint swarm.	2. Loose dilated blocky rock mass was observed in the escarpment above and adjacent to the cave, and also in areas around the cave entrance. 3. Perched boulders are situated atop the escarpment.	• Limit time spent immediately below the dripline where there is potential for blocks to detach from the dilated blocky rock mass. Avoid leaning on these areas when accessing the cave. • Check for dilation of defects in the escarpment and cave roof before accessing the cave. • Inside the cave, check for seepage along the dilated joint structures. Do not continue to access the cave if water is observed.
MEC003	Main Chamber – 5.2 m wide, 4.0 m deep, 0.7 m high. Rear Chamber – 1.8 m wide, 4.1 m deep, 0.6 m high	GSI Exterior and Main Chamber 67 – 77 Rear Chamber 63 – 73 RMR_{89} Exterior and Main Chamber 77 Rear Chamber 73	The rock mass at the site comprises interbedded hydrated BIF and chert. The rock is dilated and loose in areas around the entrance, and in the escarpment above the cave. The intact strength is high to very high. A laminated siliceous shale band was observed on the roof the main chamber, and was assessed to have a low to medium intact strength. The laminations within the shale band are intact. Bedding at the cave is well developed and forms partings with lengths between 1 and 10 m long. The partings are spaced between 80 and 200 mm, and are open up to 2 mm. Bedding dips shallowly to the west. Three joint sets were recorded at the cave: JN1 dips steeply to the east-northeast. It has lengths of 0.3 to 0.5 m and is spaced 50 to 150 mm. Joints along this orientation are typically tight to open <1 mm. JN2 controls dripline formation on the southern side of the escarpment. It dips steeply to the south-southeast and has defect lengths between 0.4 and 0.8 m. The joints are typically undulating and are spaced between 100 and 200 mm apart. JN3 dips steeply to the southeast and was observed to be tight. JN3 is typically 0.5 to 1.5 m long and spaced at 100 to 400 mm.	1. There is potential for blocks of rock to detach from bedding partings sand joints in the cave roof, evidenced by past rockfall debris throughout the cave main chamber and below the dripline. 2. A thinly laminated siliceous shale band was observed to intersect the roof of the main chamber. Although the laminations are intact, blocks below the shale band may be able to detach from the band due to the lower intact strength. 3. Loose hanging blocks up to 0.8 m wide were observed on the southern side the escarpment. The hanging blocks are bounded by dilated joints or non-systematic fractures. 4. Perched boulders are situated in the escarpment above the cave have the potential to fall.	• Limit time spent immediately below the dripline where perched boulders are at risk of falling, or loose hanging blocks have been identified. • Check for fresh rock fall debris around the cave entrance before approaching. • Check for dilation of defects bounding blocks in the escarpment and main chamber roof • Assess the main chamber for signs of water seepage, particularly around any hanging blocks bounded by joints in the cave roof.
MEC025	Entrance – 2.1 m wide and 6 m high Interior – 5.5 m wide, 1.7 m deep, 0.5 m high	GSI All Areas 66 – 76 RMR_{89} All Areas 76	Rock mass at the cave comprises interbedded hydrated BIF and chert. The cave itself is hosted within the hydrated BIF which makes up the lower part of the exposed escarpment, with blocky chert bands observed in the escarpment above the cave. The rock mass is high strength, with elongate vughs oriented parallel to BIF bedding. Bedding dips shallowly to the southwest and does not form structurally significant partings at the cave level, however, partings do persist in the rock above the cave along the contacts of interbedded chert bands. Above the cave, partings are 1 to 6 m long and spaced between 200 and 400 mm. A single joint set was observed at the cave. The joints are oriented sub-vertical and strike east-west. Only two open joints were observed along this orientation, indicating a spacing of approximately 2 m and lengths up to 1.7 m.	1. Hanging blocks bounded by open fractures were observed in the cave roof inside the cave. 2. Blocky chert bands occur in the escarpment above the cave entrance, and have the potential to release dilated blocks from the escarpment face. 3. Perched boulders were observed along the top of the escarpment in which the cave is situated 4. A large BIF slab is bounded by an open fracture on the southern side of the cave entrance.	• Before approaching the cave, assess the area for any fresh rockfall and loose blocks that may have formed in the blocky chert escarpment • Check the escarpment above the cave for perched boulders when traversing the cave dripline • Avoid leaning on or sitting below the large BIF slab on the southern side of the cave entrance • Assess the identified hanging BIF blocks inside the cave for dilation of bounding fractures and for signs of detachment.

Summary Sheet Cave ID	Approximate Dimensions	Estimated GSI Range and Typical RMR_{89}	Rock Mass Description	Observed Hazards	Recommendations
MEC042	Entrance/Overhang – 10 m wide, 2.5 m deep Main Cave – 4 m wide, 3.2 m deep, 1.5 m high Rear Adit – 5 m deep, 1.3 m wide, 0.6 m high	GSI All Areas 68 – 78 RMR_{89} All Areas: 78	The rock mass comprises high strength hydrated BIF with elongate vughs up to 50 mm oriented parallel to relict bedding, which is largely overprinted. BIF bedding becomes developed at the entrance to the rear adit and was observed to be sub-horizontal. Two parallel joints were observed at the cave entrance and appear to form a structural set. The joints dip steeply to the south, are undulating to irregular, rough, and iron stained. The joints do not persist greater than 2 m and were only observed at the cave entrance.	1. Increased rockfall risk below the dripline of the cave, evidenced by historical blocks on the cave floor. 2. Sub-vertical open joints intersecting the cave roof. 3. Increased potential for roof collapse due to the wide, flat span.	• Check for or dilation of joints at the cave entrance, and for sub-horizontal partings which may indicate opening of relict bedding planes • Avoid standing or sitting below the dripline of the cave • Check for fresh rock fall debris around the cave entrance before approaching.

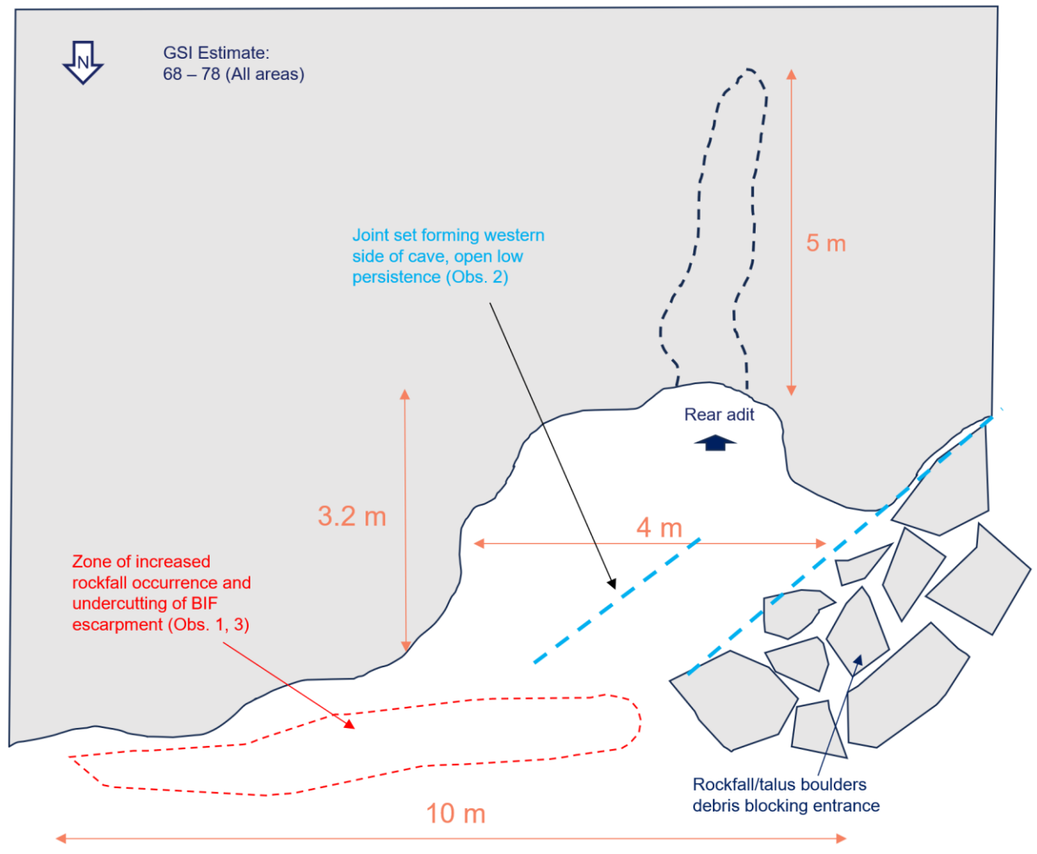






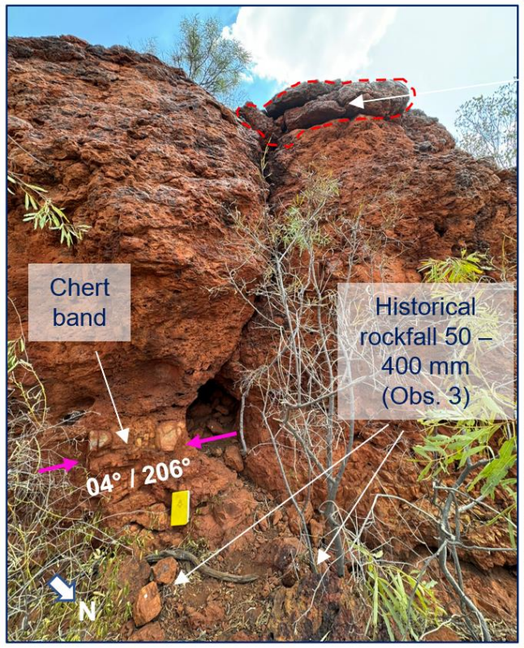


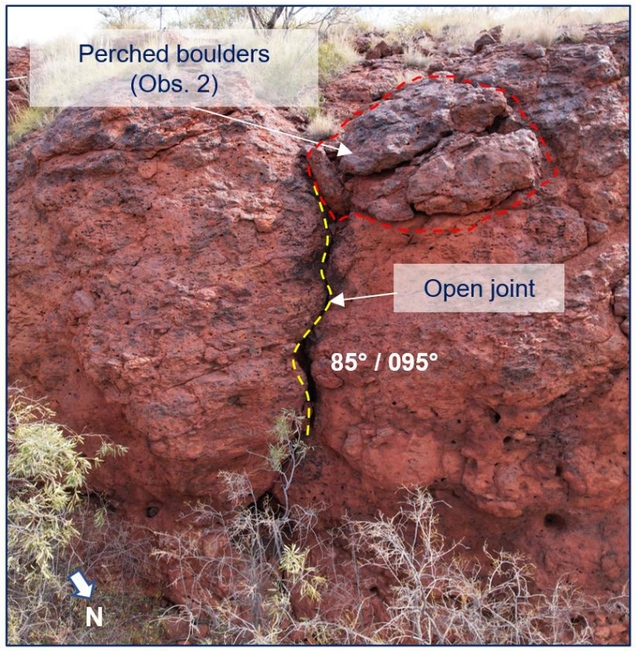
Schematic Plan View

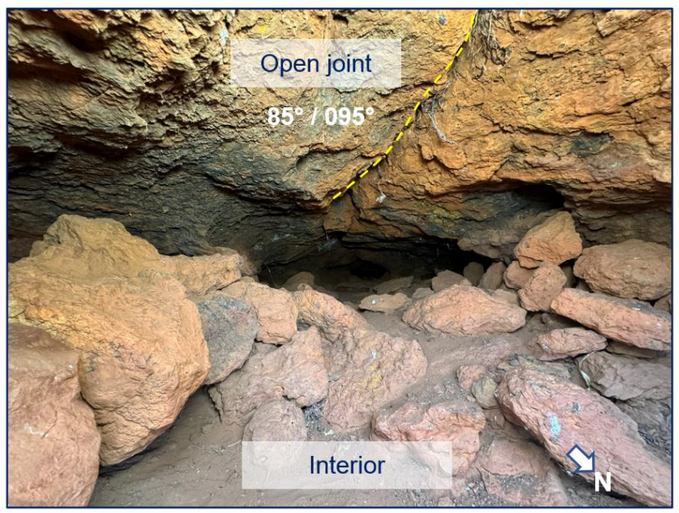


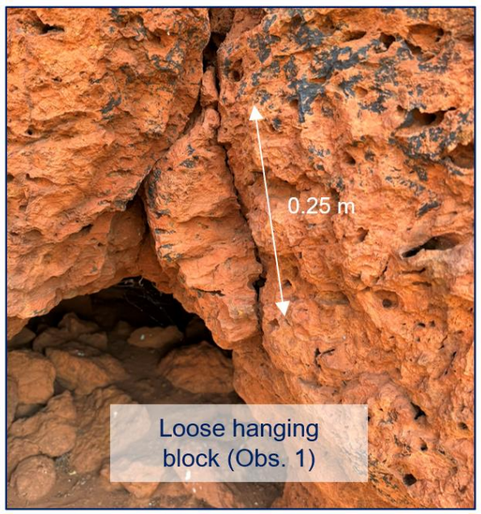
Not to scale

Summary Sheet Cave ID	Approximate Dimensions	Estimated GSI Range and Typical RMR_{89}	Rock Mass Description	Observed Hazards	Recommendations
MEC014	Cave – 6 m deep, 0.8 m wide, 0.8 m high	GSI All Areas 65 – 75 RMR_{89} All Areas: 75	The rock mass comprises medium to high strength hydrated and vughy BIF. Original bedding fabrics have largely been overprinted, though bedding parallel vughs are developed throughout the rock mass. A discrete chert band occurs at the base of the cave. Bedding was measured from the exposed chert band and dips shallowly towards the southwest. The cave has formed along an open joint which persists along the cave roof for the first ~3 m beyond the entrance. The structure dips steeply to the east and is irregular, slightly rough to rough, and infilled with a veneer of iron oxide. Water seepage along the structure is indicated by black staining and plant rootlets growing within the joint	1. A 250 mm hanging block in the dripline immediately above the cave entrance. Bounded by a sub-vertical joint and open fracture. 2. Perched and wedged boulders at the top of the bedrock escarpment, approximately 4 m above the cave entrance. 3. Increased rockfall risk at the cave entrance, with historical 50 – 400 mm fragments of BIF, some of which have detached from bedding.	• Limit time spent at the cave entrance, immediately below the escarpment due to the perched boulders atop the escarpment • Check for movement or dilation of the controlling joint in the escarpment and within the cave roof before approaching • Avoid standing or working below or leaning on the loose boulder in the dripline of the cave.

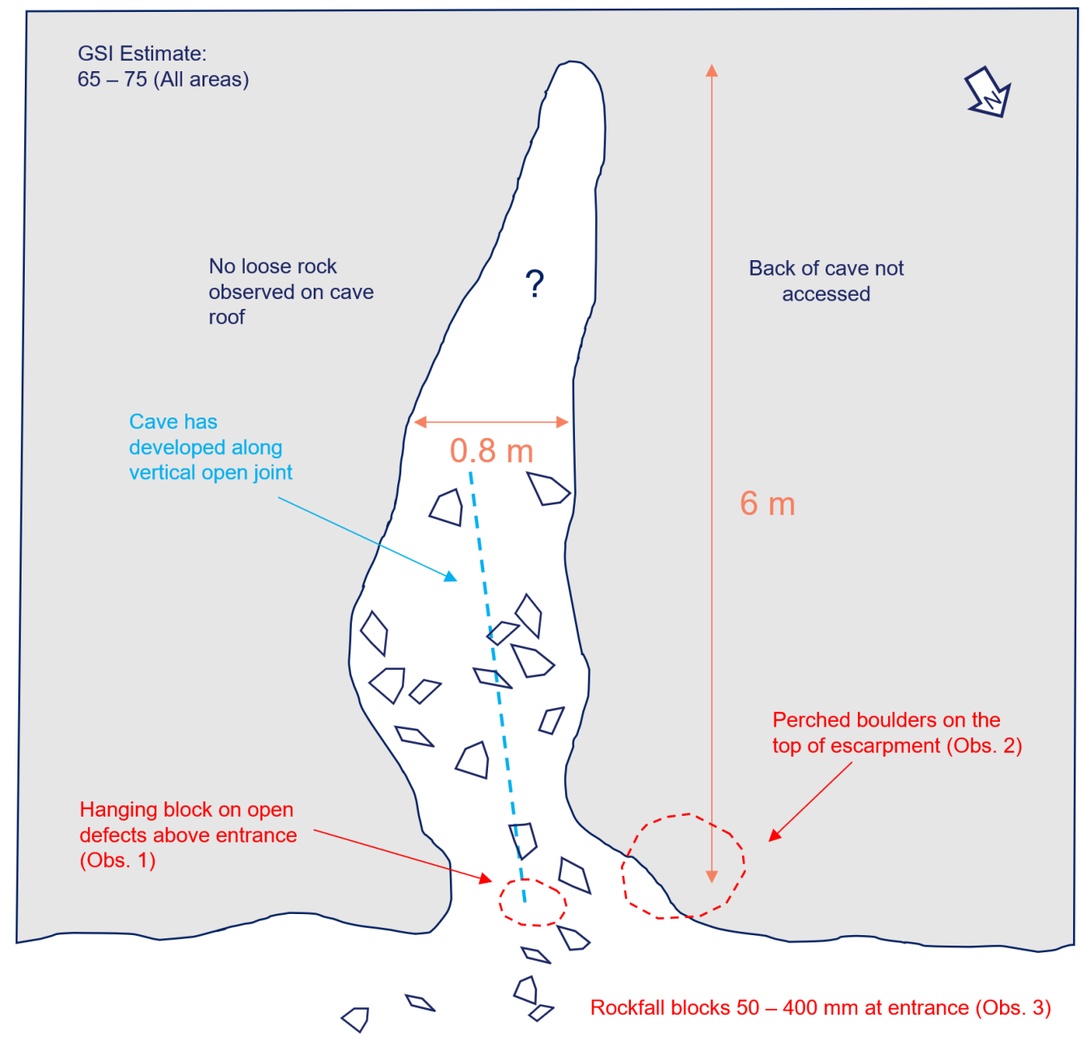








Schematic Plan View



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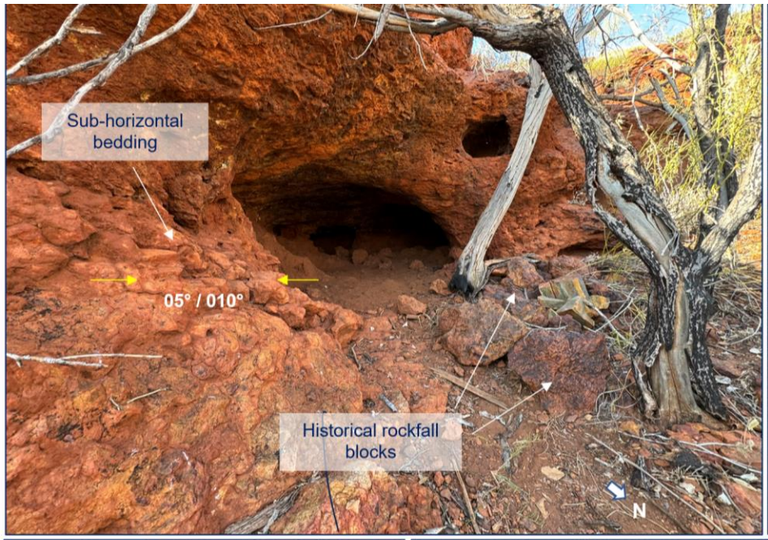
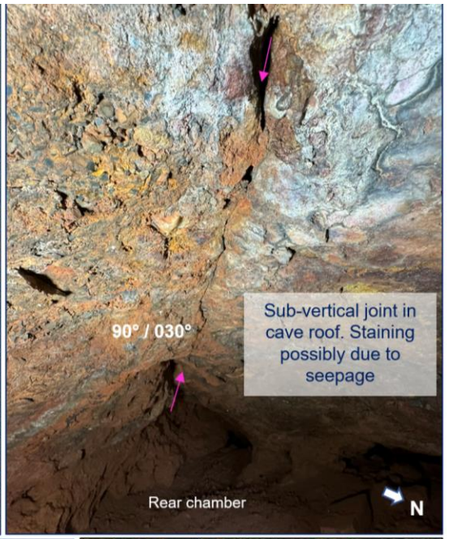
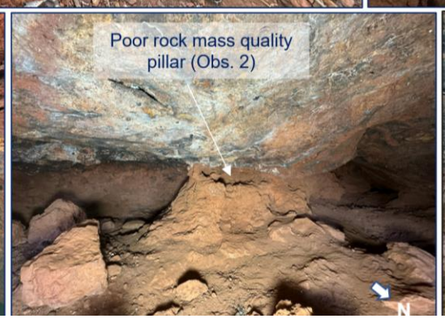
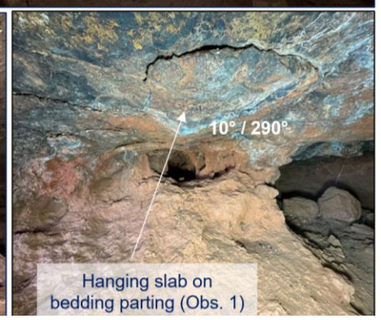
Summary Sheet Cave ID	Approximate Dimensions	Estimated GSI Range and Typical RMR_{89}	Rock Mass Description	Observed Hazards	Recommendations
MEC013	Entrance – 1.8m wide, 1 m high Main chamber – 3.0 m wide, 3.1 m deep, and 0.7 m high. Rear chamber –0.4 m wide and 2 m deep.	GSI Exterior 70 – 80 Interior 67 – 77 RMR_{89} Exterior: 80 Interior: 77	The rock mass comprises moderate to high strength, hydrated BIF and banded chert. Vughs up to 120 mm are generally elongated in the direction of bedding. Bedding has been partially overprinted and is better preserved on the cave exterior where it is sub-horizontal, undulating and thickly laminated. Bedding does not form structurally significant partings in the cave walls. The cave roof profile, however, has developed preferentially along sub horizontal bedding. A single vertical joint that strikes 220° was observed in the roof of the rear chamber. The joint is open up to 6 mm and shows evidence of water seepage. At the time of the inspection the joint surface was moist, and the adjacent wall rock showed goethitic and other iron oxide staining	1. A hanging BIF slab bounded by an open bedding parting was observed on the eastern side of the main chamber roof. 2. A rock pillar of poor rock mass quality (low intact strength inferred) identified on the eastern side of the rear chamber. 3. A cluster of loose 50 – 200 mm fragments was observed in the dripline directly above the cave entrance.	• Check for movement or dilation of defects, or fresh rock fall before approaching the cave • Limit time spent below the hanging slab in the main chamber or avoid if possible • Check for signs of fretting of the susceptible rock pillar and/or further erosion at the base • Avoid standing or leaning on the area of loose BIF fragments above the cave entrance. Do not stand in the cave entrance, move past the entrance zone when accessing the cave.

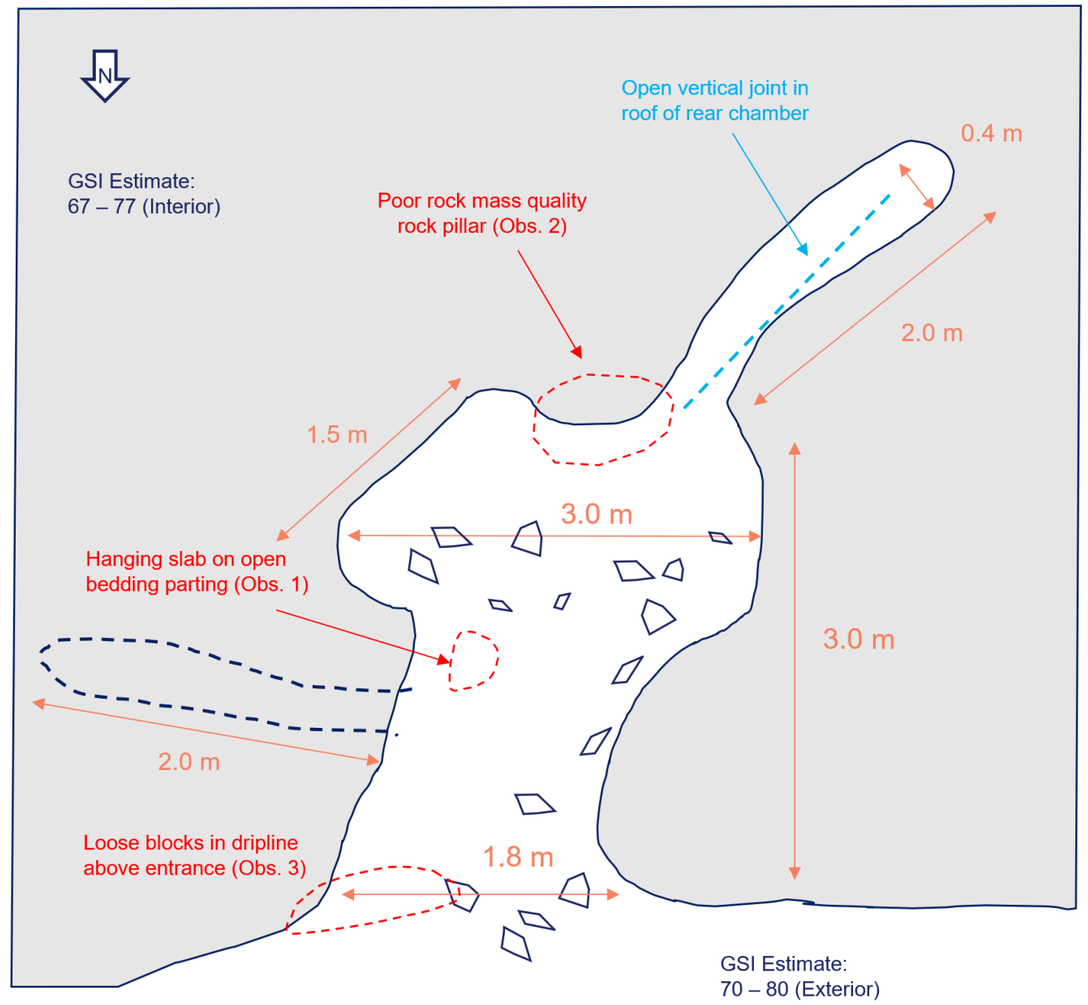








Schematic Plan View



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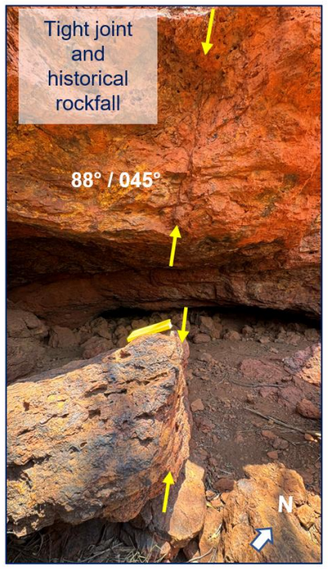
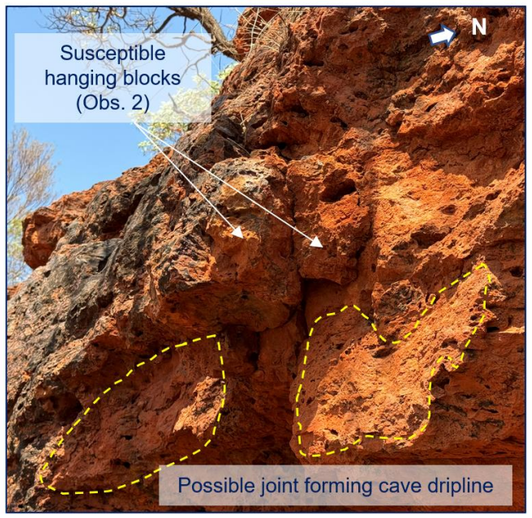
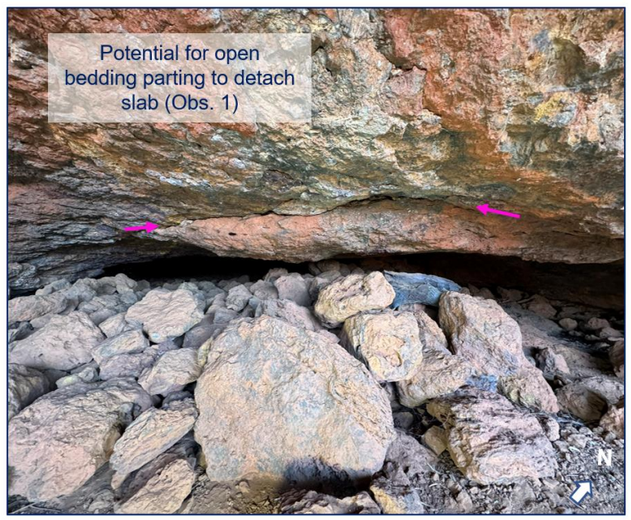
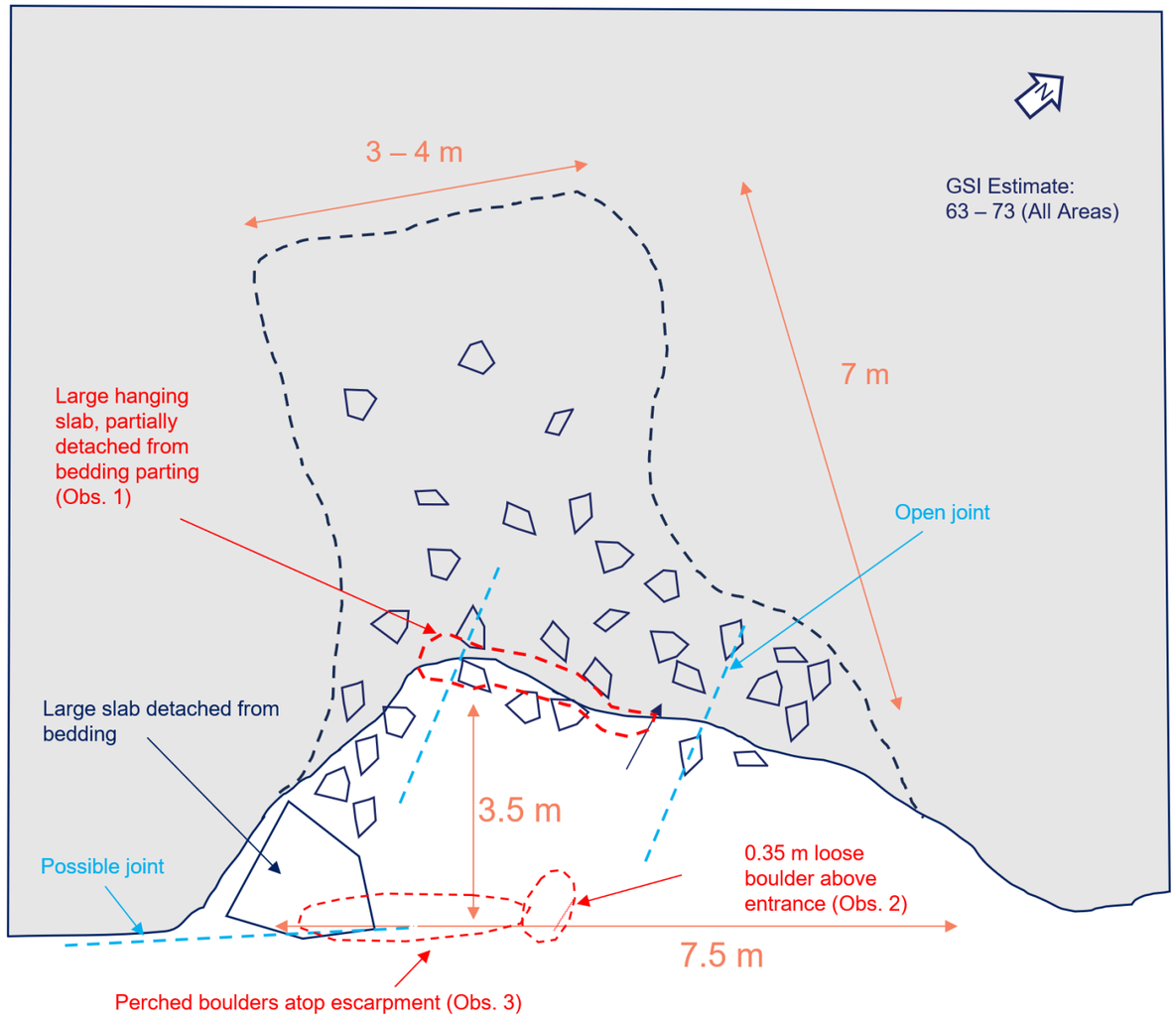
Summary Sheet Cave ID	Approximate Dimensions	Estimated GSI Range and Typical RMR_{89}	Rock Mass Description	Observed Hazards	Recommendations
MEC012	Main Overhang - 7.5 m wide, 3.5 m deep, 1.5 m high. Rear Chamber –7 m deep, 4 m wide, 0.2 to 0.5 m high	GSI All Areas 63 – 73 RMR_{89} All Areas: 73	The rock mass at the cave comprises high strength hydrated BIF with elongate vughs up to 100 mm oriented parallel to relict bedding, which dips shallowly to the northwest. Some vughs are infilled with silt and gravels which are inferred to be residual rock fragments. One steep northeast dipping joint set was identified at the cave site. It has a spacing of 3 to 4 m and is undulating, rough, and stained with iron and dark minerals. The joints appear to persist only around the cave entrance and main overhang, with observable lengths < 2 m.	1. Large BIF slabs bounded by dilated bedding partings in the cave roof, cross-cut by the northeast dipping joint set in places. 2. Loose hanging blocks up to 0.35 mm wide in the dripline above the cave entrance. 3. Two perched boulders at the top of the escarpment.	• Check for movement or of hanging blocks and perched boulders above the entrance before approaching the cave. Avoid standing and sitting in this area • Check for dilation of the bedding parting or detachment of the BIF slab in the cave roof at the back of the main overhang.







Schematic Plan View



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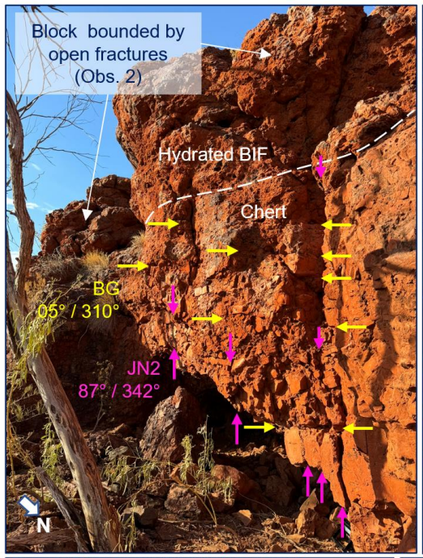
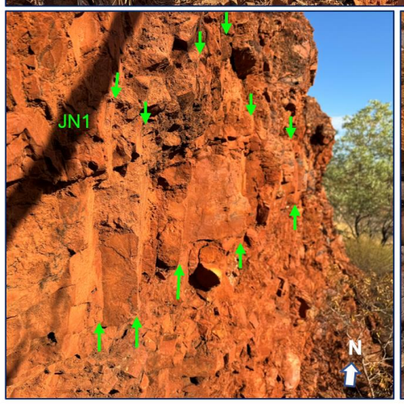
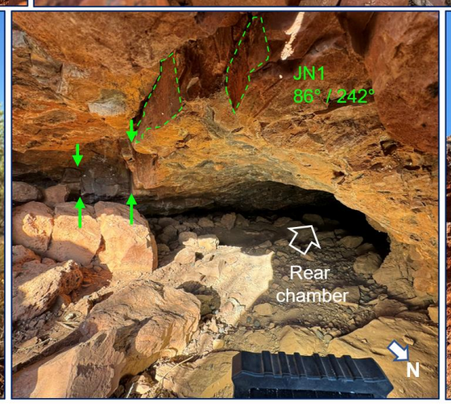
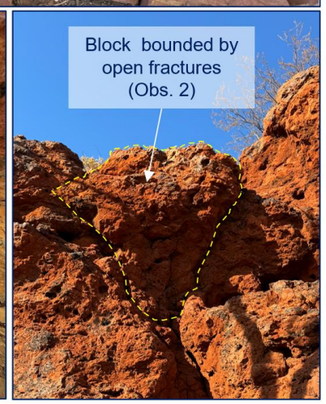
Summary Sheet Cave ID	Approximate Dimensions	Estimated GSI Range and Typical RMR_{89}	Rock Mass Description	Observed Hazards	Recommendations
MEC074	Exterior/Overhang – 3.5 m wide, 1.7 m deep and 1.1 m high. Rear Chamber – 3.5 m wide, 4.5 m deep, 0.4 m high	GSI Exterior/Overhang 55 – 65 Rear Chamber 65 – 75 RMR_{89} Exterior/Overhang 65 Rear Chamber 75	The rock mass at the cave comprises a thick chert band overlain by hydrated vughy BIF. The bat cave is hosted entirely within the chert band which approximately makes up the bottom half of the exposed escarpment. The chert rock mass is highly weathered and hydrated, with an apparent medium to high intact strength. The chert is dilated and loose in some areas. Bedding was observed to dip sub-horizontally towards the northwest. Within the chert, partings are spaced between 50 to 300 mm, and have lengths of approximately 0.5 to 1.0 m. Two joint sets were identified: Joint set 1 (JN1) strikes sub-parallel to the cave entrance and controls dripline formation. It dips sub-vertically towards the southwest, and is typically planar to undulating. Joint set 1 is spaced between 100 and 300 mm with lengths ranging from 0.3 to 0.8 m. Joint set 2 (JN2) has a typical spacing of 50 to 200 mm and strikes obliquely into the escarpment. It has an observable length of 100 to 400 mm. A single defect along this orientation on the north side of the entrance appears to bridge through the rock mass along multiple JN2 structures, resulting in a 2.5 m long defect that is open up to 2 mm.	1. Dilated, loose blocky chert rock mass was observed in some areas of the dripline and in the roof of the overhang. There is an increased potential for rockfall in these areas as evidenced by past detached blocks on the ground 2. Hanging blocks bounded by non-systematic open fractures were identified in the BIF escarpment above the cave entrance.	• Limit time spent immediately below identified hanging blocks bounded by open fractures in the escarpment above the entrance • Avoid leaning on the area of dilated loose chert in the overhang when accessing the cave, or sitting directly underneath it • Check for fresh rockfall debris around the cave entrance and overhang when approaching the cave.

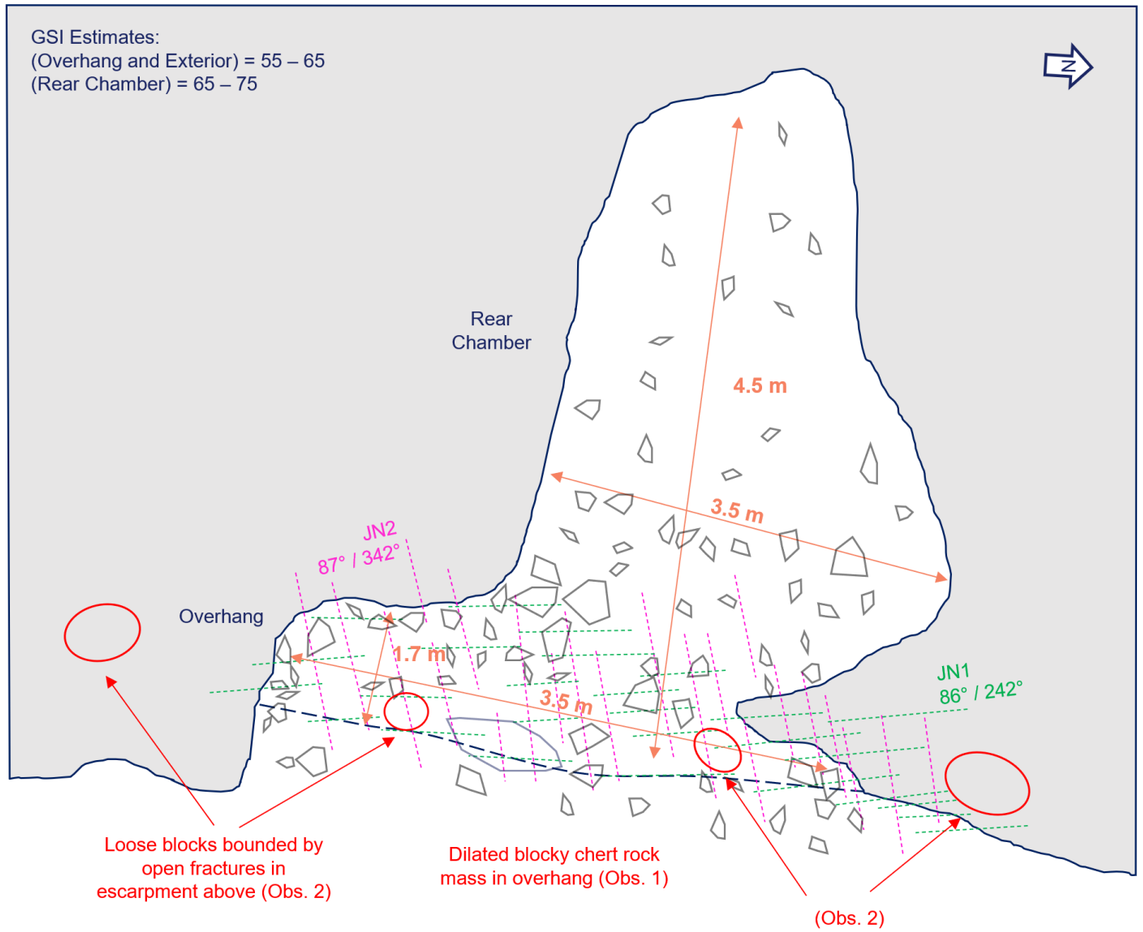








Schematic Plan View



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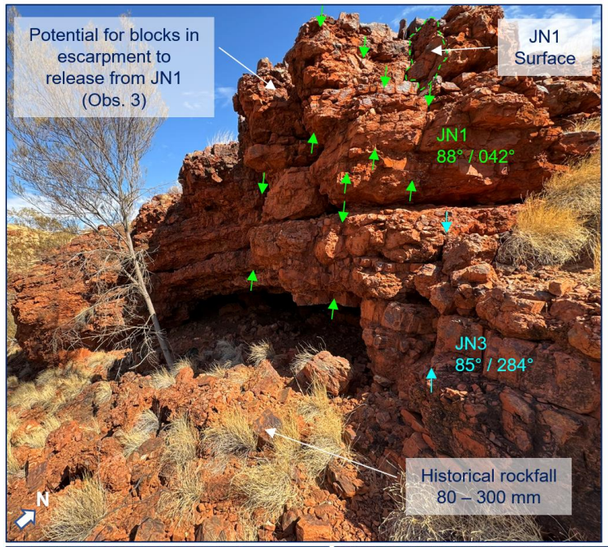
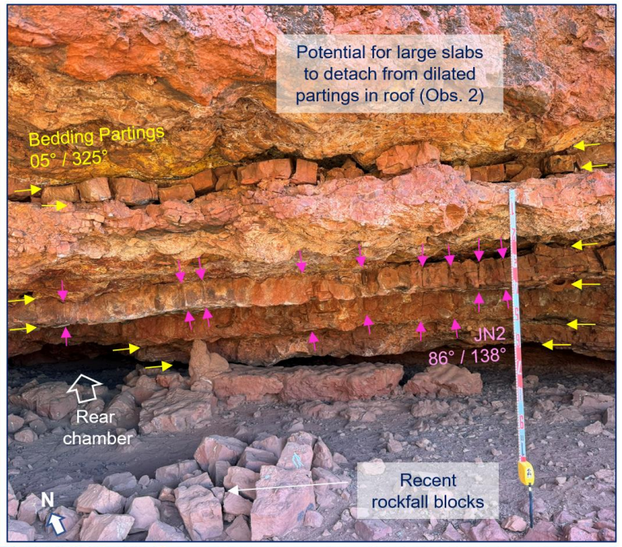
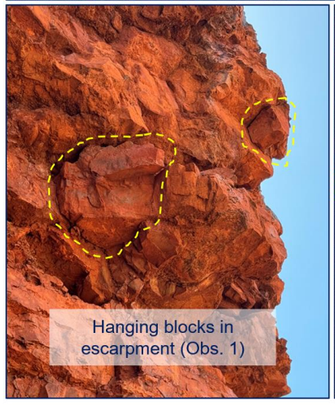
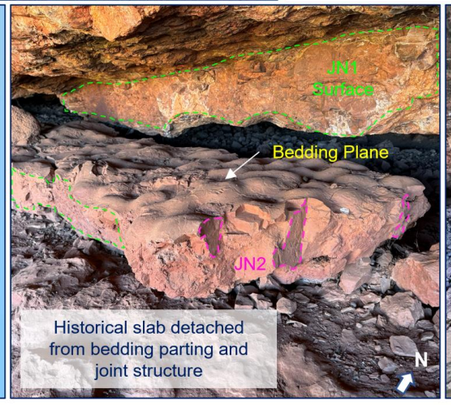
Summary Sheet Cave ID	Approximate Dimensions	Estimated GSI Range and Typical RMR_{89}	Rock Mass Description	Observed Hazards	Recommendations
MEC065	Main Chamber – 8 m wide, 5.7 m deep, and 1 m high. Rear Chamber – 5.7 m deep and up to 0.4 m high.	GSI Exterior and Main Chamber 52 – 65 Rear Chamber 59 – 69 RMR_{89} Exterior and Main Chamber 65 Rear Chamber 69	The rock mass comprises interbedded BIF and blocky chert. The rock mass is highly weathered and appears to be medium to high strength. Bedding at the cave is undulating and was measured in the main chamber to dip shallowly to the northwest. Bedding partings are spaced 0.2 to 0.5 m and are up to 8 m in length (greater than the span of the cave). Partings surfaces are slightly rough to rough, open 1 to 2 mm and iron stained. Partings become more dilated toward the cave entrance where they were observed to be open up to 5 mm. Residual hematitic silt was observed to infill dilated partings in places. Joint set 1 (JN1) is oriented parallel to the cave entrance and dips sub-vertically towards the northeast, Inset 7. It is spaced at 100 to 200 mm and is typically 0.5 to 1.0 m long. JN1 is planar to stepped, slightly rough to rough, and iron stained. Joint set 2 (JN2) is a sub-vertical joint set that strikes perpendicular to the cave entrance, Inset 7. JN2 is 0.2 to 0.5 m long and spaced between 50 to 150 mm. Joint set 3 (JN3) was only observed on the eastern side of the main chamber. It was measured to dip steeply towards the west, with a spacing between 1.0 to 1.5 m. Defect lengths up to 0.5 m were measured on the main chamber's east wall.	1. Hanging blocks bounded by open joints or non-systematic fractures occur in the dripline above the cave entrance. 2. There is significant potential for large slabs of chert and hydrated BIF to detach from dilated bedding partings and joints in the main chamber roof. This mechanism is evidenced by past detachment on the cave floor. 3. In the escarpment above the cave, there is potential for blocks to release from Joint set 1. This presents a rockfall hazard at the cave entrance.	• Limit time spent immediately outside the cave entrance due to hanging blocks in the escarpment and the potential for blocks above to detach from joint set 1. • Before entering the cave, check for fresh rockfall debris and for movement or further dilation of the open bedding partings in main chamber roof. • No standing or sitting below the area of dilated chert slabs in the main chamber roof. Move quickly past these areas if necessary.

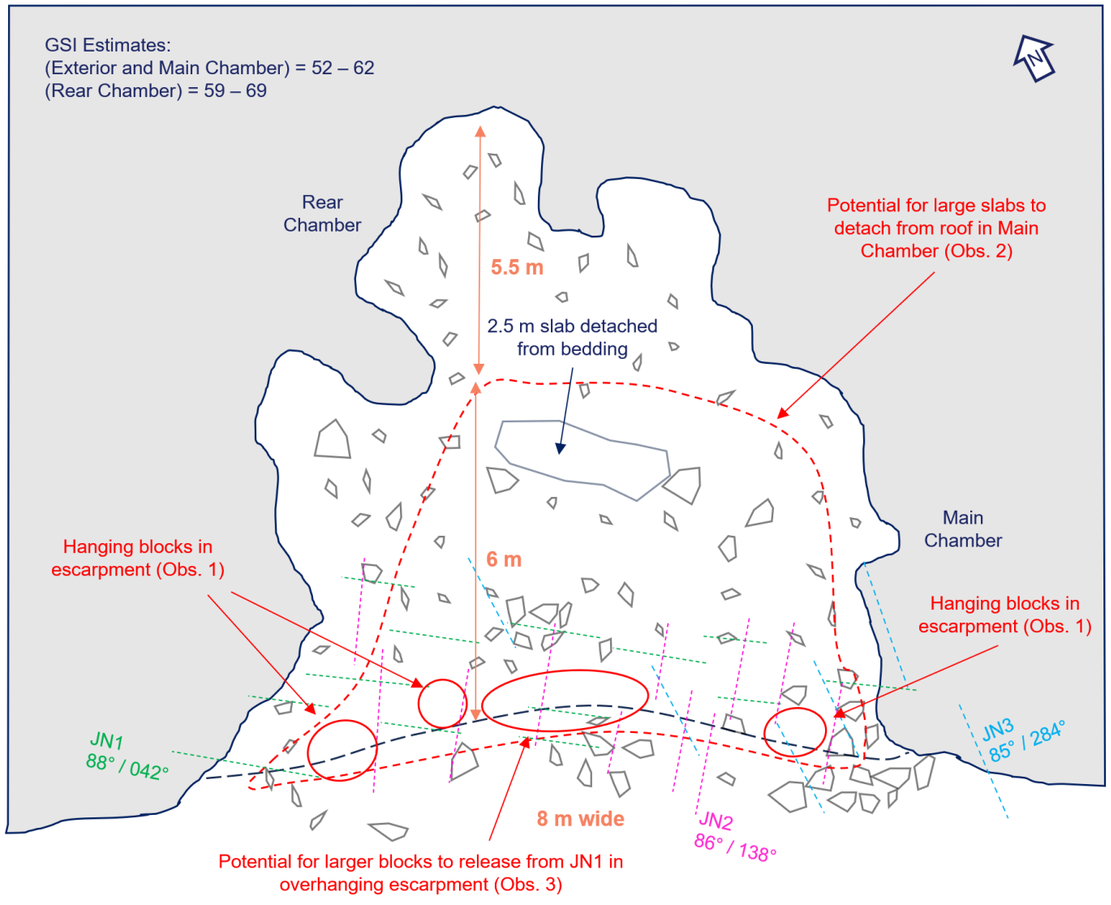








Schematic Plan View



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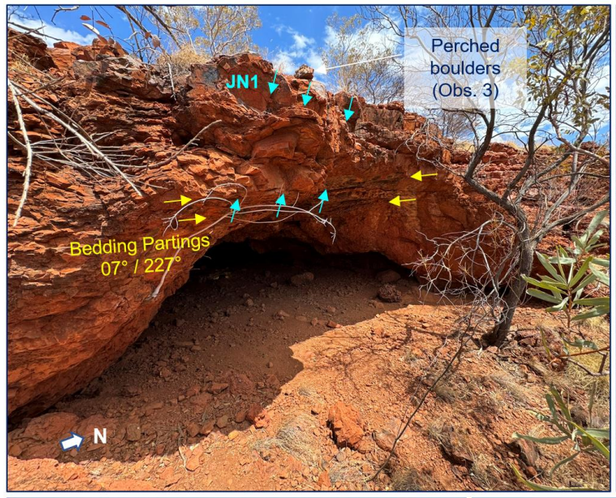
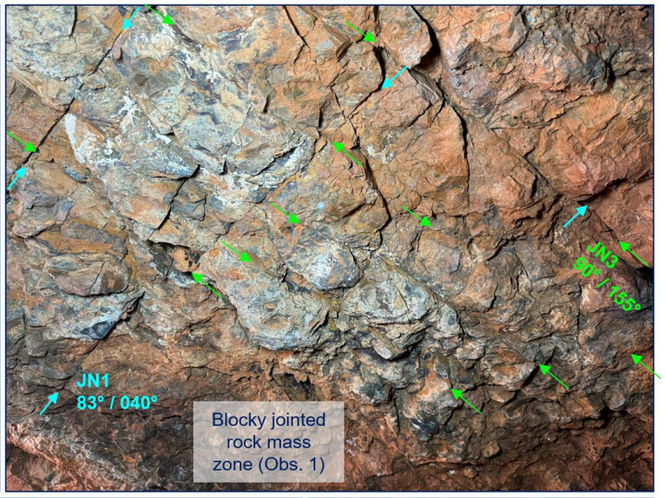
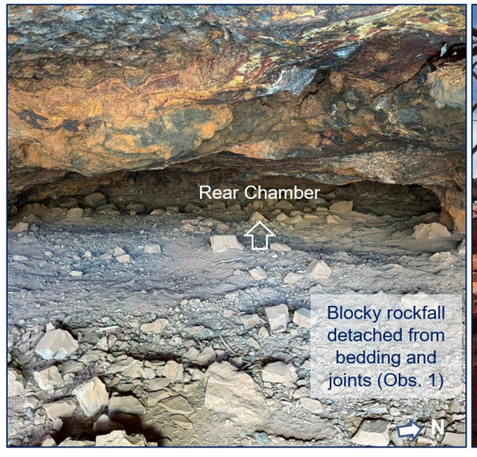
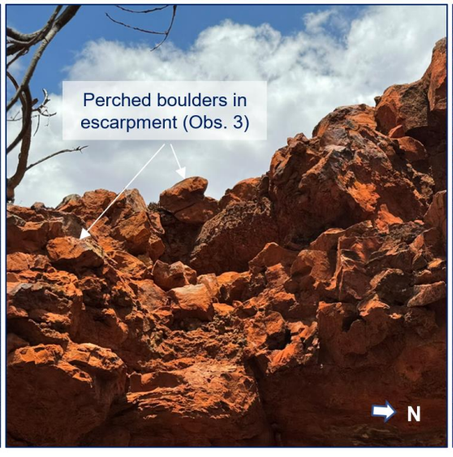
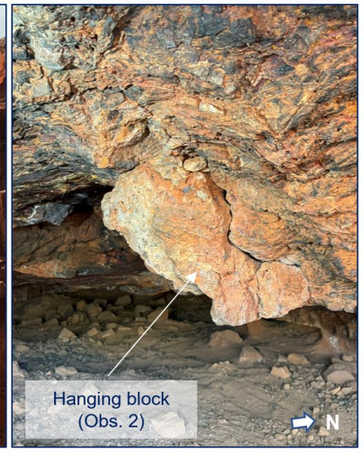
Summary Sheet Cave ID	Approximate Dimensions	Estimated GSI Range and Typical RMR_{89}	Rock Mass Description	Observed Hazards	Recommendations
MEC007	Cave – 6 m wide, 10 m deep, and up to 1 m high.	GSI Exterior and Front 62 – 72 Obs. 1 Zone 59 – 69 Rear 65 – 75 RMR_{89} Exterior and Front 72 Obs. 1 Zone 69 Rear 75	The rock mass at the cave comprises hydrated BIF and interbedded chert. It is highly weathered and has a medium to high intact strength. Water seepage into the cave was evidenced by iron staining around the entrance, which overprints original bedding fabrics in parts of the cave. Where visible, bedding partings are undulose and spaced at 60 to 150 mm, with variable lengths between 0.5 and 2.5 m. Bedding is best developed in the cave roof and southern wall, where it was measured to dip shallowly towards the southwest. Three joint sets were identified at the cave JN1 dips steeply to the northeast. Joint set 1 is typically undulating to irregular and open less than 1 mm. Joints along this orientation are up to 4.5 m long and are spaced at 0.5 to 1.5 m. Seepage along JN1 was observed at the back of the cave. JN2 is vertical joint set that strikes east northeast, and is irregular, rough and iron stained. Defect lengths range between 1 and 2 m and are spaced at 0.5 to 1.0 m. JN3 is a northeast striking joint set that is oriented sub-vertically, and is undulating, rough, and iron stained. JN3 is only developed in the central part of the cave roof. The joints are between 0.5 and 0.8 m in length and are spaced 100 to 200 mm.	1. A blocky jointed rock mass zone was observed in the roof of the cave interior. The area is limited to where joint set 3 is visible, resulting in multiple intersecting sub-vertical joint sets that produce a 'blocky' BIF rock mass. 2. Hanging blocks bounded by open fractures on the interior of the cave. 3. Multiple perched boulders are situated in the escarpment above the cave entrance.	• Assess the area for any hanging blocks that may have detached from the cave roof, or for any perched boulders that have dropped from the escarpment above the entrance • Check for dilation or water seepage in the joint structures, particularly in the 'blocky' rock mass zone • Limit time spent below the dripline and identified hanging blocks.



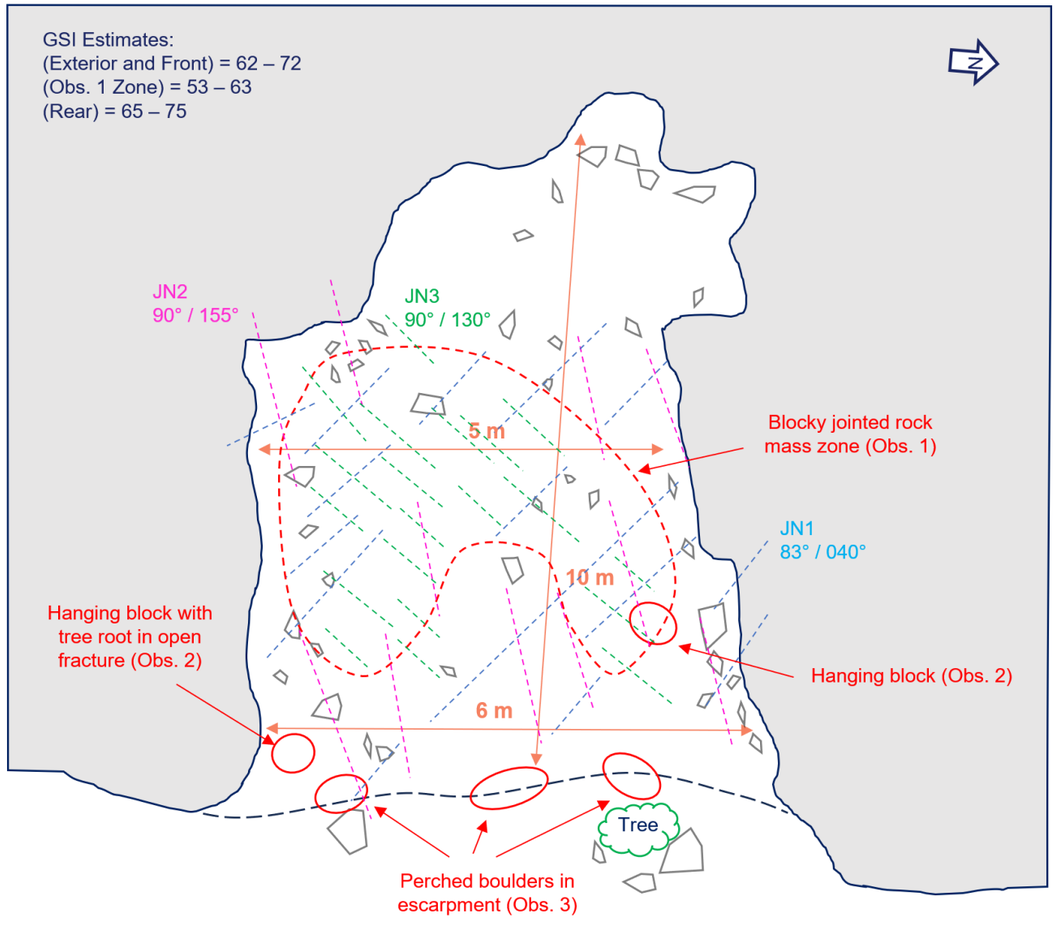








Schematic Plan View



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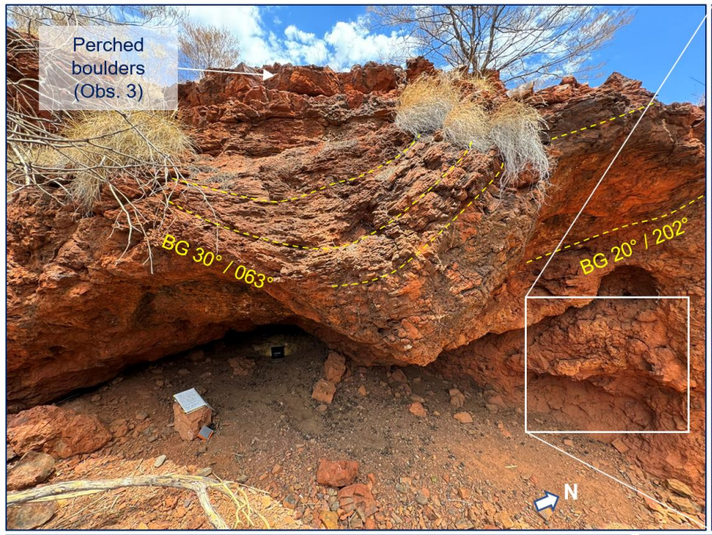
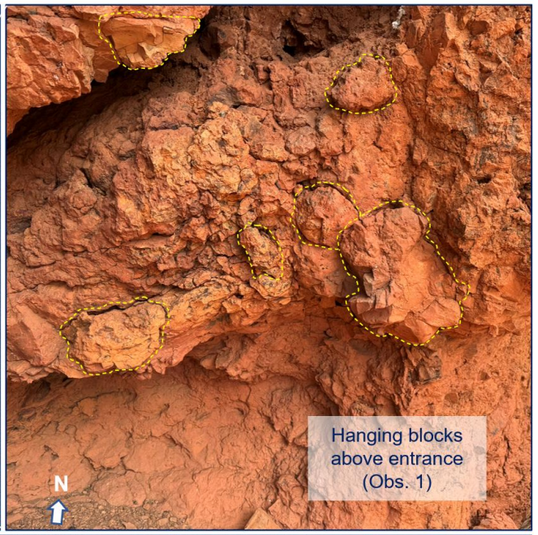
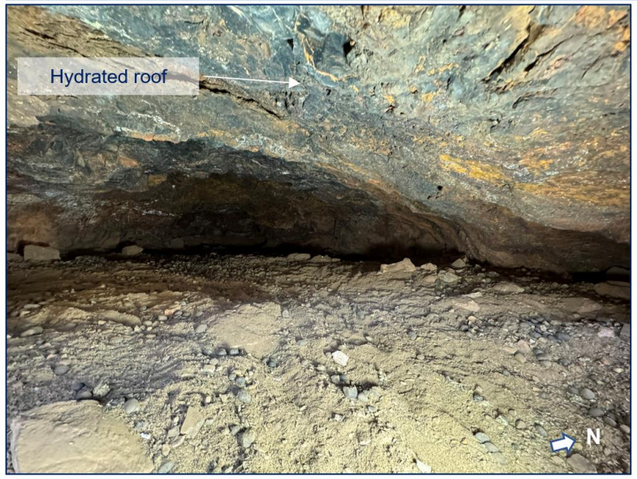
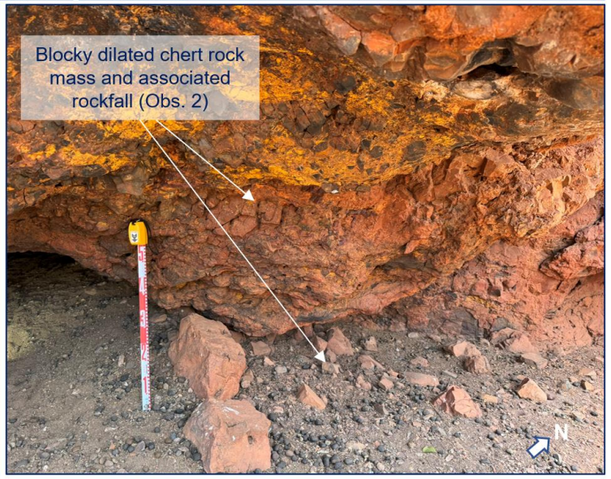
Summary Sheet Cave ID	Approximate Dimensions	Estimated GSI Range and Typical RMR_{89}	Rock Mass Description	Observed Hazards	Recommendations
MEC033	Overhang – 4.5 m wide, 1.8 m deep and 1.3 m high. Interior 2.5 m wide, 5.6 m deep, and 1 m high.	GSI Exterior and Overhang 70 – 80 Interior 64 – 74 RMR_{89} Exterior and Overhang 80 Interior 74	The rock mass at the cave comprises highly weathered, hydrated BIF, with elongate vughs oriented parallel to well-developed bedding. A thick blocky chert band forms the lower third of the cave entrance. Bedding generally has a shallow dip and is partially overprinted due to hydration of the rock mass. The dip direction of bedding is variable due to the degree of undulation, with the dip becoming moderate in some highly folded areas, as observed at the cave entrance. Partings are spaced 50 to 150 mm and are generally more persistent in the overhang and exterior with lengths between 0.8 and 1.2 m. Bedding partings are typically open less than 1 mm and exhibit iron staining. No structurally significant joint sets were observed at MEC033, though some open non-systematic fractures were observed around the exterior and overhang.	1. Loose hanging blocks were identified in the overhang. 2. Blocky dilated chert rock mass was observed in the lower part of the overhang, with detached blocky to tabular chert fragments evident on the floor below. 3. Perched boulders were identified in the escarpment above the overhang. These boulders have the potential to rill down the escarpment and over the dripline.	• Before approaching the cave, assess the top of the escarpment for perched boulders that may be at risk of falling • Check the area beneath the overhang for fresh rockfall • Check for water seepage in the cave roof.

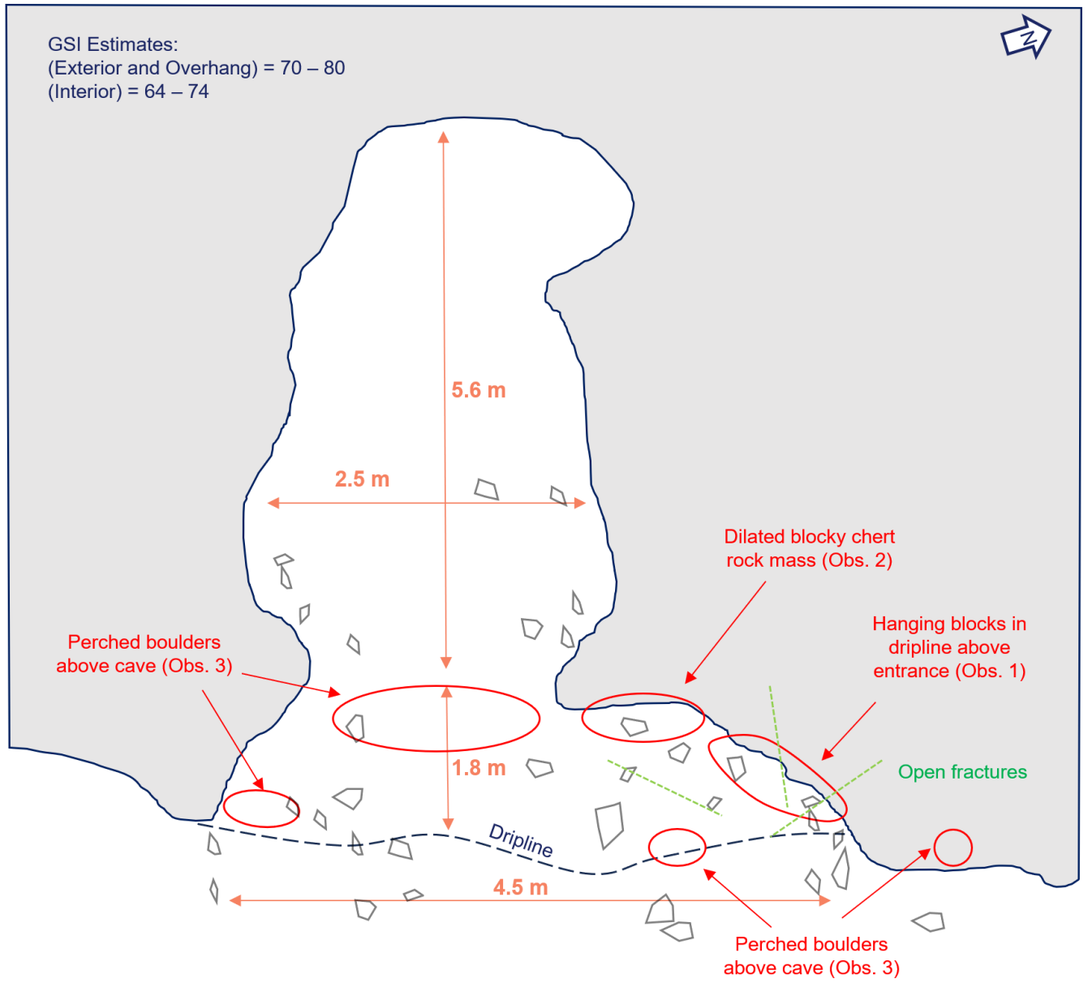








Schematic Plan View



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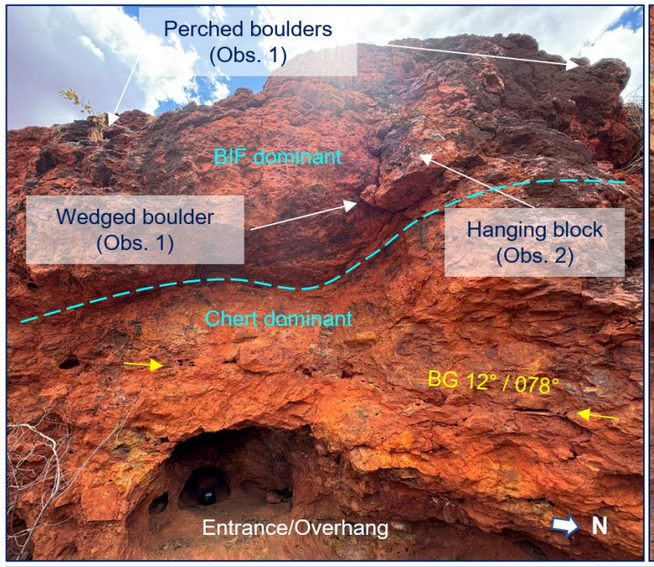
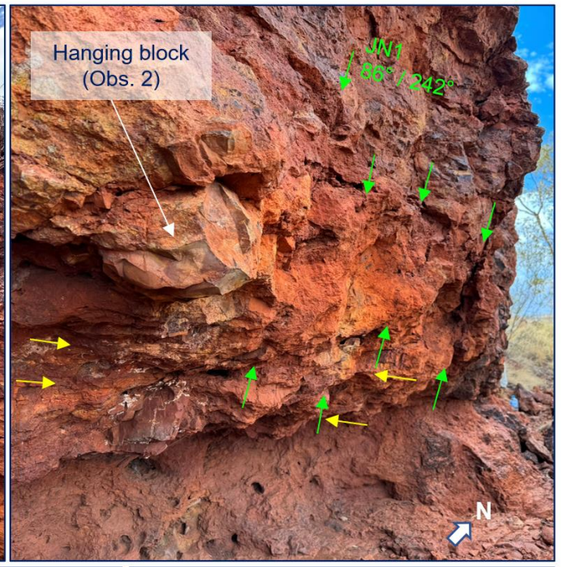
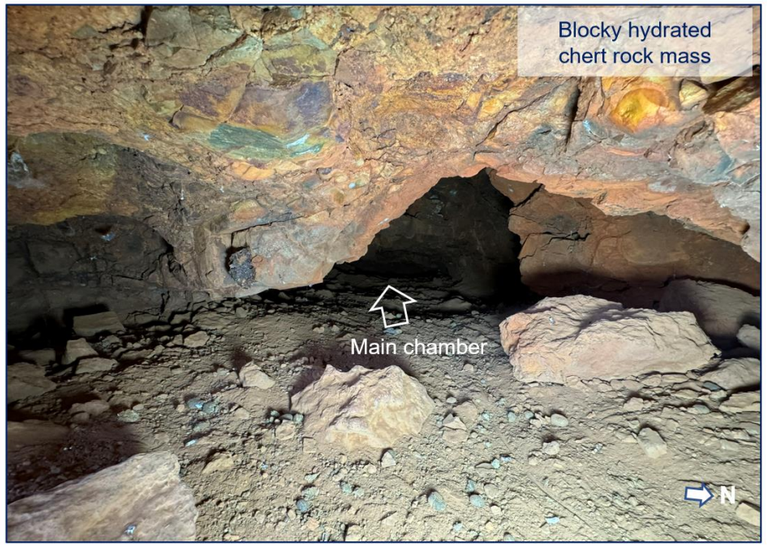
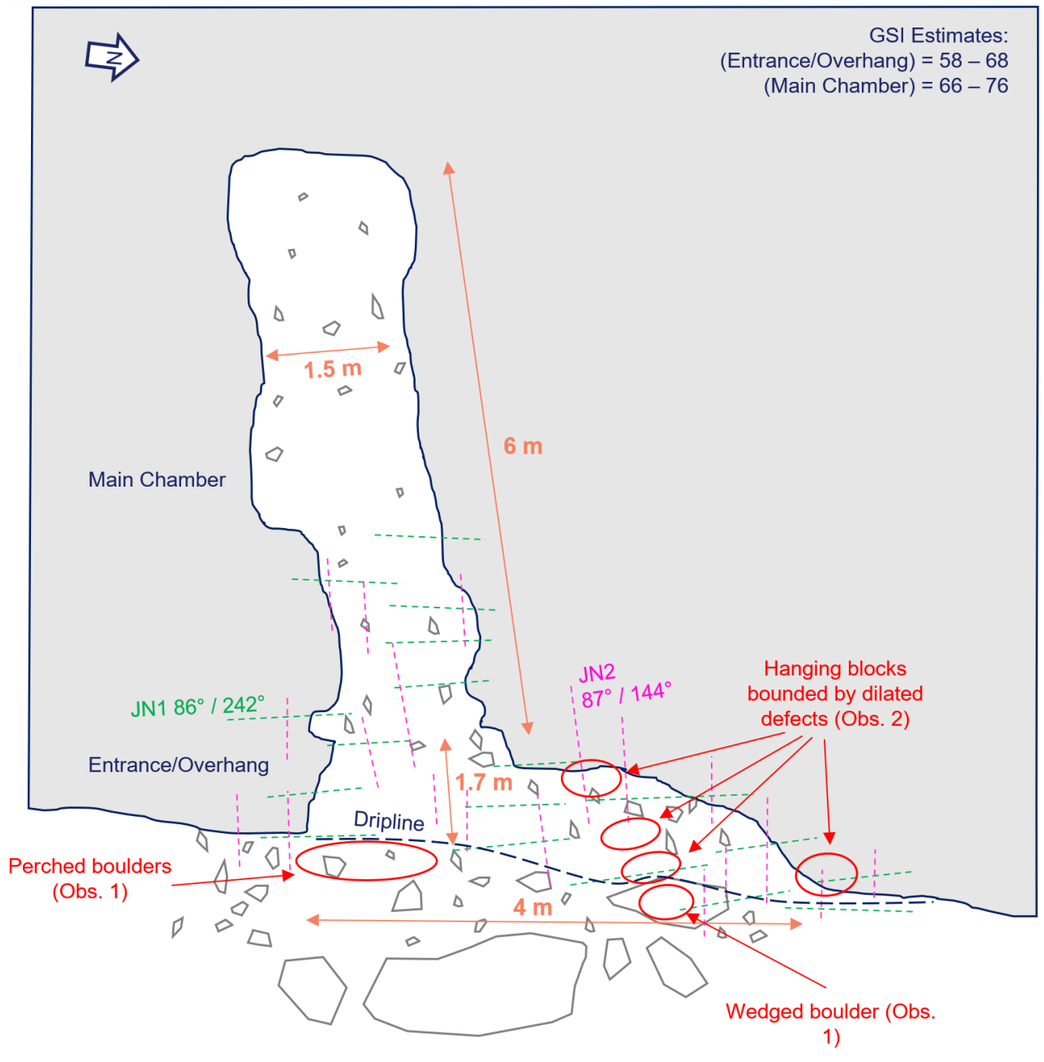
Summary Sheet Cave ID	Approximate Dimensions	Estimated GSI Range and Typical RMR_{89}	Rock Mass Description	Observed Hazards	Recommendations
MEC073	Entrance/Overhang – 4m wide, 1.7 m deep, and 1 m high. Main Chamber – 1.5 m wide, 6 m deep, and 0.5 m high.	GSI Entrance/ Overhang 58 – 68 Main Chamber 66 – 76 RMR_{89} Entrance/ Overhang 68 Main Chamber 76	The rock mass at the cave comprises hydrated chert and interbedded BIF. The chert dominant rock mass that hosts the cave is high strength and highly weathered. Bedding is developed in the chert with partings spaces at 50 to 300 mm and between 0.5 and 1.0 m long. Partings are undulating, slightly rough to rough, and have an iron oxide stain to veneer on dilated surfaces. Bedding was measured at the back of the overhang to dip shallowly to the east. Bedding appears to become overprinted in the cave's main chamber. Two joint sets were observed at the cave and are confined to the chert dominant rock mass. JN1 is oriented sub-parallel to the escarpment. It dips steeply to the southwest and is spaced at approximately 0.1 ml, and is 0.4 to 0.7 m long. JN2 dips steeply to the southeast. It is spaced between 100 to 200 mm and is typically 0.1 to 0.3 m long. Both of the joint sets are tight, and surface conditions of are undulating and rough.	1. Wedged and perched boulders were identified in the escarpment above the cave entrance. 2. Loose hanging blocks bounded by open fractures were also identified in the escarpment, both above and adjacent to the cave entrance.	• Limit time spent at against the rock face below any identified hanging or wedged boulders • Assess the area for any perched blocks that may have fallen from the escarpment above • Check for dilation of fractures bounding hanging blocks or any new cracks that may have formed in the escarpment and cave roof.





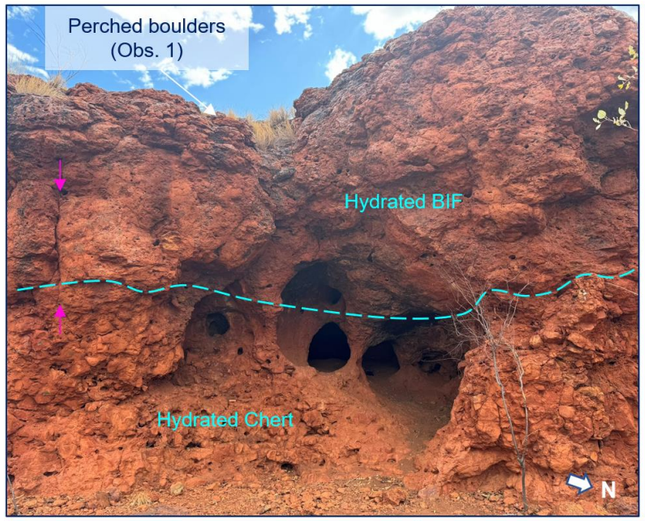


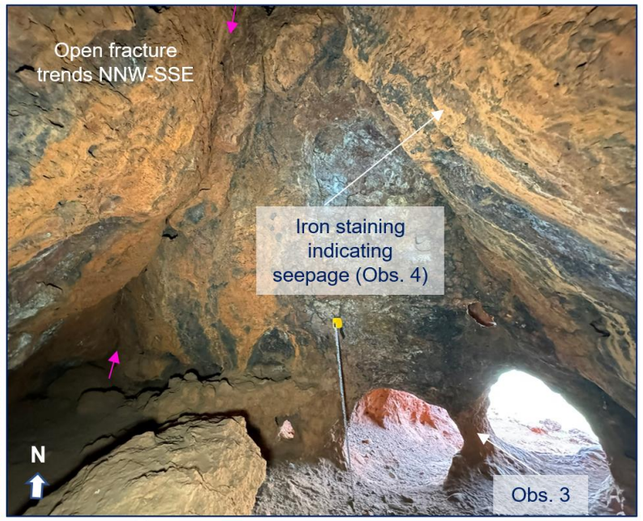
Schematic Plan View

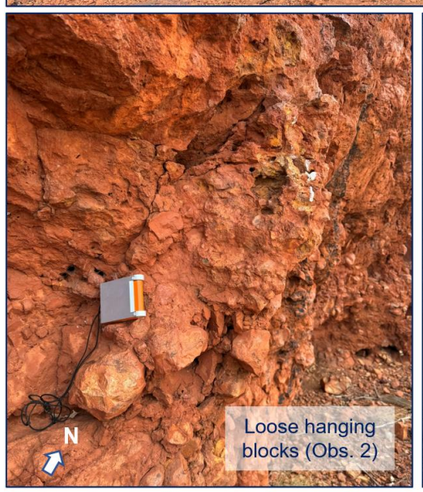


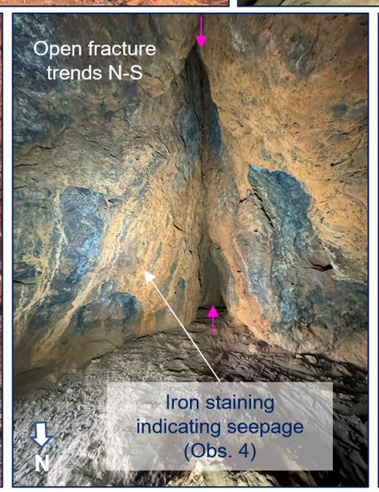
Not to scale

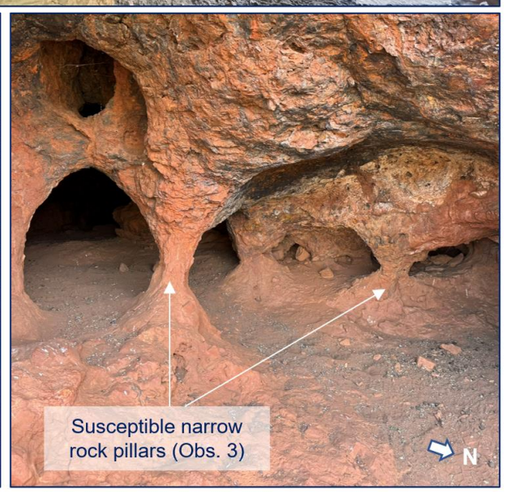
Summary Sheet Cave ID	Approximate Dimensions	Estimated GSI Range and Typical RMR_{89}	Rock Mass Description	Observed Hazards	Recommendations
MEC039	Entrance/Overhang – 2.1 m wide and 1.1 m high Interior Chamber – 4.5 m wide, 5.7 m deep and 1.8 m high.	GSI Entrance/ Overhang 67 – 77 Main Chamber 70 – 80 Exterior (chert band) 58 – 68 RMR_{89} Entrance/ Overhang 77 Main Chamber 80 Exterior (chert band) 68	The lower third of the outcropping escarpment comprises chert, which is overlain by BIF comprising the upper two-thirds of the escarpment. Both rock types are highly weathered and hydrated. The cave appears to have preferentially developed along the contact between the chert and the BIF. Due to the upward sloping floor into the cave, the cave's interior chamber is almost entirely hosted within the BIF overlying the chert. The chert rock mass which makes up the lower half of the cave entrance is blocky and loose in places. The blockiness within the chert is a product of multiple intersecting joints. These joints within the chert are considered to not be significant on the scale of the cave due to the relatively short defect lengths. In the overlying BIF, original bedding has been overprinted but can be distinguished by elongate bedding parallel vughs. Where original rock fabrics are preserved, bedding partings were observed to have a spacing of 0.4 to 0.7 m and lengths of 0.5 to 1.5 m. None of the fractures observed appear to be systematic joints. The main north to north-northwest striking fracture inside the cave is interpreted to have formed due to slumping of the bedrock escarpment. Bedding partings are not developed inside the cave and are completely overprinted.	1. Boulders are perched on the edge of the escarpment above the cave entrance. 2. Multiple hanging blocks bounded by non-systematic, dilated fractures occur in the cave dripline. 3. Narrow rock pillars located at the entrance to the interior chamber may be susceptible to cracking and collapse from blast induced vibrations. The pillars occur at the interface between the chert and overlying BIF. 4. Seepage into the cave was observed to occur along the north to north-northwest trending fracture inside the cave, evidenced by considerable iron staining.	• Check for fresh rock fall debris around the cave entrance before approaching • Limit time spent immediately below identified hanging blocks bounded by open fractures in the escarpment above the entrance • Check for signs of fretting or cracking within the susceptible rock pillars • Check for dilation or water seepage in the north to north-northwest trending fracture inside the cave before accessing.



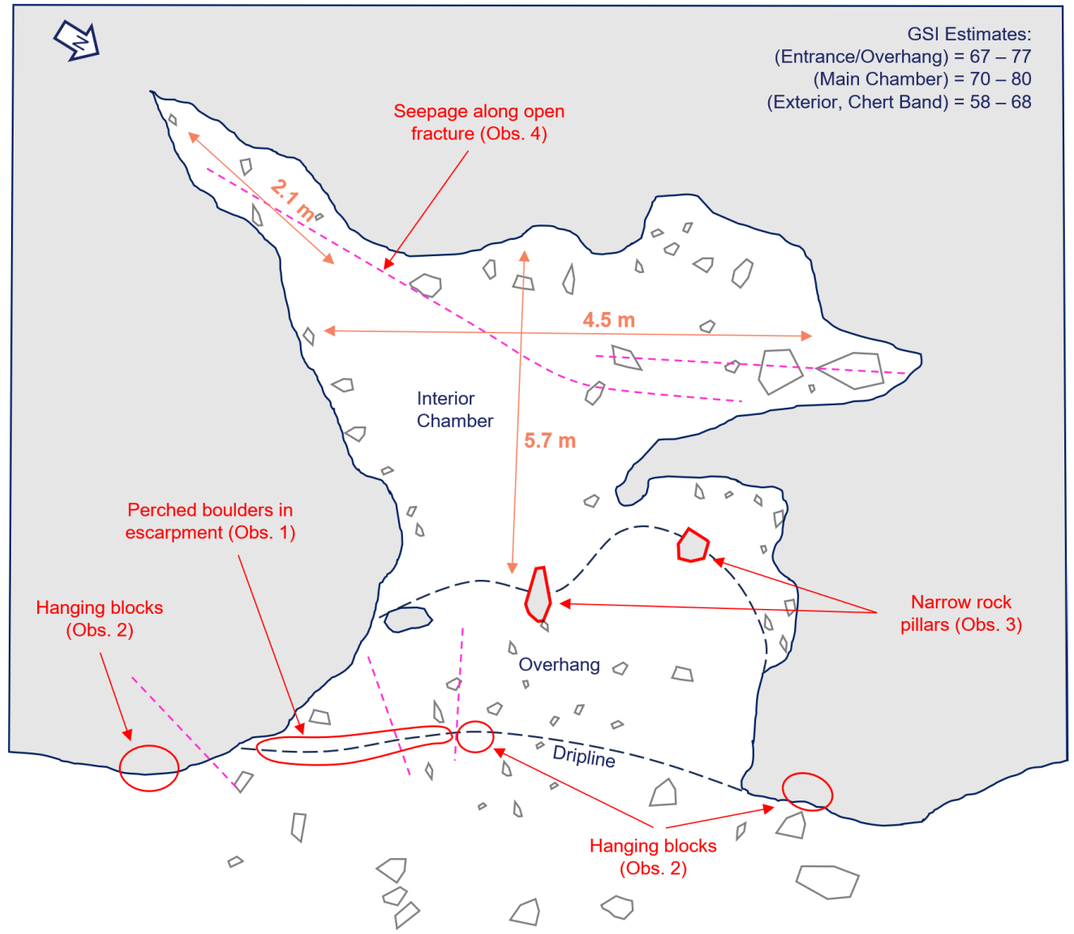






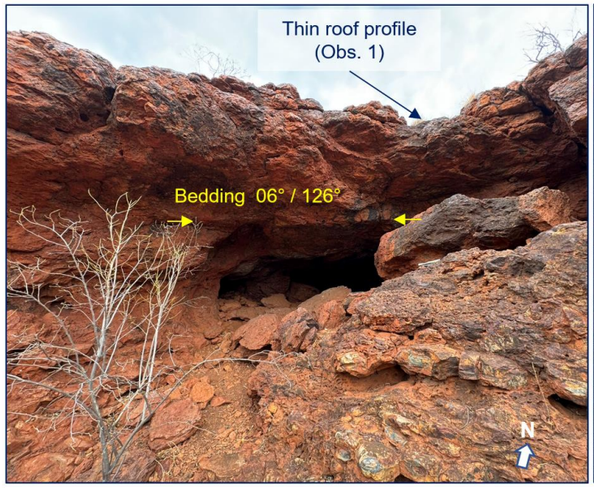


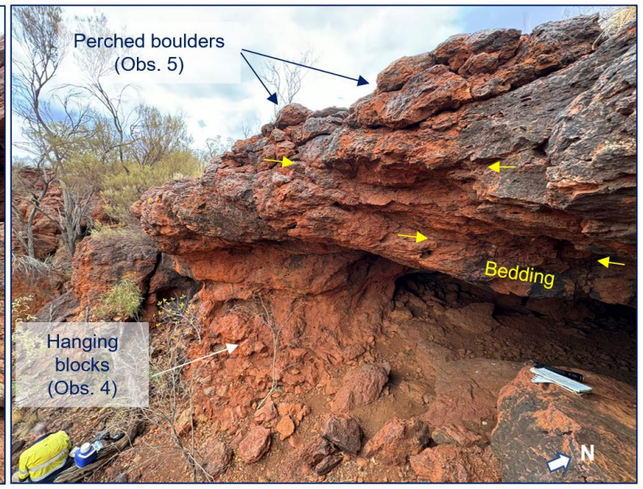
Schematic Plan View

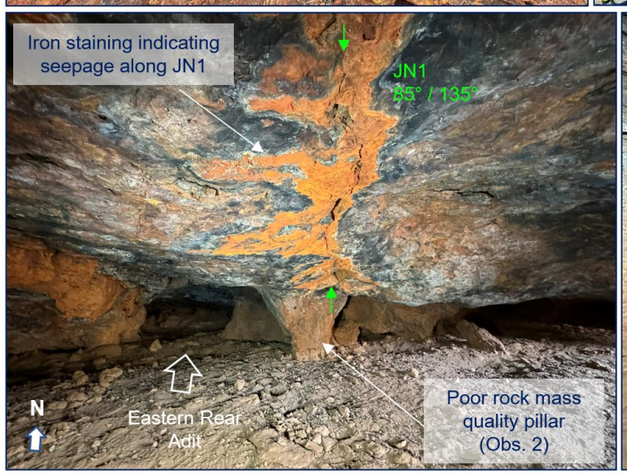


Not to scale

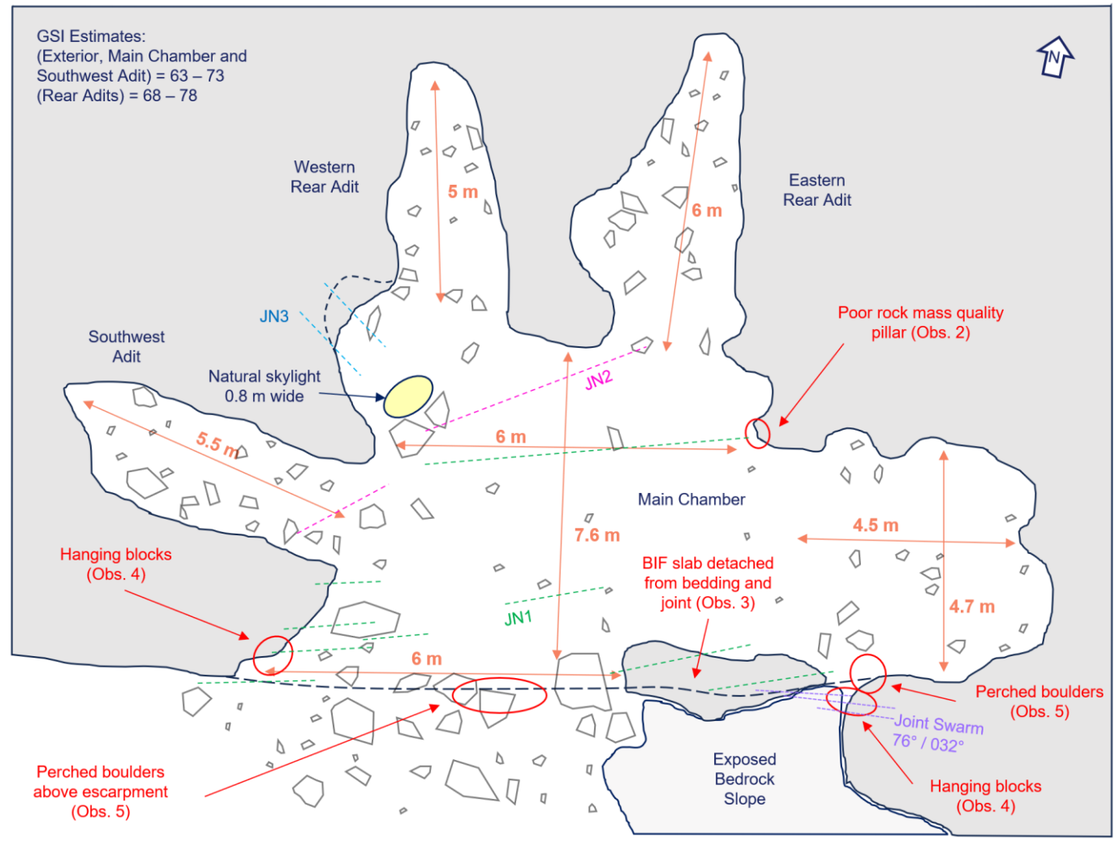
Summary Sheet Cave ID	Approximate Dimensions	Estimated GSI Range and Typical RMR_{89}	Rock Mass Description	Observed Hazards	Recommendations
MEC016 (MIB-MD13-043)	Main Chamber – 6 m wide, 7.6 m deep, and up to 1.2 m high. • A skylight 0.8m wide occurs in the roof of the central chamber • Eastern main chamber – 4.5 m deep and 0.7 m. Three natural adits: • Southwest adit 5.5 m deep • Western rear adit 5 m deep • Eastern rear adit 6 m deep The adits are 1.8 to 2.2 m wide, and all < 0.8 m high	GSI Exterior, Main Chamber and Southwest Adit 63 – 73 Western and Eastern Rear Adits 68 – 78 RMR_{89} Exterior, Main Chamber and Southwest Adit 73 Western and Eastern Rear Adits 78	The rock mass comprises partially hydrated, vughy BIF and chert that dips shallowly towards the southeast. The roof profile is undulating and sub-horizontal, suggesting the cave developed along BIF bedding planes. Bedding partings are spaced at 150 to 300 mm, though are not continuous across the cave. Parting spacings increase to 0.5 m towards the top of the escarpment where bedding becomes largely overprinted. Observed parting lengths are typically between 2 and 4 m. Three joint sets were identified and have the following characteristics: Joint set 1 (JN1) dips steeply to the southeast. It has a spacing of 0.4 to 1.0 m at the entrance. The spacing increases into the cave where it is spaced at approximately 3 m. Defect lengths are highly variable and range between 1.5 and 5.0 m. A single joint along this orientation in the main chamber roof is open up to 3 mm and infilled with silt and a veneer of iron oxide Joint set 2 (JN2) dips steeply to the east northeast. Only two joints were observed along this orientation in the roof of the main chamber, indicating a spacing of 1.2 m and lengths between 3.0 and 4.5 m. Joint set 3 (JN3) dips steeply to the northeast. Only two joints were observed on the western side of the main chamber, indicating a spacing of 0.7 m and lengths of approximately 1 m.	1. A thin roof profile (measured 1 to 2 m thick above the entrance) in combination with the cave's wide span increases the susceptibility to collapse. 2. A pillar of poorer quality rock quality is situated at the back of the main chamber, and may be susceptible to cracking. 3. There is potential for blocks to detach from bedding partings in the cave roof or overhang where cross cut by a sub-vertical joint set. This mechanism is evidenced by past tabular rockfall below the entrance. 4. Loose hanging blocks were identified in the escarpment around the entrance. No hanging blocks were identified on the interior. 5. Perched boulders are situated in the escarpment above the cave have the potential to fall.	• Assess the area for any blocks that may have detached from the overhang at the entrance • Check for dilation and water seepage in structures within the entrance overhand and inside the main chamber. Also check for any new fractures that may have formed • Limit time spent immediately below the dripline where perched boulders are at risk of falling, or loose hanging blocks have been identified • Check for signs of fretting or cracking within the susceptible rock pillar.







Schematic Plan View



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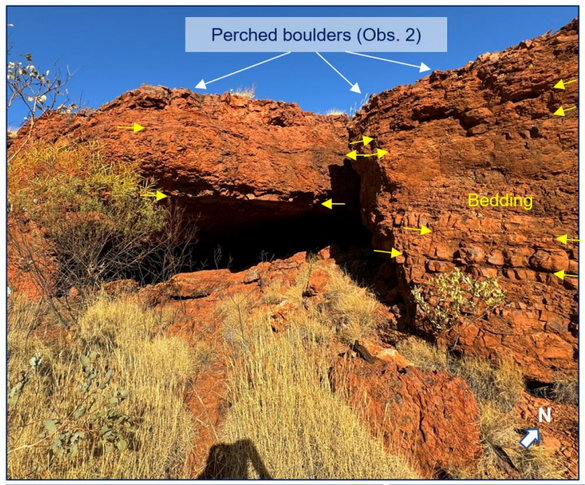
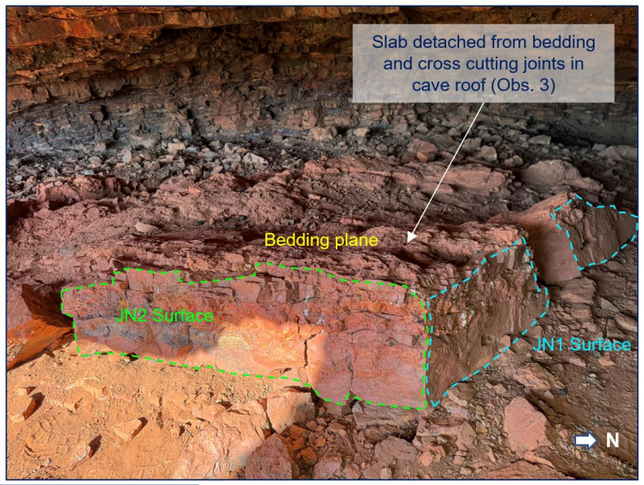
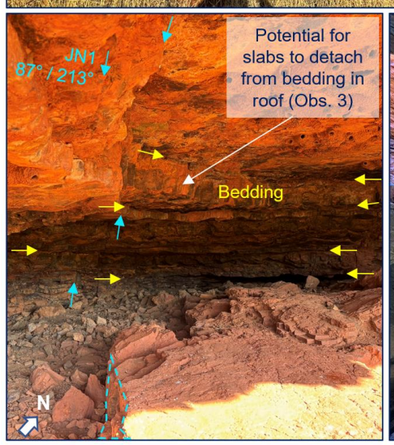
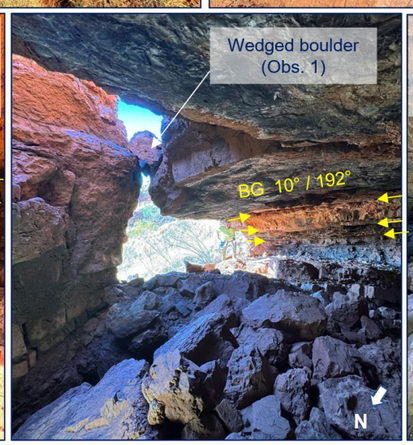
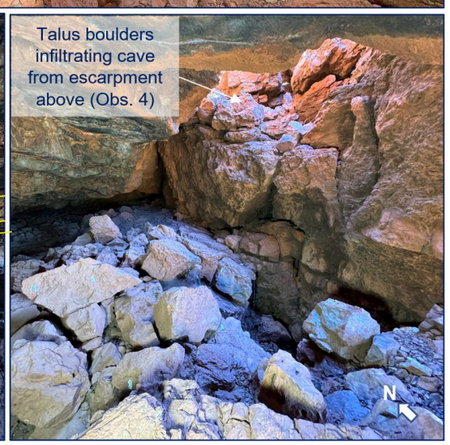
Summary Sheet Cave ID	Approximate Dimensions	Estimated GSI Range and Typical RMR_{89}	Rock Mass Description	Observed Hazards	Recommendations
MEC063	Main Chamber – 10.8 m wide, 7.8 m deep, and up to 1.2 m high.	GSI Exterior 63 – 73 Interior 58 – 68 RMR_{89} Exterior 73 Interior 68	The rock mass at the cave comprises high strength, highly weathered interbedded BIF and chert. Bedding is well developed, undulating and strongly controls cave development. Bedding was measured in the centre of the cave to dip shallowly to the south. Partings are spaced between 80 and 300 mm. Some partings persist greater than the span of the cave, though most are between 5 and 10 m in length and are open less than 1 mm. Two pervasive joint sets were identified at the cave throughout the exterior and interior: Joint set 1 (JN1) is oriented sub-vertically and strikes northeast-southwest. Defects along this orientation are typically 0.3 to 0.8 m long but some JN1 structures were observed up to 5 m in length. The joint set has a spacing of 0.2 to 0.5 m and is tight. Joint set 2 (JN2) dips steeply to the northwest, sub-parallel to the bedrock escarpment. Surfaces are planar to undulating and range between 0.3 and 1.0 m in length. Some exposed JN2 surfaces where past blocks have detached are up to 2.5 m long.	1. Wedged boulders were observed on the eastern side of the cave, in the gap between the cave dripline and escarpment. 2. Perched boulders are situated atop the escarpment above the cave entrance. 3. There is potential for large slabs of hydrated BIF and chert to detach from dilated bedding partings and joints in the cave roof. 4. Talus boulders form the escarpment above the cave were observed to infiltrate the gap between the cave dripline and eastern escarpment edge.	• Avoid spending time spent below the gap between the eastern escarpment and cave dripline, where wedged boulders and talus from the above escarpment present multiple potential rockfall sources • Watch footing below identified Obs. 1 areas due to a drop in the floor profile • Before entering the cave, check for fresh rockfall debris and for movement or further dilation of the open bedding partings in the cave roof • No standing or sitting below dilated the area of dilated rock mass in the cave roof (Obs. 3). Move quickly past these areas if necessary.



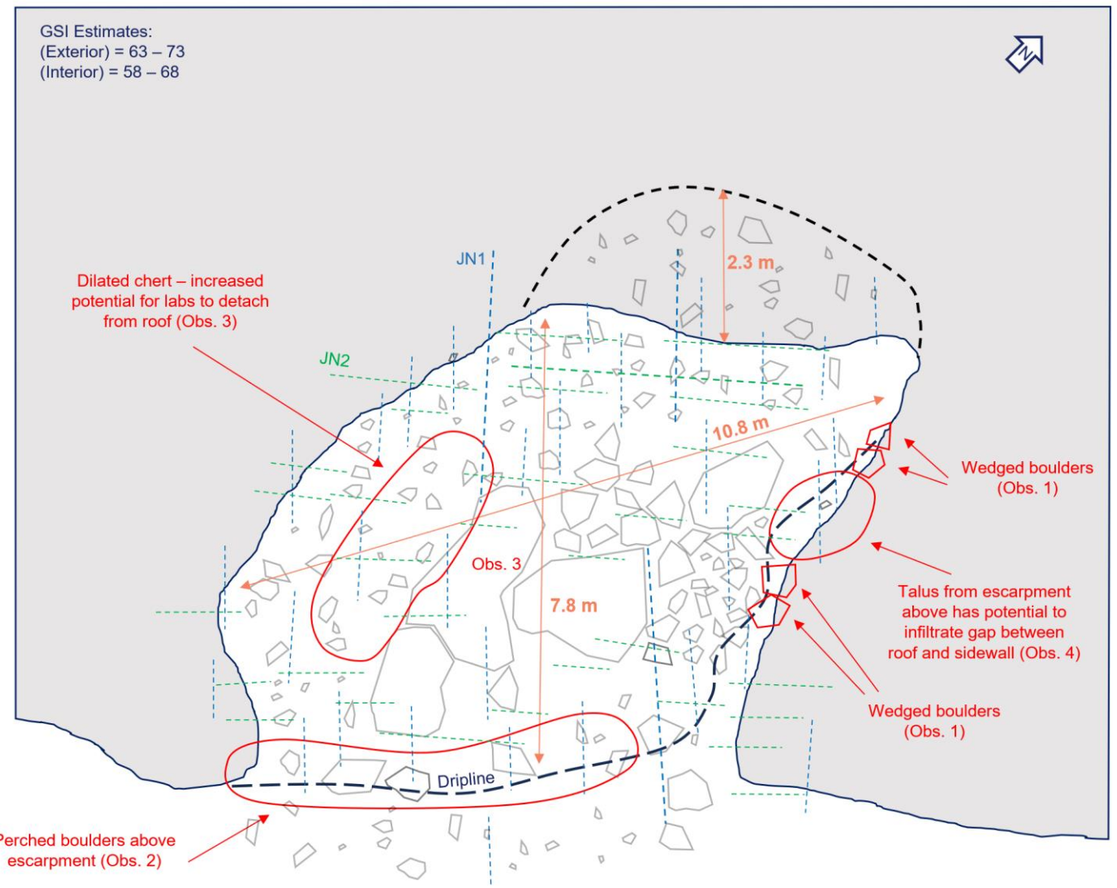








Schematic Plan View



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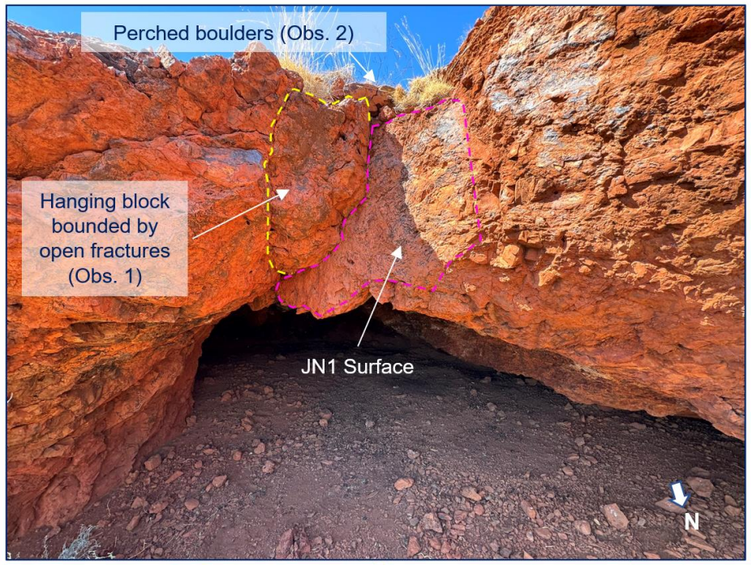
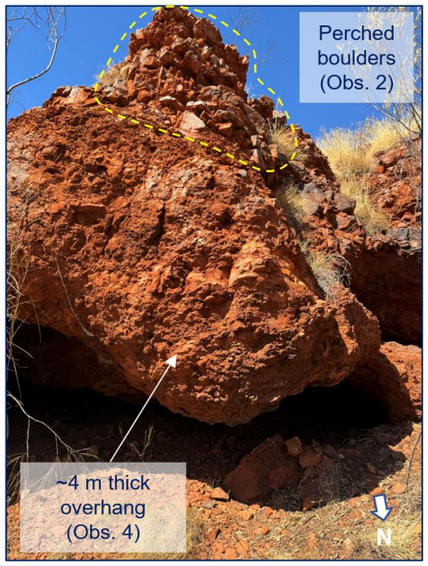
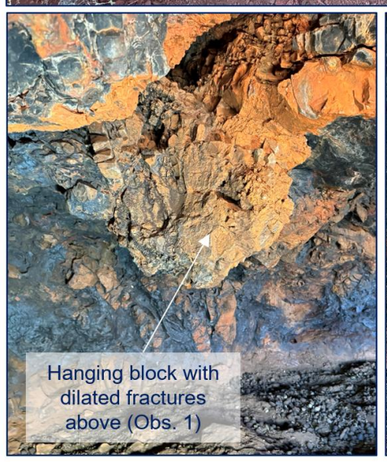
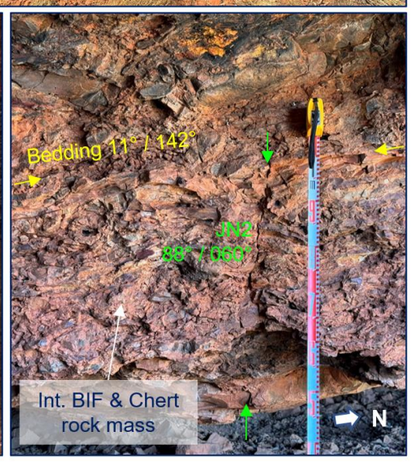
Summary Sheet Cave ID	Approximate Dimensions	Estimated GSI Range and Typical RMR_{89}	Rock Mass Description	Observed Hazards	Recommendations
MEC062	Main Chamber – 6.1 m wide, 6.7 m deep, 1.5 m high	GSI Exterior and Front of Main Chamber 60 – 70 Rear of Main Chamber 65 – 75 RMR_{89} Exterior and Front of Main Chamber 70 Rear of Main Chamber 75	The rock mass at the cave comprises hydrated, interbedded BIF and chert. The rock mass is highly weathered. Intact strength was estimated to be high. Hydration has overprinted bedding in parts of the cave, particularly on the cave roof and southern wall. Where visible, bedding is sub-horizontal and is highly undulose. The dip direction of bedding is variable due to the degree of undulation, with the dip becoming moderate to steep in some highly folded areas at the rear of the cave. Structurally significant partings were observed to have a 100 to 400 mm spacing at the front of the main chamber. The partings are between 0.5 and 1.5 m in length and are either tight or open less than 1 mm. Two joint sets were identified at the cave. Joint set 1 (JN1) dips steeply to the south-southeast and is 0.6 to 2.8 m long. The second joint set (JN2) dips sub-vertically to the northeast and is 1.0 to 2.5 m long. Both joint sets have irregular and rough surface conditions, and are typically tight with an iron stain infill. The joint sets are spaced variable between 1 and 3 m apart. A large open fracture in the cave roof appears to initiate along JN1 in at the cave entrance, and then rotates along folded bedding towards the rear of the cave.	1. Hanging blocks were observed on the cave exterior and interior. A large hanging block situated immediately above the entrance is bounded by joint set 1 and open fractures. 2. Multiple perched boulders up to 0.6 m in width were observed on the escarpment above the cave entrance. 3. Water seepage into the cave was observed along a dilated fracture in the cave roof, which is partially aligned along joint set 1. Seepage was evidenced by iron staining of the wall rock either side of the fracture. 4. The overhanging escarpment on the western side of the cave entrance is up to 4 m thick. Due to the orientation of joint set 2, there is potential for the substantial overhang to detach from the sub-vertical structure.	• Before approaching the cave, assess the area for any fresh rockfall and loose blocks that may have formed in the escarpment • Avoid standing or sitting below identified hanging blocks in the cave dripline and interior. When accessing the cave, move past the large block above the entrance quickly • Check for dilation of joint fractures inside the cave and for the formation of any new cracks in the substantial overhang on the western side of the entrance.

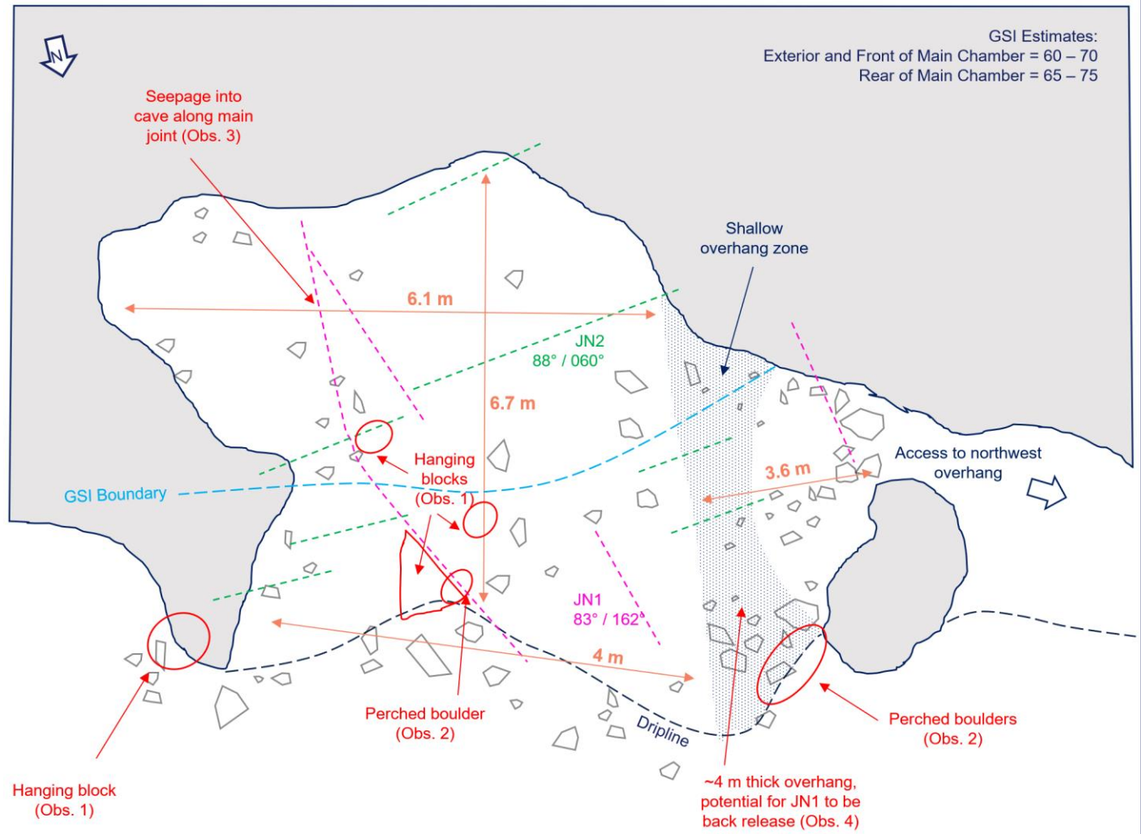








Schematic Plan View



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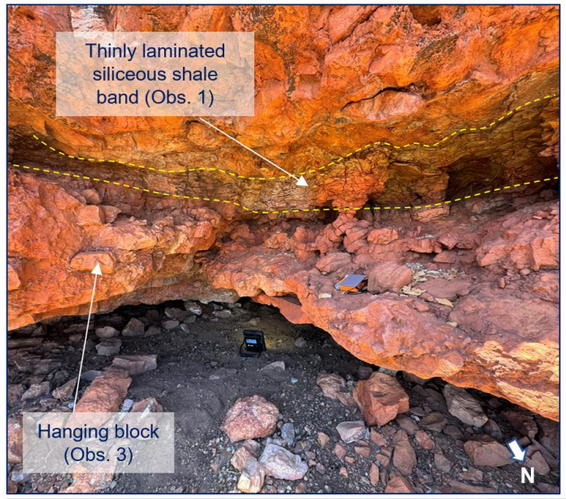
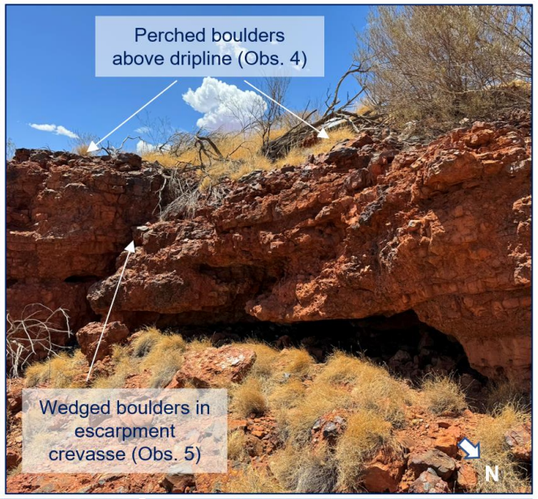
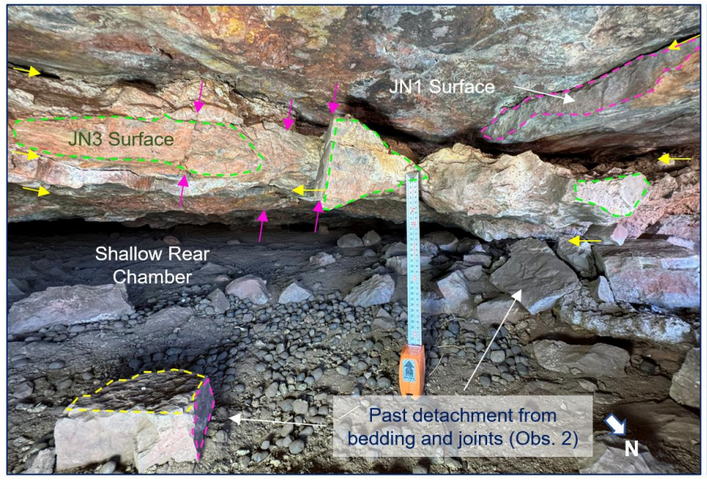
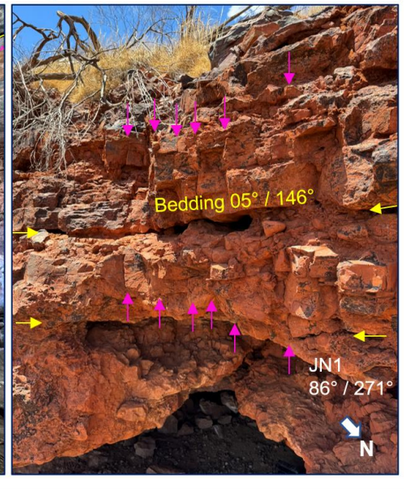
Summary Sheet Cave ID	Approximate Dimensions	Estimated GSI Range and Typical RMR_{89}	Rock Mass Description	Observed Hazards	Recommendations
MEC061	Overhang – 5.4 m wide, 1.7 m deep, 0.6 m high Rear Chamber – 4 m wide, 3 m deep, 0.3 m high (approximate)	GSI Exterior 51 – 61 Interior 58 – 68 RMR_{89} Exterior 61 Interior 68	The rock mass comprises hydrated interbedded BIF and chert. The rock mass is highly weathered and has a medium to high intact strength. A thinly laminated siliceous shale band was observed above the cave entrance. The band is approximately 100 mm thick and appears to have been preferentially weathered. Bedding is well developed and is undulating with 1.5 to 3.5 m long partings that are open less than 1 mm. Some dilated partings around the entrance are open up to 4 mm. Partings are spaced variable between 0.15 and 0.4 m. Surfaces are typically slightly rough to rough and are iron stained. Bedding was measured to dip shallowly to the southeast. Within the siliceous shale band, laminations are spaced at approximately 10 mm, though are not laterally persistent. Three major joint sets were identified: JN1 strikes into the cave and dips steeply to the west. The joint set has a spacing of 50 to 100 mm and is open over lengths of 0.2 to 0.5 m. JN2 also strikes into the cave, and dips steeply to the southeast. The joint set has a spacing of 50 to 300 mm and is open over lengths of 0.2 to 0.5 m JN3 strikes sub-parallel to the cave entrance and was measured to dip steeply to the northeast. The joint set is spaced between 100 and 200 mm and has an observable length of up to 1 m.	1. The siliceous shale band dips obliquely into the escarpment. Although not directly observed, there is potential for the shale band to intersect the rear chamber roof and for blocks to detach from the laminated band if it passes close enough to the cave roof. Observed preferential weathering of the siliceous shale band also has the potential to undermine the overlying escarpment. 2. There is potential for blocks in the escarpment and cave roof to detach from bedding where cross cut by vertical joints. A 150 mm thick dilated chert band located at the access point to the rear chamber appears to be susceptible mechanism. 3. Hanging blocks bounded by open defects were observed in areas of the cave roof and dripline. 4. Perched boulders occur at the top of the escarpment in which the cave is situated. 5. Wedged boulders were observed in a crevasse on the southern side of the cave entrance.	• Assess the area for any hanging blocks that may have detached from the cave roof, or for any perched boulders that have dropped from the escarpment above the entrance • Check for dilation of defects in the escarpment and cave roof before accessing the cave • Avoid spending time below the 150 mm thick dilated chert band just beyond the cave entrance. Check for further dilation or seepage along the dilated bedding partings and do not access if observed • Limit time spent immediately below the dripline where perched boulders are at risk of falling, or loose hanging blocks have been identified.

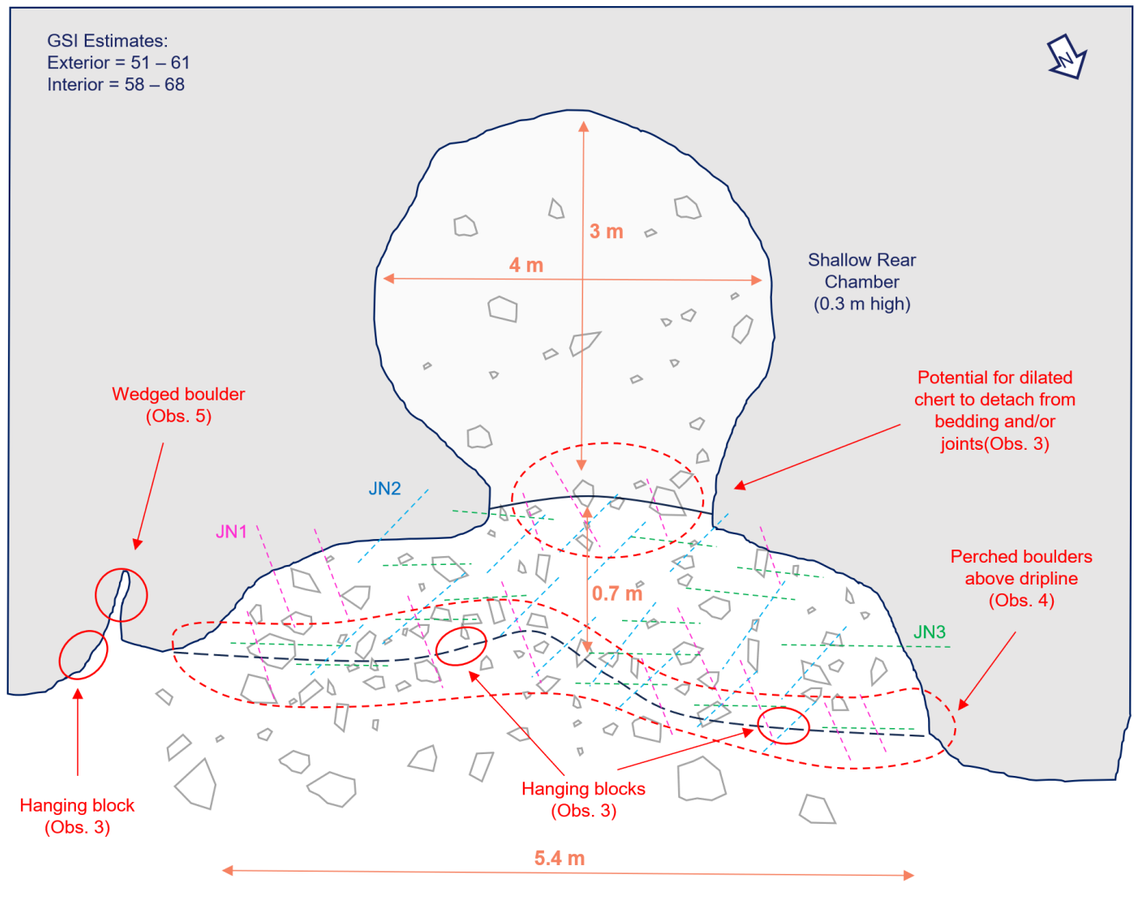








Schematic Plan View



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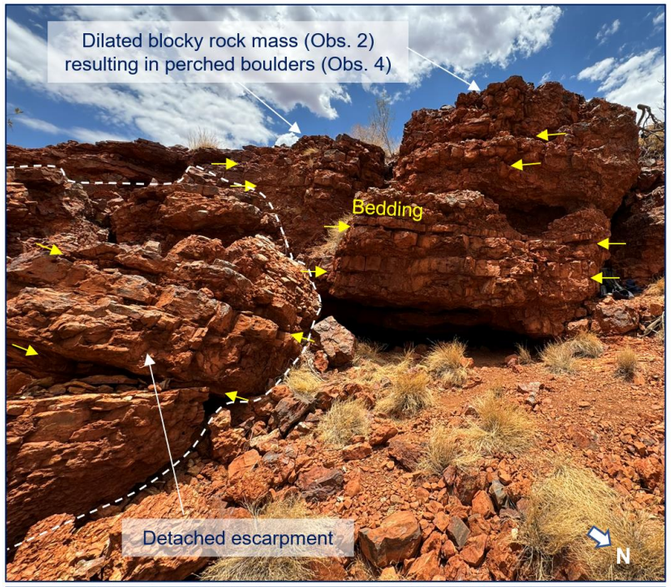
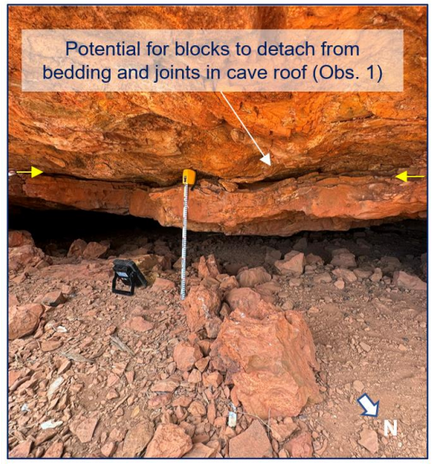
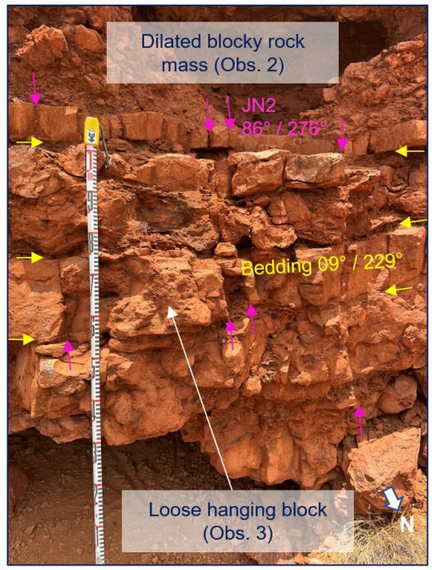
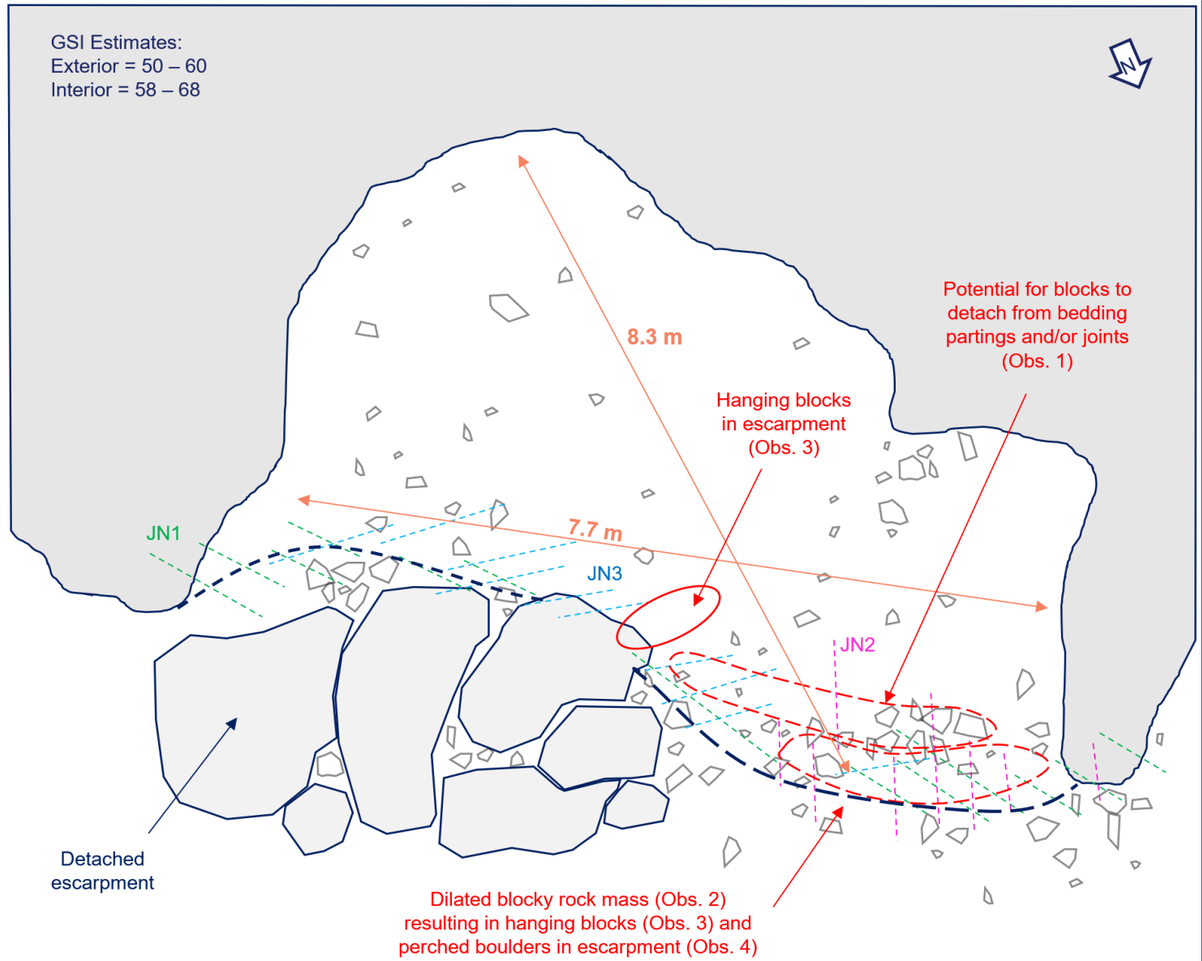
Summary Sheet Cave ID	Approximate Dimensions	Estimated GSI Range and Typical RMR_{89}	Rock Mass Description	Observed Hazards	Recommendations
MEC060	Main Chamber – 7.7 m wide, 8.3 m deep, 0.7 m high	GSI Exterior 50 – 60 Interior 58 – 68 RMR_{89} Exterior 60 Interior 68	The rock mass at the cave comprises hydrated interbedded BIF and chert. The rock mass is highly weathered and has a medium to high intact strength. The rock mass appears blocky due to multiple intersecting joint sets and bedding partings. Bedding is well developed with partings were commonly observed on the upper and lower contacts of interbedded chert bands. Bedding dips shallowly to the southwest and is undulating. Partings are typically 1 to 4 m in length and are spaced between 70 and 300 mm. Three joint sets were identified: JN1 strikes obliquely to the cave entrance, dipping steeply to the south-southwest. JN1 has an observable length of 0.2 to 0.9 m and a spacing of 100 to 200 mm, Inset 17. JN2 dips steeply to the west. It has relatively short defect lengths between 150 and 500 mm. JN2 is best preserved in the escarpment and areas around the entrance where it was observed to have a spacing of 100 to 300 mm. JN3 strikes parallel to the escarpment and was only observed on the eastern side of the cave. JN3 dips steeply to the south,	1. There is potential for slabs of hydrated BIF and chert to detach from bedding and/or joints in the cave roof. 2. The rock mass in the escarpment is loose and dilated in parts. This a potential source for future rockfall as evidenced in past rockfall product on the cave exterior. 3. Hanging blocks bounded by dilated bedding partings and joints were observed in the dripline above the cave entrance. 4. Perched boulders were observed along the top of the escarpment in which the cave is hosted. Some tabular boulders appear to have become perched due to continual weathering of the dilated blocky rock mass.	• Assess the identified hanging blocks and the BIF slab at the entrance for dilation of bedding partings and joint structures that bound them • Before approaching the cave, assess the top of the escarpment for perched boulders that may be at risk of falling. Check the area below the dripline for fresh rockfall • Limit time spent at the escarpment face where loose dilated rock mass has been identified. Avoid leaning or sitting below these areas.





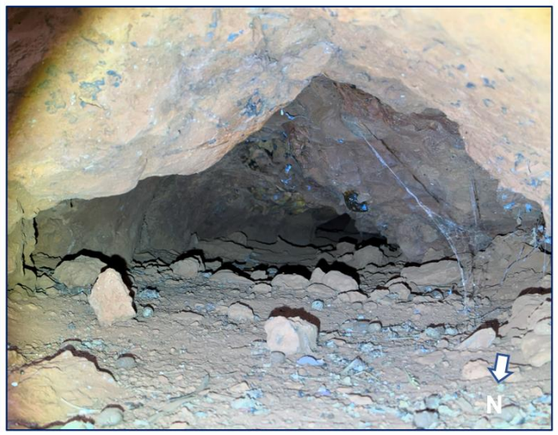


Schematic Plan View

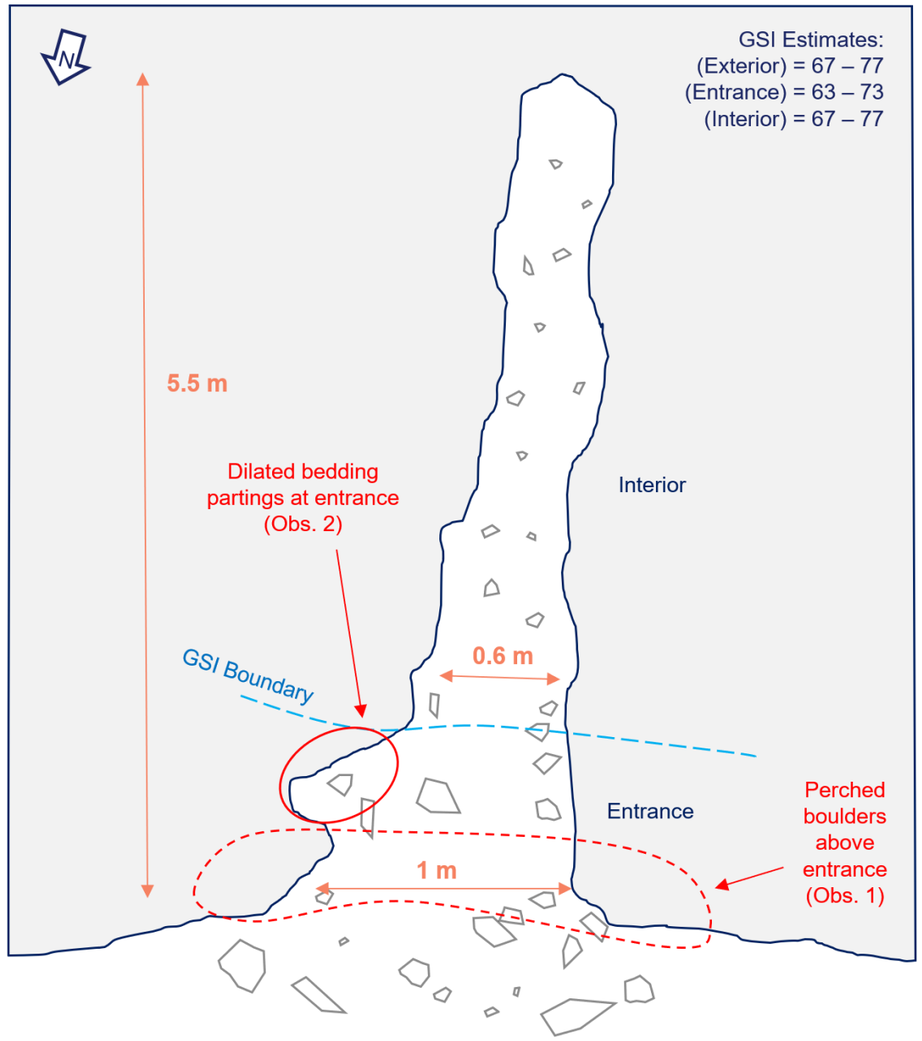


Not to scale

Summary Sheet Cave ID	Approximate Dimensions	Estimated GSI Range and Typical RMR_{89}	Rock Mass Description	Observed Hazards	Recommendations
MEC072	Entrance – 1 m wide, 0.6 m high Interior – 0.6 m wide, 5.5 m deep, 0.4 m high	GSI Exterior 67 – 77 Entrance 63 – 73 Interior 67 – 77 RMR_{89} Exterior 77 Entrance 73 Interior 77	The rock mas at the cave comprises hydrated, highly weathered BIF. The intact strength is high to very high. Bedding is developed and elongate vughs were observed on the exterior oriented parallel to bedding. Bedding dips shallowly to the southeast with partings that are undulating and up to 0.5 m long. The partings are spaced at 60 to 200 mm and have surfaces that are slightly rough to trough. They are tight to open less than 1 mm. Bedding appears to become overprinted deeper into the cave. No structurally significant joint sets were identified.	1. Perched boulders are situated above the cave entrance. 2. There is potential for blocks to detach from bedding where partings are developed around the entrance. If blocks detach they are likely not going to restrict access for bats in to the cave.	• Before accessing the cave, assess the perched blocks above the entrance that have the potential to fall and check for any fresh rockfall and on the ground.

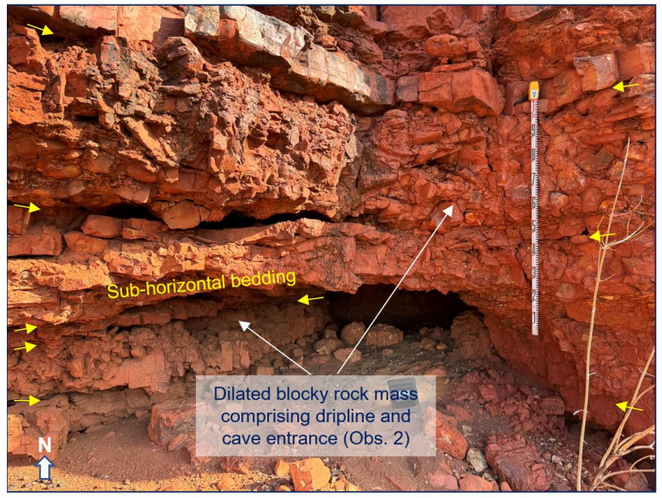


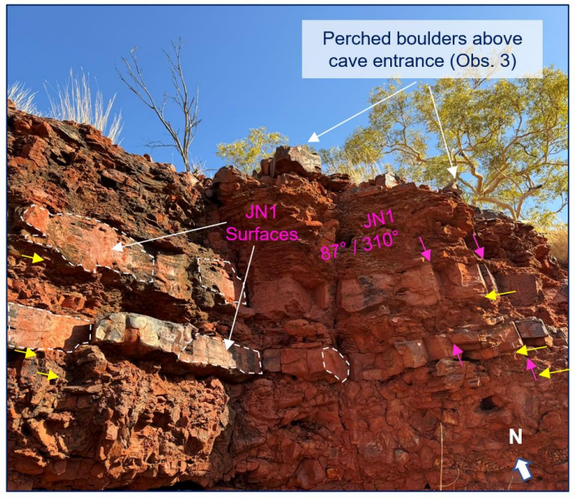
Schematic Plan View

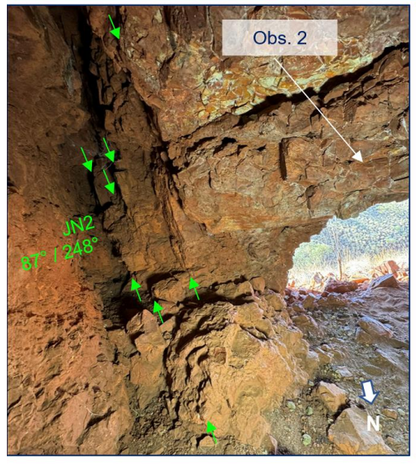


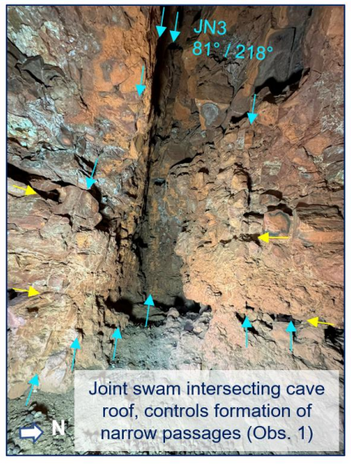
Not to scale

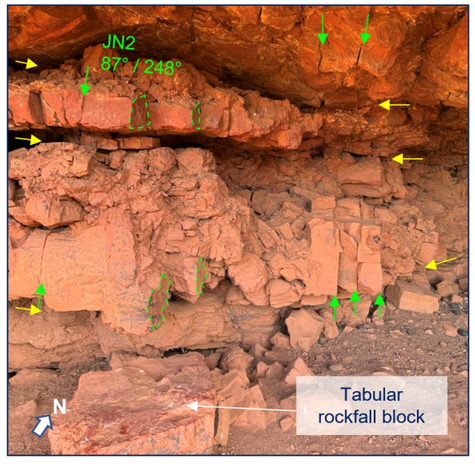
Summary Sheet Cave ID	Approximate Dimensions	Estimated GSI Range and Typical RMR_{89}	Rock Mass Description	Observed Hazards	Recommendations
MEC049	Interior – 1.5m wide, 2.8 m deep, and 0.8 m high (up to 2 m high at rear)	GSI Exterior 50 – 60 Interior 56 – 66 RMR_{89} Exterior 60 Interior 66	The rock mass comprises partially hydrated interbedded chert and BIF. It is highly weathered and typically has a high to very high intact strength. In some areas around the entrance, medium strength was observed. The rock mass is generally blocky and dilated. Bedding is well developed with partings 2 to 6 m long observed throughout the cave and surrounding escarpment. Partings are typically undulating and oriented sub-horizontally. They are open up to 4 mm in places but typically have an aperture of approximately 1 mm with an iron veneer infill. Partings are spaced at 100 to 300 mm and have rough surfaces. Three joint sets were observed: JN1 dips steeply to the northwest and has an observable length of 1 to 3 m. The set is spaced at 100 to 200. JN1 was only observed in the escarpment and around the entrance of the cave. JN2 dips steeply to the west-southwest. Joints along this orientation are relatively short with lengths between 0.1 and 0.4 m. JN2 has a spacing of 40 to 120 mm. JN3 dips steeply to the southwest and is generally spaced between 0.1 and 0.3 m. Two large open structures along this orientation occur at the back of the interior chamber resulting roof profiles up to 2 m high. At the back of the main chamber, JN3 is up to 3 m long and spaced at 50 mm proximal to the joint swarm.	1. A dilated joint swarm along joint set 3 orientation was observed to control cave development at the back of the interior chamber. 2. Loose dilated blocky rock mass was observed in the escarpment above and adjacent to the cave, and also in areas around the cave entrance. 3. Perched boulders are situated atop the escarpment.	• Before accessing the cave, assess the perched blocks above the entrance that have the potential to fall and check for any fresh rockfall and on the ground • Limit time spent immediately below the dripline where there is potential for blocks to detach from the dilated blocky rock mass. Avoid leaning on these areas when accessing the cave • Check for dilation of defects in the escarpment and cave roof before accessing the cave • Inside the cave, check for seepage along the dilated joint structures. Do not continue to access the cave if water is observed.



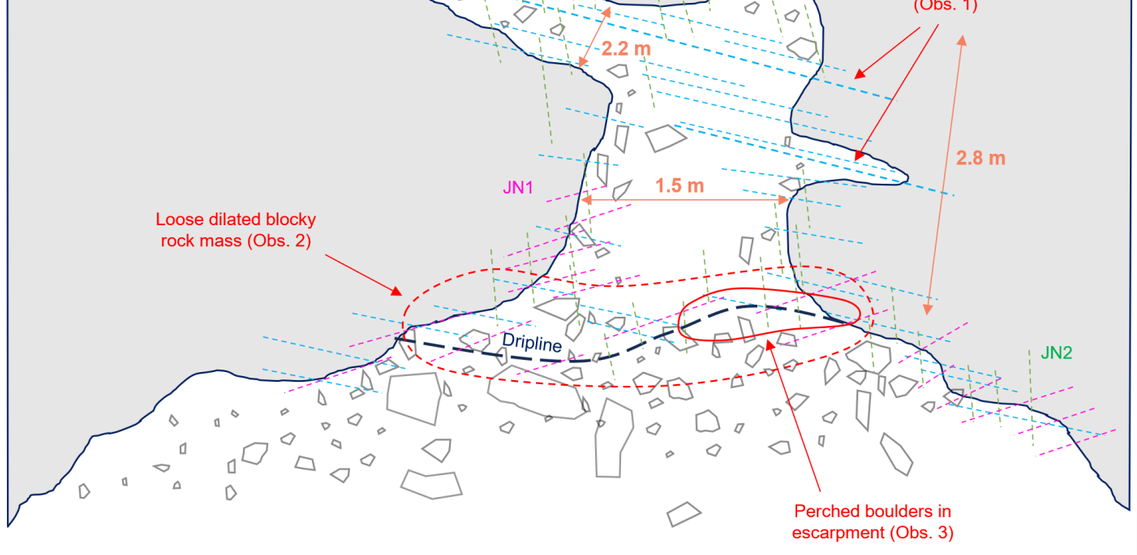






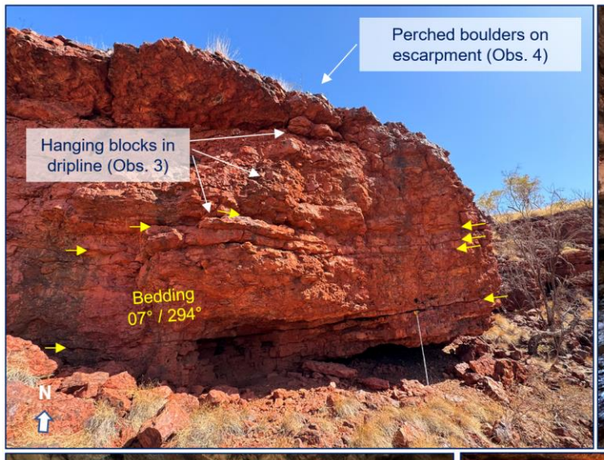


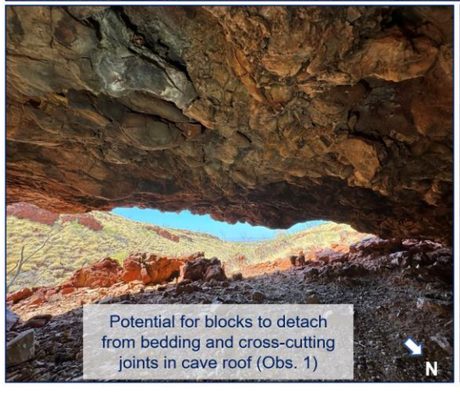
Schematic Plan View

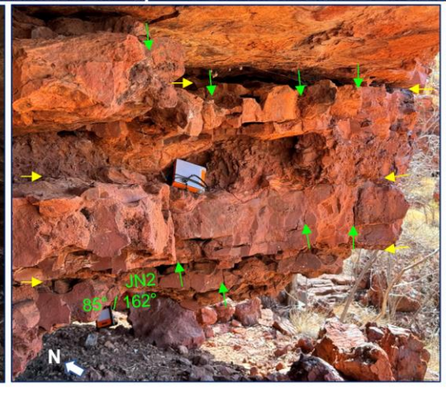


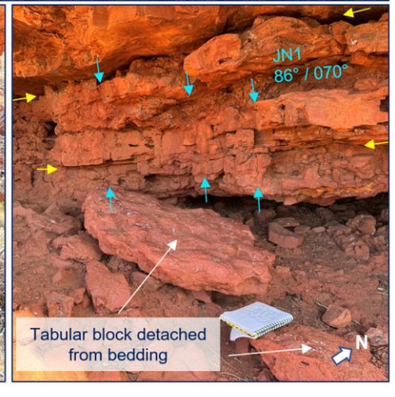
Not to scale

Summary Sheet Cave ID	Approximate Dimensions	Estimated GSI Range and Typical RMR_{89}	Rock Mass Description	Observed Hazards	Recommendations
MEC003	Main Chamber – 5.2 m wide, 4.0 m deep, 0.7 m high. Rear Chamber – 1.8 m wide, 4.1 m deep, 0.6 m high	GSI Exterior and Main Chamber 67 – 77 Rear Chamber 63 – 73 RMR_{89} Exterior and Main Chamber 77 Rear Chamber 73	The rock mass at the site comprises interbedded hydrated BIF and chert. The rock is dilated and loose in areas around the entrance, and in the escarpment above the cave. The intact strength is high to very high. A laminated siliceous shale band was observed on the roof the main chamber, and was assessed to have a low to medium intact strength. The laminations within the shale band are intact. Bedding at the cave is well developed and forms partings with lengths between 1 and 10 m long. The partings are spaced between 80 and 200 mm, and are open up to 2 mm. Bedding dips shallowly to the west. Three joint sets were recorded at the cave. JN1 dips steeply to the east-northeast. It has lengths of 0.3 to 0.5 m and is spaced 50 to 150 mm. Joints along this orientation are typically tight to open <1 mm. JN2 controls dripline formation on the southern side of the escarpment. It dips steeply to the south-southeast and has defect lengths between 0.4 and 0.8 m. The joints are typically undulating and are spaced between 100 and 200 mm apart. JN3 dips steeply to the southeast and was observed to be tight. JN3 is typically 0.5 to 1.5 m long and spaced at 100 to 400 mm.	1. There is potential for blocks of rock to detach from bedding partings sand joints in the cave roof, evidenced by past rockfall debris throughout the cave main chamber and below the dripline. 2. A thinly laminated siliceous shale band was observed to intersect the roof of the main chamber. Although the laminations are intact, blocks below the shale band may be able to detach from the band due to the lower intact strength. 3. Loose hanging blocks up to 0.8 m wide were observed on the southern side the escarpment. The hanging blocks are bounded by dilated joints or non-systematic fractures. 4. Perched boulders are situated in the escarpment above the cave have the potential to fall.	• Limit time spent immediately below the dripline where perched boulders are at risk of falling, or loose hanging blocks have been identified • Check for fresh rock fall debris around the cave entrance before approaching • Check for dilation of defects bounding blocks in the escarpment and main chamber roof • Assess the main chamber for signs of water seepage, particularly around any hanging blocks bounded by joints in the cave roof.

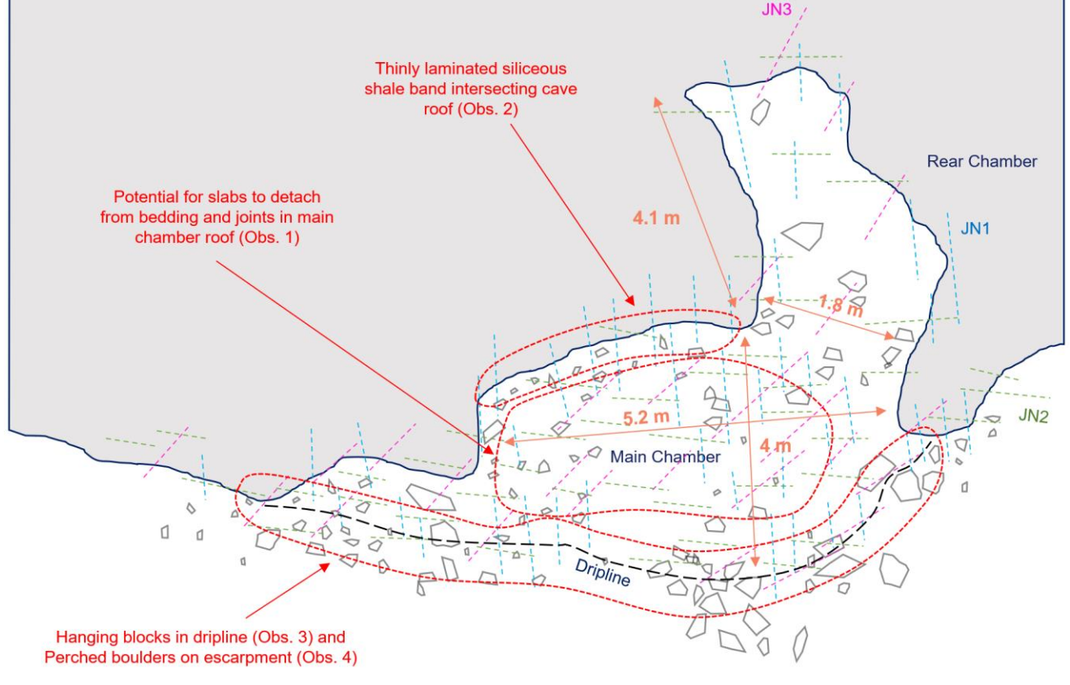






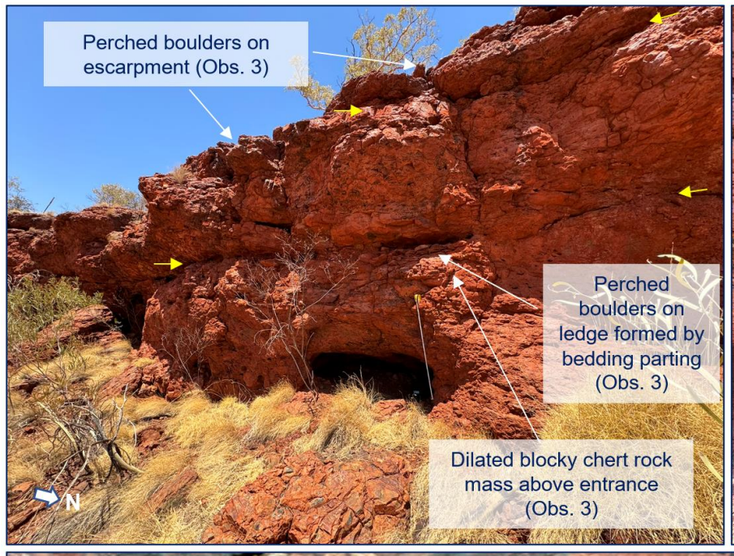


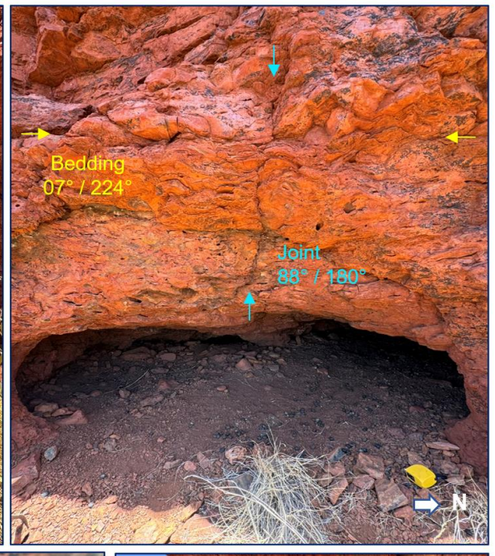
Schematic Plan View

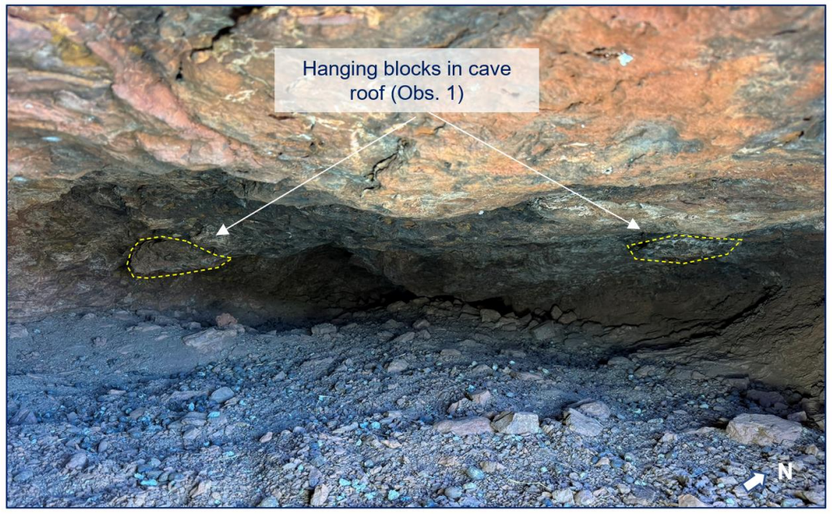


Not to scale

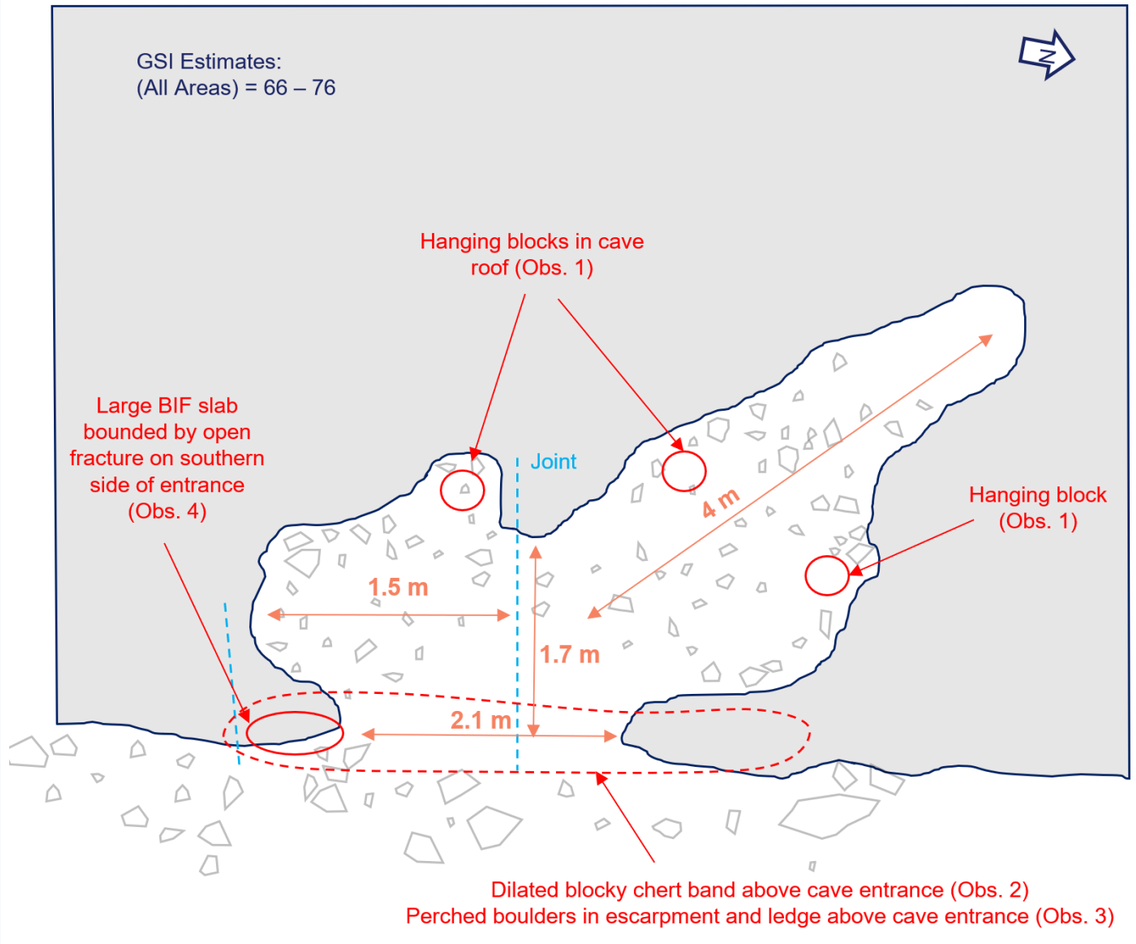
Summary Sheet Cave ID	Approximate Dimensions	Estimated GSI Range and Typical RMR_{89}	Rock Mass Description	Observed Hazards	Recommendations
MEC025	Entrance – 2.1 m wide and 6 m high Interior – 5.5 m wide, 1.7 m deep, 0.5 m high	GSI All Areas 66 – 76 RMR_{89} All Areas 76	Rock mass at the cave comprises interbedded hydrated BIF and chert. The cave itself is hosted within the hydrated BIF which makes up the lower part of the exposed escarpment, with blocky chert bands observed in the escarpment above the cave. The rock mass is high strength, with elongate vughs oriented parallel to BIF bedding. Bedding dips shallowly to the southwest and does not form structurally significant partings at the cave level, however, partings do persist in the rock above the cave along the contacts of interbedded chert bands. Above the cave, partings are 1 to 6 m long and spaced between 200 and 400 mm. A single joint set was observed at the cave. The joints are oriented sub-vertical and strike east-west. Only two open joints were observed along this orientation, indicating a spacing of approximately 2 m and lengths up to 1.7 m.	1. Hanging blocks bounded by open fractures were observed in the cave roof inside the cave. 2. Blocky chert bands occur in the escarpment above the cave entrance, and have the potential to release dilated blocks from the escarpment face. 3. Perched boulders were observed along the top of the escarpment in which the cave is situated. 4. A large BIF slab is bounded by an open fracture on the southern side of the cave entrance.	• Before approaching the cave, assess the area for any fresh rockfall and loose blocks that may have formed in the blocky chert escarpment • Check the escarpment above the cave for perched boulders when traversing the cave dripline • Avoid leaning on or sitting below the large BIF slab on the southern side of the cave entrance • Assess the identified hanging BIF blocks inside the cave for dilation of bounding fractures and for signs of detachment.







Schematic Plan View



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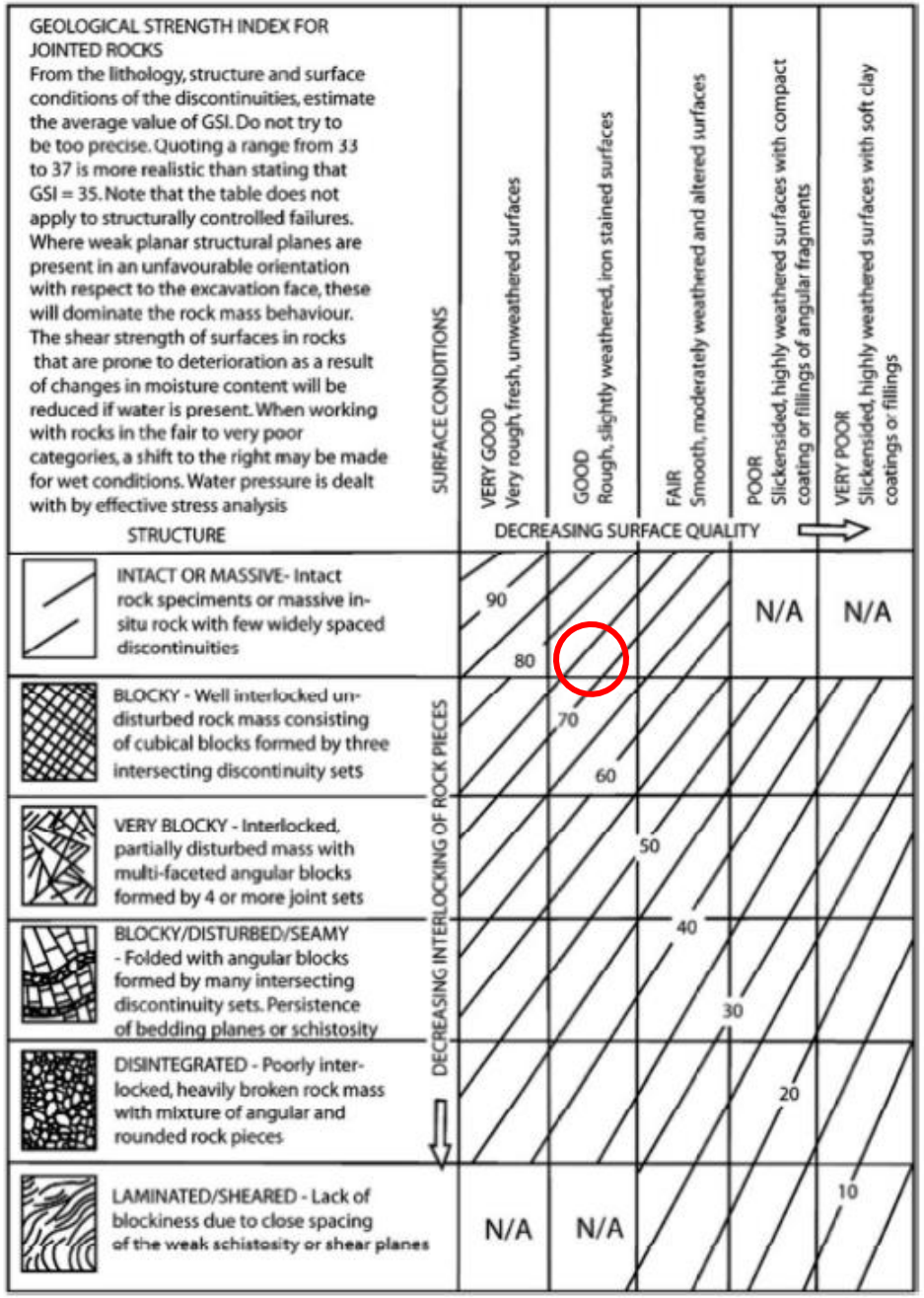
Appendix C
GSI and RMR_{89} Estimates

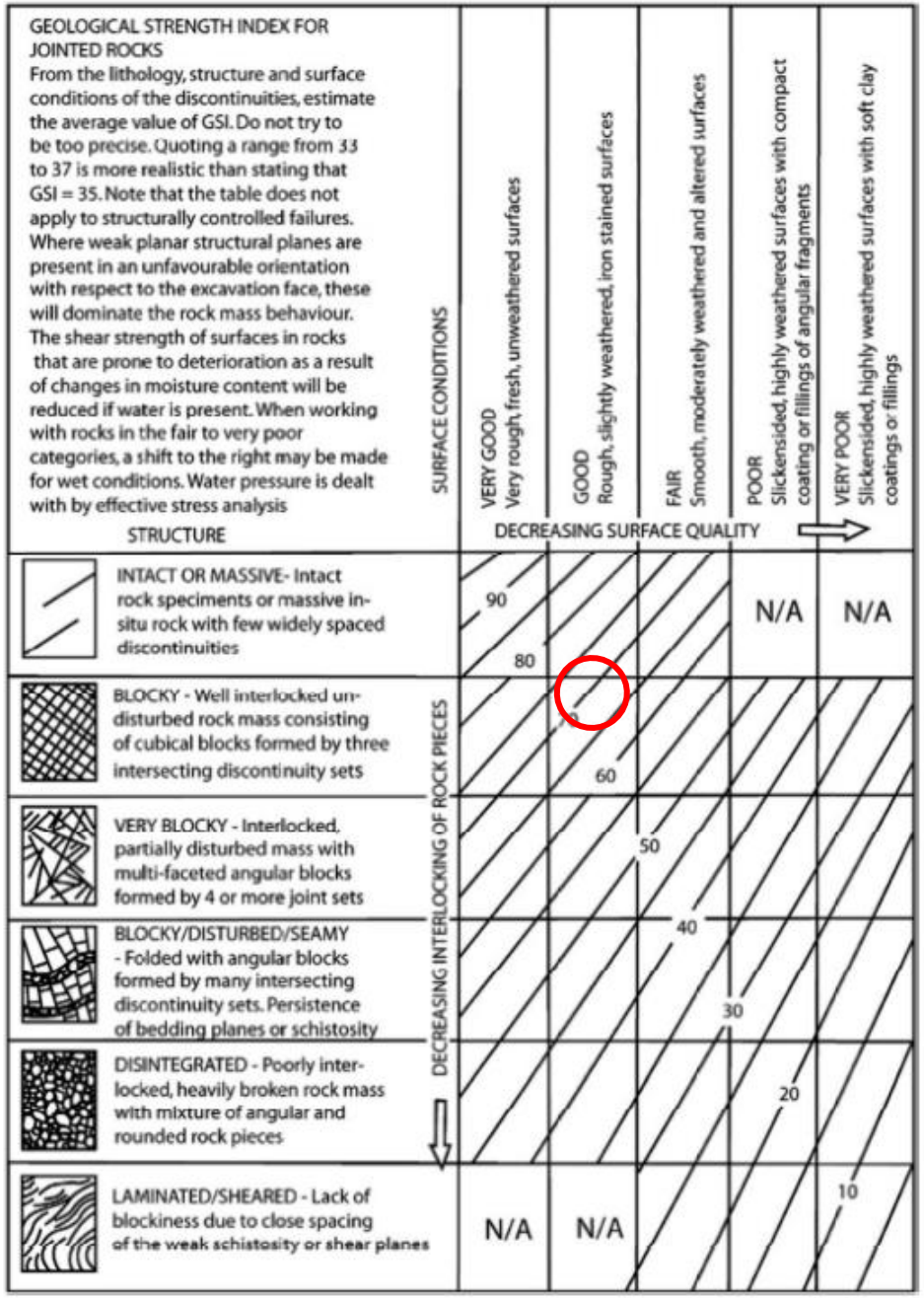
GSI Estimates MEC042

Area	GSI Range	GSI Best Estimate	Equivalent RMR89
All	68 – 78	73	78



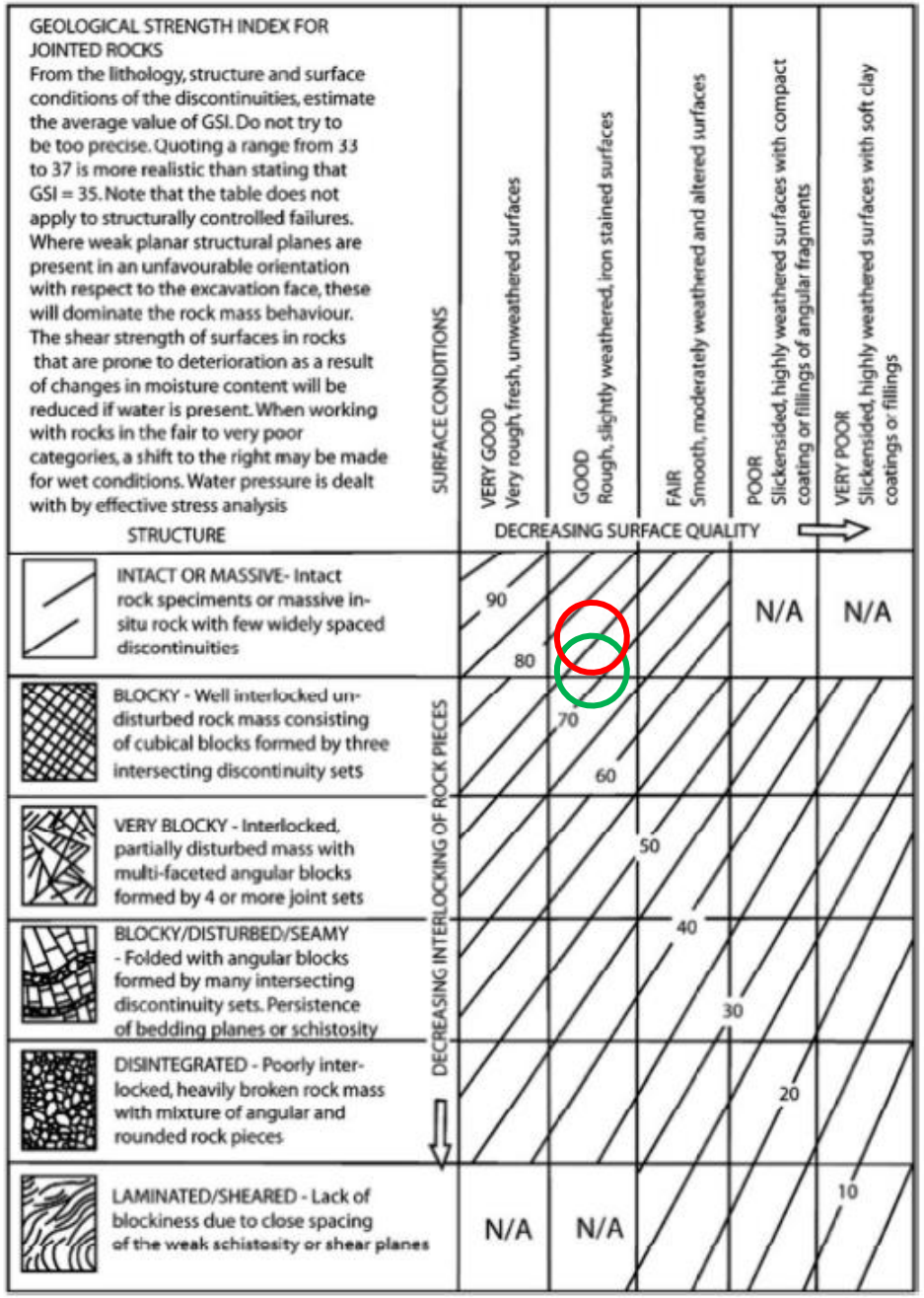
GSI Estimates MEC014

Area	GSI Range	GSI Best Estimate	Equivalent RMR89
All	65 – 75	70	75



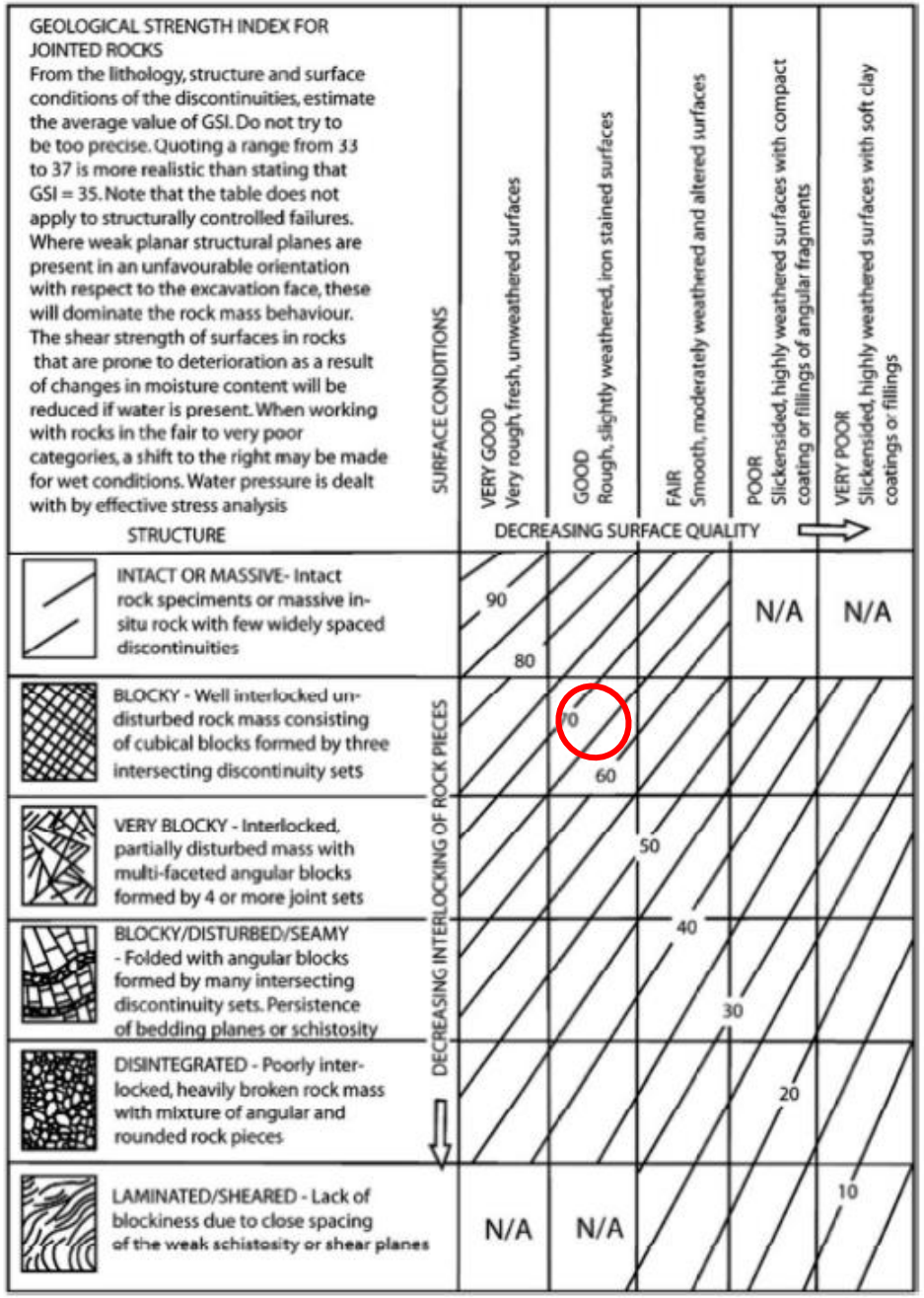
GSI Estimates MEC013

Area	GSI Range	GSI Best Estimate	Equivalent RMR89
Exterior	70 – 80	75	80
Interior	67 – 77	72	77



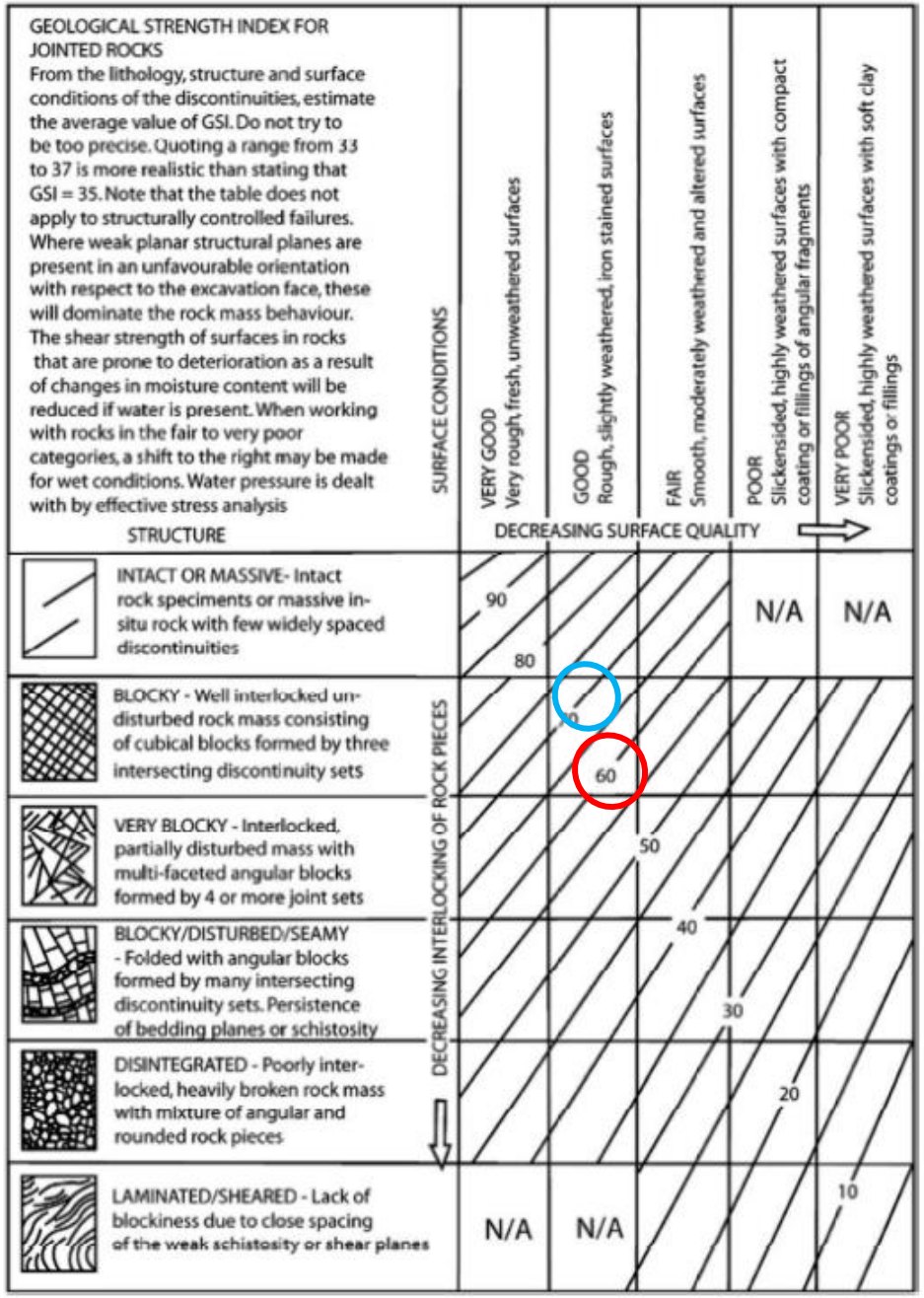
GSI Estimates MEC012

Area	GSI Range	GSI Best Estimate	Equivalent RMR89
All	62 – 72	67	72



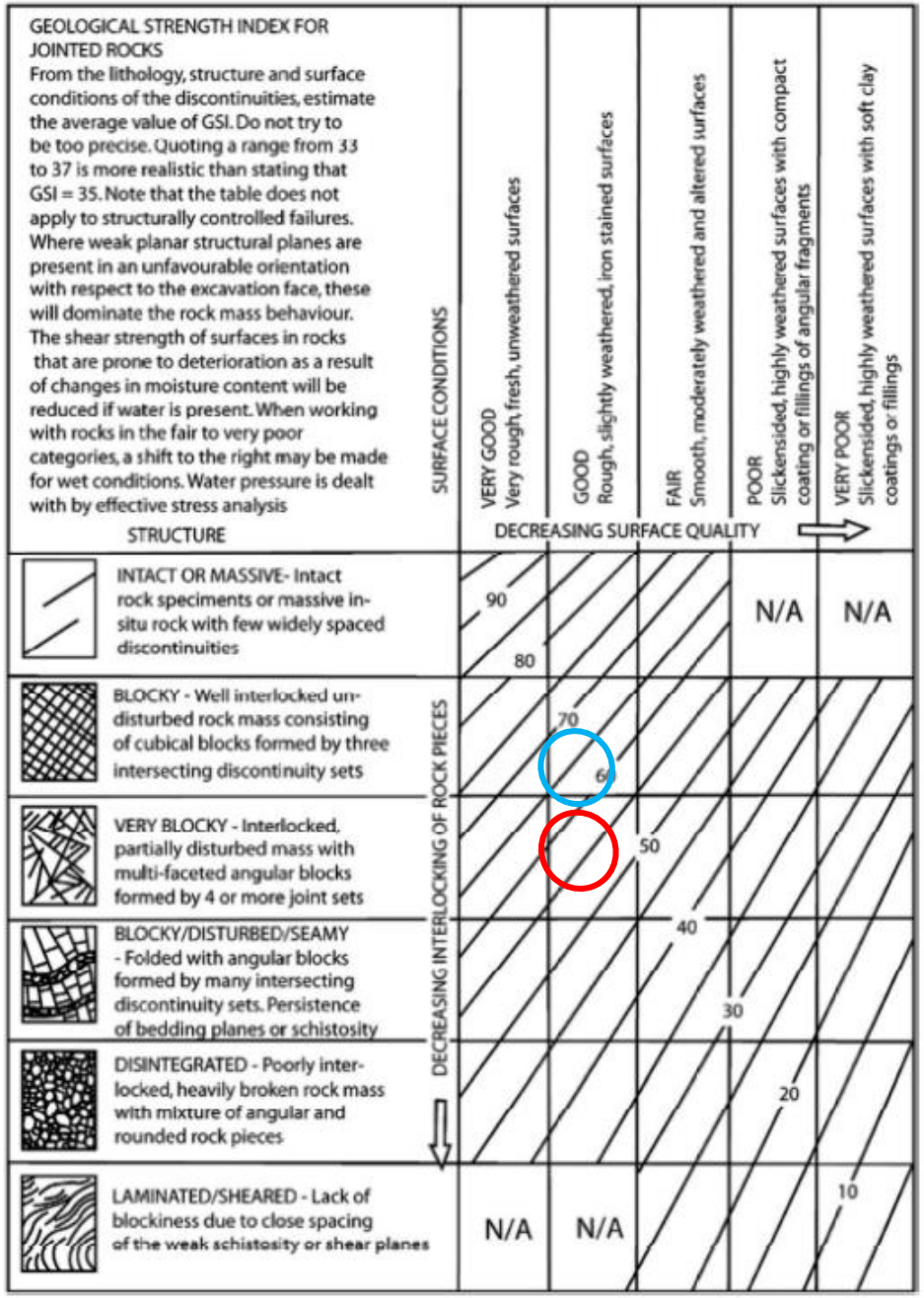
GSI Estimates MEC074

Area	GSI Range	GSI Best Estimate	Equivalent RMR89
Exterior and Overhang	55 – 65	60	65
Rear Chamber	65 – 75	70	75



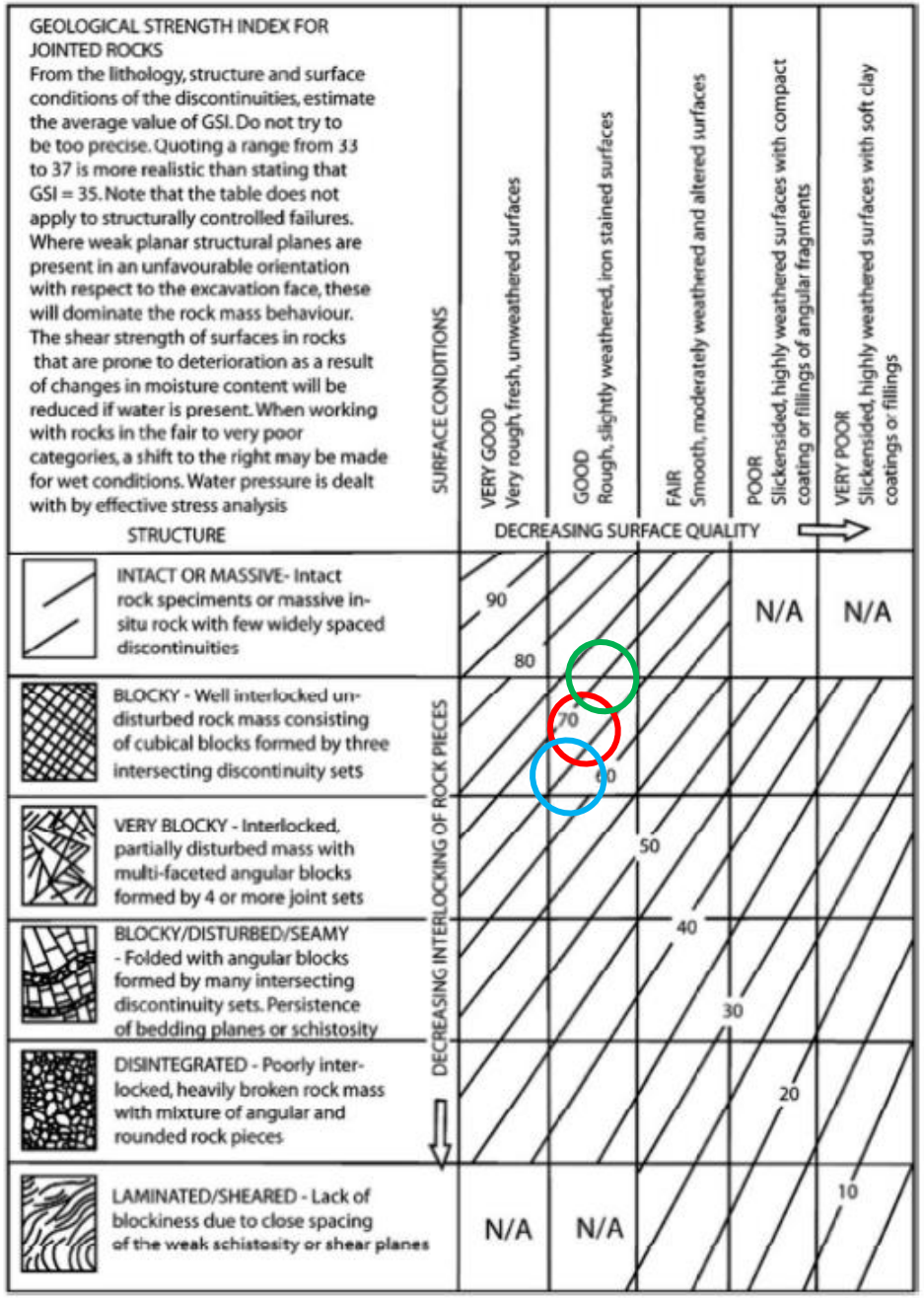
GSI Estimates MEC065

Area	GSI Range	GSI Best Estimate	Equivalent RMR89
Exterior and Main Chamber	52 – 62	57	62
Rear Chamber	59 – 69	64	69



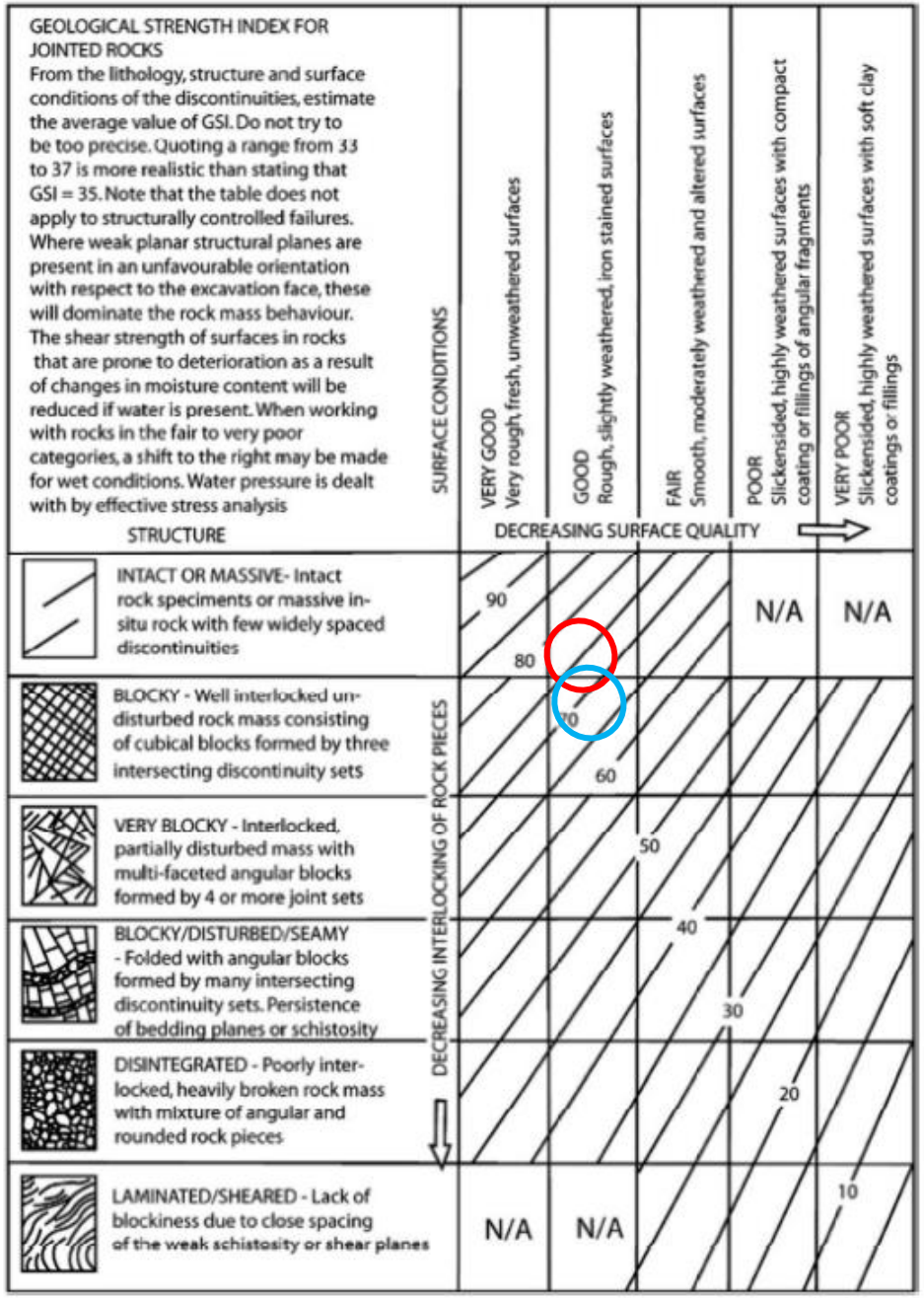
GSI Estimates MEC007

Area	GSI Range	GSI Best Estimate	Equivalent RMR89
Exterior and Front	62 – 72	67	72
Obs. 1 Zone	59 – 69	64	69
Rear	65 – 75	70	75



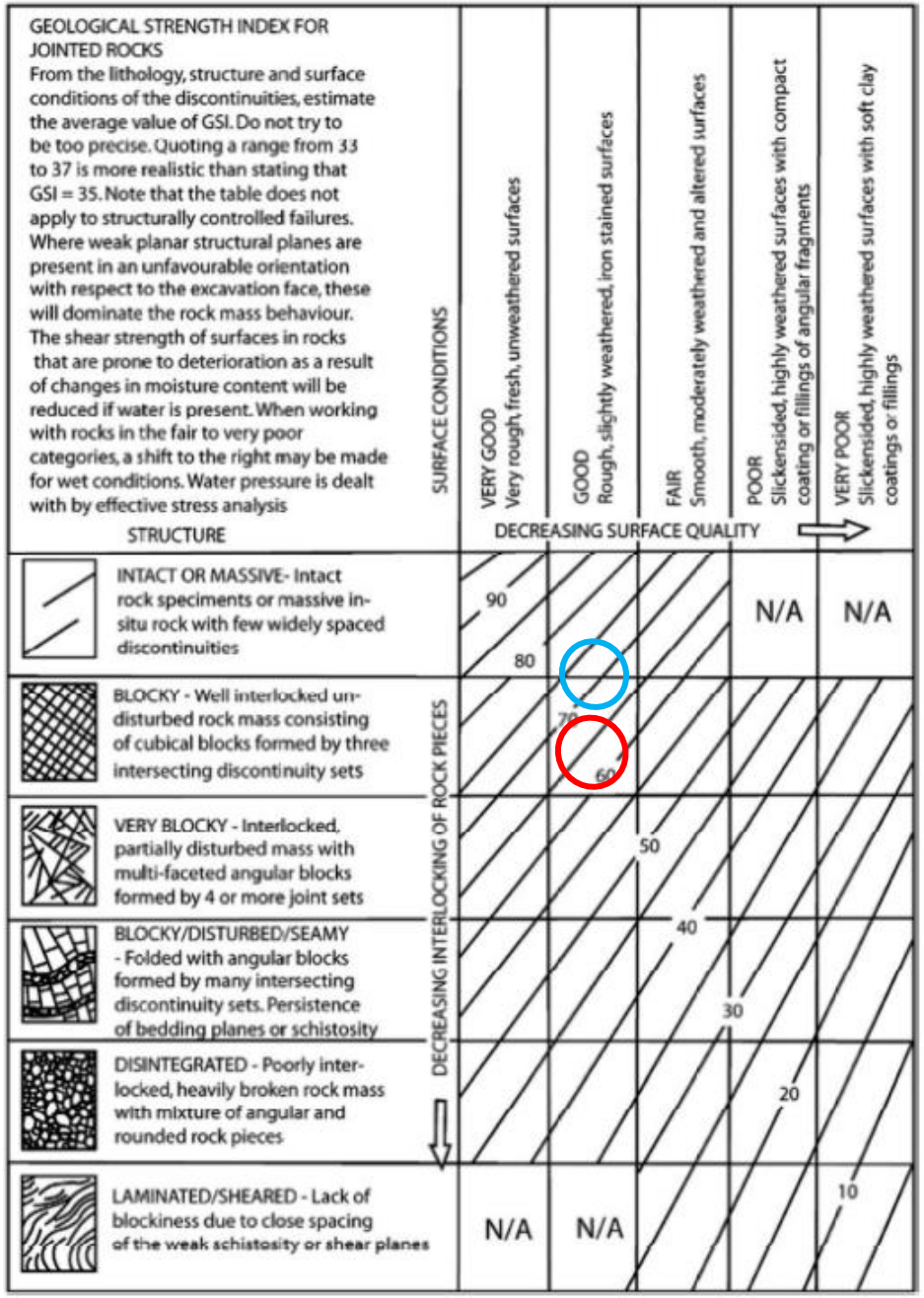
GSI Estimates MEC033

Area	GSI Range	GSI Best Estimate	Equivalent RMR89
Exterior and Overhang	70 – 80	75	80
Interior	64 – 74	69	74



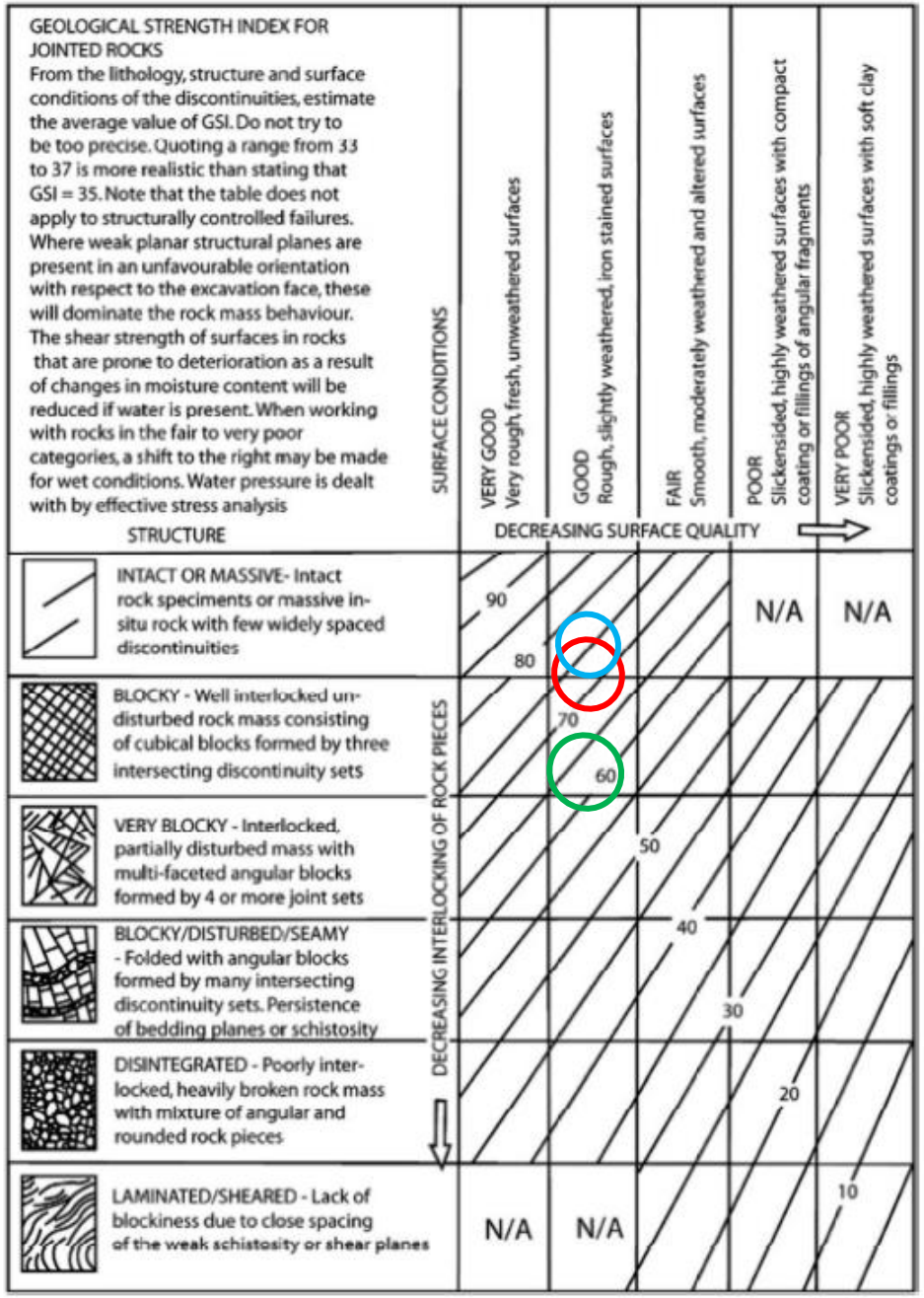
GSI Estimates MEC073

Area	GSI Range	GSI Best Estimate	Equivalent RMR89
Exterior and Overhang	58 – 68	63	68
Main Chamber	66 – 76	71	76



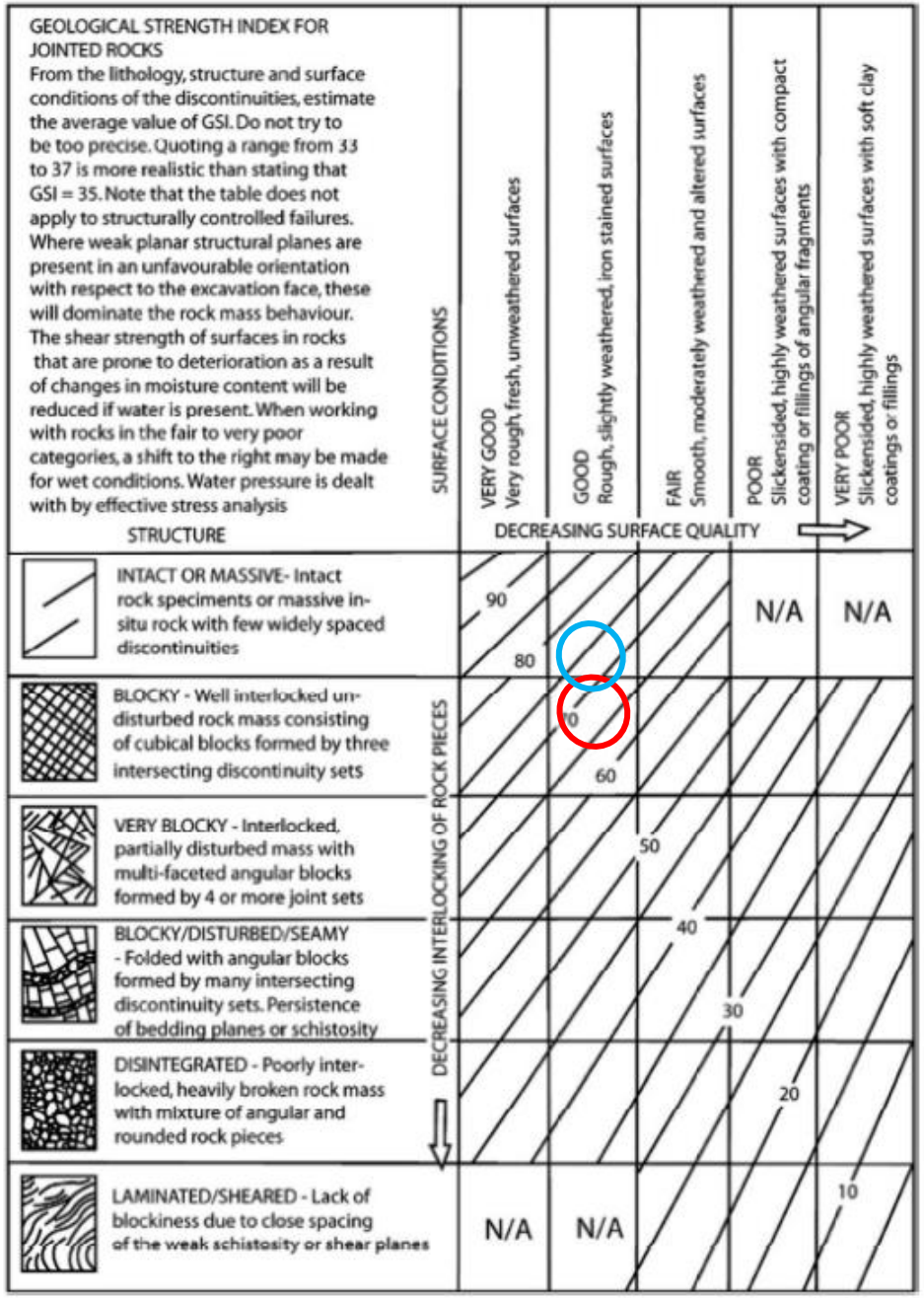
GSI Estimates MEC039

Area	GSI Range	GSI Best Estimate	Equivalent RMR89
Entrance/ Overhang	67 – 77	72	77
Main Chamber	70 – 80	75	80
Exterior (chert band)	58 – 68	63	68



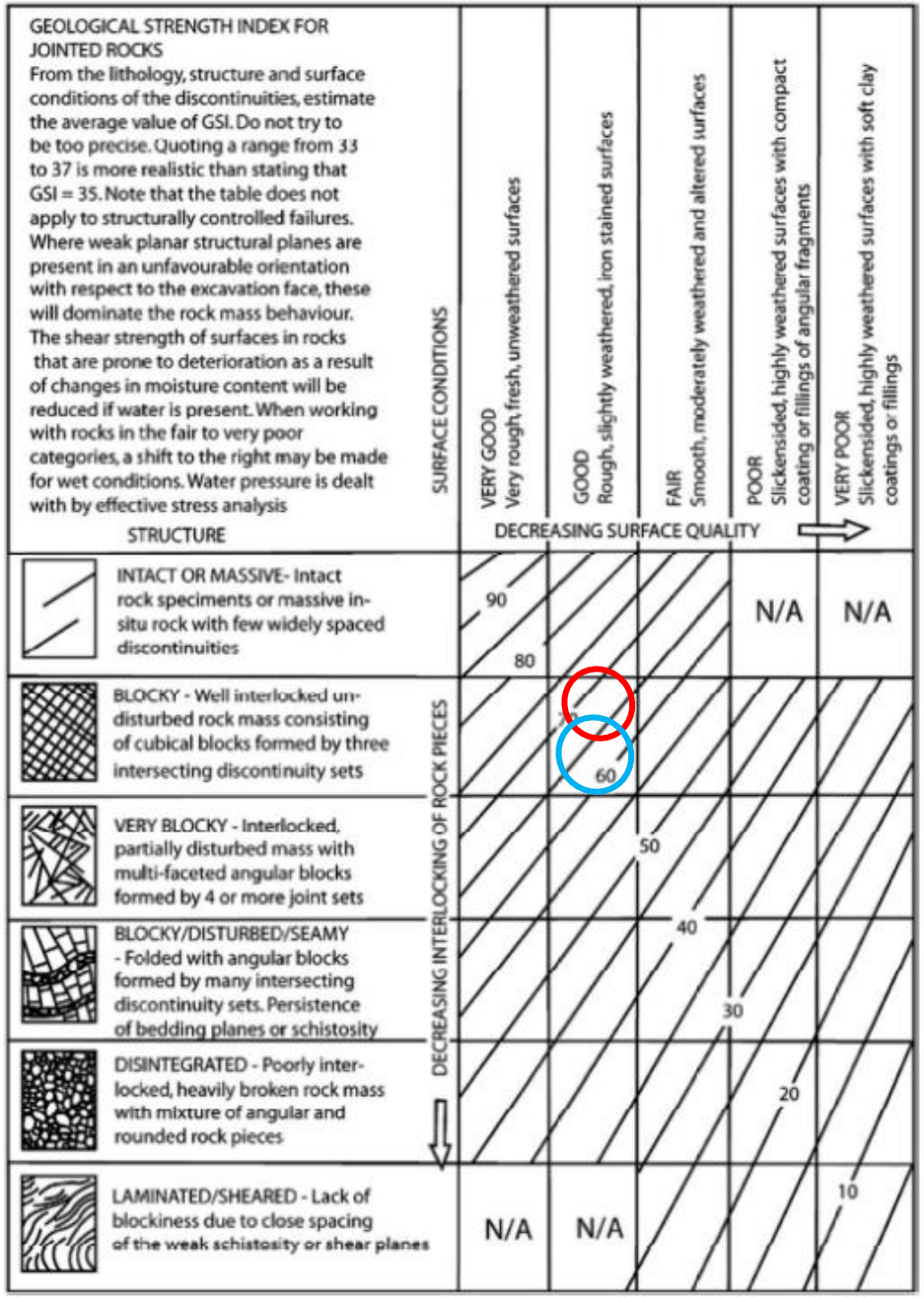
GSI Estimates MEC016 (MIB-MD13-043)

Area	GSI Range	GSI Best Estimate	Equivalent RMR89
Exterior, Main Chamber, and SW Adit	63 – 73	68	73
Western and Eastern Rear Adits	68 – 78	73	78



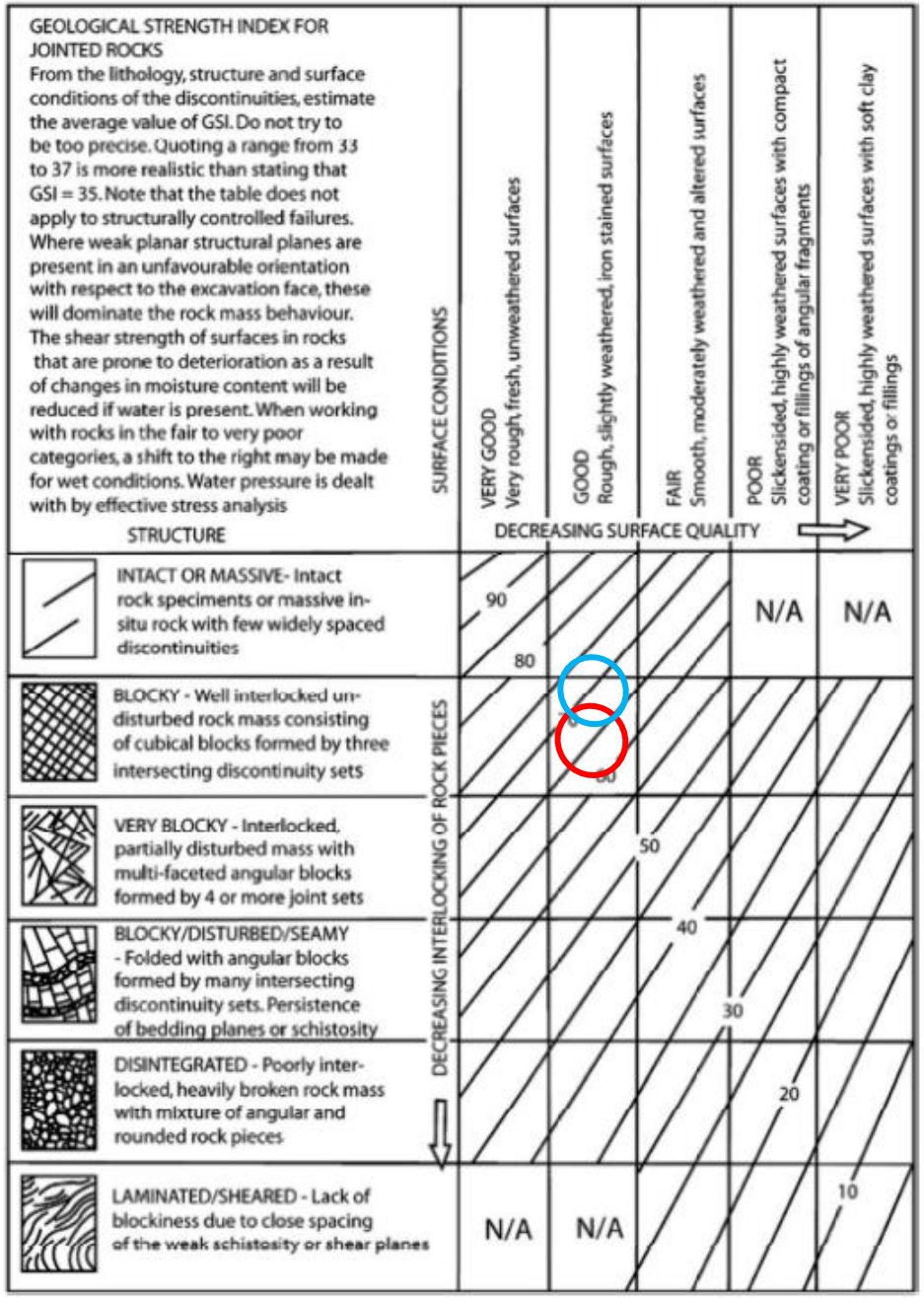
GSI Estimates MEC063

Area	GSI Range	GSI Best Estimate	Equivalent RMR89
Exterior	63 – 73	68	73
Interior	58 – 68	63	68



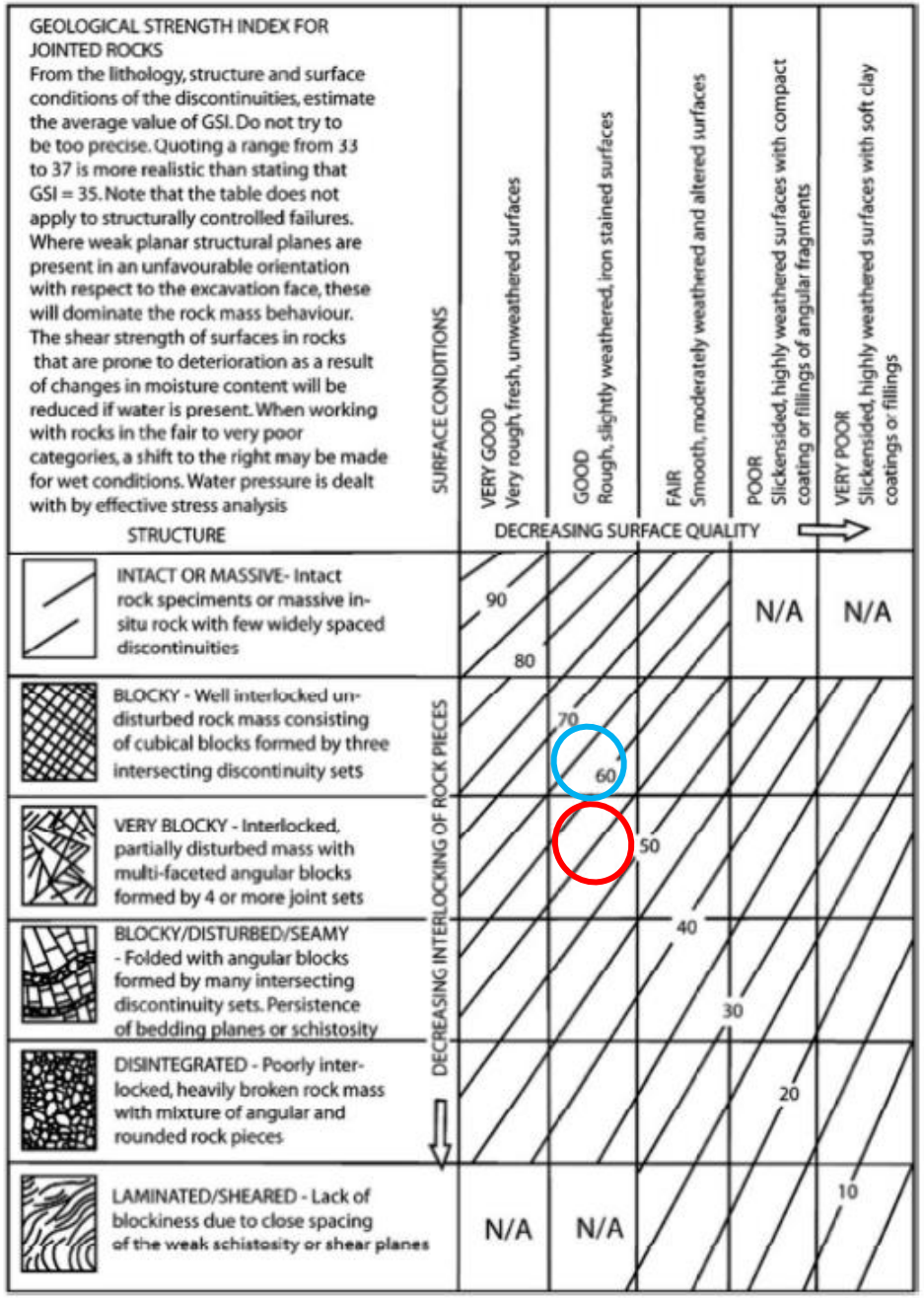
GSI Estimates MEC062

Area	GSI Range	GSI Best Estimate	Equivalent RMR89
Exterior and Front of Main Chamber	60 – 70	65	70
Rear of Main Chamber	65 – 75	70	75



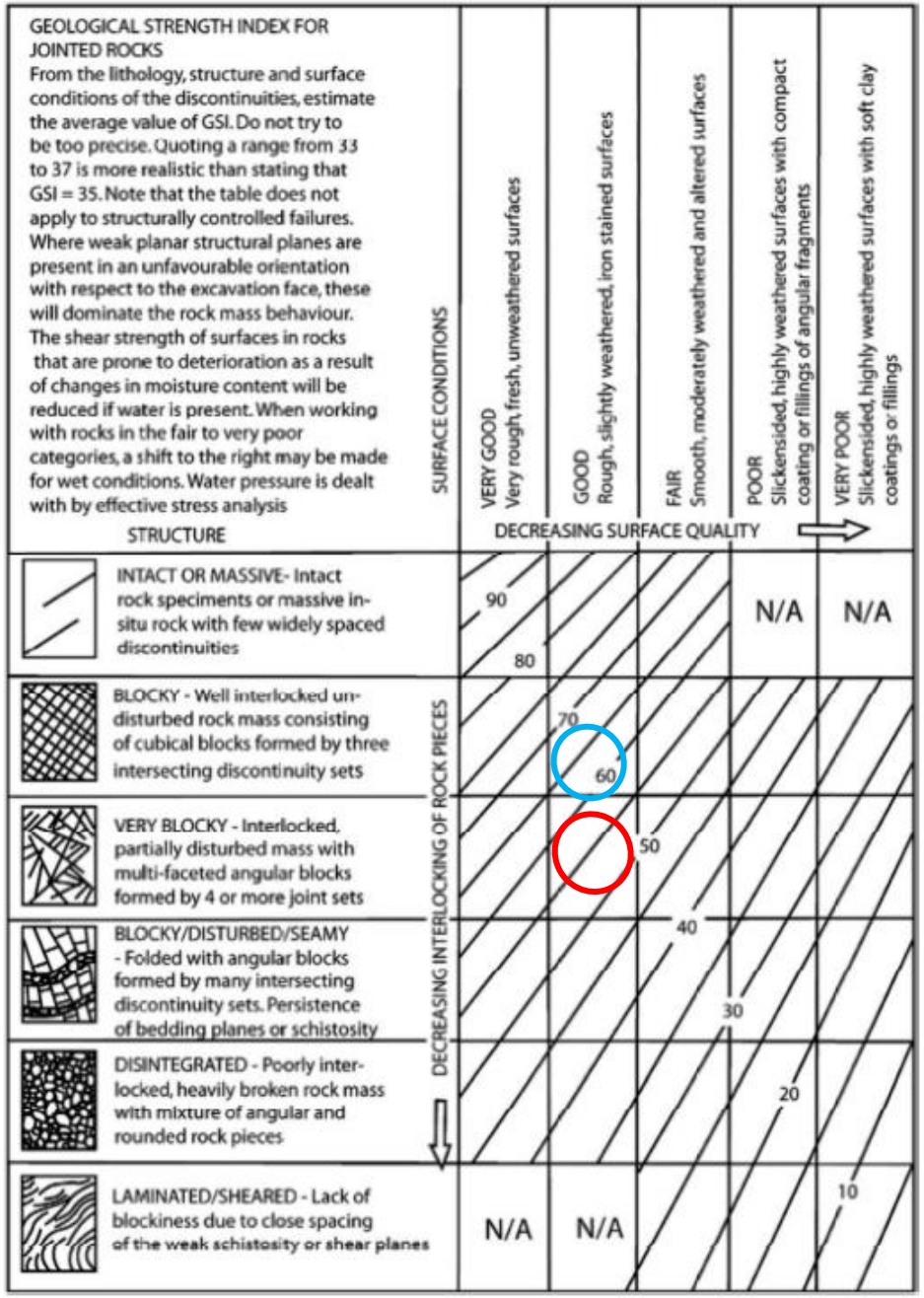
GSI Estimates MEC061

Area	GSI Range	GSI Best Estimate	Equivalent RMR89
Exterior	50 – 60	55	60
Interior	58 – 68	63	68



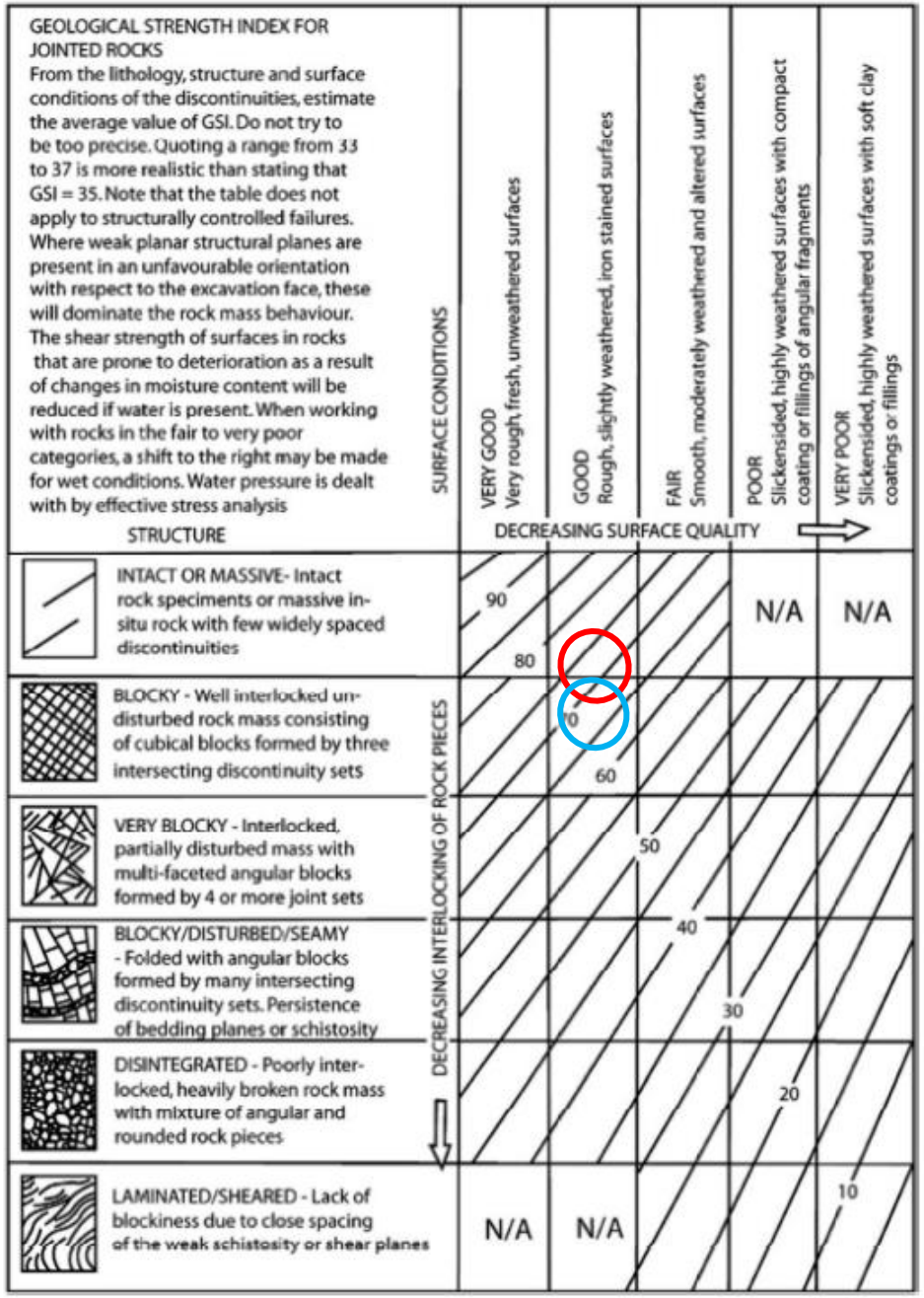
GSI Estimates MEC060

Area	GSI Range	GSI Best Estimate	Equivalent RMR89
Exterior	51 – 61	56	61
Interior	58 – 68	63	68



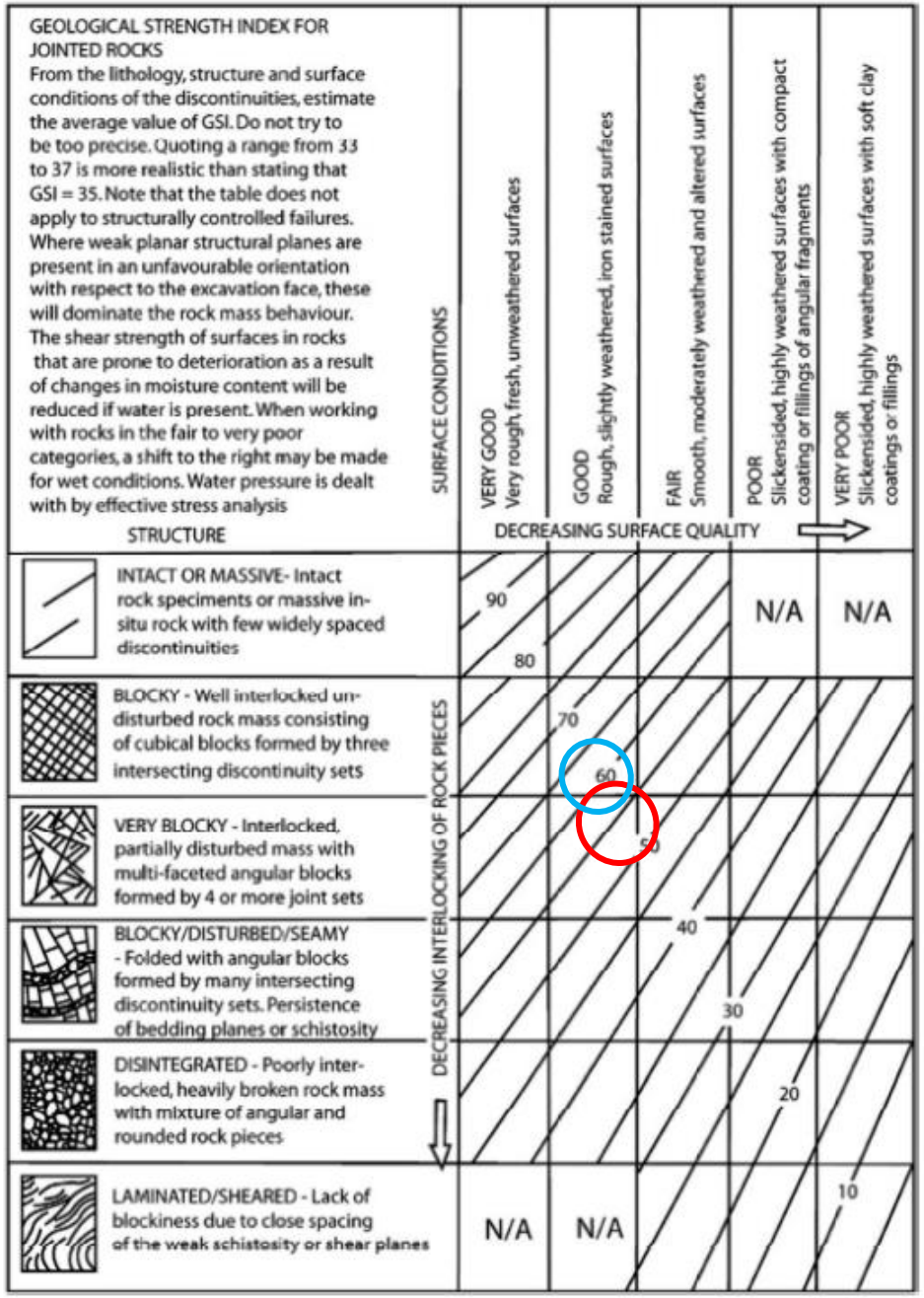
GSI Estimates MEC072

Area	GSI Range	GSI Best Estimate	Equivalent RMR89
Exterior and Interior Chamber	67 – 77	72	77
Entrance	63 – 73	68	73



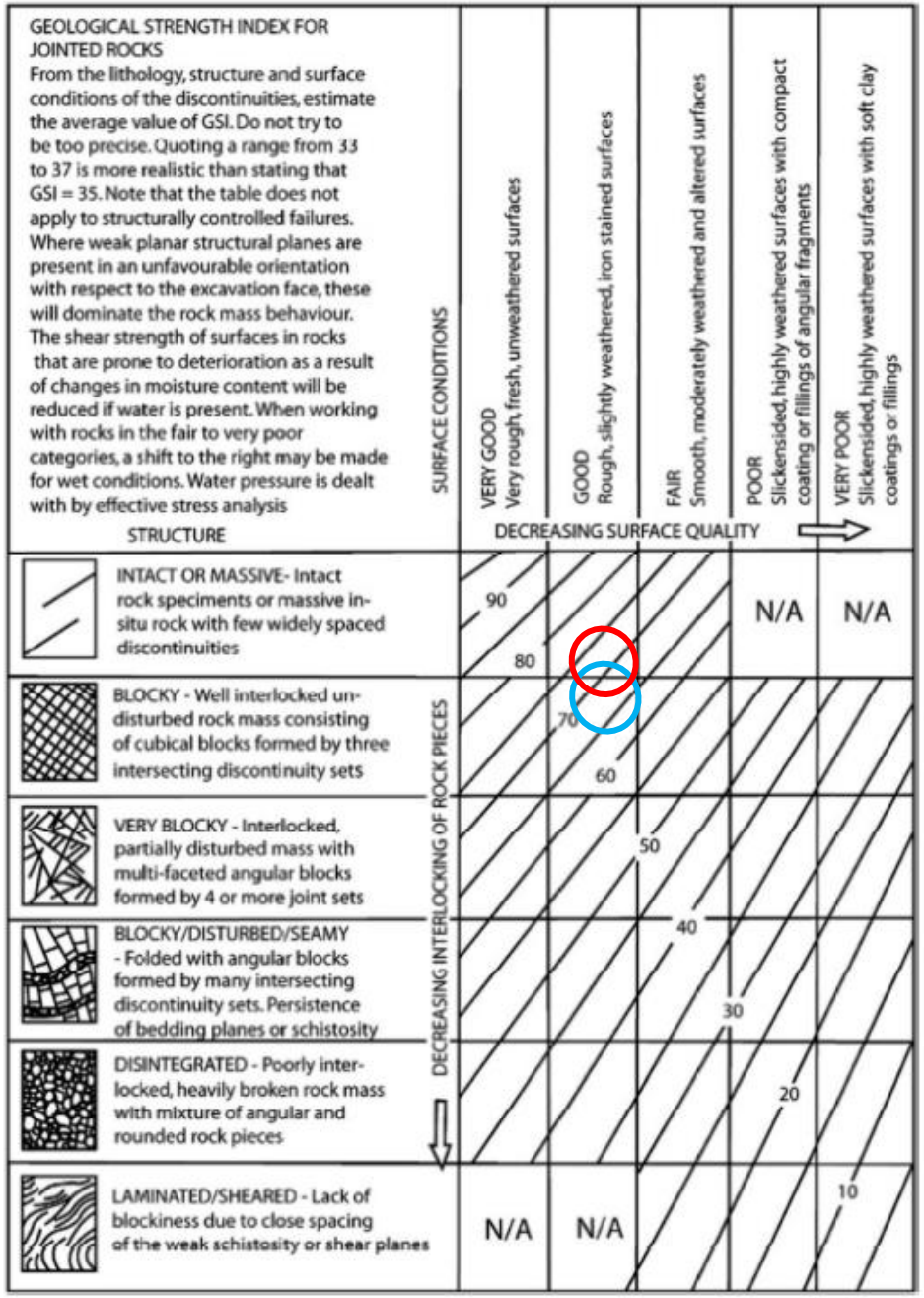
GSI Estimates MEC049

Area	GSI Range	GSI Best Estimate	Equivalent RMR89
Exterior	50 – 60	55	60
Interior	56 – 66	61	66



GSI Estimates MEC003

Area	GSI Range	GSI Best Estimate	Equivalent RMR89
Exterior and Main Chamber	67 – 77	72	77
Rear Chamber	63 – 73	68	73



GSI Estimates MEC025

Area	GSI Range	GSI Best Estimate	Equivalent RMR89
All Areas	66 – 76	71	76