ITEM 12.4

EMERALD QUARRY REHABILITATION PROJECT

Attachment 1: Emerald Quarry Monument Preservation and Quarry Stabilisation Strategy
Emerald Quarry

Monument Preservation and Quarry Stabilisation Strategy

District Council of Mount Barker

October 2014

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1 Introduction

The District Council of Mount Barker (DCMB) plans to rehabilitate Emerald Quarry and improve the visual amenity from the site and improve the educational experience and recreational use of the site. Remediation of the site will give back to the community areas of natural bushland that border the Mount Barker Summit Conservation Reserve and preserve significant geological landmarks, such as the Nairne fault which is exposed at the quarry site. The Nairne fault exposure has been classified as a Geological Monument and is occasionally visited by educational groups to study fault-line that delineates an unconformity between Kanmantoo Group rocks and the older Neoproterozoic Mt Barker Quartzite, making it a valuable educational location. The quarry is presently unsafe for general public access with erosion and loose rock faces and scree creating unsafe footing and potential for rock-fall. Rehabilitation of geologically significant areas requires consideration of principles outlined in the Heritage Places Act 1993 South Australia; Sections 25 and 28.

The DCMB has commissioned Tonkin Consulting to provide a Landscape Masterplan to redevelop the Emerald Quarry site as a recreational landmark that links to the existing Mount Barker Summit conservation park and meets stakeholder expectations on environmental and cultural heritage values. The Landscape Masterplan includes reports and plans contained in: EBS Ecology - Emerald Quarry Biodiversity Assessment and Management Plan, Sept 2014; EBS Heritage - Emerald Quarry Cultural Heritage Assessment, July 2014 and this Report (Tonkin Consulting Monument Preservation and Quarry Stabilisation Strategy, Nov 2014).

To facilitate the Landscape Masterplan stabilisation works will be required to make the site safe during construction, to enable public access for recreational use and to preserve and enhance the geological features present at the site. Tonkin Consulting has undertaken a geological and stability assessment of the site to determine the stabilisation strategies required to facilitate the design concepts proposed in the Landscape Masterplan.

1.1 Objective

The objective of this work was to define the extent of the Nairne Fault exposure and other significant geological features present at the site and stabilisation strategies required to enable public access for recreational use and to preserve and enhance the geological features present at the Emerald Quarry site (the Site).

The scope of work undertaken was to:

1. Review background reports, including the Rehabilitation Proposal report prepared for the Highways Department; “Geological Monuments in South Australia” and other available geological reports and maps;

2. Map the geology of the Site to:
   • Develop a conceptual site geological model and map, showing geological units, define the probable extent of the fault exposure and identify potentially unstable geological units;
   • Visually assess the Site for evidence of site contamination;
   • Provide preliminary advice on stability from observed slopes, rock types, bedding and fracture orientations, weathering, rock fall history; and

3. Assess the geology of the Site and quarry faces to determine areas where stabilisation works are required and provide potential strategies for site stabilisation and geological monument preservation.
1.2 Site Details

1.2.1 Site Location and Use

Emerald Quarry was an open cut quarry positioned adjacent to the South Eastern Freeway, approximately 40 kilometres from Adelaide. The quarry is located on the northern end of the Mt Barker Summit Reserve, approximately 5.5 kilometres east of the township of Mt Barker. Emerald Quarry’s location is shown in Figure 1.1 and site features are presented in Appendix A – Site Plans.

Mt Barker Quartzite was quarried at Emerald Quarry for concrete aggregate used in the construction of the South Eastern Freeway in the mid 1970’s. The quarry has remained unused since approximately 1977 and was left in a partially rehabilitated condition.

Figure 1.1 Emerald Quarry site investigation area located adjacent to the South Eastern Freeway in the Adelaide Hills. Map and site plan sourced from Google Maps.
1.2.2 Geological Setting

Rocks exposed in the Emerald Quarry area range in age from Precambrian (Neoproterozoic)\(^1\), approximately 650 million years, through to Tertiary\(^2\), approximately 20 million years old. Locally, the upper Precambrian Marino Group meta-sediments occur to the west of the enduring Neoproterozoic Mt Barker Quartzite, known regionally as ABC Range Quartzite (Figure 1.2). Mt Barker quartzite is oriented in a north south direction and forms Mount Barker Summit. The north trending Nairne fault runs through the quarry and marks the boundary between Mt Barker Quartzite and the younger, Lower Cambrian Kanmantoo Group metamorphics to the east, approximately 450 million years. Emerald Quarry is the only known location where the fault is exposed in the Adelaide Hills region. Detailed geological maps are presented in Appendix A – Site Plans.

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\(^3\) DMITRE, 2012, Milang 1:100 000 Geological map; 2012, and Geological Monuments in South Australia DVD – Department for Manufacturing, Innovation, Trade, Resources and Energy
1.2.3 Geological Heritage

Nairne Fault traverses the eastern face of Mount Barker Summit. A section of the fault was exposed through quarry activities in the north east of Emerald Quarry (Figure 1.3). Emerald Quarry is the only locality other than the south coast of Fleurieu Peninsula where Kanmantoo Group rocks are seen in contact with older rocks along the exposure of Nairne Fault. Geologically, the fault zone is considered highly significant and makes the Emerald Quarry site a valuable educational and conservation location.

![Figure 1.3 Photograph of the Nairne fault zone (Geological Monument) when exposed in mid 1970s (Sourced from Reed, J.A. 1976)](image)

The exposure of Nairne fault at Emerald Quarry is a known and registered Geological Heritage Site\(^4\). The geological heritage site is registered as File No. OM20 - South Eastern Freeway (Mt Barker to Callington) and contains two items:

- Item 1 (OM20.1) refers to the exposure of the Nairne fault within the Emerald Quarry located along the South Eastern Freeway between Mt Barker and Callington, and
- Item 2 (OM20.1) refers to a road cutting through the Nairne Pyrite member.

Geological Heritage Sites provide evidence of the geological processes that formed the Earth and of the plants and animals that have lived on it. They encompass landforms and natural rock outcrops, river banks, sea cliffs and shore platforms in road cuttings, mines, quarries and other excavations. Some of the features of these sites are so outstanding or so rare that they are part of our natural heritage. Such places were previously called Geological Monuments but are now referred to as Geological Heritage Sites. Site boundaries to Geological Heritage Sites give


\(^5\) Government of South Australia: Department for Manufacturing, Innovation, Trade, Resources and Energy (2008) Geological Monuments in South Australia (DVD), MEDP No. 17, first edition March 2008 (Primary Industries and Resources South Australia) for the Geological Heritage sub-committee of the Geological Society of Australia (South Australia Division)
certainty of preservation. While Nairne Fault is a feature, not an area, which has heritage value, it is essential for land managers and land users to have a clearly defined boundary outside of which they know that the integrity of a site is not threatened by present or proposed activities. While each of the Geological Heritage Sites (item 1 and item 2) has established boundaries, some land within the boundary may not contain features of heritage value. The boundary for the Geological Heritage Site at Emerald Quarry is defined in the Geological Monuments of South Australia DVD data file as the entire Emerald Quarry. The map demarcating the Site boundary is provided with other relevant documents and images from the Geological Monuments DVD in Appendix B – Geological Heritage.
2 Geological Assessment

2.1 Review of Background Documentation and Previous Reports

Review of the November 1992 Rehabilitation Proposal for Emerald Quarry Mount Barker\(^6\) compiled for the Department of Road Transport was undertaken by Tonkin Consulting. The proposal included reports written for:

- Geological Monument submission (File No. OM20)\(^1\). The Geological Monument report was written in 1978 by S. Toeteff who completed his PhD Thesis on the geology of the Adelaide Hills region\(^7\); and
- The Mount Barker Quartzite Quarry, by J.A. Reed (1976)\(^4\).

Geological Monuments of South Australia DVD contains report File No. OM20 relating to the Emerald Quarry and other geological monuments currently registered in South Australia. The report document is titled File No. OM20 - South Eastern Freeway (Mt Barker to Callington) and contains information about:

- Item 1 (OM20.1): The only exposure of the Nairne Fault; and
- Item 2 (OM20.2): Road cutting through the Nairne Pyrite.

2.1.1 Geological Monument (Geological Heritage Site)

Item 1 of File No. OM20 registered as OM20.1 (the only exposure of the Nairne Fault) refers to the Emerald Quarry site. Significant sites such as this have been nominated and registered as part of SA’s natural heritage and were originally known as Geological Monuments however are now referred to as Geological Heritage Sites.

A photograph taken of the Nairne Fault exposure within the Emerald Quarry during the 1970s is provided in File No. OM20.1 and reproduced as Figure 6. Other relevant documentation from the file including a map of the Geological Heritage Site and the “feature” location (Fault Zone) are provided in Appendix B.

The significance of the monument as described in the nomination is:

- The only known exposure (at the time of writing) of the Nairne Fault which separates Adelaidean sedimentary rocks to the west from the metasediments of the lower Cambrian Kanmantoo Group to the east.

2.1.2 Mt Barker Quartzite Quarry (Emerald Quarry)

Mount Barker Quarry, now known as Emerald Quarry, was first worked by Emerald Quarry Industries Pty Ltd until the site was acquired by the Commissioner of Highways in 1973 for realignment and construction of the South Eastern Freeway.

The Mount Barker Quartzite Quarry report notes the quartzite bedding as striking approximately magnetic north-south and dipping towards the east at angles varying from 55-60 degrees on the western edge, 25-35 degrees in the centre and steepening to 40 degrees on the eastern edge. Structure within the quartzite includes jointing and fractures which strike at both right angles and parallel to bedding and dipping to the north, west or east. Normal faults have formed striking north-south and dipping steeply east due to stresses developed during folding with faulting. The surface of fault planes varies from planar to broadly curved and undulating with linear slickensides.

\(^6\) Savarton and Potter, Rehabilitation Proposal, Emerald Quarry Mount Barker, SA. Department of Road Transport, November 1992

2.2 Environmental and Geological Site Inspection

An environmental and geological site inspection of Emerald Quarry was conducted on 17 February 2014. Site details follow in Table 2.1 and Table 2.2.

### Table 2.1 Site Details

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>Council Area</td>
<td>District Council of Mount Barker</td>
</tr>
<tr>
<td>Site Ownership</td>
<td>Currently DPTI. Proposed upon variation of property boundary to become owned by or responsibility of District Council of Mount Barker</td>
</tr>
<tr>
<td>Property Address</td>
<td>Access is via Summit Road, Mount Barker Summit in Hundred of Kanmantoo</td>
</tr>
<tr>
<td>Property Description</td>
<td>Public Road or Other Tenure (Road Reserve for the South Eastern Freeway)</td>
</tr>
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The main observations from the site inspection are summarised in Table 2.2. Site inspection photos are referenced in the table and are presented following.

### Table 2.2 Environmental and Geological Observations

<table>
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<th>Item</th>
<th>Description</th>
<th>Plate</th>
<th>(photos)</th>
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<tbody>
<tr>
<td>Current Site Usage</td>
<td>Currently unused (former quarry) and Geological Heritage Site</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Previous Site Usage</td>
<td>Quartzite Quarry</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Land use to the North</td>
<td>South Eastern Freeway. Broadscale agriculture and horticulture, north of the freeway</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Land use to the South</td>
<td>Mt Barker Summit Conservation Reserve</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Land use to the East</td>
<td>Summit Road and agriculture</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Land use to the West</td>
<td>Agriculture</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Access to Site</td>
<td>Inaccessible unless in a 4x4/AWD vehicle with high clearance. The site is accessed by a steep track from Summit Road. The track has a sealed entranceway followed by an steep, unsealed section (approximately 200 m long) that is rough and has been washed out over the majority of its length. Washed out erosion gullies are up to 1 m deep.</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Onsite Site Access</td>
<td>Uneven rocky terrain, old unsealed track prone to erosion and weed growth.</td>
<td>5 &amp; 6</td>
<td></td>
</tr>
<tr>
<td>Vegetation</td>
<td>The majority of the vegetation is in good health, with large established trees throughout the quarry. The eastern slope has moderate cover of shrubs and trees. Large sections of the site are covered in Ulex europaeus (gorse) a thorny shrub that is listed under the Weed of National Significance (WONS). Some sectors within the site have established Cyprus spp. and Pinus spp (pine) trees, which have been ring barked previously and present a safety hazard. Near these trees are a significant number of pine and other exotic species seedlings that could eventually become established. Further information on vegetation type and condition is provided in EBS 2014, Emerald Quarry Biodiversity Assessment and Management Plan, prepared by EBS for DCMB.</td>
<td>5 &amp; 6</td>
<td></td>
</tr>
<tr>
<td>Waste present on site</td>
<td>Minimal amounts of waste left throughout the quarry. Old tyres, 44 gallon drums, oil drums, old machinery or vehicle parts and sheets of galvanised iron.</td>
<td>6 &amp; 7</td>
<td></td>
</tr>
<tr>
<td>Base soil patches</td>
<td>Bare soil patches are evident throughout the quarry and on the uppermost plateaus.</td>
<td></td>
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Stockpiles - Rock
The rock stockpiles consist of quartz boulders, ranging from 30 cm to 1.5 m in diameter, and gravel materials. Some of the materials could be recovered and reused as part of the site's infrastructure, such as barriers, seats and walking tracks. Some boulders have flat planes on all surfaces due to the orientation of fracture sets.

Soil stockpile
The soil stockpile has established trees and shrubs located on it. The stockpile consists of top soil and rocks from the quarry surface. On the south side of the pile, there are mature trees and established vegetation. Metal and other waste is located within the pile, including corrugated/galvanised iron, a rusted drum, canvas, and other miscellaneous fragments of waste. Large erosion gullies have formed approximately 3-4 metres from the stockpile, leading down to the site access track and out through the entrance of the property.

Warning Signs/Notices
No warning signs or notices are visible.

Stability of rock faces
Rock debris occurs at the base of rock faces. Many of the rock faces and debris (scree) mounds are unstable, particularly where overhanging or steep rock faces occur.

Erosion
On the eastern and western hillsides of the site, signs of erosion are evident. Minor signs of erosion are present within the quarry. Gully erosion exists at the soil stockpile and site access track.

Groundwater
Evidence of groundwater seeping through the centre of the red/brown rock face on the second tier of the quarry.

Features of Interest
- Nairne fault exposure:
The Nairne fault zone is exposed in a relatively small (0.5 Ha) portion of the Emerald Quarry site. The main structural features of the fault zone have been obscured by scree and topsoil that has eroded from above the fault however the distinction between the major lithological units can be seen. The visible features are best viewed from the quarry bench located immediately below the fault zone. Additional information on the condition of the fault exposure is provided in Section 2.3 and site plans in Appendix A.
  - Drill/blast holes:
    Drill holes / blast holes are evident in quarry faces in the southern portion of the site.
  - Sedimentary bedding:
The gradational contact between the Mt Barker Quartzite can be clearly seen overlying older meta-siltstone layers belonging to the Ulupa Siltstone. The east dipping bedding planes and transition between the geologic units are most obvious in the western portion of the quarry.
  - Tertiary conglomerates and tillite:
    Tertiary sandstones and conglomerates also outcrop at the Site and can be seen unconformably overlying the Cambrian rocks to the south east of quarry and above the Nairne fault zone.
  - Proximity to the Summit Conservation Reserve:
    Mt Barker Summit Conservation Reserve shares the southern boundary of Emerald Quarry site. The proximity to the Conservation Reserve provides an opportunity to enhance the natural, cultural and geological heritage values of the area once rehabilitation has been completed.
Plate 1 View from a quarry bench at Emerald showing quartzite in the foreground, looking north across the South Eastern Freeway

Plate 2 View of Emerald Quarry from Summit Road
Plate 3 View of Summit Road from Emerald Quarry, looking north east

Plate 4 On site access road –erosion channelling of track
Plate 5  *Ulex europaeus* (gorse) and native vegetation occurring within the quarry

Plate 6  Dead bushes and ring barked pine trees (dead)
Plate 7  Old tyre found on first tier of the quarry (most northern quarry bench)

Plate 8  Rock stockpiles (to left and right of view)
Plate 9 Soil stockpile with self-seeded native plants

Plate 10 Unstable rock faces and scree covered quarry benches (front right of view)
Plate 11  Unstable rock face located in the north western portion of Emerald Quarry, view looking south

Plate 12  Surface erosion of tracks located in the south eastern portion of Emerald Quarry
Plate 14  View of drill holes (blast holes) in rock face in the upper (southern) portion of Emerald Quarry

Plate 15  Nairne Fault Zone obscured by overburden (scree material)
The outcomes from the environmental and geological site investigation are presented in Table 2.2 and highlighted on Figure 3 – Appendix A. This information was used to progress the remediation design. Additional site photographs and panoramas are presented in Appendix C.

The outcomes from the environmental and geological site investigation are presented in Table 2.3 and highlighted on Figure 3 – Appendix A. This information was used to progress the remediation design. Additional site photographs and panoramas are presented in Appendix C.

Table 2.3 Implications for Landscape Masterplan concept design

| Location of pathways, viewing platforms and Educational Nodes | Walkways, viewing platforms and educational nodes proposed to for the site should be located away from unstable quarry faces and cliff-tops or unstable rock faces that are potentially undercut. The view from proposed Educational Node 1 (depicted on the draft Landscaping Plans, Figures 2-3 in Appendix A) should be relocated away from the rock face near the entrance to the quarry bench due to the occurrence of unstable, crumbling quartzite. Rock stability issues prevent access to or construction of Educational Node 2 (depicted on the draft Landscaping Plan in Appendix A) and could be repositioned to ‘point 12’ (shown on the Plan) to provide significant views of the landscape and of historic drill holes in the rock face (depicting quarrying methods). |

| Geological Heritage | The Nairne fault zone requires considerable earthworks to be re-exposed to the full extent visible in the late 1970s and remove unstable material surrounding the area that present a hazard to potential site users. The fault zone is best viewed from below the quarry face in which it is exposed. This preferred viewing location is at the top of a significant cliff edge which is partially undercut. A specifically designed platform will need to be constructed at the base of the fault zone to protect site users from potential hazards at this location. Other accessible locations do not provide the correct proximity to the fault or aspect to view the structural features of the Nairne fault. The location of the Nairne Fault Zone is shown in Figures 7a-7c, Appendix A. These plans outline a proposed “preservation area” required to protect the geological features of the Fault Zone from damage during rehabilitation works. |

2.3 Conceptual Site Geological Plan

In the Emerald Quarry area several formations can be observed ranging in age from Precambrian (Neoproterozoic), approximately 650 million years through to Tertiary, approximately 20 million years old. Regional and local geology maps of the Emerald Quarry area are presented in Figure 2 and in Appendix A – Site Plans. The local geology map and conceptual geological cross-section through a portion of the quarry have been prepared and are presented in Figure 4 and Appendix A – Site Plans.

The north-south trending ridge that forms Mount Barker Summit south of the Site, has resulted from differential weathering between the hard Mount Barker Quartzite and the adjacent, less resistant, phyllites and greywackes (meta-siltstones and meta-sandstones). The Mount Barker Quartzite is one of the southern-most equivalents of the extensive ABC Quartzite, which makes up a large proportion of the peaks and ridges of the Flinders Ranges.

Quarrying activities have exposed the contact between the Proterozoic aged Mt Barker Quartzite and younger Cambrian Kanmantoo Group Carrickalinga Head Formation rocks. The contact is marked by the north trending Nairne Fault zone. Bedding planes of the Mt Barker Quartzite strike north-south within the quarry area and dip to the east at varying angles, ranging from 58°E to 10°E. Bedding dips more steeply (60°E) at the Nairne Fault where the quartzite is sharply truncated and folded at the western margin of the fault zone.
To the west of the Mt Barker Quartzite there is outcropping of weathered meta-siltstones of the Ulupa Siltstone which regionally underlies the ABC Range Quartzite with a gradational contact. Locally the contact between the Ulupa Siltstone and Mt Barker Quartzite may be covered by scree and/or disguised by a zone of weathering.

Tertiary sandstones and conglomerates also outcrop at the Site and can be found unconformably overlying the Cambrian rocks to the south east of Emerald Quarry (Table 2.1). The Tertiary sandstones and conglomerates can be seen overlying the quartzite from the higher elevations of the quarry. The Tertiary unit occurs as ferruginous conglomerates. Based on the outcrop of Tertiary sediments, it is likely they were present above the quartzite throughout the south eastern portion of the Site prior to quarrying activities.

![Figure 2.1 Local Geological outcrop map of the Emerald Quarry site. Cross-section A-A' is presented in Figure 4.](image-url)
Figure 2.2  Geological Cross-section (east-west) through the Emerald Quarry Site, looking north.
3 Monument Preservation Strategy

A Monument Preservation Strategy is required to provide the overarching guidance and objectives for the longer-term maintenance and management to protect the important geological monument, in this case the Nairne Fault, during the rehabilitation works and also once incorporated as part of the Mount Barker Summit Conservation Reserve. The Monument Preservation Strategy has been prepared in consideration of guidance provided by the Government of South Australia: DMITRE (2008) Geological Monuments in South Australia, and the (South Australian) Heritage Places Act 1993, which include:

- Defining the extent of the area to be preserved to ensure that the strategy is focussed to the area requiring preservation;
- Aligning the Strategy with identified Aboriginal heritage items and Council expectations;
- Assessing the risks to the preservation of the monument, including risks associated with environmental factors, such as weathering and stability, and human factors, such as graffiti and souveniring; and
- Developing management and mitigation strategies to ensure protection of the monument from the identified risks. These strategies have informed other deliverables and management requirements at the Site.

3.1 Extent of Monument to be Preserved

The extent of the Geological Heritage Site ‘Preservation Area’ is indicated on in Figure 3.1 below and encompasses the deformation zone where bedding planes are folded and deflected by the Nairne fault. The ‘Preservation Area’ outlined in yellow on Figure 3.1 contains an area of undeformed bedding on either side of the fault zone to enable the destination between deflected and undeformed bedding planes to be made. Site plans demarcate the Preservation Area in Figures 7A and 7B, Appendix A – Site Plans. The ‘Preservation Area’ should be marked on-site prior to any site works being undertaken and also included on any plans for earthworks, pathways, stormwater run-off and catchment design or any other relevant plans. Outside of this area infrastructure needs to be designed to divert stormwater away from the area. Geological features to be preserved are shown in Figure 3.2 and Figure 3.3.

![Figure 3.1 Monument Preservation Area for Nairne Fault (yellow outline). Overburden covering exposure of Nairne Fault (centre top of quarry view, outlined in red)](image-url)
3.2 Preservation of the Monument

The (South Australian) **Heritage Places Act 1993** has provision (Sections 25 and 28) for special protection for sites that may be declared of geological or paleontological significance. Excavating or disturbing such sites and removing, damaging, destroying or disposing of...
specimens collected from these sites is prohibited without a Permit from the State Heritage Authority. Councils are encouraged to become involved in the preservation of Geological Heritage Sites because of their amenity value and potential tourist attraction. A number of councils have included such sites in their Development Plans and have acted to protect some sites, featuring them along walking trails and within reserves with interpretive brochures and/or signage. The rehabilitation of the Emerald Quarry provides this opportunity (where the recorded Geological Heritage site - Nairne Fault is exposed) by connecting the quarry, once rehabilitated, with the Mt Barker Summit Conservation Reserve via walking paths.

3.2.1 Current Condition and risks

When comparing the original image of the fault exposure taken in 1970s\(^3\) (Figure 3.2), with the photographs taken during the site inspection (Figure 3.3) it is apparent that the main risk to preservation of the monument is from; (i) earthworks during remediation works and (ii) environmental factors. Human factors such as vandalism and souveniring are not considered a major risk due to the massive nature of the feature but are included for consideration. Key risks include:

**Earthworks**

1. Physical damage during earthworks required to expose the Nairne Fault;
   - The Fault zone is currently obscured by a scree slope of overburden material that has spilled over from the top of the feature due to erosion and previous clean up of the quarry surface above the feature;
   - The overburden obscuring the western portion of the Fault zone would need to be removed if the entire Fault zone is to be exposed, however complete exposure is not required for use as an educational monument;
   - Access to the Fault zone by earth moving equipment is limited and removing material by hand is unlikely to be feasible or safe;
   - A long reach excavator could push scree to the lower bench however supervision by an Engineering Geologist will be required to prevent over-excavation and damage to the feature.

**Environmental**

2. Weathering and erosion of both the Fault Zone and rock faces in the vicinity of the Fault exposure;
   - Continuing erosion of the large quarry bench which is the main level of the quarry above the Nairne Fault zone is directing stormwater run-off and sediment to the Fault Zone, increasing weathering and erosion of the Fault Zone and obscuring the Fault;
   - Erosion control measures will be implemented through stormwater management.

3. Rock Fall;
   - Loose rock consisting of quartzite and Tertiary conglomerate is positioned above the approach to the monument viewing area, above the exposed Fault zone and obscures the western portion of the Fault zone;
   - Rocks located at the toe of the Fault zone are unstable due their rounded shape and proximity to the edge of the lower quarry face;
   - The quarry face located immediately to the west of the Fault Zone has an unstable edge with overhangs which will require stabilizing prior to remedial works to expose the Fault.

**Human Factors**

4. Vandalism and souveniring;
• Vandalism and souveniring of the rock faces is considered unlikely given the ‘massive’ nature of the geological feature. Vandalism by graffiti is possible.

5. Climbing on monument;
• The blocky structure of rock within the Fault Zone is unlikely to remain stable if climbed upon and the monument viewing area is located adjacent to an unstable edge (to the west of the viewing platform).

3.2.2 Key Preservation Strategies for Monument

Key preservation strategies include, but are not limited to:

• Control erosion and runoff, though the Stormwater and Landscape design elements of the Landscape Masterplan:
  − Manage stormwater run-off by diverting runoff away from the top of the Fault Zone. Elements of the stormwater management and landscape design planned for the area above the Fault Zone will capture and divert run-off to a detention basin located a sufficient distance east and down gradient of the Fault Zone to prevent infiltration and seepage of water in the vicinity of the Fault Zone. Aquatic planting of the stormwater diversion drains and the detention basin would further minimise erosion of material that has potential to further degrade the Fault Zone exposure;

• Remove precarious material from areas immediately up slope of the Fault Zone that is unstable and moving down slope to cover the Fault exposure. Precarious material located above the Fault zone, viewing platform and walking paths should be removed or ‘made safe’ prior to undertaking remediation works in this area of the site;

• Improve soil stability in the vicinity of the car park and bus turnaround areas by providing a hardstand area to reduce water infiltration and direct stormwater flow away from the Monument area. Soil stability should be improved by revegetated verges;

• Revegetate the area immediately atop the feature to improve stability of the scree material and reduce soil movement down-slope;

• Stabilise the quarry bench and areas above the Fault Zone through:
  − Hand removal (barring down) or stabilizing Tertiary rocks prior to site remediation to avoid further destabilizing the soil and scree slope that obscures the Fault Zone;

• Remove loose rocks by hand or mechanical scaling from slopes and cut faces and clear debris from quarry benches and paths;

• Protect public accessing the area by constructing raised viewing platforms that maximise the size of the accessible area allocated to viewing of the monument, prevents erosion and prohibits people from accessing unstable areas or dangerous edges;

• Prevent erosion by limiting foot traffic to defined paths and the raised viewing platform located at the base of the Monument area;

• Locate paths and viewing platform a suitable distance from unstable slopes and edges;

• Carefully expose the Fault Zone:
  − Due to the nature of the Site it may not be feasible to re-expose the entire Fault zone Monument;
  − Supervision of earthworks by an engineering geologist is essential to minimise the potential for damage to the Fault Zone, ensure appropriate features of the Fault Zone are exposed and maintain slope stability;
- Topsoil and boulders of Tertiary conglomerate that obscure the Fault Zone may be used to landscape or create barriers (to prevent public access or contain rock falls) elsewhere on the site, such as the quarry platform located immediately below the Monument.
4 Quarry Stability Assessment

4.1 Introduction

Geological characteristics pertaining to instability of rock faces and edges were inspected to identify areas of high risk and where stabilisation requirements may present impacts to aspects of the conceptual design. Stability management options for the quarry faces were assessed with respect to the remediation design. The assessment was undertaken by geologists from Tonkin Consulting and Geotechnical Engineer Roger Grounds from Wallbridge and Gilbert. A Preliminary Geotechnical Assessment report is provided in Appendix D with extracts from this report included in the commentary below.

4.2 Observations

The key observations reported for the Site by the Geotechnical Engineer were:

- Within the Quarry, siltstone and quartzite is capped in places by Tertiary aged sand, sandstone and lateritic conglomerates. In places the conglomerates contain large, rounded boulders up to 1 m across;
- The quartzite is typically slightly weathered and estimated to be of very high (possibly extremely high) strength. The quartzite ranges from highly fractured to relatively massive (defect spacing ranging from about 100 mm to over 1 m);
- Defects observed within the quartzite included bedding and several joint sets. The perpendicular orientation of these persistent defects results in extensive planar surfaces being exposed in the quarry faces in many places;
- The quarry faces were of varying height and shape, with the profile largely governed by the nature and orientation of the defects;
- At the base of some quarry faces, stockpiles of rock from past quarrying activities or recent instability were evident.

4.3 Stability Considerations

Debris from recent and historic rock falls from the quarry faces as well as from potentially unstable zones in the cut batters was abundant on quarry benches. The fragments of debris from the recent rock falls ranged from about 0.002 m³ to around 1 m³ in size. The volume of debris appeared to be relatively small, consistent with localised small scale instability in the quarry faces (several cubic metres in size). There was no evidence of any large scale instability (tens to hundreds of cubic metres). The small scale instability observed is considered to be associated with mechanisms such as:

- Existing unfavourably orientated defects in the quartzite (e.g. defects dipping out of the face);
- Intersecting joint sets;
- General stress relief and opening of existing defects;
- On-going weathering;
- Blasting induced damage;
- Loose debris at the crest of the slope.

The presence of unfavourably orientated defects has resulted in toppling, sliding and wedge-type failure mechanisms and, in places, has formed under cut or over hanging sections. The predominantly easterly dipping and persistent defects near the northern end of the quarry are considered to be conducive for on-going sliding and toppling failure. Particular areas of instability
noted during the site walk-over are summarised in Table 4.1 below. Stabilisation options applicable to these areas are provided also.

**Table 4.1 Significant Environmental and Geological Features (refer to areas identified on the Stabilisation Site Plan in Appendix E)**

<table>
<thead>
<tr>
<th>Geologic Unit</th>
<th>Area of Quarry</th>
<th>Geological Characteristics</th>
<th>Potential Stabilisation Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil, Tertiary conglomerate, siltstone and quartzite</td>
<td>Platforms</td>
<td>Debris located on platforms, slopes, near edges and on quarry faces</td>
<td>Clearing the debris and barring down (scaling) unstable rocks from slopes, Rock debris is sufficient to be used to construct catch ditches and barriers at the foot of rock faces, Use larger boulders to create barriers to protect paths from rock falls and set exclusion zones at the base of rock faces and at the top of dangerous edges.</td>
</tr>
<tr>
<td>Soil, Tertiary conglomerate, siltstone and quartzite</td>
<td>Nairne Fault Zone</td>
<td>Loose quartzite boulders at crest of slopes, Loose conglomerate boulders on western side, Undercut</td>
<td>Prevent erosion and run off from above the feature with stormwater and erosion management systems, Create catch ditches and barriers on the lower platform, Excavate soil and debris under the supervision of an engineering geologist to re-expose the Fault zone as far as practically possible. Debris can be knocked down to lower platform, Stabilize boulders by dental concrete, where required, Maintain safe distance for paths and viewing platform footings atop undercut areas.</td>
</tr>
<tr>
<td>Quartzite and siltstone</td>
<td>Ridgeline in northern end of quarry</td>
<td>Extensive cracking (blast induced) in the quarry face, numerous potentially unstable blocks of quartzite and overhangs, Recent debris includes individual blocks up to about 1m³ in size at base</td>
<td>Bar down loose blocks and remove overhangs by trimming to slope consistent with bedding planes or fracture sets, Where west dipping bedding planes exist as the quarry rock faces the rock faces are relatively free of debris and currently in their most stable form, Excessive disturbance of the areas above or below these faces may contribute to instability of the surfaces and therefore increase risk of rock fall or collapse,</td>
</tr>
<tr>
<td>Quartzite and siltstone</td>
<td>Upper (older) quarry faces</td>
<td>Over-hanging and undercut sections</td>
<td>Create catch ditches and barriers using large quartzite boulders and maintain maximum buffer zone for paths within the space available, Catch netting may be required to prevent rocks rolling to the road reserve, Catch netting may be required during earthworks.</td>
</tr>
<tr>
<td>Soil, Tertiary conglomerate, siltstone and quartzite</td>
<td>Crest of cut batters</td>
<td>Extensive loose cobbles and boulders of varying sizes (including surficial fill).</td>
<td>Bar down loose blocks and remove overhangs by trimming to slope consistent with bedding planes or fracture sets.</td>
</tr>
<tr>
<td>Soil, fill, and stockpiles</td>
<td>Main quarry bench</td>
<td>Erosion</td>
<td>Prevent erosion by diverting storm water away from easily eroded soil, Re-use soil materials on-site and profile stockpiles for landscaping and re-vegetation.</td>
</tr>
</tbody>
</table>
4.4 Stabilisation Options

The geological and geotechnical assessments were undertaken to support the Stability Options (Table 4.1), Monument Preservation Strategy (Section 3) and proposed Landscape Masterplan. Commonly available stabilisation options considered suitable to improve the stability of rock cuts and thereby reduce the likelihood and potential for rock falls at the Emerald Quarry include:

- Selective scaling of quarry faces and barring down loose or unstable rock fragments;
- Excavation of loose surface materials;
- Rock fall netting;
- Rock bolts;
- Passive dowels;
- Shotcrete or dental concrete.

The various options are used in different applications and cost. The options should be used in conjunction with the formation of “buffer” zones (or in unfavourable areas “exclusion” zones) around the base of the quarry faces to reduce the potential for rock falls impacting on the public. A buffer or exclusion zone would also be required at the crest of the quarry faces to keep the public away from the edge.

To ensure appropriate stability options are selected and correctly applied or installed, the stabilization works should be supervised by an Engineering Geologist. During the initial remedial works, the Engineer shall assess the condition and stability of the quarry faces and the requirements for remedial works.

The assessment would typically involve geotechnical mapping of the quarry faces to target the more critical or sensitive areas along the proposed walking trails. It is essential that liaison be maintained with the designer of the walking trails to ensure that the key areas are addressed.

On completion of the stabilisation works the Engineer shall provide Geotechnical Certifications in the form of a stability assessment report and management plan for the site stating that the site is suitable for the intended uses detailed in the Landscape Masterplan. As part of the stability assessment report, aftercare management and monitoring requirements are to be outlined that ensure an appropriate level of safety can be maintained for Site users. The aftercare requirements shall be specified by the Engineer.

4.5 Stabilisation Strategy

With consideration of the proposed Landscaping Masterplan a Stabilization Plan (Appendix D) was developed for the site and to preserve the Nairne Fault Zone. Once the Landscape Masterplan has been finalised by DCMB the stabilisation requirements will be refined in consultation with the Earthworks Contractor and Engineering Geologist (engaged by the Earthworks Contractor).

A suitable stabilisation strategy for cut faces in the Emerald Quarry would comprise:

<table>
<thead>
<tr>
<th>Stabilization Strategy</th>
<th>Purpose and Limitations</th>
<th>Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial Works to make site safe for remediation</td>
<td>Scrape back loose material from atop slopes and cut faces Clear debris from paths and access / working areas</td>
<td>Cut faces and benches (whole site)</td>
</tr>
<tr>
<td>Hand Scaling</td>
<td>Remove loose rock from slopes and cut faces, clear debris</td>
<td>Cut faces and benches (whole site)</td>
</tr>
<tr>
<td>Stabilization Strategy</td>
<td>Purpose and Limitations</td>
<td>Area</td>
</tr>
<tr>
<td>------------------------</td>
<td>-------------------------</td>
<td>------</td>
</tr>
<tr>
<td><strong>Stabilisation Works – to be supervised by an Engineering Geologist</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reshaping</td>
<td>Re-cut steep and eroding faces to reduce overall angle and height of profiles and divert runoff. Debris generated may be suitable for fill, capping or top dressing,</td>
<td>Tertiary units, scree slopes and soil/rock stockpiles</td>
</tr>
<tr>
<td>Hand and Mechanical Scaling</td>
<td>Remove additional loose rock from slopes and cut faces by hand and mechanical methods. Trim blasting may be required in some areas to remove larger over-hangs. Remove rock fragments from the crest of cut faces, The scaling and barring should be done where possible working from an elevated platform with hand operated tools. Care must be taken to remove only potentially unstable rock fragments. The use of excessive force may be detrimental to the face and result in a significant volume of extra material being removed, In some places (e.g. northern end of quarry) the use of a long reach excavator, fitted with a rock pick would be more appropriate to remove unstable materials, During scaling and barring, care must be taken to control rock falls so as to avoid rocks travelling to the lower section of the quarry (or possibly rolling to the freeway).</td>
<td>Cut faces and benches (whole site)</td>
</tr>
<tr>
<td>Catch Ditches</td>
<td>Construct catch ditches at the base of slopes and quarry faces, and where necessary construct barriers and fences using site won rock,</td>
<td>Base and top of slopes adjacent paths</td>
</tr>
<tr>
<td>Buffer / Exclusion Zones</td>
<td>Establish buffer zones (exclusions zones) at the base of quarry faces and the top of edges to limit public access, The buffer zones should be demarcated using large boulders of quartzite. Vegetation planted within the buffer zone would assist in restraining any rock falls, The width of the buffer zone at the base of the quarry faces would depend on the height and condition of the rock face (following remedial works) with a wider buffer zone required for less stable faces. Shorter buffer distances may require additional scaling works and barrier systems, Provision of exclusion zones in areas of high risk, where stabilisation work is cost prohibitive or otherwise difficult. For example, given the unstable conditions of the northern section of the quarry face, and the more extensive remedial works required, an exclusion zone could be considered in this region, Raised viewing platforms, boardwalks, fencing and other structures (including strategic placement of large quartzite boulders or rubble stockpiles or water features) can provide physical barriers to rock fall and public access,</td>
<td>Base and top of slopes adjacent paths</td>
</tr>
<tr>
<td>Buttressing</td>
<td>Support unstable faces with suitable rock debris and compacted soil to provide lateral support and flatten slopes,</td>
<td>Lower cut faces</td>
</tr>
<tr>
<td>Barriers</td>
<td>Create barriers using a combination of large rocks dry-stack walls, fencing and netting to catch rock-falls and prevent public to buffer zones and exclusion zones, Planting along walkways and car parking spaces to provide physical barriers. Clear benches for placing top soil in areas where re-vegetation is planned,</td>
<td>Base and top of slopes adjacent paths</td>
</tr>
</tbody>
</table>
## Stabilization Strategy

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Purpose and Limitations</th>
<th>Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dental Concrete</td>
<td>Dental concrete may be required in some areas and this would need to be determined during the Hand and Mechanical Scaling by the Supervising Geotechnical or Engineering Geologist.</td>
<td>Whole site</td>
</tr>
<tr>
<td>Rock anchors and bolting</td>
<td>Rock reinforcement techniques are not considered suitable for the majority of the site due to the blocky nature of the quartzite and siltstone;</td>
<td>Whole site</td>
</tr>
<tr>
<td>Shotcrete</td>
<td>Shotcrete is not recommended for use at the site due to its impact on site aesthetics;</td>
<td>Whole site</td>
</tr>
<tr>
<td>Netting</td>
<td>Permanent rock netting is not recommended for use at the site due to its impact on site aesthetics and potential for misuse by site users (for climbing). Rock netting may be a suitable temporary protection measure to arrest rockfalls and rolls during earthworks.</td>
<td>Whole site</td>
</tr>
</tbody>
</table>

## Drainage and erosion control

<table>
<thead>
<tr>
<th>Surface water management</th>
<th>Purpose and Limitations</th>
<th>Area</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Particular consideration should be given to surface drainage, particularly in the Tertiary sediments and extremely weathered siltstone which flank the quartzite. Runoff has resulted in significant scour and gully erosion in places in the more weathered siltstone and Tertiary sediments,</td>
<td>Whole site</td>
</tr>
<tr>
<td></td>
<td>The use of drainage swales, berms and rock pitching is recommended to prevent or reduce the velocity of concentrated surface flows,</td>
<td></td>
</tr>
<tr>
<td>Weep Drains</td>
<td>Reduce water pressure within slopes using horizontal drains,</td>
<td>Cut faces where seepage water evident</td>
</tr>
<tr>
<td>Vegetation</td>
<td>Establish high water use and wetland vegetation in soakage areas and to reduce erosion,</td>
<td>Whole site</td>
</tr>
</tbody>
</table>

## Signage and Security

<table>
<thead>
<tr>
<th>Purpose and Limitations</th>
<th>Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>The provision of appropriate signage to warn the public of the potential rock fall hazards, shear drops and to prohibit climbing on the faces,</td>
<td>Whole site</td>
</tr>
<tr>
<td>Lockable gates and fencing should be erected as required to prevent irresponsible use of the site,</td>
<td></td>
</tr>
</tbody>
</table>

## Aftercare

<table>
<thead>
<tr>
<th>Purpose and Limitations</th>
<th>Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Following completion of remedial works a detailed Management Plan should be prepared, which details the requirements for regular monitoring and reassessment of the quarry faces.</td>
<td>Whole of site</td>
</tr>
<tr>
<td>It is inevitable that the condition of the faces will deteriorate over time from a variety of natural processes (such as weathering, animal activity, tree root jacking. The Management Plan will need to document a mechanism which provides an expeditious response to rock fall events.</td>
<td></td>
</tr>
<tr>
<td>Provisional requirements for Monitoring are provided below.</td>
<td></td>
</tr>
</tbody>
</table>

## Additional considerations during the rehabilitation of Emerald Quarry are:

- As far as practical, seating, shelters or interpretive signs should be located in areas of the quarry outside of the buffer zones where the cut faces are more stable;
• In front (north) of the Nairne Fault Zone, an elevated viewing platform could be considered to reduce the risk to public from local rock falls. The platform would need to be positioned at least 3 m from (east of) the top edge of a vertical and undercut quarry face located further to the west.

4.6 Monitoring

On-going monitoring of rock faces will be required to manage risks associated with site stability following events. This will help prevent further slope failures or rock falls following or due to:

• Rain / storm events;
• Track and site maintenance;
• Displacement by vegetation, and;

Displacement by animals or public access.

4.6.1 Targets for success

Monitoring of slope and rock face stability and integrity of paths, barriers, gates and safety signage should be undertaken to ensure an acceptable standard of safety is achieved.

Suggested targets include:

• No injuries to Council or contractors during site remediation works;
• No injuries to public or Council or contractors once site is opened;
• No rock fall debris to encroach on public access areas;
• Damage sustained by protective infrastructure to be assessed and repaired prior to public access being re-instated.

4.6.2 Monitoring requirements

Permanent photo points should be established to monitor quarry faces during each stage of the restoration process and following complete rehabilitation to give an indication of the success of rehabilitation and provide a baseline from which to assess change. Photo points should be maintained indefinitely and utilised/monitored quarterly in the first 12 months (reviewed biannually thereafter) and following storm events or extended wet periods. Site walkover inspections should accompany each monitoring event.

Potential hazards and indicators of increased risk should be observed during inspections. The hazards and indicators of note include the following:

• Rock fall history / frequency, as indicated by new debris in catch ditches and benches or paths. Further investigatory action should be undertaken if rock fall debris is noted on paths;
• Presence or evidence of water or erosion on or of slopes or rock faces should be noted. Further action should be undertaken if slopes appear instable or stormwater infrastructure is in need of maintenance;
• Slope instability or precarious rocks should be noted and the hazard remediated. Access to hazardous areas should be restricted until the hazard is removed;
• Unsafe behaviour of public observed or evidence of public accessing restricted areas should be noted. Appropriateness of barriers and signage should be reviewed.
Appendix A

Figures
Appendix B

Baseline Data and Background Information
Appendix C

Site Photographs and Panoramas
Appendix D

Stabilization Plan
Appendix E

Geotechnical Assessment Report