Hornsby Shire Council

Hornsby Quarry Rehabilitation Environmental Impact Statement

VOLUME 3 – APPENDICES G to K

February 2019

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Appendix G – Aboriginal survey report

Hornsby Quarry

Aboriginal Archaeological Survey Report

Report to GHD

Hornsby Local Government Area

November 2018

artefact

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EXECUTIVE SUMMARY

Artefact Heritage Services Pty Ltd (Artefact Heritage) has been engaged by GHD on behalf of Hornsby Council (the proponent), to undertake an Aboriginal Archaeological Survey Report (ASR). The aim of this ASR is to assess and identify any potential Aboriginal sites or places within the study area that might be impacted by the proposed works.

Hornsby Shire Council proposes to rehabilitate the Hornsby Quarry void to create a landform suitable for future development as community parkland, which will require filling and stabilisation. The landform would include a lake directly below the exposed eastern face of the quarry.

Artefact Heritage has prepared this ASR in accordance with the 'Code of Practice for Archaeological Investigation of Aboriginal Objects in New South Wales' (the OEH Code of Practice). This report has been prepared in accordance with the Secretary's Environmental Assessment Requirements (SEARs 1167) to assess and identify whether Aboriginal sites or areas of archaeological potential may be impacted by the proposal.

Overview of findings

- The archaeological survey was undertaken on 21 September 2018. The survey was undertaken by Ryan Taddeucci (Senior Heritage Consultant, Artefact Heritage) and Jennifer Norfolk (Heritage Consultant, Artefact Heritage). Kevin Telford (Aboriginal Site Officer, Metropolitan LALC) represented the LALC during the survey. Craig Clendinning (Project Manager, Hornsby Council) and James Frawley (Hornsby Council) acted as escort.
- No Aboriginal archaeological site or areas of PAD were identified within the study area

Recommendations

- No further Aboriginal archaeological investigations or assessment is recommended for the study area and currently proposed works.
- Where changes to the scope of the proposal result in impacts beyond the extent of what has been assessed in this report, further archaeological survey and addendum ASR reporting will be required.
- If there is a variation to the proposed works design or impact area that will affect land that has not been assessed in this report, further Aboriginal heritage assessment will be required.
- If the proposed works are altered to include scope for removal of the potentially intact natural ground surface beneath the spoil mounds, further Aboriginal heritage assessment will be required.
- An unexpected finds policy should be implemented, which should include the following conditions:
    - Stop work within the affected area, protect the potential archaeological find, and inform environment staff or supervisor.
    - Contact a suitable qualified archaeologist to assess the potential archaeological find.
    - If Aboriginal archaeological objects are identified, works in the affected area should cease, and the OEH should be informed. Further archaeological mitigation may be required prior to works recommencing.

- If human remains are found:
  - Do not further disturb or move these remains
  - immediately cease all work at the particular location
  - notify NSW Police
  - notify OEH’s Environment Line on 131 555 as soon as practicable and provide available details of the remains and their location
  - do not recommence any work at that location unless authorised in writing by the relevant government agency.

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ABBREVIATIONS

ACHAR	Aboriginal Cultural Heritage Assessment Report
AHC	Australian Heritage Council
AHIP	Aboriginal Heritage Impact Permit
AHIMS	Aboriginal Heritage Information Systems
ALR	*Aboriginal Land Rights Act 1983*)
Artefact Heritage	Artefact Heritage Services Pty Ltd
ASR	Aboriginal Archaeological Survey Report
ATSHIP Act	*Aboriginal and Torres Strait Islander Heritage Protection Act 1984*
BP	Before Present (that is 1950)
Code of Practice	Code of Practice for Archaeological Investigation of Aboriginal Objects in New South Wales 2010
CHL	Commonwealth Heritage List
Consultation Requirements	Aboriginal cultural heritage consultation requirements for proponents 2010
DCP	Development Control Plan
DECCW	Department of Environment, Climate Change and Water (now OEH)
Due Diligence Code of Practice	Due Diligence Code of Practice for the Protection of Aboriginal Objects in New South Wales
EP&A Act	*Environmental Planning and Assessment Act 1979*
EPBC Act	*Environment Protection and Diversity Conservation Act 1999*
Guide	Guide to investigating, assessing and reporting on Aboriginal cultural heritage in NSW
ha	hectares
JMcD CHM	Jo MacDonald Cultural Heritage Management
km	kilometres
KNC	Kelleher and Nightingale Consulting
LALC	Local Aboriginal Land Council
LEP	Local Environmental Plan
LGA	Local Government Area
m	metres

mm	millimetres
NHL	National Heritage List
NPW Act	*National Parks and Wildlife Act 1974*
OEH	Office of Environment and Heritage
PAD	Potential Archaeological Deposit
RAP	Registered Aboriginal Party
RNE	Register of the National Estate

1.0 INTRODUCTION

1.1 Introduction

Artefact Heritage Services Pty Ltd (Artefact Heritage) has been engaged by GHD, on behalf of Hornsby Shire Council (Council), to undertake an Aboriginal Archaeological Survey Report (ASR). The aim of this ASR is to assess and identify any Aboriginal sites or areas of archaeological potential that might be impacted by proposed rehabilitation works at Hornsby Quarry.

Hornsby Quarry is a former breccia hard rock quarry that was operated by private business from the early 1900s and ceased in the late 1990s. The quarry is considered a safety risk and has therefore been closed to the public since that time.

Hornsby Shire Council (Council) acquired the site in 2002 and has since undertaken a number of investigations and studies with regard to the future use of the site and the environmental and technical constraints that the site poses. Through these studies, Council identified the need to:

- stabilise the quarry
- manage the site in a safe and environmentally sustainable manner
- actively seek opportunities to fill the quarry void with spoil arising from major infrastructure projects in the region

Council also resolved to ultimately develop the site into a community parkland. In 2016 approval was granted to Roads and Maritime Services, to beneficially reuse up to 1.5 million cubic metres of excavated rock and soil (spoil) from the construction of the NorthConnex tunnel to partially fill Hornsby Quarry (the ‘2016 Planning Approval’). Filling has been undertaken at the site under this approval. Following completion of filling by NorthConnex, Council is proposing to rehabilitate and reshape the site in a suitable way to ensure public safety and allow future development into a parkland for community use (the project).

An Aboriginal heritage due diligence assessment of Hornby Quarry was prepared by Artefact in 2018 for GHD, on behalf of Council. The due diligence assessment was prepared in accordance with the OEH ‘Due Diligence Code of Practice for the Protection of Aboriginal Objects in New South Wales’ (DECCW 2010a). The due diligence assessment identified two portions of the investigation area as archaeologically sensitive and recommended that further archaeological investigation and consultation with the Metropolitan Local Aboriginal Land Council (Metropolitan LALC) should be undertaken.

This ASR outlines the findings of archaeological survey and consultation with Metropolitan LALC undertaken in accordance with the OEH ‘Code of Practice for Archaeological Investigation of Aboriginal Objects in New South Wales’ (the OEH Code of Practice).

1.2 Study area

The investigation area for Stage 2 works in Hornsby Quarry has been revised since completion of the Aboriginal heritage due diligence assessment. The revision has resulted in the majority of the identified archaeologically sensitive area being removed from the Stage 2 impact area. Therefore, the scope of this ASR is the revised Stage 2 works footprint (Figure 2), with detailed archaeological investigation focussing on those portions of the identified areas of archaeological sensitivity that remain within the revised project footprint (Figure 2).

The study area, to be known in future as Hornsby Park, includes portions of the original Hornsby Park, Old Mans Valley, and the Quarry Lands. The study area is bounded to the north by bushland and residential properties off Manor Road, to the east by bushland and residential and community lots, to the south by bushland and residential blocks which align with Dural Street, Lochinvar Place, and Rosemead Road, and to the west by National Parks land.

The study area predominantly consists of the now disused quarry pit, which occupies much of the central portion of the study area, and the former industrial structures used to process rock form the quarry to the south. The area to the east of the former quarry pit is currently utilised as a processing area for the NorthConnex back-filling operations within the adjacent disused quarry pit. Much of the site is covered by regrowth vegetation and is crossed by numerous tracks.

The study area falls within the Parish of South Colah, County of Cumberland. The study area is within the boundaries of the Metropolitan Local Aboriginal Land Council (LALC).

1.3 Description of Stage 2 works

Key features of the project include:

- Rehabilitation, stabilisation and geotechnical safety management works around various parts of the site
- Earthworks and placement of material retrieved from within the site to create a final landform similar to Option 1 in the Clouston Associates (2014) ‘Recreation Potential Study for Hornsby Quarry and Old Mans Valley Lands’ (p.88).

Approximately 500,000 m^3 of spoil is expected to be generated from stabilisation of the northern face as well as obtained from nearby onsite earthworks. Much of this material would be placed on the NorthConnex spoil to create a landform that generally slopes from the proposed lake up to the top of the western quarry face and would allow for the creation of a new parkland to be constructed within the quarry void. The landform would include a lake directly below the exposed eastern face of the quarry. There would also be cut and fill works on Old Mans Valley to create a landform suitable for future development into playing fields.

It is expected that a combination of ripping, rock breaking and rock sawing will be required to shift the material. Rock fragments would be crushed onsite using a mobile crusher or rock breaker prior to placement as fill.

No additional spoil is proposed to be imported to the site for filling purposes nor would the excavated material be transported off the site.

1.4 ASR scope and objectives

This ASR has been prepared in accordance with the OEH Code of Practice. The scope of this project is to undertake an Aboriginal archaeological survey, with representatives from Metropolitan LALC, of those identified areas of archaeological sensitivity within the study area. The purpose of the ASR is to identify any Aboriginal sites or areas of potential archaeological deposit (PAD) that may be located within the study area and provide for further archaeological investigation and consultation with Aboriginal stakeholders that may be required.

Key objectives of this ASR include:

- Assessing the Aboriginal cultural heritage values of the study area in accordance with the Code of Practice

- Identify Aboriginal archaeological and cultural heritage values that may be impacted by the proposed works
- Identify any further investigations, and mitigation and management measures that may be required, should the project proceed
- This report has been prepared in accordance with the Secretary's Environmental Assessment Requirements (SEARs 1167) to assess and identify whether Aboriginal sites or areas of archaeological potential may be impacted by the proposal.

The SEARs require the following tasks are undertaken for Aboriginal heritage:

> *'an assessment of the potential impacts on Aboriginal heritage (cultural and archaeological), including evidence of appropriate consultation with relevant Aboriginal communities/parties and documentation of the views of these stakeholders regarding the likely impact of the development on their cultural heritage'*

This report includes:

- A description of the project and the extent of the study area (Section 1)
- A description of the statutory requirements for the protection of Aboriginal heritage (Section 2)
- A description of consultation with Metropolitan Local Aboriginal Land Council (Section 3)
- An archaeological significance assessment of the study area (Section 9)
- An impact assessment for any identified Aboriginal sites and areas of archaeological potential (Section 10)
- Provision of measures to avoid, minimise, and if necessary, offset the predicted impacts on Aboriginal heritage values (Sections 11 and 12).

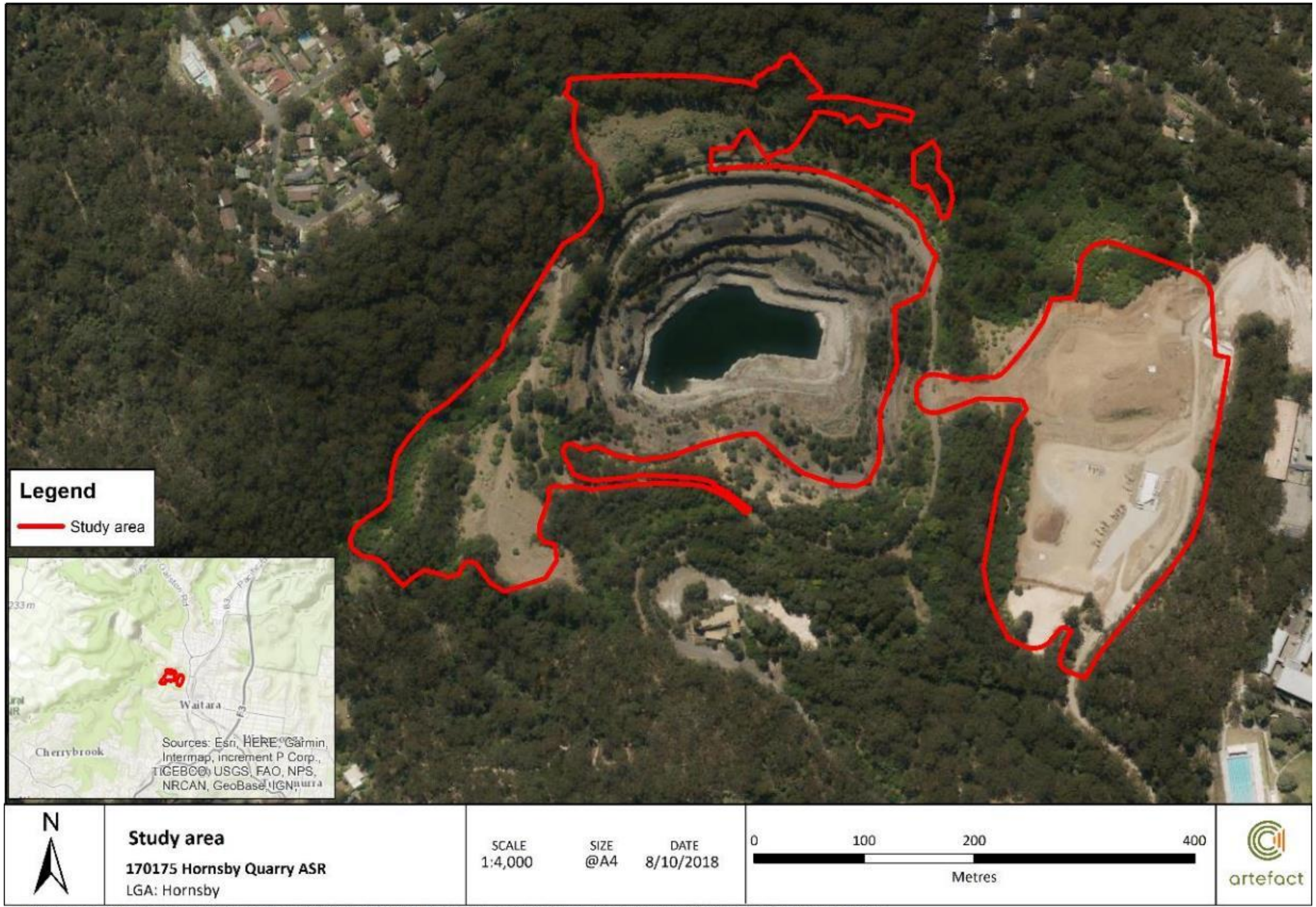
1.5 Limitations

No areas outside the provided study area boundary were assessed during preparation of this ASR.

1.6 Authors

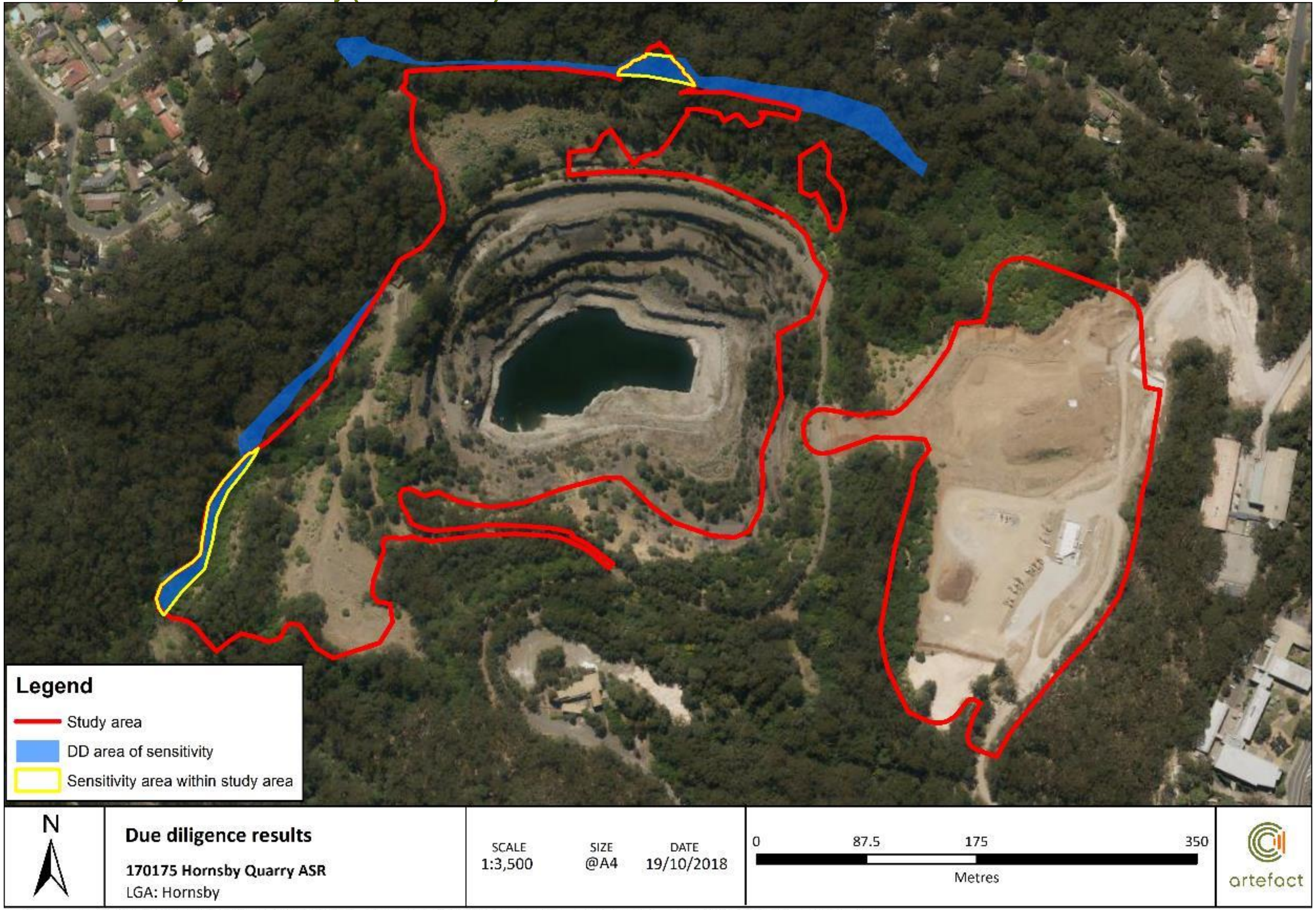
Jennifer Norfolk (Heritage Consultant, Artefact Heritage) assisted the archaeological survey and prepared this report. Jennifer has a Master's degree in Archaeology and has five years' experience in Aboriginal cultural heritage management in NSW.

Figure 1: Location of the study area



Document Path: C:\Users\GIS\Desktop\GIS\GIS_Mapping\170175 Hornsby Quarry Assessments\MXD\ASR\Study_area.mxd

Figure 2: Areas of archaeological sensitivity identified during preparation of the Aboriginal heritage due diligence assessment (shown in blue), in relation to the revised study area boundary (shown in red)



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2.0 LEGISLATIVE CONTEXT

2.1 State legislation

2.1.1 *National Parks and Wildlife Act 1974*

The *National Parks and Wildlife Act 1974* (NPW Act) provides statutory protection to all Aboriginal places and objects. An Aboriginal object is defined as:

> *any deposit, object or material evidence (not being a handicraft made for sale) relating to the Aboriginal habitation of the area that comprises New South Wales, being habitation before or concurrent with (or both) the occupation of that area by persons of non-Aboriginal extraction and includes Aboriginal remains.*

The protection provided to Aboriginal objects applies irrespective of the level of their significance or issues of land tenure. However, areas are only gazetted as Aboriginal Places if the Minister is satisfied that sufficient evidence exists to demonstrate that the location was and/or is of special significance to Aboriginal culture.

There are no gazetted Aboriginal Places in the study area. All Aboriginal objects, whether recorded or not are protected under the NPW Act.

In order, to undertake a proposed activity which is likely to involve harm to an Aboriginal place or object, it is necessary to apply to Office of Environment and Heritage (OEH) for an Aboriginal Heritage Impact Permit (AHIP). AHIPs are issued by OEH under Section 90 of the NPW Act, and permit harm to certain Aboriginal objects or Aboriginal places.

2.1.2 Native Title Act 1994

The *Native Title Act 1994* was introduced to work in conjunction with the Commonwealth *Native Title Act 1993*. Native Title claims, registers and Indigenous Land Use Agreements are administered under the Act. There are no Native Title claims currently registered in the study area.

2.1.3 Aboriginal Lands Right Act 1983

The *Aboriginal Land Rights Act 1983* (ALR Act) established Aboriginal Land Councils (at State and Local levels). These bodies have a statutory obligation under the ALR Act to:

> (a) take action to protect the culture and heritage of Aboriginal persons in the council's area, subject to any other law, and
>
> (b) promote awareness in the community of the culture and heritage of Aboriginal persons in the council's area.

The study area is within the boundary of the Metropolitan LALC.

2.1.4 Environmental Planning & Assessment Act 1979

The *Environmental Planning & Assessment Act 1979* (EP&A Act) provides planning controls and requirements for environmental assessment in the development approval process. The EP&A Act consists of three main parts of direct relevance to Aboriginal cultural heritage; Part 3 which governs the preparation of planning instruments, Part 4 which relates to development assessment processes for local government (consent) authorities, and Part 5 which relates to activity approvals by governing (determining) authorities.

Planning decisions within LGAs are guided by Local Environmental Plans (LEPs). Each LGA is required to develop and maintain and LEP that includes Aboriginal and historical heritage items which are protected under the EP&A Act and the *Heritage Act 1977*. The study area is located in the boundaries of the Hornsby LGA and is covered by the Hornsby LEP 2013. One of the aims of Hornsby LEP 2013 (Part 1, Clause 1.2 (2) (i)) is to '…conserve, protect and enhance the heritage of Hornsby, including places of historic, aesthetic, architectural, natural, cultural and Aboriginal significance…'.

Under Part 5, Clause 5.10 (2) (d) development consent is therefore required for:

- disturbing or excavating an Aboriginal place of heritage significance.

The Hornsby Development Control Plan (DCP) 2013 provides guidance for development which may impact upon Aboriginal cultural heritage within the Hornsby Local Government Area (LGA). The provisions of the DCP are consistent, and in many cases the same, as that provided in the due diligence code of practice. Due to the similarities, the report will address the due diligence code of practice, and thereby address the DCP requirements concurrently.

2.2 Commonwealth legislation

2.2.1 Environment Protection and Biodiversity Conservation Act 1999

The *Environment and Heritage Legislation Amendment Act (No.1) 2003* amends the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) to include 'national heritage' as a matter of National Environmental Significance and protects listed places to the fullest extent under the Constitution. It also establishes the National Heritage List (NHL) and the Commonwealth Heritage List (CHL).

The *Australian Heritage Council Act 2003* (AHC Act) establishes a new heritage advisory body - the Australian Heritage Council (AHC), to the Minister for the Environment and Heritage and retains the Register of the National Estate (RNE).

The *Australian Heritage Council (Consequential and Transitional Provisions) Act* 2003 repeals the *Australian Heritage Commission Act* 1975, amends various Acts as a consequence of this repeal and allows the transition to the current heritage system.

Together the above three Acts provide protection for Australia's natural, Indigenous and non-Indigenous heritage. The new features include:

- A new NHL of places of national heritage significance.
- A new CHL of heritage places owned or managed by the Commonwealth.
- The creation of the AHC, an independent expert body to advise the Minster on the listing and protection of heritage places.
- Continued management of the Register of the National Estate (RNE).

2.2.2 Aboriginal and Torres Strait Islander Heritage Protection Act 1984

The Commonwealth *Aboriginal and Torres Strait Islander Heritage Protection Act 1984* (ATSIHP Act), deals with Aboriginal cultural property (intangible heritage) in a wider sense. Such cultural property intangible heritage includes any places, objects and folklore that 'are of particular significance to Aboriginals in accordance with Aboriginal tradition'. These values are not currently protected under the NPW Act. In most cases, archaeological sites and objects registered under the State Act will also be Aboriginal places subject to the provisions of the Commonwealth Act. There is no cut-off date and the ATSIHP Act may apply to contemporary Aboriginal cultural property as well as ancient sites. The ATSIHP Act takes precedence over state cultural heritage legislation where there is conflict. The Commonwealth Minister who is responsible for administering the ATSIHP Act can make declarations to protect these areas and objects from specific threats of injury or desecration. The responsible Minister may make a declaration under Section 10 of the Commonwealth Act in situations where state or territory laws do not provide adequate protection of intangible heritage places.

3.0 CONSULTATION

Consultation with Metropolitan LALC was undertaken throughout preparation of this ASR. Metropolitan LALC was engaged to participate in the archaeological survey.

Kevin Telford (Aboriginal Site Officer, Metropolitan LALC) participated in the survey on 21 September 2018 and provided comments and observations on the potential for Aboriginal sites or objects in the study area as follows.

- Rockshelters that were located outside of the study area are likely to be habitation sites.
- The clusters of grass trees are an indication of habitations sites, the seed was used to keep fire going, and to transport the fire between camps (These indicators were located adjacent to the area of sensitivity in the north of the study area).
- The study area had been subject to disturbance and is unlikely to retain Aboriginal objects.

4.0 ENVIRONMENTAL CONTEXT

The provision of the following environmental context for the study area is to assist in the prediction of:

- The potential of the landscape over time to have accumulated and preserved Aboriginal objects
- The ways Aboriginal people have used the landscape in the past, with reference to the presence of resource areas, surfaces for art, and other focal points for activities and settlement
- The likely distribution of the material traces of Aboriginal land use based on the above.

4.1 Landscape and geology

The landforms of the study area consist of several types, including slopes, crests, rock outcrops, and drainage channels. The broader landscape of the Hornsby area consists of gently undulating rises and steep low hills. Slopes can range from gentle slopes of less than 5 degrees to steep sixty-five-degree slopes.

The study area is located within the Sydney Basin, a large depositional geological feature that spans from Batemans Bay to the south, Newcastle to the north and Lithgow to the west. The underlying geology of the area consists of Hawkesbury Sandstone and a Jurassic diatreme. Diatremes are the remains of Maar Volcanos, which typically form as a result of the explosive interaction between molten volcanic material and groundwater. Maar Volcanos are formed when hot magma extrudes up through overlying strata and meets with groundwater, resulting in stream pressure-driven explosions that eject rock from below the Earth's crust upwards, with the fragments subsequently falling into a conical cavity, or core, within a compact area.

The 2017 Geological Report on Hornsby Quarry (Pells 2007) describes the process as:

> *This geological deposit comprises material ejected from deep in the earth's crust in a succession of explosive events which forced this material up through fractures and vents in the overlying rocks. This violent injection of material from deep beneath the earth's crust occurred in trumpet-like or column-like features with the material being blown up through the overlying Triassic sandstone and shales, and at the same time encapsulating pieces of sandstone and shale. Unlike other diatreme deposits in the Sydney area the Hornsby diatreme is made up of several of these trumpet or column intrusions from deep in the earth's crust.*

Within the study area, the core is composed of dolerite, which is surrounded by volcanic breccia containing coal, sandstone and shale.

Hawkesbury Sandstone consists of medium to coarse-grained sandstone, very minor shale, and laminate lenses (eSpade 2015). Hawkesbury Sandstone is one of the most ubiquitous geological layers of the Sydney Basin, and was used extensively by both Aboriginal and colonists for a variety of shelter and subsistence requirements.

4.2 Soils

The study area covers three soil profiles, the Hornsby soil landscape, Hawksbury soil landscape, and Lucas Heights soil landscape.

The Hornsby soils are generally deep (150-300 cm) Yellow Podzolic Soils on upper and mid slopes; Yellow-Brown Earths and Red Podzolic Soils on sandstone colluvium; Yellow Podzolic Soils on volcanic breccia; and deep (>200 cm) structured loams in drainage lines. They are highly plastic, low wet-strength, and a highly reactive subsoil.

The Hawksbury soils are generally shallow (<50 cm), discontinuous Lithosols/Siliceous Sands associated with rock outcrops; Earthy Sands, Yellow Earths and some Yellow Podzolic Soils on inside of benches and along joints and fractures; localised Yellow and Red Podzolic Soils associated with shale lenses; siliceous sands and secondary Yellow Earths along drainage lines. They have an extreme soil erosion hazard, steep slopes, rock outcrop, shallow, are a highly permeable soil, and have low soil fertility.

The Lucas Heights soils are generally moderately deep (50-150 cm), hard setting Yellow Podzolic Soils and Yellow Soloths; and Yellow Earths on outer edges. They are a stony soil, with low soil fertility, and low available water capacity.

4.3 Hydrology

The study area is situated within the Hawkesbury-Nepean Catchment area with the local topography generally draining northwards. The study area is located on the former course of Old Mans Creek, a second order stream, which joins Waitara Creek, a third order stream to the west before flowing north. Waitara Creek flows into Berowra Creek a major creek line that connects to the Hawkesbury River near Mooney Mooney.

4.4 Vegetation

The ecology of the study area is varied dependent on the soil on which it sits. The Hawksbury soils support open-woodland (dry sclerophyll) with pockets of tall open-forest (wet sclerophyll) and closed-forest (rainforest). The Hornsby soils support tall open-forest (wet sclerophyll forest) on side slopes to closed-forest (depauperate rainforest) on valley floors. The Lucas Heights soils support low eucalypt open-forest and low eucalypt woodland with a sclerophyll shrub understorey.

The open woodland along the crests and ridges contained red bloodwood (*Eucalyptus gummifera*), narrow leafed stringybark (*E. oblonga*). Scribbly gum (*E. haemostoma*), brown stringybark (*E. capitellata*) and old man banksia (*Banksia serrata*). On the more sheltered side slopes species such as black ash (*E. sieberi*), Sydney peppermint (*E. piperita*), smooth barked apple (*Angophora costata)* and black she oak (*Allocasuarina littoralis*) would have been dominant. The understorey shrub species present will be from the Epacridaceae, Myrtaceae, Fabaceae and Proteaceae families. Within the gullies wet schlerophyll closed forests would have been dominated by blackbutt (*E. pilularis*), Sydney blue gum (*E. saligna*), water gum (*Tristaniopsis laurina*). Blackwattle (*Callicoma serratifolia*), native myrtle (*Backhousia myrtifolia*) and bracken (*Pteridium esculentum*) forma closed scrubby understorey.

Along the valley floors of the Hornsby soil landscape common rainforest species present would include sassafras (*Doryphora sassafras*), coachwood (*Ceratopetalum apetalum*) and black wattle (*C erratifolia*). In some locations cabbage tree palm (*Livistona australis*) and bangalow palm (*Archontophoenix cunninghamiana*) indicate the presence of volcanic soils.

4.5 Historical background

The harvesting of Blue Gums and Grey Ironbarks, which grew on the ridges, was the first economic activity undertaken by European settlers in the Hornsby area. Timber was transported by river for sale to Sydney builders. The activities of timber cutters opened the district for permanent settlement by farmers who took up the most fertile land located on the ridge tops.

Samuel Horne and John Thorne were among the notable early settlers within Hornsby, the earlier of which inspired the name of the village, and Constable Thorne land later became known as the suburb of Thornleigh. Horne and Thorne were police constables who were rewarded with sizable land grants for their role in the shooting of John MacNamara, an accomplice to the bush ranger John Donohue, and the capture of other members of his gang in 1830 (Kass 1993).

Throughout the 19th century, the region remained fairly remote and rural with large land holdings primarily utilised for agriculture. The fruit growing industry commenced in the 1830’s and was the main industry within the region. The subdivision of the original Horne and Thorne grants resulted in a number of orchards lots being released to the market. Until the early twentieth century, the majority of subdivisions involved the development of small acreages developed as orchard lots (Kass 1993). In the 1890s, Dural and the Hills district was the chief supplier of citrus fruit for most of Australia. As well as growing fruit for sale in the Sydney market, local growers also entered the market as suppliers of seeds and seedlings of ornamental and fruit bearing plants (Schofield 1988).

5.0 ABORIGINAL CONTEXT

5.1 Ethnohistoric context

Prior to the appropriation of Aboriginal land by Europeans, Aboriginal people lived in small family or clan groups that were associated with particular territories or places. A number of references suggest that certain areas of land ('estates' or 'country'), in the Sydney region, were associated with a named clan (Aboriginal Heritage Office [AHO] 2015: 37; Attenbrow 2010: 22-30; Irish 2017: 17). Analysis of historical records by Attenbrow (2010: 23-35) suggests that the Hornsby region may have formed part of the Garigal clan areas. The Garigal is associated with Broken Bay and surrounding country. Other closely associated clan areas include the Gayamaygal, Borogegal and Darramurragul clan. Gayamaygal is associated with Manly Cove and surrounding country, and the Borogegal clan is associated with Bradleys Head and surrounding country, and the Darramurragul is associated with the headwaters of Lane Cove River [Turramurra area] (Attenbrow 2010: 24-25).

Attenbrow (2010: 27-29) and the AHO (2015: 41) both note that there is often incomplete information associated with records of clan names and associated area. Attenbrow (2010: 28-29) lists some of the difficulties in accurately establishing clan names and associated areas:

> *'It is difficult to determine how many clans there actually were because of various spellings given by different authors for the same clan and other groups, and it is also unlikely that the names of all clans were recorded. The colonists were also unsure when they started recording people's names whether the names they were told were personal names or the clans to which the person belonged. Mapping precise boundaries is even more difficult, if not impossible, even where clans' areas were described.'*

The AHO (2015: 41) note with reference to specifying clan names for particular areas that 'the AHO would recommend the use of clan names for local areas, with the understanding that these too have their limitations and problems'.

Aboriginal people lived in groups known as 'bands', which were formed of individuals from different clans (Attenbrow 2010: 22; Irish 2017: 18). Irish (2017: 18) notes that the names of land-using bands in Sydney are not known, if they had names at all. With regard to the individuals in each band, Irish notes the following:

> *'…Aboriginal people lived on a daily basis in groups known as bands, which were made up of the male members of a clan, their wives (married in from other clans) and children, and unmarried female clan members. As such, they were multilingual groups comprising members of different clans, given them connections and rights to much broader areas that single-clan estates.'*

British colonisation had a profound and devastating effect on the Aboriginal population of the Sydney region. In the early days of the colony Aboriginal people were disenfranchised from their land as the British claimed areas for settlement and agriculture. The colonists, often at the expense of the local Aboriginal groups, also claimed resources such as pasture, timber, fishing grounds and water sources. Overall the devastation of the Aboriginal culture did not come about through war with the British, but instead through disease and forced removal from traditional lands. It is thought that during the 1789 smallpox epidemic over half of the Aboriginal people of the Sydney region died (Hornsby Shire Council).

The Garigal area is rich in natural resources as they had access to coastal and inland areas. They utilised the riverine and coastal stretches for fish and shellfish, evident in the surviving shell middens and fish traps (Kuring-Gai Council 2013). Inland resources that were exploited were yams, bulbs and seeds, nuts, fern roots and lillypillies for food. Possums, birds and wallabies would have been hunted for their meat (Gibberagong Environmental Education Centre 1983). The local vegetation would have provided them with everyday living essentials. Grass trees were essential for making spears and fishing line along with shells and fish bone for barbs and fishing hooks.

The existing archaeological record is limited to materials that have withstood degradation and decay. The most common types of Aboriginal objects remaining in the archaeological record are stone artefacts, followed by bone and shell. The locality of the study area on an unrelieved hinterland plain indicates that the predominant site type would likely be isolated or low-density stone artefact deposits and transient open camp sites associated with hunting and ranging. Guringai occupation is evident in throughout their traditional country in the form of rock art and engravings depicting their life and resources.

Evidence of Aboriginal use of Hawkesbury Sandstone in the Sydney area includes occupation deposits in natural shelter formations created by weathering processes in exposed sandstone, grinding grooves where edge-ground stone axes were manufactured or maintained, and rock engravings or pigment motifs that were applied to exposed sandstone. British colonisers primarily utilised Hawkesbury Sandstone for building material, and many buildings and bridges were constructed with sandstone before clay bricks became the predominant construction material.

5.2 Archaeological context

5.2.1 Previous archaeological investigations in the study area

Artefact Heritage 2017 – Hornsby Quarry Aboriginal Heritage Due Diligence Assessment

Artefact was engaged to assess the potential impacts to Aboriginal cultural heritage for the proposed rehabilitation works at Hornsby Quarry. Artefact undertook a site visit of the area to be impacted, the majority of the study area was identified as being disturbed and did not demonstrate archaeological sensitivity. Two areas on the eastern and northern margins were identified as archaeologically sensitive, with the potential for Aboriginal objects associated with natural sandstone outcrops to occur.

AECOM 2015 - Hornsby Quarry: Road Construction Spoil Management Project Stage 2

AECOM surveyed part of the current project area to assessed impacts from NorthConnex operations for site establishment, operations and quarry filling.

A single small rock overhang and PAD was identified, which lies outside of the NorthConnex project area and outside the current study area. REDACTED (see Section 5.3 paragraph 1)

This site did not appear in the AHIMS search and may not have been registered as yet.

5.2.2 Previous archaeological investigations in the locality

There have been several Aboriginal assessments undertaken within the vicinity of the Hornsby Quarry. Most of this work has been completed in response to planning requirements for Sydney transport infrastructure. A summary of previous reports is provided below in Table 1.

Table 1: Previous assessments intersecting with, and adjacent to the activity area

Report	Assessment type	Key outcomes
Artefact Heritage (2014) Epping to Chatswood Railway – Conversion to Rapid Transit	Aboriginal heritage Due Diligence assessment	Artefact Heritage (2014) conducted an Aboriginal heritage due diligence assessment for five stations on the Epping to Chatswood railway including, Epping, Macquarie University, North Ryde and Chatswood. The closest station Epping is located approximately seven kilometres south of the current study area. There were no Aboriginal objects or areas of potential identified within the localities of any of the assessed stations, based on the assessment of that study area as heavily impacted by the construction and maintenance of the railway, the absence of any major watercourses within 200 metres of the assessment areas and the lack of Aboriginal sites located within the vicinity of the assessment areas.
Artefact Heritage (2013) Westleigh Ancillary Facility	Due Diligence Aboriginal heritage assessment	Artefact Heritage conducted an Aboriginal heritage due diligence assessment for the Westleigh Ancillary Facility as part of the ETTT project. The proposed ancillary facility was located within a large cleared area formerly used as a stone quarry approximately 2.5 kilometres south west of the current study area. The assessment area was assessed as being highly disturbed and modified as a result of quarrying activities. The assessment area was not located within a sensitive landform and was located approximately one kilometre south from the major watercourse in the area – Berowra Creek. That study area was therefore assessed as having a low archaeological potential and no Aboriginal objects were identified.
Artefact Heritage (2012) Northern Sydney Freight Corridor Epping to Thornleigh Third Track (ETTT) Project	**Rail corridor assessment**	Artefact Heritage prepared an Aboriginal Cultural Heritage Assessment for the ETTT project from Epping to Thornleigh, approximately 3.5 kilometres south of the study area. The rail corridor was assessed as highly disturbed due to construction and maintenance of the railway. The construction of the railway has involved major landform modifications. Three registered AHIMS sites and one previously unidentified site were located within and adjacent to the rail corridor. These sites consist of isolated quartz and silcrete artefacts and one artefact scatter. That study area was assessed to be of low archaeological potential due to the high level of disturbance and landform modification associated with construction and maintenance of the rail corridor. That study area was also over 200 metres away from any substantial watercourses and therefore not considered to be located within a sensitive landform.

Report	Assessment type	Key outcomes
Koettig (1996) Hornsby Shire	**Aboriginal Heritage Study**	Koettig conducted a heritage study that encompassed the entirety of the Hornsby Shire. That study found that the Hornsby area is evidentially rich in Aboriginal occupation and utilisation. The predominant sites found in the landscape are rock shelters with art and exposed sandstone with engravings and axe grinding grooves. Some shelters were found to contain shell middens and the potential for intact occupation deposit. That study found that sites are found in all topographic units of the Hawkesbury Sandstone. It was concluded that it was not possible to create a predictive model for site distribution however it was possible to predict what site types are more likely to occur in different parts of the landscape. The estuarine foreshore is believed to contain the greatest site frequency. Engravings likely to be identified predominantly in ridge crest landform contexts, whilst axe grinding grooves will frequently occur on exposed sandstone near/in creeks.

5.2.3 Summary

Previous investigations in the region demonstrate the low archaeological potential of disturbed landscape contexts. However, the results of the OEH AHIMS search and the identification of a potential Aboriginal shelter site adjacent to the study area demonstrate the high archaeological potential of intact sandstone landform contexts. The sensitivity of areas of outcropping sandstone is likely to be generally unrelated to distance from a watercourse.

Therefore, within the current study area the previously disturbed disused quarry and NorthConnex processing plant are likely to demonstrate low archaeological sensitivity, whilst any remaining intact sandstone landform context is likely to demonstrate archaeological sensitivity for Aboriginal sites including rock engravings, grinding grooves, and shelter sites with archaeological deposit and/ or art.

5.3 Aboriginal Heritage Information Management System

The location of Aboriginal sites is considered culturally sensitive information. It is advised that this information, including the AHIMS data appearing on the heritage map for the proposal be removed from this report if it is to enter the public domain.

An extensive search of the Aboriginal Heritage Information Management System (AHIMS) database was undertaken on the 18 September 2018 (AHIMS search ID 371229).

An area of approximately 4 km surrounding the study area was included in the search. The AHIMS search provides archaeological context for the area and identifies whether any previously recorded Aboriginal sites are located within or near the study area. The parameters of the search were as follows:

GDA 1994 MGA 56	E 320939 - 324957 N 6267635 - 6271625
Buffer	0 m
Number of sites	17
AHIMS Search ID	371229

A total of 17 sites are recorded in the extensive AHIMS search area. The distribution of recorded sites within the AHIMS search area is shown in Figure 3. A registered site is made up of one or more features and these features should not be confused with registered sites. OEH lists 20 standard site features that can be used to describe a site registered with AHIMS. The frequency of recorded site types (as opposed to the number of registered sites) is summarised in Table 2. For the 17 sites within the search area, three site features were recorded. Most recorded site features are Art sites (n=14) followed by Grinding Grooves (n=3).

The nature and location of the registered sites reflects the past Aboriginal occupation from which they derive, but is also influenced by historical land-use, and the nature and extent of previous archaeological investigations. Although Aboriginal occupation covered the whole of the landscape, the availability of fresh water, and associated resources, was a significant factor in repeated and long-term occupation of specific areas within the landscape. Certain site types, such as culturally modified trees, are particularly vulnerable to destruction through historical occupation, while others, such as stone artefacts, are more resilient. Within the current search area, the majority of recorded sites are art sites in the form of rock engraving.

Table 2: Frequency of site features from AHIMS data

Site Feature	Frequency	Percentage (%)
Art (Pigment or Engraved)	13	76.5
Grinding groove	3	17.6
Artefact, Art (Pigment or Engraved)	1	5.9
Total	17	100

AHIMS ID 45-6-2821 (Arrionga GG1) is located approximately REDACTED (see Section 5.3 of the current study area. This site was identified by John Appleton on Arrionga Place, Hornsby on REDACTED (see Section 5.3 paragraph 1) [redacted]. It is situated on a similar landform that is found within the study area. The current study area was the site of Old Mans Creek and is associated drainage lines, Old Mans Creek flows into Waitara Creek which eventually joins Berowra Creek.

[redacted] REDACTED (see Section 5.3 paragraph 1)

[redacted] REDACTED (see Section 5.3 paragraph 1)

5.4 Predictive modelling

Assumptions about Aboriginal land use patterns are made on the basis of archaeological information gained from the local area, from observations made by Europeans after settlement of the area, and from information known about available natural resources. The information has its limitations due to the disturbance caused by urbanisation of the region.

As Aboriginal people were mobile hunter-gatherers, it would be likely that they moved across the landscape between resources. That movement and utilisation of their territories is dictated by the topography, vegetation and resource availability. Other factors that would have influenced their interaction with the environment is related to the socio/cultural aspect of people and groups such as gatherings and ceremonial obligations.

Archaeological data suggests that art sites will be the most common Aboriginal site type in the locality, such as engraving sites exposed sandstone surfaces and pigment sites in naturally occurring sandstone shelter formations. Grinding groves are the next most likely site type to occur within the locality, generally being located on areas of exposed sandstone in or adjacent to a water course.

Previous documentary and archaeological research indicate that archaeological evidence is likely to be found within certain landform contexts, largely as a result of the resources that were associated with these landforms, or their suitability for long-term and/or repeated occupation. OEH lists five such sensitive landforms:

- Within 200 m of waters
- Within a sand dune system
- On a ridge top, ridge line or headland
- Within 200 m below or above a cliff face
- Within 20 m of or in a cave, rock shelter, or a cave mouth.

The predictive model comprises a series of statements about the nature and distribution of evidence of Aboriginal land use that is expected in the study area. These statements are based on the information gathered regarding:

- Landscape context and landform units
- Ethno historical evidence of Aboriginal land use
- Distribution of natural resources
- Results of previous archaeological work in the vicinity of the study area
- Predictive modelling proposed in previous investigations

Predictive statements regarding the study area are as follows:

- Art (Pigment or Engraved) will be the most likely Aboriginal site types found
- Engraved art will be located on exposed sandstone surfaces, pigment art sites will be located within rock shelters or rock overhangs.

- Identification of art will be dependent on visibility and vegetation density – artefacts will more frequently be identified on exposed surfaces
- Rock shelters will be present along the sandstone ridgelines and have the potential to contain potential archaeological deposit (PAD) that could should evidence of occupation.
- Grinding grooves are most likely to occur on exposed sandstone surfaces along the foreshore of creek lines or in areas with a water source.
- Modified trees may be identified within the study are if suitable old growth trees remain. They were used as path markers, indicators of sensitive areas and warning posts.

5.4.1 Summary

It is predicted that areas of archaeological potential will be located within sensitive landforms such as sandstone outcrops along the perimeter of the study area and along creek lines and tributaries. The potential for finding sites will be dependent on the level of disturbance in the area and the level of visibility. As previous investigations by Artefact (2018) and AECOM (2015) have demonstrated, the majority of the study area has been comprehensively impacted by quarrying activities, which have entirely removed large sections of the landscape.

It is expected that should intact landform contexts remain, art sites and grinding groves will be the main evidence of Aboriginal occupation in the study area and are likely to be located on suitable exposed sandstone surfaces. Modified trees and potential archaeological deposits could be identified within the study area, but these are dependent on past land use and disturbance levels.

6.0 ARCHAEOLOGICAL SURVEY

6.1 Aims

The aims of the archaeological survey were to:

- cover a representative sample of the study area and to include all landforms that will potentially be impacted by the proposed works
- record the landform, general soil information, surface conditions and vegetation conditions encountered during the survey and how these impact on the visibility of objects
- record any Aboriginal objects/sites observed during the survey
- to identify areas of potential archaeological deposit (PAD) that may be present in areas that have had no or minimal disturbance
- to collect information to ascertain whether further archaeological investigations are required.

6.2 Site definition and recording

An Aboriginal site is generally defined as an Aboriginal object or place. An Aboriginal object is the material evidence of Aboriginal land use, such as stone tools, scarred trees or rock art. Some sites, or Aboriginal places can also be intangible and although they might not be visible, these places have cultural significance to Aboriginal people.

Office of Environment and Heritage guidelines state in regard to site definition that one or more of the following criteria must be used when recording material traces of Aboriginal land use:

- The spatial extent of the visible objects, or direct evidence of their location
- Obvious physical boundaries where present, e.g. mound site and middens (if visibility is good), a ceremonial ground
- Identification by the Aboriginal community on the basis of cultural information.

For the purposes of this study an Aboriginal site would be defined by recording the spatial extent of visible traces or the direct evidence of their location.

6.3 Protocol for recording Potential Archaeological Deposits

Where areas of PAD are identified towards the margins of each survey unit, efforts must made by the survey team to delineate each area of potential beyond the survey unit. Where PAD extents extend beyond the survey unit, efforts must be made to map the extent of that feature up to approximately 70 m outside the survey unit. If it is likely that these PADs continue beyond that point, the survey team must justify that the distance is adequate to provide an accurate representation of the PAD with regard to future planning and design for the project.

6.4 Timing and personnel

The archaeological survey was undertaken over one day on the 21 September 2018. The survey was supervised by Ryan Taddeucci (Senior Heritage Consultant, Artefact Heritage) and assisted by Jennifer Norfolk (Heritage Consultant, Artefact Heritage). Kevin Telford (Aboriginal Site Officer, Metropolitan LALC) represented the LALC during the survey. Craig Clendinning (Project Manager, Hornsby Council) and James Frawley (Hornsby Council) acted as escort.

6.5 Survey sampling strategy

The study area had previously been subjected to a site inspection under the due diligence code of practice (Artefact Heritage 2017). The due diligence assessment identified two areas of archaeological sensitivity and recommended a targeted archaeological survey of the area, with the Metropolitan LALC, in accordance with the OEH Code of Practice. As a result, only the areas of archaeological sensitivity were subject to the site survey.

Natural landform contexts were identified in small areas in the eastern and northern portions of the study area. These areas were located in slope landform contexts, the eastern area is located adjacent to Old Mans Creek, whilst the northern area is located on the southern margin of the ridge crest associated with Manor Road. Outcropping sandstone was identified in both areas, although no shelter formation suitable for habitation or art was identified, and no engravings or grinding grooves were identified. However, due to leaf litter and dense vegetation, surface visibility was limited in both areas, and outcropping sandstone in these areas should be considered archaeologically sensitive

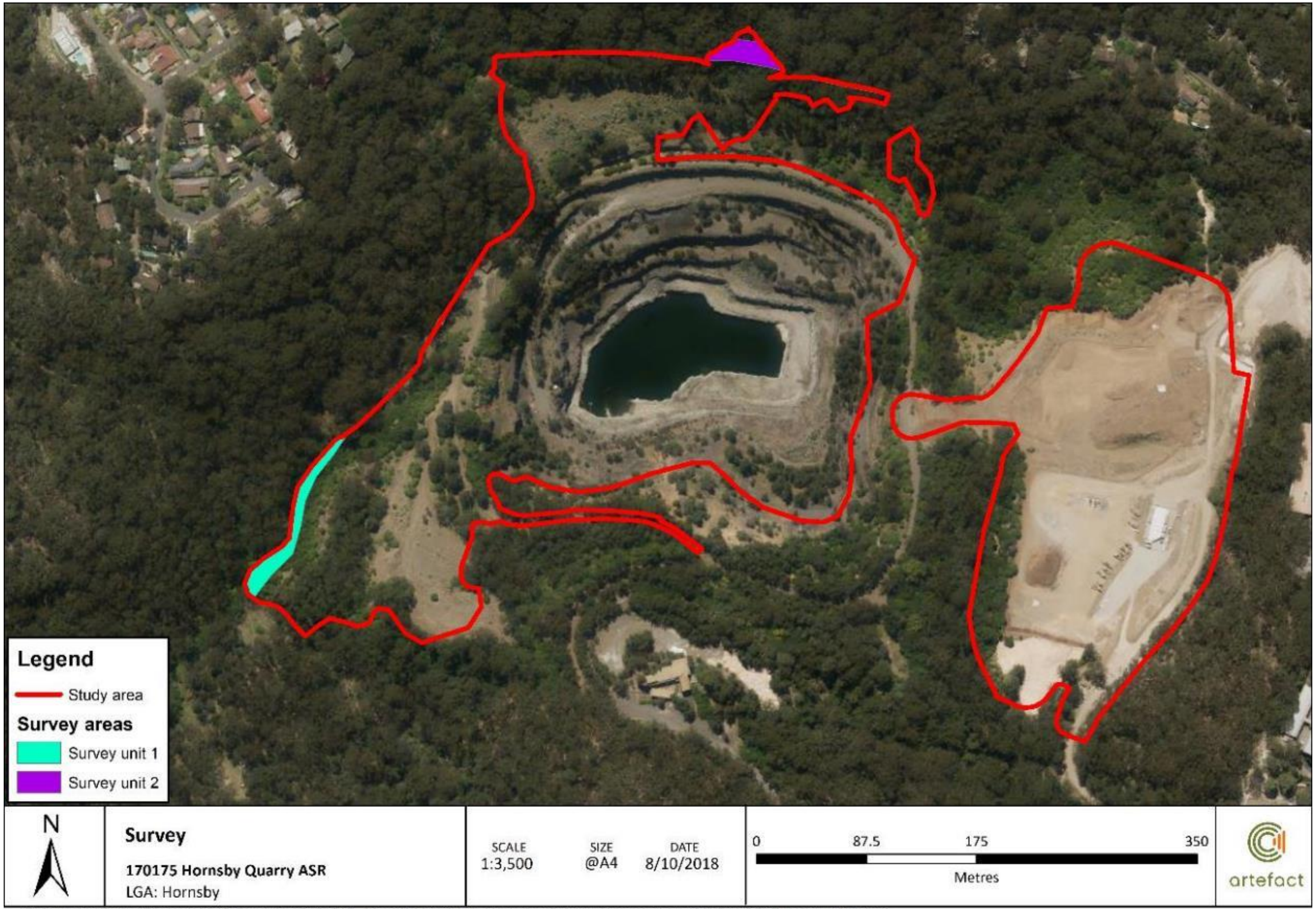
6.6 Methodology

Survey consisted of two survey units defined by the areas of sensitivity, property boundaries and the disturbance present on the site (Figure 6.1).

A handheld Global Positioning System (GPS) was used to track the path of the survey team and record the coordinates of survey transects, as well as, the locations of sandstone outcrops and any Aboriginal sites. Detailed aerial maps marked with grid coordinates for each of the two survey units were carried by the survey team in the field. The coordinate system projection used for all data recording was GDA94 MGA 56. All ground exposures were examined for Aboriginal objects which may have been imported into the study area with the fill.

A photographic record was kept during the survey. Photographs were taken to record aspects of survey units including stone outcrops, stone platforms, vegetation, disturbance and recorded Aboriginal sites. Scales were used for photographs where appropriate.

Figure 4: Location of the survey units



Document Path: C:\Users\GIS\Desktop\GIS\GIS_Mapping\170175 Hornsby Quarry Assessments\MXD\ASR\Survey units.mxd

7.0 SURVEY RESULTS

7.1 Survey Unit 1

Survey unit 1 is the mapped extent of archaeological sensitivity located at the western extent of the study area. The survey unit is located on fill deposited as spoil during the quarry activities. The fill is in an existing drainage line that runs north south.

Survey unit 1 was densely vegetated around the margins of the survey unit, there was a clearing through the middle that was well grassed with evidence of the unnatural nature of the survey unit. There was a mixture of native and non-native vegetation, all immature growth. Survey unit 1 was generally flat with a few mounds (Figure 7.1), the southern extent of the survey unit has a steep gradient to the base of the existing drainage line.

Ground visibility was low across survey unit 1, less than 2 per cent and no exposures. The visibility was due to erosion along pedestrian access and along the surface of the mounds. Evidence of the disturbed an unnatural landform included concrete slabs, wood planks and fencing, metal drums and various other items were visible on the ground surface.

Figure 5: View north along the showing signs of disturbance (R Taddeucci, 21/9/2018)

Figure 6: View north showing level platform of fill, next to slope (R Taddeucci, 21/9/2018)

Figure 7: Ground disturbance, fill deposit, showing concrete and rubble (R Taddeucci, 21/9/2018)

Figure 8: Young dense vegetation along the perimeter of fill (R Taddeucci, 21/9/2018)

7.2 Survey Unit 2

Survey unit 2 is the mapped extent of sensitivity located at the northern portion of the study area. The survey unit is located on a large spoil mound constructed as a buffer between the quarry activities and the local community. The spoil mound is located on the natural slope of the northern side of the quarry.

There was limited access to survey unit 2, with the exception of a narrow access track ran along the top of the mound with steep slopes to the north and south. A fence line ran along the edge of the access. The slopes were densely vegetated with immature native tree growth, the ground surface was covered in leaf litter and various small understorey species. A collapsed drainage tunnel connects the remainder of Old Mans Creek to the quarry and is located approximately centre of the survey unit.

Ground visibility was approximately 2 per cent with no exposures. The visibility was due to erosion along pedestrian access. The previous landform/ slope was visible north east and west of the survey unit.

Figure 9: View north east of steep slope of the survey unit 2 (R Taddeucci, 21/9/2018)

Figure 10: View south west showing steep drop and disturbance (R Taddeucci, 21/9/2018)

Figure 11: View of fenced boundary of the spoil heap and the natural slope in the background (R Taddeucci, 21/9/2018)

Figure 12: Ground conditions at the eastern most edge of the survey unit (R Taddeucci, 21/9/2018)

Figure 13: Immature vegetation regrowth along the spoil. (R Taddeucci, 21/9/2018)

7.3 Survey coverage

A summary of survey coverage, in accordance with the OEH Code of Practice, is outlined in Table below. It should be noted that because the area is entirely covered in fill/ spoil, a calculation of survey coverage is not an accurate reflection of the potential for Aboriginal objects to occur unless they have been introduced with the fill.

Grass and vegetation coverage were dense in both survey units and the majority of survey unit 2 was steep slope that could not be traversed, resulting in poor visibility and nil exposures. All surfaces were inspected, and old growth native trees were similarly targeted for evidence of cultural modification. Local landforms, evidence of land use history, and previous research, were used to inform assessments of archaeological potential

Table 3: Survey coverage summary

Survey unit	Survey unit area (m^2)	Landform	Visibility (%)	Exposure (%)	Effective coverage (m^2)	Effective coverage (%)	Sites	PAD
SU1	1489	Disturbed	2	0	0	0	0	0
SU2	889	Disturbed	2	0	0	0	0	0

8.0 DISCUSSION

8.1 Ground disturbance

Based on previous studies in the locality and historical records, the study area has been subject to major subsurface disturbance, and therefore has low potential to contain intact archaeological resources. The potential for intact archaeology will be along the margins of the quarry obscured by the spoil mounds, the nature of the disturbance beneath is unknown and remaining natural soils and sandstone outcrops could be present.

Overall, based on the land use history and results of previous studies, there is low potential for archaeological remains to be present within the study area.

8.2 Analysis of archaeological potential

8.2.1 Introduction

The archaeological potential of an area is determined by its landform, its location and the level of disturbance. Certain landscapes, such as sandstone outcropping, are conducive to Aboriginal occupation if rock shelters or overhang are present. The location of appropriate landforms in relation to natural resources, in particular their proximity to a permanent water source, increases levels of potential. Correlations between site location and proximity to a water source have been proven in previous archaeological investigations where the number of sites and their densities is highest in close proximity to a water source.

In areas where there is high level of disturbance however, the archaeological potential is lowered. It is unlikely that surface finds in these areas are in their original context and it is unlikely that subsurface archaeological deposits are intact. The archaeological potential of an area is rated high, moderate or low, based on all of the above considerations.

- High - Intact archaeological material is likely to be found in this area
- Moderate - Intact archaeological material may be found in this area
- Low - It is unlikely that intact archaeological material will be found in this area.

8.2.2 Analysis of the study area

The overall archaeological potential of the study area has been assessed as low. While the study area has been located on a slope in close proximity to a permanent waterway, previous studies and observations in the field indicate that the all potential artefact yielding deposit has been removed by previous impacts to the area.

9.0 SIGNIFICANCE ASSESSMENT

9.1 Significance assessment criteria

An assessment of the cultural heritage significance of an item or place is required in order to form the basis of its management. The OEH (2011) provides guidelines for heritage assessment with reference to the Burra Charter (Australia ICOMOS 2013) and the Heritage Office guidelines (2001). OEH requires consideration that includes the following:

- Research potential: does the evidence suggest any potential to contribute to an understanding of the area and/or region and/or state's natural and cultural history?
- Representativeness: how much variability (outside and/or inside the subject area) exists, what is already conserved, how much connectivity is there?
- Rarity: is the subject area important in demonstrating a distinctive way of life, custom, process, land-use, function or design no longer practised? Is it in danger of being lost or of exceptional interest?
- Education potential: does the subject area contain teaching sites or sites that might have teaching potential?

It is important to note that heritage significance is a dynamic value.

9.2 Archaeological significance assessment

The survey did not result in the identification of any Aboriginal sites or areas of PAD. Therefore, the study area does not demonstrate archaeological significance.

Aboriginal archaeological material, PAD or sandstone outcropping may be present below the fill/ spoil if the former landscape is intact. If the landscape below the fill is intact there is potential for Aboriginal archaeological potential to be high scientific significance as there is limited information on the Aboriginal occupation of the surrounding landscape.

10.0 IMPACT ASSESSMENT

10.1 Proposed development

Key features of the project include:

- Rehabilitation, stabilisation and geotechnical safety management works around various parts of the site
- Earthworks and placement of material retrieved from within the site to create a final landform similar to Option 1 in the Clouston Associates (2014) ‘Recreation Potential Study for Hornsby Quarry and Old Mans Valley Lands’ (p.88).

Approximately 500,000 m^3 of spoil is expected to be generated from stabilisation of the northern face as well as obtained from nearby onsite earthworks. Much of this material would be placed on the NorthConnex spoil to create a landform that generally slopes from the proposed lake up to the top of the western quarry face and would allow for the creation of a new parkland to be constructed within the quarry void. The landform would include a lake directly below the exposed eastern face of the quarry. There would also be cut and fill works on Old Mans Valley to create a landform suitable for future development into playing fields.

It is expected that a combination of ripping, rock breaking and rock sawing will be required to shift the material. Rock fragments would be crushed onsite using a mobile crusher or rock breaker prior to placement as fill.

No additional spoil is proposed to be imported to the site for filling purposes nor would the excavated material be transported off the site.

10.2 Impacts to potential archaeological resources

Due to the highly disturbed nature of the ground, archaeological deposits are not likely to exist within the quarried portion of the site. The portion of the site that was surveyed that may contain Aboriginal archaeological sites will not be impacted by the proposed works as there is no planned earthmoving of the spoil, rehabilitation will be undertaken. The proposed development is unlikely to impact Aboriginal archaeological remains.

11.0 MANAGEMENT MEASURES

The proposal is unlikely to impact any intact archaeological remains therefore no further archaeological investigation or mitigation is recommended.

An unexpected finds policy would be implemented in the event of Aboriginal archaeological deposits being identified during ground works and excavation.

An unexpected finds policy would involve the following actions:

- Stop work within the affected area, protect the potential archaeological find, and inform environment staff or supervisor.
- Contact a suitable qualified archaeologist to assess the potential archaeological find.
- If Aboriginal archaeological material is identified, works in the affected area should cease, and the OEH should be informed. Further archaeological mitigation may be required prior to works recommencing.
- If human remains are found:
  - Do not further disturb or move these remains
  - immediately cease all work at the particular location
  - notify NSW Police
  - notify OEH’s Environment Line on 131 555 as soon as practicable and provide available details of the remains and their location
  - do not recommence any work at that location unless authorised in writing by the relevant government agency.

12.0 RECOMMENDATIONS

The following recommendations were based on consideration of:

- Statutory requirements under the National Parks and Wildlife Act 1974
- The requirements of the relevant guidelines: Guide (OEH 2011), Code of Practice (DECCW 2010a) Consultation Requirements (DECCW 2010b)
- The results of the background research and archaeological survey results

It was found that:

- No Aboriginal archaeological site or areas of PAD were located within the study area

It is therefore recommended that:

Recommendations

- No further Aboriginal archaeological investigations or assessment is recommended for the study area and currently proposed works.
- Where changes to the scope of the proposal result in impacts beyond the extent of what has been assessed in this report, further archaeological survey and addendum ASR reporting will be required.
- If there is a variation to the proposed works design or impact area that will affect land that has not been assessed in this report, further Aboriginal heritage assessment will be required.
- If the proposed works are altered to include scope for removal of the potentially intact natural ground surface beneath the spoil mounds, further Aboriginal heritage assessment will be required.
- An unexpected finds policy should be implemented, which should include the following conditions:
  - Stop work within the affected area, protect the potential archaeological find, and inform environment staff or supervisor.
  - Contact a suitable qualified archaeologist to assess the potential archaeological find.
  - If Aboriginal archaeological objects are identified, works in the affected area should cease, and the OEH should be informed. Further archaeological mitigation may be required prior to works recommencing.
- If human remains are found:
  - Do not further disturb or move these remains
  - immediately cease all work at the particular location
  - notify NSW Police
  - notify OEH’s Environment Line on 131 555 as soon as practicable and provide available details of the remains and their location
  - do not recommence any work at that location unless authorised in writing by the relevant government agency.

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Appendix H – Statement of heritage impacts

Hornsby Quarry Stage 2

Statement of Heritage Impact

Report to GHD

November 2018

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GLOSSARY

The following acronyms and abbreviations may be used in this report

Term	Definition
Burra Charter, the	*The Burra Charter: The Australia ICOMOS Charter for Places of Cultural Significance, 2013*
CHL	Commonwealth Heritage List
DCP	Development Control Plan
EIS	Environmental impact statement
Element	An individual piece of fabric, or an assemblage of fabric which contributes to the place's significance
EP&A Act	Environmental Planning and Assessment Act 1979
EPBC Act	Environment Protection and Biodiversity Conservation Act 1999
Fabric	The physical elements of a heritage place
Heritage Division	Part of OEH, formerly the NSW Heritage Branch and Heritage Office
HMP	Heritage Management Plan
ICOMOS	International Council on Monuments and Sites
LEP	Local environmental plans
LGA	Local Government Area
NHL	National Heritage List
NSW	New South Wales
OEH	Office of Environment and Heritage
Place	Defined by the Burra Charter as *a geographically defined area. It may include elements, objects, spaces and views. Place may have tangible and intangible dimensions*.
SHI	State Heritage Inventory
SHR	State Heritage Register
SoHI	Statement of Heritage Impact
WHL	World Heritage List

EXECUTIVE SUMMARY

Artefact Heritage has been engaged by GHD, on behalf of Hornsby Shire Council (the proponent), to undertake a Statement of Heritage Impact (SoHI), to assess the heritage impacts of Stage 2 works relating to the rehabilitation of the Hornsby Park site as a recreational parkland through cut and fill works. The project area contains several heritage items listed on the Hornsby Local Environment Plan 2013 (Hornsby LEP) and one State Heritage Register (SHR) listed heritage item, and is adjacent to several additional locally listed items on the Hornsby LEP (see Chapter 2.0).

Stage 1 of the project is the current works by NorthConnex (NCX) to deposit fill within the existing Quarry Pit. Stage 2 focuses on cut and fill works within Hornsby Park, and Stage 3 will involve detailed design for the future use of the site. Bulk earthworks by Council are expected to take approximately two years from 2019, and then Council will landscape the site. It is expected the recreational park will be open to the public in 2023.

The aim of this SoHI is to identify heritage items and archaeological areas which may be impacted by the proposed works, determine the level of heritage significance of each item, assess the potential impacts to those items, recommend mitigation measures to reduce the level of heritage impact and identify other management or statutory obligations.

Conclusions

The proposed cutting and filling works that extend over the eastern and central parts of the study area will involve the movement of large volumes of fill, which is intended to sculpt the study area to develop the modern recreational space. The site has the potential to yield important archaeological information of State significance, and as a cultural landscape has values which should be conserved and retained as part of the future plans for the study area. Despite large areas of disturbance over the past 70 years, the study area contains several heritage items and areas of archaeological potential.

The proposal would result in a neutral physical impact and a negligible visual impact to the SHR listed ‘Old Man’s Valley Cemetery’ (SHR 01764), and potential indirect impacts by way of vibrations. The proposal would result in a moderate physical impact and a moderate visual impact to the locally listed ‘Diatreme Hornsby Quarry and surrounding vegetation’ heritage item and archaeological item (LEP 538, A54).

The proposal would result in neutral to negligible physical and visual impacts on other heritage items located within the study area including the locally listed ‘Old Man’s Valley Cemetery, including Higgins’ Family Cemetery, sandstone receptacle, cool room and site of Higgins homestead on which the Higgins Family Memorial is located’ heritage item (LEP A55), the ‘Hornsby Park—Lone Pine and sandstone steps’ heritage item (LEP 513), and ‘Sandstone steps’ heritage item (LEP 537). Neutral to negligible impacts are anticipated for heritage items located adjacent to the study area.

The proposal, by improving safety and accessibility of the site, would potentially result in enhanced community visitation and engagement with the heritage items located within this historic precinct, and provide opportunities for greater understanding of their significant values and associations. These positive heritage outcomes would balance physical and visual impacts associated with the proposed works, and, as such, the proposal is considered acceptable from a heritage perspective.

Two areas of archaeological potential have been identified within the impact footprint. There is some chance archaeological remains associated with the Higgins family occupation of the site may be impacted in one of these areas to the north, which is partially within the earthworks impact area.

Recommendations

The recommendations set out below will aid in mitigating the impact to the study area, and other heritage items in the vicinity. The recommendations are designed to enable the proponent to determine the most appropriate mitigation, based on other advice and the design of the proposed works. This follows the tenants of the Burra Charter, where avoidance of impact, followed by mitigation of impact, and recording of impact are advised.

The following recommendations regarding the study area are based on consideration of:

- Statutory requirements under the *NSW Heritage Act 1977* and the Hornsby LEP 2013
- The results of background research, site survey and assessment
- The likely impacts of the proposed development.

Photographic recording

A Photographic Archival Recording (PAR) should be prepared prior to works. A copy of this report, plus the PAR, must be kept in the Hornsby Council archives as a record of the site prior to the proposed works. The PAR should be tailored to meet the changes to the property and is not required to be a detailed fabric analysis. The PAR should focus on recording part of the property which will undergo change, to form a record of that change for the future.

Section 140 Permit and archaeological works

An Archaeological Research Design (ARD) should be prepared for the project. The ARD will determine if the project is likely to be located in areas where there may be significant archaeological remains, and recommend whether a permit under Section 140 or an exception under Section 139 of the *NSW Heritage Act 1977* will be required. The ARD would be prepared by a suitably qualified archaeologist.

Where the ARD identifies that significant archaeological remains may be impacted, processes for undertaking the archaeological investigations would be outlined and suitable research questions would be developed which will add to the knowledge of the site and work with Hornsby Council to determine how any relics recovered from site could be used in interpretation or stored.

Unexpected archaeological finds

Should any unexpected archaeological finds be made during works, work must cease immediately and a suitably qualified archaeologist contacts to assess the finds before any works can continue. Additional approvals and investigation may be required.

Future of industrial buildings

To determine the future of the industrial buildings, a structural integrity assessment should be undertaken, in particular for the Former Crushing Plant. Options for its adaptive reuse and interpretation should be explored by Hornsby Council. Dependent on the findings of these investigations, consideration would be given for the suitability of listing the Former Crushing Plant onto Schedule 5 of the Hornsby LEP 2013 as an item of local environmental significance.

Remediation of impacted landscapes

Upon completion of the proposed works, either separately, or as part of Stage 3 of the redevelopment of the study area, the impacted landscapes of the Diatreme Hornsby Quarry and surrounding vegetation (Hornsby LEP 2013 A54/538) will require rehabilitation to reduce the long-term impacts of the works.

Heritage Management Plan

Prior to the detailed design of Stage 3 of the redevelopment of the study area, a comprehensive Heritage Management Plan (HMP) should be commissioned by Hornsby Council. The HMP must provide clear guidance of the management of the numerous significant values of the listed items within the study area, and how this management should be integrated into the future design and use of the study area. This is especially critical for the areas and items of State significance.

Vibration management – 'Old Man's Valley Cemetery'

No impacts to the SHR listed 'Old Man's Valley Cemetery' (SHR 01764) are to occur. Given the potential for indirect physical impacts by way of vibrations to headstones, a condition report should be prepared prior to commencement of the works and integrated into the HMP. The HMP would include monitoring of vibrations and the condition of headstones and other structures located within the curtilage of this item for the duration of construction works.

Interpretation of the historic landscape

The cultural landscape of the study area should be properly and thoroughly interpreted as part of future development. Guidance on interpretation should come through the HMP and then be developed in detail as part of the detailed planning for the study areas Stage 3 development.

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FIGURES

TABLES

1. INTRODUCTION

1.1 Project Background

Artefact Heritage has been engaged by GHD, on behalf of Hornsby Shire Council (the proponent), to undertake a SoHI, to assess the heritage impacts of Stage 2 works relating to the rehabilitation of the Hornsby Park site as a recreational parkland through cut and fill works. The project area contains several heritage items listed on the Hornsby LEP 2013 and one SHR listed heritage item, and is adjacent to several additional locally listed items on the Hornsby LEP (see Chapter 2.0).

Stage 1 of the project is the current works by NCX to deposit fill within the existing Quarry Pit. Stage 2 focuses on cut and fill works within Hornsby Park, and Stage 3 will involve detailed design for the future use of the site. Bulk earthworks by Council are expected to take approximately two years from 2019, and then Council will landscape the site. It is expected the recreational park will be open to the public in 2023.

The aim of this SoHI is to identify heritage items and archaeological areas which may be impacted by the proposed works, determine the level of heritage significance of each item, assess the potential impacts to those items, recommend mitigation measures to reduce the level of heritage impact and identify other management or statutory obligations.

1.2 Study Area

Hornsby Quarry (the study area) consists of:

- Lots A, B, C, D, and E DP318676
- Lot 1 DP114323
- Lots 1 and 2 DP 169188
- Lot 1 DP926103
- Lot 1 DP926449
- Lot 1 DP743359
- Lot 1 DP1157797
- Lot 13 DP734459
- Lot 7079 DP 1050579
- Lot 7017 DP 1052646
- Lots 7018 and 7019 DP1059310
- Lots 7081 and 7082 DP1059313
- Lot 1 DP 594698
- Lot 1 DP 859646
- Part of the Bridge Road road reserve
- Part of the Quarry Road road reserve
- Part of the Summers Avenue road reserve.

The study area, to be known in future as Hornsby Park, includes the original Hornsby Park, Old Mans Valley and the Quarry Lands. The study area is bounded to the north by residential bush blocks, which extend south from Manor Road, to the east by residential and community lots which face Peats

Ferry Road, to the south by residential blocks which align with Dural Street, Lochinvar Place, and Rosemead Road, and to the west by National Parks land (Figure 1).

The study area is dominated by the now disused quarry pit, which occupies much of the central-north of the site, and the former industrial structures used to process rock form the quarry to the south. Much of the site is covered by regrowth vegetation and is crossed by numerous tracks. A detailed site description is provided in Chapter 4.0.

1.3 Report Authorship

This report was prepared by Matthew Alexander (Senior Heritage Consultant, Artefact Heritage) with input from Charlotte Simons (Heritage Consultant, Artefact Heritage). Sandra Wallace (Director, Artefact Heritage) reviewed the report.

1.4 Report Methodology

This SoHI consisted of the following stages:

- Searches of statutory and non-statutory heritage registers, including the NSW State Heritage Register (SHR), NSW State Heritage Inventory (SHI), Hornsby LEP, Commonwealth Heritage List (CHL), National Heritage List (NHL) and World Heritage List (WHL)
- Preparation of a short and concise historical context of the study area
- A site survey and site description
- Statements of significance from listings
- An outline of the proposed works
- A statement of heritage impact, including any physical representation of the proposed works and an assessment of impacts to State and local historic heritage items
- Provision of mitigation and management measures (including measures to avoid significant impacts and an evaluation of the effectiveness of the mitigation measures) generally consistent with the guidelines in the NSW Heritage Manual.

1.5 Relevant Standards

This report was undertaken in accordance with the following standards, guides, codes and best practice documents:

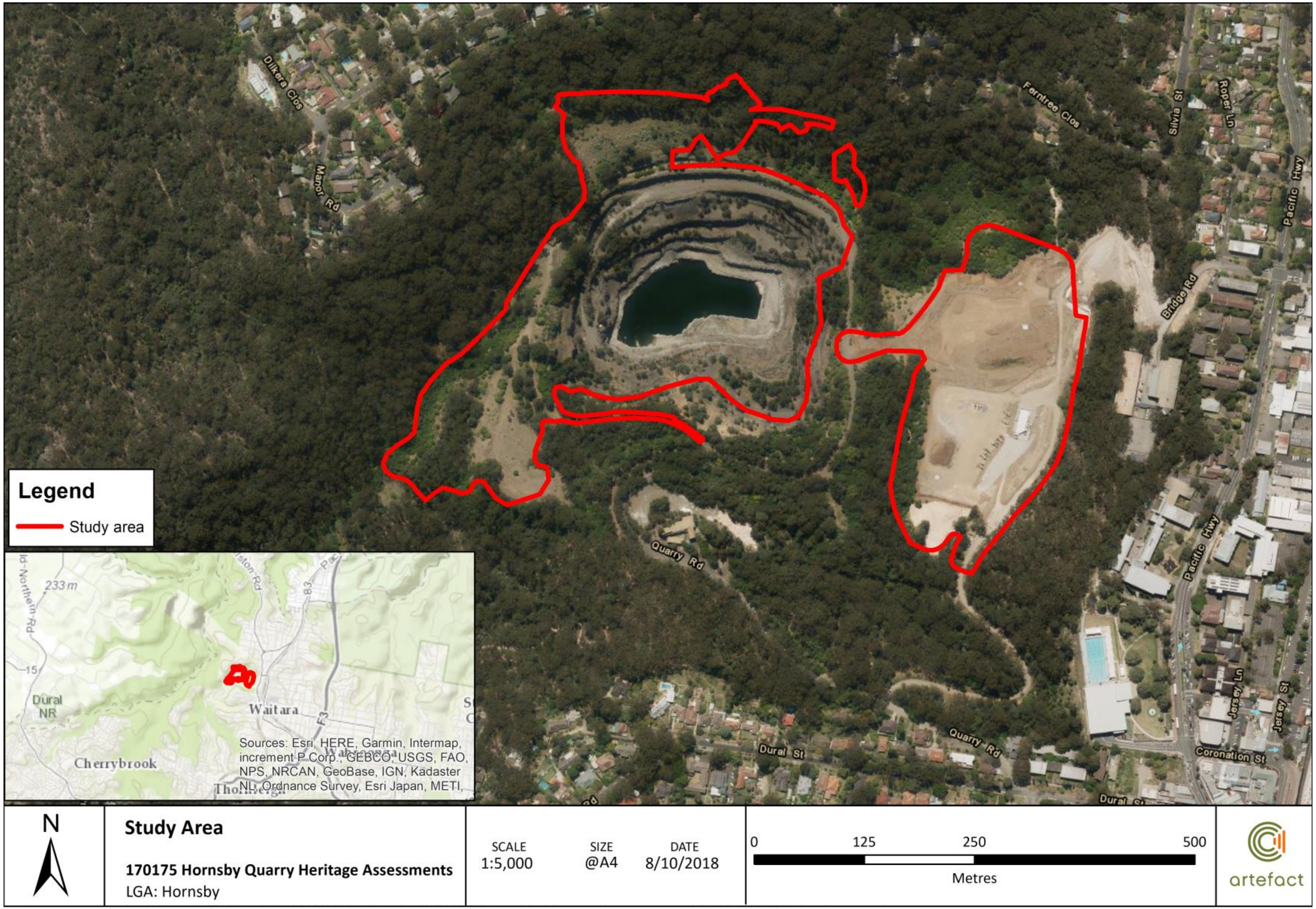
- Australia ICOMOS:
  - The Burra Charter.
- NSW Office of the Environment and Heritage:
  - *Assessing Heritage Significance*
  - *Statements of Heritage Impact*
  - *The NSW Heritage Manual*
  - *Maintenance Series*
  - *Historical Archaeology Code of Practice*.

1.6 Limitations

The following limitations relate to this report:

- This report has been prepared to address non-Aboriginal heritage values only
- No new archival research was undertaken
- No sub-surface archaeological investigations were made
- Only areas accessible during the inspection are described and assessed
- No community consultation was undertaken.

Figure 1: Location of the study area (Artefact Heritage)



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2.0 STATUTORY FRAMEWORK

This chapter outlines the relevant statutory controls for the study area. Relevant heritage curtilages described in this chapter are shown in Figure 2.

2.1 Environmental Protection and Biodiversity Conservation Act 1999

The *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) provides a legislative framework for the protection and management of matters of national environmental significance, that is, flora, fauna, ecological communities and heritage places of national and international importance. Heritage items are protected through their inscription on the WHL, CHL or NHL.

Under Part 9 of the EPBC Act, approval under the EPBC Act is required for any action occurring within, or outside, a Heritage place that has, will have, or is likely to have a 'significant impact' on the heritage values of a World, National or Commonwealth heritage listed property (referred to as a 'controlled action' under the Act). A 'significant impact' is defined as:

> *an impact which is important, notable, or of consequence, having regard to its context or intensity. Whether or not an action is likely to have a significant impact depends upon the sensitivity, value, and quality of the environment which is impacted, and upon the intensity, duration, magnitude and geographic extent of the impacts*.

The EPBC Act stipulates that a person who has proposed an action that will, or is likely to, have a significant impact on a site that is listed on the WHL, NHL, or CHL must refer the action to the responsible minister (hereafter the Minister). The Minister will then determine if the action requires approval under the EPBC Act. If approval is required, an environmental assessment would need to be prepared. The Minister would approve or decline the action based on this assessment.

2.1.1 National Heritage List

The National Heritage List (NHL) was established under the EPBC Act, which provides a legal framework to protect and manage nationally and internationally important flora, fauna, ecological communities and heritage places. Under the EPBC Act, nationally significant heritage items are protected through listing on the NHL or the Commonwealth Heritage List.

There are **no** National Heritage items within the project area or in proximity to the project area that would be affected by the proposed activity.

2.1.2 Commonwealth Heritage List

The Commonwealth Heritage List (CHL) was established under the EPBC Act, which provides a legal framework to protect and manage heritage places owned by the Commonwealth and managed by its various Departments and other organisations. Under the EPBC Act, significant heritage items owned by the Australian Government are protected through listing on the Commonwealth Heritage List.

There are **no** Commonwealth Heritage items within the project area or in proximity to the project area that would be affected by the proposed activity.

2.2 The Heritage Act 1977

The NSW *Heritage Act 1977* (Heritage Act) is the primary piece of State legislation affording protection to heritage items (natural and cultural) in New South Wales. Under the Heritage Act, ‘items of environmental heritage’ include places, buildings, works, relics, moveable objects and precincts identified as significant based on historical, scientific, cultural, social, archaeological, architectural, natural, or aesthetic values. State significant items can be listed on the NSW SHR and are given automatic protection under the Heritage Act against any activities that may damage an item or affect its heritage significance. The Heritage Act also protects 'relics', which can include archaeological material, features, and deposits.

In some circumstances, a Section 60 permit (s60) may not be required if works are undertaken in accordance with the Standard Exemptions for Works Requiring Heritage Council Approval, under Section 57(2) of the act, or in accordance with agency specific exemptions.

The Heritage Act states that:

> *“57 EFFECT OF INTERIM HERITAGE ORDERS AND LISTING ON STATE HERITAGE REGISTER*
>
> *(1) When an… listing on the State Heritage Register applies to a place, building, work, relic, moveable object, precinct, or land, a person must not do any of the following things except in pursuance of an approval granted by the approval body under Subdivision 1 of Division 3:*
>
> *(a) demolish the building or work,*
>
> *(b) damage or despoil the place, precinct or land, or any part of the place, precinct or land,*
>
> *(c) move, damage or destroy the relic or moveable object,*
>
> *(d) excavate any land for the purpose of exposing or moving the relic,*
>
> *(e) carry out any development in relation to the land on which the building, work or relic is situated, the land that comprises the place, or land within the precinct,*
>
> *(f) alter the building, work, relic or moveable object,*
>
> *(g) display any notice or advertisement on the place, building, work, relic, moveable object or land, or in the precinct,*
>
> *(h) damage or destroy any tree or other vegetation on or remove any tree or other vegetation from the place, precinct or land…*
>
> *(2) The Minister, on the recommendation of the Heritage Council, may, by order published in the Gazette, grant an exemption from subsection (1) or such of the provisions of that subsection as are specified in the order in respect of the engaging in or carrying out of such activity or class of activities by such person or class of persons in such circumstances as may be so specified. The Minister's power under this subsection extends to apply in respect of interim heritage orders made by councils.”*

This SoHI seeks to comply with the NSW Heritage Act, by assisting the proponent in meeting their obligations under the NSW Heritage Act in respect to the listed items in Table 1 below, and ensuring that any known or potential impact is managed in accordance with Section 57 of the Heritage Act.

There is **one** item on the SHR within the study area.

Mount Wilga House (SHR No.00535) is located 220m north of the study area. As there are no direct sight lines to the study area, Mount Wilga house is not assessed as part of this report.

Table 1: SHR listed items within the study area

Item	Address	Significance	Listing No.
Old Man's Valley Cemetery	Old Mans Valley, off Quarry Road, Hornsby, NSW 2077	State	01764

2.2.1 Archaeological relics

Part 6 Division 9 of the Heritage Act protects archaeological 'relics' from being exposed, moved, damaged or destroyed. This protection extends to situations where a person has reasonable cause to suspect that archaeological remains may be affected by the disturbance or excavation of the land. It applies to all land in NSW that is not included in the SHR. Section 4(1) of the Heritage Act (as amended 2009) defines ‘relic’ as follows:

> *“relic means any deposit, artefact, object or material evidence that:*
>
> *(a) relates to the settlement of the area that comprises New South Wales, not being Aboriginal settlement, and*
>
> *(b) is of State or local heritage significance.”*

Sections 139-145 of the Heritage Act prevent the excavation or disturbance of land known or likely to contain relics, unless in accordance with an excavation permit. Excavation permits are issued under Section 140 of the Heritage Act, or Section 60 for sites listed on the SHR. Excavation Permit Applications must be supported by an Archaeological Research Design. Section 146 of the Heritage Act requires that any discovery or location of a ‘relic’ is reported to the Heritage Council.

2.3 Environmental Planning and Assessment Act 1979

The *Environmental Planning and Assessment Act 1979* (EP&A Act) establishes the framework for cultural heritage values to be formally assessed in the land use planning and development consent process. The EP&A Act requires that environmental impacts are considered prior to land development; this includes impacts on cultural heritage items and places as well as archaeological sites and deposits. The proposal is subject to assessment under Part 4 of the EP&A Act.

The EP&A Act also requires that local governments prepare planning instruments (such as Local Environmental Plans [LEPs] and Development Control Plans [DCPs]) in accordance with the EP&A Act to provide guidance on the level of environmental assessment required.

The project area falls within the boundaries of the Hornsby Local Government Area (LGA), which incorporates the Hornsby LEP 2013 (HLEP). Schedule 5 of the HLEP includes a list of items/sites of heritage significance within the relevant LGA. Figure 2 illustrates the locations of these items.

The Development Application for the proposal will not be assessed by Council but an independent assessor and is expected to be referred to the North District Planning Panel for approval.

2.3.1 Hornsby Local Environmental Plan 2013

The environmental planning instrument that applies to the project area is the HLEP. The instrument controls development with regard to heritage within the Hornsby LGA. The relevant clauses of Schedule 5.10 of the Hornsby LEP 2013 state:

> *"(1) Objectives*
>
> *The objectives of this clause are as follows:*
>
> *(a) to conserve the environmental heritage of Hornsby,*
>
> *(b) to conserve the heritage significance of heritage items and heritage conservation areas, including associated fabric, settings and views,*
>
> *(c) to conserve archaeological sites,*
>
> *(d) to conserve Aboriginal objects and Aboriginal places of heritage significance.*
>
> *(2) Requirement for consent*
>
> *Development consent is required for any of the following:*
>
> *(a) demolishing or moving any of the following or altering the exterior of any of the following (including, in the case of a building, making changes to its detail, fabric, finish or appearance):*
>
> *(i) a heritage item,…*
>
> *(iii) a building, work, relic or tree within a heritage conservation area,*
>
> *(b) altering a heritage item that is a building by making structural changes to its interior or by making changes to anything inside the item that is specified in Schedule 5 in relation to the item,*
>
> *(c) disturbing or excavating an archaeological site while knowing, or having reasonable cause to suspect, that the disturbance or excavation will or is likely to result in a relic being discovered, exposed, moved, damaged or destroyed,…*
>
> *(4) Effect of proposed development on heritage significance*
>
> *The consent authority must, before granting consent under this clause in respect of a heritage item or heritage conservation area, consider the effect of the proposed development on the heritage significance of the item or area concerned. This subclause applies regardless of whether a heritage management document is prepared under subclause (5) or a heritage conservation management plan is submitted under subclause (6).*
>
> *(5) Heritage assessment*

> *The consent authority may, before granting consent to any development:*
>
> *(a) on land on which a heritage item is located, or*
>
> *(b) on land that is within a heritage conservation area, or*
>
> *(c) on land that is within the vicinity of land referred to in paragraph (a) or (b),*
>
> *require a heritage management document to be prepared that assesses the extent to which the carrying out of the proposed development would affect the heritage significance of the heritage item or heritage conservation area concerned.*
>
> *(7) Archaeological sites*
>
> *The consent authority must, before granting consent under this clause to the carrying out of development on an archaeological site (other than land listed on the State Heritage Register or to which an interim heritage order under the Heritage Act 1977 applies):*
>
> *(a) notify the Heritage Council of its intention to grant consent, and*
>
> *(b) take into consideration any response received from the Heritage Council within 28 days after the notice is sent.1"*

This SoHI seeks to comply with the HLEP, by assisting the proponent in meeting their obligations under the HLEP.

The study area has **five** listings within it on Schedule 5 of the HLEP. Additionally, the study area is adjacent to **five** items of environmental significance on Schedule 5 of the HLEP.

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[1] NSW Government, (2013). 'Hornsby Local Environmental Plan,' *NSW Legislation*. Accessed: https://www.legislation.nsw.gov.au/#/view/EPI/2013/569/part5/cl5.10 (04/10/2017)

Table 2: Items listed on the Hornsby Local Environmental Plan 2013 within or adjacent to study area

Item	Location	Address	Significance	Listing No.
Diatreme Hornsby Quarry and surrounding vegetation	Within study area	1X Quarry Road	Local	A54
Old Man's Valley Cemetery, including Higgins' Family Cemetery, sandstone receptacle, cool room and site of Higgins homestead on which the Higgins Family Memorial is located	Within study area	1X Quarry Road	State	A55
Hornsby Park—Lone Pine and sandstone steps	Within study area	203X Pacific Highway	Local (regional)*	513
Sandstone steps	Within study area	Quarry Road	Local	537
Diatreme Hornsby Quarry and surrounding vegetation	Within study area	1X Quarry Road	Local	538
Mount Errington Precinct, Hornsby West Side Heritage Conservation Area	Adjacent to study area	N/A	Local	C3
Peats Ferry Road Precinct, Hornsby West Side Heritage Conservation Area	Adjacent to study area	N/A	Local	C5
"Norwood"	Adjacent to study area	6 Dural Street, Hornsby	Local	469
Road median, lights and palms	Adjacent to study area	Pacific Highway, Hornsby	Local	500
"Birklands"	Adjacent to study area	52 Dural Street	Local	824

** Regional significance is no longer recognised within the NSW heritage system, instead local or State significance is used*.

2.3.2 Hornsby Development Control Plan 2013

The NSW Department of Planning and the Environment describes the purpose of DCP's as providing:

> *"…detailed planning and design guidelines to support the planning controls in the Local Environmental Plan (LEP) and is prepared and adopted by councils. It identifies additional development controls and standards for addressing development issues at a local level and can be applied more flexibly than a LEP."*

The Hornsby DCP 2013 provides planning guidelines for heritage within the Hornsby LGA, however, it is largely focused on built residential and commercial heritage, and the landscapes associated with such heritage. However, some guiding principles can be summarised from the DCP to enable an assessment of the proposal against the DCP. Section 9.2 of the Hornsby DCP provides general guidance development, however, the industrial and extractive nature of the site is not directly addressed by the DCP. However, Sections 9.2.1, 9.2.3, and 9.2.6 are broadly applicable to the study area.

2.4 'Hornsby Park, Old Man's Valley and Hornsby quarry draft Plan of Management 2015'

The *Hornsby Park, Old Man's Valley and Hornsby quarry draft Plan of Management 2015* provides general long-term guidance for the management of the various cultural, social, and environmental values of the study area.[2] The Master Plan does not provide specific requirements for heritage within the study area, instead referring to the relevant legislation which governs the management of the listed items within the study area, and focuses on the opportunities the redevelopment of the site would have for those items.

2.5 Non-Statutory Listings

2.5.1 Register of the National Estate

The Register of the National Estate (RNE) is no longer a statutory list, however, it remains available as an archive.

There are **two** items on the Register of the National Estate within the study area.

Table 3: Register of the National Estate items within the study area

Item	Address	Significance	Listing No.
Higgins Family Cemetery	Quarry Rd, Hornsby, NSW, Australia	Indicative Place	2614
Hornsby Diatreme Area	Quarry Rd, Hornsby, NSW, Australia	Registered Place	2613

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[2] Hornsby Shire Council, 2015. *Hornsby Park, Old Man's Valley and Hornsby quarry draft Plan of Management 2015*.

2.5.2 National Trust of Australia (NSW)

Listing on the National Trust Heritage Register does not impose statutory obligations and is more an indication in which the item is held by the heritage community.

There is **one** item on the National Trust List in the vicinity.

Table 4: National Trust listed items within the study area

Item	Address	Significance	Listing No.
Old Man's Valley Cemetery	Old Mans Valley, off Quarry Road, Hornsby, NSW 2077	State	9167

2.6 Unlisted Items

The *Hornsby Park Site Analysis*, noted that an additional feature of the study area was significant, though it currently remains unlisted. The *Hornsby Park Site Analysis* notes that item as Industrial Heritage – Former Crushing Plant. The site was assessed as being locally significant by the assessments for Stage 1 of the project.[3]

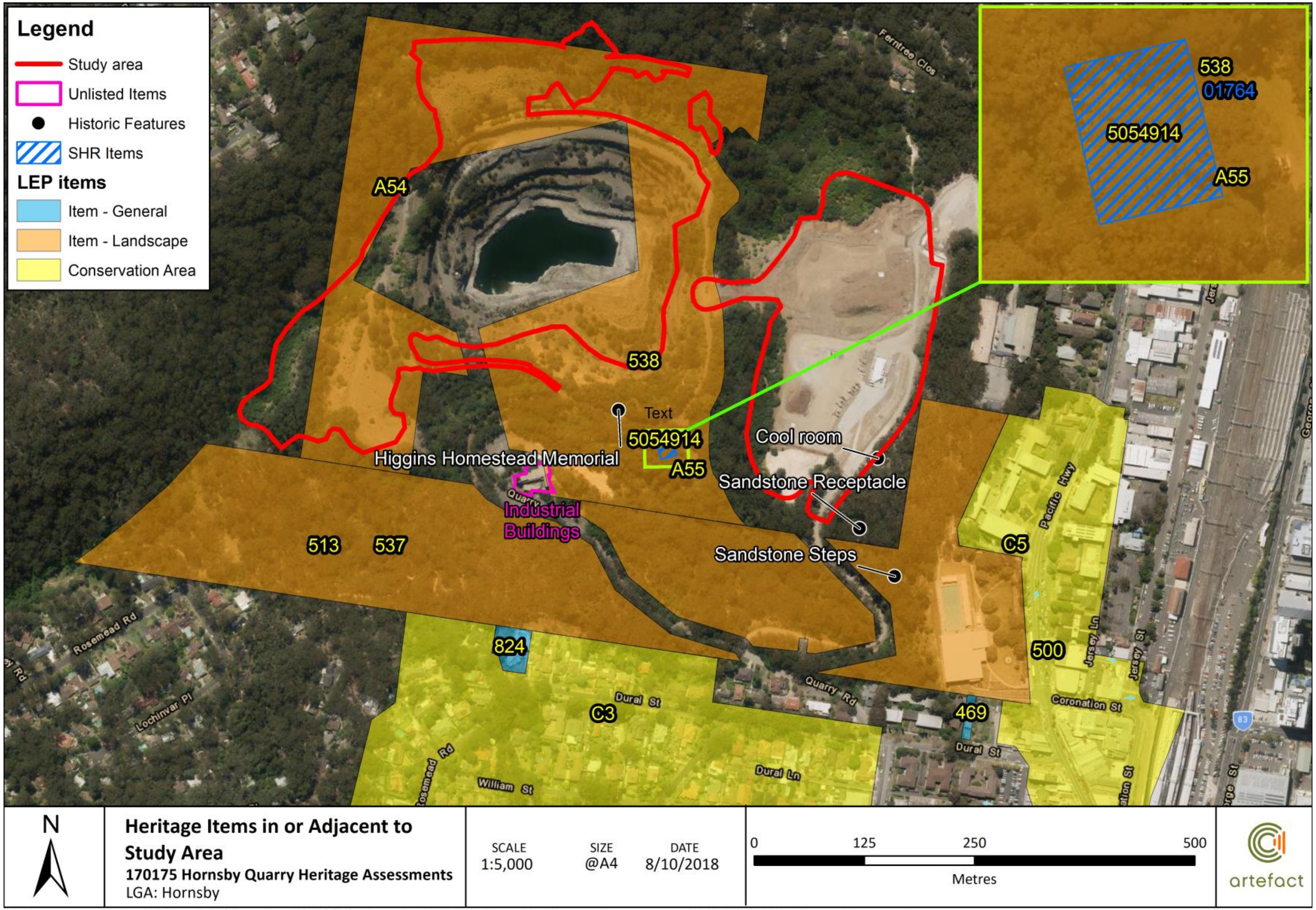
Table 5: Unlisted items within the study area

Item	Address	Significance	Listing No.
Industrial Heritage – Former Crushing Plant	Old Mans Valley, off Quarry Road, Hornsby, NSW 2077	Local	NA

---

[3] AECOM, 2015. Hornsby Quarry Road Construction Spoil Management Project Technical working paper: non-Aboriginal heritage assessment. p.30.

Figure 2: Heritage items within and near the study area. (Source: Artefact Heritage)



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3.0 HISTORICAL CONTEXT

3.1 Introduction

This section provides a general historical overview of the site of Hornsby Quarry. The information is summarised from a number of sources, particularly:

- *Hornsby Quarry Environmental Impact Statement Technical Working Paper Appendix I* (AECOM 2015)
- *Hornsby Heritage Study* (GML 2013)
- *Old Man's Valley Community Land Plan of Management* (Hornsby Council 2012)
- *Hornsby Park, Old Man's Valley and Hornsby Quarry Draft Plan of Management* (Hornsby Council 2015)
- *Hornsby Shire Heritage Study*, (Perumal Murphy Wu 1993).

3.2 Geological Background

The study area is located in an unusual geological formation - a diatreme.[4] Diatremes are the remains of Maar Volcanos, which typically form as a result of the explosive interaction between molten volcanic material and groundwater. Maar Volcanos are formed when hot magma extrudes up through overlying strata and meets with groundwater, resulting in stream pressure-driven explosions that eject rock from below the Earth's crust upwards, with the fragments subsequently falling into a conical cavity, or core, within a compact area.

The 2017 Geological Report on Hornsby Quarry describes the process as: [5]

> *This geological deposit comprises material ejected from deep in the earth's crust in a succession of explosive events which forced this material up through fractures and vents in the overlying rocks. This violent injection of material from deep beneath the earth's crust occurred in trumpet-like or column-like features with the material being blown up through the overlying Triassic sandstone and shales, and at the same time encapsulating pieces of sandstone and shale. Unlike other diatreme deposits in the Sydney area the Hornsby diatreme is made up of several of these trumpet or column intrusions from deep in the earth's crust.*

Within the study area, the core is composed of dolerite, which is surrounded by volcanic breccia containing coal, sandstone and shale.

The study area is situated within the Sydney Basin, a geological structure that spans 64,000 km^2, extending from Australia's east coast, inland to the Blue Mountains and Hunter Valley. While 95 diatremes have been mapped within the Basin, the diatreme in the study area, which is part of the diatreme complex of Hornsby and Thornleigh, is one of the largest and most accessible (Figure 3).

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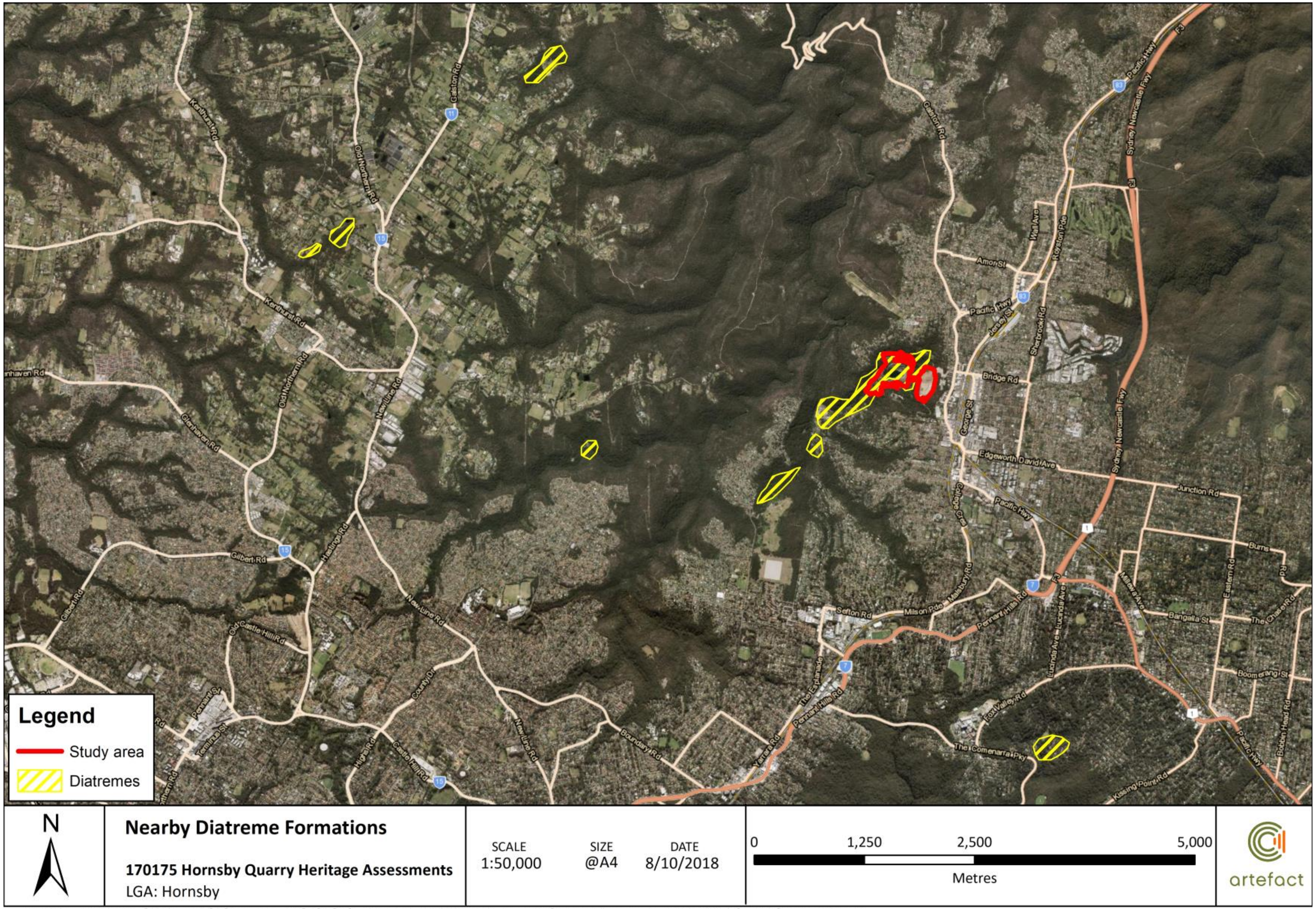
[4] http://www.environment.nsw.gov.au/heritageapp/ViewHeritageItemDetails.aspx?ID=1780064

[5] Pells, Sullivan, Meynink. 2007. *Geotechnical and Hydrological report on Hornsby Quarry*. Submission to Hornsby Shire Council.

Figure 3: Diatremes within the Hornsby area. (Source: Artefact Heritage)



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The diatreme has been exposed in the wall of the Hornsby Quarry as a result of quarrying activities between 1903 and the quarry's closure in the 1990s. This activity exposed a cross-section of the structure of the diatreme in the eastern face of the quarry. Hornsby Quarry is the largest diatreme known in the Sydney Basin, and the only cross section though a diatreme in the State.[6]

Figure 4: Hornsby Quarry (Source: http://www.rms.nsw.gov.au/projects/sydney-north/hornsby-quarry/index.html)

Studies of pollen, coal and wood fragments included in the diatreme at Hornsby Quarry indicate that the diatreme was formed in the Jurassic age (200-146 million years ago), suggesting that, at that time, the Sydney Basin was a region with high groundwater levels with exploding volcanoes and crater lakes. The ancient volcanic activity in the area produced fertile soils making the surrounding area a prime location for tall timber growth and horticultural activities.[7]

The Hornsby diatreme also shows unusual 'dish beds' or basinal layering in a U shape, which occurred when the layers of rock fell back into the vent. The Geological Society of Australia states that there are no other sites in NSW or Australia where dish beds in a diatreme are exposed.[8]

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[6] Joplin, 1968; Taylor, 1976; Morgan, 1976, 1977, 1978; Helby & Morgan, 1979, as cited in Geological Society of Australia 2016 - Response to 2015 EIS Hornsby Quarry Road Construction Spoil Management Project.

[7] Geological Society of Australia 2016, Response to 2015 EIS Hornsby Quarry Road Construction Spoil Management Project.

[8] ibid

Figure 5: Dish bed layering in eastern wall of Hornsby Quarry (Source: http://www.hornsby.nsw.gov.au/council/major-projects/hornsby-quarry)

3.3 Aboriginal History[9]

Prior to the appropriation of their land by Europeans, Aboriginal people lived in small family or clan groups that were associated with particular territories or places. Traditional Aboriginal tribal boundaries within Australia have been reconstructed, primarily, based on surviving linguistic evidence and are therefore only approximations. Social interaction, tribal boundaries and linguistic evidence may not always correlate, and it is likely boundaries and interaction levels varied and fluctuated over time. Aboriginal people traditionally lived in small family or clan groups that were associated with particular territories or places.[10]

The Hornsby area was home to members of the Darug language group and the study area is within the traditional country area of the Guringai (Kuringgai, Kurikgai and Kuring-gai) Aboriginal people. The coastal dialect of the Darug language group is thought to have been spoken on the Sydney peninsula (north of Botany Bay, south of Port Jackson, west to Parramatta) and north of Port Jackson, possibly as far as Broken Bay. The hinterland dialect is believed to have been spoken on the Cumberland Plain, west of the Georges River, Parramatta, the Lane Cove River and Berowra Creek; from Appin in the south to the Hawkesbury River in the north.[11]

British colonisation had a profound and devastating effect on the Aboriginal population of the Sydney region. In the early days of the colony Aboriginal people were disenfranchised from their land as the British claimed areas for settlement and agriculture. The colonists, often at the expense of the local Aboriginal groups, also claimed resources such as pasture, timber, fishing grounds, and water sources. Overall the devastation of the Aboriginal culture did not come about through war with the British, but instead through disease and forced removal from traditional lands. It is thought that during the 1789 smallpox epidemic over half of the Aboriginal people of the Sydney region died.[12]

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[9] A separate report "*Hornsby Quarry Due Diligence Assessment*, Artefact Heritage, 2017" provides more detail on the Aboriginal cultural history of the study area.

[10] Tindale's Catalogue of Australian Aboriginal Tribes. Accessed online at http://archives.samuseum.sa.gov.au/tindaletribes/daruk.htm on 05/10/2017

[11] Attenbrow, V. 2010. *Sydney's Aboriginal Past: Investigating the archaeological and historical records*. UNSW Press. p34

12 Hornsby Shire Council www.hornsby.nsw.gov.au/council/history

3.4 Early Settlement at Hornsby

The history of Hornsby Quarry and Old Mans Valley, immediately to the east of the Quarry, are closely linked, therefore the following sections summarise the history of both these areas.

Six weeks after the arrival of the first fleet, Governor Phillip led an expedition through Broken Bay in search of a large river to provide fertile land capable of cultivating crops for the colony. The Hawkesbury River was not discovered until the second expedition in the following year. This expedition continued the exploration of the River before reaching the fertile plains at Windsor. The Hawkesbury River provided the major transport route for the earliest settlers. The shoreline also provided a good location for commercial activities such as salt production, flour milling, and boat building.[13]

The harvesting of Blue Gums and Grey Ironbarks, which grew on the ridges, was the first economic activity undertaken by European settlers in the Hornsby area. Timber was transported by river for sale to Sydney builders. The activities of timber cutters opened the district for permanent settlement by farmers who took up the most fertile land located on the ridge tops.

Figure 6: First settlement at Hornsby n.d. (Source: Hornsby Library)

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[13] Perumal Murphy Wu (1993) Hornsby Heritage Study. Prepared for Hornsby Council.

Figure 7: Old Mans Valley, c1920s (Source: Hornsby Library)

Samuel Horne and John Thorne were among the notable early settlers within Hornsby, the earlier of which inspired the name of the village, and Constable Thorn's land later became known as the suburb of Thornleigh. Horne and Thorne were police constables who were rewarded with sizable land grants for their role in the shooting of John MacNamara, an accomplice to the bush ranger John Donohue, and the capture of other members of his gang in 1830.[14]

Figure 8: Spencer Higgins helping his father Ned cut timber near their home in Old Mans Valley, n.d. (Source: ancestry.com)

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14 Kass T, 1993, Hornsby Shire Heritage Study, Thematic History, Prepared for Hornsby Council: 8

Throughout the 19th century, the region remained fairly remote and rural with large land holdings primarily utilised for agriculture. The fruit growing industry commenced in the 1830's and was the main industry within the region. The subdivision of the original Horne and Thorne grants resulted in a number of orchard lots being released to the market. Until the early twentieth century, the majority of subdivisions involved the development of small acreages developed as orchard lots.[15] In the 1890s, Dural and the Hills district was the chief supplier of citrus fruit for most of Australia. As well as growing fruit for sale in the Sydney market, local growers also entered the market as suppliers of seeds and seedlings of ornamental and fruit bearing plants.[16]

Figure 9: 'Four members of what was possibly the Higgins family in a large cross-cutting pit' n.d. (Source: Friend of Berowra Valley)

3.5 The Higgins Family

The first permanent settlers to the Hornsby area were the Higgins family. Thomas Edward Higgins (1800-1865) was the son of a convict transported on the Second Fleet. Higgins was promised a grant of 250 acres of land in the Hornsby area by Governor Brisbane in 1823, in the area called Old Mans Valley. The grant was formally recorded in 1835, though by that time Higgins had cleared the site and started to establish timber getting and sawmilling, felling the blue gums and ironbarks for the Sydney market. He also developed orchards and market gardens on the land, taking advantage of the fertile volcanic soils of the area. These activities were continued by the Higgins extended family on part of the land up until the 1960s.

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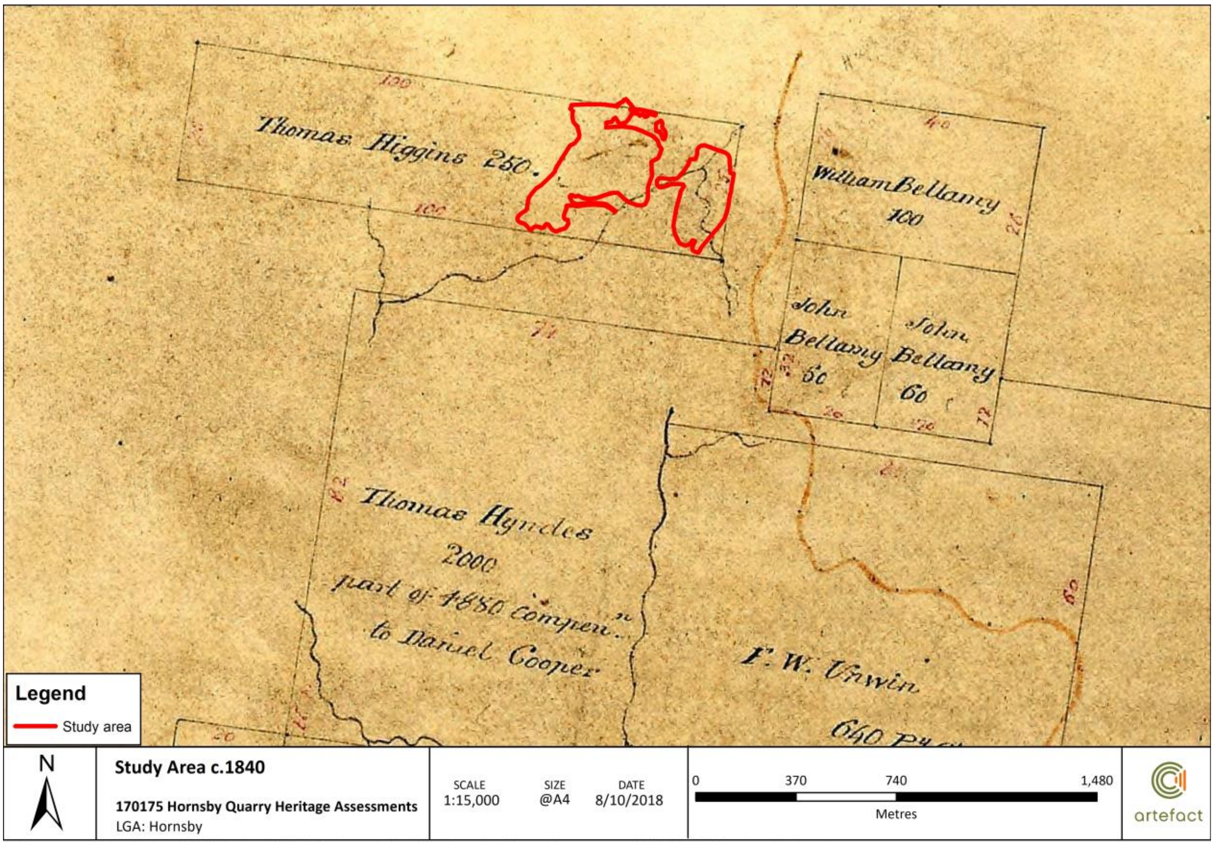
[15] Kass T, 1993, op cit: 11

[16] Schofield 1988, The shaping of Hornsby Shire, Hornsby Shire Council: 112

From the 1860s to the 1890s, several houses and structures were built within the study area to accommodate members of the Higgins family. Thomas Higgin's only son, also named Thomas (1832-1885), inherited his father's grant in 1868, and after he died in 1885 his wife, Ann Higgins, sold almost half the property to John Nobbs in 1887. John Nobbs called his land 'Hornsby Park' and subdivided it, but the descendants of Higgins family maintained a continuous presence in Old Mans Valley up until 1970, when Freda Jones, daughter of Percy Higgins, left the site when quarrying operations expanded. The origin of the name Old Mans Valley is not clear, but could be related to 'old man Higgins' the original settler, or to the grey kangaroos ('old man kangaroos') that inhabited the valley.

Figure 10: Section of c.1840 Parish of South Colah map, showing Higgins 250 acres and the study area (Source: NSW Historical Lands Record Viewer)



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In addition to the Higgins homestead and the homes for various family members, the Higgins family and their descendants also developed other structures and features in the landscape. In Old Mans Valley, a 'cool room' was built into a sandstone overhang, which is evidence of the domestic activities of the Higgins family. A sandstone receptacle was carved into the sandstone further up the slope that contains the cool room, and is also likely to have been associated with the Higgins family.[17] Chapter 4.0 provides addition additional on these items.

The Higgins family also developed their own cemetery at the Hornsby Quarry site just to the western side of Old Mans Valley. The cemetery contains twenty-three known burials dating from 1879 until 1931, with listed family names including Higgins, Jansson and McKenzie. The isolation of Old Mans Valley would have led to the need for a private cemetery due to the difficulties of transporting the dead to established communal cemeteries. Sandstone and marble headstones and other monumental masonry, and cast iron rail surrounds were erected for some of the graves. A recent restoration of the cemetery restored headstones and railings, installed an interpretation board at the

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[17] Parsons Brinckerhoff, 2004 as cited in AECOM 2015.

site with a layout plan of the burials, and constructed protective fencing. [18]

There are also tracks and staircases winding into the valley to the south, and to the west of Old Mans Valley is a set of hand carved sandstone steps called the ‘Depression Steps’. They are thought to have been built in the 1930s as part of unemployment relief works, however some oral history evidence from Higgins family descendants stating that the stairs may have predated this, having been present in the 1920s linking some of the Higgins family houses in the area.[19]

As well as the original Higgins family homestead, several houses were built for family members from the 1860s until the 1890s - the home of Ann (nee Higgins) and Mathew Harrington, the house of Thomas Harrington, the home of Clara (nee Higgins) and Peter McKenzie, the home of Nairn (nee Higgins) and Thomas McKinnon, and the home of Thomas Edward Higgins IV and Maria Agnes Duffy. At the site of the original family homestead an area has been fenced off and a memorial was erected there in 1970 stating ‘On this site stood the homestead of the Higgins Family, Pioneers of the Hornsby District 1834 – 1970’. Some houses were destroyed by rot or bushfire, while others survived until demolished in the 1960s during the development works for the Hornsby Quarry.[20]

As the original descendants of the Higgins family left Old Mans Valley, Council purchased those landholdings. In 1969, Hornsby Shire Council came to acquire Lots 1 and 2 of Plan Number 169188 (forming the greater southern portion of Old Mans Valley) and in 1980 Council acquired the remainder (Lot 1, DP 114323). In 1982, Council filled part of Old Mans Valley to establish playing fields.

Figure 11: Two of the former Higgins family homes in Old Mans Valley and in the adjoining Hornsby Quarry lands c1959. Based on the direction of the photo, the residence in the foreground may be that of Freda Jones, which was occupied until 1970 (Source: Hornsby Shire Council)

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[18] http://www.environment.nsw.gov.au/heritageapp/ViewHeritageItemDetails.aspx?id=5054914
[19] Parsons Brinckerhoff, 2004 as cited in AECOM 2015.
[20] Parsons Brinckerhoff, 2004 as cited in AECOM 2015.

Figure 12: Study area in 1930 (Source: Artefact Heritage)

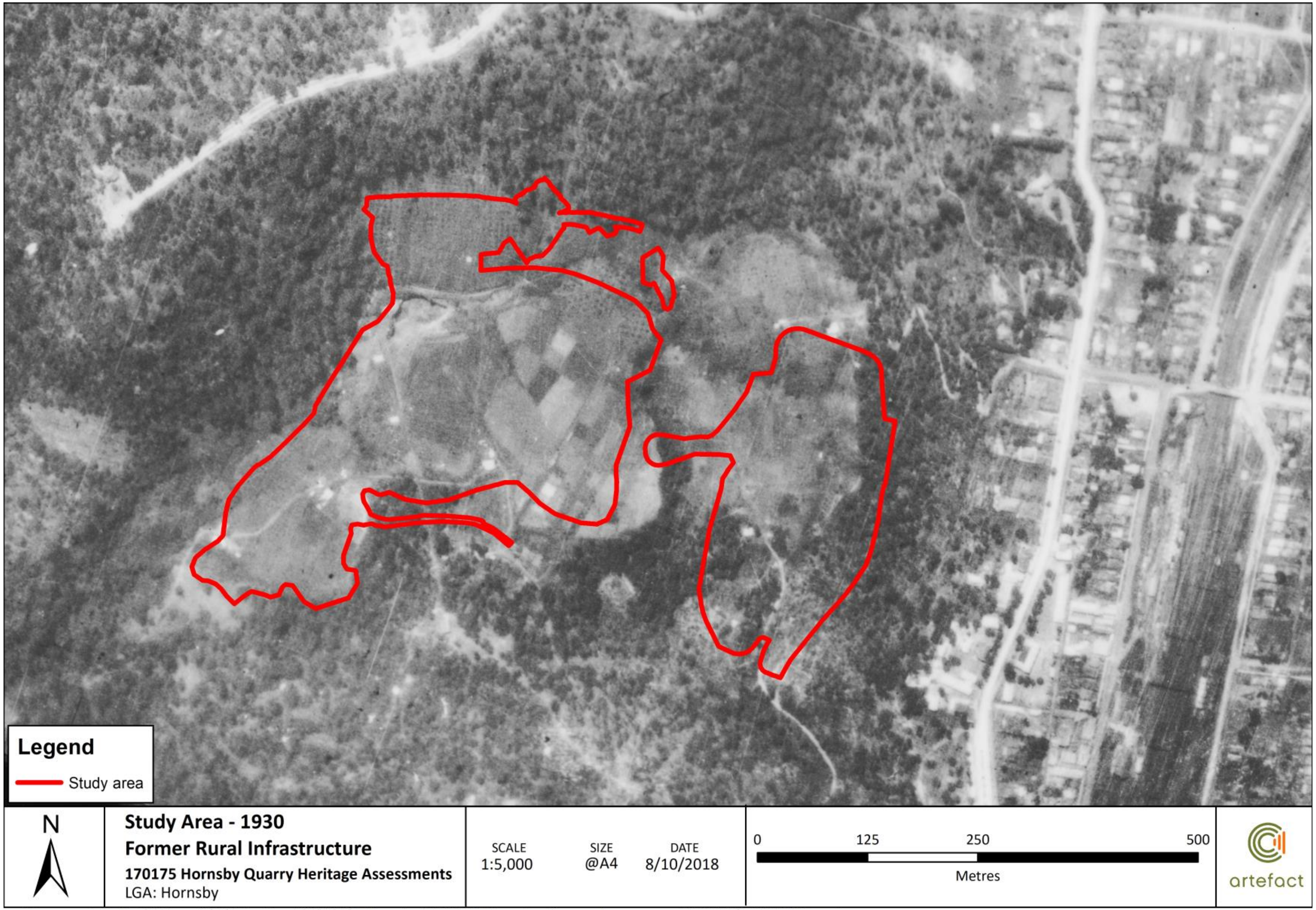

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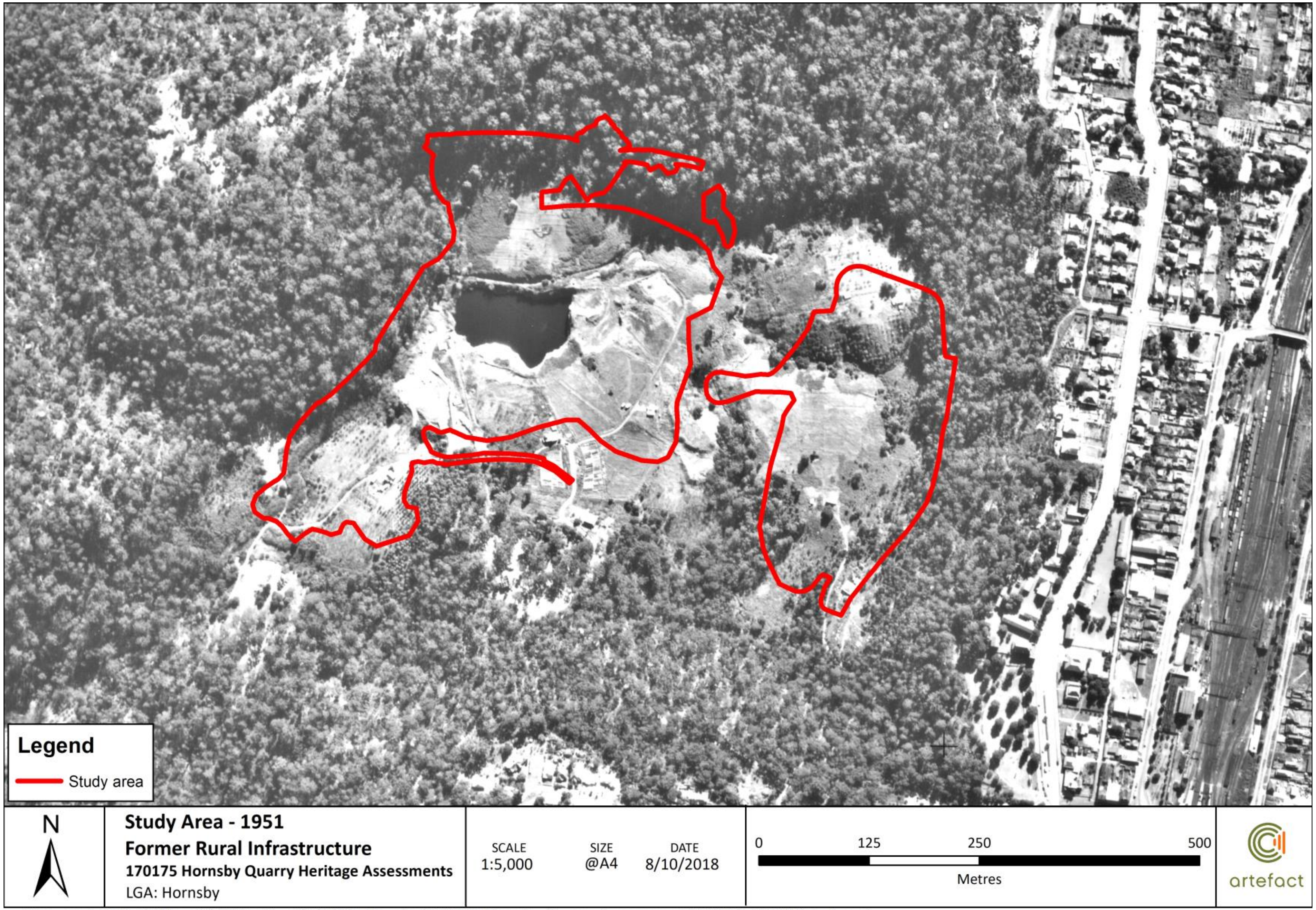
Figure 13: Study area in 1951 (Source: Artefact Heritage)



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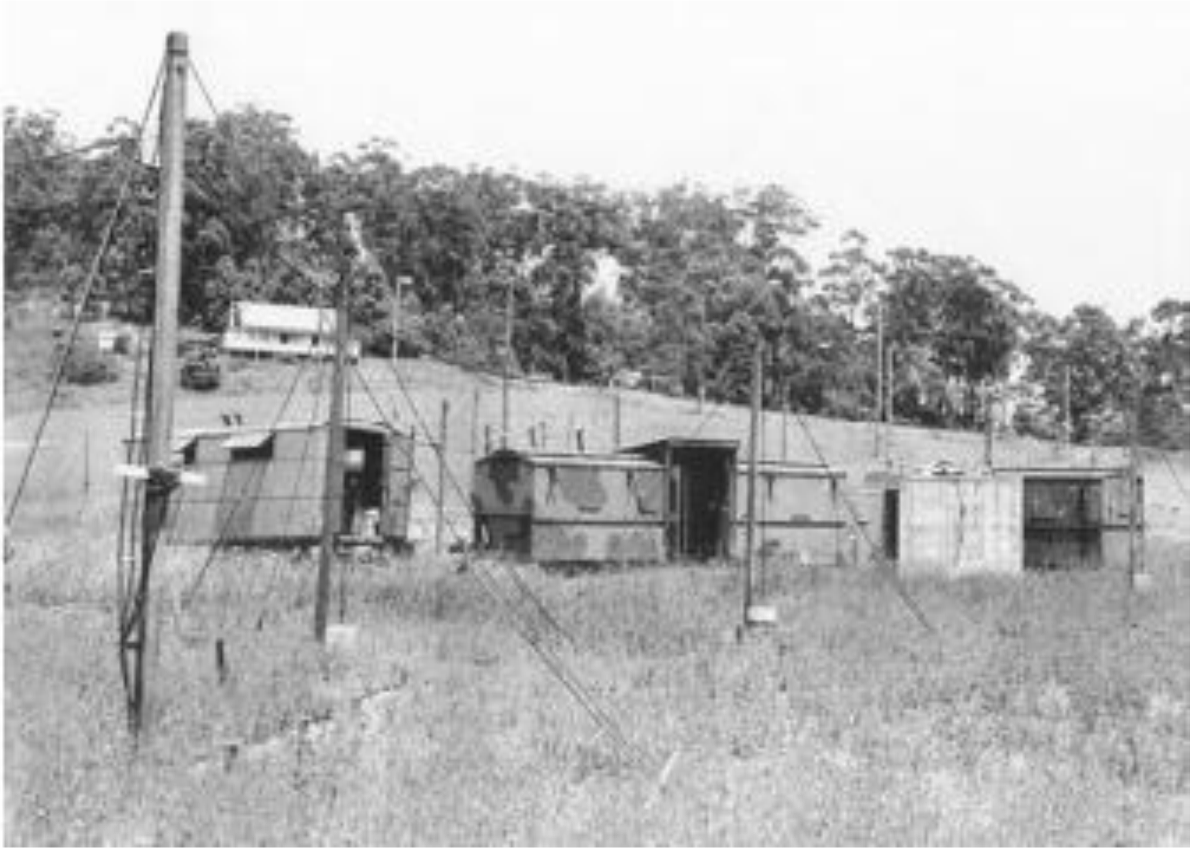
3.6 Radio Astronomy

Between 1947 and 1955, the Hornsby Radio Astronomy Field Station existed in Old Mans Valley, where over 30 different experiments in radar astronomy were conducted. The Field Station contained a number of radio telescopes which bounced signals off the Moon to explore the structure of the Earth's upper ionosphere. In 1948, Ruby Payne-Scott (1912-1981), the first female radio astronomer and a pioneer in radiophysics and radio astronomy, made discoveries of types of solar bursts at the Field Station. The work of Payne-Scott and other scientific teams made great contributions to studies in lunar, solar and galactic astronomy before the Field Station closed and relocated to Badgerys Creek in 1955, making way for a continuation of the expansion of quarrying on the site.

Figure 14: Hornsby Radio Astronomy Field Station c1950 (Source: http://www.hornsby.nsw.gov.au)



3.7 Hornsby Quarry

By 1903, mining for blue metal (dolerite) for road base and gravel had commenced at Hornsby Quarry. At that time, it was excavated by hand and transported out of the quarry by horse and cart. Mining in this area developed into a commercial enterprise in the 1920s, and Hornsby Council briefly held the quarry lease until it was taken over by Hornsby Road Metal Ltd from 1924 until the mid-1930s. Mining operations ceased during World War II and were resumed by Perry and Norman Higgins in the 1950s. Prior to the mid-1950’s, the quarry consisted of only a small excavation in the valley floor up against the steep, natural slopes at the western side of the current pit. In 1954, Council briefly acquired the lease to Hornsby Quarry and a stockpile of blue metal, for the sum of £5,000, and the quarry was only mined sporadically in the 1950s.

Figure 15: Work in Hornsby Quarry, 1961 (Source: Daily Telegraph, 24 March 2015)

A scoop is operating on the floor of the Hornsby Quarry, then owned by Farley and Lewers in 1961. Around that time, Hornsby Council had to deal with noise complaints from the quarry.

Mining activities continued at Hornsby Quarry from 1959 onwards. Farley & Lewers acquired the quarry lease for a brief period in 1959 before being appropriated into the CSR mining company. Quarrying works increases in scale during 1960s, with the pit doubling in size from 1956 to the mid-1960s, and a crusher plant operation was established at the end of Quarry road during this period. The slopes to the north were being mined but there was no works in eastern area in the 1960s.

In the 1960s and 1970s, with the quarry's expansion, the remains of houses and structures relating to the Higgins family were demolished, and machinery, infrastructure and offices were gradually added to the area as part of the quarrying operations. During the 1970s, access roads were built in the south, and excavations extended into the slopes to the north of the site with haul road ramps established up the slopes at the north-eastern side of the quarry. The pit was deepened and extended to the east, and in the mid-1980's the quarry void was further deepened.[21]

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[21] Clouston 2014. Recreation Potential Study for Hornsby Quarry and Old Man's Valley Lands

Figure 16: Hornsby Quarry, 1963 (Source: Hornsby Shire Council)

By the 1990s, the quality of extracted material at the quarry had lessened, which lead to its closure. Structures from the quarry's operations, such as a steel-frame workshop, concrete block office, a crushing and screening plant, an administration building, a sub-station, pieces of equipment, pumps, stairs, pipes and fences, remained in-situ though have suffered from deterioration and vandalism.

Figure 17: Crusher Plant, 2013 (Source: www.hornsbypark.com.au)

CSR maintained ownership of the site until 2002, when Hornsby Shire Council was required to purchase the site at a price of $26 million, established through the Land and Environment Court. Since 2003, the quarry site has been fenced for safety reasons as the sides are unstable and the pit has filled with water to create a lake. Bushwalking tracks, heritage walks, and 6kms of mountain bike trails have been developed in the Old Mans Valley area.[22] The most recent activities within the study area has been Stage 1 of the current project, with NorthConnex using the quarry pit to deposit fill.

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[22] Clouston 2014. Recreation Potential Study for Hornsby Quarry and Old Man's Valley Lands

4.0 SITE DESCRIPTION

An inspection of the project area was conducted by Matt Alexander (Senior Heritage Consultant) and Jennifer Norfolk (Heritage Consultant) on 30 November 2017. The aim of this inspection was to identify the significant elements of the study area, its contribution to any broader heritage precincts, and the relationship between the study area and its locality. The following section provides a physical analysis of the study area. All photographs, unless indicated otherwise, were taken by Artefact Heritage on 30 November 2017.

4.1 Study Area Description

4.1.1 General description of study area

The Hornsby Quarry is located west of Hornsby City Centre, the quarry is situated in a steeply sloped drainage channel with two elevated ridgelines along the northwest and south east in the study area. The site has been heavily disturbed by the historic mining practices for its diorite resource and the associated infrastructure, such as site compounds, fuelling station, access roads and previous occupation sites. There are several amenities located around the quarry margins including sewerage systems, electricity, drainage conduits.

Historically the vegetation of the area has been impacted by logging. There has been recent impacts for recreational purposes with the addition of bike tracks spread over the south east, eastern and north eastern portions of the site. Fill has been brought in and heavy excavation works have been undertaken to form the bike tracks and ramps.

The study area is densely vegetated, and the ground visibility is limited due to thick leaf litter. There is a vehicle access track around the periphery of the quarry. The majority of the northern section the study area is densely vegetated, and the steep slope made it inaccessible to traverse.

4.1.2 ‘Old Man’s Valley Family Cemetery’ (SHR 01764, Hornsby LEP A55)

The ‘Old Man's Valley Cemetery’ heritage item is enclosed by cyclone fencing, set back two metres from the original cemetery boundary, which is a twenty by twenty metre square. within a setting of dense surrounding vegetation, both regrowth and original, with materials from the quarry works piled to the south west. The cemetery sits on a slope that steeply rises from east to west. There are twenty-three recorded burials within the cemetery, though of these, only fifteen possess head stones, with another five visibly marked.

The earliest graves face east in rows, with later burials grouped by family, broken into the Higgins, McKenzie, and Jansson areas, and a separate area for unmarked infant’s graves. Headstones are either sandstone or marble, with the former utilised for the earliest burials. Other elements of the cemetery include iron fences with hooped railings, sandstone kerbing, "barley twist" pattern cast iron railings, and some grave borders are formed by white-painted bricks with a zig-zag profile. Paths link the graves, which are also interspersed with native and exotic plantings. There are also interpretive signs at the access gate to the cemetery

Figure 18:The entrance to the enclosed graveyard.

Figure 19: View of the visible graves stones from the south side of graveyard.

4.1.3 Diatreme and Quarry (Hornsby LEP A54 and 538)

The quarry is enclosed by cyclone fencing, set back from the quarry edge and is inaccessible for safety reasons. The Diatreme was not visible during the survey as the infilling of the quarry by NorthConnex has covered it.

Figure 20: View south of the quarry showing impacts to the landscape.

Figure 21: View north east of the quarry and the infill covering the Diatreme.

4.1.4 Hornsby Park (Hornsby LEP 513)

Hornsby Park lies on the western slope over Old Mans Valley. The park possesses flagstone paths, lawns pergolas, annual planting beds, ornamental fountain, the Higgins memorial plaque, and a series of 1930s period lights. The park contains several notable trees, including:

- A group of mature Turpentine trees
- Camphor Laurels from 1920s
- Argyle Apple
- Jacaranda Palm
- Golden Cypress
- Chinese Elm

- Japanese Maple
- Camellias
- Agave.

It is noted this heritage item previously comprised a commemorative Allepo Pine, ‘Lone Pine’, which was removed in August 2012 to necessitate construction of the new Hornsby Aquatic and Leisure Centre. The Hornsby Park – Lone Pine and sandstone steps heritage item is in the process of being revised to discount reference to the pine.

Hornsby Park is well maintained and laid out in an orderly fashion, which integrates well with Old Mans Valley to the North and provides several vantage points for the viewing of the valley.

Figure 22: View west of the manicured gardens and flower beds

Figure 23: View north of the pavements and aesthetic features of the gardens

4.1.5 Sandstone Steps (Hornsby LEP 537)

The sandstone stairs run from the current vehicle track to an area close behind the Hornsby Aquatic Centre and are constructed of hand-carved sandstone. Conflicting accounts of the stairs construction exists, with construction as part of a Depression era program or by the Higgins family at an earlier date have been referenced in earlier reports. The stairs, if constructed by the Higgins family may be of a similar age to the nearby cool room carved into a rock overhang by the Higgins family.

Figure 24: View east of Sandstone Steps at the lowest point of the slope.

Figure 25: View east of the Sandstone Steps at the highest point of the slope.

4.1.6 Industrial structures

On the western side of the Quarry along the vehicle access track is a vehicle refuelling station with concrete pads, two large fuel storage containers and a pumping system. In the south eastern section of the study area is located the processing plant for the quarry. The are several office structures and a crushing facility.

Figure 26: The refuelling station on west side of quarry void.

Figure 27: Crushing plant on the south east section of the study area.

4.2 Adjacent Heritage Items

4.2.1 Mt Ermington Precinct (Hornsby LEP C3)

The Mt Ermington Precinct is located adjacent to the southern border of the study area. The Conservation Area is noted for its bushy character and collection of Federation and Interwar residences that demonstrate the historic development of Hornsby. Due to the heavy vegetation and setting of the Conservation Area, there are no notable views to or from the parts of the study area where works are proposed.

4.2.2 Peats Ferry Road Precinct (Hornsby LEP C5)

Like the Mt Ermington Precinct, the Peats Ferry Road Conservation Area is located adjacent to the southern border of the study area. The Conservation Area is noted for its bushy character and collection of Federation and Interwar residences that demonstrate the historic development of Hornsby. Due to the heavy vegetation and setting of the Conservation Area, there are no notable views to or from the parts of the study area where works are proposed.

4.2.3 “Norwood” (Hornsby LEP 469)

Norwood is a simple, single story timber frame and board Federation style dwelling, which is currently utilised as a preschool. Norwood is adjacent to the south-east corner of the study area, however, views into the study area from Norwood are blocked by taller modern structures to the north and west.

Figure 28: Norwood – street view

4.2.4 “Road Median, Lights, and Palms” (Hornsby LEP 500)

The median strip located on Peats Ferry Road between Dural Street and the Northern Sydney Institute of TAFE. The median is 120 metres long and contains two extant palm trees and three historic light posts. The item has no direct view lines into the study area, due to its setting and the high-rise structures to its west.

Figure 29: View north east of road median and Palms

Figure 30: View south east of Road median, Lights and Palms

4.2.5 “Birklands” (Hornsby LEP 824)

Birklands, built in 1902, is a double gabled, well detailed, Federation dwelling with later additions constructed to the rear. Birklands sits within a well-established garden to the south of the study area, and though located on the study area border, is over 300 meters from the proposed works area and has no view lines to the works area, due to thick intervening vegetation.

Figure 31: Street view of Birklands

5.0 ASSESSMENT OF SIGNIFICANCE

5.1 Introduction

An assessment of significance is undertaken to explain why a particular place is important and to enable the appropriate site management and curtilage to be determined. Cultural significance is defined in The Burra Charter as meaning ‘aesthetic, historic, scientific, social or spiritual value for past, present or future generations’ (Article 1.2). Cultural significance may be derived from a place’s fabric, association with a person or event, or for its research potential. The significance of a place is not fixed for all time, and what is of significance to us now may change as similar sites are located, more historical research is undertaken and community tastes change.

The guideline *Assessing Heritage Significance, 2001,*[23] originally published as part of the *NSW Heritage Manual* by the NSW Heritage Office & NSW Department of Urban Affairs and Planning in 1996, establishes seven criteria (which reflect five categories of significance and whether a place is rare or representative) under which a place can be evaluated in the context of State of local historical themes.

Similarly, a heritage site can be significant at a local level (i.e. to the people living in the vicinity of the site), as a State level (i.e. to all people living within NSW) or to be significant to the country as a whole and be of National significance. In accordance with the guideline *Assessing Heritage Significance* a site (item) will be considered to be of State or local heritage significance if it meets one or more of the criteria.

5.2 Existing Significance Assessments

The Statement of Significance is the foundation for future management and impact assessment. Statements of Significance for the heritage items within the study area are provided below. Each is extracted from the NSW State Heritage Inventory, Hornsby DCP, or Hornsby Heritage Register.

5.2.1 ‘Old Man’s Valley Family Cemetery’

> *The Old Man's Valley Cemetery is of State significance for its rarity as one of the few fully conserved family cemeteries in New South Wales and possibly the only one. It is also of State significance for the social value that this high state of conservation represents - firstly to a wide array of Higgins family descendants (now living all over Australia) who have funded its conservation over many years, accessing both professional advice and their own labour. Its social significance to the wider community is also demonstrated by its role as a heritage destination by visitors, cemetery enthusiasts and educational institutions. Acquired by Hornsby Shire Council in 2006, it provides an exemplary model of how a family cemetery may be conserved and valued.*
>
> *Sited in Old Man's Valley, which was first agricultural land then a bluestone quarry (recently decommissioned), the cemetery is associated with the economic development of the locality and also has high local historical significance for its graves memorialising the descendants of Hornsby's earliest European settler family, Thomas Edward Higgins, son of Thomas Higgins and his wife Eleanor*

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[23] NSW Heritage Office. (2001). *Assessing Heritage Significance*. Parramatta. Accessed: http://www.heritage.nsw.gov.au/docs/assessingheritagesignificance.pdf (28/06/2017).

> *McDonald. Containing twenty-three known burials with internments dating from 1879 to 1931, its dates are unusually late for a private cemetery. Its establishment and use appears to have been a direct response to the isolation of Old Man's Valley and the difficulties of transporting the dead to established communal burial grounds. It is also of high local significance for its representative examples of late nineteenth and early twentieth century monumental masonry, providing a good record of the designs, inscriptions, motifs indicative of funerary symbolism and practices used in a modest family cemetery in NSW at that time. The cemetery also has high representative significance at a local level for its landscape setting amid both remnant natural vegetation and traditional European grave plantings.*

5.2.2 Diatreme and Quarry

> *This item is associated with the period of use of the Hornsby Quarry and is a physical example of the works untaken for the quarry. Eroded valley of volcanic rock surrounded by parkland. Volcanic Rock in an area predominantly of sandstone has created an unusual environment, part of which is recreational reserve, part used for quarrying blue metal. Due to the link to quarrying in this area, the site has the potential to contribute to the local community's sense of place, and can provide a connection to the local community's past.*[24]

5.2.3 Hornsby Park

> *A well laid out and well-constructed park of 1930s period conserving old trees with bushland glimpses. Includes Anzac commemorative Lone Pine tree and fountain with plaques. Of significance for the northern area of Sydney. Of regional significance.*

5.2.4 Sandstone Steps (including assessment of other remnant built items)

This assessment includes information on the Higgins' Family Cemetery, sandstone receptacle, cool room and site of Higgins homestead on which the Higgins Family Memorial is located

> *This complex of relics represents an important component of the heritage of the Hornsby Shire by providing evidence of the settlement and occupation of Old Man's Valley by the Higgins family. It has social significance to Higgins family descendants and the local community.*
>
> *This complex of relics represents an important component of the heritage of the Hornsby Shire by providing evidence of the settlement and occupation of Old Man's Valley by the Higgins family. The Higgins family were pioneer settlers not only of the valley itself, but also of the wider Hornsby area. Members of the Higgins family occupied the Old Man's Valley for over 140 years, from c. 1830 to 1970. Due to the large scale modification to the surrounding landscape caused by the quarry operation, these relics, in conjunction with the Higgins family cemetery, represent*

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[24] AECOM, 2015. Hornsby Quarry Road Construction Spoil Management Project Technical working paper: non-Aboriginal heritage assessment. p.26.

the only surviving physical evidence in the valley of almost 150 years of occupation by the descendants of Thomas Higgins II.

Due to the possible link to early settlement in this area, the site has the potential to contribute to the local community's sense of place, and can provide a connection to the local community's past. "This complex of items has social significance to the many descendants of the Higgins family, many of whom remember these relics from childhood days spent in the valley.

They also have social significance to the wider community as they represent physical evidence associated with the pioneering settlers of the Hornsby area". The site of the Higgins Homestead, marked by a fenced off area and memorial, has the potential for subsurface deposits. Immediately to the east of this is an area cited in a past study to have the potential for further deposits associated with at least six residences, possibly damaged or buried under overburden deposit (Parsons Brinckerhoff Australia Pty Ltd, 2004:176-177).

These areas have the potential for further research. This complex of relics provides physical evidence of an isolated rural settlement and lifestyle during the late 19th and early 20th century where luxuries such as electricity and mains water were not available. It appears that the cool room may have been a communal facility used by several of the surrounding households and thus provides evidence of the close knit family based pioneering community".[25]

5.2.5 Industrial structures

The Hornsby quarry machinery serves as an important remnant and reminder of early bluestone quarry activities that commenced at the turn of century and continued until the mid 1960s. The blue metal quarried from the valley from as early as 1903 provided a much needed building material for the construction of industrial, commercial, and domestic buildings and a major resource for the construction of major and minor roads within the Shire and the rail systems throughout the Sydney area. The quarry machinery provides physical evidence of local industrial achievement and can provide a connection to the local Hornsby community's past.[26]

5.2.6 Mt Ermington Precinct

The Mount Errington Precinct demonstrates the historic development of Hornsby, with surviving evidence of early development. Houses and gardens from the Federation and Inter War periods, and the landscape contribute to quality streetscapes. The dramatic setting contributes to a high level of aesthetic significance, with bush encircling the area on three sides providing a green

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[25] AECOM, 2015. Hornsby Quarry Road Construction Spoil Management Project Technical working paper: non-Aboriginal heritage assessment. p.29.

[26] AECOM, 2015. Hornsby Quarry Road Construction Spoil Management Project Technical working paper: non-Aboriginal heritage assessment. p.30.

backdrop that is reinforced by the dominant tree canopy of remnant and regeneration forest.[27]

5.2.7 Peats Ferry Road Precinct

The Peat Ferry Road Precinct is significant for its association with the development of Hornsby as a railway town, and role within the old town centre. The area is historically and socially significant as an extant example of the earliest commercial precinct in Hornsby. The Peats Ferry Road precinct contains a fine collection of Federation and Inter War period commercial and civic buildings.[28]

5.2.8 "Norwood"

Historic period and style building with important connections to the community.[29]

5.2.9 Road Median, Lights, and Palm Trees

Notable lighting standards and palms from c1920 forming a sophisticated streetscape. Of local significance.[30]

5.2.10 "Birklands"

The siting and design of 'Birklands' was oriented to enjoy specific views of Hornsby's remarkable bushland valleys on the spurs and ridges to the west. Former home of local architect Louis S. Robertson c1901-1932, whose work in the LGA includes the Hornsby War Memorial and extension to Beecroft School of Arts. 'Birklands' is representative of the earlier houses in the Hornsby area which sought healthful locations with bushland views on the edge of Sydney suburbia.[31]

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[27] Hornsby Shire Development Control Plan 2013. Section 9.3.7.

[28] Hornsby Shire Development Control Plan 2013. Section 9.3.7.

[29] Hornsby Shire Council: Heritage Register, accessed at http://hscenquiry.hornsby.nsw.gov.au/pages/xc.track.heritage/heritage.aspx?id=23417

[30] 5.2.10 Road Median, Lights, and Palm Trees, accessed at http://www.environment.nsw.gov.au/heritageapp/ViewHeritageItemDetails.aspx?ID=1780628 on 20/11/2017.

[31] Hornsby Shire Council: Heritage Register, accessed at http://hscenquiry.hornsby.nsw.gov.au/pages/xc.track.heritage/heritage.aspx?id=24970

6.0 ARCHAEOLOGICAL ASSESSMENT

6.1.1 Assessing significance

Assessing significance for archaeological sites can be difficult, in that the extent and nature of the remains is generally unknown and value judgements based on potential or expected attributes need to be made. Heritage significance in NSW is assessed using the Heritage Council of NSW's seven specific criteria based on the principles of the *Burra Charter*. How these apply to archaeological heritage assessment is further explained in *'Assessing Significance for Historical Archaeological Sites and Relics'* guidelines from the NSW Heritage Manual (2009). Consideration of the research potential of an archaeological resource is necessary in determining archaeological significance. In addition, the expected intactness or integrity of an archaeological resource influences the evaluation of research potential and significance.

6.1.2 Archaeological potential assessment – non-Aboriginal heritage

Old Mans Valley represents a rare example of a complex of sites owned and occupied by one family from the initial settlement of the place until the middle of the twentieth century. Old Mans Valley provides encapsulation of the life of those who pioneered the settlement of the area and how the land was developed over a century. In order to assess the archaeological potential and significance of the study area, the archaeology has been broken into several phases as follows:

- Phase 1 – Early settlement (c.1835-1900)
- Phase 2 – Later rural development (1901-1950)
- Phase 3 – Quarrying and public use (1951-present).

6.1.2.1 Phase 1

Phase 1 encompasses the period from the initial settlement of the study area by the Higgins family, the opening up of the valley through timber getting and clearing, and the establishment of agricultural production. The location of archaeological remains from this period is difficult to determine, however it is likely, though not certain, that any settlement of the valley would have been close to water, and therefore in proximity to the streams running through the valley as shown in Figure 10. The spatial distribution of structures in the 1930s aerial photo supports this hypothesis, as the majority of structures present are less than eighty meters from the streams.

Remains from this period could consist of footings of earlier structures, pathways, waste pits, along with elements of the cemetery up to 1900. It is unlikely that other remains associated with this period would be present, as early farming infrastructure and works would likely have been lost (being of timber construction) or removed by later development on the site as structures were progressively modernised.

Figure 32: Higgins 250 acres, the study area (red) and streams within Higgins holding (blue) (Source: NSW Historical Lands Record Viewer)

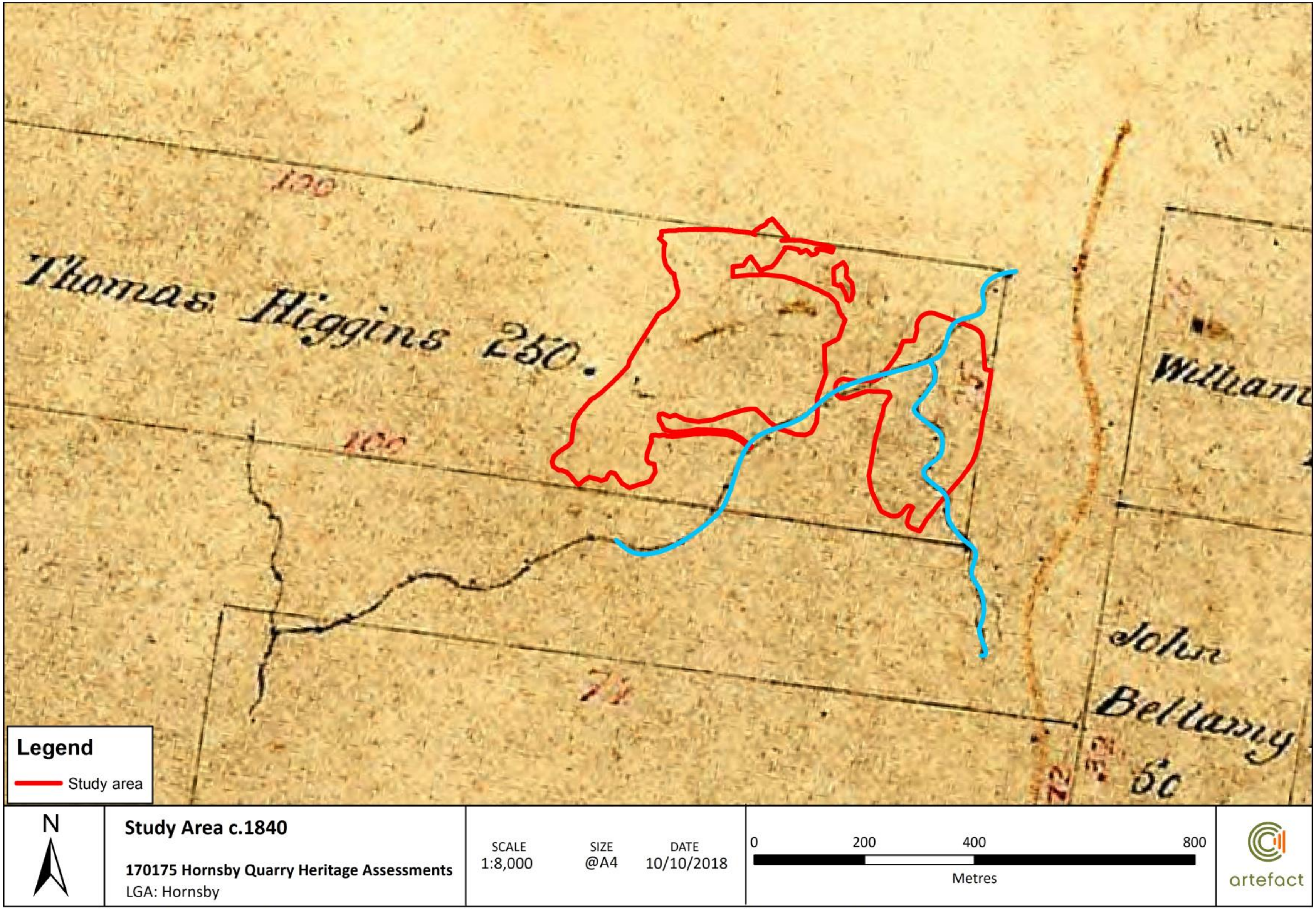

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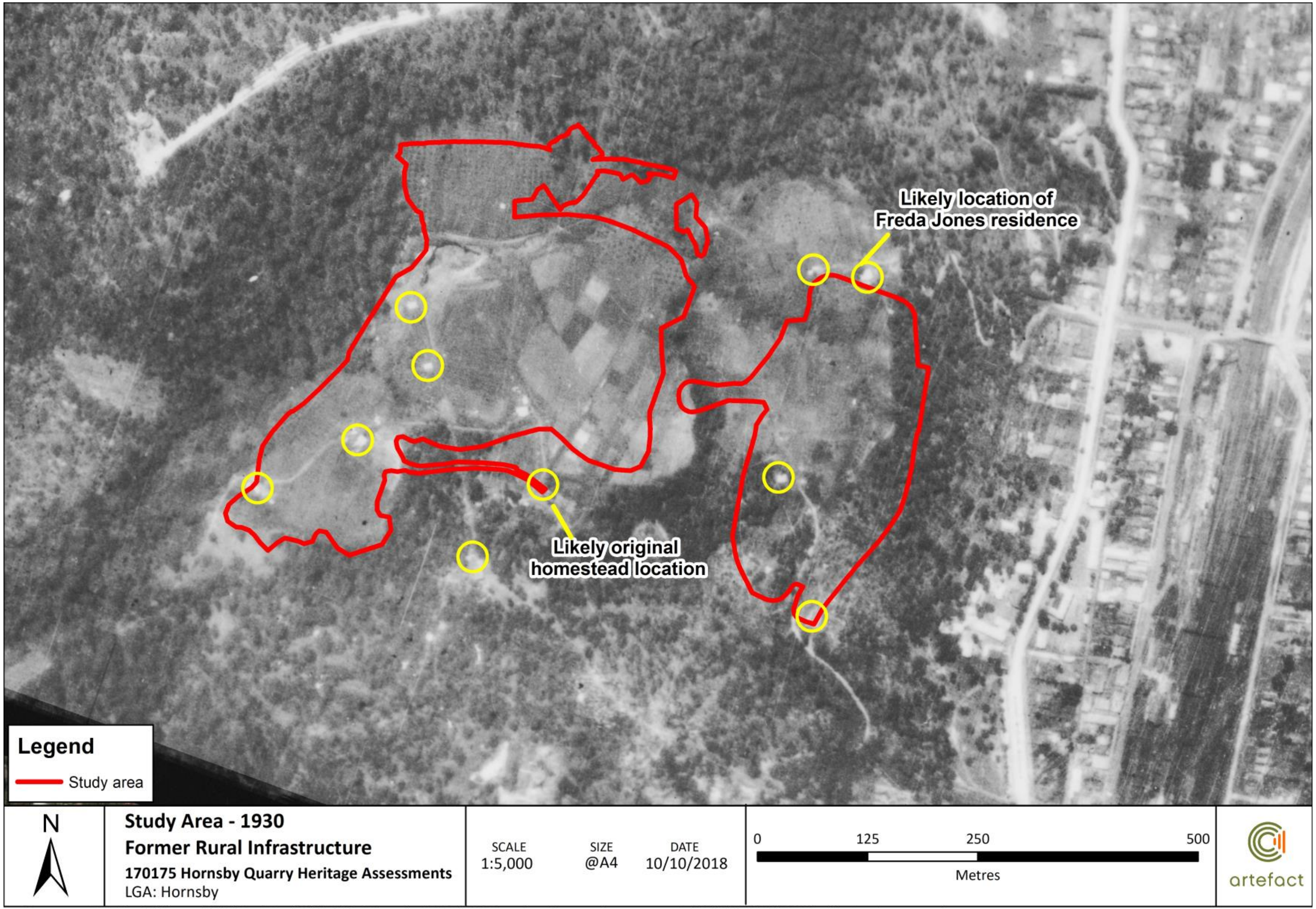
Figure 33: Study area in 1930, with yellow circles indicating areas with built structures (Source: http://trove.nla.gov.au)



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6.1.2.2 Phase 2

Phase 2 encompasses the development of the study area from 1901 until the main phase of quarrying activity began in 1951. The aerial images from 1930, 1950, and 1951 examined for the study area show large areas under cultivation, either as market gardens or orchards. Ten areas of built structures are visible across this period, consisting of at least twenty separate buildings.

Remains from Phase 2 could consist of footings of structures, pathways and roads, agricultural infrastructure, residential and rural waste pits, and remnant planting, along with elements of the cemetery up to 1931.

6.1.2.3 Phase 3

Phase 3 coincides with the expansion of quarrying in the study are, and the tapering off of the settlement of the valley by the Higgins family. Although the last member of the family left in 1970, impacts across the valley from the quarrying activities and associated infrastructure has heavily impacted much of the landscape, as have later works involved with developing the study area for recreation.

The quarry pit, roads and associated structures are clearly evident in the landscape and any later remains in the homes that remained during this period would likely be collocated with those from phase two, consisting of similar remains, though without the large scale agricultural components.

6.1.3 Areas of rural development

A series of aerial images up to 1951 were examined to determine the footprint of the agricultural and residential development of the study area prior to quarrying beginning. This assessment has determine the general footprint of development for the study area to 1950 to develop a base line potential for archaeological remains. Figure 34 illustrates the extents of development within the valley to 1950.

6.1.4 Defining disturbance

Disturbance to the valley since 1950 has greatly altered the landscape, impacting potential archaeology across much of the study area. Disturbance mapping was based on aerial images from 1951 to 2017. The term “gross disturbance” has been used to define areas where the ground surface and underlying layers has been totally altered. Figure 35 illustrates the extent of gross disturbance across the study area since 1950.

6.1.5 Areas of potential archaeology

To determine areas of remaining potential archaeology, the results of the mapping of the Higgins family’s development of the study area were overlaid with the assessment of gross disturbance to determine areas of remaining archaeological potential. Figure 36 illustrate these areas.

Figure 34: Former rural infrastructure (Source: Artefact Heritage)

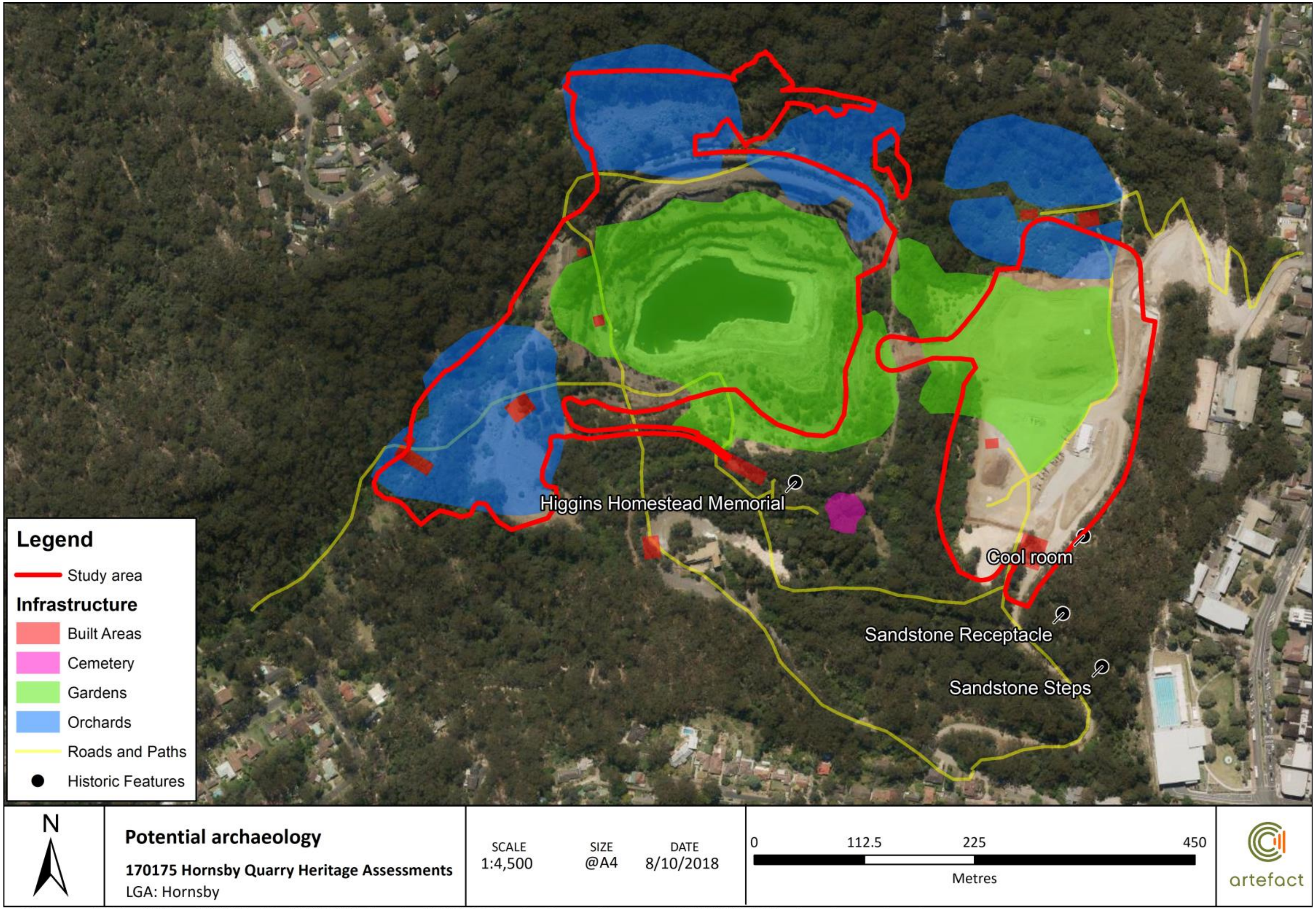

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Figure 35: Disturbance within the study area (Source: Artefact Heritage)

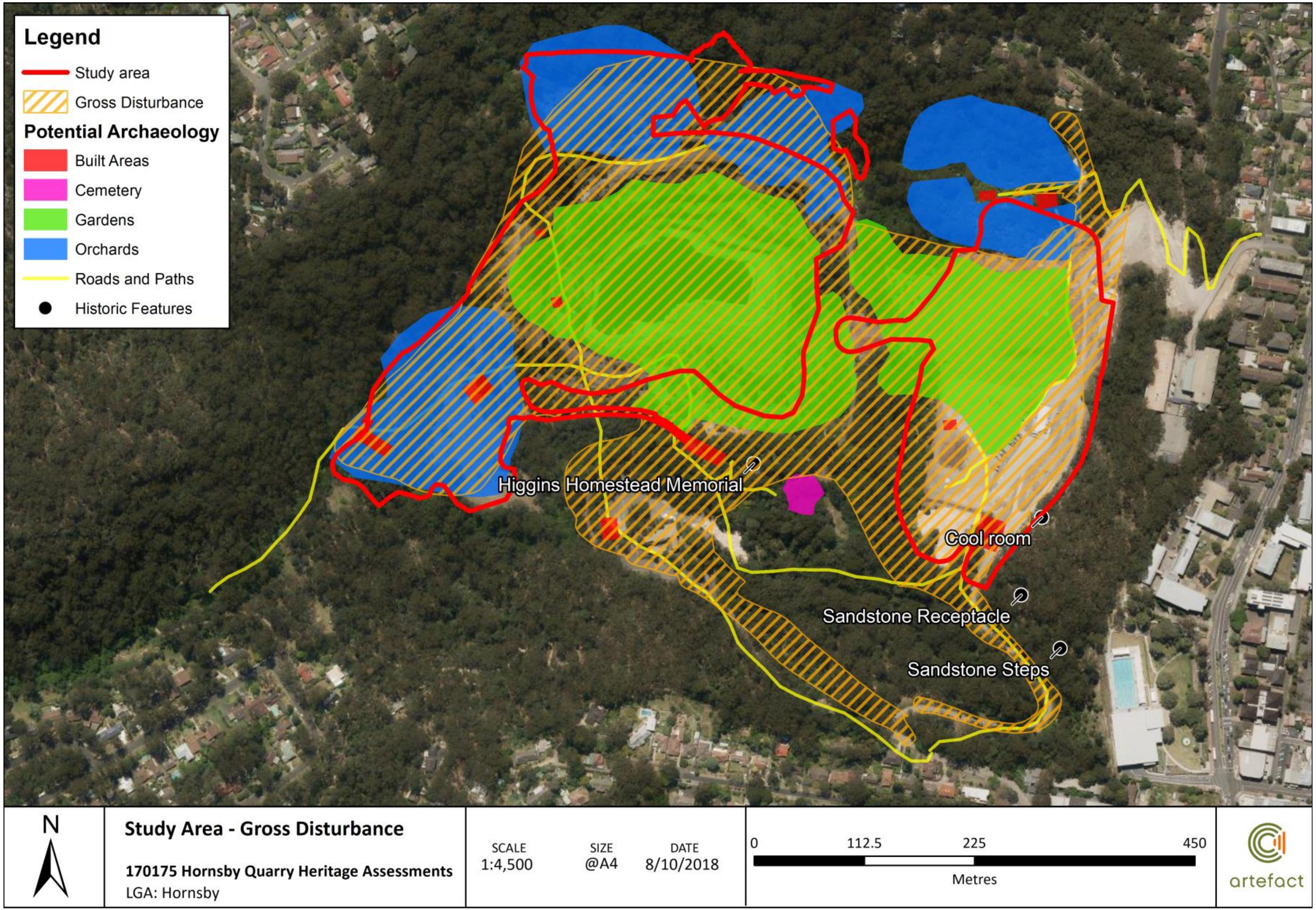

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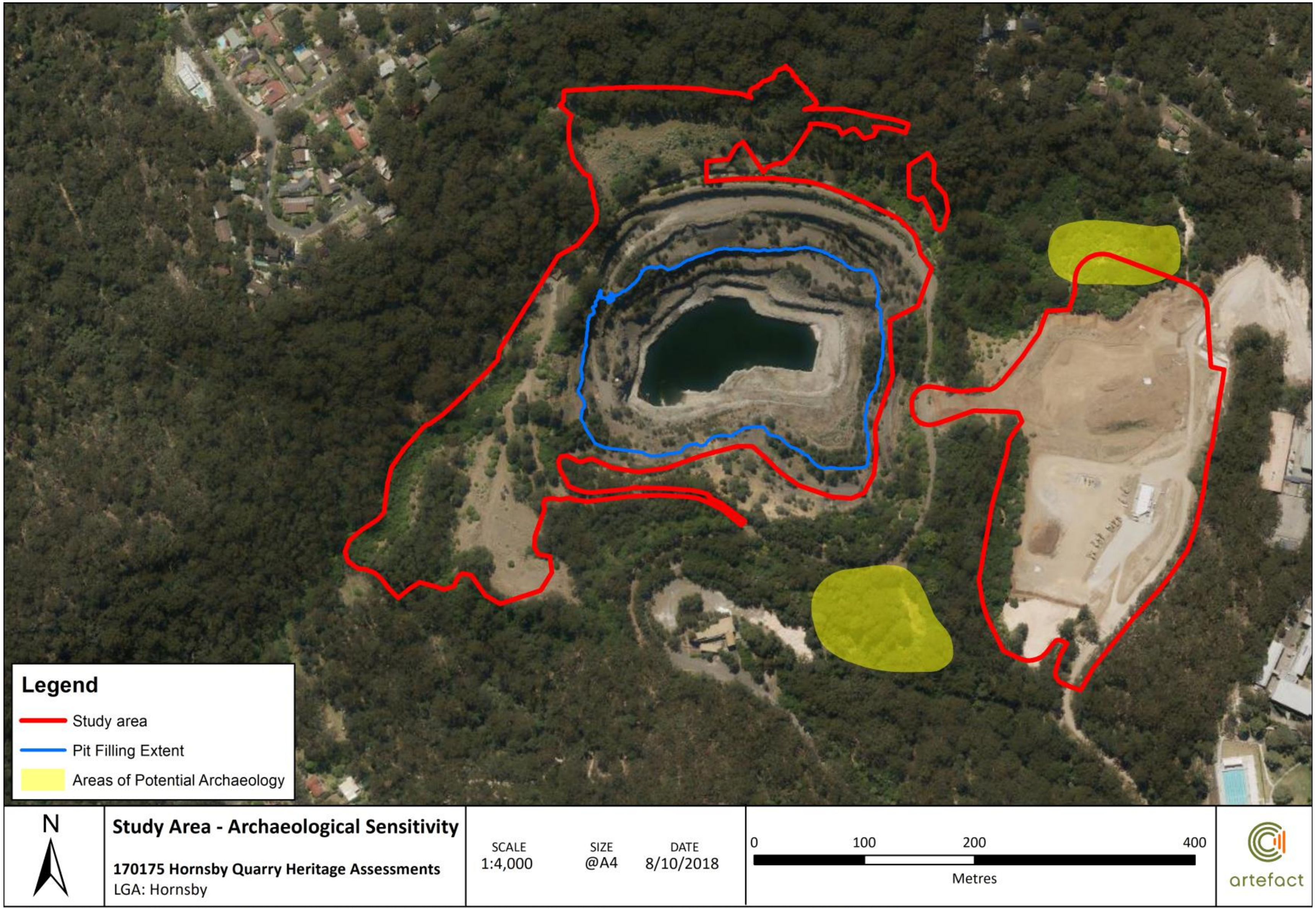
Figure 36: Archaeological potential (Source: Artefact Heritage)



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6.1.6 Statement of archaeological significance

The remaining areas of archaeological potential within the study area have the potential to provide the material history of part of the Higgins family from the 1830s until the 1970s, nearly 150 years of a single family, with the associated cemetery providing the resting place of many members of that family. The cemetery is already recognised as state significant for it values.

The potential material remains of this occupation by the Higgins family and its ability to tell the story of the occupation of the study area through new means, across such a length of time is of great research value. Such deposits are of significance at the State level, due to their ability to shed light on early development of the Sydney basin and the continuation of that development into the late twentieth century.

Table 6: Summary of archaeological potential and significance in the study area

Phase	Potential remains	Significance	Potential
Phase 1	Footings, waste pits, occupation deposits	State (if long term deposits located with phase 2 below)	Nil for most of study area, low-moderate in northern area of potential
Phase 2	Footings, waste pits, occupation deposits, rural infrastructure	State (if long term deposits located with phase 1 above)	Nil for most of study area, moderate to high in northern area of potential
Phase 3	Evidence of quarrying activities	Nil	High

7.0 DESCRIPTION OF PROPOSED WORKS

7.1 Overview of Proposed Works

Hornsby Quarry is a former breccia hard rock quarry that was operated by private business from the early 1900s and ceased in the late 1990s. The quarry is considered a safety risk and has therefore been closed to the public since that time.

Hornsby Shire Council (Council) acquired the site in 2002 and has since undertaken a number of investigations and studies with regard to the future use of the site and the environmental and technical constraints that the site poses. Through these studies, Council identified the need to:

- Stabilise the quarry
- Manage the site in a safe and environmentally sustainable manner
- Actively seek opportunities to fill the quarry void with spoil arising from major infrastructure projects in the region.

Council also resolved to ultimately develop the site into a community parkland.

In 2016 approval was granted to Roads and Maritime Services to beneficially reuse up to 1.5 million cubic metres of excavated rock and soil (spoil) from the construction of the NorthConnex tunnel to partially fill the Hornsby Quarry (the ‘2016 Planning Approval’). Filling has recently commenced at the site under this approval.

Following completion of filling by NorthConnex, Council is proposing to rehabilitate and reshape the site in a suitable way to ensure public safety and allow future development into a parkland for community use (the project).

GHD Pty Ltd (GHD) has been engaged by Council to prepare documentation to support a development application for approval of the project under Part 4 of the New South Wales (NSW) *Environmental Planning and Assessment Act* 1979 (the EP&A Act). The Environmental Impact Statement (EIS) will be prepared in accordance with the provisions of the EP&A Act, and will address the requirements of the Secretary of the NSW Department of Planning and Environment (the Secretary’s Environmental Assessment Requirements (SEAR No 1167) dated 6 September 2017.

Key features of the project include:

- Stabilisation works within the Hornsby Quarry
- Earthworks across other parts of Hornsby Park in order to rehabilitate the site
- Placement of material from stabilisation works and other earthworks in the quarry void to create a final landform suitable for future development into a community parkland.

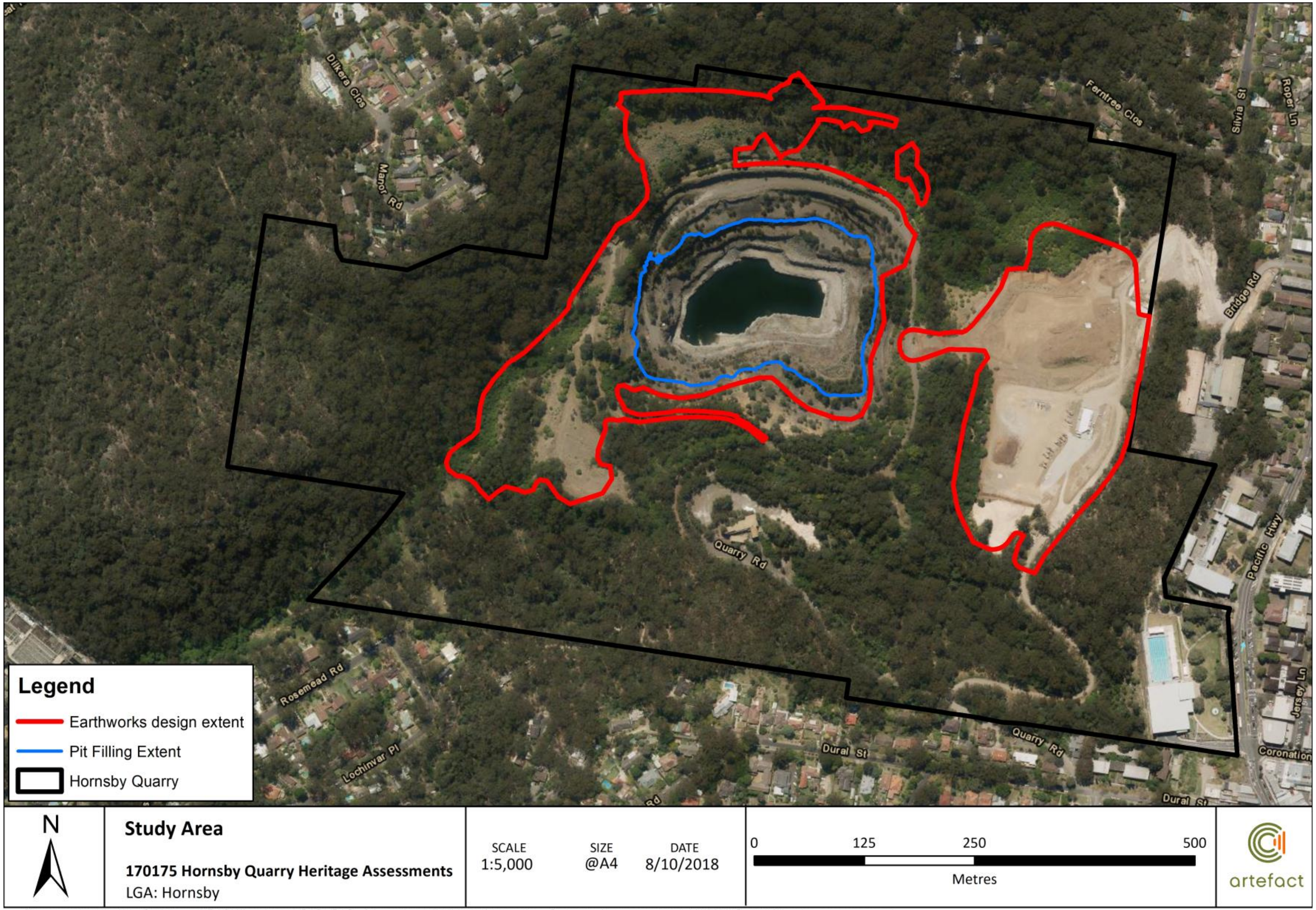
The project proponent is Hornsby Shire Council. Hornsby Shire is a local government area in the northern region of Sydney that manages the area of land called Hornsby Shire Council, an area of approximately 500 square kilometres (km^2) extending from Brooklyn in the north, to Wisemans Ferry and Glenorie/Dural in the west, Wahroonga and Ku-ring-gai Chase National Park in the east and the M2 motorway in the south.

Significant quantities of spoil are expected to be generated from the stabilisation works as well as obtained from nearby onsite earthworks. This material would be placed onto the NorthConnex spoil to create a landform that generally slopes from the proposed lake up to the top of the western quarry face and would allow for the creation of a new parkland to be constructed within the quarry void. The landform would include a lake directly below the exposed eastern face of the quarry. No spoil would be imported or transported off the site.

A conceptual design for the proposed reshaping and stabilisation works has been developed by Council. The design has been developed in parallel with the planning for the proposed future parkland. The detailed design will be completed once the required parkland landform is refined as a result of further definition of site constraints and consultation with the community.

The following Figure 37 shows the proposed extent of works on the site. The ‘extent of works’ refers to both the quarry pit filling extent and the earthworks design extent plus an additional 5 m outside these areas to allow for construction fencing, etc. This can be considered the proposed disturbance footprint. It incorporates site access and internal roads/tracks.

Figure 37: Plan of the study area showing earthworks design extent and pit filling extent (Source: Artefact Heritage)



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8.0 STATEMENT OF HERITAGE IMPACT

8.1 Introduction

The objective of a SoHI is to evaluate and explain how the proposed development, rehabilitation, or land use change will affect the heritage value of a place. A SoHI should also address how the heritage value of the place can be conserved or maintained, or preferably enhanced by the proposed works.

This report has been prepared in accordance with the following guidelines:

- NSW Heritage Manual (NSW Heritage Office & Department of Urban Affairs and Planning 1996)
- Statements of Heritage Impact (NSW Heritage Office 2002).

The guidelines pose a series of questions as prompts to aid in the consideration of impact due to the proposed work. The questions vary in the guideline, depending on the nature of the impact to the heritage site. Each of these questions is addressed below.

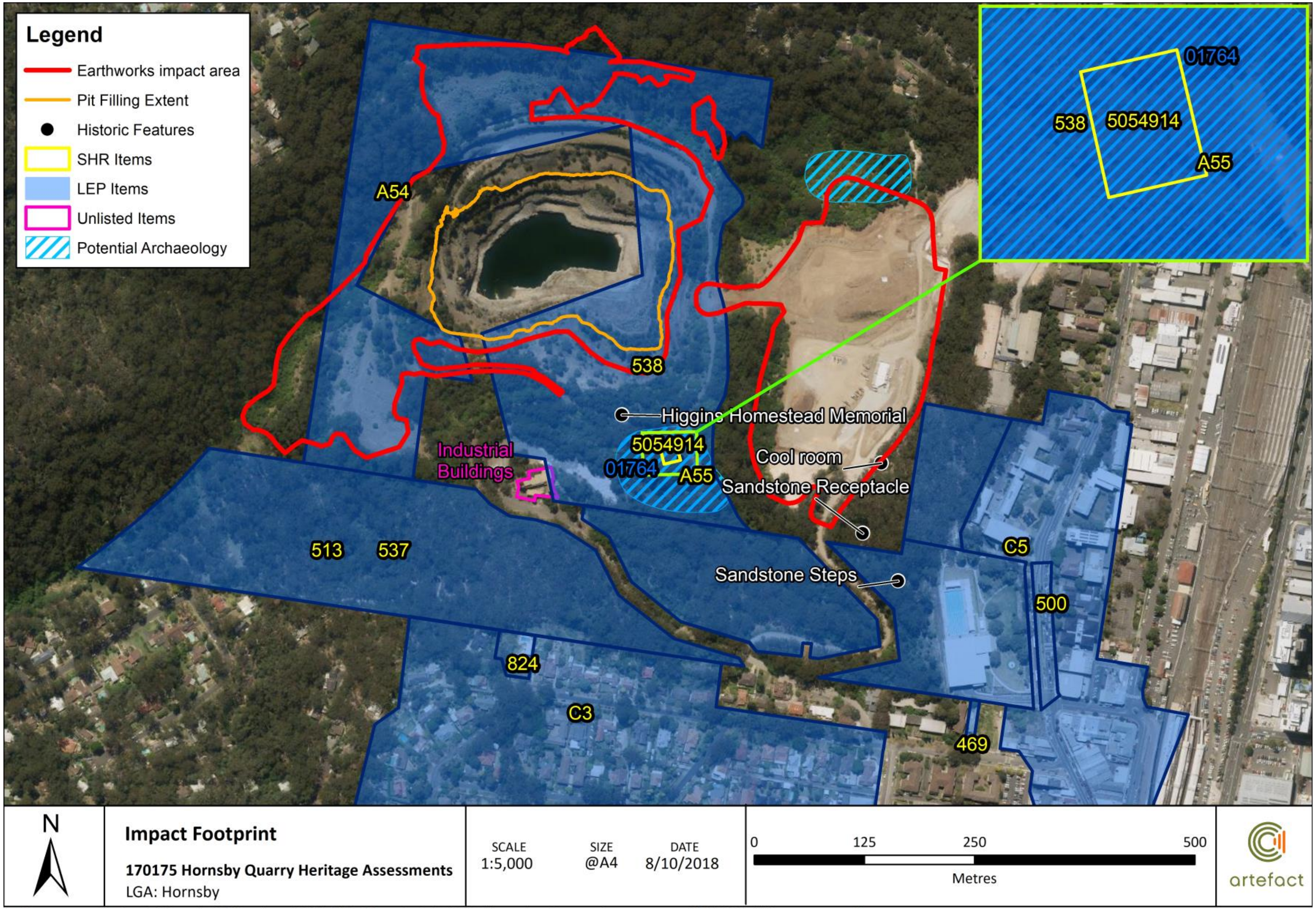
8.1.1 Impact assessment terminology

In order to consistently identify the potential impact of the proposal, the terminology contained in Table 7 has been referenced throughout this document.

Table 7: Terminology for assessing the magnitude of heritage impact

Grading	Definition
Major	Actions that would have a long-term and substantial impact on the significance of a heritage item. Actions that would remove key historic building elements, key historic landscape features, or significant archaeological materials, thereby resulting in a change of historic character, or altering of a historical resource. These actions cannot be fully mitigated.
Moderate	Actions involving the modification of a heritage item, including altering the setting of a heritage item or landscape, partially removing archaeological resources, or the alteration of significant elements of fabric from historic structures. The impact arising from such actions may be able to be partially mitigated.
Minor	Actions that would result in the slight alteration of heritage buildings, archaeological resources, or the setting of an historical item. The impact arising from such actions can usually be mitigated.
Negligible	Actions that would result in very minor changes to heritage items.
Neutral	Actions that would have no heritage impact.

Figure 38: Impacts from works (Source: Artefact Heritage)



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8.2 Assessment of Impacts to Significance

8.2.1 Impact assessment

The impacts of the proposal on the listed items within and adjacent to the study area are outlined in Table 8 below:

Table 8: Impact of proposal on heritage items within and adjacent to study area

Item	Listing No.	Location	Significance	Physical impact	Visual impact	Discussion
Old Man's Valley Cemetery	SHR 01764	Within study area Outside earthworks design extent	State	Neutral (Potential indirect by way of vibration)	Negligible	The earthworks design extent would not encroach on the SHR curtilage of the 'Old Man's Valley Cemetery'. The proposal would not result in a reduction of the item's curtilage or changes to any of the fabric of the place, and no physical impacts are anticipated. The proposal would require stabilisation and rehabilitation works in the vicinity of the cemetery, which would result in visual changes that would alter the existing setting and character of the surrounding area. The significance of the cemetery is associated with its landscape setting amidst both remnant natural vegetation and traditional European plantings. The earthworks design extent would not substantially affect the bushland and vegetation surrounding the cemetery. Given the proposal would ultimately involve reinstatement of vegetation following works and large-scale landscaping works, visual impacts associated with any localised areas of impact would be temporary in nature. The proposed use of the quarry site as a community parkland would increase public usage of the place, and could potentially enhance community engagement with and appreciation of the cemetery and its significant values. This would result in a positive heritage outcome for the 'Old Man's Valley Cemetery'. There is potential for indirect physical impact by way of vibrations, in particular to headstones within the cemetery.

Item	Listing No.	Location	Significance	Physical impact	Visual impact	Discussion
Old Man's Valley Cemetery, including Higgins' Family Cemetery, sandstone receptacle, cool room and site of Higgins homestead on which the Higgins Family Memorial is located	LEP A55	Within study area Outside earthworks design extent	Local (Old Man's Valley Cemetery on SHR)	Neutral	Negligible	This LEP item encompasses a range of elements within and adjacent to the study area. The 'Old Man's Valley Cemetery, sandstone receptacle, cool room and Higgins Family Memorial' would not be within the earthworks design extent. The proposal would not directly affect any of these element, and no physical impacts are anticipated. The proposal would require stabilisation and rehabilitation works in the vicinity of the elements of this heritage item, which would result in visual changes to the setting and character of the surrounding area. The existing quarry landscape in the vicinity of the heritage item is not considered to be an important part of its significance, and the bushland around these elements would not be affected by the earthworks design extent. Given the proposal involves reinstatement of vegetation following works and large-scale landscaping works to the quarry, any visual impacts would be temporary in nature.
Diatreme Hornsby Quarry and surrounding vegetation	LEP A54	Within study area and earthworks design extent	Local	Moderate	Moderate	Direct impacts will extend across much of curtilage of the Diatreme Hornsby Quarry archaeological item. This would involve stabilising works which would directly impact the archaeological item. It is noted that the approved Stage 1 works of the NorthConnex project involve infill of the quarry to RL55 metres, and fill from Stage 2 would not exceed this level. The proposal would involve works and visual changes that would impact on the setting of the area. It is understood that the vegetation of the site generally would be reinstated following works. The exposed diatreme would be preserved and the significant geological strata left exposed and free of vegetation. These measures would assist in mitigating potential visual impacts of the proposal, and would assist in the visual clarity and interpretation of the former quarry landscape.

Item	Listing No.	Location	Significance	Physical impact	Visual impact	Discussion
Diatreme Hornsby Quarry and surrounding vegetation	LEP 538	Within study area	Local	Moderate	Moderate	Direct impacts will extend across much of curtilage of the Diatreme Hornsby Quarry archaeological item. This would involve stabilising works which would directly impact the archaeological item. It is noted that the approved Stage 1 works of the NorthConnex project involve infill of the quarry to RL55 metres, and fill from Stage 2 would not exceed this level. The proposal would involve works and visual changes that would impact on the setting of the area. It is understood that the exposed diatreme would ultimately be preserved and left exposed, and the vegetation would be reinstated following works. These measures would assist in mitigating potential visual impacts of the proposal.
Hornsby Park—Lone Pine and sandstone steps	LEP 513	Within study area	Local (regional)*	Neutral	Negligible	The proposal has been developed to not involve any earthworks within the curtilage of the ‘Hornsby Park – Lone Pine and sandstone steps’ heritage item and, as such, the proposal would not directly impact this heritage item. The proposal would potentially involve installation of fencing and localised removal of vegetation in the locality, however impacts associated with this aspect of the proposal are considered to be temporary in nature. The significant elements within the curtilage of the heritage item would not be affected. While the proposal would result in small visual changes within the vicinity of the heritage item, it is considered that reinstatement of any removed vegetation in the future and provision of enhanced public access would mitigate any visual impacts.

Item	Listing No.	Location	Significance	Physical impact	Visual impact	Discussion
Sandstone steps	LEP 537	Within study area	Local	Neutral	Negligible	The proposal has been developed to not involve any earthworks within the curtilage of the ‘Hornsby Park – Lone Pine and sandstone steps’ heritage item and, as such, the proposal would not directly impact this heritage item. The proposal would potentially involve installation of fencing and localised removal of vegetation in the locality, however impacts associated with this aspect of the proposal are considered to be temporary in nature. The significant elements within the curtilage of the heritage item would not be affected. While the proposal would result in small visual changes within the vicinity of the heritage item, it is considered that reinstatement of any removed vegetation in the future and provision of enhanced public access would mitigate any visual impacts.
Mount Errington Precinct, Hornsby West Side Heritage Conservation Area	LEP C3	Adjacent to study area	Local	Neutral	Neutral	This conservation area is located outside the study area and, as such, the proposal would not directly impact this heritage item. No physical impacts within the conservation area would occur. The proposed stabilisation and rehabilitation works would be in the vicinity of the conservation area, which would result in visual changes to the broader setting and character in the locality. It is noted that the proposed earthworks would not be immediately visible from this area. Given the proposal involves reinstatement of vegetation following works and large-scale landscaping works, any visual impacts would be temporary in nature, and are considered to result in a positive impact that would improve the presentation and amenity of the area.

Item	Listing No.	Location	Significance	Physical impact	Visual impact	Discussion
Peats Ferry Road Precinct, Hornsby West Side Heritage Conservation Area	LEP C5	Adjacent to study area	Local	Neutral	Neutral	This conservation area is located outside the study area and, as such, the proposal would not directly impact this heritage item. No physical impacts within the conservation area would occur. The proposed stabilisation and rehabilitation works would be in the vicinity of the conservation area, which would result in visual changes to the broader setting and character in the locality. It is noted that the proposed earthworks would not be immediately visible from this area. Given the proposal involves reinstatement of vegetation following works and large-scale landscaping works, any visual impacts would be temporary in nature, and are considered to result in a positive impact that would improve the presentation and amenity of the area.
“Norwood”	LEP 469	Adjacent to study area	Local	Neutral	Neutral	This heritage item is located outside the study area and, as such, no physical impacts to “Norwood” would occur. The proposed works are located a considerable distance from the property, and therefore it is not anticipated that the proposal would result in any changes to views to and from this heritage item, and no visual impacts would occur.
Road median, lights and palms	LEP 500	Adjacent to study area	Local	Neutral	Neutral	This heritage item is located outside the study area and, as such, no physical impacts to “Norwood” would occur. The proposed works are located a considerable distance from the property, and therefore it is not anticipated that the proposal would result in any changes to views to and from this heritage item, and no visual impacts would occur.
“Birklands”	LEP 824	Adjacent to study area	Local	Neutral	Neutral	This heritage item is located outside the study area and, as such, no physical impacts to “Norwood” would occur. The proposed works are located a considerable distance from the property, and therefore it is not anticipated that the proposal would result in any changes to views to and from this heritage item, and no visual impacts would occur.

Item	Listing No.	Location	Significance	Physical impact	Visual impact	Discussion
Industrial Buildings		Within study area	Local	Neutral	Minor	This unlisted item is not located within the earthworks design extent of the proposal, and as such, no direct impacts to the Industrial Buildings is anticipated. The proposal would result in changes to the visual qualities and character of the building's quarry setting, which relate to the item's historical associations. The proposed preservation of the exposed diatreme, and surrounding revegetation works in the site generally following works would assist in mitigating potential visual impacts of the proposal.
Area of Archaeological Potential - North		Within study area	State	Moderate	n/a	The eastern portion of this archaeological area, which remained relatively undisturbed from 1835-2015, will be directly impacted by the proposal.
Area of Archaeological Potential - South		Adjacent to study area	State	Neutral	n/a	This archaeological area, which appears to be part of the broader cemetery areas in the 1930s-1950s aerials, is not located within the earthworks impact area and would not be directly impacted by the proposal.

8.3 Summary of Impacts

The following Statement of Heritage Impact is based on the assessed significance of heritage items in and near the study area, their relationship with the surrounding area and assessed impacts.

Table 9: Statement of Heritage Impact

Development	Discussion
What aspects of the proposal respect or enhance the heritage significance of the study area and nearby heritage items?	The proposal has been developed as far as possible to minimise direct impact on heritage items. The proposal would not result in any direct physical impact to the State listed 'Old Man's Valley Cemetery' (SHR 01764), or locally listed items within the study area including the 'Old Man's Valley Cemetery, including Higgins' Family Cemetery, sandstone receptacle, cool room and site of Higgins homestead on which the Higgins Family Memorial is located' heritage item (LEP A55), 'Hornsby Park—Lone Pine and sandstone steps' heritage item (LEP 513) and 'Sandstone steps' heritage item (LEP 537). Neutral to negligible impacts are anticipated for heritage items located adjacent to the study area. The overall project, by improving safety and accessibility of the site, would ultimately allow for enhanced community visitation and engagement with the heritage items located within this historic precinct, and provide opportunities for greater understanding of their significant values and associations. The majority of areas identified as having archaeological potential would be avoided in the proposal.
What aspects of the proposal could have a detrimental impact on the heritage significance of the study area and nearby heritage items?	The proposal would result in direct impacts across much of the locally listed curtilage of the 'Diatreme Hornsby Quarry and surrounding vegetation' heritage item. These works would involve stabilising works which would directly impact the fabric and archaeological potential of the item, and would permanently change the form and configuration of the former quarry. The proposal would result in visual changes to the 'Diatreme Hornsby Quarry and surrounding vegetation' heritage item and its setting. There is potential for indirect physical impact by way of vibration during the proposed works to heritage items in the vicinity. This particularly relates to the headstones located within the 'Old Man's Valley Cemetery'. Two areas of archaeological potential have been identified, one of which is within the impact footprint. There is some chance archaeological remains associated with the Higgins family occupation of the site may be impacted in this area. As covered above, it is noted that stabilising works would ultimately allow for improved public engagement and accessibility with the former Diatreme Hornsby Quarry site and the surrounding historic precinct of Old Mans Valley. Preservation of the exposed diatreme and reinstatement of surrounding vegetation in the site generally as part of the future scope of works would assist in mitigating any potential physical and visual impacts and, as such, Stage 2 of the proposal is considered acceptable from a heritage perspective.
Have more sympathetic options been considered and discounted?	It is understood that a 'do nothing' approach was the only sympathetic option identified. However, this approach was not found to meet the immediate objectives of the proposal. As the site is being filled with spoil from the NorthConnex project, a 'do nothing' approach would mean that the quarry would remain inaccessible to the public, even after the NorthConnex works would reach completion.

8.4 Justification of Impacts

The filling works associated with the NorthConnex project alleviate safety hazards associated with the previous state of the quarry, which were that the site poses a danger to the public, due to its unstable rock faces and fill areas, and presence of a deep and unfenced body of water. At present, the diatreme and heritage items in the vicinity including ‘Old Man’s Valley Cemetery’, which have identified heritage significance, are inaccessible to the public and poses safety risks. The proposed works address these safety aspects and will enable a public park to be created. The proposal, by improving safety and accessibility of the site, would potentially result in enhanced community visitation and engagement with the heritage items located within this historic precinct, and provide opportunities for greater understanding of their significant values and associations.

9.0 CONCLUSIONS AND RECOMMENDATIONS

9.1 Conclusions

The proposed cutting and filling works that extend over the eastern and central parts of the study area will involve the movement of large volumes of fill, which is intended to sculpt the study area to develop the modern recreational space. The site has the potential to yield important archaeological information of State significance, and as a cultural landscape has values which should be conserved and retained as part of the future plans for the study area. Despite large areas of disturbance over the past 70 years, the study area contains several heritage items and areas of archaeological potential.

The proposal would result in a neutral physical impact and a negligible visual impact to the SHR listed ‘Old Man’s Valley Cemetery’ (SHR 01764), and potential indirect impacts by way of vibrations. The proposal would result in a moderate physical impact and a moderate visual impact to the locally listed ‘Diatreme Hornsby Quarry and surrounding vegetation’ heritage item and archaeological item (LEP 538, A54).

The proposal would result in neutral to negligible physical and visual impacts on other heritage items located within the study area including the locally listed ‘Old Man’s Valley Cemetery, including Higgins’ Family Cemetery, sandstone receptacle, cool room and site of Higgins homestead on which the Higgins Family Memorial is located’ heritage item (LEP A55), the ‘Hornsby Park—Lone Pine and sandstone steps’ heritage item (LEP 513), and ‘Sandstone steps’ heritage item (LEP 537). Neutral to negligible impacts are anticipated for heritage items located adjacent to the study area.

The proposal, by improving safety and accessibility of the site, would potentially result in enhanced community visitation and engagement with the heritage items located within this historic precinct, and provide opportunities for greater understanding of their significant values and associations. These positive heritage outcomes would balance physical and visual impacts associated with the proposed works, and, as such, the proposal is considered acceptable from a heritage perspective.

Two areas of archaeological potential have been identified within the impact footprint. There is some chance archaeological remains associated with the Higgins family occupation of the site may be impacted in one of these areas to the north, which is partially within the earthworks impact area.

9.2 Recommendations

The recommendations set out below will aid in mitigating the impact to the study area, and other heritage items in the vicinity. The recommendations are designed to enable the proponent to determine the most appropriate mitigation, based on other advice and the design of the proposed works. This follows the tenants of the Burra Charter, where avoidance of impact, followed by mitigation of impact, and recording of impact are advised.

The following recommendations regarding the study area are based on consideration of:

- Statutory requirements under the *NSW Heritage Act 1977* and the Hornsby LEP 2013
- The results of background research, site survey and assessment
- The likely impacts of the proposed development.

9.2.1 Photographic recording

A Photographic Archival Recording (PAR) should be prepared prior to works. A copy of this report, plus the PAR, must be kept in the Hornsby Council archives as a record of the site prior to the proposed works. The PAR should be tailored to meet the changes to the property and is not required to be a detailed fabric analysis. The PAR should focus on recording part of the property which will undergo change, to form a record of that change for the future.

9.2.2 Section 140 Permit and archaeological works

An Archaeological Research Design (ARD) should be prepared for the project. The ARD will determine if the project is likely to be located in areas where there may be significant archaeological remains, and recommend whether a permit under Section 140 or an exception under Section 139 of the *NSW Heritage Act 1977* will be required. The ARD would be prepared by a suitably qualified archaeologist.

Where the ARD identifies that significant archaeological remains may be impacted, processes for undertaking the archaeological investigations would be outlined and suitable research questions would be developed which will add to the knowledge of the site and work with Hornsby Council to determine how any relics recovered from site could be used in interpretation or stored.

9.2.3 Unexpected archaeological finds

Should any unexpected archaeological finds be made during works, work must cease immediately and a suitably qualified archaeologist contacts to assess the finds before any works can continue. Additional approvals and investigation may be required.

9.2.4 Future of industrial buildings

To determine the future of the industrial buildings, a structural integrity assessment should be undertaken, in particular for the Former Crushing Plant. Options for its adaptive reuse and interpretation should be explored by Hornsby Council. Dependent on the findings of these investigations, consideration would be given for the suitability of listing the Former Crushing Plant onto Schedule 5 of the Hornsby LEP 2013 as an item of local environmental significance.

9.2.5 Remediation of impacted landscapes

Upon completion of the proposed works, either separately, or as part of Stage 3 of the redevelopment of the study area, the impacted landscapes of the Diatreme Hornsby Quarry and surrounding vegetation (Hornsby LEP 2013 A54/538) will require rehabilitation to reduce the long term impacts of the works.

9.2.6 Heritage Management Plan

Prior to the detailed design of Stage 3 of the redevelopment of the study area, a comprehensive Heritage Management Plan (HMP) should be commissioned by Hornsby Council. The HMP must provide clear guidance of the management of the numerous significant values of the listed items within the study area, and how this management should be integrated into the future design and use of the study area. This is especially critical for the areas and items of State significance.

9.2.7 Vibration management – 'Old Man's Valley Cemetery'

No impacts to the SHR listed 'Old Man's Valley Cemetery' (SHR 01764) are to occur. Given the potential for indirect physical impacts by way of vibrations to headstones, a condition report should be prepared prior to commencement of the works and integrated into the HMP. The HMP would include monitoring of vibrations and the condition of headstones and other structures located within the curtilage of this item for the duration of construction works.

9.2.8 Interpretation of the historic landscape

The cultural landscape of the study area should be properly and thoroughly interpreted as part of future development. Guidance on interpretation should come through the HMP and then be developed in detail as part of the detailed planning for the study areas Stage 3 development.

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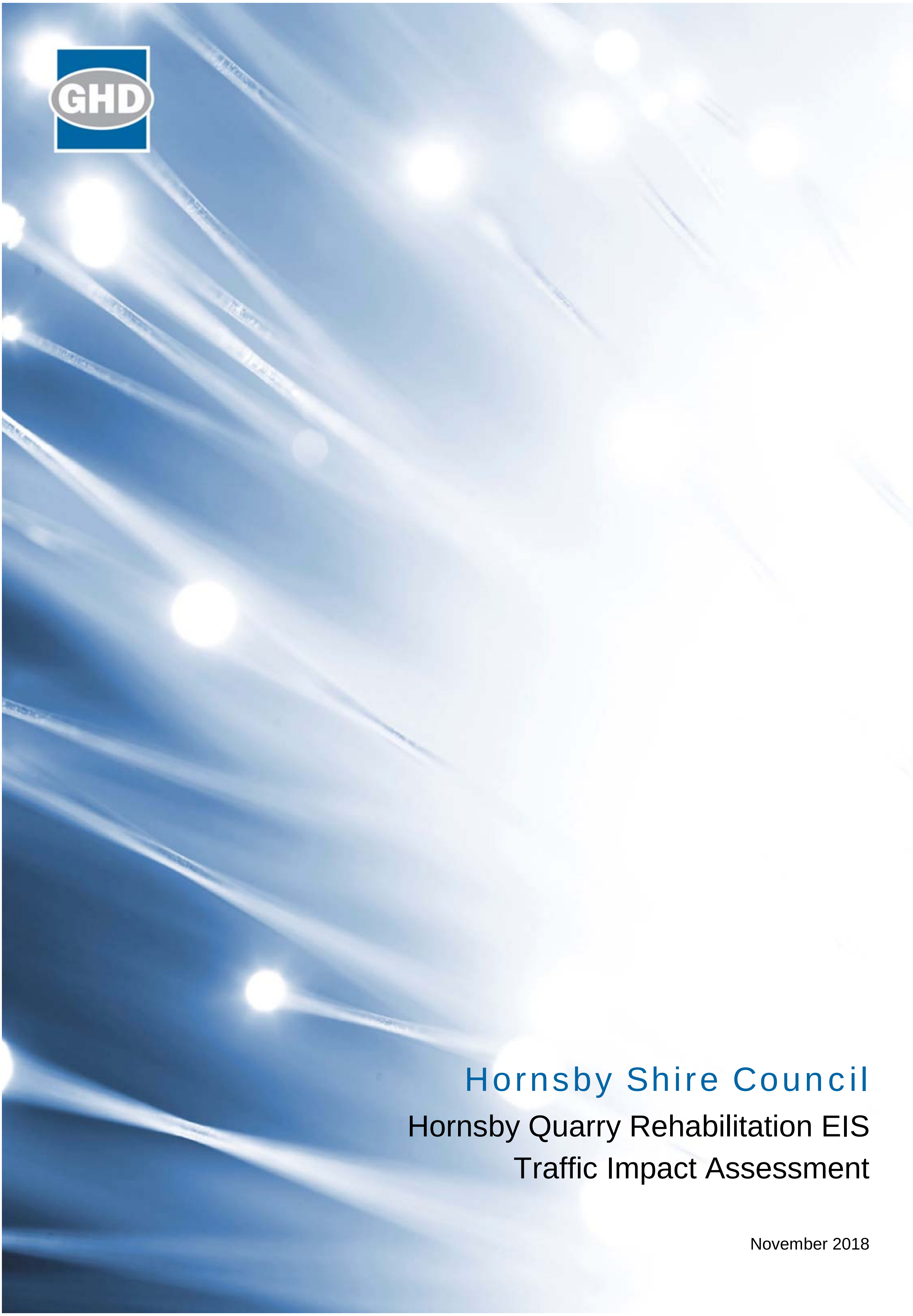
Appendix I – Traffic assessment



Hornsby Shire Council

Hornsby Quarry Rehabilitation EIS
Traffic Impact Assessment

November 2018

WATER | ENERGY & RESOURCES | ENVIRONMENT | PROPERTY & BUILDINGS | TRANSPORTATION

Executive summary

Hornsby Shire Council (Council) proposes to rehabilitate the Hornsby Quarry void to create a landform suitable for future development as community parkland, which will require filling and stabilisation. The landform would include a lake directly below the exposed eastern face of the quarry. This Traffic Impact Assessment has been prepared in accordance with the Secretary's Environmental Assessment Requirements to assess impacts to traffic and transport.

GHD has been engaged by Council to undertake a traffic impact assessment to support a development application for approval of the project under Part 4 of the EP&A Act. The EIS is being prepared in accordance with the provisions of the EP&A Act. The key objectives of this study are to:

- Identify the existing situation within proximity of the site with respect to traffic, parking, public and active transport.
- Identify the impacts proposed construction activities will have on the surrounding road network.

The following key findings were identified as part of the traffic, transport and parking assessment:

A total of 39 crashes occurred between 2011 – 2016 in the vicinity of the project site. 15 of the crashes resulted in injury and the remaining were non-casualty. The most frequent crash type was rear end (20 percent), followed by right through (15 percent) and off road left – object (15 percent). Between December 2017 and May 2018 two crashes were recorded at the intersection of Peats Ferry Road and Bridge Road. These crashes resulted in pedestrian fatalities with heavy vehicles hitting pedestrians.

The results from SIDRA Intersection 7 modelling software indicated that the existing intersection performance at Peats Ferry Road / Bridge Road is operating at level of service B. The modelling results also indicated that the intersection is operating with acceptable delays in both the AM and PM peak periods.

It is estimated that there will be 30 veh/h entering the project site in the AM peak and 30 veh/h leaving the project site in the PM peak. There would also be a fuel truck and 19 heavy plant and equipment deliveries during off-peak hours.

The anticipated traffic distribution associated with the project is:

In the AM peak:

- 50 percent of light vehicles northbound along Peats Ferry Road.
- 27 percent of light vehicles southbound along Peats Ferry Road.
- 23 percent of light vehicles westbound along Bridge Road.

In the PM peak:

- 50 percent of light vehicles southbound along Peats Ferry Road.
- 27 percent of light vehicles northbound along Peats Ferry Road.
- 23 percent of light vehicles eastbound along Bridge Road.

The results from SIDRA Intersection 7 for the construction traffic generated scenario during both AM and PM peak periods are not likely to be significantly different to that of the existing situation (level of service B; intersection is near capacity). Traffic generated by the TAFE would be occurring outside of the road network peak and thereby would not affect the peak operational efficiency of the intersection.

The proposed site access is adjacent to Roper Lane and provided directly from Bridge Road, linking to Peats Ferry Road. In accordance with Section 3.2.2 of the *Austroads Guide to Road Design Part 4A: Un-signalised and Signalised Intersections*, both the approach sight distance and safe intersection sight distance are satisfactory in both directions.

The impacts on the public transport services operating in proximity to the subject site as well as the walking and cycling amenities are expected to be insignificant and minimal due to the low volumes of vehicle movements associated with the construction phase,.

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1. Introduction

1.1 Background

Hornsby Shire Council (Council) acquired the Hornsby Quarry site in 2002 and has since undertaken a number of investigations and studies with regard to its future use and the environmental and technical constraints that the site poses. Through these studies, Council identified the need to:

- Stabilise the quarry.
- Manage the site in a safe and environmentally sustainable manner.
- Actively seek opportunities to fill the quarry void with spoil arising from major infrastructure projects in the region.

Council also resolved to develop the site into a community parkland ultimately.

In 2016 approval was granted to Roads and Maritime Services, to beneficially reuse up to 1.5 million cubic metres of excavated rock and soil (spoil) from the construction of the NorthConnex tunnel to partially fill the Hornsby Quarry (the ‘2016 Planning Approval’). The filling has recently commenced at the site under this approval.

Following completion of filling by NorthConnex, Council is proposing to rehabilitate and reshape the site in a suitable way to ensure public safety and allow future development into a parkland for community use (the project).

1.2 Purpose of this report

GHD Pty Ltd (GHD) has been engaged by Council to prepare documentation to support a development application for approval of the project under Part 4 of the New South Wales (NSW) *Environmental Planning and Assessment Act 1979* (the EP&A Act). The Environmental Impact Statement (EIS) is being prepared in accordance with the provisions of the EP&A Act.

This report has been prepared by GHD to provide an assessment of the traffic impact as an input to the EIS. This report addresses the Secretary of the NSW Department of Planning and Environment’s Environmental Assessment Requirements (EAR 1167) dated 6 September 2017.

1.3 Project location

The project is located in the Hornsby Local Government Area (LGA), approximately 21 kilometres (km) to the north west of the Sydney Central Business District. The site is accessible via Quarry Road (off Dural Street and other local roads) from the south-east and from Bridge Road (off the Peats Ferry Road from the north-east).

The location of the site is illustrated in Figure 1.1.

1.4 Project overview

Key features of the project include:

- Rehabilitation, stabilisation and geotechnical safety management works around various parts of the site.
- Earthworks and placement of material from within the site to create a final landform similar to Option 1 in the Clouston Associates (2014) ‘Recreation Potential Study for Hornsby Quarry and Old Mans Valley Lands’ (p.88).

Approximately 500,000 m^3 of spoil is expected to be generated from stabilisation of the northern face of the quarry as well as obtained from nearby onsite earthworks. Much of this material would be placed on the NorthConnex spoil to create a landform that generally slopes from the proposed lake up to the top of the western quarry face and would allow for the creation of a new parkland to be constructed within the quarry void.

The landform would include a lake directly below the exposed eastern face of the quarry. There would also be cut and fill works on Old Mans Valley to create a landform suitable for future development into playing fields and other recreational activities.

It is expected that a combination of ripping, rock breaking and rock sawing will be required to shift the material. Rock fragments would be crushed onsite using a mobile crusher or rock breaker prior to placement as fill.

No additional spoil is proposed to be imported to the site for filling purposes nor would the excavated material be transported off the site.

The project is expected to take approximately two years to complete.

The proposed extent of works is shown in Figure 1.2.

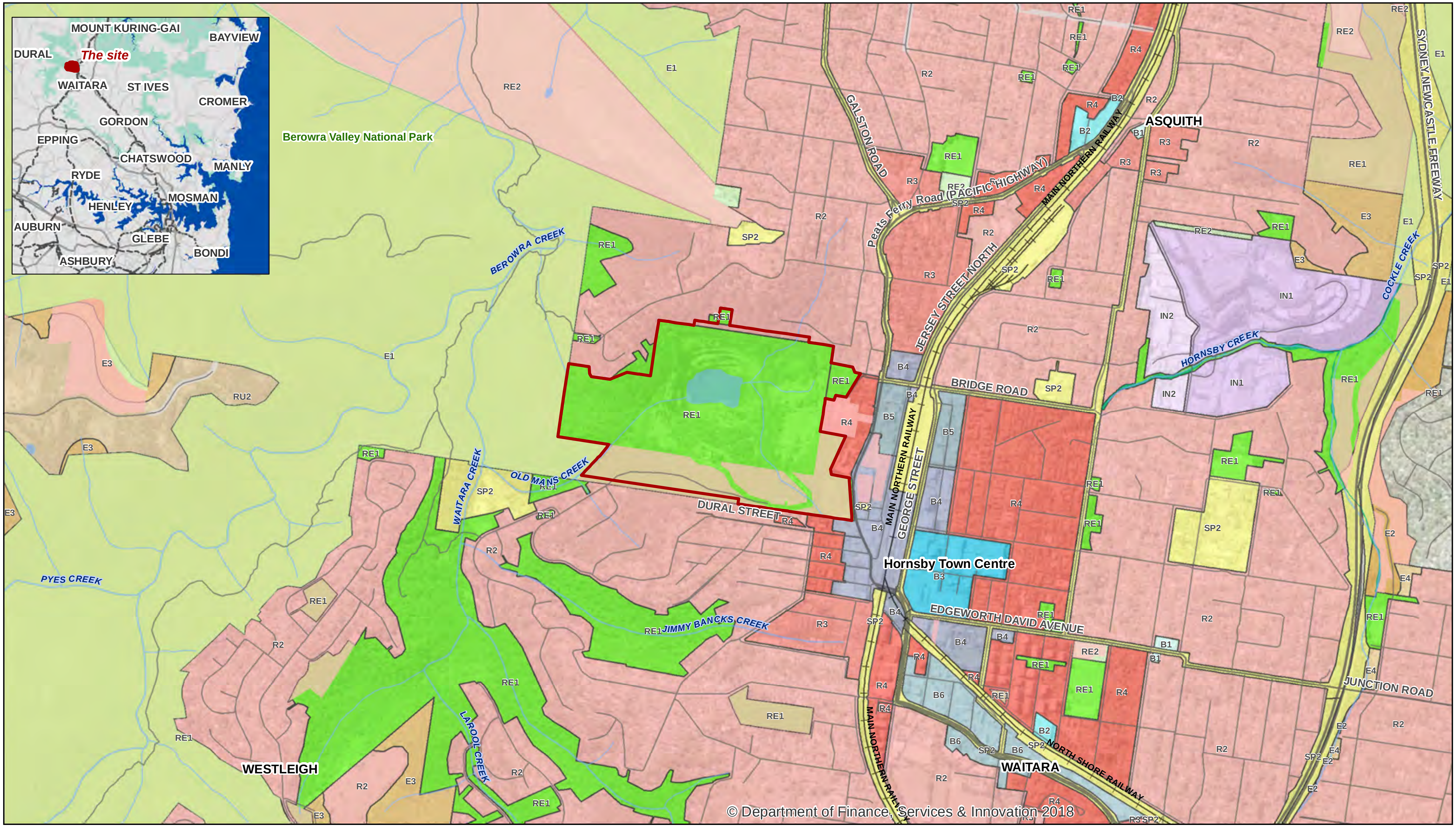
1.5 Definitions

The following terms are used within this report:

- The 'site' refers to the entirety of:
  - Lots A, B, C, D and E in Deposited Plan (DP) 318676
  - Lot 1 DP 926103
  - Lot 1 DP 926449
  - Lot 1 DP 114323
  - Lots 1 and 2 in DP 169188
  - Lot 7306 DP 1157797
  - Lot 1 DP 859646
  - Lot 1 DP 926449
  - Lot 13 DP 734459
  - Lot 114 DP 749606
  - Lot 213 DP 713249
  - Summers Avenue, Hornsby partly formed
  - Old Mans Valley Trail

  The boundary of the site is shown in Figure 1.1.
- Level of service (LOS) is a measure to determine the operational conditions and efficiency of a roadway or intersection.

The 'extent of works' refers to both the quarry pit filling extent and the earthworks design extent plus an additional 2 to 5 m outside these areas to allow for construction fencing, etc. The boundary of the extent of works is shown in Figure 1.2.



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Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

Legend

▭	The site	🟥	Crown parcel
—	Watercourses	⬜	Crown road
🟩	Parks and reserves	🟩	Crown waterway

GHD

Hornsby Shire Council
Hornsby Quarry Rehabilitation

Job Number	21-26457
Revision	A
Date	09 Nov 2018

Site location, surrounding land uses and zoning

Figure 1.1

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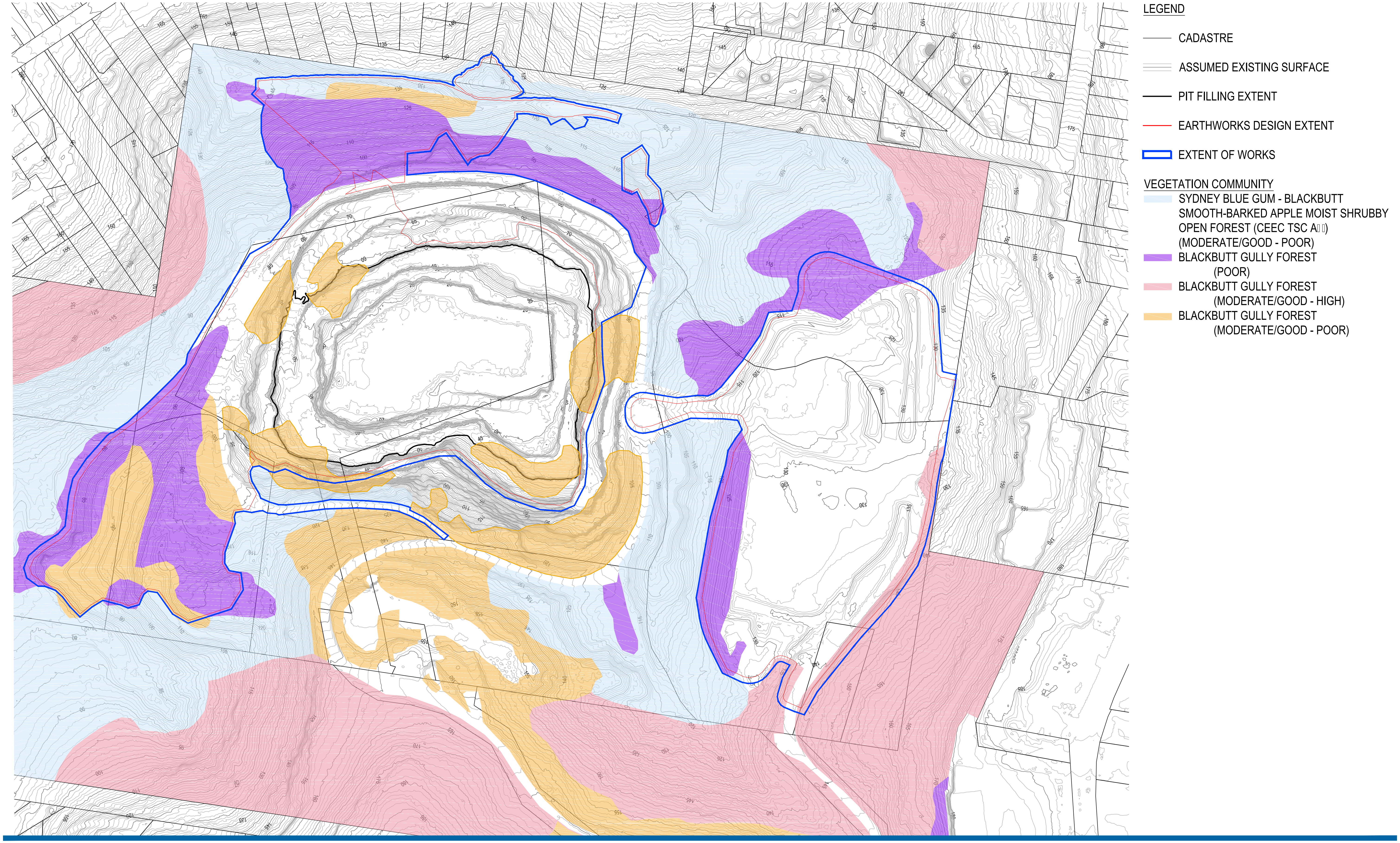
Level 15, 133 Castlereagh Street Sydney NSW 2000 **T** 61 2 9239 7100 **F** 61 2 9239 7199 **E** sydmail@ghd.com.au **W** www.ghd.com.au

Data source: NSW LPI (DTDB), Topographic base data, 2012; NSW LPI (DCDB), Topographic base data, 2015. Created by:jwatson2



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HORNSBY SHIRE COUNCIL
HORNSBY QUARRY REHABILITATION
EXTENT OF WORKS

Job Number	21-26457
Revision	A
Date	SEP 2018

Figure 1.2

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1.6 Secretary's Environmental Assessment Requirements and agency requirements (SEARs)

The specific SEARs and agency requirements addressed in this report are summarised in Table 1.1.

Table 1.1 SEARS requirements (extract)

Assessment requirements	Where addressed in report
Daily and peak traffic movements generated from the proposed development	Section 5.2
Details of the proposed accesses and the parking provisions associated with the proposed development	Section 5.5
Proposed number of car parking spaces and compliance with appropriate codes	Section 6
Details of service vehicle movements	Section 5.3
Implications of the proposed development for non-car travel modes (including public transport use, walking and cycling)	Section 5.6 – 5.7

1.7 Scope and structure of the report

1.7.1 Scope of the report

The scope of this report is to examine and report on the following elements:

- Existing traffic and transport patterns.
- Historical crash trends.
- Traffic demand forecast for the project.
- Forecast and assess peak hour traffic demands on key roads and turning movements at the key intersection within the local road network for the current year and construction staging.
- Operational performance of the key intersection under existing and construction staging scenarios.
- Assessing the traffic impacts of the construction stages.

1.7.2 Structure of the report

This report is structured as follows:

- **Chapter 1 – Introduction**: This chapter introduces the project and describes the site.
- **Chapter 2 – Existing environment**: This chapter describes the existing characteristics of the site relevant to traffic and transport assessment.
- **Chapter 3 – The project**: This chapter summarises the specifics of the project with a focus on the traffic and transport element.
- **Chapter 4 – Method**: This chapter outlines the methodology that was undertaken to assess the traffic impacts associated with the construction and operation of the project.
- **Chapter 5 – Impact assessment**: This chapter examines the potential traffic and transport related impacts associated with the construction and operation of the project.
- **Chapter 6 – Parking assessment**: This chapter assesses the parking requirements and provisions of the project.

- **Chapter 7 – Management and mitigation measures**: This chapter outlines the proposed mitigation strategies during the construction and operation to manage the identified impacts.
- **Chapter 8 – Summary and Conclusions**: This chapter provides a conclusion to the report and presents the next steps in the advancement of the project.

1.7.3 Assumptions and limitations

This report is subject to assumptions being accurate at the time of assessment and report writing, as follows:

- The report is based on data and information provided by Council about the proposed traffic generation assumptions.
- Data collection has been limited to traffic count surveys completed by SkyHigh on Wednesday, 13th May 2018.
- Traffic distribution estimates have been based on high level assumptions on light and heavy vehicle routes.
- Background traffic growth has been based on available historical traffic volume data of Peats Ferry Road acquired from Roads and Maritime Traffic Volume Viewer.

This study has been limited by the following:

- The analysis is a desktop study and no site visits have been undertaken.
- The conditions of the surrounding network are based on information either supplied by the traffic surveys mentioned above and Google Maps / Google Street View.

1.8 Limitations

This report has been prepared by GHD for Hornsby Shire Council may only be used and relied on by Hornsby Shire Council for the purpose agreed between GHD and the Hornsby Shire Council as set out in section 1.2 of this report.

GHD otherwise disclaims responsibility to any person other than Hornsby Shire Council arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring after the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this report (refer section(s) 1.7.3 of this report). GHD disclaims liability arising from any of the assumptions being incorrect.

2. Existing environment

2.1 Existing road network characteristics

2.1.1 Road hierarchy

Roads within NSW are categorised in the following two ways:

- By classification (ownership)
- By the function that they perform.

Road classification

Roads are classified (as defined by the *Roads Act 1993*) based on their importance to the movement of people and goods within NSW (as a primary means of communication).

The classification of a road allows Roads and Maritime to exercise authority of all or part of the road. Classified roads include Main Roads, State Highways, Tourist Roads, Secondary Roads, Tollways, Freeways and Transitways.

For management purposes, Roads and Maritime has three administrative classes of roads. These are:

- **State Roads –** Major arterial links through NSW and within major urban areas. They are the principle traffic carrying roads and fully controlled by Roads and Maritime with maintenance fully funded by Roads and Maritime. State Roads include all Tollways, Freeways and Transitways and all or part of a Main Road, Tourist Road or State Highway.
- **Regional Roads** – Roads of secondary importance between State Roads and Local Roads which, with State Roads provide the main connections to and between smaller towns and perform a sub-arterial function in major urban areas. Regional roads are the responsibility of councils for maintenance funding, though Roads and Maritime funds some maintenance based on traffic and infrastructure. Traffic management on Regional Roads is controlled under the delegations to local government from Roads and Maritime. Regional Roads may be a Main Road, Secondary Road, Tourist Road or State Highway; or other roads as determined by Roads and Maritime.
- **Local Roads** – The remainder of the council controlled roads. Local Roads are the responsibility of councils for maintenance funding. Roads and Maritime may fund some maintenance and improvements based on specific programs (e.g. urban bus routes, road safety programs). Traffic management on Local Roads is controlled under the delegations to local government from Roads and Maritime.

Functional Hierarchy

Functional road classification involves the relative balance of mobility and access functions. Roads and Maritime define four levels in a typical functional road hierarchy, ranking from high mobility and low accessibility, to high accessibility and low mobility. These road classes are:

- **Arterial Roads** – controlled by Roads and Maritime, typically no limit in flow and designed to carry vehicles long distance between regional centres.
- **Sub-Arterial Roads** – can be managed by either council or Roads and Maritime under a joint agreement. Typically, their operating capacity ranges between 10,000 and 20,000 vehicles per day, and their aim is to carry through traffic between specific areas in a sub region or provide connectivity from arterial road routes (regional links).
- **Collector Roads** – provide connectivity between local sites and the-arterial road network, and typically carry between 2,000 and 10,000 vehicles per day.
- **Local Roads** – provide direct access to properties and the collector road system and typically carry between 500 and 4,000 vehicles per day.

2.1.2 Key roads

Key roads relevant to the project include the following:

- Bridge Road
- Peats Ferry Road
- Dural Street
- Quarry Road.

The surrounding road network to the quarry is illustrated in Figure 2.1.

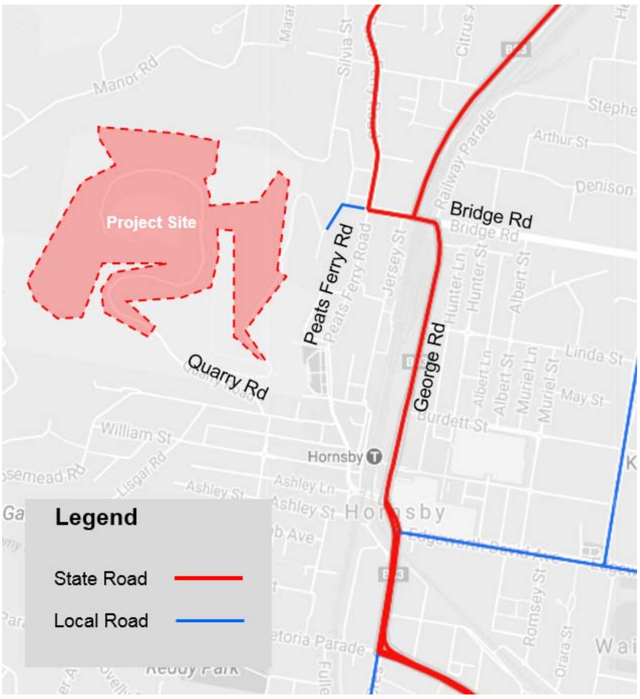


Figure 2.1 Surrounding roads

Source: Roads and Maritime – State and Regional Roads – Modified by GHD

2.1.3 Bridge Road

Bridge Road (west of Peats Ferry Road) is a local road that provides access to the quarry site with a speed limit of 50 km/h. The section immediately west of Peats Ferry Road performs a sub-arterial function linking George Street and Jersey Street.

Bridge Road is a two-way sealed road divided by double continuous solid lines. Within the NorthConnex construction zone, the speed limit is set at 30 km/h. At the time of assessment, only construction vehicles associated with NorthConnex are permitted access to the NorthConnex site via Bridge Road.

The northern TAFE carpark area is accessed via Bridge Road and is comprised of a small multi-deck and general carpark.

A view of Bridge Road is presented in Figure 2.2.

Figure 2.2 Bridge Road viewed east

Source: Google Maps Street View accessed April 2018

2.1.4 Peats Ferry Road

Peats Ferry Road forms part of the Pacific Highway through the Hornsby Town Centre and is a sub-arterial road that runs in a north-south direction between George Street and Bridge Road. The predominately one-lane, two-way road provides a link between Hornsby in the south and Asquith in the north at which point it links back up to the Pacific Highway (B83).

Peats Ferry Road provides links to the site via Bridge Road, Quarry Road and Dural Street. The posted speed limit on the road within proximity of the site and Hornsby Town Centre (with high pedestrian activity) is 40 km/h up to Jersey Lane (northbound) and becomes 60 km/h after that.

Southbound, a 50 km/h signposted speed limit exists after the Peats Ferry Road / Bridge Street intersection. This limit changes to 40 km/h high pedestrian zone after Jersey Lane and continues through to the Hornsby Town Centre and Hornsby Station.

Peats Ferry Road carries approximately 27,747 vehicles per day (vpd).

A view of Peats Ferry Road is presented in Figure 2.3.

Figure 2.3 Peats Ferry Road viewed north

Source: Google Maps Street View accessed April 2018

2.1.5 Quarry Road

Quarry Road is a local road that runs in a north-east direction. Quarry Road is a two-way sealed road without any line marking that provides direct access to the project site. No speed limit signs are available and the default urban speed limit of 50 km/h applies.

A view of Quarry Road is presented in Figure 2.4.

Figure 2.4 Quarry Road viewed northwest

Source: Google Maps Street View accessed April 2018

2.1.6 Dural Street

Dural Street is a local connector road that runs in an east-west direction, linking to Peats Ferry Road, which is a sub-arterial road that connects with the arterial road network, including the Sydney-Newcastle Freeway.

The one-lane, two-way street provides access to residential properties in Hornsby and the project site via Quarry Road. No speed limit signs are available and the default urban speed limit of 50 km/h applies. Approximately 70 metres west of the intersection with Peats Ferry Road a regulatory 40 km/h speed limit applies.

A view of Dural Street is presented in Figure 2.5.

Figure 2.5 Dural Street viewed west

Source: Google Maps Street View accessed April 2018

2.1.7 George Street

George Street functions as an arterial road within the Hornsby Town Centre. The route is intended to divert traffic from Peats Ferry Road on the west of Hornsby to the east of Hornsby Station. It has two lanes in each direction separated by a double solid line.

The southern section of George Street provides a narrow median with pedestrian fencing to discourage pedestrians from crossing the road in an unsafe manner. The posted speed limit is 60 km/h and parking is not permitted on either side of the road.

A view of George Street is presented in Figure 2.6.

Figure 2.6 George Street viewed north

Source: Google Maps Street View accessed April 2018

2.2 Travel Modes

A comparison of the average travel mode in Hornsby LGA was compared to that of the Sydney Greater Metropolitan Area (GMA). This data was based on TfNSW, Household Travel Survey from 2015/2016). Private vehicles are the predominant mode of transport in the study area (65 percent as driver and passenger) followed by walking (16 percent) then train (12 percent) whereas the Sydney greater statistical area has a higher portion of ‘other. The mode split for Hornsby compared to the Sydney GSA is shown in Table 2.1.

Table 2.1 Average weekday travel mode share for Hornsby LGA and Sydney GSA (2015/16)

Mode	Hornsby (%)	Sydney Greater Statistical Area (%)
Driver	45	53
Passenger	20	7
Rail	12	11
Bus	4	6
Walk	16	4
Other	3	19

Source: TfNSW, Household Travel Survey 2015/16

2.3 Public transport services

2.3.1 Existing bus services

HillsBus and Transdev NSW buses service the area. HillsBus operate a bus service which stops at Hornsby Station and travels south on the Pacific Highway. Transdev operates nine bus routes that stop at Hornsby Station. The bus routes which stop at Hornsby Station are summarised in Table 2.2.

Table 2.2 Bus services at Hornsby Station

Route	AM peak services	Frequency (min)	PM peak services	Frequency (min)
M60 – Parramatta to Hornsby	8	15	12	10
595 – Hornsby to Mt Colah	4	30	3	40
597 – Hornsby to Berowra	2	60	1	120
598 – Hornsby to Asquith	5	24	4	30
100 – Port Stephens to Sydney Coach	0	-	0	1
587 – Hornsby to Westleigh	4	30	4	30
588 – Hornsby to Normanhurst West	4	30	4	30
575 – Hornsby to Macquarie University via Turramurra	5	24	5	24

Source: TfNSW – Routes and Timetables, January – April 2018

2.3.2 Existing train services

Hornsby train station is located to the east of Peats Ferry Road opposite Dural Lane, approximately 1 km away from the site location. The North Shore, Northern and Central Coast and Newcastle Lines stop at Hornsby Station.

Table 2.3 Train services at Hornsby Station

Line	Major destinations	AM peak services (07:00 am – 09:00 am)	Frequency (min)	PM peak services (04:00 pm – 06:00 pm)	Frequency (min)
Northern and North Shore	Chatswood, Sydney CBD	28	4.5	29	4

Source: Sydney Trains, March 2018

2.4 Walking and cycling

Walking represents 16 percent of the average weekday travel mode share in the Hornsby LGA as indicated in Table 2.1.

Cycling as a specific travel mode is not represented in the mode share data. This data is accounted for in the 'Other' category, representing three percent for the Hornsby LGA.

Pedestrian footpaths are provided along the sides of the roads in proximity to the subject site including a signalised pedestrian crossing on Peats Ferry Road (providing access to the TAFE), regular crossings at signalised intersections, and a pedestrian overpass at Hornsby Station.

There is no separated cycling infrastructure within the vicinity of the project site. However, the Hornsby Mountain Bike Trail is available within the study area. It provides six kilometres of off-road trail that can be accessed from Quarry Road.

2.5 Existing road network performance

2.5.1 Traffic crashes

Crash statistics within the vicinity of the project site was taken from the Transport for NSW Centre for Road Safety website. Crash data was available for a five year period between 2011 – 2016 were reviewed and included reference to the Roads and Maritime Road user movement code table. A copy of this table is available in Appendix C.

A total of 39 crashes occurred on the local road network in proximity to the project site. No fatal crashes occurred during this period. 15 crashes involved some form of injury and the remaining crashes were non-casualty. A summary of the crashes which resulted in injuries are outlined below:

- Five (5) serious injury crashes caused by:
  - A vehicle turning right colliding with a vehicle travelling straight through the intersection of Peats Ferry Road and Bridge Road during the day.
  - A vehicle turning right colliding with a vehicle travelling straight through the intersection of George Street, Bridge Road and Railway Parade resulting in two injuries during the day.
  - A vehicle travelling straight through colliding with a vehicle travelling in the adjacent direction at the intersection of George Street, Bridge Road and Railway Parade resulting in one injury during the day.
  - A vehicle colliding with a pedestrian from the far side at the T-junction of Bridge Road and Albert Street during the day.
  - A vehicle rear ending another vehicle at the T-junction of Bridge Road and Jersey Road North during the night.
- Four (4) moderate injury crashes caused by:

  - A vehicle rear ending another vehicle on Peats Ferry Road near the TAFE exit during daylight resulting in two moderate injuries.
  - A vehicle becoming out of control at the T-junction of Peats Ferry Road and Dural Road during the day.
  - A vehicle colliding with another vehicle emerging from a driveway on Bridge Road during the day.
  - A vehicle travelling straight through colliding with a vehicle travelling in the adjacent direction at the T-junction of Bridge Road and Miller Avenue during the day.
- Six (6) minor injury crashes caused by:
  - A vehicle rear ending another vehicle at the intersection of Peats Ferry Road and Bridge Road during the day.
  - Two incidences involving a vehicle rear ending another vehicle at the intersection of Bridge Road and Jersey Street North during daylight resulting in one and two injuries respectively.
  - A vehicle sideswiping another vehicle during a left turn manouevre at the intersection of Peats Ferry Road and Bridge Road during the day.
  - Two incidences involving a right-turning vehicle being hit on the driver side at the intersection of Peats Ferry Road and Bridge Road during daylight and dusk respectively.

After December 2017 two crashes were recorded which resulted in pedestrian fatalities. These incidents took place at the intersection of Peats Ferry Road and Bridge Road and involved the following:

- Incident involving NCX truck in the evening at the intersection of Peats Ferry Road and Bridge Road.
- Incident involving northbound bus turning right from Peats Ferry Road into Bridge Road hitting a pedestrian.

The location of the crashes are shown in Figure 2.7 and a detailed summary of the crashes is included in Appendix B.

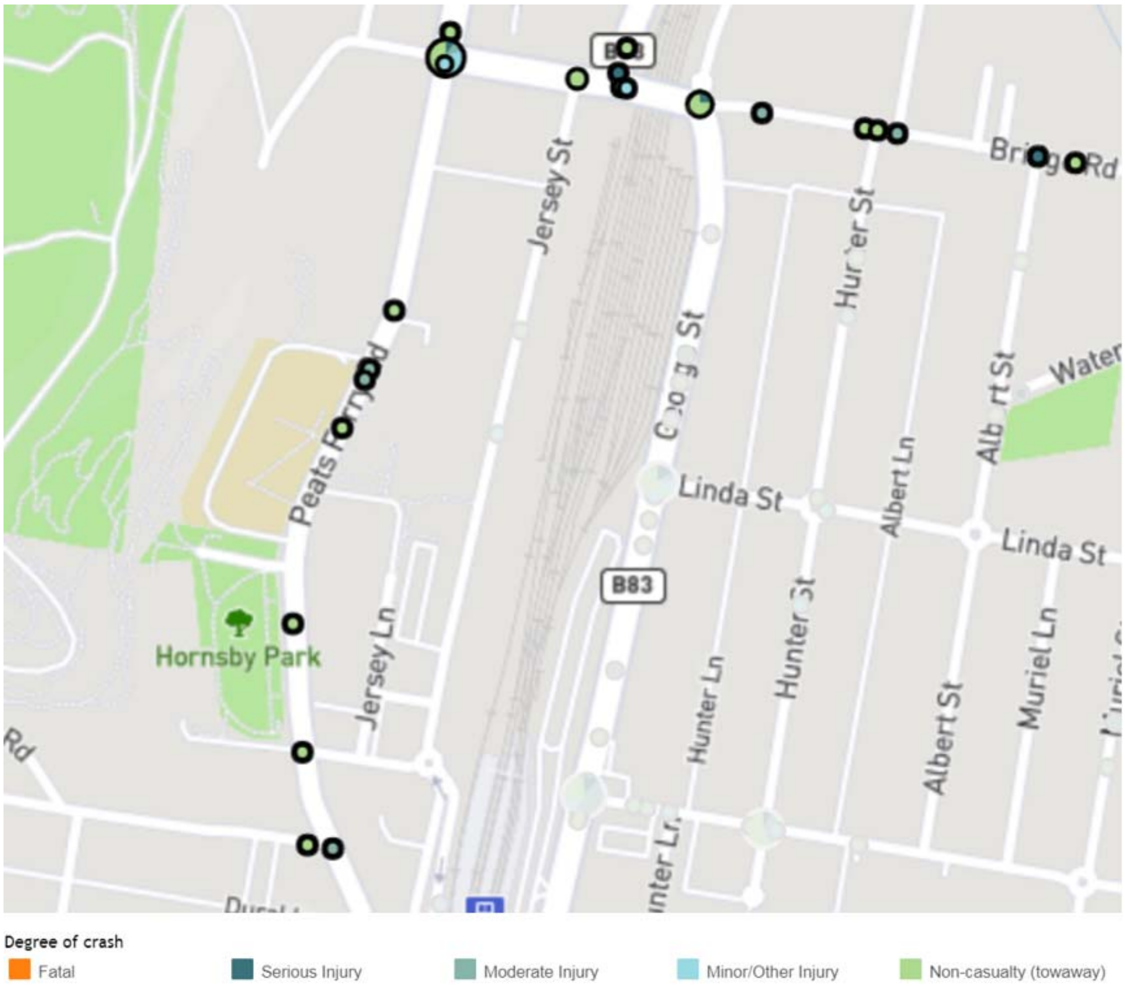


Figure 2.7 Crashes map

Source: TfNSW Centre for Road Safety

The most common type of crash were rear end crashes, making up 20 percent of the total. This could be due to vehicles following too closely to allow sufficient time to stop.

This is followed by right through and off road left either into a parked vehicle or other object which both made up 15 percent respectively. The types of crashes are categorised in Figure 2.8.

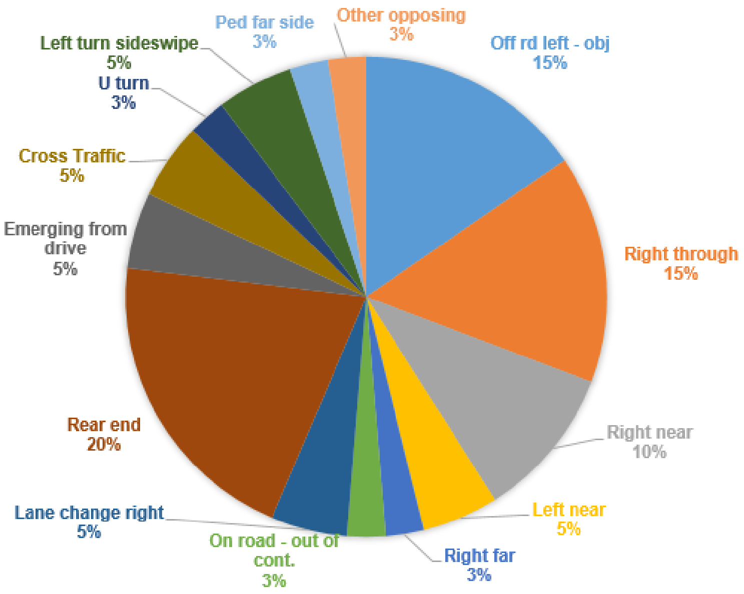


Figure 2.8 Types of crashes

2.5.2 Existing intersection traffic volumes

Council provided a turn count for the Peats Ferry Road / Bridge Road intersection. The survey was undertaken on 15th May 2015. The peak periods were identified as follows:

- AM peak: 7:30 am – 8:30 am
- PM peak: 5:00 pm – 6:00 pm.

The turn movements in the AM and PM peak hours of the Peats Ferry Road / Bridge Road intersection are shown in Figure 2.9 and Figure 2.10.

It is noted that the left turn from Peats Ferry Road (northbound) into Bridge Road and the right turn from Peats Ferry Road into Bridge Road (southbound) were not banned during the time of survey.

During the duration of construction of the NorthConnex project, these left and right turns from Peats Ferry Road were illegal. Following completion and demobilisation of the NorthConnex project, the banned left turn into Bridge Road from Peats Ferry Road and right turn from Peats Ferry Road into Bridge Road (west) will be made legal.

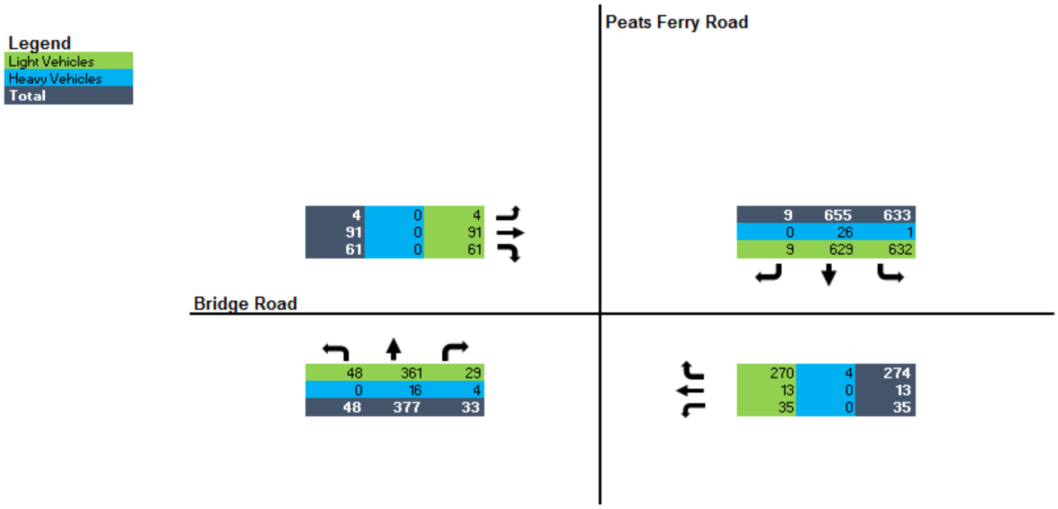


Figure 2.9 Traffic volume 2015 survey results AM peak

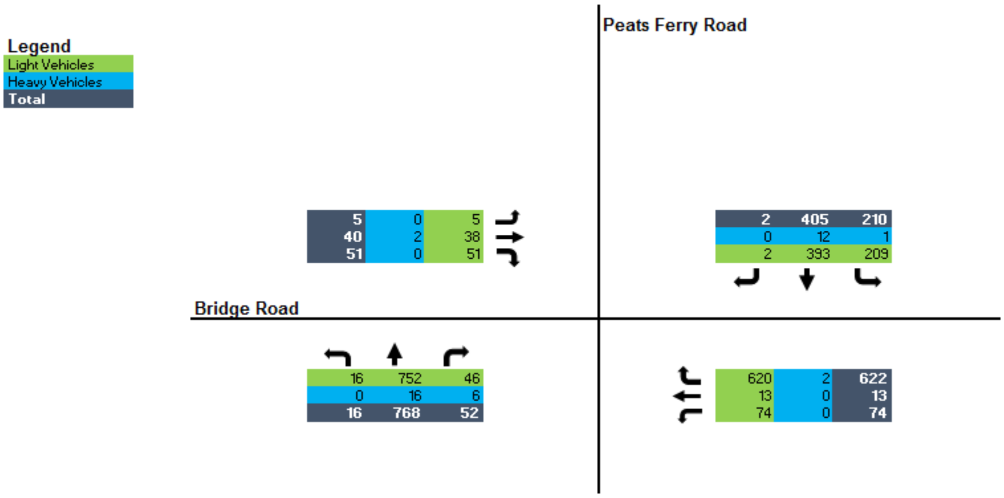


Figure 2.10 Traffic volume 2015 survey results PM peak

2.5.3 Existing intersection performance

The performance of the existing road network is largely dependent on the operating performance of key intersections, which are critical capacity control points on the road network. SIDRA intersection modelling software was used to assess the peak hour operating performance of intersections on the surrounding road network at key intersections within proximity of the site.

The criteria for evaluating the operational performance of intersections is provided by the *Guide to Traffic Generating Developments (Roads and Maritime 2002)* and reproduced in Table 2.4. The criteria for evaluating the operational performance of intersections is based on a qualitative measure (i.e. Level of Service), which is applied to each band of average vehicle delay.

Table 2.4 Level of service criteria for intersections

Level of service	Average delay per vehicle (secs/veh)	Traffic signals, roundabouts	Give way & stop signs
A	< 14	Good operation	Good operation
B	15 to 28	Good with acceptable delays & spare capacity	Acceptable delays & spare capacity
C	29 to 42	Satisfactory	Satisfactory, but accident study required
D	43 to 56	Operating near capacity	Near capacity & accident study required
E	57 to 70	At capacity; at signals, incidents will cause excessive delays Roundabouts require other control modes	At capacity, requires other control mode
F	> 70	Over Capacity Unstable operation	Over Capacity Unstable operation

Source: Guide to Traffic Generating Developments (Roads and Maritime 2002)

Notes:

1. *The average delay for priority-controlled intersections is selected from the movement on the approach with the highest average delay.*
2. *The level of service for priority-controlled intersections is based on the highest average delay per vehicle for the most critical movement.*
3. *The degree of saturation is defined as the ratio of the arrival flow (demand) to the capacity of each approach.*

The 2018 traffic volumes were analysed using SIDRA Intersection 7 modelling software and the forecasted volumes outlined in Section 5.1 to assess the operation of the intersections near the site access at Bridge Road. The results of the SIDRA assessment are summarised in Table 2.5, with detailed SIDRA outputs are provided in Appendix B.

Table 2.5 indicates that the overall intersection at Peats Ferry Road / Bridge Road was mainly operating at level of service B, with acceptable delays and available capacity, in both the AM and PM peak periods.

Table 2.5 Existing Intersection Performance Modelling Results (2018)

Intersection	Priority type	AM peak			PM peak		
		LoS	Ave. Delay (s)	Deg of Sat.	LoS	Ave. Delay (s)	Deg of Sat.
Peats Ferry Road / Bridge Road	Signalised	B	26.8	0.844	B	27.3	0.834

Notes:

1. *The average delay (Ave. Delay) for priority-controlled intersections is selected from the movement on the approach with the highest average delay, given in seconds per vehicle.*
2. *The level of service (LOS) for priority-controlled intersections is based on the highest average delay per vehicle for the most critical movement.*
3. *The degree of saturation (Deg of Sat) is defined as the ratio of the arrival flow (demand) to the capacity of each approach.*

3. The project

3.1 Proposed development

Following completion of filling by NorthConnex, Council is proposing to rehabilitate and reshape the site in a suitable way to ensure public safety and allow future development into parkland for community use. These works form the basis for the project as outlined in Section 1.1.

3.2 Access

The site is accessible for construction vehicles via Bridge Road in the north-east direction of the project.

Larger vehicles (e.g. low loaders) will be exempt from using Bridge Road if they cannot negotiate the steep grades safely. Instead of this, they are to access the site outside peak hours from Peats Ferry Road via William Street, Frederick Street and Quarry Road.

Hornsby Station is approximately 500 m to the east of the site. Rail access to the Hornsby Shire is provided by two rail lines which form part of the Sydney suburban rail network.

Local bus services operate in the Hornsby area serving surrounding suburbs with a key interchange at Hornsby Station.

3.3 Work hours and associated traffic

3.3.1 Work hours

All works associated with the construction of the project would be limited to standard daytime hours as outlined in Table 3.1.

Table 3.1 Project work hours

Day	Time
Monday to Friday	7:00 am to 6:00 pm
Saturday	8:00 am to 1:00 pm
Sunday	No work
Public holiday(s)	No work

3.3.2 Plant and equipment

The typical vehicles required to undertake the construction works by load and haul operation include the following:

- Excavators – with rippers or rock-breakers
- Rock saw
- Vibratory roller/compactor
- Bulldozers
- Loader
- Articulated dump truck
- Mobile screen
- Mobile crusher
- Fuel truck

- Off-road - water cart
- Tub grinder and mulcher

Except fuel trucks, all these vehicles would be delivered to the site at the start of the construction period and removed at the end of the construction period or beforehand if no longer required.

3.3.3 Staging and timing

The project is expected to take approximately two years to complete.

3.3.4 Rehabilitation and future use

Any temporary project facilities such as construction compounds and plant and equipment would be removed from the site upon completion of works. Erosion and sediment controls would be kept in place until the site is stabilised and/or retained for future development works.

The final rehabilitation and development of the site to recreational land use does not form part of this project and would be subject to a separate planning approval. The landform that would be created as part of this project has been designed to be suitable for this future development.

4. Method

This Traffic Impact Assessment (TIA) addresses the requirements of the SEARs for the Traffic & Transport issues component. The TIA has been undertaken with reference to the *Guide to Traffic Generating Development (formerly Roads and Transport Authority, now Roads and Maritime 2002)* and *Austroads Guide to Traffic Management Part 12: Traffic Impacts of Developments*.

While not mandatory, the guidelines suggest a process and method to assist in the development of the TIA. The traffic operation assessment process outlined in the guidelines stipulates that the operating characteristics need to be compared with established performance criteria.

This TIA report discusses the following:

- Existing conditions – a review of existing road features, traffic volumes and crash data.
- Proposed traffic – a review of additional traffic generated by the site for a worst-case construction traffic scenario.
- Operational traffic impact – assessment of the performance of the existing intersections and future case scenarios with and without the construction of the proposed site development.

5. Impact assessment

5.1 Background traffic growth

Roads and Maritime Traffic Volume viewer was used to determine traffic growth trends on Pacific Highway (now named Peats Ferry Road) in the vicinity of the project site (Traffic counter ID 74202 and 74011).

Table 5.1 shows that the average annual daily traffic volumes (AADT) on Peats Ferry Road north and south of the project site has increased by 687 vehicles per day and decreased 1,884 vehicles per day (veh/day) respectively over the three years. The background traffic growth rate of approximately one to two percent per year can be extracted from these background figures for a conservative assessment.

This growth rate has been projected to the surveyed traffic volumes on the local road network to calculate the background and construction scenario traffic volumes. The stick diagram of the traffic distributions for the AM and PM peaks are illustrated in Figure 5.1 and Figure 5.2 respectively.

Table 5.1 Peats Ferry Road (Pacific Highway) traffic volumes

Daily Traffic Volumes (vpd)	2015	2016	2017	Traffic volume increase (%)
South of Mills Avenue ID 74202	19258	20372	19945	2
North of Pennant Hills Rd ID 74011	37393	36205	35549	1

Source: Roads and Maritime – Traffic Volume Viewer, retrieved 5 April 2018

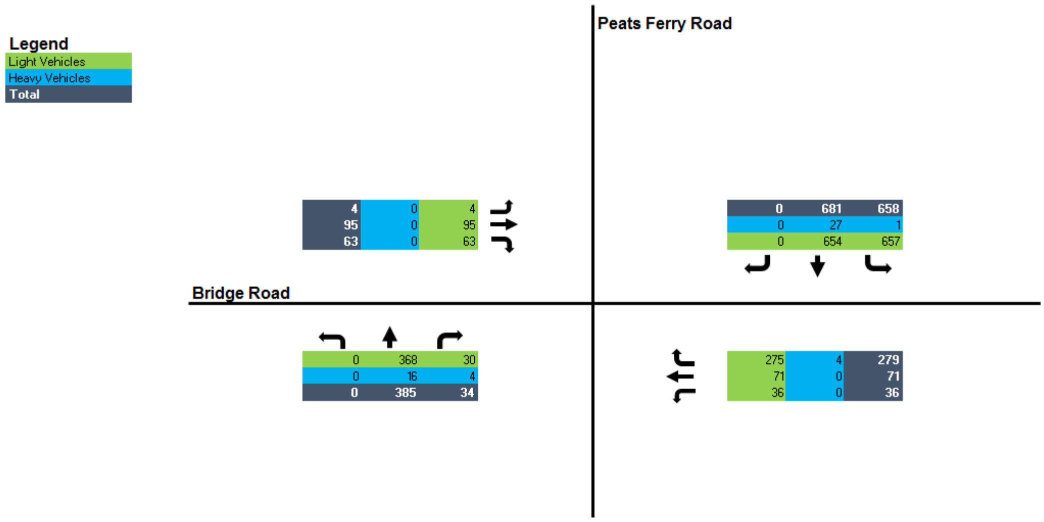


Figure 5.1 Projected 2018 traffic volumes AM peak

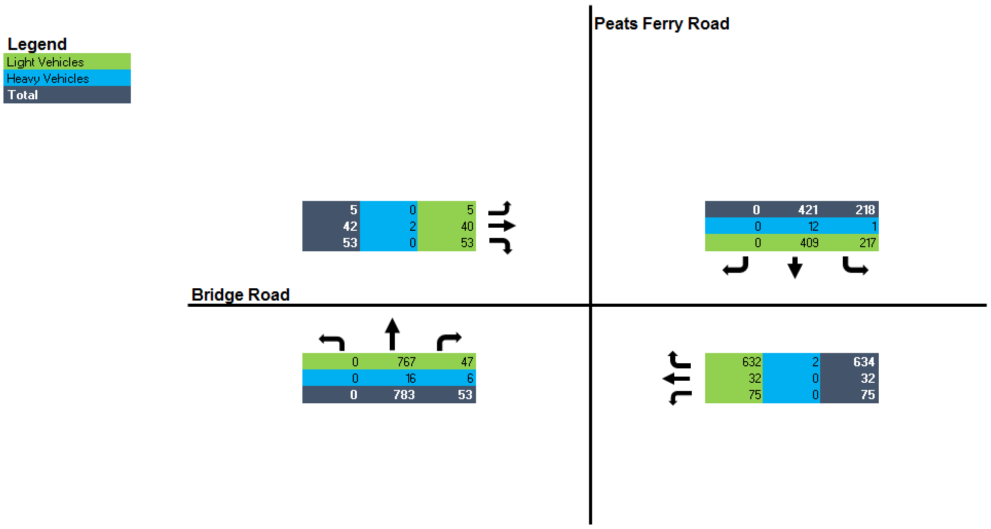


Figure 5.2 Projected 2018 traffic volumes PM peak

5.2 Projected traffic generation

Data and Information on the expected construction vehicle activity was obtained from Council.

The employee traffic and any visitor movements have been estimated for a period of one hour to account for the peak periods of activity for a worst-case scenario. It is noted that in reality, workers will likely be arriving at the site before the road network peak activity (7:30 am) but there is the possibility of overlap due to the time difference. No reductions to account for potential ride-sharing has been made. Thus the figures indicate that each worker will be driving to / from the site (a vehicle occupancy of one) provides a conservative assessment.

The figures for the AM and PM peak periods are summarised in Table 5.2 and Table 5.3 respectively. Note that a trip is defined as a one-way vehicular movement from one point to another excluding the return journey. Incorporating the return trip to / from a land use is classified as two trips.

Table 5.2 AM peak hour traffic trip generation

Vehicle types	Light vehicles (veh/h)		Heavy vehicles (veh/h)		Total vehicles (veh/h)	
	Inbound	Outbound	Inbound	Outbound	Inbound	Outbound
Construction workforce	30	0	0	0	30	0

Table 5.3 PM peak hour traffic trip generation

Vehicle types	Light vehicles (veh/h)		Heavy vehicles (veh/h)		Total vehicles (veh/h)	
	Inbound	Outbound	Inbound	Outbound	Inbound	Outbound
Construction workforce	0	30	0	0	0	30

Furthermore, there would be a delivery of heavy plant and equipment as specified in Section 3.3.2 at the beginning of the works and the collection of the plant and equipment following the completion of the work.

It is anticipated that a total of 26 heavy plant and equipment vehicles will be generated for this project. It is expected that this delivery would be made during off-peak hours and therefore not impact on the peak hour operational performance of the road network.

On a more regular basis, a fuel truck would be making deliveries to the site. Again, this would have a negligible impact similar to the abovementioned conditions due to an insignificant increase in traffic volumes.

5.3 Projected traffic distribution

The anticipated distribution of the traffic associated with the development from the quarry site has been based upon staff residency locations and location population densities.

It is expected that vehicle trips generated by the construction activity will travel along Bridge Road and Peats Ferry Road and use the existing Peats Ferry Road / Bridge Road intersection to gain access to the project site. The distribution of the peak hour traffic volumes generated from the development is summarised in Table 5.4, - Table 5.5 and Figure 5.3 - Figure 5.6.

Table 5.4 Traffic distribution AM peak

Vehicle component	Percentage split	Road section	Direction	Volume
Light vehicle	50	Peats Ferry Road	Northbound	15
Light vehicle	27	Peats Ferry Road	Southbound	8
Light vehicle	23	Bridge Road	Westbound	7
Total				**30**

Table 5.5 Traffic distribution PM peak

Vehicle component	Percentage split	Road section	Direction	Volume
Light vehicle	50	Peats Ferry Road	Southbound	15
Light vehicle	27	Peats Ferry Road	Northbound	8
Light vehicle	23	Bridge Road	Eastbound	7
Total				**30**

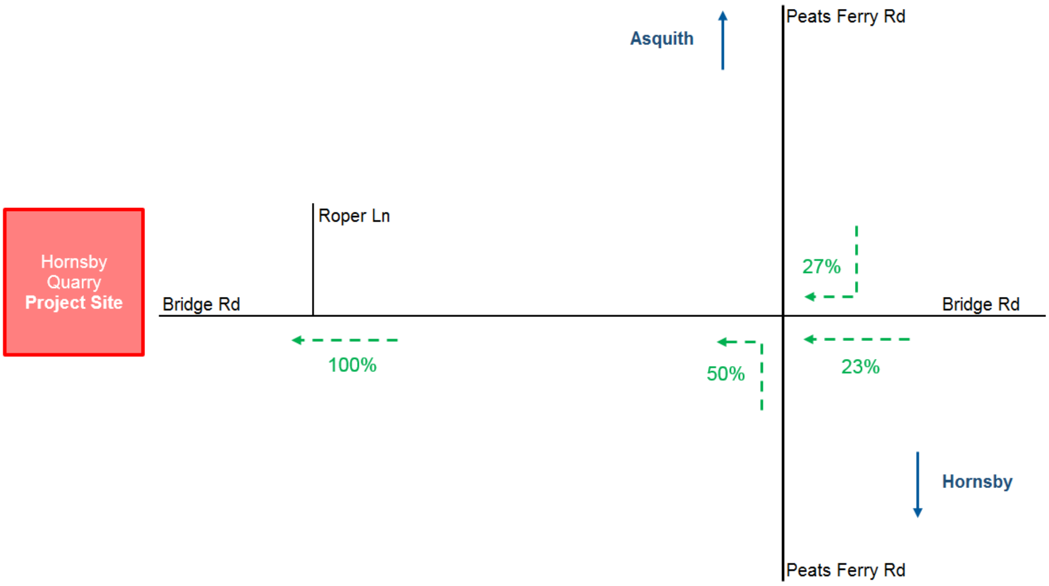


Figure 5.3 Trip distribution AM peak

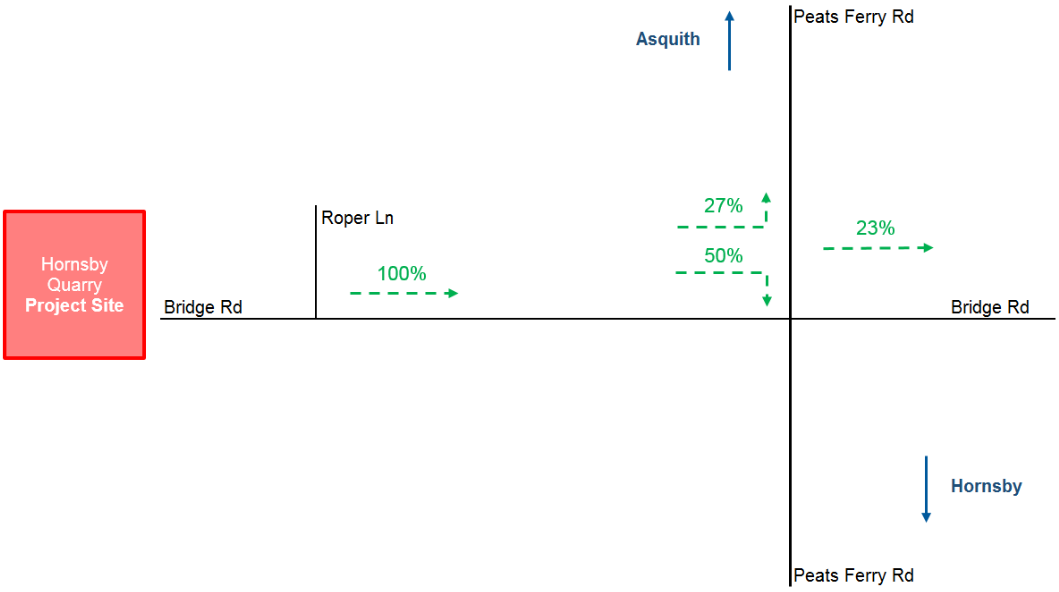


Figure 5.4 Trip distribution PM peak

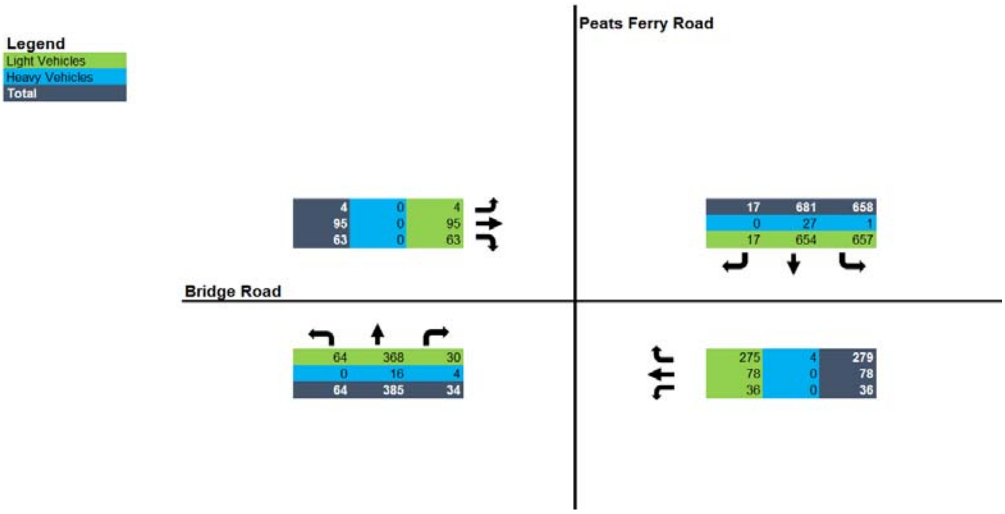


Figure 5.5 Projected 2018 traffic volumes plus construction volumes AM peak

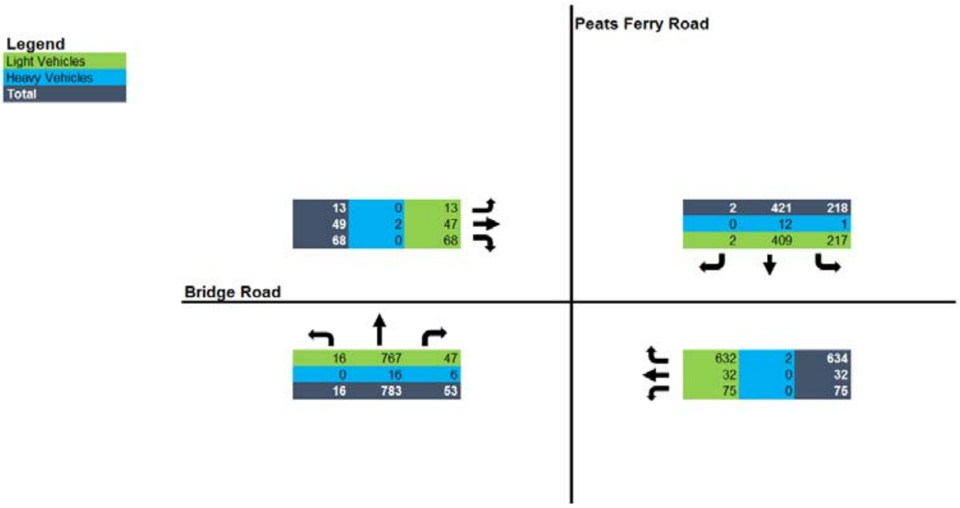


Figure 5.6 Projected 2018 traffic volumes plus construction volumes PM peak

5.4 Intersection performance construction scenario

5.4.1 Peats Ferry Road / Bridge Road

The SIDRA Intersection results for Peats Ferry Road / Bridge Road for the construction traffic scenario during the morning and evening peak jours is summarised in Table 5.6. For detailed SIDRA outputs refer to Appendix D.

As indicated by the SIDRA output results the magnitude of the impacts are not likely to be significantly different to that of the existing situation and would fall within typical daily fluctuations of traffic volumes. The LoS remains B for the AM and PM cases but the average delay increased by approximately one second for the PM case. The degree of saturation also remained relatively similar.

The traffic generated by the construction works at the quarry site are expected to have negligible impacts on the safety and efficiency of the local road network.

Table 5.6 Construction Intersection Performance Modelling Results (2018)

Intersection	Priority Type	AM peak			PM peak		
		LoS	Ave. Delay (s)	Deg of Sat.	LoS	Ave. Delay (s)	Deg of Sat.
Peats Ferry Road / Bridge Road	Signalised	B	26.9	0.744	B	28.4	0.772

Traffic management and road safety will be improved with the implementation of the mitigation measures outlined in Section 7.1.

5.4.2 Peats Ferry Road / William Street

The delivery of the heavy plant and equipment vehicles would be undertaken outside of the peak hours of the surrounding road network. No intersection modelling has been completed for this intersection since the impact on the capacity as a result of this delivery would be negligible.

5.5 Proposed access

Access to the site is adjacent to Roper Lane and provided directly from Bridge Road, which links to Peats Ferry Road forming part of the Pacific Highway.

The relevant sight distances have been evaluated against criteria for intersections in the *Austroads Guide to Road Design Part 4A: Un-signalised and Signalised Intersections*.

5.5.1 Approach Sight Distance

Approach Sight Distance (ASD) is the minimum level of sight distance which must be available on the minor road approaches to all intersections to ensure that drivers are aware of the presence of an intersection and possible conflicting vehicle movements. The ASD for the project has been assessed in accordance with Section 3.2.1 of the *Austroads Guide to Road Design Part 4A: Un-signalised and Signalised Intersections*.

For this observation, the relevant approach considers the layout of Bridge Road, as pictured in Figure 5.7.

Figure 5.7 Bridge Road viewed east

Source: Google Maps Street View accessed April 2018

5.5.2 Safe Intersection Sight Distance

Safe Intersection Sight Distance (SISD) is the minimum sight distance which should be provided on the major road at an intersection. The SISD has been assessed in accordance with Section 3.2.2 of the *Austroads Guide to Road Design Part 4A: Un-signalised and Signalised Intersections*.

For this observation, the relevant approach considers the layout of Roper Lane as pictured in Figure 5.8.

Figure 5.8 Roper Lane viewed north

Source: Google Maps Street View accessed April 2018

The minimum requirements for the ASD and SISD applicable to the project access are summarised in Table 5.7 adopting a driver reaction time, R_T of 2.0 and design speed of 40 km/h.

The table illustrates that the available sight distances are satisfactory in both directions. The measured distances exceed the minimum required distances, taking into consideration adjoining property boundaries and parked vehicles.

It is noted that Roper Lane is currently closed at the time of report writing and during the NorthConnex works. Council is proposing to keep Roper Lane closed following the completion of the NorthConnex works.

Table 5.7 Sight Distance requirements

Road	Sight distance type	Minimum required (m)	Measured (m)
Bridge Road	ASD	40	58
Roper Lane	SISD	73	105

5.6 Public transport services

In accordance with the low volumes of vehicle movements associated with the project, the impacts on the public transport services operating in proximity to the subject site are expected to be negligible.

5.7 Walking and cycling

An increase in vehicle volumes along the surrounding road network would potentially impact on the walking and cycling facilities. The associated impacts, although minimal, may include the following:

- Walking
  - The overall walking amenities throughout the study area, particularly around the key roads
  - Delays to pedestrians are expected to be minimal.
- Cycling
  - On road cyclists could experience minor increases in delays at intersections due to the increase in traffic volumes

A Construction Traffic Management Plan, which will be prepared at a later time, will identify measures to minimise impacts on pedestrians and bicycle riders.

6. Parking assessment

6.1 Parking demand

The project would operate with 30 employees at the site and adopting the conservative estimate as per Section 5.2 (assuming a vehicle occupancy of one), 30 parking spaces would be required.

6.2 Parking provision

Provision has been made for on site parking. It has been assumed that workers to the site would utilise a designated available area to park their vehicles on site.

It is recommended that a designated parking zone is provided for construction crew members / workers. Parking zone should also consider the space for loading and unloading of equipment and materials.

It has been assumed that the parking demands generated by the project would be satisfactorily accommodated on-site with no demand for on-street parking.

Therefore, the proposed parking provisions are considered supportable.

7. Management and mitigation measures

7.1 Management and mitigation

Based on the assessment, the following mitigation measures are suggested to minimise traffic and access impacts of the project:

- A detailed Construction Traffic Management Plan (CTMP) should be prepared and approved by Council prior to construction commencing. The CTMP would include appropriate Traffic Control Plans and include detail with respect to:
  - Traffic control measures in works areas.
  - Restrictions on the delivery of heavy plant and materials to site during peak traffic periods.
  - Appropriate entry/exit points for the proposed construction compound area(s).
  - Advising motorists of the change in traffic conditions associated with the work.
- Appropriate exclusion barriers, signage and site supervision is to be employed to ensure that the project site is controlled and that unauthorised vehicles and pedestrians are excluded from the works area.
- The construction contractor to liaise with Council in relation to the location of proposed construction compound areas and any requirements they might have. If alternate construction compound locations are identified approval would be obtained from Council and further assessment carried out.
- Only existing roads and access roads are to be utilised.
- The community is to be kept informed about the project through advertisements in the local media, notices and / or signs.
- All traffic control devices are to be in accordance with AS 1742.3-2009 – Manual of uniform traffic control Devices: Traffic control for works on roads and Roads and Maritime Traffic control at worksites manual.

7.2 Proposed upgrade

Council has prepared plans for an upgrade of the Peats Ferry Road / Bridge Road intersection. The upgrade works is proposed to be complete by the time the project is complete (Hornsby Park is open). The upgrade to the Peats Ferry Road / Bridge Road intersection includes the following:

- Addition of dedicated right turn lane on Peats Ferry Road (northbound) into Bridge Road (eastbound).
- Addition of dedicated right turn lane on Peats Ferry Road (southbound) into Bridge Road (westbound).
- Addition of dedicated left turn slip lane on Peats Ferry Road (southbound) into Bridge Road (eastbound).

For the further details of the proposed upgrade concept plan, see Appendix E.

8. Conclusions

GHD has been engaged by Hornsby Shire Council to undertake a Traffic Impact Assessment to support a development application for approval of the project under Part 4 of the EP&A Act. The EIS is being prepared in accordance with the provisions of the EP&A Act. The key objectives of this study were to:

- Identify the existing situation within proximity of the site with respect to traffic, parking, public and active transport.
- Identify the impacts of that construction staging will have on the surrounding road network.

The following key findings were identified as part of the traffic, transport and parking assessment:

A total of 39 crashes occurred between 2011 – 2016 within the vicinity of the project site. 15 of the crashes resulted in injury and the remaining were non-casualty. The most frequent crash type was rear end (20 percent), followed by right through (15 percent) and off road left – object (15 percent). Between December 2017 and May 2018 two crashes were recorded at the intersection of Peats Ferry Road and Bridge Road. These crashes resulted in pedestrian fatalities with heavy vehicles hitting pedestrians.

The results from SIDRA Intersection 7 modelling software indicated that the existing intersection performance at Peats Ferry Road / Bridge Road is operating at level of service B. This indicates that the intersection operates with acceptable delays in both the AM and PM peak periods.

It is estimated that there will be 30 veh/h entering the project site in the AM peak and 30 veh/h leaving the project site in the PM peak. There would also be a fuel truck and 19 heavy plant and equipment deliveries during off-peak hours.

The anticipated traffic distribution associated with the project is:

- In the AM peak:
  - 50 percent of light vehicles northbound along Peats Ferry Road.
  - 27 percent of light vehicles southbound along Peats Ferry Road.
  - 23 percent of light vehicles westbound along Bridge Road.
- In the PM peak:
  - 50 percent of light vehicles southbound along Peats Ferry Road.
  - 27 percent of light vehicles northbound along Peats Ferry Road.
  - 23 percent of light vehicles eastbound along Bridge Road.

The results from SIDRA Intersection 7 for the construction traffic generated scenario during both AM and PM peak periods are not likely to be significantly different to that of the existing situation (level of service B; intersection experiences acceptable delays and has available capacity).

The proposed site access is adjacent to Roper Lane and directly provided from Bridge Road, linking to Peats Ferry Road. In accordance with Section 3.2.2 of the *Austroads Guide to Road Design Part 4A: Un-signalised and Signalised Intersections*, both the approach sight distance and safe intersection sight distance were satisfactory in both directions. Roper Lane will be reopened after NorthConnex is demobilised however, Council is proposing to keep Roper Lane closed and is preparing a submission to the Local Traffic Committee.

The impacts on the public transport services operating in proximity to the subject site as well as the walking and cycling amenities due to the low volumes of vehicle movements associated with the construction phase, are expected to be insignificant and minimal.

9. References

Roads and Maritime (2002) ‘Guide to Traffic Generating Developments’

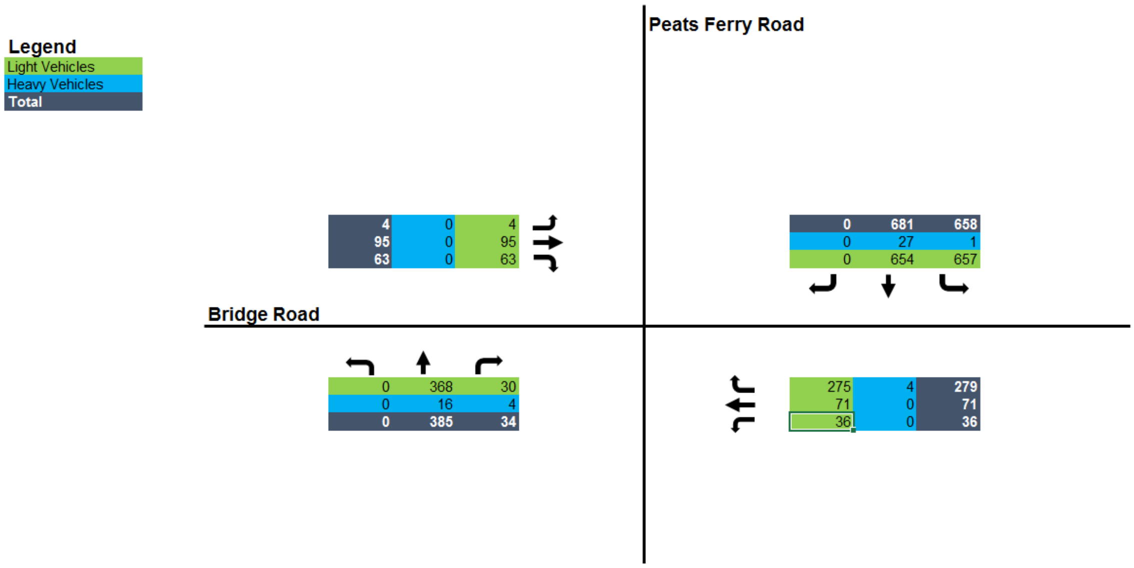
Austroads (2016) ‘Guide to Traffic Management Part 12: Traffic Impacts of Developments’

Austroads (2017) ‘Guide to Road Design Part 4A: Un-signalised and Signalised Intersections’

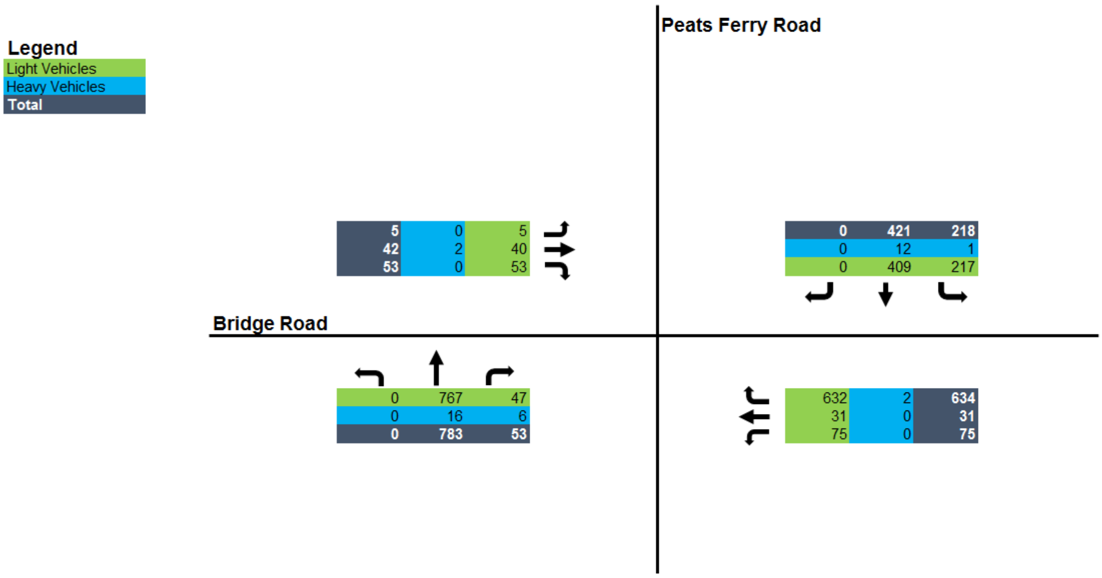
Appendices

Appendix A – Traffic volumes

AM Peak (excluding construction)_2018

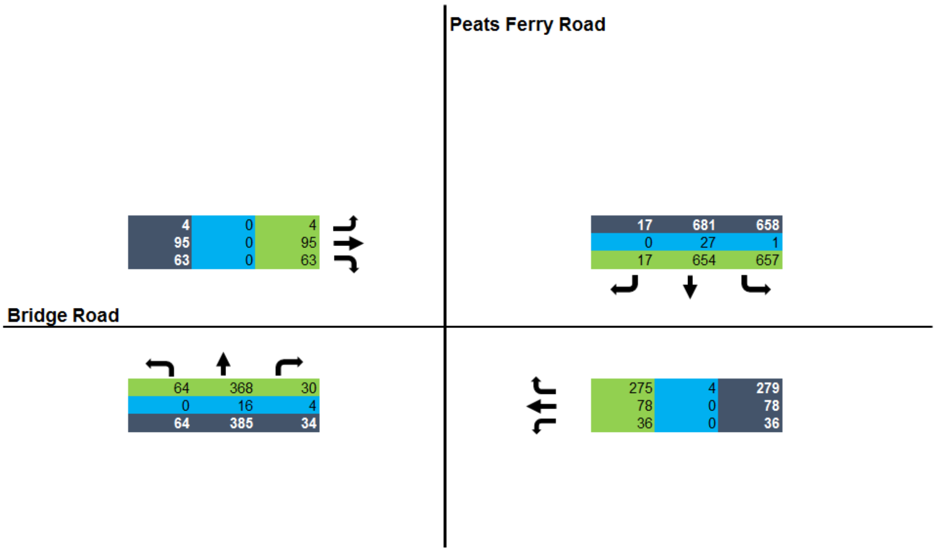


PM Peak (excluding construction)_2018



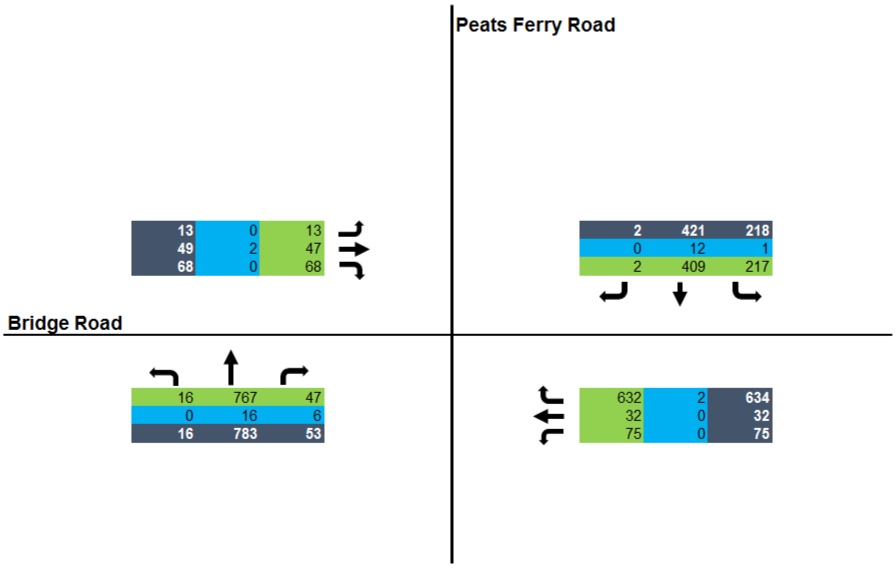
AM Peak (including construction)_2018

Legend
🟩 Light Vehicles
🟦 Heavy Vehicles
⬛ Total



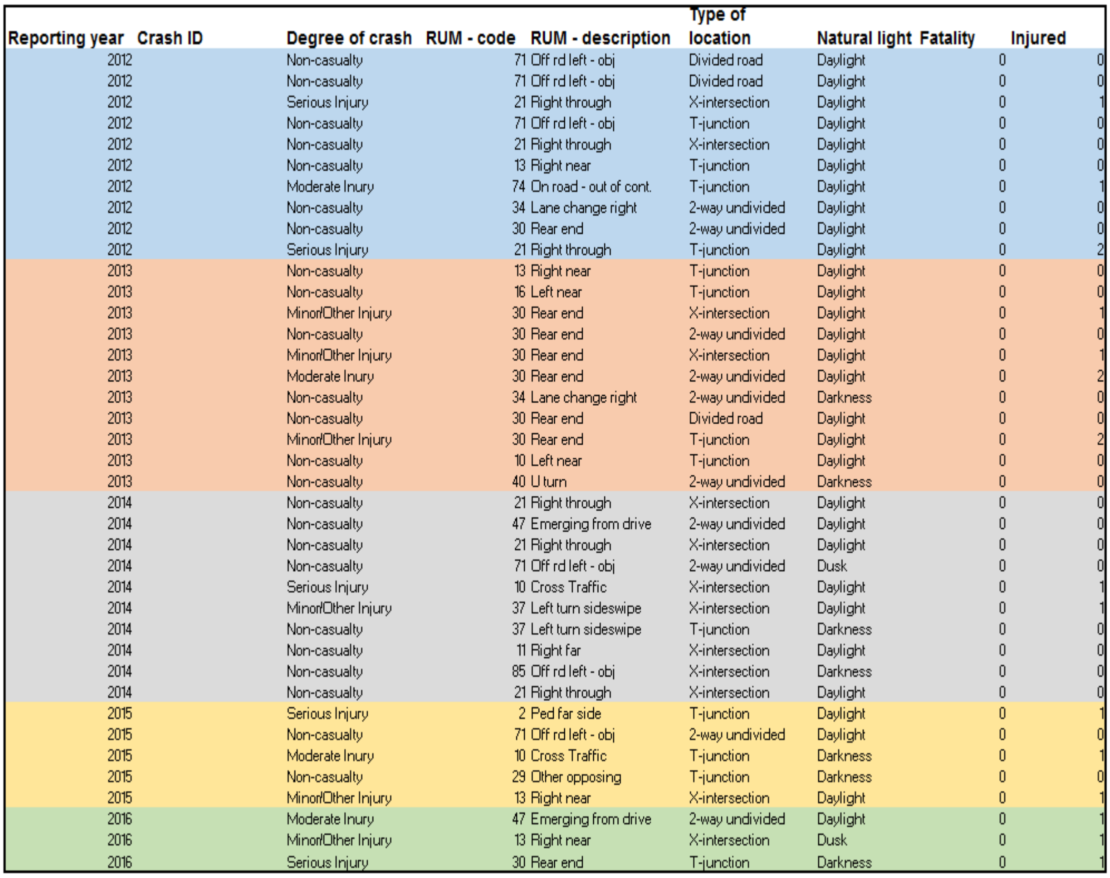
PM Peak (including construction)_2018

Legend
🟩 Light Vehicles
🟦 Heavy Vehicles
⬛ Total



Appendix B – Detailed crash summary

Crash data recorded between 2012 to 2016



Reporting year	Crash ID	Degree of crash	RUM - code	RUM - description	Type of location	Natural light	Fatality	Injured
2012		Non-casualty	71	Off rd left - obj	Divided road	Daylight	0	0
2012		Non-casualty	71	Off rd left - obj	Divided road	Daylight	0	0
2012		Serious Injury	21	Right through	X-intersection	Daylight	0	1
2012		Non-casualty	71	Off rd left - obj	T-junction	Daylight	0	0
2012		Non-casualty	21	Right through	X-intersection	Daylight	0	0
2012		Non-casualty	13	Right near	T-junction	Daylight	0	0
2012		Moderate Inury	74	On road - out of cont.	T-junction	Daylight	0	1
2012		Non-casualty	34	Lane change right	2-way undivided	Daylight	0	0
2012		Non-casualty	30	Rear end	2-way undivided	Daylight	0	0
2012		Serious Injury	21	Right through	T-junction	Daylight	0	2
2013		Non-casualty	13	Right near	T-junction	Daylight	0	0
2013		Non-casualty	16	Left near	T-junction	Daylight	0	0
2013		Minor/Other Injury	30	Rear end	X-intersection	Daylight	0	1
2013		Non-casualty	30	Rear end	2-way undivided	Daylight	0	0
2013		Minor/Other Injury	30	Rear end	X-intersection	Daylight	0	1
2013		Moderate Inury	30	Rear end	2-way undivided	Daylight	0	2
2013		Non-casualty	34	Lane change right	2-way undivided	Darkness	0	0
2013		Non-casualty	30	Rear end	Divided road	Daylight	0	0
2013		Minor/Other Injury	30	Rear end	T-junction	Daylight	0	2
2013		Non-casualty	10	Left near	T-junction	Daylight	0	0
2013		Non-casualty	40	U turn	2-way undivided	Darkness	0	0
2014		Non-casualty	21	Right through	X-intersection	Daylight	0	0
2014		Non-casualty	47	Emerging from drive	2-way undivided	Daylight	0	0
2014		Non-casualty	21	Right through	X-intersection	Daylight	0	0
2014		Non-casualty	71	Off rd left - obj	2-way undivided	Dusk	0	0
2014		Serious Injury	10	Cross Traffic	X-intersection	Daylight	0	1
2014		Minor/Other Injury	37	Left turn sideswipe	X-intersection	Daylight	0	1
2014		Non-casualty	37	Left turn sideswipe	T-junction	Darkness	0	0
2014		Non-casualty	11	Right far	X-intersection	Daylight	0	0
2014		Non-casualty	85	Off rd left - obj	X-intersection	Darkness	0	0
2014		Non-casualty	21	Right through	X-intersection	Daylight	0	0
2015		Serious Injury	2	Ped far side	T-junction	Daylight	0	1
2015		Non-casualty	71	Off rd left - obj	2-way undivided	Daylight	0	0
2015		Moderate Inury	10	Cross Traffic	T-junction	Darkness	0	1
2015		Non-casualty	29	Other opposing	T-junction	Darkness	0	0
2015		Minor/Other Injury	13	Right near	X-intersection	Daylight	0	1
2016		Moderate Inury	47	Emerging from drive	2-way undivided	Daylight	0	1
2016		Minor/Other Injury	13	Right near	X-intersection	Dusk	0	1
2016		Serious Injury	30	Rear end	T-junction	Darkness	0	1

Appendix C – Road user movement code table


PEDESTRIANS (on foot or in toy/pram)
VEHICLES FROM ADJACENT DIRECTION (intersections only)
VEHICLES FROM OPPOSING DIRECTION
VEHICLES FROM SAME DIRECTION
MANOEUVRING
OVERTAKING
ON PATH
OFF PATH, ON STRAIGHT
OFF PATH, ON CURVE OR TURNING
MISCELLANEOUS
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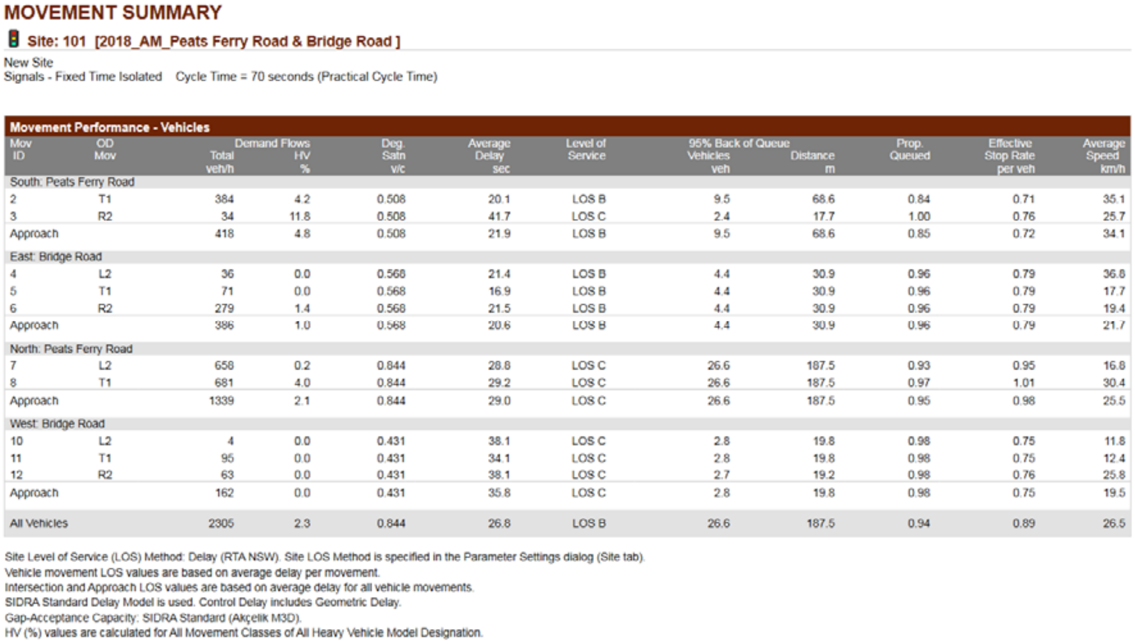
Appendix D – SIDRA results



MOVEMENT SUMMARY

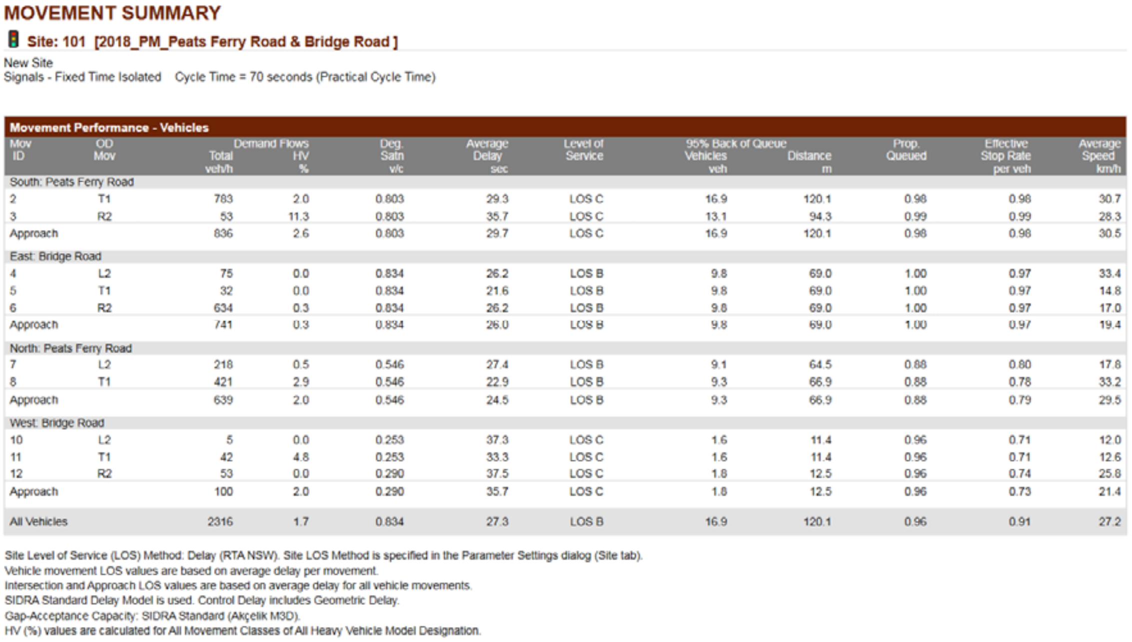
Site: 101 [2018_AM_Peats Ferry Road & Bridge Road]

New Site
Signals - Fixed Time Isolated   Cycle Time = 70 seconds (Practical Cycle Time)

Movement Performance - Vehicles

Mov ID	OD Mov	Demand Flows Total veh/h	Demand Flows HV %	Deg. Satn v/c	Average Delay sec	Level of Service	95% Back of Queue Vehicles veh	95% Back of Queue Distance m	Prop. Queued	Effective Stop Rate per veh	Average Speed km/h
South: Peats Ferry Road											
2	T1	384	4.2	0.508	20.1	LOS B	9.5	68.6	0.84	0.71	35.1
3	R2	34	11.8	0.508	41.7	LOS C	2.4	17.7	1.00	0.76	25.7
Approach		418	4.8	0.508	21.9	LOS B	9.5	68.6	0.85	0.72	34.1
East: Bridge Road											
4	L2	36	0.0	0.568	21.4	LOS B	4.4	30.9	0.96	0.79	36.8
5	T1	71	0.0	0.568	16.9	LOS B	4.4	30.9	0.96	0.79	17.7
6	R2	279	1.4	0.568	21.5	LOS B	4.4	30.9	0.96	0.79	19.4
Approach		386	1.0	0.568	20.6	LOS B	4.4	30.9	0.96	0.79	21.7
North: Peats Ferry Road											
7	L2	658	0.2	0.844	28.8	LOS C	26.6	187.5	0.93	0.95	16.8
8	T1	681	4.0	0.844	29.2	LOS C	26.6	187.5	0.97	1.01	30.4
Approach		1339	2.1	0.844	29.0	LOS C	26.6	187.5	0.95	0.98	25.5
West: Bridge Road											
10	L2	4	0.0	0.431	38.1	LOS C	2.8	19.8	0.98	0.75	11.8
11	T1	95	0.0	0.431	34.1	LOS C	2.8	19.8	0.98	0.75	12.4
12	R2	63	0.0	0.431	38.1	LOS C	2.7	19.2	0.98	0.76	25.8
Approach		162	0.0	0.431	35.8	LOS C	2.8	19.8	0.98	0.75	19.5
All Vehicles		2305	2.3	0.844	26.8	LOS B	26.6	187.5	0.94	0.89	26.5

Site Level of Service (LOS) Method: Delay (RTA NSW). Site LOS Method is specified in the Parameter Settings dialog (Site tab).
Vehicle movement LOS values are based on average delay per movement.
Intersection and Approach LOS values are based on average delay for all vehicle movements.
SIDRA Standard Delay Model is used. Control Delay includes Geometric Delay.
Gap-Acceptance Capacity: SIDRA Standard (Akçelik M3D).
HV (%) values are calculated for All Movement Classes of All Heavy Vehicle Model Designation.



MOVEMENT SUMMARY

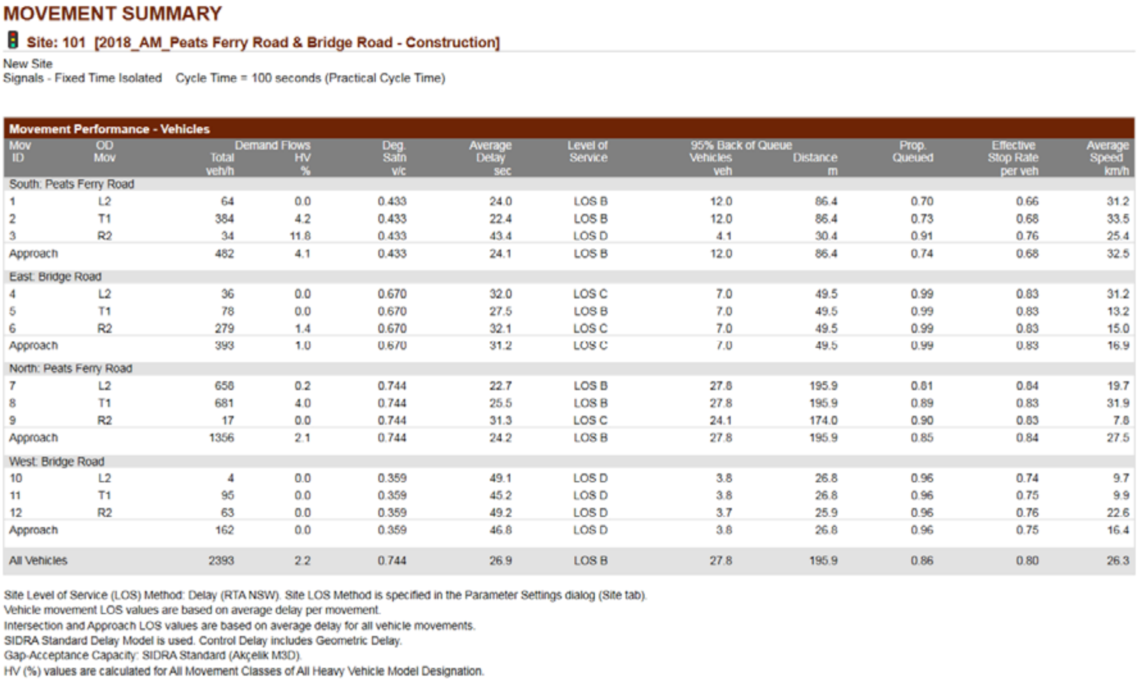
Site: 101 [2018_PM_Peats Ferry Road & Bridge Road]

New Site
Signals - Fixed Time Isolated   Cycle Time = 70 seconds (Practical Cycle Time)

Movement Performance - Vehicles

Mov ID	OD Mov	Demand Flows Total veh/h	Demand Flows HV %	Deg. Satn v/c	Average Delay sec	Level of Service	95% Back of Queue Vehicles veh	95% Back of Queue Distance m	Prop. Queued	Effective Stop Rate per veh	Average Speed km/h
South: Peats Ferry Road											
2	T1	783	2.0	0.803	29.3	LOS C	16.9	120.1	0.98	0.98	30.7
3	R2	53	11.3	0.803	35.7	LOS C	13.1	94.3	0.99	0.99	28.3
Approach		836	2.6	0.803	29.7	LOS C	16.9	120.1	0.98	0.98	30.5
East: Bridge Road											
4	L2	75	0.0	0.834	26.2	LOS B	9.8	69.0	1.00	0.97	33.4
5	T1	32	0.0	0.834	21.6	LOS B	9.8	69.0	1.00	0.97	14.8
6	R2	634	0.3	0.834	26.2	LOS B	9.8	69.0	1.00	0.97	17.0
Approach		741	0.3	0.834	26.0	LOS B	9.8	69.0	1.00	0.97	19.4
North: Peats Ferry Road											
7	L2	218	0.5	0.546	27.4	LOS B	9.1	64.5	0.88	0.80	17.8
8	T1	421	2.9	0.546	22.9	LOS B	9.3	66.9	0.88	0.78	33.2
Approach		639	2.0	0.546	24.5	LOS B	9.3	66.9	0.88	0.79	29.5
West: Bridge Road											
10	L2	5	0.0	0.253	37.3	LOS C	1.6	11.4	0.96	0.71	12.0
11	T1	42	4.8	0.253	33.3	LOS C	1.6	11.4	0.96	0.71	12.6
12	R2	53	0.0	0.290	37.5	LOS C	1.8	12.5	0.96	0.74	25.8
Approach		100	2.0	0.290	35.7	LOS C	1.8	12.5	0.96	0.73	21.4
All Vehicles		2316	1.7	0.834	27.3	LOS B	16.9	120.1	0.96	0.91	27.2

Site Level of Service (LOS) Method: Delay (RTA NSW). Site LOS Method is specified in the Parameter Settings dialog (Site tab).
Vehicle movement LOS values are based on average delay per movement.
Intersection and Approach LOS values are based on average delay for all vehicle movements.
SIDRA Standard Delay Model is used. Control Delay includes Geometric Delay.
Gap-Acceptance Capacity: SIDRA Standard (Akçelik M3D).
HV (%) values are calculated for All Movement Classes of All Heavy Vehicle Model Designation.



MOVEMENT SUMMARY

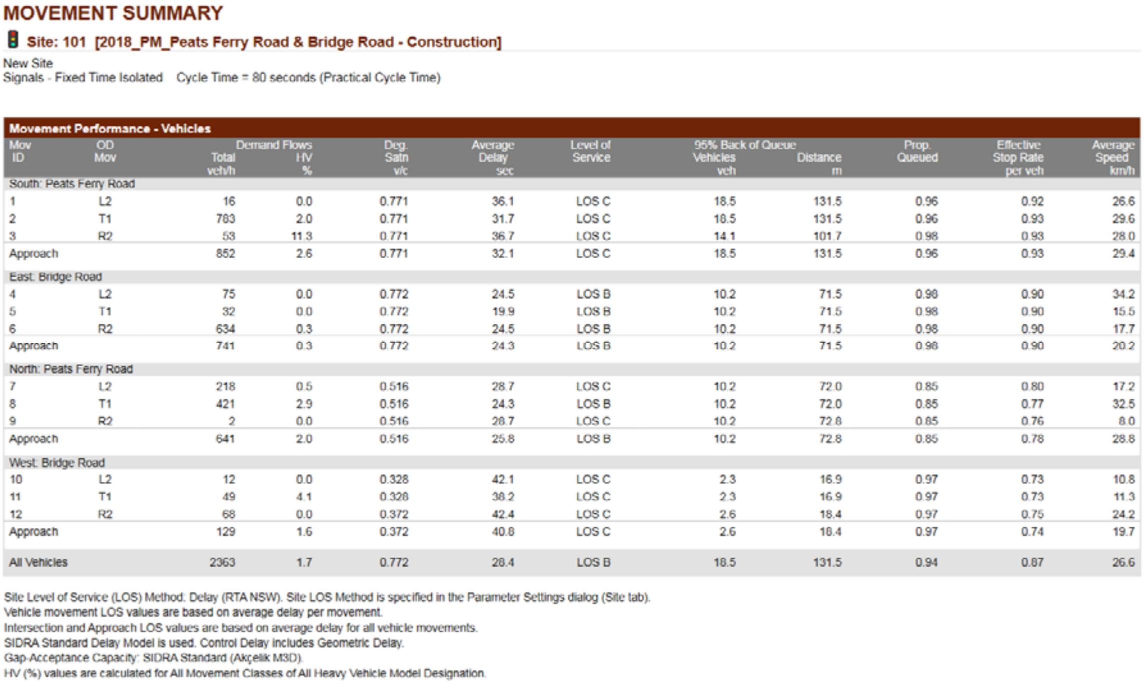
Site: 101 [2018_AM_Peats Ferry Road & Bridge Road - Construction]

New Site
Signals - Fixed Time Isolated   Cycle Time = 100 seconds (Practical Cycle Time)

Movement Performance - Vehicles

Mov ID	OD Mov	Demand Flows		Deg. Satn	Average Delay	Level of Service	95% Back of Queue		Prop. Queued	Effective Stop Rate	Average Speed
		Total veh/h	HV %	v/c	sec		Vehicles veh	Distance m		per veh	km/h
South: Peats Ferry Road											
1	L2	64	0.0	0.433	24.0	LOS B	12.0	86.4	0.70	0.66	31.2
2	T1	384	4.2	0.433	22.4	LOS B	12.0	86.4	0.73	0.68	33.5
3	R2	34	11.8	0.433	43.4	LOS D	4.1	30.4	0.91	0.76	25.4
Approach		482	4.1	0.433	24.1	LOS B	12.0	86.4	0.74	0.68	32.5
East: Bridge Road											
4	L2	36	0.0	0.670	32.0	LOS C	7.0	49.5	0.99	0.83	31.2
5	T1	78	0.0	0.670	27.5	LOS B	7.0	49.5	0.99	0.83	13.2
6	R2	279	1.4	0.670	32.1	LOS C	7.0	49.5	0.99	0.83	15.0
Approach		393	1.0	0.670	31.2	LOS C	7.0	49.5	0.99	0.83	16.9
North: Peats Ferry Road											
7	L2	658	0.2	0.744	22.7	LOS B	27.8	195.9	0.81	0.84	19.7
8	T1	681	4.0	0.744	25.5	LOS B	27.8	195.9	0.89	0.83	31.9
9	R2	17	0.0	0.744	31.3	LOS C	24.1	174.0	0.90	0.83	7.8
Approach		1356	2.1	0.744	24.2	LOS B	27.8	195.9	0.85	0.84	27.5
West: Bridge Road											
10	L2	4	0.0	0.359	49.1	LOS D	3.8	26.8	0.96	0.74	9.7
11	T1	95	0.0	0.359	45.2	LOS D	3.8	26.8	0.96	0.75	9.9
12	R2	63	0.0	0.359	49.2	LOS D	3.7	25.9	0.96	0.76	22.6
Approach		162	0.0	0.359	46.8	LOS D	3.8	26.8	0.96	0.75	16.4
All Vehicles		2393	2.2	0.744	26.9	LOS B	27.8	195.9	0.86	0.80	26.3

Site Level of Service (LOS) Method: Delay (RTA NSW). Site LOS Method is specified in the Parameter Settings dialog (Site tab).
Vehicle movement LOS values are based on average delay per movement.
Intersection and Approach LOS values are based on average delay for all vehicle movements.
SIDRA Standard Delay Model is used. Control Delay includes Geometric Delay.
Gap-Acceptance Capacity: SIDRA Standard (Akçelik M3D).
HV (%) values are calculated for All Movement Classes of All Heavy Vehicle Model Designation.



MOVEMENT SUMMARY

Site: 101 [2018_PM_Peats Ferry Road & Bridge Road - Construction]

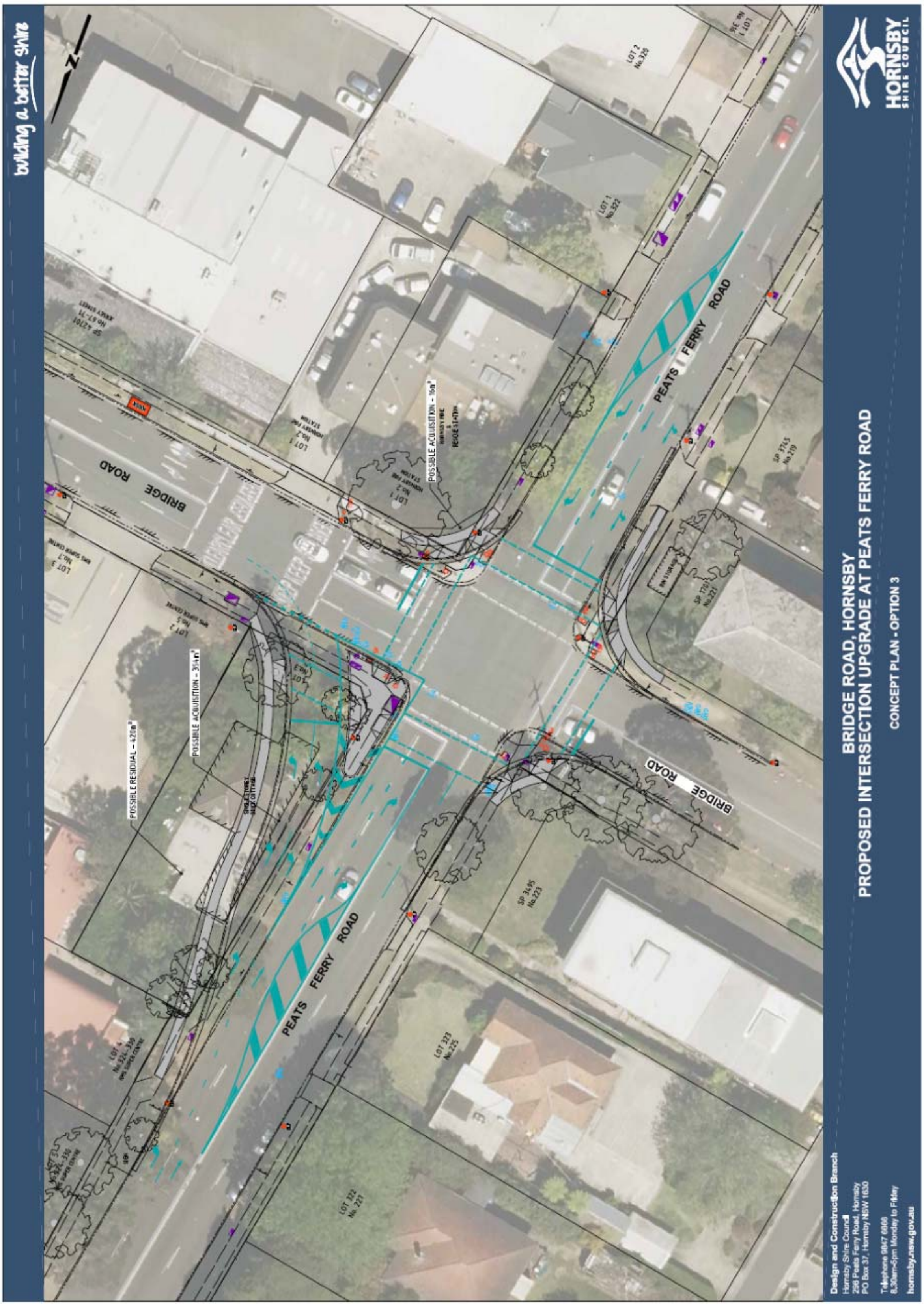
New Site
Signals - Fixed Time Isolated   Cycle Time = 80 seconds (Practical Cycle Time)

Movement Performance - Vehicles

Mov ID	OD Mov	Demand Flows		Deg. Satn	Average Delay	Level of Service	95% Back of Queue		Prop. Queued	Effective Stop Rate	Average Speed
		Total veh/h	HV %	v/c	sec		Vehicles veh	Distance m		per veh	km/h
South: Peats Ferry Road											
1	L2	16	0.0	0.771	36.1	LOS C	18.5	131.5	0.96	0.92	26.6
2	T1	783	2.0	0.771	31.7	LOS C	18.5	131.5	0.96	0.93	29.6
3	R2	53	11.3	0.771	36.7	LOS C	14.1	101.7	0.98	0.93	28.0
Approach		852	2.6	0.771	32.1	LOS C	18.5	131.5	0.96	0.93	29.4
East: Bridge Road											
4	L2	75	0.0	0.772	24.5	LOS B	10.2	71.5	0.98	0.90	34.2
5	T1	32	0.0	0.772	19.9	LOS B	10.2	71.5	0.98	0.90	15.5
6	R2	634	0.3	0.772	24.5	LOS B	10.2	71.5	0.98	0.90	17.7
Approach		741	0.3	0.772	24.3	LOS B	10.2	71.5	0.98	0.90	20.2
North: Peats Ferry Road											
7	L2	218	0.5	0.516	28.7	LOS C	10.2	72.0	0.85	0.80	17.2
8	T1	421	2.9	0.516	24.3	LOS B	10.2	72.0	0.85	0.77	32.5
9	R2	2	0.0	0.516	28.7	LOS C	10.2	72.8	0.85	0.76	8.0
Approach		641	2.0	0.516	25.8	LOS B	10.2	72.8	0.85	0.78	28.8
West: Bridge Road											
10	L2	12	0.0	0.328	42.1	LOS C	2.3	16.9	0.97	0.73	10.8
11	T1	49	4.1	0.328	38.2	LOS C	2.3	16.9	0.97	0.73	11.3
12	R2	68	0.0	0.372	42.4	LOS C	2.6	18.4	0.97	0.75	24.2
Approach		129	1.6	0.372	40.8	LOS C	2.6	18.4	0.97	0.74	19.7
All Vehicles		2363	1.7	0.772	28.4	LOS B	18.5	131.5	0.94	0.87	26.6

Site Level of Service (LOS) Method: Delay (RTA NSW). Site LOS Method is specified in the Parameter Settings dialog (Site tab).
Vehicle movement LOS values are based on average delay per movement.
Intersection and Approach LOS values are based on average delay for all vehicle movements.
SIDRA Standard Delay Model is used. Control Delay includes Geometric Delay.
Gap-Acceptance Capacity: SIDRA Standard (Akçelik M3D).
HV (%) values are calculated for All Movement Classes of All Heavy Vehicle Model Designation.

Appendix E – Proposed Upgrade Concept Plan


building a better shire
BRIDGE ROAD
PEATS FERRY ROAD
POSSIBLE ACQUISITION - 16m²
POSSIBLE ACQUISITION - 354m²
POSSIBLE RESIDUAL - 420m²
LOT 1 No.322
LOT 2 No.320
SP 3765 No.219
SP 3495 No.223
LOT 323 No.225
LOT 322 No.227
HORNSBY
SHIRE COUNCIL
BRIDGE ROAD, HORNSBY
PROPOSED INTERSECTION UPGRADE AT PEATS FERRY ROAD
CONCEPT PLAN - OPTION 3
Design and Construction Branch
Hornsby Shire Council
296 Peats Ferry Road, Hornsby
PO Box 37, Hornsby NSW 1630
Telephone 9847 6666
8.30am-5pm Monday to Friday
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2126457-96615/https://projects.ghd.com/oc/Sydney/hornsbyquarryrehabil/Delivery/Documents/2126457_REP_Traffic Impact Assessment.docx

Document Status

Revision	Author	Reviewer		Approved for Issue		
		Name	Signature	Name	Signature	Date
0	Michael Tran	Mark Lucas	Mark Lucas	David Gamble	David Gamble	23/11/18

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Appendix J – Geotechnical assessment

Hornsby Shire Council

Hornsby Quarry Rehabilitation Review and Risk Assessment

November 2018

Executive summary

This executive summary is written with the assumption that the reader has existing btrackscheme knowledge and should not be used in isolation from the full context of the main report.

Hornsby Shire Council ("Council") is in the process of finalising concept designs for the rehabilitation of the Hornsby Quarry and the subsequent re-development of the site into public parkland. GHD was commissioned to review existing geotechnical reports and information, and provide Council with an assessment of geotechnical issues and how they could be managed.

GHD identified some potential geotechnical challenges associated with redeveloping the site economically. These included global slope stability, erosion, rock-fall and long-term settlement.

Stability issues with the existing quarry can be summarised as follows:

- Southern quarry wall global and localised stability
- Northern quarry spoil mound stability
- Localised rock-falls or soil erosion (encompassing discrete blocks detaching and falling from the quarry face or shallow depth soil slumping).

GHD undertook a series of Factor of Safety and risk-based assessments, which enabled the following recommendations to be made:

- Further detailed assessment of the southern quarry wall global stability shows that the stability is acceptable. Therefore, no access constraints or design response are proposed to address the global stability of the southern quarry wall. The existing quarry access track arrangements can be maintained and monitored to keep the factor of safety within acceptable limits. Details can be found in Section 2 of this report.
- The Southern Access Track at the crest of the southern quarry wall has localised instability issues associated with residual soils and fill material eroding and 'slipping off' the rock profile beneath. A robust structural solution (raked mini-pile wall including capping beam with edge protection) is suggested. It is envisaged that this will enable the existing southern access track to continue to be used for maintenance and pedestrian access in the long term. Details of the concept level proposed solution are contained in Section 6 of this report.
- Northern Spoil Mound stability issues are proposed to be addressed by a combination of proactive engineering measures to improve stability (regrading to a shallower angle, slope reinforcement and drainage measures) with a continuance of long term monitoring and maintenance preferred in some areas.
- Throughout the site a combined approach is proposed to address the localised effects of erosion and small scale slope failures in soil and rock slopes A 'tool box' of measures is proposed including:
  - Toe exclusion zones to prevent park users from exposure to rock-fall and small-scale soil slope failure hazards.
  - Preventative measures such as rock bolts, face mesh, catch fences, catch ditches, facing 'skin' walls (e.g. gabions secured to exposed rock faces) and maintained erosion protection on soil slopes (vegetation erosion protection envisaged in most areas).
  - Monitoring and maintenance as required, in all areas.

The future parkland layout proposes widening, re-alignment and extension of access tracks to enable the public to drive into the quarry space. This generates several new retaining / deck structures and new cuttings of differing heights and curved geometries.

Some of the proposed new retaining structures will be founded over deep (up to 55 m) NorthConnex fill material and in some areas founded within a few metres of dolerite bedrock at the edges of the park. This situation creates the potential for high differential settlement within the same structure and between adjacent structures.

The structures will need to be carefully designed to minimise the potential for high differential settlements. The following suite of design solutions is proposed as part of this report: See Section 5 of this report for details.

- Reinforced earth retaining walls or steep reinforced earth slopes (50 to 70 degrees) are suggested in fill areas. The walls can be faced with gabions or similar architectural finishes and steep slopes can be vegetated. Reinforced earth walls/slopes are relatively flexible structures and can make use of the existing fill on the site. They are also able to tolerate significant post construction settlement.
- Where existing access tracks need to be extended out beyond the current cliff-line, a short distance (approx. 4 m or less), a structural solution (suspended deck on column arrangement) is considered more favourable than using retaining solutions. Simple gravity or reinforced earth retaining structures are unlikely to be practical or economic in these areas due to the rock slope geometry.
- Existing and proposed new cut slopes in rock should be mapped during and post excavation to identify any rock reinforcement (rock bolts for large blocks and mesh for extensive weak or rubbly zones) and assessed on a case-by-case basis.
- Earthworks to form the foundation for the retaining walls in fill areas should be subject to suitable levels of compaction to achieve the required soil strength parameters and limit post construction settlement to manageable levels. Ground improvement may be required in some areas subject to detailed design level investigation and assessment.

The strategies and preferred options described above require further investigative work in some cases to confirm the concepts and inform the detailed design process. GHD’s suggested investigation requirements are summarised below. See Section 8 of this report for details.

- Physical investigation is required to confirm the concept and inform detailed design of the Southern Access Track (where a raked mini-piles and capping beam solution is proposed). The investigation should involve a geophysical survey to estimate bedrock levels followed by a series of short boreholes to confirm the rock profile and provide soil engineering properties.
- A geophysical survey of the Northern Spoil Mound is required to assess the underlying fill and bed-rock profile. This would be useful in determining stability for construction and long term operation. The survey would also assist in determining excavation conditions and identify potential areas of rock, which may influence costs and quantities estimates.
- Rock-fall trials are needed to refine the rock-fall predictive models and identify the location of protective measures such as ditches or bunds. Rock-fall trial data may justify the use of smaller protection zones / reduced preventative measures than predicted by the analytical methods used for this report.
- Investigation and testing of the NorthConnex fill would enable levels of compaction, permeability properties and densification with depth to be determined. The investigation

could include two boreholes with piezometer installations (to measure ground water recharge rates in the fill) with sampling and in situ strength testing, along with a suite of laboratory (earthworks) testing and cone penetration testing. It is also advisable during early park construction to install settlement plates and piezometers to monitor creep and inundation settlement within the fill over time to make predictions regarding when retaining walls can be built, pavements sealed or if ground improvement measures may be required in some areas.

This report presents the outcomes of concept level geotechnical design that has been undertaken to inform the master planning and EIS process. Additional geotechnical investigations and design activities are required to confirm some of the concepts described in this report and to further develop all the concepts to a level where they are suitable for Council to enter into a tender process for the park construction.

In GHD's opinion, if the detailed design work commences after the required additional investigations to inform detailed design are completed, this will avoid the need to potentially rework the detailed design.

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Glossary

AGS	Australian Geomechanics Society
AHD	Australian Height Datum
ALARP	As Low As Reasonably Practicable Australian
ANCOLD	National Committee on Large Dams
ARL	Assessed Risk Level
CBR	California Bearing Ratio
CPT	Cone Penetrometer Test
EIS	Environmental Impact Statement
GI	Geotechnical Investigation
GSI	Geotechnical Strength Index
GTD	Geotechnical Technical Direction
FOPS	Fall Object Projection System
FoS	Factor of Safety
LLBJV	Lend Lease Bouygues Joint Venture
MDD	Maximum Dry Density
NAVFAC	Naval Facilities Engineering Command
PSD	Particle Size Distribution
RL	Reference Level
RMS	Roads and Maritime Services
ROPS	Rolling Object Protection System
RSW	Reinforced Soil Wall
RTA	Trackand Traffic Authority
UCS	Unconfined Compression Strength

1. Introduction

1.1 General

This report summarises the geotechnical assessments and analysis undertaken in support of the Hornsby Quarry Rehabilitation project (the Project) for Hornsby Shire Council (Council). The report provides guidance on potential geotechnical solutions to slope stability concerns, retaining wall design, earthworks and the approximate unit rates associated with the available solutions presented for initial guidance purposes. The report represents a consolidation of ongoing Project design development at this time and may be subject to change should the rehabilitation concepts change at a later date to the date of this report.

1.2 Scope

The scope of works presented in this document is as follows:

- Assessment of the global stability of the Southern Quarry Wall to determine whether the quarry face is sufficiently stable to allow existing access tracks above the Southern Quarry wall to be utilised. Establish whether any remedial or monitoring measures are required to protect the future users of the park beneath the quarry wall from global (large scale) failures.
- Assessment of the viability of maintaining the existing track located immediately above the Southern Quarry wall. The track is located on residual soil materials, which are eroding down the southern face gradually removing support for the track. Potential engineering measures to stabilise the track in the long-term are discussed so that it may be incorporated as a feature into the park development as a walkway / vista area and for maintenance access for light vehicles.
- Assessment of the stability of the Northern Spoil Mound comprising fill material placed on rock benches above the northern quarry wall. The factor of safety, likelihood and consequence of failure are assessed to develop a suitable engineering response and long-term monitoring and maintenance plan as appropriate in accordance with relevant standards and guidelines.
- Undertake assessments and provide guidance on suitable rock-fall protection measures to mitigate against the potential for small rocks detaching from the quarry face to cause harm to future park users. Undertake rock-fall simulation analysis to establish the extent of ‘safe’ exclusion zones for the public at the base of quarry faces, along with commentary on other measures such as catch fences, rock mesh and catch ditches. Provide recommendations for future work to refine rock-fall protection requirements in a given area.
- Provide proof of concept level retaining wall assessments to establish suitable and economic soil retaining methods to be employed to form future access and parking for future park users. Comment on the relative economics and aesthetics of different retaining wall or reinforced soil slope solutions.
- Provide general advice on earthworks requirements to form a suitable foundation to retaining structures along with other salient advice regarding future investigation, site preparation and design work to address the geotechnical issues associated with the park development.

1.3 Limitations

This report: has been prepared by GHD for Hornsby Shire Council and may only be used and relied on by Hornsby Shire Council for the purpose agreed between GHD and the Hornsby Shire Council as set out in this report.

GHD otherwise disclaims responsibility to any person other than Hornsby Shire Council arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this report. GHD disclaims liability arising from any of the assumptions being incorrect.

GHD has prepared this report on the basis of information provided by Hornsby Shire Council and others who provided information to GHD (including Government authorities), which GHD has not independently verified or checked beyond the agreed scope of work. GHD does not accept liability in connection with such unverified information, including errors and omissions in the report which were caused by errors or omissions in that information.

The opinions, conclusions and any recommendations in this report are based on information obtained from, and testing undertaken at or in connection with, specific sample points. Site conditions at other parts of the site may be different from the site conditions found at the specific sample points.

Investigations undertaken in respect of this report are constrained by the particular site conditions, such as the location of buildings, services and vegetation. As a result, not all relevant site features and conditions may have been identified in this report.

Site conditions (including the presence of hazardous substances and/or site contamination) may change after the date of this Report. GHD does not accept responsibility arising from, or in connection with, any change to the site conditions. GHD is also not responsible for updating this report if the site conditions change.

1.4 Site Conditions

1.4.1 General

The Hornsby Quarry is located in the northern Sydney suburb of Hornsby, NSW 2077. A number of existing access tracks encircle the quarry void, which is over 100 m deep (prior to Northconnex filling operations).

The area immediately surrounding the quarry void is generally moderately to densely vegetated.

To the west of the quarry is a valley associated with Berowra and Waitara Creeks. The areas to the north, east and south of the quarry comprise residential and commercial land-use associated with Hornsby town.

A former crusher plant and weigh station is situated to the south of the quarry. The existing main quarry access track approaches the quarry from the south, diverts around the former crusher plant, and continues north, encircling the quarry void. Access tracks into the void split off from this main access.

1.4.2 Site Geology

The 1:100,000 Sydney Sheet of the Geological Survey of NSW (1983) indicates that the Hornsby quarry is located within the Hornsby diatreme, a volcanic intrusion comprising volcanic breccia and basalt. The diatreme is mapped at surface as an irregular, elongated body oriented in a northeast/southwest direction. Hawkesbury Sandstone surrounds the diatreme, with some outcrop of Ashfield Shale to the east and south of the quarry.

1.4.3 Groundwater

The PSM (2007) report infers that two groundwater systems are present on the site, a shallow perched water system at the base of overlying fill and weathered breccia, and a deeper system within the fresh breccia and surrounding Hawkesbury sandstone, with piezometric head at about RL 75 m, adjacent to the rim of the quarry. The deeper system is inferred to be partially shielded from rainwater recharge by the upper system.

1.5 References

The following reports and commercial documents have been referred to in the course of undertaking the works in this document:

Coffey (1989), Proposed Filling, Old Man’s Valley, Hornsby, Coffey Ref: S8463/2-AC

Coffey (1990a), Rock Mechanics Study – Hornsby Quarry, Old Man’s Valley, Coffey Ref: S8463-4-AD

Coffey (1990b), Geotechnical Investigations, Old Man’s Valley, Hornsby, Coffey Ref: S8463/3-AG

Coffey (2016), Geotechnical Assessment of the Hornsby Quarry Void, Geotechnical Assessment Report, Coffey Reference GEOTLCOV25707AA-AB, dated 16 November 2016

Department of Mineral Resources (1983), Geological Survey of NSW, Sydney 1:100,000 Geological Series Sheet 9130

GHD (2017), Southern Access Track and Track– Options and Risk Assessment variation request letter, GHD Ref: 2126457-71904, dated 20 November 2017

Hornsby Shire Council (2017), Pit Area Design digital file dated 4 September 2017

InfraSol (2018), Hornsby Quarry, Hornsby Proposed Development – Order of Cost Estimate dated 28 August 2018

PSM (2007), Former CSR Quarry Hornsby & Associated Lands, PSM Ref: PSM1059.TR1 dated 6 February 2007

PSM (2013), Concept Development for Hornsby Quarry, PSM Ref: PSM2010-007L dated 25 October 2013

PSM (2016), Northconnex – Hornsby Quarry, Geotechnical Assessment and Recommendation for Access and Filling Works, PSM Ref: PSM2820-004R, dated 23 February 2016

PSM (2017a), Hornsby Quarry Redevelopment Study – Geotechnical Study and Stability Assessment Report, PSM Ref: PSM2542-004R, dated 19 June 2017

PSM (2017b), Hornsby Quarry Redevelopment Study – Slope Design and Hazard Mitigation Assessment Report, PSM Ref: PSM2542-008R, dated 19 June 2017

The following standards and guidelines have been referred to in the course of undertaking the works in this document:

AGS (2007c), Practice Note Guidelines for Landslide Risk Management 2007

AGS (2007d), Commentary on Practice Note Guidelines for Landslide Risk Management 2007

Hong Kong Buildings Department (2009), AP-109 Practice Note for Authorized Persons and Registered Structural Engineers, Geotechnical Manual for Slopes – Guidance on Interpretation and Updating

AGS (2007e), The Australian GeoGuides for Slope Management and Maintenance

The following technical papers have been referred to in the course of undertaking the works in this document:

Fell, Ho, Lacasse & Leroi (2005), State of the Art Paper 1, A framework for landslide risk assessment and management

Leroi, Bonnard, Fell & McInnes (2005), Risk assessment and management, Proceedings of the International Conference on Landslide Risk Management, (2005: Vancouver, Canada)

Silva, Lambe & Marr (2008), Probability and risk of slope failure, ASCE Journal of geotechnical and geoenvironmental engineering

Wadell (2010), Design prediction and monitoring of deep fill settlement, ICE Proceedings Institution of Civil Engineers

Charles (2008), The engineering behaviour of fill materials: the use, misuse and disuse of case histories

Wadel & Wong (2005), Settlement characteristics of deep engineered fills

Hills & Denby (1996), The prediction of opencast backfill settlement

Gregory & Cross (2007), Correlation of California Bearing Ratio (CBR) with shear strength parameters, Journal of the Transportation Research Board

2. Southern Quarry Face Instability and Risk Assessments

2.1 Southern Quarry Face

Several geotechnical hazards are present in the vicinity of the southern quarry wall and access tracks. Council has engaged GHD to review the available information, undertake risk assessments for each option, and compare the alternatives under consideration.

The options for access along the southern wall of the quarry broadly consist of the following:

Option 1 – maintain existing southern access tracks

Option 2 – build new access road

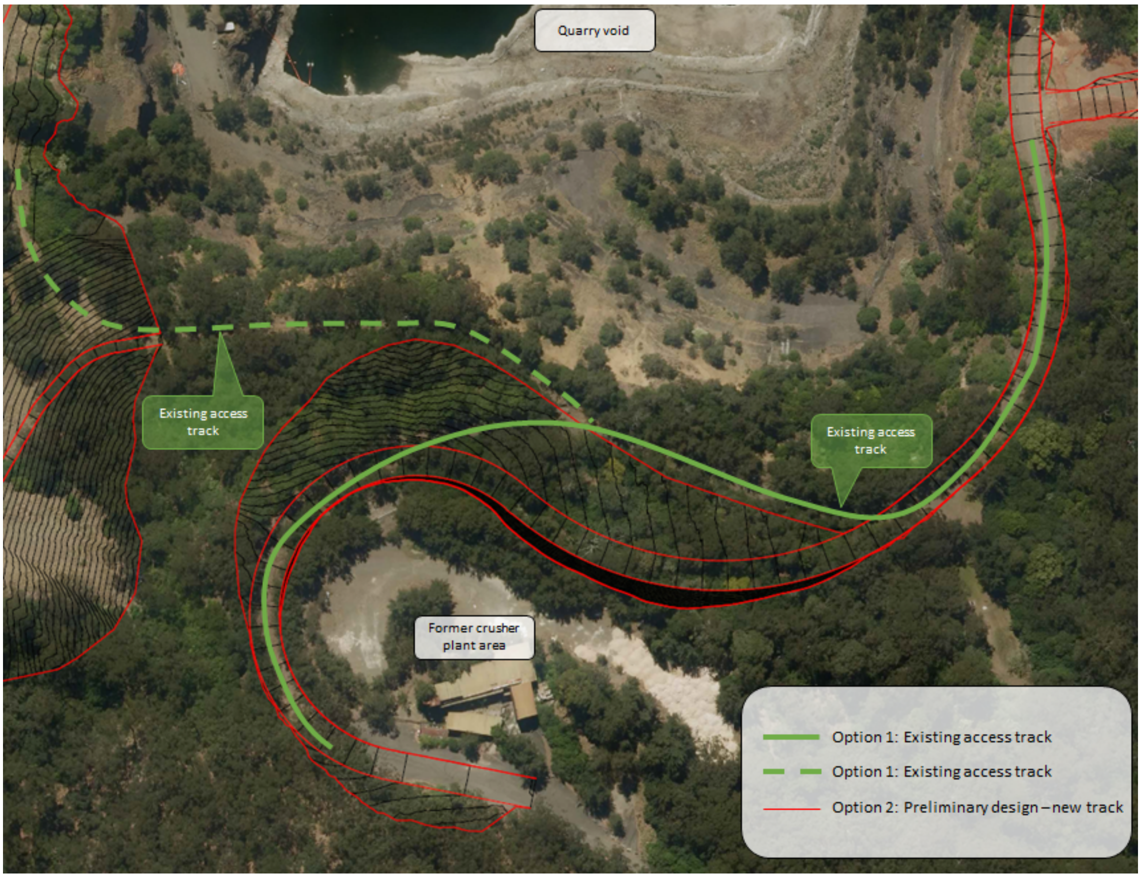


Figure 1 Southern access area – layout of options

2.2 Information Review

2.2.1 Previous Reports and Studies

The following discussion presents some key observations from the previous reports and studies that relate to the southern quarry wall. The review observations provided are not exhaustive, and the original documents should be referred to for context and further information.

The discussion is presented in chronological order, from oldest to newest. The PSM Stability Assessments and Slope Design reports were initially released as draft in 2015, hence have been taken as effectively pre-dating the Coffey (2016) and PSM (2016) reports.

Coffey (1990) Old Man's Valley reports

A number of Coffey reports (1989, 1990a and 1990b) detail geotechnical investigations and assessments undertaken in response to works proposed at "Old Man's Valley", above the eastern wall of the quarry. These reports have not been reviewed in detail although specific details (e.g. geotechnical logs for BH 103) have been examined where referred to in other reports relating to the southern portion of the quarry.

PSM (2007), Former CSR Quarry Hornsby & Associated Lands

In 2007, PSM undertook a study of geotechnical and hydrological constraints to the development of the Hornsby Quarry.

Geotechnical investigation activities included collation of factual data from technical publications, aerial photos, previous studies, site walkovers/mapping, drilling and downhole imaging of an inclined borehole (BH HQ1) in the south-western area of the quarry, and subsequent installation of a Vibrating Wire Piezometer in the same borehole.

The stability of the southern quarry faces (Section 12 – southwestern face, and Section 11 – southeastern face) was found to be marginal (Factor of Safety <1 to 1.3), as was stability of the upper slopes in fill and weathered/residual rock. The stability analyses within the upper soil strata were undertaken on back-calculated shear strength parameters, and a high groundwater table, assumed to be at surface level.

PSM (2011), Letter to Council Re: Access for quarry backfilling (PSM1059-105L Rev B)

In August 2011, PSM and Council discussed access into the quarry for quarry backfilling purposes. The stated preferred route was the existing haul road, however, an "alternate alignment" was also presented that avoided the tops of the quarry walls, and hence mitigated the risk of travelling over potentially unstable areas.

PSM (2012), Hornsby Quarry Lake Options Study

In 2012, PSM conducted a study to assess feasibility level options for forming a lake within the quarry void. Four options were considered, three of them involving different levels of stabilisation measures and monitoring systems to control the risk of local and global slip failures and hence, allowing public access into the quarry void. The fourth option consisted of allowing the site to fill with water and observe the slope behaviour through monitoring with little or no remedial work. This option restricts public access into the Hornsby Quarry.

The 2012 PSM report notes that the FoS against slope failure of the quarry walls may fall to values of between about 1 and 1.4 if the quarry fills with water to the natural overflow level and if continuous defects with low shear strengths are present. However, it highlights that if these defects are either not present and/or the strength or condition of the defect surfaces is better than assumed, then computed values of about 1.5 or greater would likely be found.

Table 2 of the report provides a summary of cost estimates for the different options considered, ranging from $5.6 million (water filling to overflow level and monitoring) to $16 million (stabilisation of quarry wall by mechanical means – mesh, rock bolts, etc. and monitoring).

PSM (2013), Concept Development for Hornsby Quarry Study

In 2013, Council commissioned PSM to provide feasibility level options for quarry remediation and allowing full public access for a variety of quarry treatment options involving different degrees of quarry filling, wall cut-back and mechanical stabilisation.

In order to develop the options for costing, PSM established a table of guidelines for slope design outlining typical slope dimensions and exclusion zones for each strata.

Table 8 of the report provides a summary of cost estimates for the different options considered, ranging from $9.5 million (partial filling with minimum cut volume for wall stabilisation) to $30.5 million (no imported filling, with maximum area at the base of the partially filled quarry).

PSM (2017a), Hornsby Quarry Redevelopment – Geotechnical Study and Stability Assessment Report (PSM2542-004R)

PSM undertook further investigations and assessments in 2014 to update the geotechnical interpretation and stability analysis of the eastern and southern quarry walls. The subsequent Geotechnical Study and Stability Assessment Report was initially released as a draft in 2015, and finalised in 2017. The investigations reported included geological mapping (direct and remote mapping), drilling and downhole imaging for two additional boreholes behind the southern quarry wall (HQU14001 and HQU14002) and associated laboratory testing.

The assessment was limited to the eastern and southern walls as the proposed site layout at the time indicated that the northern and western walls would be buttressed, and not left exposed.

A number of limit equilibrium stability analyses were undertaken for global instability via sliding of a large portion of the southeastern quarry face along muddy breccia bands. The computed Factors of Safety ranged from just below 1 (unstable) to above 2, depending on the modelled assumptions regarding the persistence of sub-horizontal joints that could daylight onto the southern quarry wall and form a “toe release” to the sliding mass.

Where the “toe release” joints were modelled as being continuous along, and into, the rock mass, the computed FoS was less than 0.9. However, Table 8.3 of the report indicates that the defect continuity measured in rock face mapping is less than 10 m. Where the stability models took this lower joint persistence into account, the FoS increased to 2, due to the failure surface passing through intact breccia rock.

PSM (2017b), Hornsby Quarry Redevelopment – Slope Design and Hazard Mitigation Assessment Report (PSM2542-008R)

The PSM Slope Design Report (PSM2542-008R) provides Council with design recommendations for the Hornsby Quarry Redevelopment, continuing on from the geotechnical investigations and stability analyses undertaken and presented in PSM2542-004R. The report includes recommendations regarding design and risk management processes, slope cut-back angles and construction (see 2), and filling of the quarry.

Section 5.4.2 of the report provides some commentary on the adequacy of stability of the southern quarry wall, and reiterates that the persistence of toe release joints on the southern face is limited, and that the Factor of Safety is somewhere between the cases of toe breakout purely along defects, and purely through breccia rock mass. The report goes on to state that *“… an engineering judgement has been made that adopting the existing slopes for the recommended design at the southern face is suitable…”*.

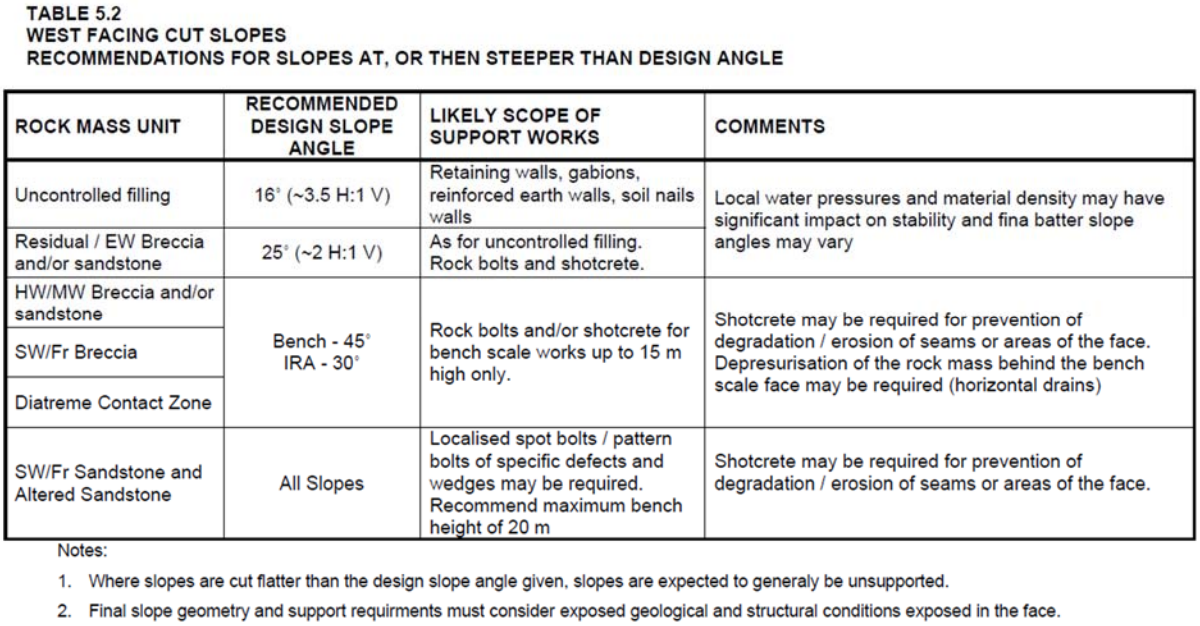


TABLE 5.2
WEST FACING CUT SLOPES
RECOMMENDATIONS FOR SLOPES AT, OR THEN STEEPER THAN DESIGN ANGLE

ROCK MASS UNIT	RECOMMENDED DESIGN SLOPE ANGLE	LIKELY SCOPE OF SUPPORT WORKS	COMMENTS
Uncontrolled filling	16° (~3.5 H:1 V)	Retaining walls, gabions, reinforced earth walls, soil nails walls	Local water pressures and material density may have significant impact on stability and fina batter slope angles may vary
Residual / EW Breccia and/or sandstone	25° (~2 H:1 V)	As for uncontrolled filling. Rock bolts and shotcrete.	
HW/MW Breccia and/or sandstone	Bench - 45° IRA - 30°	Rock bolts and/or shotcrete for bench scale works up to 15 m high only.	Shotcrete may be required for prevention of degradation / erosion of seams or areas of the face. Depresurisation of the rock mass behind the bench scale face may be required (horizontal drains)
SW/Fr Breccia			
Diatreme Contact Zone			
SW/Fr Sandstone and Altered Sandstone	All Slopes	Localised spot bolts / pattern bolts of specific defects and wedges may be required. Recommend maximum bench height of 20 m	Shotcrete may be required for prevention of degradation / erosion of seams or areas of the face.

Notes:

1. Where slopes are cut flatter than the design slope angle given, slopes are expected to generaly be unsupported.
2. Final slope geometry and support requirments must consider exposed geological and structural conditions exposed in the face.

Figure 2 PSM (2017b) recommendations for slope design

Coffey (2016), Geotechnical Assessment of the Hornsby Quarry Void

In 2016, Coffey prepared for Roads and Maritime Services (RMS) an independent assessment of geotechnical risks associated with the infilling of the Hornsby Quarry with spoil generated by the NorthConnex Public Infrastructure Project.

The assessment included a review and re-run of stability analysis on the northern (Section 5) and southern walls (Sections 11, 12), quantitative risk assessment with respect to quarry filling operations (“construction” of the filling infrastructure, and “operation” of the filling infrastructure), and recommendations for further visual inspection and survey monitoring.

The findings of the stability analyses were in general agreement with the findings of PSM, in that the global stability of the southern quarry wall was anticipated to be controlled by failure along both existing defects and intact rock mass between defects. It was noted that the slope performance over a significant period of time was acceptable, and that the slope was anticipated to remain stable.

The quantitative risk assessment undertaken found that the estimated annual loss of life risk for the person most at risk for the construction phase was 4.0 x 10^{-5}, while that for the “operation” phase was 2.8 x 10^{-6}. Both of these levels of risk would be “tolerable” if assessed against the AGS 2007 annual loss of life risk criteria of 1.0 x 10^{-4} for “existing developments”.

PSM (2016), Geotechnical Assessment and Recommendation for Access and Filling Works

In 2016, PSM provided geotechnical advice and recommendations to Lend Lease Bouygues Joint Venture (LLBJV) regarding access into Hornsby Quarry for filling works as part of the NorthConnex project. The report provides a summary of recommendations for safe access into/working within the quarry along the entire access track, as well as rainfall triggers and inspection regimes to be adopted by LLBJV during filling.

The 2016 PSM report notes that the east, west, north and south walls for the current pit topography have “satisfactory” stability for major slides, with satisfactory meaning a computed FoS greater than 1.5. The risk mitigation measures offered for major slides include scheduled inspections and survey monitoring.

Minor failures (shallow rock mass slides and erosion) around the existing batters are also noted as having occurred, with the impacts of such minor failures being obstruction of the access track and loss of ground. The report recommends that these be mitigated by the use of offsets and/or physical safety barriers between the batter face and the access track, Roll Over Protection Systems (ROPS) and Fall Object Protection Systems (FOPS) for vehicles, and inspections and maintenance regimes.

The report reiterates the position of an adequate factor of safety for the south quarry wall against sliding along the muddy breccia band with release along a shallow dipping joint set along the toe, on the basis of the shallow dipping joint set having a persistence of less than 10m. The stated FoS in this case is 2.

The report includes recommendations regarding exclusion zones on the basis of updated rock-fall modelling with a friction angle of 30°. The exclusion zone recommended consisted of a 10 m wide perimeter ditch between the existing batters and fill operations.

2.2.2 Existing Geotechnical Investigations

The following physical geotechnical investigations were undertaken by others. The factual results of these investigations have been used to inform the current assessment.

Table 1 Borehole and test pit details

ID	Dip/Dip dir (true North)	Easting	Northing	Surface RL (mAHD)	Depth-inclined [vertical] (m)	Source
TP1	-	323033.3	6269547.5	154.25	5.5	PSM (2007)
TP2	-	323086.6	6269525.7	152.9	2.5	PSM (2007)
TP3	-	323130.7	6269509.8	153.5	4	PSM (2007)
TP4	-	322871.2	6269586.8	114	4.5	PSM (2007)
TP5		322867.4	6269621.2	111.4	3.8	PSM (2007)
HQ1	-60°/127°	322916.2	6269635.9	105.4	90.65 [78.5]	PSM (2007)
HQU14001	-84°/343°	323088	6269600	130.7	60 [59.7]	PSM (2017a)
HQU14002	-58°/174°	323085	6269599	130.7	83.52 [70.8]	PSM (2017a)
BH 103[1]	-65°/155°	323216	6269591	112.6	92.8 [84.1]	Coffey (1990)

[1] Co-ordinates for BH103 converted to MGA 56, original co-ordinates assumed to be in ISG 56.1. Magnetic declination for study area in 1990 assumed as 12.6°

2.2.3 Groundwater monitoring

Data from the following groundwater monitoring points is available, and has been used to inform the current assessment.

Table 2 Groundwater monitoring

Piezo ID	Piezo RL (mAHD)	GW RL (mAHD)	Date of last reading	Source
HQ1 @ 90m depth	27.5	79.3	20/12/2006 (1 month after installation)	PSM (2007) Appendix A
HQU14001	74.5	-	None recorded	PSM (2017a)
BH18 (Coffey standpipe east of site)	-	75	Jan 1990 (dipped by PSM)	PSM (2007) Appendix G

2.3 Basis of Assessment

2.3.1 Proposed Works

Option 1

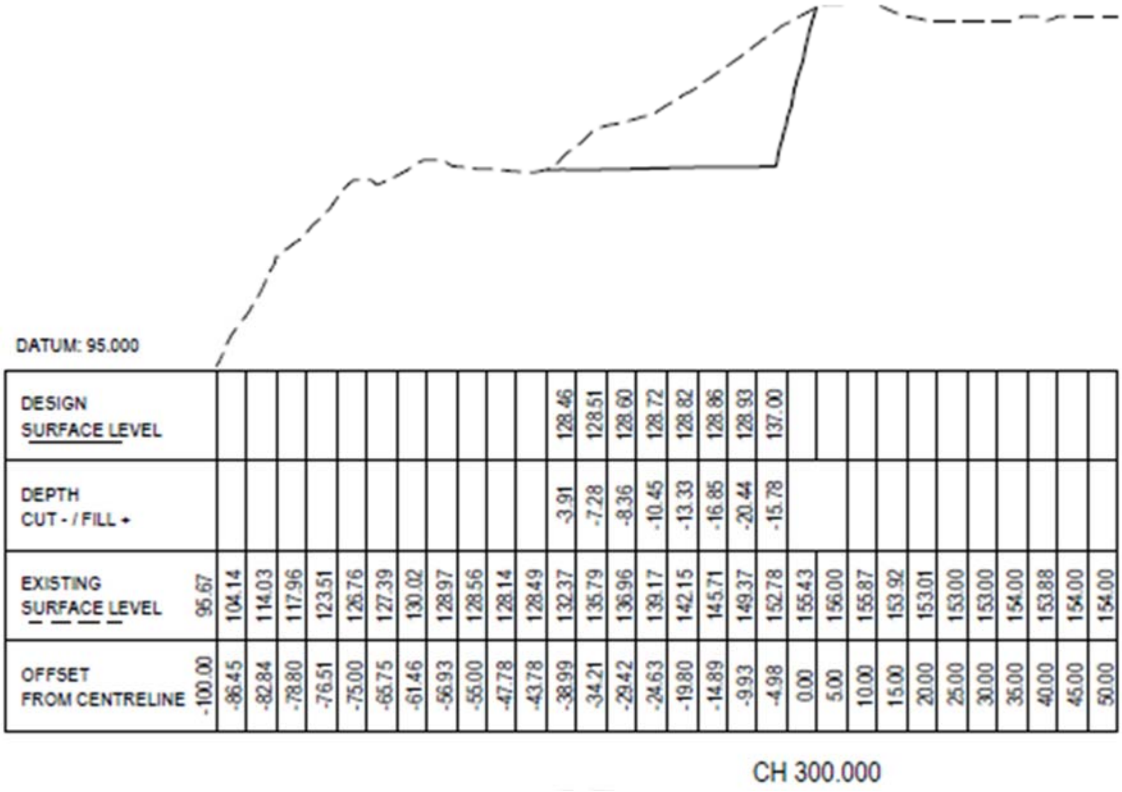
Option 1 is understood to comprise maintenance of the existing access tracks, in conjunction with:

- Backfilling of the quarry void with spoil from Northconnex to the design levels as provided by Council. The fill levels range from about RL 50 m at the base of the proposed lake at the eastern side of the quarry to about RL 80 m at the western quarry face.
- Implementation of inspection, monitoring and management regimes to detect the development of slope instability and/or guide decision making with regards to evacuation of the quarry, or closing the quarry to access pending inspection.

Option 2

Option 2 is understood to comprise construction of a new access track, and maintenance of the existing walking track with:

- Backfilling of the quarry void with spoil from Northconnex to the pit area design levels as provided by Council.
- Cut of a relatively flat area with new track to the south of the existing track, and construction of a new retaining wall approximately 180 m long and up to 26 m high.
- Implementation of inspection, monitoring and management regimes to detect the development of slope instability and/or guide decision making with regards to evacuation of the quarry.
- Figure 4 provides a plan view of the design levels for the new access track and quarry filling levels proposed by Council. Figure 3 provides a typical cross-section through the new access track.



DESIGN SURFACE LEVEL													128.46	128.51	128.60	128.72
DEPTH CUT - / FILL +													-3.91	-7.28	-8.36	-10.45
EXISTING SURFACE LEVEL	95.67	104.14	114.03	117.96	123.51	126.76	127.39	130.02	128.97	128.56	128.14	128.49	132.37	135.79	136.96	139.17
OFFSET FROM CENTRELINE	-100.00	-86.45	-82.84	-78.80	-76.51	-75.00	-65.75	-61.46	-56.93	-55.00	-47.78	-43.78	-38.99	-34.21	-29.42	-24.63

DESIGN SURFACE LEVEL	128.82	128.86	128.93	137.00											
DEPTH CUT - / FILL +	-13.33	-16.85	-20.44	-15.78											
EXISTING SURFACE LEVEL	142.15	145.71	149.37	152.78	155.43	156.00	155.87	153.92	153.01	153.00	153.00	154.00	153.88	154.00	154.00
OFFSET FROM CENTRELINE	-19.80	-14.89	-9.93	-4.98	0.00	5.00	10.00	15.00	20.00	25.00	30.00	35.00	40.00	45.00	50.00

Figure 3 Option 2 – typical cross-section through new access track. Existing shown in dashed line, design levels in solid line.

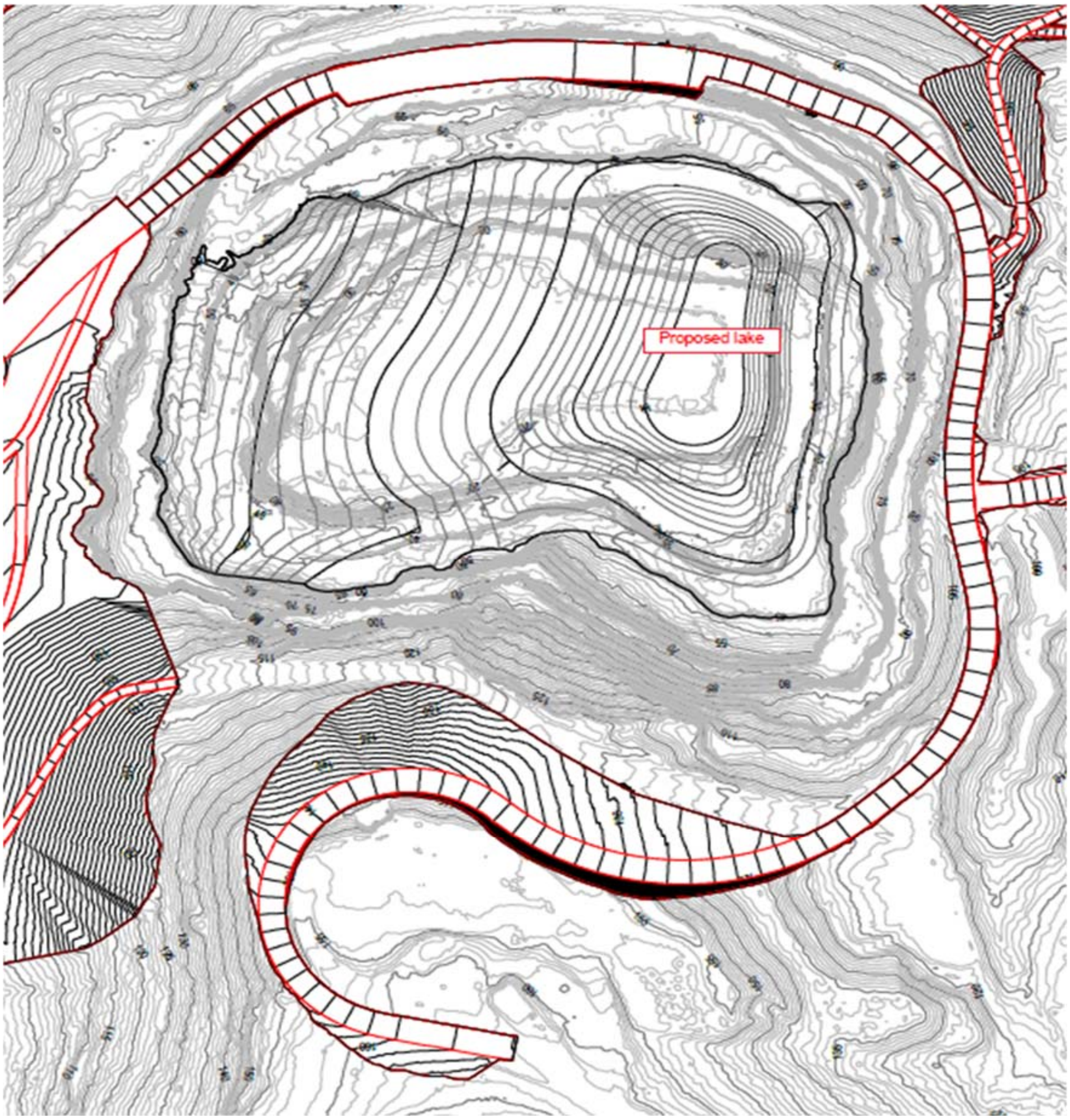


Figure 4 Option 2 – new access track and quarry filling levels

2.3.2 Assessment Criteria

Factor of Safety vs Risk Based Approach

The methodology of assessing the acceptability of a slope may vary depending on the type of slope and context of the assessment. Two commonly adopted approaches of slope assessment are:

- Factor of Safety approach – the proportion of calculated “resisting forces” and “disturbing forces” must be above a certain ratio. A common FoS applied in NSW is 1.5, as specified by the RMS and frequently adopted by local councils as the minimum requirement for new slopes and global stability of retaining walls supporting slopes. It should be noted that lower FoS than 1.5 may be adopted for existing slopes after suitable assessment. See Section 3.2.
- Risk-based approach – The risk associated with the likelihood and consequences of slope failure must be below a certain level as defined by the probability of a failure causing a fatality in a given year being below a certain threshold as established by international practice (e.g. ANCOLD guideline for dam construction). This method is commonly

employed when it is not practical or economic to retrospectively remediate an existing slope to the required standards for new slope infrastructure.

For the design of new slopes, it is common to specify a relatively high minimum FoS against slope failure in order to minimise future maintenance requirements (e.g. RMS minimum 1.5 requirement for new slopes). However, for existing (historic) slope infrastructure that pre-dates modern standards it is often un-economic or impractical to retrospectively apply new-build standards to existing slopes which may not have experienced any stability or maintenance problems over many years.

In recognition of the above, in February 2018, the RMS released a technical guidance document (GTD 2018), which allows for the minimum factor of safety of existing slopes to be reduced to as low as 1.2 depending on the slopes particular risk category. Therefore GHD has used the GTD 2018 RMS guidance as the starting point to establish minimum criteria for the Project.

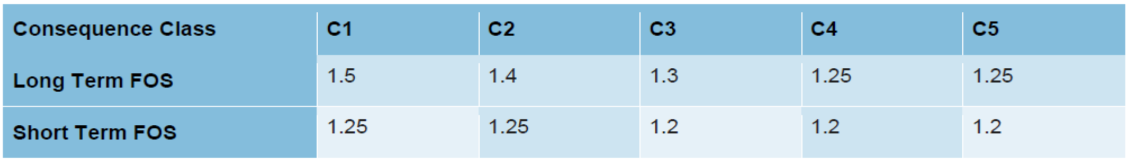
It should be noted that even if the GTD 2018 requirements cannot be met it is still possible and acceptable to adopt a purely risk based approach as described in the Australian Geomechanics Society (AGS) publication, AGS (2007c) Guidelines for Landslide Risk Management. A purely risk based approach allows the Regulator/Council to more directly assess the impacts of slope failure in terms of safety and economic terms rather than approaches which only consider factors of safety. This potentially allows for more pragmatic and economical decision-making where the factor of safety may be below 1.25 but the likelihood of any impact on the public is very low and within established guidelines.

RMS GTD 2018/001

The new technical RMS direction “Geotechnical Design for Remediation of Existing Slopes and Embankments” published in February 2018, stipulates a set of minimum acceptable FoS required for the remediation of existing soil slopes and fill embankments given an Assessed Risk Level (ARL) of three or better has been achieved in accordance with the RMS Guide to Slope Risk Analysis.

As stated in this technical direction *“if the design standard for new works is adopted for remedial works, the associated repair costs could be unnecessarily high in many situations and might exceed the minimum ARL requirements”.* Thus, the RMS document improves the cost effectiveness of slope remedial works by reducing the minimum acceptable FoS depending on the consequences of failure and increasing the level of maintenance and monitoring requirements of the slope.

The new minimum long-term and short-term FoS and minimum levels of site investigation and testing are introduced in this technical direction based on the outcomes of the risk assessment conducted in accordance with RTA Guide to Slope Risk Analysis (ref: The RTA Guide to Slope Risk Analysis, Version 3.1, dated May 2002). Figure 5 presents the FoS vs Consequence matrix defined in RMS GTD 2018/001:



Consequence Class	C1	C2	C3	C4	C5
Long Term FOS	1.5	1.4	1.3	1.25	1.25
Short Term FOS	1.25	1.25	1.2	1.2	1.2

Figure 5 Consequence class and minimum FoS values as per RMS GTD 2018/001

Consequence is related to risk for life and to economic loss. These two variables are analysed separately to obtain the Consequence Class that will be used to define the minimum acceptable FoS as per RMS GTD 2018/001. The more unfavourable the implications of a landslide event are, the higher the minimum acceptable FoS is.

AGS (2007) Guidelines

Within Australia, the Australian Geomechanics Society Guidelines for Landslide Risk Management, AGS (2007c), provide a commonly accepted methodology/framework for the analysis, assessment and management of the risks associated with landslides/slope failure.

The guidelines recommend the use of quantitative risk assessment, particularly where landslides hazards have the potential to cause loss of human life. Quantitative risk assessment involves the calculation of the annual probability of loss of life (i.e. risk of fatality), which is then considered by the Regulator (Council), and assessed/evaluated against the Regulator’s chosen risk criteria.

Although the AGS guidelines provide well-established industry and regulator accepted risk criteria, the level of risk considered to be tolerable is ultimately needs to be accepted by the local regulator / asset owner.

AGS Suggested tolerable risk criteria – person most at risk

When considering risks to life, the AGS 2007 guidelines distinguish between the loss of life risk for the (single) person most at risk, and the loss of life risk where multiple fatalities may occur in one event (societal risk).

For the single person most at risk, AGS (2007c) offers the following “*Tolerable Loss of Life Risk for the person most at risk*”, refer Figure 6:

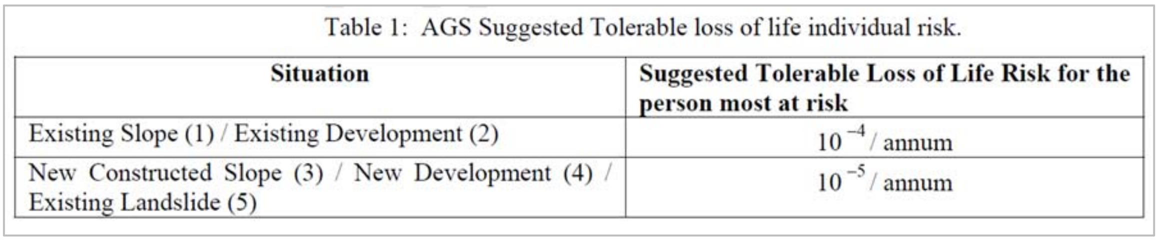


Table 1: AGS Suggested Tolerable loss of life individual risk.

Situation	**Suggested Tolerable Loss of Life Risk for the person most at risk**
Existing Slope (1) / Existing Development (2)	10^{-4} / annum
New Constructed Slope (3) / New Development (4) / Existing Landslide (5)	10^{-5} / annum

Figure 6 AGS (2007c) suggested tolerable risk criteria – life

AGS Suggested tolerable risk criteria – societal risk

For situations where multiple fatalities may occur in one landslide event, the AGS guidelines refer to the ANCOLD (2003) Guidelines on Risk Assessment, and Leroi et al (2005). To assess the societal risks, Fell et al (2005) provide suggested criteria depending on the number and frequency of fatalities, as per Figure 7.

The cumulative frequency (“F”) of “N” or more fatalities (“F-N” curve) is plotted on the graph, and assessed according to the delineated boundaries as being either broadly acceptable, “ALARP” (as Low as Reasonably Practicable), unacceptable, or subject to intense scrutiny.

With regards to societal risks in the ALARP region, ANCOLD (2003) refer to the Health and Safety Executive of the United Kingdom who state “*Risk is tolerable only if risk reduction is impracticable or if its cost is grossly disproportionate to the improvement gained*”. Leroi et al (2005) states that “*Determination of whether the ALARP principle has been satisfied is a matter of judgement for the owner, subject to any regulatory requirements that must be met.*”

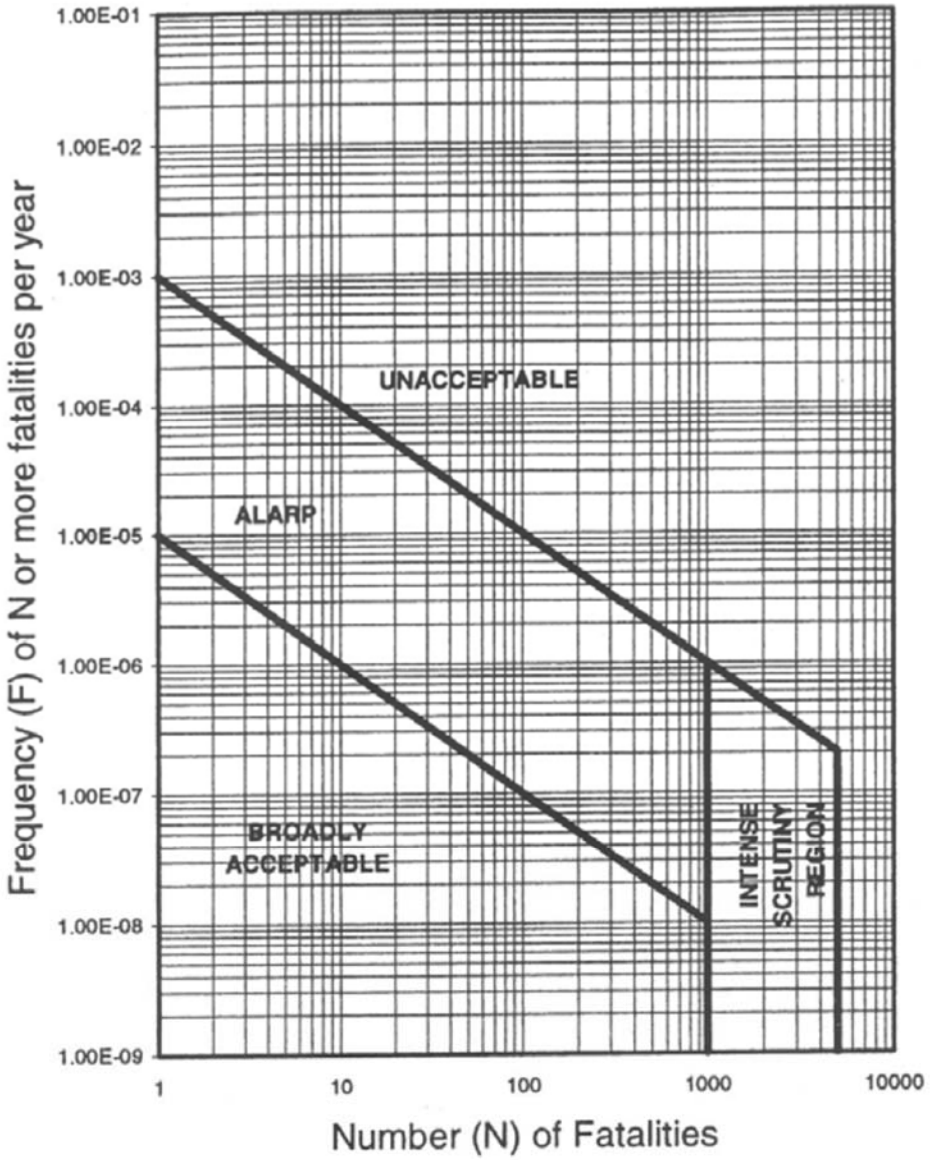


Figure 4 – Interim societal risk tolerance criteria (Geotechnical Engineering Office, 1998).

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Figure 7 Societal risk tolerance criteria, Ref: Fell et al (2005)

2.4 Stability Assessment

2.4.1 Key Landslide Hazards

From the document review outlined in Section 2.2 above, discussions with Council, several site walkovers with Council and the proposed design levels as provided by Council, the following geotechnical hazards/groups of hazards and corresponding failure mechanisms were identified:

- Sliding failure of the south-eastern quarry wall along shear planes within muddy breccia bands, with failure on the toe of the sliding rockmass occurring along a combination of shallow dipping joints and through intact SW/F volcanic breccia (Hazard 1, or H1).
- Steep fill and residual soil slopes above the access track, that could slide or slump onto the thoroughfares (H2).
- Steep fill and residual soil slopes below the access track, that could slide or slump, undermining the thoroughfares (H3).

- Upper part of the southern quarry wall, comprising steep residual soil/weathered rock slopes below the access track (H4).
- Minor/local rock-fall from the exposed quarry walls (H5). This group of hazards has not been included in the risk assessment, as it has is assumed it will be addressed by the inclusion of exclusion zones in the redevelopment master planning.

Figures 8 and 9 present sketches outlining the approximate spatial extent and typical details of these landslide hazards for Options 1 and 2.

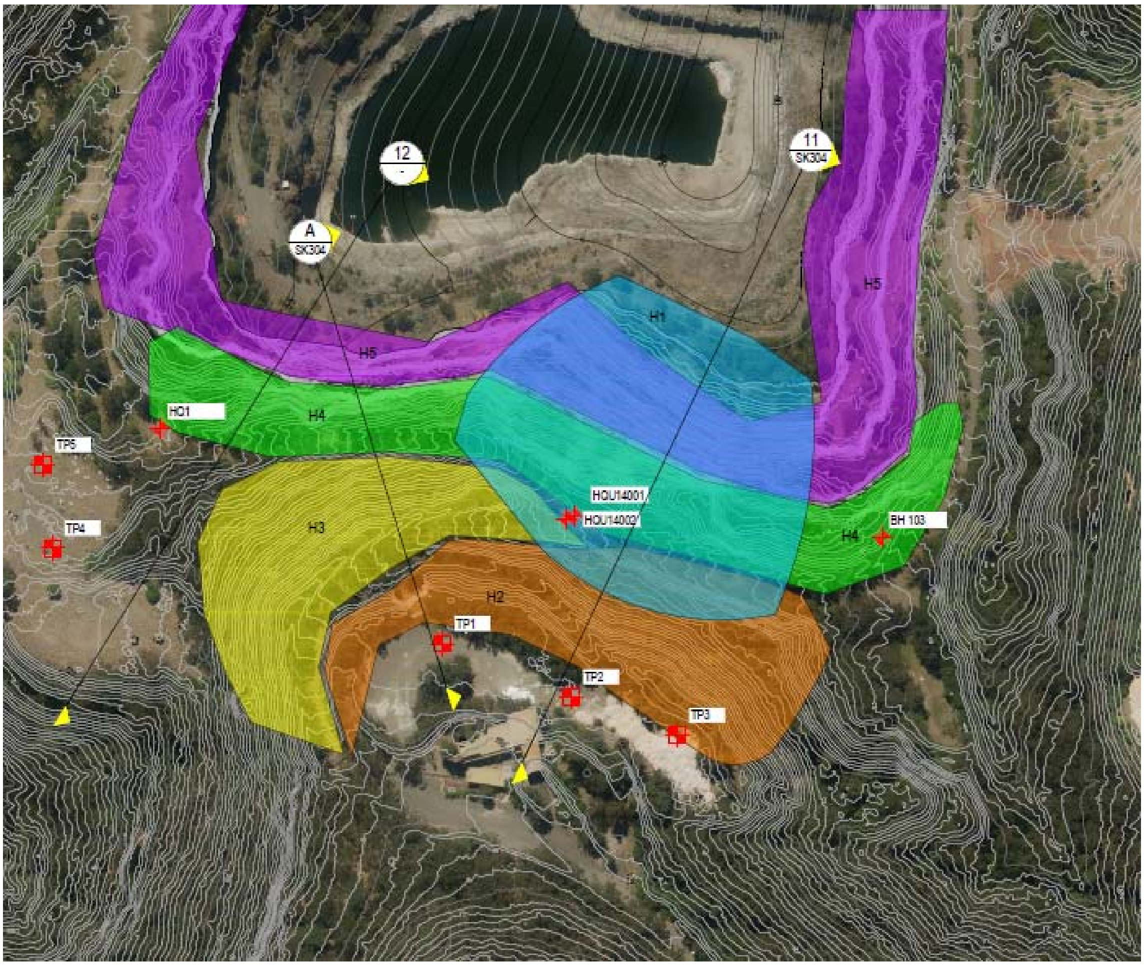


Figure 8 Southern Access Option 1 – Landslide Hazards

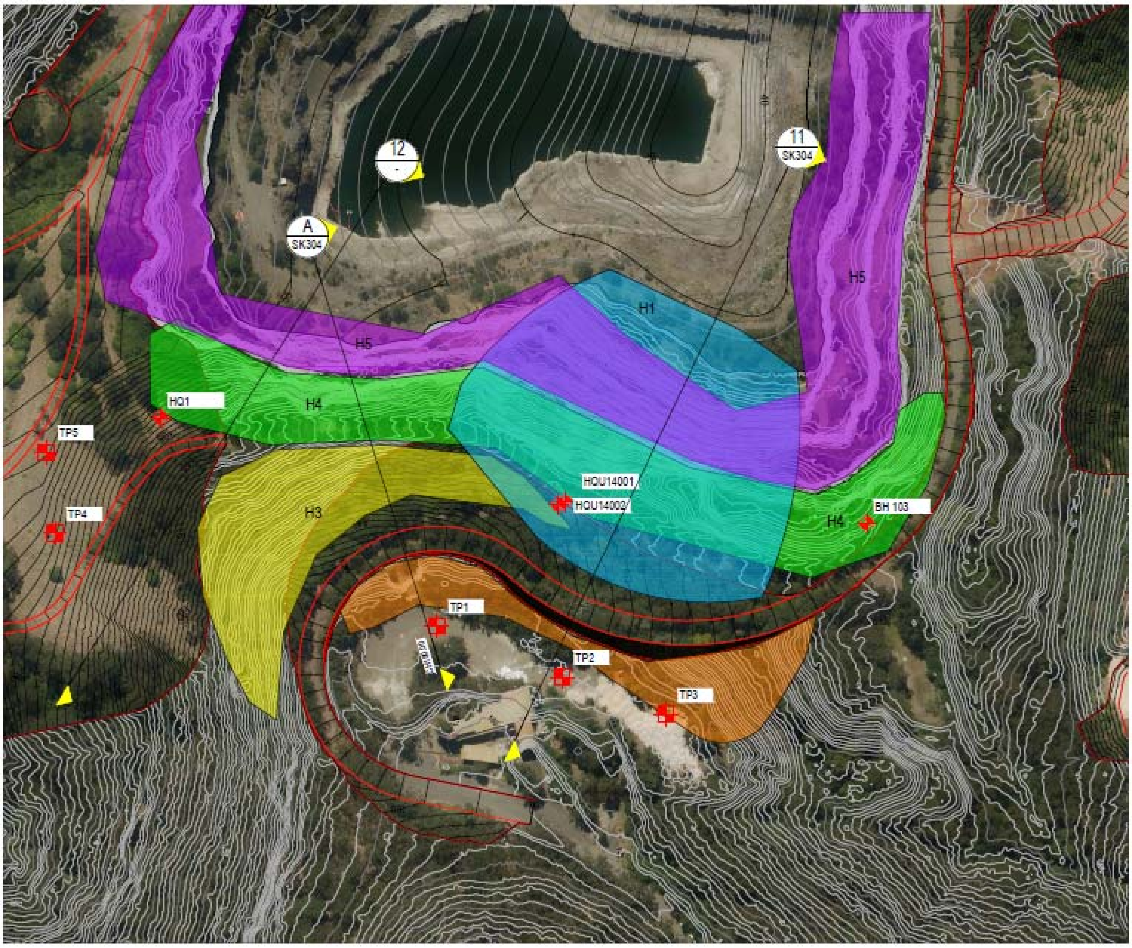


Figure 9 Southern Access Option 2 – Landslide Hazards

2.4.2 Methodology

General

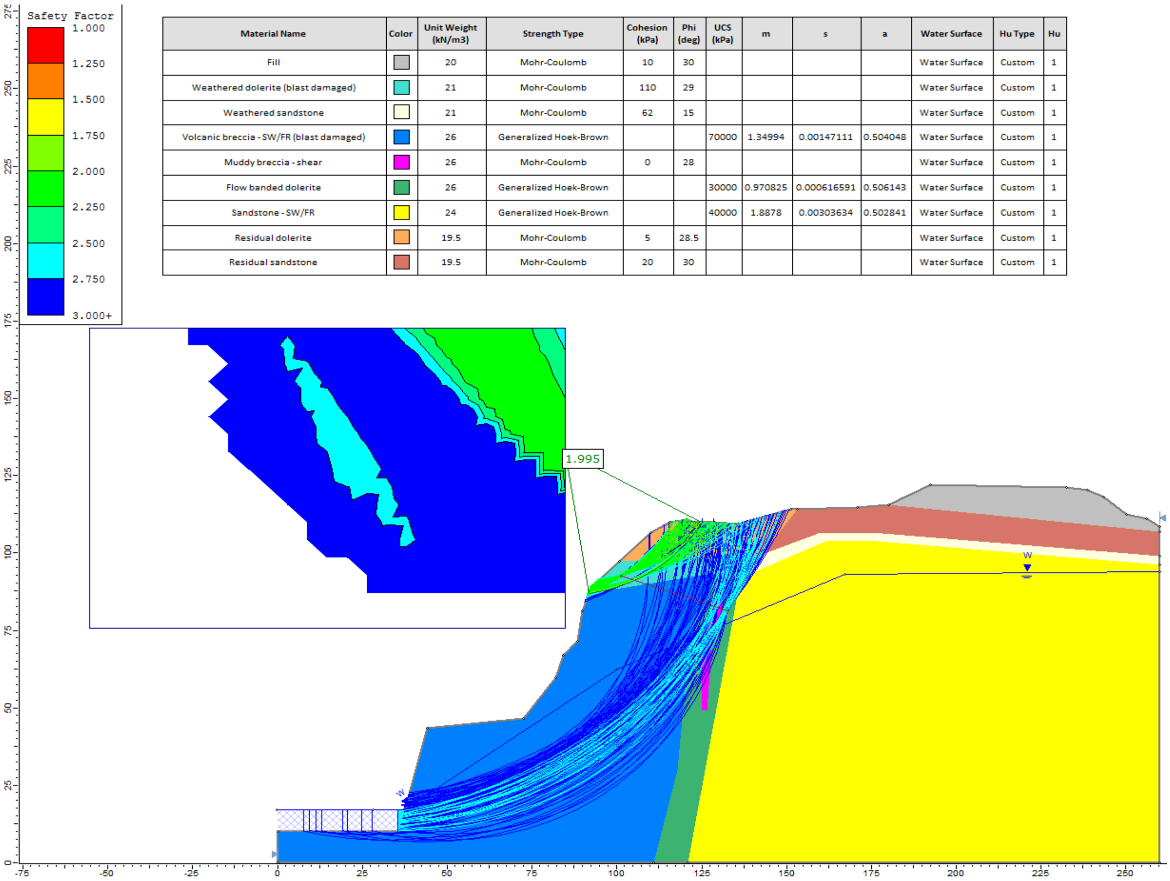
To review the stability assessments undertaken by PSM (2017a) and Coffey (2016) in light of the quarry rehabilitation design, as well as to facilitate a reasonable understanding of the slope failure mechanisms postulated, a number of stability analyses were run of key cross-sections at the southern face, namely PSM's "Section 11" and "Section 12".

The stability analyses were undertaken using limit equilibrium methods, with the modelled geological boundaries, features and strength parameters generally in accordance with PSM (2017a) interpretation. Geological features were corroborated with the available factual geotechnical data where available, although some specific details (e.g. precise location of muddy breccia bands behind the southern quarry face) were not able to be verified without detailed geological mapping records.

Stability analyses were run for Section 11 under the following key scenarios:

- Existing conditions
- Option 1 – maintain existing access track
- Option 2 – build new access track

A stability analysis was run for Section 12 under existing conditions (Refer to Figure 10). However, due to the high Factor of Safety calculated for global stability under existing conditions, and the lack of feasible global failure mechanisms under quarry filling situations, no further stability models were run for Section 12.



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	UCS (kPa)	m	s	a	Water Surface	Hu Type	Hu
Fill	⬜	20	Mohr-Coulomb	10	30					Water Surface	Custom	1
Weathered dolerite (blast damaged)	🟦	21	Mohr-Coulomb	110	29					Water Surface	Custom	1
Weathered sandstone	⬜	21	Mohr-Coulomb	62	15					Water Surface	Custom	1
Volcanic breccia - SW/FR (blast damaged)	🟦	26	Generalized Hoek-Brown			70000	1.34994	0.00147111	0.504048	Water Surface	Custom	1
Muddy breccia - shear	🟪	26	Mohr-Coulomb	0	28					Water Surface	Custom	1
Flow banded dolerite	🟩	26	Generalized Hoek-Brown			30000	0.970825	0.000616591	0.506143	Water Surface	Custom	1
Sandstone - SW/FR	🟨	24	Generalized Hoek-Brown			40000	1.8878	0.00303634	0.502841	Water Surface	Custom	1
Residual dolerite	🟧	19.5	Mohr-Coulomb	5	28.5					Water Surface	Custom	1
Residual sandstone	🟥	19.5	Mohr-Coulomb	20	30					Water Surface	Custom	1

Figure 10 Stability analysis output for Section 12, existing conditions

Modelling package

Two modelling packages were used: Geostudio's Slope/W 2012 package and Rocscience's Slide 7.0. For the Slope/W software, the model geometry (steeply dipping slip surfaces) and significant discrepancy in material properties (very weak planes in stronger rock) resulted in computational errors, with very low computed factors of safety, and poor solution convergence.

This was able to be addressed by running a coupled finite-element and limit equilibrium analysis, which resulted in no model convergence difficulties, and FoS values considered to be more in line with the modelled situation.

However, given the assumptions required to run a coupled analysis, Slide 7.0 was used, as its formulation did not exhibit poor model convergence or "nonsensical" results.

The analytical difficulties encountered demonstrate the limits of fusing limit equilibrium methods to assess complex rock mass slope stability, as encountered in the Hornsby diatreme.

2.4.3 Geotechnical Profile

The ground model adopted for the current assessment was in general accordance with PSM's (2017a) interpretation. Figure 11 below reproduces PSM's interpreted geotechnical profile at Section 11 for illustration.

The main geotechnical units encountered around the south wall of the quarry are generally as follows:

- Fill – Associated with the former crusher plant area, comprising silty sandy gravel underlain by uncontrolled clayey sandy gravel and gravelly sand with large boulders, up to 1m in diameter. Fill depths were inferred by PSM (2007) on the basis of a comparison of historical contours based on stereographic analysis of aerial photographs dated 1961, and current contours.
- Volcanic breccia – angular to sub-rounded fragments of volcanic rock in a fine to medium grained matrix. The rock mass exhibits significant variability in engineering properties depending on the degree of weathering:
  - Residual to extremely weathered – orange to red, high plasticity clay with some sub-rounded coarse gravel clasts
  - Highly to moderately weathered dolerite – mottled orange and grey, with very low to medium strength
  - Slightly weathered to fresh volcanic breccia – grey, high to very high strength
- Muddy breccia – volcanic breccia with a fine-grained matrix, inferred to have originated from reworked shale units, of low to medium strength, potentially with some reactivity in response to moisture changes
- Sandstone (host bedrock) – generally slightly weathered to fresh at depth, with high strength.
- Diatreme-sandstone contact – transitional region of volcanic breccia, siltstone and interbedded sandstone breccia and volcanic breccia, with the surrounding sandstone region having undergone thermal metamorphism into quartzite.

The southern area of the quarry is overlain by the uncontrolled fill associated with the former crusher plant, at various slope angles typically ranging from 1V:1H to 1V:2H. This is underlain by residual soil formed from the diatreme, which grades to highly to moderately weathered rock, and then to slightly weathered to fresh rock.

The southern quarry wall itself is cut into this profile, at an overall angle ranging from about 50 to 60°. The depth of residual soil on the quarry face is mapped by PSM (2017a) as being about 5 m high, with highly to moderately weathered rock present to about 30 m below the quarry crest.

A steeply dipping bed of muddy breccia is inferred to be present behind the south-eastern face of the quarry wall, on the basis of bedding planes that daylight around the centre of the southern quarry wall.

The contact between the diatreme and host sandstone is located further behind the quarry wall, and is inferred to be relatively steeply dipping.

Numerous defect sets within the diatreme rock mass exposed on the southern quarry wall are interpreted in the PSM (2017a) report, with the following key sets taken into consideration in this assessment:

- Persistent shear planes within the muddy breccia bands, observed both on and behind the current southeastern quarry face
- Shallow dipping joints in SW-F volcanic breccia, generally dipping to the south. PSM (2017a and 2017b) indicate that this joint set has limited persistence (generally less than 10m).

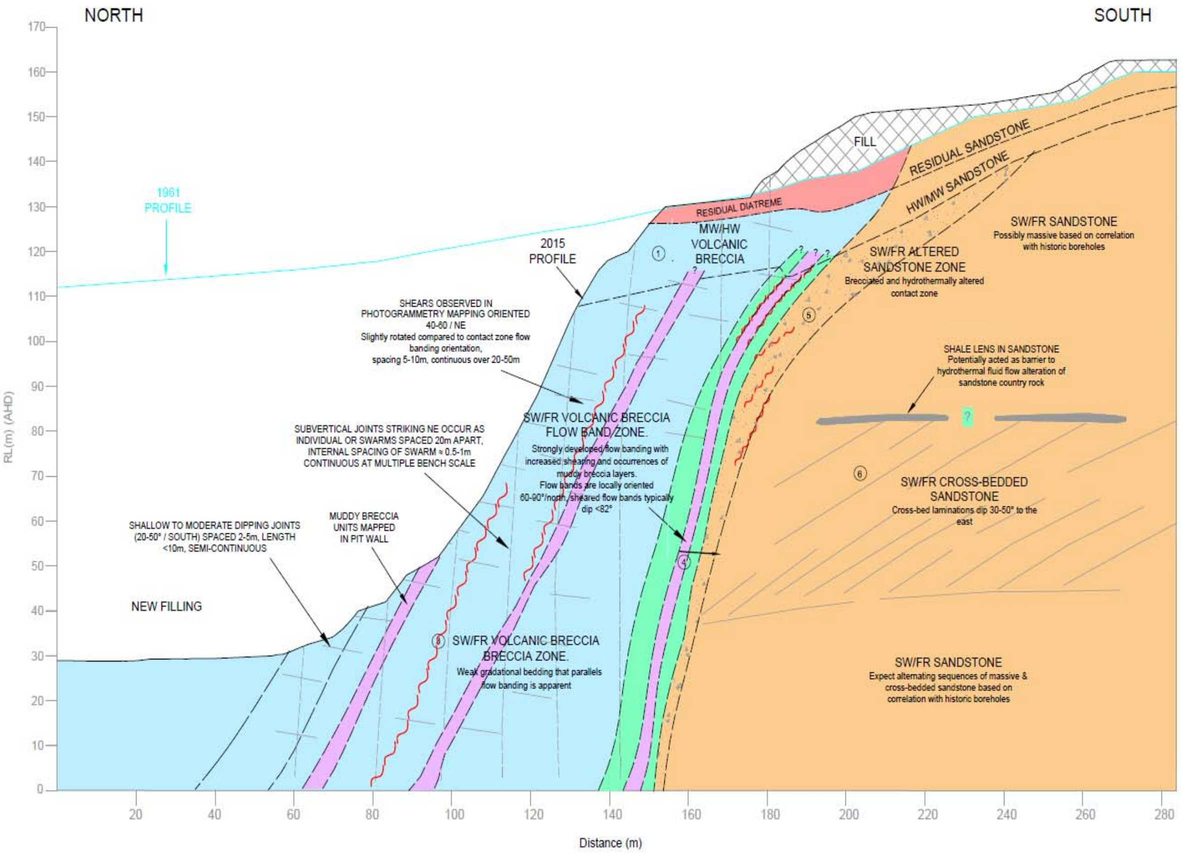


Figure 11 Ground model for Section 11, refer PSM (2017a)

2.4.4 Groundwater

Groundwater levels have been adopted on the basis of the level at the base of the quarry, and are assumed to rise away from the exposed quarry walls. As the breccia rock mass is inferred to be of relatively high permeability, with no groundwater readings in installed piezometers, this is considered to be a valid assumption for the purpose of stability modelling, and is consistent with that adopted in the PSM (2017a) report.

2.4.5 Geotechnical Parameters

Rock mass and defect shear strength parameters were adopted after PSM (2017a), and are summarised in Table 3. The following comments are made regarding these parameters:

- The strength parameters for all rock units are noted as having been downgraded by a "Disturbance" factor of 0.7 to account for damage to the rock mass from blasting. This is relatively conservative, as such disturbance is typically only applicable near the blasting face (i.e. within metres of the face). Application of the disturbance factor to rock well behind the quarry face is not strictly correct, and may result in underestimation of the rock mass shear strength for slip surfaces that are within rock that is relatively undamaged by blasting.
- Notwithstanding the above disturbance factor issue, the stated Hoek-Brown failure parameters have been adopted for use. The disturbance factor has been incorporated to allow for ease of comparison of results with previous models.
- To reflect shallow dipping joints within the SW/F breccia, a ~10m wide region of the SW/F breccia was replaced on select stability runs with an anisotropic material model which allowed for a reduced shear strength for sliding surfaces at ± 20° from horizontal. This scenario is likely slightly conservative, as:

- The material model allows for failure at any point within the specified region, whereas in reality the sub-horizontal joints are located at finite, discrete locations.
- The presence of the sub-horizontal joint set is double counted, first within the determination of the Geological Strength Index (GSI), and secondly within the specified strength anisotropy. A more representative view point may be to upgrade GSI to take into account one less joint set.

Table 3 Adopted geotechnical parameters

Unit	Unit weight (kN/m^3)	UCS (MPa)	GSI	m_i	Dist. Factor	Drained cohesion (kPa)	Drained friction angle (°)
Fill	20	-	-	-	-	10	30
Weathered dolerite	21	-	-	-	-	110	29
SW/F breccia	26	70	55	16	0.7	-	-
SW/F breccia (anisotropic, defects ± 20° from horiz.)	26	As for SW/F breccia for planes oriented outside of ± 20° from horiz				0	32
Muddy breccia – shear regions	26	-	-	-	-	0	28
Weathered sandstone	21	-	-	-	-	62	15
SW/F sandstone	24	40	60	17	0.7	-	-
Altered sandstone	24	25	51	13	0.7	-	-
Flow banded dolerite	26	30	49	16	0.7	-	-

2.4.6 Results

Table 4 provides a summary of the stability analysis undertaken of each hazard, with the corresponding calculated FoS under each design scenario.

Table 4 Computed FoS results

Hazard No.	Case	Computed FoS		
		Existing	Option 1	Option 2
H1	Block failure along shear plane in muddy breccia with failure along rockmass at toe (most likely failure scenario)	1.9	2.0	As for Option 1[1]
H1	Block failure along shear plane in muddy breccia with “stepped” failure along 10m defect and rockmass at toe.	1.2[1]	1.2	As for Option 1[2]
-	Circular failure along muddy breccia at diatreme-host rock contact and intact rock mass that affects new access track	-	-	2.5

Hazard No.	Case	Computed FoS		
		Existing	Option 1	Option 2
H2 [3]	Fill and residual soil landslide onto access track	1.3 to 1.4	As for existing	N/A
H3/H4 [3]	Landslide in fill and residual soil undermining access track	2.2	As for existing	2.3

Notes:

[1] Considered unrealistic and only produced for checking / sensitivity of the analysis to modelling. Min FoS of 1.9 is considered to be the upper and FoS 1.2 the lower bound extents of the analysis with a mid-value most appropriate to use for a FoS approach.

[2] Block failure unlikely to undermine access track for Option 2

[3] Stability analysis for hazards H2, H3 and H4 indicative only due to the nature of the uncontrolled fill, and potential for degradation of fill/weathered rock with changes in surface drainage/deterioration over time

2.4.7 Discussion of stability analysis results

H1 – sliding along shear plane in muddy breccia

The critical mechanism for global failure of the southern quarry wall remains sliding of the breccia rock mass along shear planes within muddy breccia units behind the quarry face, with “toe release” occurring through a shallow dipping defect in the SW/F breccia in conjunction with shearing through intact rock. The computed FoS values range from about 1.2 for the conservative (considered unrealistic) case where a 10 m long defect is present, to 1.9 to 2.0 for the case where no defect is present.

As the available mapping does not identify the presence of such persistent defects, a more realistic FoS value is considered to lie between these two values notionally FoS 1.55.

A FoS of 1.55 is deemed to be an acceptable value for global slope stability with no further assessment required. However, basic long term monitoring is still advisable to periodically check for any material changes in the slope condition.

H2 – Fill and residual soil landslide onto access track

For the scenario where a significant depth of fill, and potentially underlying residual soil, collapses onto the access track, the computed FoS was about 1.4 for Option 1.

This FoS is considered indicative only, as the fill properties may vary significantly due to its uncontrolled nature, and potential sensitivity in the event of changes in surface drainage which could cause local slumping. Furthermore, localised variations in slope geometry that have not been captured in the stability model will also contribute to the risk of slope instability in fill. This will need to be further assessed at detailed design but is not anticipated to be an area of significant works or concern and will be manageable with minor engineering measures.

H3/H4 - Landslide in fill and residual soil undermining access track

The computed FoS values for slip surfaces through fill/residual soil that could undermine the access track were generally quite high, above 2.2 for all scenarios. This high FoS is attributed to the shear strength parameters adopted, which are generally reasonable for the existing condition. However this may not necessarily be valid in the event of significant changes in drainage or water ingress into the soil/rock mass causing erosion.

With relatively steep slopes in residual soil/weathered rock underlying the existing track, and the observation of existing slumps in the weathered profile (e.g. Coffey 2016, Plate 12, reproduced in Figure 12), there remains a significant likelihood of instability that could undermine the existing access track, unless engineering measures are implemented. Furthermore, the presence of large trees along the crest line may pose a hazard with trees being up-rooted in high winds, falling into the quarry and exposing steep soil slopes subject to further erosion.

Plate 12. View of recent slide in extremely weathered rock at crest of south wall.

Figure 12 Slump in EW rock at south wall, adjacent to access track. Ref: Coffey (2016)

2.5 Options Comparison and Discussion

2.5.1 Options Comparison

Table 5 provides a comparison of each option in terms of key features, required monitoring systems, preliminary constructability considerations, risk to life, and qualitative costs.

Table 5 Option comparison

Item	Option 1 – maintain existing	Option 2 – new track
Key access track features	Maintain existing tracks layout.	Extensive cut operation in southern area. Construct retaining walls up to 26m high over approximately 180 m.
Preliminary constructability considerations	No significant new construction.	Potential to encounter high strength rock with poor excavatability Presence of large boulders in fill may be challenging to handle/excavate. Steep fill slopes with potentially marginal stability in areas. Significant retained height (26m) may preclude certain types of construction, e.g. soil nails.
Monitoring considerations	Slope monitoring and warning systems: - Global stability - Steep residual soil/weathered rock slopes - Steep fill slopes	Slope monitoring and warning systems: - Global stability - Steep residual soil/weathered rock slope.
Risk to life	Potentially intolerable risk to life for "individual most at risk" due to steep slopes in residual soil/weathered rock. Societal risks in ALARP region.	Slightly lower risk for "individual most at risk" compared to Option 1, however still potentially intolerable. Societal risks in ALARP region, slightly lower than for Option 1.
Cost (qualitative)	Significantly less	Significantly more
Further action to implement	Additional geotechnical investigation at crusher area, southern access track. Scope slope monitoring and warning systems. Design measures to reduce risks from steep residual soil at quarry crest.	Additional detailed geotechnical investigation at crusher area, access track. Scope slope monitoring and warning systems. Design measures to reduce risks from steep residual soil at quarry crest. Design retaining walls.

2.5.2 Discussion and Recommendations

The comparison of each option shows that, in general, Option 2 provides only slight benefits in terms of reduced risk to life, while requiring costly works that will encounter significant constructability issues.

Additionally, undertaking of the works in Option 2 will result in significant disruption to the southern area of the quarry, in terms of changing ground levels, removal of vegetation, modified plant/vehicle movements in the area and modified surface water flow regimes.

These disruptions (unquantified as yet) may have some impact on the stability of the existing slopes, and may modify, expose or create additional geotechnical hazards. As such, any proposed works will need to be carefully considered in terms of the existing groundform and drainage regime.

If the southern access track is to be opened for general usage (under either Option 1 or 2), the risk associated with steep residual soil/weathered rock undermining the access track should be considered for mitigation. A robust structural solution is proposed to stabilise the Southern Access track involving the construction of a raked micro-pile (or similar) with integral capping beam and edge protection.

Therefore on the balance of assessments undertaken in this report it is considered that Option 1 is preferable in terms of practicalities and cost with no significant impact on safety. Both Option 1 and Option 2 are considered to provide a global factor of safety above the generally accepted minimum requirement. Further, a detailed risk assessment indicated the risks to be within the acceptable socio-economic range (Refer to Appendix A).

3. Northern Spoil Mound

3.1 Introduction

The Northern Spoil Mound area was identified in previous reports (PSM 2007) as an area with potential high instability. Therefore, as part of developing an overall quarry rehabilitation strategy (ecology, cost, aesthetics, access and stability), GHD has assessed Council's preferred rehabilitation option for the Northern Spoil Mound. The results and recommendations arising from GHD's assessment are presented below.

From correspondence with Council on 2nd August 2018 it is understood that a preferred option (referred to as Option 5a) is under detailed consideration.

Option 5a allows for extensive re-grading works of poorly vegetated areas to simultaneously improve the slope stability and improve the quality of the flora able to be supported by the slope in the long term for reasons of aesthetic appeal. As part of the regrading works an access track provides access to the back of the spoil mound via a new entry track to be built from the existing haul trackon the north-eastern corner of the quarry void (Refer to Figure 13).

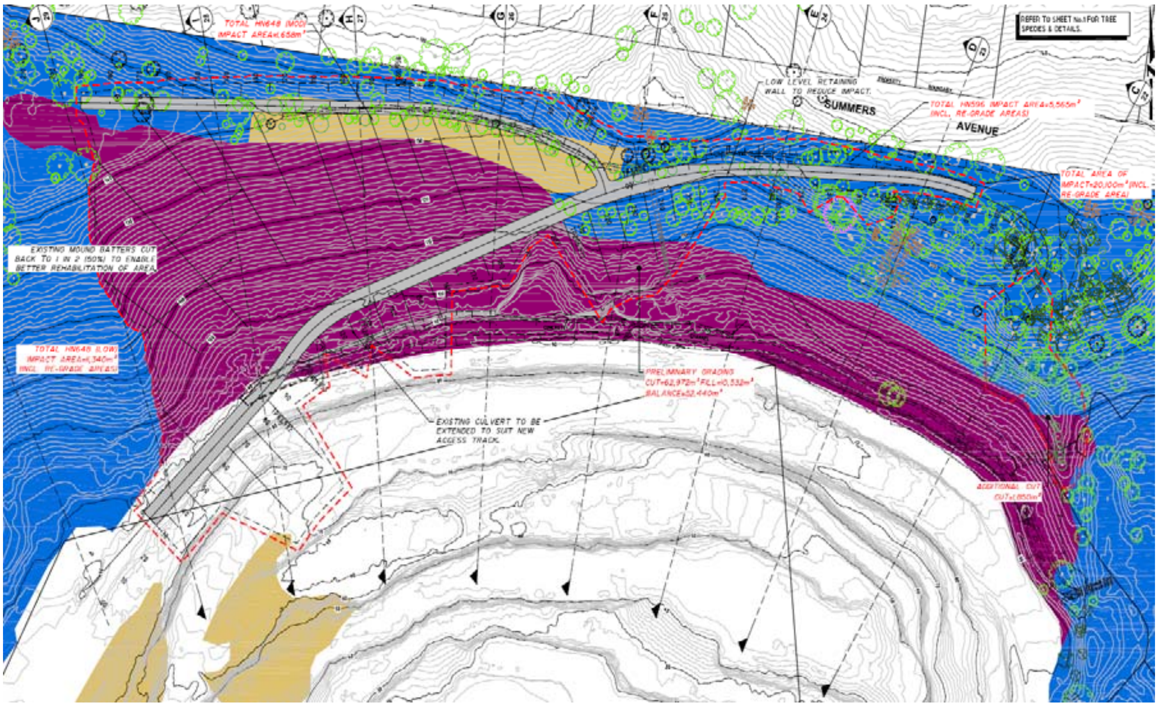


Figure 13 Option 5a - Schematic Plan View Layout.

3.2 Assessment Criteria

3.2.1 Prior to RMS GTD 2018/001

The methodology of assessing the acceptability of a slope was based on two commonly adopted approaches:

- Factor of Safety (FoS) approach – the proportion of calculated "resisting forces" and "disturbing forces" must be above a certain ratio; and
- Risk-based approach – the risk associated with the likelihood and consequences of slope failure must be below a certain level.

For new Roads and Maritime Services (RMS) infrastructure projects, it is common to adopt a FoS approach given an Assessed Risk Level (ARL) of four or better has been achieved in accordance with the RMS Guide to Slope Risk Analysis. Thus, typical project Scope of Works and Technical Criteria (SWTC) requires slopes and fill embankments to be designed with a minimum long term FoS of 1.5 and a minimum short term FoS of 1.2 to 1.3.

For remediation of existing slopes and embankments, it is common to adopt a risk-based approach as historically existing slopes have often been designed to less stringent standards (or not designed at all in the case of natural slopes) and cannot comply with the above mentioned minimum FoS values. Within Australia, the Australian Geomechanics Society (AGS) Guidelines, which provide a commonly accepted methodology/framework to carry out the risk assessment, suggest that the "Tolerable Loss of Life Risk for the person most at risk" is below the values shown in the figure below:

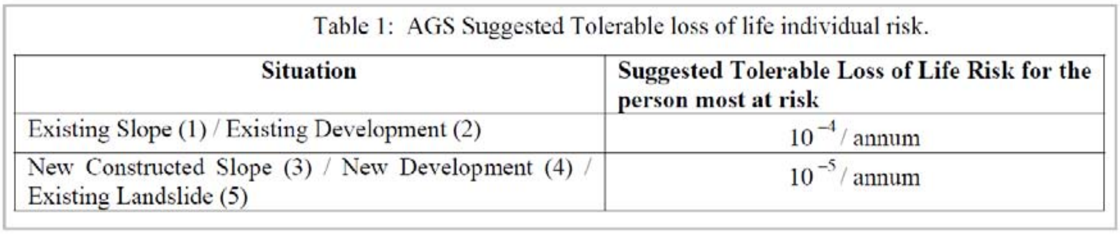


Table 1: AGS Suggested Tolerable loss of life individual risk.

Situation	Suggested Tolerable Loss of Life Risk for the person most at risk
Existing Slope (1) / Existing Development (2)	10^{-4} / annum
New Constructed Slope (3) / New Development (4) / Existing Landslide (5)	10^{-5} / annum

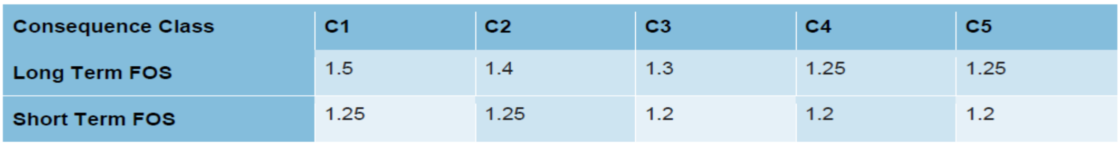
Figure 14 AGS (2007c) suggested tolerable risk criteria

3.2.1 RMS GTD 2018/001

The new technical RMS direction "Geotechnical Design for Remediation of Existing Slopes and Embankments" published in February 2018, stipulates a set of minimum acceptable FoS required for the remediation of existing soil slopes and fill embankments given an ARL of three or better has been achieved in accordance with the RMS Guide to Slope Risk Analysis.

As stated in this technical direction "*if the design standard for new works is adopted for remedial works, the associated repair costs could be unnecessarily high in many situations and might exceed the minimum ARL requirements*". Thus, this document attempts to improve the cost effectiveness of slope remedial works by reducing the minimum acceptable FoS depending on the consequences of failure and increasing the level of maintenance and monitoring requirements of the slope.

The new minimum long term and short term FoS and minimum levels of site investigation and testing are introduced in this technical direction based on the outcomes of the risk assessment conducted in accordance with RTA Guide to Slope Risk Analysis (ref: The RTA Guide to Slope Risk Analysis, Version 3.1, dated May 2002). Figure 15 presents the FoS vs Consequence matrix defined in RMS GTD 2018/001:



Consequence Class	**C1**	**C2**	**C3**	**C4**	**C5**
Long Term FOS	1.5	1.4	1.3	1.25	1.25
Short Term FOS	1.25	1.25	1.2	1.2	1.2

Figure 15 Consequence class and minimum FoS values as per RMS GTD 2018/001

For the Hornsby Quarry rehabilitation project the intent is to provide remedial designs for all slopes in order to meet the RMS GTD 2018/001 requirements.

3.3 Stability Assessment

3.3.1 Study sections

Figure 16 presents the cross sections that have been adopted in the design to assess the stability of Council's preferred rehabilitation option for the Northern Soil Mound. These sections are considered to represent the worst-case combinations of fill height/thickness, water infiltration and slope grading throughout the mound's length.

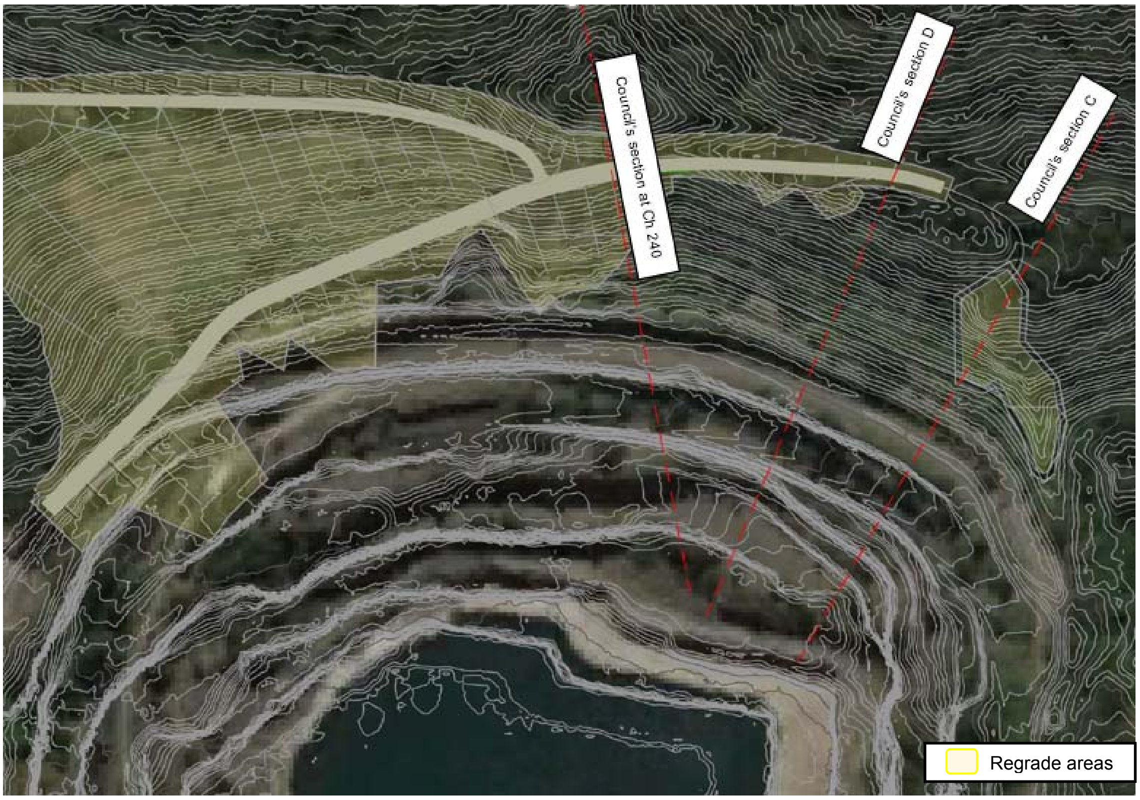


Figure 16 Plan view showing adopted cross section for the stability analysis

In absence of geotechnical investigation at the mound's location, review and interpretation of available historical photogrammetry was necessary to define the interface between the mound and the quarried north wall. This interpretation will need to be confirmed or amended (as required) by ground investigation as part of the normal design development process.

3.3.2 Regrade areas

Under option 5a all designated regrade areas are required to be cut back to a slope angle of 1V:2H to improve stability and provide maintainable stable vegetation cover in the long term.

The proposed section through chainage CH240 (section through the lowest point of the gully behind the Spoil Mound) and the regraded section C (section through the over steep area towards the eastern end of the mound) have been assessed for a 1V:2H regrade with a minimum FoS calculated as 1.39 (can be considered as 1.40) as shown in Figures 17 and 18 below. It is noted that, despite conservatively considering water ponding behind the existing mound during major rainfall events, it has been assumed that effective drainage measures will be in place and maintained to avoid pore pressure build-up beyond the levels assumed in this assessment.

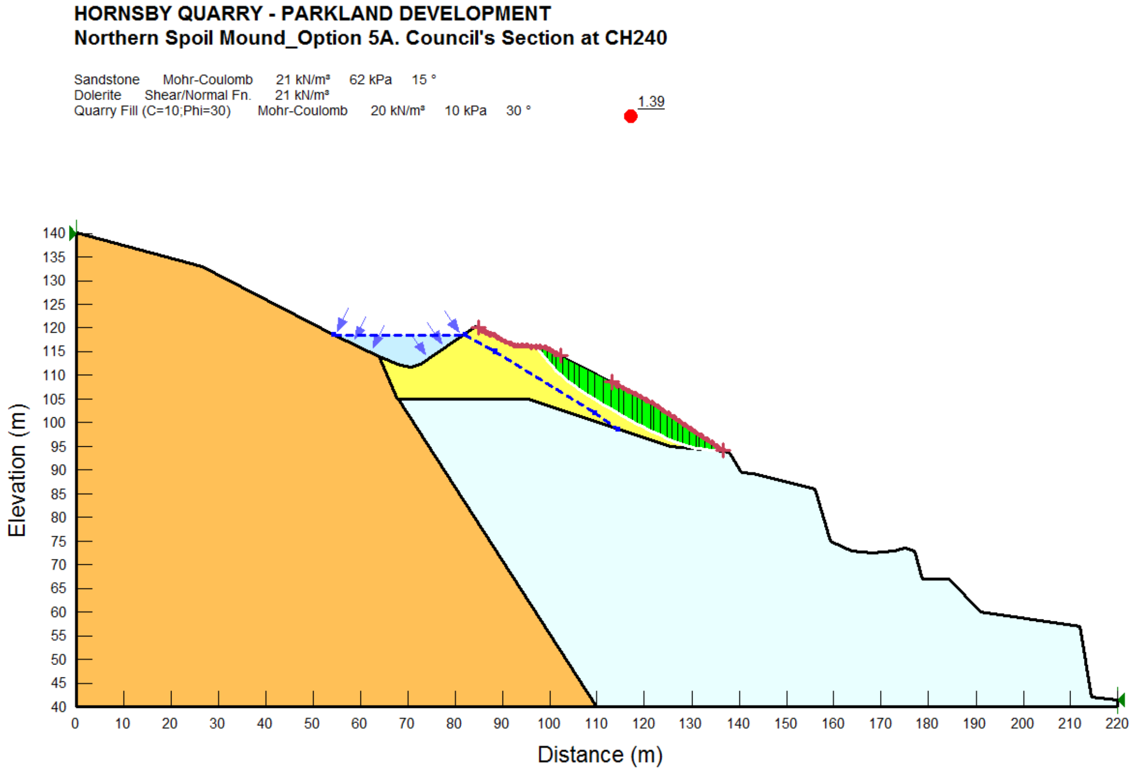


Figure 17 Stability results for proposed regrade section at CH240

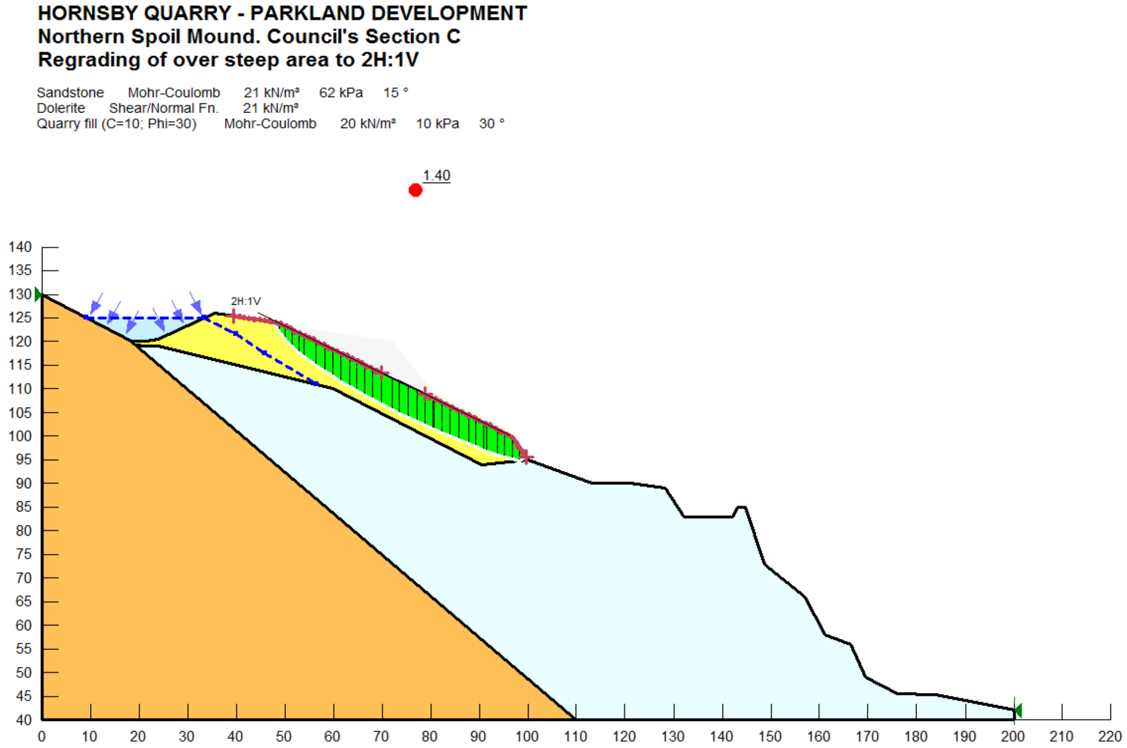


Figure 18 Stability results for proposed regrade section C

3.3.3 Existing areas (no regrade proposed)

Some of areas in the east of the spoil mound are proposed to remain in their existing condition due to environmental concerns. The FoS for the existing untreated slope is estimated to be less than 1.25 (See Figure below) and therefore, without further refinement of the adopted geotechnical model or incorporation of stabilisation techniques (refer to section 3.5), only an AGS risk based approach can be adopted including a commitment to maintain and monitor this area of slope in the long term. Subject to detailed design, an initial AGS risk assessment indicated the existing slopes can be monitored and maintained to keep the risk to life within commonly adopted limits. However, it is recommended that remedial options which do not require tree removal are considered for this area to meet GTD 2018/001 requirements (e.g. soil nails) during the detailed design process.

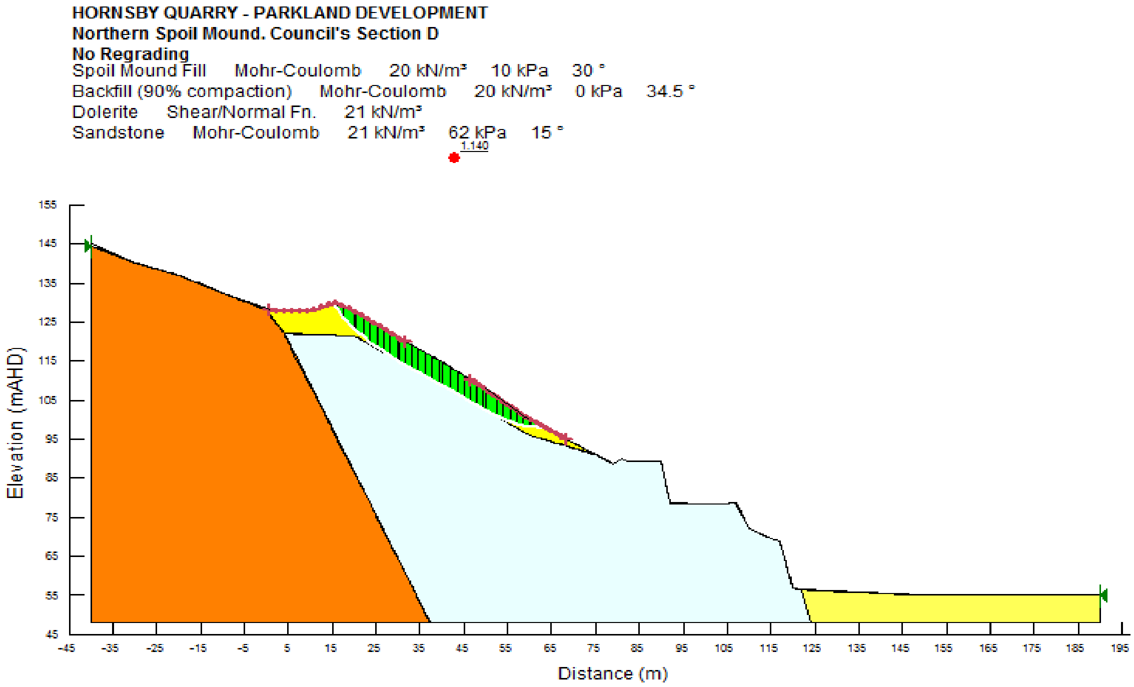


Figure 19 Slope/W results for untreated section D

3.4 Assessed Risk Level and Consequence class

3.4.1 RTA Guide to Slope Risk Analysis

As required by RMS technical direction GTD 2018/001, a slope risk assessment needs to be conducted in accordance with the RTA Guide to Slope Risk Analysis to identify the consequence class and to determine the ARL associated with the potential failure mechanism.

The risk assessment process is developed around the basic risk equation:

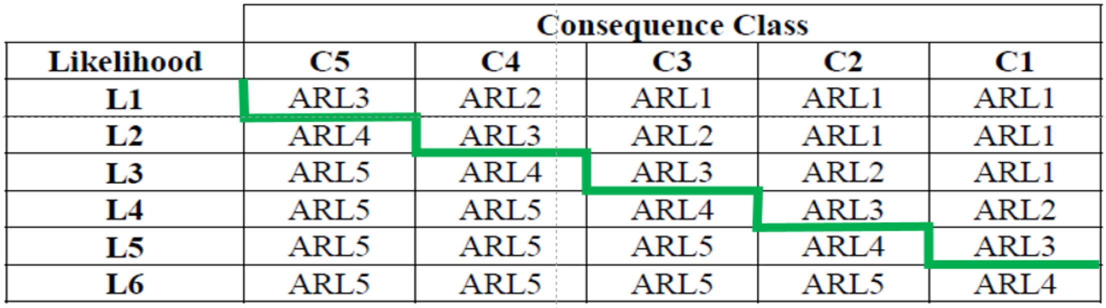
Risk = Likelihood x Consequences

Where:

- Risk is usually defined as a situation of exposure to hazards (in this case potential slope failure mechanisms). Thus, first step in the risk assessment process is the recognition and identification of the potential and actual failure mechanisms which may affect a slope. Once the hazards have been identified, they need to be assessed.
- Likelihood is generally considered as the chance of the hazard occurring. As stated in AGS Guidelines (2007c), in the case of slope failure, “the assessment of frequency, or likelihood, is the most difficult part of the risk assessment process”. Likelihood of slope failure mechanisms is often expressed in terms of annual probability.

- Consequence is related to risk for life and to economic loss. These two variables are analysed separately to obtain the Consequence Class that will be used to define the minimum acceptable FoS as per RMS GTD 2018/001.

The assessed likelihood and consequence class are combined through a matrix to determine the ARL for the hazard (refer to Figure 20). This value will need to satisfy the RMS GTD 2018/001 requirement of ARL of 3 or better in order to adopt a FoS approach to assess the acceptability of the maintenance access track batter slopes.



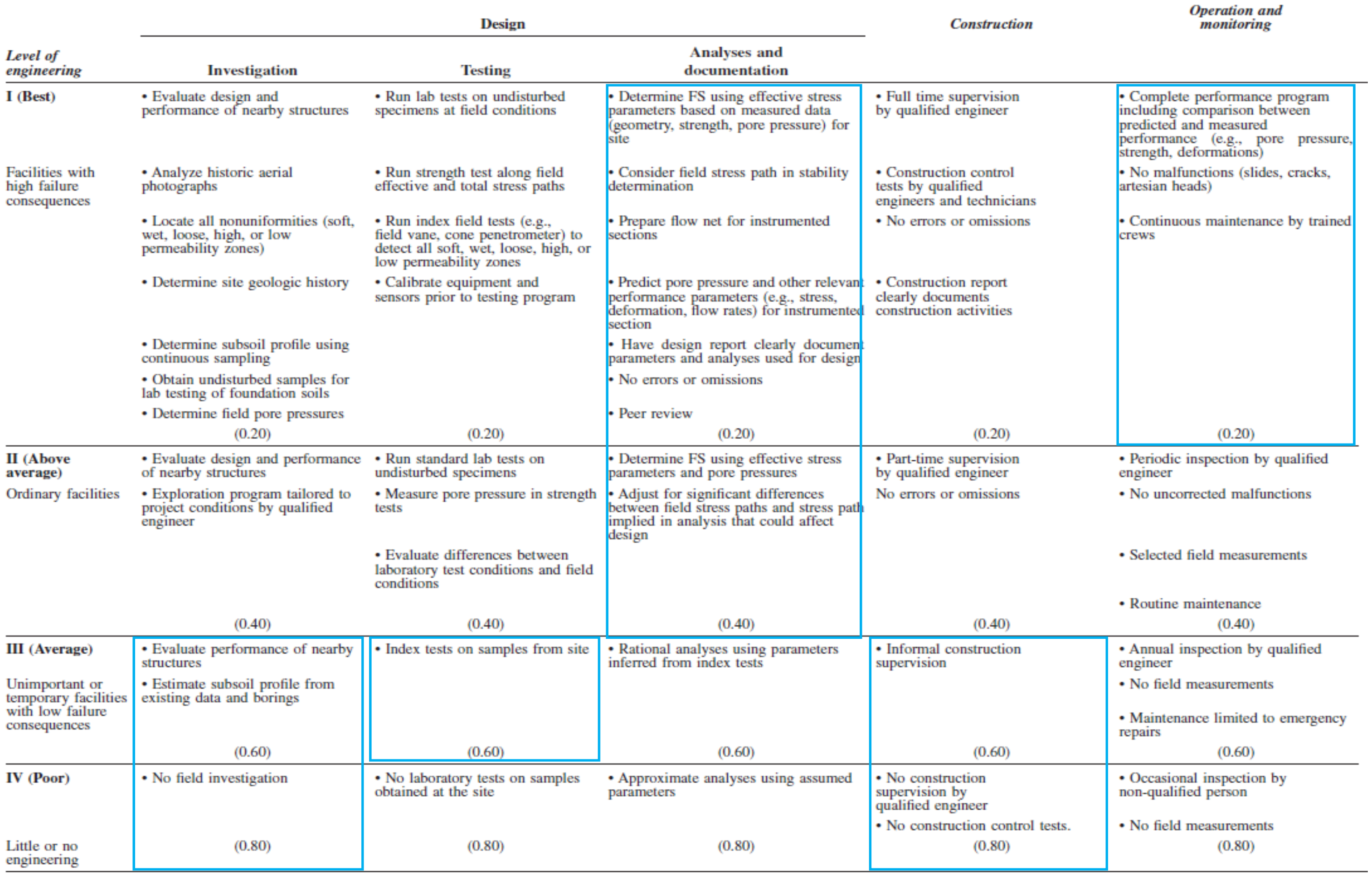
	Consequence Class				
Likelihood	**C5**	**C4**	**C3**	**C2**	**C1**
L1	ARL3	ARL2	ARL1	ARL1	ARL1
L2	ARL4	ARL3	ARL2	ARL1	ARL1
L3	ARL5	ARL4	ARL3	ARL2	ARL1
L4	ARL5	ARL5	ARL4	ARL3	ARL2
L5	ARL5	ARL5	ARL5	ARL4	ARL3
L6	ARL5	ARL5	ARL5	ARL5	ARL4

Figure 20 Likelihood - Consequence matrix

It is noted that AGS Guidelines (2007c) mentions the inherent danger of basing the likelihood and consequence assessment solely on the qualitative descriptors provided on published risk assessment guidelines. Thus, the risk assessment presented in this report has followed the quantitative analysis approach proposed in the AGS Guidelines and has been crossed-checked with the RTA Guidelines qualitative descriptive scales.

Likelihood

The empirical correlations between the computed slope stability FoS and the assessed project category in accordance with Silve, Lambe & Marr (2008) have been used to estimate the likelihood expressed in terms of annual probability of failure. Extracts from the relevant guidance reproducing the key reference tables and charts are presented in Figures 21 and 22 below.



	Design			*Construction*	*Operation and monitoring*
Level of engineering	**Investigation**	**Testing**	**Analyses and documentation**		
I (Best)	• Evaluate design and performance of nearby structures	• Run lab tests on undisturbed specimens at field conditions	• Determine FS using effective stress parameters based on measured data (geometry, strength, pore pressure) for site	• Full time supervision by qualified engineer	• Complete performance program including comparison between predicted and measured performance (e.g., pore pressure, strength, deformations)
Facilities with high failure consequences	• Analyze historic aerial photographs	• Run strength test along field effective and total stress paths	• Consider field stress path in stability determination	• Construction control tests by qualified engineers and technicians	• No malfunctions (slides, cracks, artesian heads)
	• Locate all nonuniformities (soft, wet, loose, high, or low permeability zones)	• Run index field tests (e.g., field vane, cone penetrometer) to detect all soft, wet, loose, high, or low permeability zones	• Prepare flow net for instrumented sections	• No errors or omissions	• Continuous maintenance by trained crews
	• Determine site geologic history	• Calibrate equipment and sensors prior to testing program	• Predict pore pressure and other relevant performance parameters (e.g., stress, deformation, flow rates) for instrumented section	• Construction report clearly documents construction activities	
	• Determine subsoil profile using continuous sampling		• Have design report clearly document parameters and analyses used for design		
	• Obtain undisturbed samples for lab testing of foundation soils		• No errors or omissions		
	• Determine field pore pressures		• Peer review		
	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)
II (Above average)	• Evaluate design and performance of nearby structures	• Run standard lab tests on undisturbed specimens	• Determine FS using effective stress parameters and pore pressures	• Part-time supervision by qualified engineer	• Periodic inspection by qualified engineer
Ordinary facilities	• Exploration program tailored to project conditions by qualified engineer	• Measure pore pressure in strength tests	• Adjust for significant differences between field stress paths and stress path implied in analysis that could affect design	No errors or omissions	• No uncorrected malfunctions
		• Evaluate differences between laboratory test conditions and field conditions			• Selected field measurements
					• Routine maintenance
	(0.40)	(0.40)	(0.40)	(0.40)	(0.40)
III (Average)	• Evaluate performance of nearby structures	• Index tests on samples from site	• Rational analyses using parameters inferred from index tests	• Informal construction supervision	• Annual inspection by qualified engineer
Unimportant or temporary facilities with low failure consequences	• Estimate subsoil profile from existing data and borings				• No field measurements
					• Maintenance limited to emergency repairs
	(0.60)	(0.60)	(0.60)	(0.60)	(0.60)
IV (Poor)	• No field investigation	• No laboratory tests on samples obtained at the site	• Approximate analyses using assumed parameters	• No construction supervision by qualified engineer	• Occasional inspection by non-qualified person
				• No construction control tests.	• No field measurements
Little or no engineering	(0.80)	(0.80)	(0.80)	(0.80)	(0.80)

Figure 21 Earth structure categories

Project category estimation:

Investigation: 0.70

No investigation is available at the mound's location. Investigation was carried out on eastern and southern quarry faces. Original quarry profile was estimated after exhaustive review of historical photogrammetry.

Testing: 0.60

No testing is available at the site location. However, laboratory testing was conducted on undisturbed specimens of fill material encountered on the eastern side of the void is assumed to be of similar characteristics to the mound's fill.

Analyses: 0.30

Even though methodology used is closer to level I of engineering, the absence of measured geotechnical data on the mound's site reduces the level of engineering rating.

Construction: 0.60

There is no evidence of construction supervision during the mound's construction. However, from the review of the historical photogrammetry, it has been observed that two access tracks were built after construction of the mound. Thus, it is expected that some level of supervision was deployed to ensure safe vehicle/plant transit.

Operation and monitoring: 0.20

Required

Total

0.70 + 0.60 + 0.30 + 0.70 + 0.20 = 2.5 (between project categories II and III)

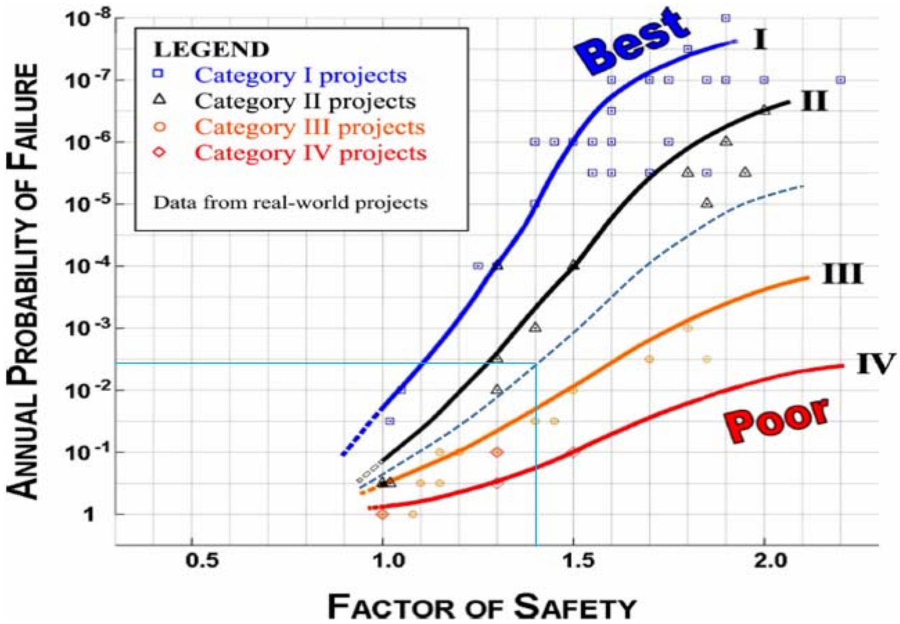
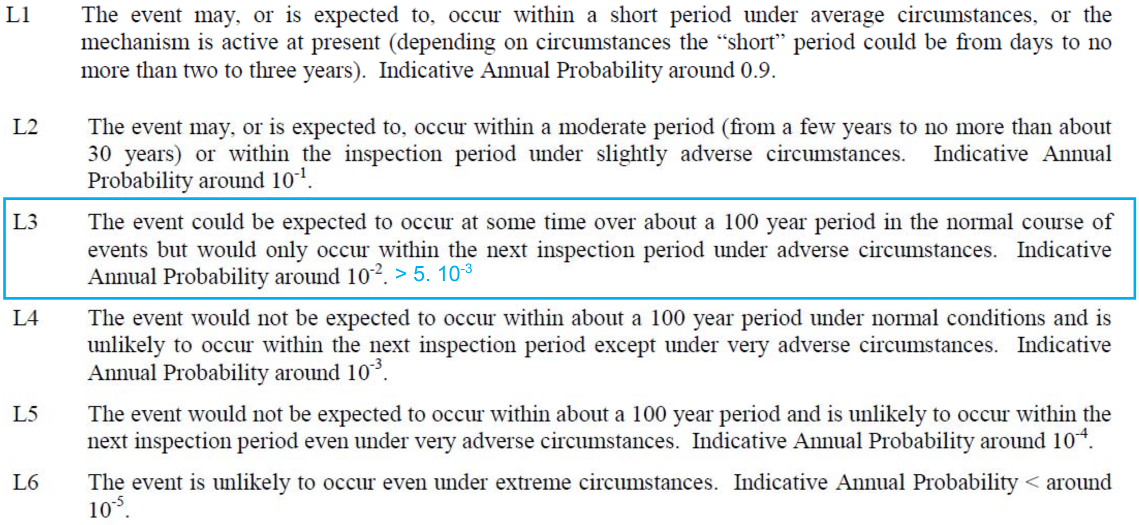


Figure 22 Factor of safety versus annual probability of failure

From the matrix shown in Figure 15, it is inferred that the level of engineering for the Northern Spoil Mound rehabilitation falls between categories II and III (i.e. above average and average level of engineering) due to the limited available investigation, testing and supervision done during the mound's construction but high level of monitoring that will be recommended for the construction and operational phases.

Additionally, based on the assessed long term factor of safety of 1.4 obtained from the adopted stability sections for the regrade areas, an annual probability of failure of approximately 5. 10^{-3} has been interpolated from Figure 22.

Figure 23 presents and extract of RTA qualitative guidelines to define the likelihood of landslide failure. Based on the annual probability of failure defined previously, a likelihood class L3 (i.e. annual probability around 10^{-2}) has conservatively been adopted.



L1	The event may, or is expected to, occur within a short period under average circumstances, or the mechanism is active at present (depending on circumstances the "short" period could be from days to no more than two to three years). Indicative Annual Probability around 0.9.
L2	The event may, or is expected to, occur within a moderate period (from a few years to no more than about 30 years) or within the inspection period under slightly adverse circumstances. Indicative Annual Probability around 10^{-1}.
L3	The event could be expected to occur at some time over about a 100 year period in the normal course of events but would only occur within the next inspection period under adverse circumstances. Indicative Annual Probability around 10^{-2}. > 5. 10^{-3}
L4	The event would not be expected to occur within about a 100 year period under normal conditions and is unlikely to occur within the next inspection period except under very adverse circumstances. Indicative Annual Probability around 10^{-3}.
L5	The event would not be expected to occur within about a 100 year period and is unlikely to occur within the next inspection period even under very adverse circumstances. Indicative Annual Probability around 10^{-4}.
L6	The event is unlikely to occur even under extreme circumstances. Indicative Annual Probability < around 10^{-5}.

Figure 23 RTA Likelihood classes

Loss of life criteria

It should be noted that formal probabilistic assessment of this nature necessarily contain emotive terms such as “loss of life”, “person crushed” “fatality”, etc. which can seem alarming when aligned with abstract numbers expressing probability. However, this is only a function of the terminology used and not an indication of the actual level of risk. Probabilistic aassessment can be considered as an alternative way of establishing an overall acceptable FoS and is a robust and established approach used by engineers and adopted within standards (e.g. RMS GTD 2018/001).

The consequences for risk to life are derived based on the temporal spatial probability that persons are present to interact with the hazards and on the vulnerability of the individual if the interaction takes place.

Temporal Spatial Probability, $P_{(T:S)}$

The temporal spatial probability of a mobile element (e.g. person on foot or in vehicle) was evaluated as the proportion of time that an individual would be in the area affected by the landslide, multiplied by the probability that the individual at risk would fail to recognise warning signs/measures (e.g. directives to leave the parkland in event of bad weather) and fail to evacuate.

$$P_{(T:S)} = \frac{Landslide\ Length\ (m)}{Element\ velocity\ (\frac{m}{h})} \times \frac{1\ year}{365\ days} \times \frac{1\ day}{24\ hours} \times \frac{No\ trips}{year} \times probability\ of\ no\ evacuation$$

For the purposes of assessment only the landslide length has been conservatively adopted as 300m, which is approximately the full length of the Northern Spoil Mound and, in reality, an extremely unlikely/unfeasible event. It is noted that this kind of failure is not expected to occur and that further refinement of the possible landslide dimension could be achieved during detail design phase introducing 3D effects into the modelling.

The element velocity has been taken as 4km/h for pedestrians and 50 km/h for motor vehicles at this stage.

The “probability of failure to evacuate” was adopted as 0.1, on the basis of Council employing effective risk mitigation measures to prevent users from accessing the quarry at times when landslide triggering factors are high (e.g. high rainfall), and to alert users who are present in the parkland during warning periods (e.g. observation of significant ground movements).

Figure 24 highlights the tracks considered in this assessment.

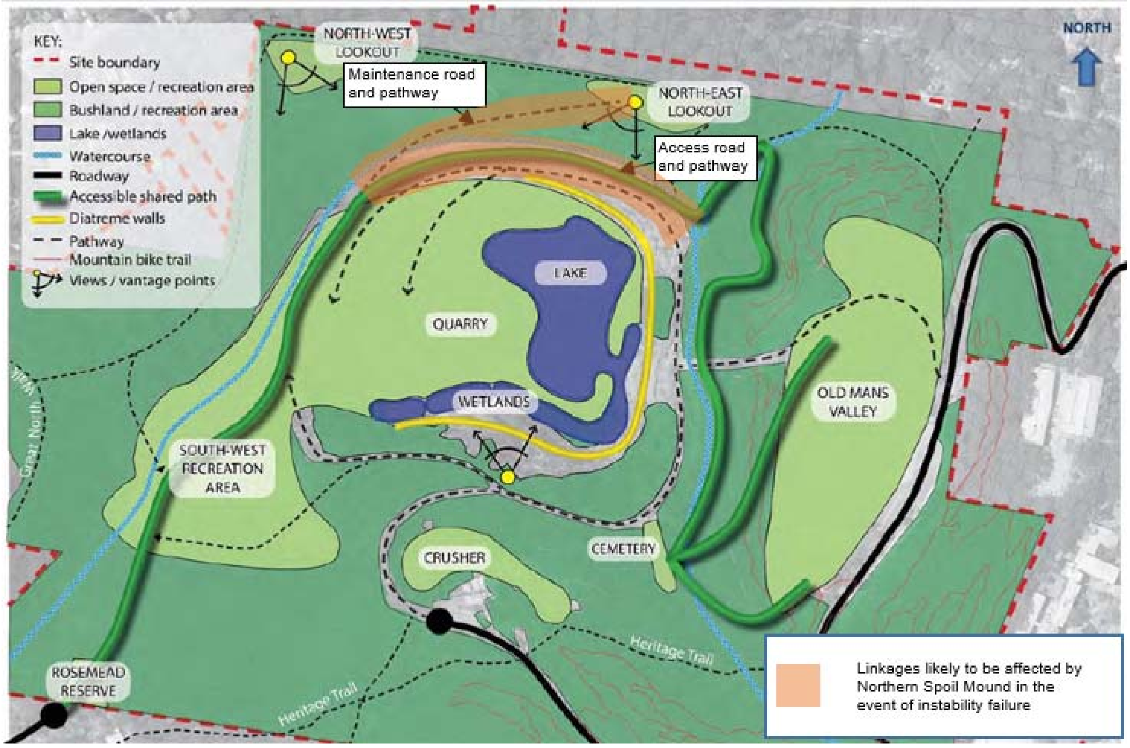


Figure 24 Proposed Hornsby Parkland linkages

Table 6 presents the temporal spatial probability of vehicles and pedestrian travelling on the proposed quarry void access trackalong the North Wall and vehicles and pedestrians travelling through the proposed maintenance track to access the top of the Northern Spoil Mound (refer to Figure 13).

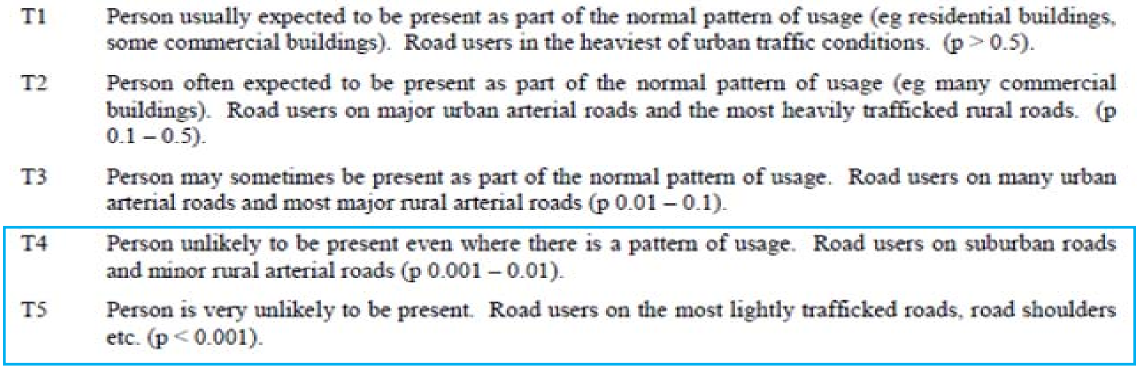
Table 6 Estimated temporal spatial probability $P_{(T:S)}$ for slip failures along Northern Spoil Mound

Case	No Trips per year	Estimated $P_{(T:S)}$ $^{(1)}$
Vehicle going to quarry void (Recreational purposes – group of 4)	13, 000 (50 vehicles x 2 weekend days x 52 weeks/year x 2ways + 5 vehicles x 5 week days x 52 weeks/year x 2 ways)	9.10^{-4} (<0.001)
Vehicle going to top of Northern Spoil Mound (Maintenance purposes –group of 2)	20 trips (10 maintenance visits per year x 2 ways)	1.10^{-6} <0.001
Single pedestrian on access track or maintenance track	5,000 (approximately 10% of the quarry visitors - estimated 13,000 vehicles x 4 occupants)	0.004
Multiple pedestrians on access track or maintenance track (group of 5)	1,000 (approximately 2% of the quarry visitors)	9.10^{-4} <0.001

Notes:

1. Societal risk within “ALARP” (As Low As Reasonably Practicable) region

The estimated temporal spatial probabilities for vehicles travelling into the quarry void or to the top of the Northern Spoil Mound correspond to RTA temporal spatial probability class T4 and T5 respectively, as shown in Figure 25.

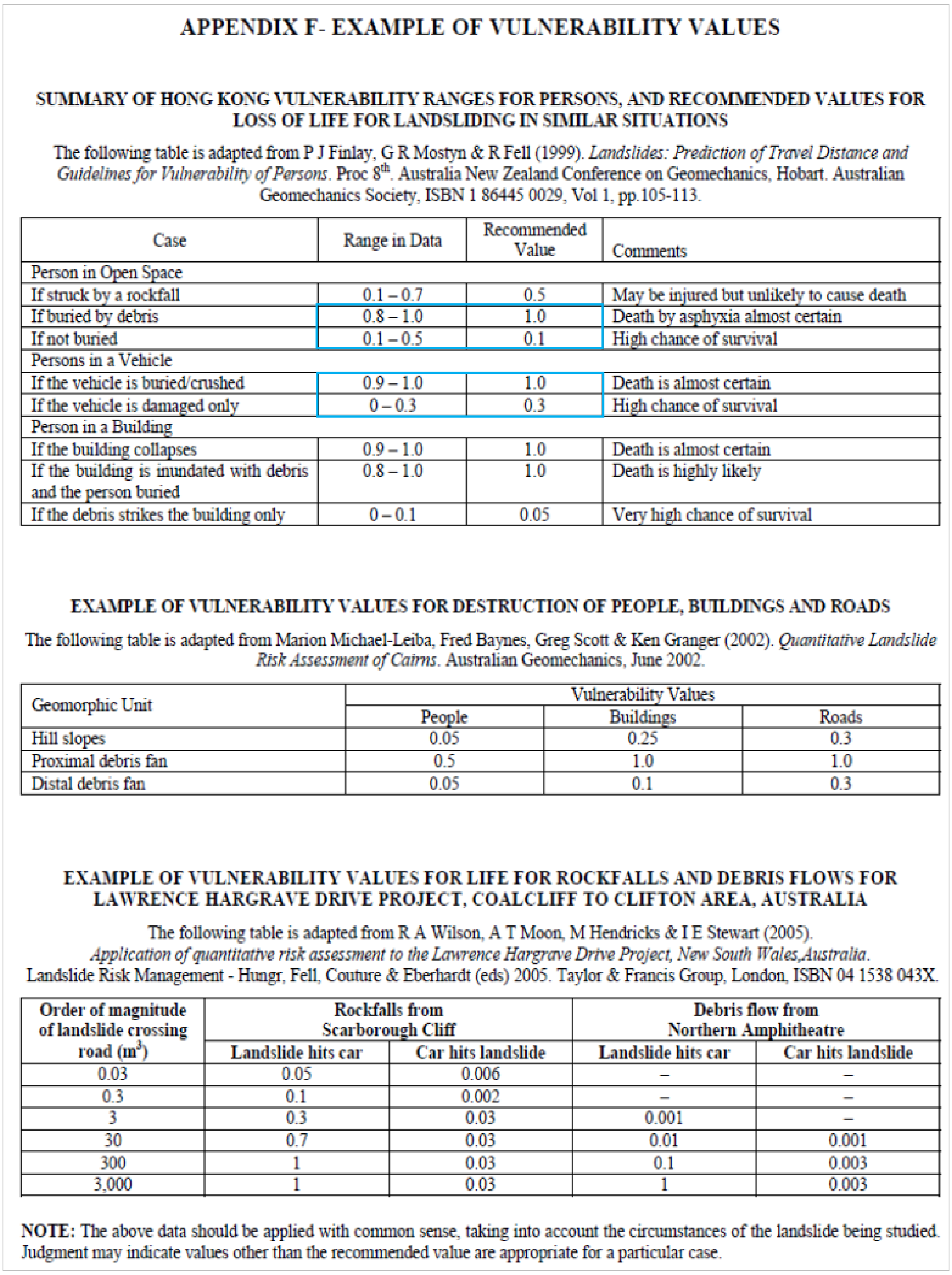


T1	Person usually expected to be present as part of the normal pattern of usage (eg residential buildings, some commercial buildings). Road users in the heaviest of urban traffic conditions. $(p > 0.5)$.
T2	Person often expected to be present as part of the normal pattern of usage (eg many commercial buildings). Road users on major urban arterial roads and the most heavily trafficked rural roads. (p 0.1 – 0.5).
T3	Person may sometimes be present as part of the normal pattern of usage. Road users on many urban arterial roads and most major rural arterial roads (p 0.01 – 0.1).
T4	Person unlikely to be present even where there is a pattern of usage. Road users on suburban roads and minor rural arterial roads (p 0.001 – 0.01).
T5	Person is very unlikely to be present. Road users on the most lightly trafficked roads, road shoulders etc. $(p < 0.001)$.

Figure 25 RTA Temporal spatial probability classes

Vulnerability. Criteria ($V_{(D:T)}$)

The vulnerability refers to the probability of the event causing loss of life. The quantitative values of vulnerability were adopted on the basis of the ranges and recommended values presented in Appendix F of the AGS Guidelines (2007c).



APPENDIX F- EXAMPLE OF VULNERABILITY VALUES

SUMMARY OF HONG KONG VULNERABILITY RANGES FOR PERSONS, AND RECOMMENDED VALUES FOR LOSS OF LIFE FOR LANDSLIDING IN SIMILAR SITUATIONS

The following table is adapted from P J Finlay, G R Mostyn & R Fell (1999). *Landslides: Prediction of Travel Distance and Guidelines for Vulnerability of Persons*. Proc 8th. Australia New Zealand Conference on Geomechanics, Hobart. Australian Geomechanics Society, ISBN 1 86445 0029, Vol 1, pp.105-113.

Case	Range in Data	Recommended Value	Comments
Person in Open Space			
If struck by a rockfall	0.1 – 0.7	0.5	May be injured but unlikely to cause death
If buried by debris	0.8 – 1.0	1.0	Death by asphyxia almost certain
If not buried	0.1 – 0.5	0.1	High chance of survival
Persons in a Vehicle			
If the vehicle is buried/crushed	0.9 – 1.0	1.0	Death is almost certain
If the vehicle is damaged only	0 – 0.3	0.3	High chance of survival
Person in a Building			
If the building collapses	0.9 – 1.0	1.0	Death is almost certain
If the building is inundated with debris and the person buried	0.8 – 1.0	1.0	Death is highly likely
If the debris strikes the building only	0 – 0.1	0.05	Very high chance of survival

EXAMPLE OF VULNERABILITY VALUES FOR DESTRUCTION OF PEOPLE, BUILDINGS AND ROADS

The following table is adapted from Marion Michael-Leiba, Fred Baynes, Greg Scott & Ken Granger (2002). *Quantitative Landslide Risk Assessment of Cairns*. Australian Geomechanics, June 2002.

Geomorphic Unit	Vulnerability Values		
	People	Buildings	Roads
Hill slopes	0.05	0.25	0.3
Proximal debris fan	0.5	1.0	1.0
Distal debris fan	0.05	0.1	0.3

EXAMPLE OF VULNERABILITY VALUES FOR LIFE FOR ROCKFALLS AND DEBRIS FLOWS FOR LAWRENCE HARGRAVE DRIVE PROJECT, COALCLIFF TO CLIFTON AREA, AUSTRALIA

The following table is adapted from R A Wilson, A T Moon, M Hendricks & I E Stewart (2005). *Application of quantitative risk assessment to the Lawrence Hargrave Drive Project, New South Wales,Australia*. Landslide Risk Management - Hungr, Fell, Couture & Eberhardt (eds) 2005. Taylor & Francis Group, London, ISBN 04 1538 043X.

Order of magnitude of landslide crossing road (m^3)	**Rockfalls from Scarborough Cliff**		**Debris flow from Northern Amphitheatre**	
	Landslide hits car	**Car hits landslide**	**Landslide hits car**	**Car hits landslide**
0.03	0.05	0.006	–	–
0.3	0.1	0.002	–	–
3	0.3	0.03	0.001	–
30	0.7	0.03	0.01	0.001
300	1	0.03	0.1	0.003
3,000	1	0.03	1	0.003

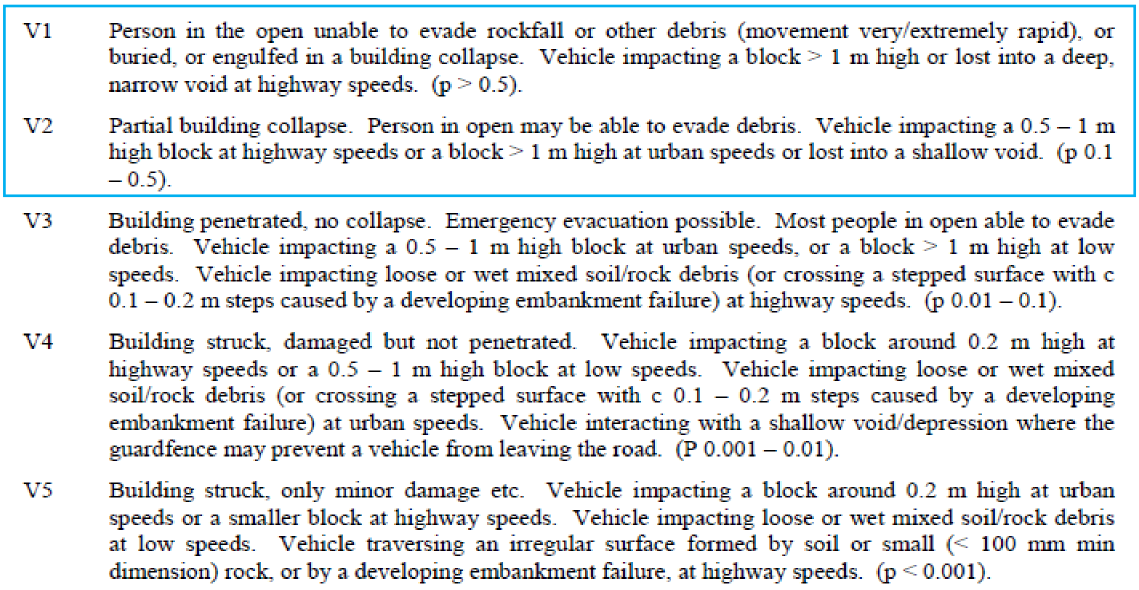
NOTE: The above data should be applied with common sense, taking into account the circumstances of the landslide being studied. Judgment may indicate values other than the recommended value are appropriate for a particular case.

Figure 26 AGS Appendix F – Vulnerability values

Based on the proposed parkland geometry along the northern side of the quarry void, it is expected that in the event of major landslide, the majority of the debris will be contained in the uppermost quarry bench at RL 90mAHD. Thus, the estimated vulnerability of the vehicles travelling through the access track into the quarry void ranges between 0 to 0.3 (i.e. person in vehicle if vehicle is just damaged but not buried or crushed) and 0 to 0.5 (i.e. person in open space if not buried).

For vehicles travelling on the proposed maintenance track during a major landslide event, the vulnerability range ranges from 0.9 to 1.0 (i.e. person in vehicle if vehicle is buried or crushed) and from 0.8 to 1.0 (i.e. person in open space if buried by debris).

The corresponding RTA vulnerability classes are V1 and V2 for vehicles travelling on the maintenance track and vehicle travelling on the access track, respectively.

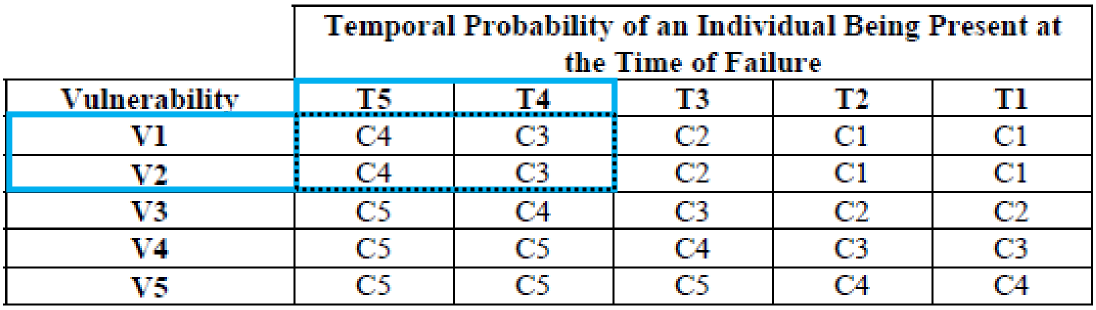


V1	Person in the open unable to evade rockfall or other debris (movement very/extremely rapid), or buried, or engulfed in a building collapse. Vehicle impacting a block > 1 m high or lost into a deep, narrow void at highway speeds. (p > 0.5).
V2	Partial building collapse. Person in open may be able to evade debris. Vehicle impacting a 0.5 – 1 m high block at highway speeds or a block > 1 m high at urban speeds or lost into a shallow void. (p 0.1 – 0.5).
V3	Building penetrated, no collapse. Emergency evacuation possible. Most people in open able to evade debris. Vehicle impacting a 0.5 – 1 m high block at urban speeds, or a block > 1 m high at low speeds. Vehicle impacting loose or wet mixed soil/rock debris (or crossing a stepped surface with c 0.1 – 0.2 m steps caused by a developing embankment failure) at highway speeds. (p 0.01 – 0.1).
V4	Building struck, damaged but not penetrated. Vehicle impacting a block around 0.2 m high at highway speeds or a 0.5 – 1 m high block at low speeds. Vehicle impacting loose or wet mixed soil/rock debris (or crossing a stepped surface with c 0.1 – 0.2 m steps caused by a developing embankment failure) at urban speeds. Vehicle interacting with a shallow void/depression where the guardfence may prevent a vehicle from leaving the road. (P 0.001 – 0.01).
V5	Building struck, only minor damage etc. Vehicle impacting a block around 0.2 m high at urban speeds or a smaller block at highway speeds. Vehicle impacting loose or wet mixed soil/rock debris at low speeds. Vehicle traversing an irregular surface formed by soil or small (< 100 mm min dimension) rock, or by a developing embankment failure, at highway speeds. (p < 0.001).

Figure 27 RTA Vulnerability classes

Consequence Matrix for Risk to Life

The RTA Guidelines directs that the consequence class for the loss of life is assessed based on the temporal spatial probability and vulnerability ratings using the matrix shown in Figure 28.



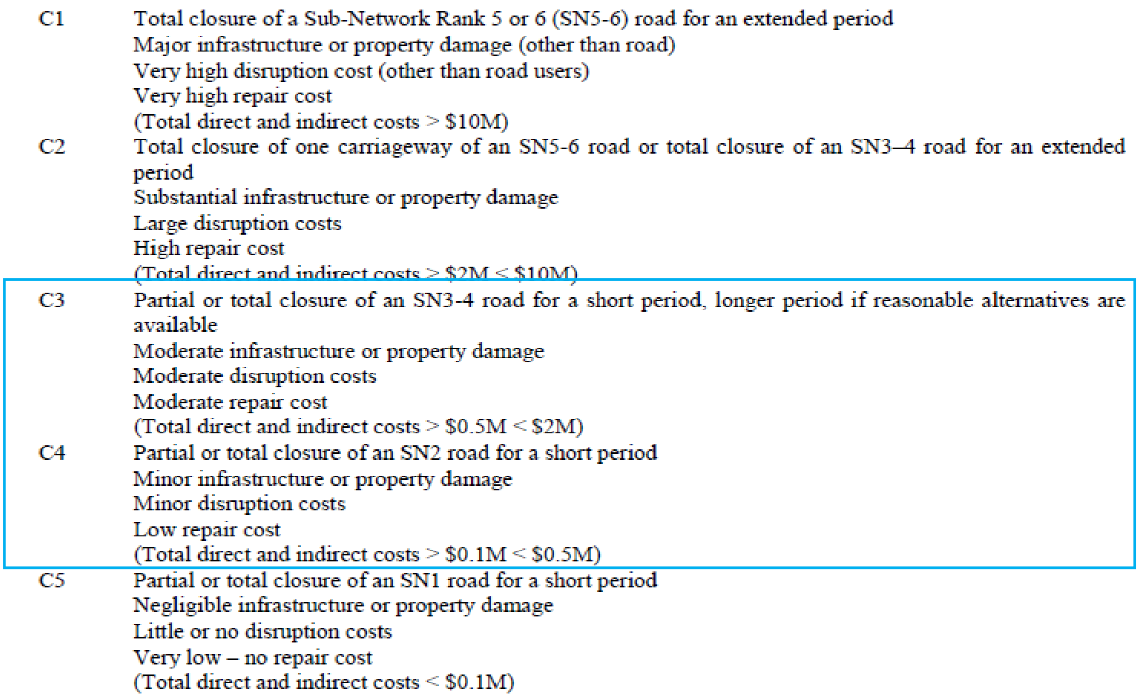
	Temporal Probability of an Individual Being Present at the Time of Failure				
Vulnerability	**T5**	**T4**	**T3**	**T2**	**T1**
V1	C4	C3	C2	C1	C1
V2	C4	C3	C2	C1	C1
V3	C5	C4	C3	C2	C2
V4	C5	C5	C4	C3	C3
V5	C5	C5	C5	C4	C4

Figure 28 Consequence matrix for risk to life

Based on the assessed temporal spatial probability and vulnerability classes, RTA consequence matrix for risk to life suggests a consequence class C3/C4.

Economic Loss

The consequences in respect of property damage and other consequential effects of the failure are assessed to be class C3/C4 using the RTA Guidelines scale shown in Figure 29.

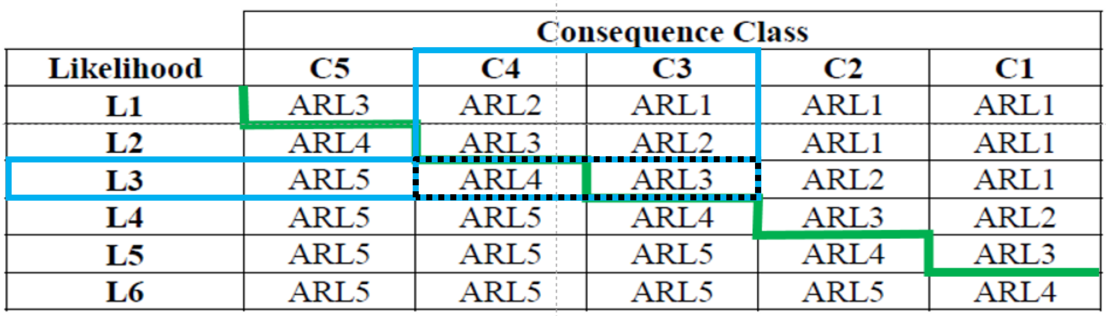


C1	Total closure of a Sub-Network Rank 5 or 6 (SN5-6) road for an extended period Major infrastructure or property damage (other than road) Very high disruption cost (other than road users) Very high repair cost (Total direct and indirect costs > $10M)
C2	Total closure of one carriageway of an SN5-6 road or total closure of an SN3–4 road for an extended period Substantial infrastructure or property damage Large disruption costs High repair cost (Total direct and indirect costs > $2M < $10M)
C3	Partial or total closure of an SN3-4 road for a short period, longer period if reasonable alternatives are available Moderate infrastructure or property damage Moderate disruption costs Moderate repair cost (Total direct and indirect costs > $0.5M < $2M)
C4	Partial or total closure of an SN2 road for a short period Minor infrastructure or property damage Minor disruption costs Low repair cost (Total direct and indirect costs > $0.1M < $0.5M)
C5	Partial or total closure of an SN1 road for a short period Negligible infrastructure or property damage Little or no disruption costs Very low – no repair cost (Total direct and indirect costs < $0.1M)

Figure 29 RTA Economic loss classes

3.4.2 Results

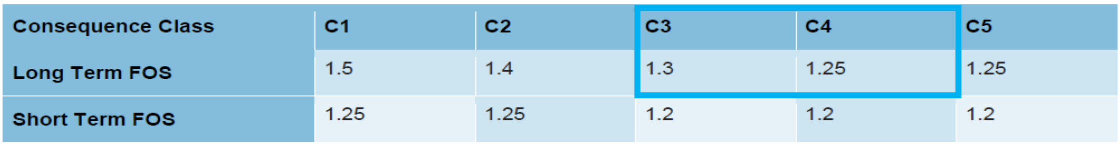
The combined assessed likelihood class L3 and consequence class C3/C4 results in ARL 3/4 (refer to Figure 30 below) and hence, satisfying the RMS GTD 2018/001 requirement of ARL of 3 or better in order to adopt a FoS approach to assess the acceptability of the Northern Spoil Mound rehabilitation works.



	Consequence Class				
Likelihood	C5	C4	C3	C2	C1
L1	ARL3	ARL2	ARL1	ARL1	ARL1
L2	ARL4	ARL3	ARL2	ARL1	ARL1
L3	ARL5	ARL4	ARL3	ARL2	ARL1
L4	ARL5	ARL5	ARL4	ARL3	ARL2
L5	ARL5	ARL5	ARL5	ARL4	ARL3
L6	ARL5	ARL5	ARL5	ARL5	ARL4

Figure 30 Likelihood - Consequence matrix

According to the FoS vs Consequence matrix defined in RMS GTD 2018/001, the minimum acceptable FoS can be reduced to 1.25 for consequence class C4 and 1.3 for consequence class C3. Thus, a conservative FoS of 1.3 has been established as the minimum long term FoS. It is noted that the stability analyses results performed in the regrade areas show a long term FoS of 1.4 and hence, satisfy this requirement.



Consequence Class	C1	C2	C3	C4	C5
Long Term FOS	1.5	1.4	1.3	1.25	1.25
Short Term FOS	1.25	1.25	1.2	1.2	1.2

Figure 31 Estimated minimum Long Term FoS based on assessed consequence class

3.5 Summary Conclusions

From the stability analysis and risk assessment described above the following summary conclusions are drawn:

- In areas where the existing slopes are proposed to be cut back to 1V:2H the analysis indicates a minimum FoS of 1.39 and is therefore considered to meet current RMS guidelines for existing slopes and embankments and no further slope stabilisation measures except the proposed regrade are required (refer to section 3.3.2).
- In areas where existing slopes are proposed to be maintained, the minimum FoS is below 1.25 (minimum long term FoS required in RMS GTD 2018/001).This does not mean that the combined risk assessment and FoS approach cannot be used for these areas as further refinement of the model or the design of stabilisation techniques which do not require removal of protected trees can be explored to increase the assessed FoS to the acceptable RMS GTD 2018/001 limits. This can only be undertaken following additional investigation and analysis of the area concerned.
- In this regard the following should be noted:
  - The areas that remain untreated are densely covered with vegetation as part of the Blue-gum Diatreme Forest. It is well-known that the presence of vegetation is highly influential on soil slope stability (note can be detrimental to rock slope stability in some circumstances). Roots aid in binding the soil it is contained within, reducing the soil erosion and improving the slope stability through hydrological effects (by removal of soil water by evapotranspiration and creating cavities that increase natural drainage) and mechanical effects (fine roots increase the soil tensile strength while coarser roots extending deep into the soil and crossing shear planes provide stability against shear and bending failures). It is noted that the beneficial effects of the existing vegetation to slope stability have not been considered in the analyses at this stage but can be assessed and implemented during detailed design phase. This together with further refinement of the possible landslide dimensions introducing 3D effects into the modelling might probably increase the FoS to acceptable limits without remedial works.
  - Some ground investigation at the mound’s site is required to better understand the geometry of the mound’s interface with the quarry north wall prior to conduct any further refinement. The mound’s spoil thickness is a major contributing factor to stability and its definition (if different to the assessed after review of historical photogrammetry) could lead to greater FoS, removing the need to incorporate 3D and vegetation effects into the model; or lower FoS, in which case stabilisation measures such as soil nails or micropiles might be required to intercept the slip surface and engineer the slope FoS within acceptable levels.

The global stability assessment described above do not consider surface erosion processes. In particular if overland water flows become concentrated on the slope this can lead to erosional slope failures (wash-outs). Therefore the above assessment is subject to adequate slope profiling and drainage measures to control surface waters to prevent concentrated surface water run-off from damaging the slopes.

4. Rock-fall Analysis

4.1 Methodology

Rock-fall analysis has been conducted at selected profiles across the site to assess the trajectory, run-out distance and bounce height of falling rocks. The results of this assessment have been used to estimate the preliminary exclusion zone widths around the quarry faces. The analyses were carried out using the commercially available software RocFallTM V6 produced by Rocscience Inc.

Rock-falls in Hornsby Quarry are expected to be caused by climatic events (e.g. pore pressure rise due to rainfall event) or biological events (e.g. root growth) that change the equilibrium of the forces acting on the rock. Once the rock's movement has been initiated, some of the most important factors controlling its trajectory, run-out distance and bounce height are the geometry of the slope, the retarding capacity of the slope surface and the rock block elastic characteristics.

4.1.1 Geometry of the slope

Rock-fall modelling has been conducted at one section at each of the east, west and south quarry walls and at two sections at the northern wall. The slope profiles used for the modelling were extracted from the survey data and sections provided by Council. The profile section used for the rock-fall analysis are presented below:

- North wall: Section provided by Council through the spoil mound eastern end [refer Section D, Quarry Void Option Plans 03052018).
- North wall: Section provided by Council through the spoil mound plateau at the western corner of the north wall (refer Section CH110, Hornsby Quarry – Proposed Redevelopment, Northern Spoil Mound Stability Assessment, dated August 2018).
- West wall: Section provided by Council through roughly the middle of the west wall (refer Section F, Quarry Void Option Plans 03052018).
- South wall: Section shown on previous geotechnical reports done by others through roughly the middle of the south wall (refer Section 7, Various geotechnical reports done by others).
- East wall: Section shown on previous geotechnical reports done by others through roughly the middle of the east wall (refer Section 2, Various geotechnical reports done by others).

4.1.2 Retarding capacity of the slope surface

The restitution coefficients used for the quarry faces surface material have been selected in accordance with the software default/recommended values and the published values from trials performed on sites with similar characteristics to the Hornsby Quarry site. The Table below summarises the parameters used for the assessment

Table 7 Adopted parameters for rock-fall analysis

Surface type	Tangential Restitution Coefficient		Normal Restitution Coefficient		Dynamic Friction Coefficient		Rolling Friction Coefficient	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Vegetated soil	0.55	0.02	0.25	0.02	0.50	0.04	0.50	0.04
Vegetated soil slope	0.80	0.02	0.30	0.02	0.50	0.04	0.50	0.04
Weathered rock	0.55	0.23	0.47	0.30	0.50	0.04	0.25	0.04
Bedrock outcrops	0.85	0.04	0.35	0.04	0.50	0.04	0.15	0.02
Clean hard bedrock	0.99	0.04	0.53	0.04	0.50	0.04	0.05	0.01
Gravel Road	0.85	0.04	0.35	0.04	0.50	0.04	0.15	0.02
Asphalt Road	0.90	0.04	0.40	0.04	0.50	0.04	0.10	0.01
Concrete	0.53	0.17	0.48	0.19	0.50	0.04	0.15	0.02

It should be noted that some of the dynamic friction coefficients could not be obtained from published sources and have been estimated based on the recommended correlation between the coefficient of tangential restitution and friction angle presented below:

$$\textit{Friction angle} = \frac{(1-R_T)}{R_T}$$

The adopted surface roughness spacing and amplitude of the quarry face materials are shown in the Table below:

Table 8 Adopted surface roughness spacing and amplitude

Surface type	Slope Roughness Spacing (m)		Slope Roughness Amplitude (m)	
	Mean	Std. Dev.	Mean	Std. Dev.
Vegetated soil	Not considered			
Vegetated soil slope	2.0	0.2	0.0	0.2
Weathered rock	2.0	0.2	0.0	0.2
Bedrock outcrops	1.0	0.2	0.0	0.2
Clean hard bedrock	Not considered			

Surface type	Slope Roughness Spacing (m)		Slope Roughness Amplitude (m)	
	Mean	Std. Dev.	Mean	Std. Dev.
Gravel Road	0.05	0.01	0.0	0.005
Asphalt Road	Not considered			
Concrete	Not considered			

4.1.3 Rock block characteristics

Rigid body rock-fall analysis was selected for the assessment to take into account the geometric shape of the falling rocks. This type of analysis is expected to provide a more realistic simulation of the actual rock-fall events. Thus, a wide range of geometric shapes has been contemplated (i.e. spherical, hexagonal, octagonal, square and rectangular shapes) to ensure that all the possible rock block configurations are covered by the analysis. The model has also considered that angular boulders with moderately sharp edges will predominate over boulders with smooth edges.

A typical rock block weight of 350 kg and density of 2700 kg/m3 have been adopted for the rock-fall analysis. These values would roughly correspond to a cube of 0.5 m long edges or a sphere of 0.3 m radius. These dimensions are in line with the typical boulder's dimensions observed on site.

Figure 32 Boulders at the top of the Northern Spoil Mound and bottom of South wall

The rock-fall analysis results are presented in Appendix B. The results have been divided in two groups, viz: rounded geometric shapes (i.e. spherical, hexagonal and octagonal shapes) and blocky geometric shapes (i.e. square and rectangular shapes) based on the observed modelled behaviour of these groups. Rounded shaped rocks will achieve longer run-out distances and greater bounce heights than blocky shaped rocks.

It should be noted that despite the effort made to reproduce the exiting site conditions and to achieve a realistic simulation of the actual rock-falling events, the results presented in this section and in Appendix B are preliminary. As suggested in Section 8 of this report, rock-fall trials should be conducted to better define the extents of the proposed exclusion zone around the quarry floor and/or rock-fall prevention measures. It is likely that following rock-fall trials the simulated run-out distances will be substantially reduced once trial data is available to calibrate the models.

4.2 Rock-fall analysis sections

4.2.1 North wall

The north wall comprises six quarry benches with steeply inclined batters and one more gently inclined batter covered with dense grasses, shrubs and scattered trees that forms the northern spoil mound face. Once the quarry void backfilling is completed, the lower three benches will be buried and rock-falls could only be initiated from the spoil mound batter or the three uppermost bench batters (refer to Figure 33).

Figure 33 Indicative final filling level at the quarry northern wall

Furthermore, from the latest documentation received from Council (refer Hornsby Quarry – Proposed Redevelopment, Northern Spoil Mound Stability Assessment, dated August 2018) it is understood that Council will present Option 5A for the Environmental Impact Statement (refer to Figure 34). This option comprises a regrading of the spoil mound western end to an approximate 1V:2H batter to allow for better regeneration of trees and to use the exceeding spoil as backfill in the quarry void. The eastern end of the mound will also be slightly altered in order to remove an over-steep area, improving the local stability of this section.

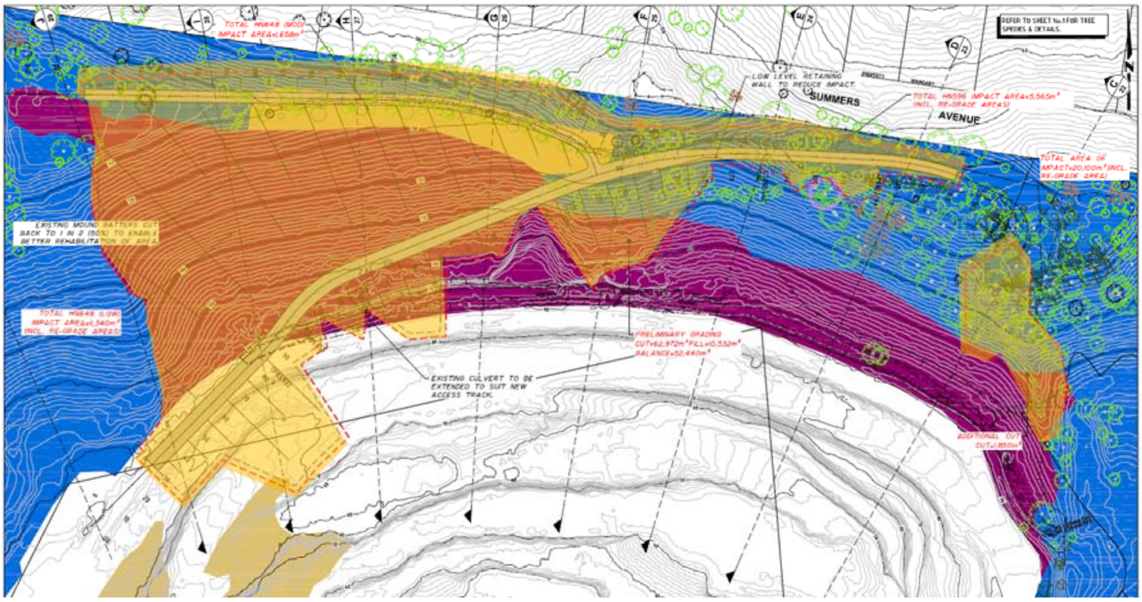


Figure 34 Scheme proposed geometry – Northern Spoil Mound

Two rock-fall analyses have been conducted on the northern quarry face:

- First analysis: section through the western end of the mound with the regraded geometry;
- Second analysis: section through the eastern end of the mound using its current geometry.

The results of the first analysis indicate that all the rock-falls initiated at the top of the existing spoil mound were contained within the spoil bund slope before reaching the uppermost quarry bench. The results of the second analysis indicate that all the rock-falls initiated at the top of the existing spoil mound were contained within the slope and the uppermost northern quarry bench at roughly RL 90mAHD.

Additionally, the model showed that less than 50% of the rocks got to the uppermost quarry bench and that, out of those, 95% of the boulders are contained within the existing concrete drainage channel. Approximately 1% of the boulders that are not retained by the channel reach the proposed access track, leaving the remaining 4% contained within the uppermost northern quarry bench. Thus, it is expected that the large majority of the rock-falls reaching the access track or the quarry void floor would originate in the lower quarry benches.

Note these results will be refined during later design phases when rock-fall trial data is available and design measures implemented accordingly where / if required.

4.2.2 West wall

A series of retaining structures have been proposed as part of the Hornsby Quarry Parkland Development project to allow vehicle access Thus, only rock-falls initiated within the natural hill slope adjacent to the uppermost quarry bench are expected to impact on the proposed access tracks (refer to Figure 35).

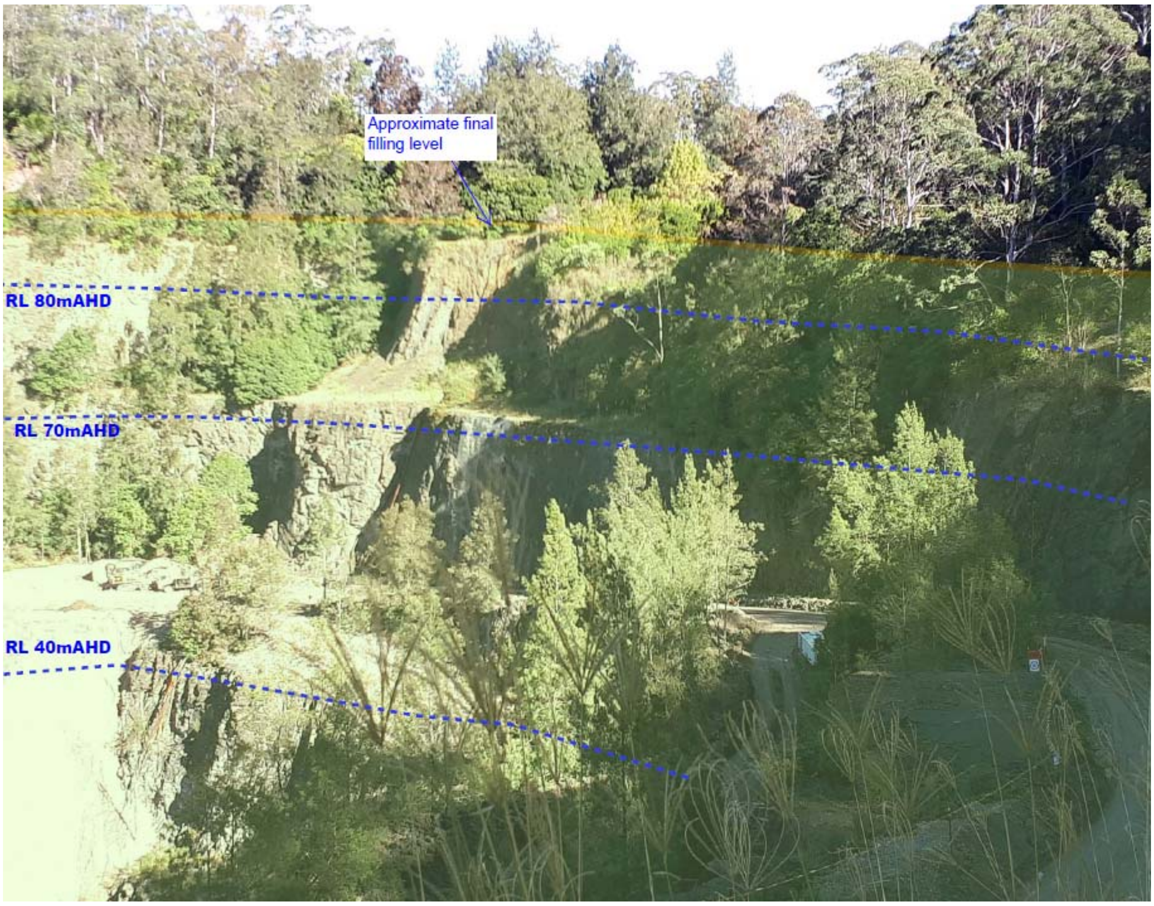


Figure 35 Indicative final filling level at the quarry western wall

The results of the analysis conducted on the west wall section profile indicate that all the rock-falls initiated near the top of the hill will be contained within the batter slope due to the existing dense vegetation. Similarly, most of the boulders falling from the lower half of the hill will be stopped within the slope of the hill and will not reach the access track bench at approximately RL 88mAHD.

4.2.3 South wall

The south eastern wall comprises one steeply inclined batter that appears to be defined by a previous planar sliding failure along the muddy breccia band and two lower quarry benches. The western end of the south wall comprises four steeply inclined batters. The two lower quarry benches will be covered once the filling of the quarry void is completed (refer to Figure 36).

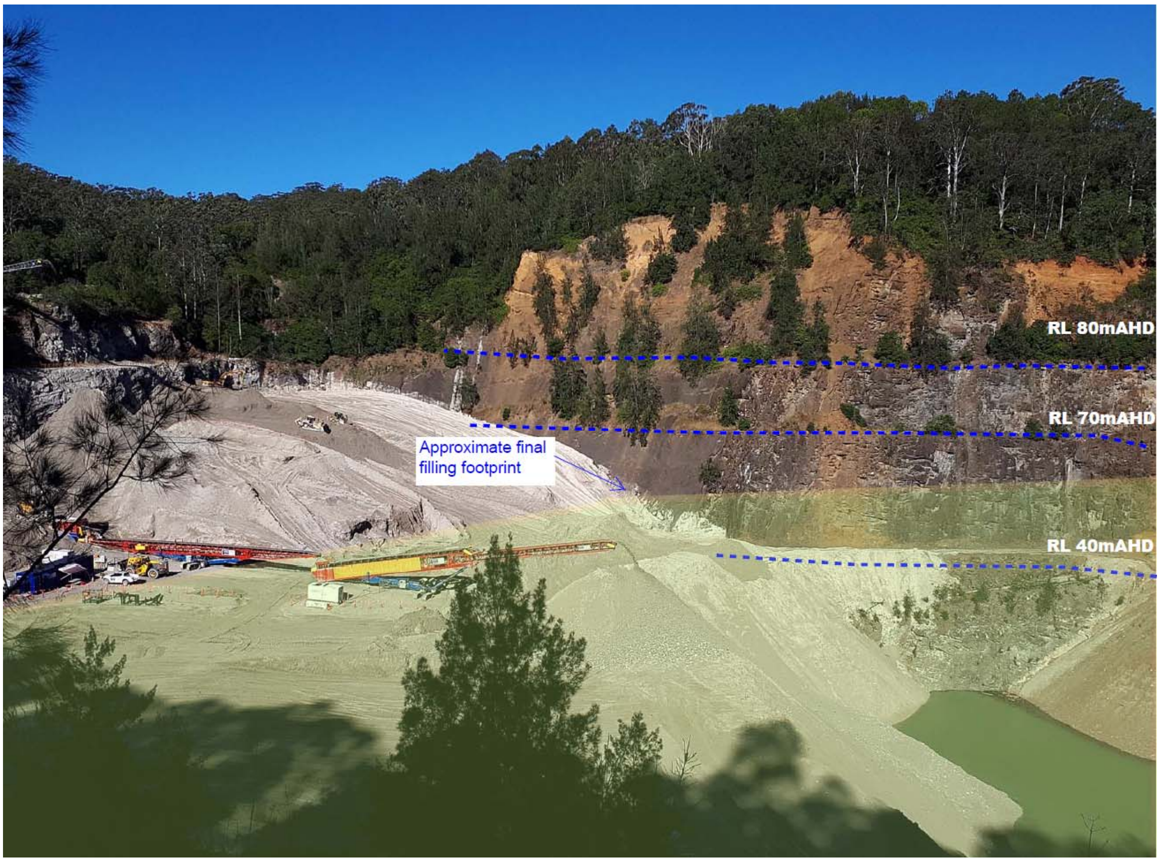


Figure 36 Indicative final filling level at the quarry southern wall

The results of the analysis conducted on the south wall section profile indicate that the majority of the rock-falls initiated just below the southern access track will have a run-out distance across the backfilled quarry floor of up to 30m. The rock-fall modelling shows that the benches are not sufficiently wide to contain most of boulders.

4.2.4 East wall

The east wall comprises five steeply inclined batters up to 30m in height of which only the uppermost three will be exposed once the void is backfilled (refer to Figure 37).

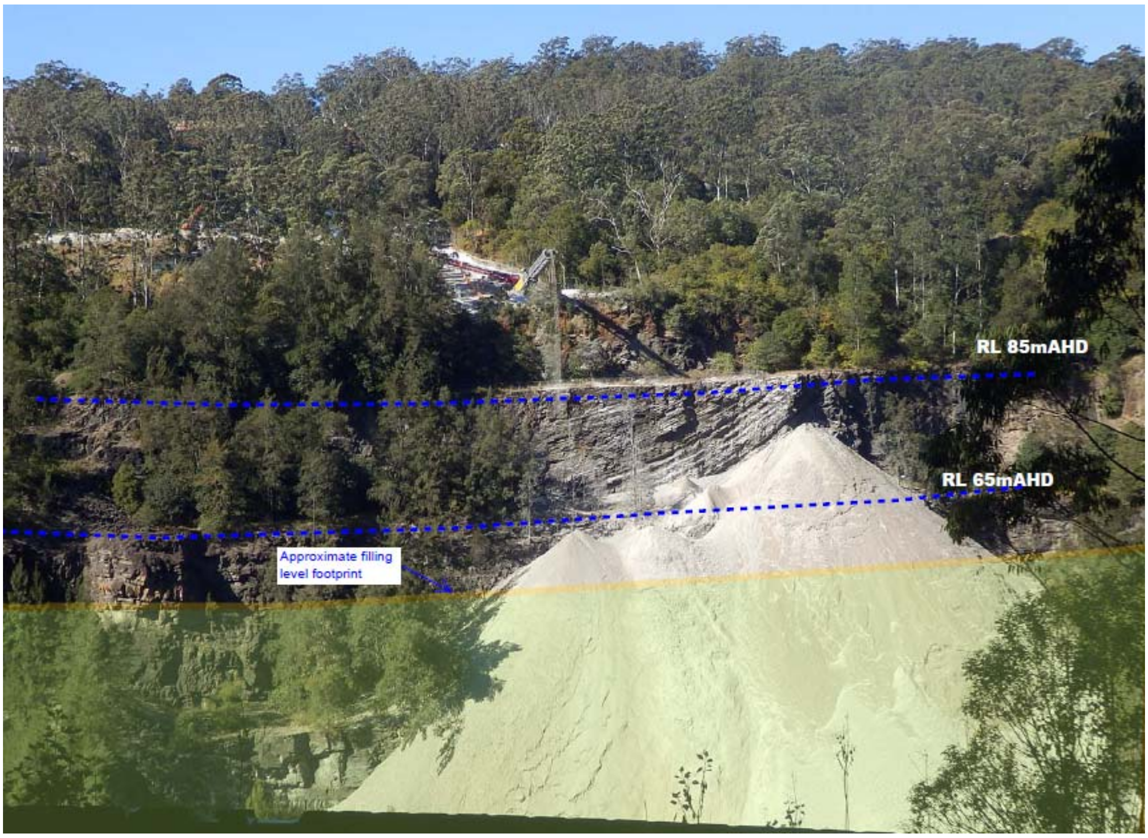


Figure 37 Indicative final filling level at the quarry eastern wall

The results of the analysis conducted on the east wall section profile indicate that more than half of the rock-falls will be contained within the uppermost quarry bench at approximately RL 85mAHD. Only about 20% of the boulders will reach the backfilled quarry floor with run-out distances of up to 17m (i.e. rock blocks will fall into the proposed lake feature).

4.3 Summary of results

The results of the analysis conducted on the different wall sections are summarised in Table 9 and graphically shown in Figure 38.

Table 9 Summary of rock-fall analysis results

Quarry wall	Section ID	Seeder Location	Rock shape	Run-out distance into quarry floor(m)
East Wall	Section 2	Top of East Wall	Rounded	16.97
			Rectangular	9.73
West Wall	Section F	Top of hill	Rounded	NA
			Rectangular	NA
North Wall	Section D	Top of Northern Spoil Mound	Rounded	NA [1]
			Rectangular	NA [1]
		Top of proposed RW02 / RW03A	Rounded	12.67
			Rectangular	13.67
	Section CH110	Top of Northern Spoil Mound	Rounded	NA
			Rectangular	NA
South Wall	Section 7	Below southern access track	Rounded	29.7
			Rectangular	26.2

Notes:

1. About 1% of the rock blocks reach the proposed access trackbut do not reach the quarry floor.

4.4 Conclusions

The above results are likely to be a “worst case” and should be revisited and refined following rock-fall trials. The refined results can be used to finalise rock-fall mitigation locations and measures including:

- Catch pitches or bunds;
- Catch fences; and
- Exclusion areas.

The above final solutions can be adopted as appropriate to reflect the final park design requirements for aesthetics and access, using control measures to reduce the extent of the exclusion zones where required.

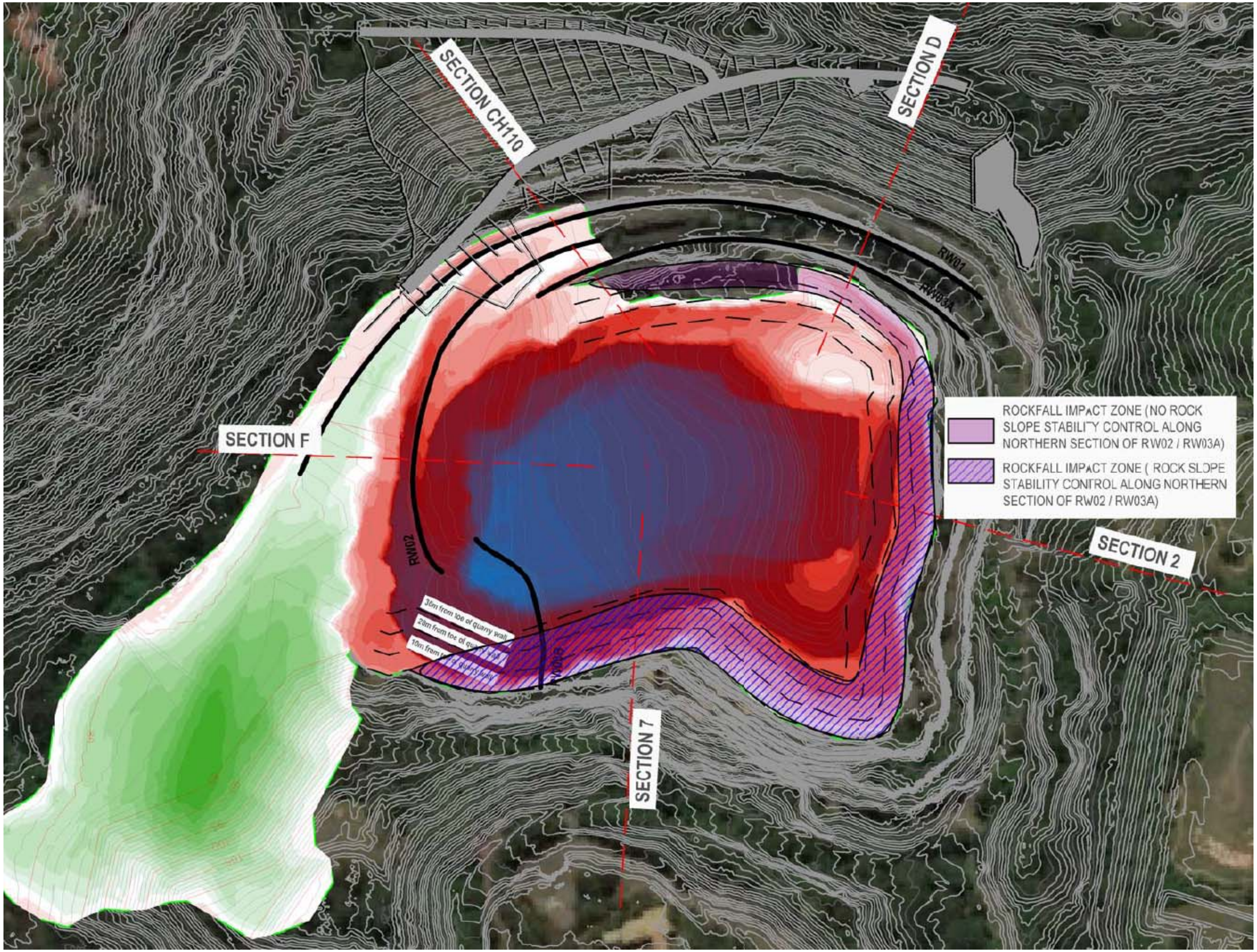


Figure 38 Indicative rock-fall impact zone into quarry floor

5. Quarry Access – Retaining Structures and Cuts

5.1 Introduction

As part of the quarry rehabilitation proposal existing access tracks are required to be widened and new earth retaining structures built to afford car parking areas and pedestrian access to the new facilities.

The following sections describe the process, rationale employed and resulting outcomes from examining the functional requirements to develop appropriate concept design retaining structures. It should be noted that the level of assessment undertaken is only sufficient establish feasible concepts. Additional investigation and design development work will be required to develop the design measures more fully for potential future tender activities.

5.2 Structural Forms and geometries

From examination of the required parkland geometry, access and ground conditions the following factors drive the selection of appropriate access widening or soil retaining solutions:

- Distance from the proposed retaining solution to the existing quarry face. It is noted that the design of reinforced soil structures is to be in accordance with RMS QA Specification R57 which specifies the minimum soil reinforcement length as a function of the wall height. Thus, deck structures will be proposed for those cases where a reinforced soil wall cannot fit due to space constraints.
- Depth of quarry void backfill. It is noted that large settlement values are expected in areas where considerable fill thickness is being placed. Flexible soil retaining solutions such as reinforced embankments or staged construction to let settlement dissipate to acceptable levels prior to completion of the track are suggested for these areas.

In order to define the most suitable access widening solution, GHD prepared a set of drawings containing sections every 20m showing the proposed parkland geometry [Ref: Quarry Void Option Plans 03052018, dated May 2018] superimposed to the existing quarry survey. Figure 32 shows an extract of Council’s proposed parkland geometry and the naming adopted for the proposed retaining elements for future reference.

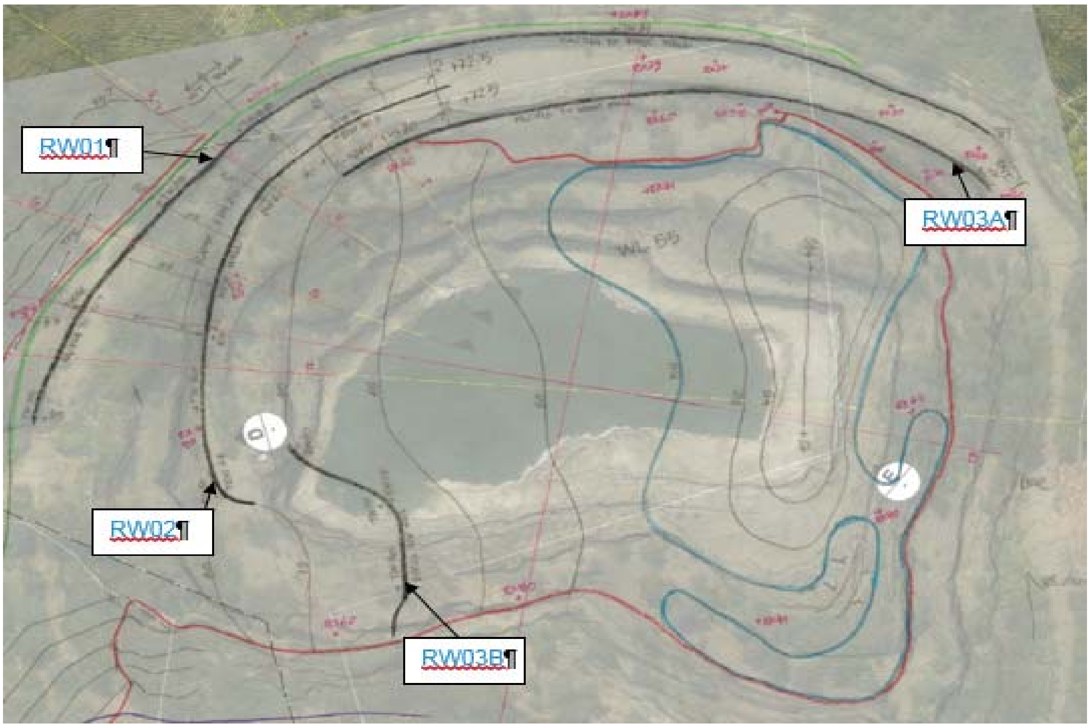


Figure 39 Proposed parkland geometry

After examination of the produced sections, the following observations are made in Table 10 and visually plotted in Figure 40.

Table 10 Summary of proposed retaining elements

Element ID	Approximate length (m)	Observations
R0W01	440	Distance from the rock face is not sufficient to fit a reinforced earth structure for the first 260m starting from the eastern side of the quarry. Pier & deck structures (Refer to Section 5.4) will need to be considered if the existing access above RW01 requires widening. RW01 cuts into the existing western quarry walls for the final 180m. Sections where widening is not required or the proposed geometry cuts into the existing quarry may need rock slope stabilisation measures (bolts, mesh or facing) for instability areas identified via geological mapping during detailed design and construction phase.
RW02	200	Retaining wall solution. Reinforced Soil Wall (RSW) type proposed.
RW03A	260	Distance from the rock face is not sufficient to fit a reinforced earth or gravity retaining wall structure for the first 200m starting from the eastern side of the quarry. Pier & deck structures (Refer to Section 5.4) will need to be considered if the existing access requires widening.

Element ID	Approximate length (m)	Observations
		Sections where widening is not required may need rock slope stabilisation measures (bolts, mesh or facing) for instability areas identified via geological mapping. Final 60m: RSW or reinforced embankment.
RW03B	70	Possible retaining wall solution (RSW) or reinforced embankment for the section close to the quarry wall. Roughly 40m of RW03B are located within a deep fill area (backfill thickness over 55m). Settlements in this area are expected to be greater than the allowable design standard requirements. Therefore a stage approach to construction and/or ground improvement may be required subject to further investigation and detailed design.

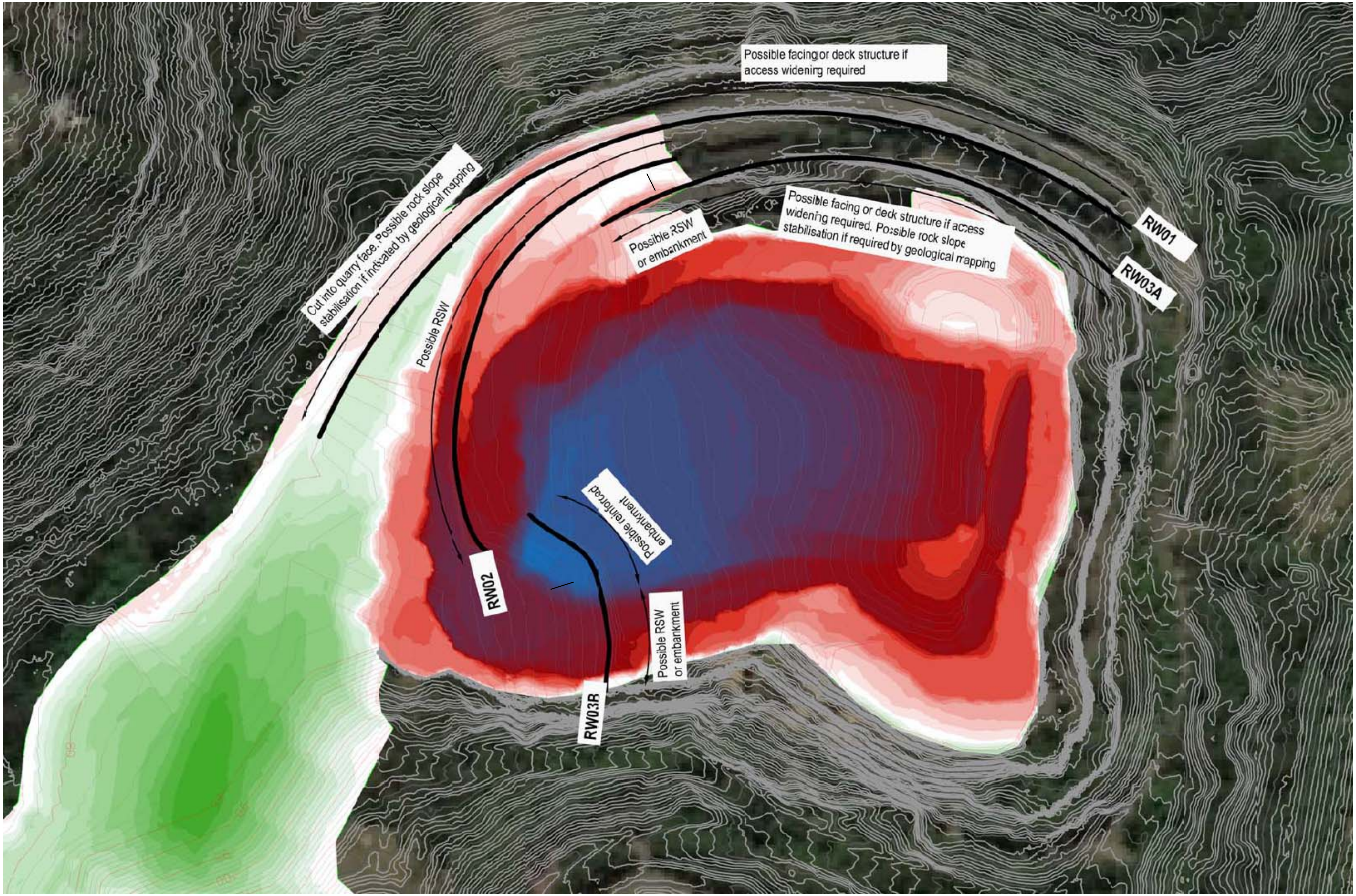


Figure 40 Visual summary of proposed retaining elements with observations

5.3 Reinforced Soil Walls

Preliminary internal and external stability analyses of the Reinforced Soil Wall (RSW) block have been conducted in compliance with RMS QA Specification R57. The intent of this concept RSW design is to evaluate the dimensions and reinforcement of the RSW block to satisfy the internal stability (i.e. capacity check against slip failure inside the RSW block) and external stability (i.e. capacity checks against sliding, overturning, eccentricity, bearing and global slip failures) requirements specified in RMS QA Specification R57.

It is highlighted that a geotechnical investigation and laboratory testing will be proposed to assess the strength properties of the backfill material. Thus, assumptions and interpretation of the available geotechnical data have been necessary at this stage. Consequently, the design presented in this report will be subjected to review and refinement once this information is available through later phases of design.

5.3.1 Summary of RSW retaining walls

The details of the RSW retaining walls under consideration are presented in Table 11.

Table 11 Summary of RSW details

RSW ID	Approximate length (m)	Maximum retained wall height (m)[1]	Maximum RSW block width (m)
RSW02	200	2.5 to 10.5	3.0 to 10
RSW03A	60[2]	0.0 to 7.0	0.0 to 7.0
RSW03B	70[3]	2.5 to 6.5	3.0 to 7.0

Notes:

1. RW01 not been included as it is considered a facing element or deck structure at this stage
2. Maximum retained wall height includes 0.5m embedment into founding material
3. Total length 260m (Refer to Table 10)
4. May require a staged construction approach and/or ground improvement in some areas subject to detail design.

5.3.2 Founding material

The material used to partially backfill the Hornsby Quarry void is being imported from the NorthConnex Public Infrastructure project. Up to approx. 1,000,000 cubic metres of tunnel spoil principally composed of mudstone (Ashfield Shale) and sandstone (Hawkesbury Sandstone) fragments, with sandstone predominating, will be deposited in the quarry.

5.3.3 Available geotechnical information

The quarry filling operations are ongoing and therefore, no ground investigation is available at this stage. However, a total of three California Bearing Ratio (CBR) and four Particle Size Distribution (PSD) laboratory testing result reports conducted on the stockpiled tunnelling spoil prior to be deposited into the quarry voided were made available to determine the strength parameters of this backfill material. It is highlighted that this laboratory testing does not provide a direct measurement of the material strength and, thus, correlations from published information sources have been used at this stage pending site investigation.

5.3.4 Methodology and Geotechnical design parameters

The following two methodologies have been used to estimate the strength properties of the backfill material under different compaction efforts:

Methodology 1: CBR correlation with Meyerhof's bearing capacity equation

PSD result reports have been used to classify the material in accordance with AS1726:2017.

Table 12 Summary of data inferred from PSD result reports

	Sample number			
	12385/S/215832	12385/S/215833	12385/S/215834	12385/S/215836
Material Description	*Sandstone*	*Sandstone*	*Sandstone*	*Sandstone*
Coefficient of uniformity C_u(-)	>4	>4	>4	>4
Coefficient of curvature C_c(-)	<1	<1	<1	<1
Percent passing AS sieve 0.075mm (%)	15	15	8	15
Group symbol	GM or GC (1)	GM or GC(1)	GM or GC (2)	GM or GC(1)

Notes:

1. Group symbol GM or GC for materials with more than 12% fines content. GM or GC classification depends on fines behaviour.
2. Material does not classify as GP or GM or GC as fines content is greater than 5% but lower than 12%.

The material maximum dry density (MDD), dry density when placed in the mould and CBR at 2.5mm penetration values have been extracted from the CBR result reports and are summarised in Table 13.

Table 13 Summary of data extracted from CBR results reports

	Sample number		
	12385/S/344967	12385/S/344975	12385/S/344976
Material Description	*Grey sandstone*	*Grey sandstone*	*Grey sandstone*
Maximum Dry Density (t/m^3)	2.043	2.105	2.059
Placement Dry Density (t/m^3)	2.028	2.097	2.047
Optimum Moisture Content (%)	11.3	10.0	10.5
Field Moisture Content (%)	13.8	10.6	12.9
Compaction (%)	98.7	99.6	99.1
Moisture Content Deviation (%)	2.5 wet	0.6 wet	2.4 wet
CBR surcharge (kg)	4.5	4.5	4.5
CBR value @ 5.0mm (%)	30	20	30
CBR value @ 2.5mm (%)	20(1)	15(2)	20(1)

Notes:

1. CBR value to the nearest 5% as per RMS T117
2. CBR value to the nearest 1% as per RMS T117

Based on the paper published by Gregory and Cross [Ref: Correlation of California Bearing Ratio with Shear Strength Parameters, dated January 2007], the CBR apparatus has been ressembled to a miniature shallow circular foundation on a single homogeneous soil layer as shown in Figure 14.

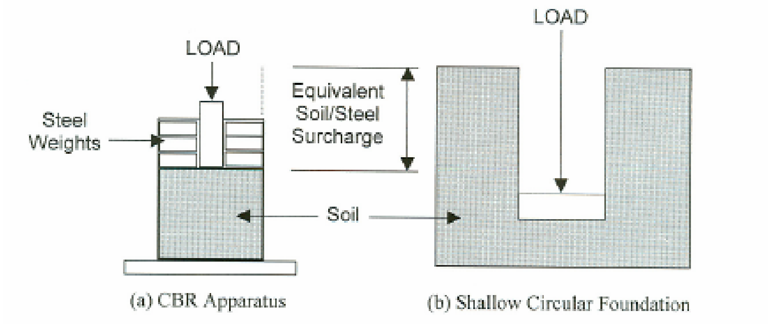


Figure 41 Visual correlation between CBR test and shallow circular foundation

This publication presents the following correlation between Meyerhof's ultimate bearing capacity equation and the CBR value at 2.5mm penetration.

$$CBR_{2.5mm} = (q_{ult} *100)/6895$$

For cohesionless soils, Meyerhof's ultimate bearing capacity equation can be expressed as:

$$q_{ult}= qN_q\ S_{q1}S_{q2}S_{q3}S_{q4}\ +\ 0.5\gamma B'N_\gamma\ S_{g1}S_{g2}S_{g3}S_{g4}$$

Where:

$\gamma =$ Soil unit weight (Dry density of the material placed in the CBR mould – 99% compaction);

q = Surcharge stress (Weight of steel disks as per RMS T117)

B' = Footing width (Piston diameter as per RMS T117)

$N_{q,}$ N = $_\gamma$Bearing Capacity Factors (Function of the material's friction angle)

S_{c1}, S_{q1}, S_{g1} = Foundation Shape Factors (Function of the material's friction angle and foundation dimensions)

S_{c2}, S_{q2}, S_{g2} = Load Inclination Factors (Not used due to vertical loading)

S_{c3}, S_{q3}, S_{g3} = Embedment factors (Function of the material's friction angle and foundation dimensions)

S_{c4}, S_{q4}, S_{g4} = Ground slope factors (Not used due to horizontal ground surface)

As it can be observed, the above equation is a function of the friction angle of the material, which can be obtained once the ultimate bearing capacity is calculated based on the CBR value. As a result of this process, friction angle values of 43° to 45° have been obtained for the spoil material at 99% compaction.

Methodology 2: Correlation between Dry Unit Weight and Relative Density

The material MDD extracted from the CBR result reports has been used to calculate the material dry density at 100%, 98%, 95% and 90% relative compaction and is presented in Table 41.

Table 14 Summary of estimated dry densities at different compactive states

	Sample number		
	12385/S/344967	12385/S/344975	12385/S/344976
Maximum Dry Density (100% compaction)	2.043 (127.5)	2.105 (131.4)	2.059 (128.5)
Dry Density @ 98% compaction	2.002 (125.0)	2.063 (128.8)	2.018 (126.0)
Dry Density @ 95% compaction	1.941 (121.2)	2.000 (124.9)	1.956 (122.1)
Dry Density @ 90% compaction	1.839 (114.8)	1.895 (118.3)	1.853 (115.7)

The material relative density (Dr) has been inferred based on Holtz empirical equation that relates relative compaction and relative density:

$$RC = 80 + 0.2\ Dr\ (Dr > 40\%)$$

Where:

RC = Relative Compaction;

Correlation chart between material relative density, dry density and classification from NAVFAC DM 7.01, 1986 has been used to estimate the material's friction angle for different compaction efforts. As it can be observed, all samples classify as gravel / sand mixtures which is in line with the results presented in the PSD reports and the fact that fractions larger than 19mm need to be removed from the samples to conduct the CBR testing as per RMS T117.

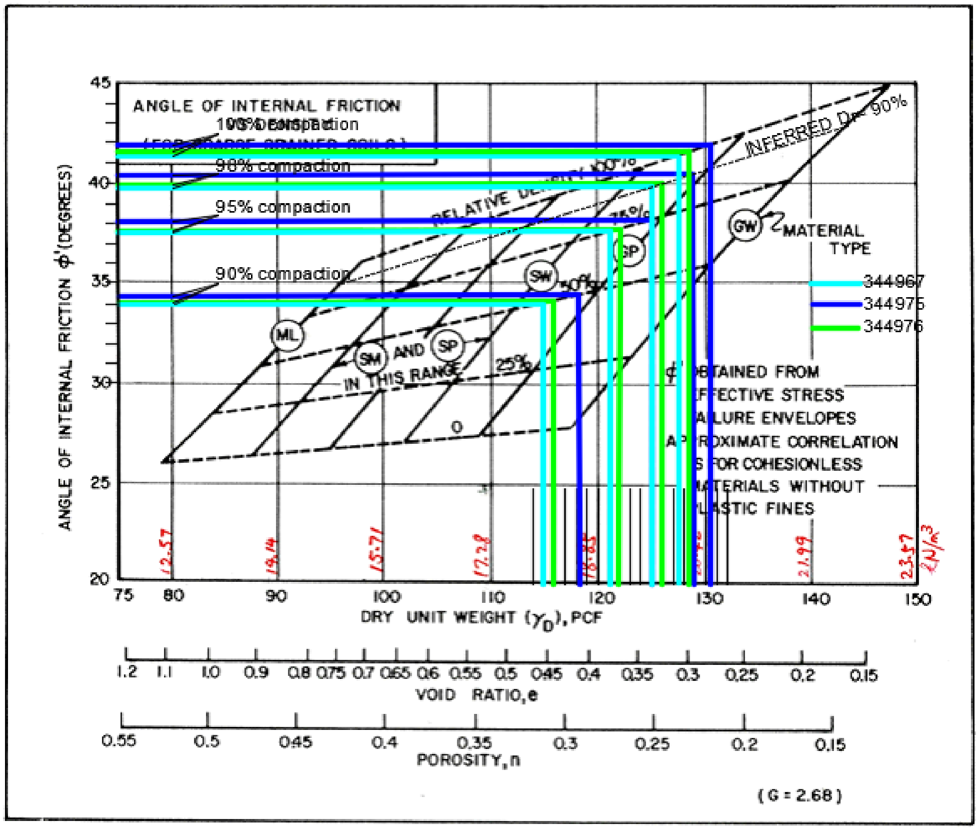


FIGURE 7
Correlations of Strength Characteristics for Granular Soils

Figure 42 Correlation between dry density and friction angle for granular soils

Table 15 Summary of results obtained from methodology 2

	Sample Number		
	12385/S/344967	12385/S/344975	12385/S/344976
Material @ 100% compaction	41.5	42	41.5
Material @ 98% compaction	40	40.5	40
Material @ 95% compaction	37.5	38	37.5
Material @ 90% compaction	34	34.5	34

Summary

Similar friction angle values have been obtained from the two approaches based on different correlations, being more conservative the results obtained from correlations between the material's dry unit weight and its relative density. Thus, the following strength parameters have been adopted for the preliminary design of the retaining structures:

Table 16 Adopted strength parameters for quarry void backfill material at different compactive states

Compaction Effort	Dry Density Y' (kN/m^3)	Undrained Shear C' (kPa)	Friction Angle Φ' (°)
Material @ 98% compaction	20	0	40
Material @ 95% compaction	20	0	37.5
Material @ 90% compaction	18	0	34

5.3.5 Load cases

The Table below provides a description of the six load cases (A to F) recommended in Section 4.3 of RMS QA Specification R57.

Table 17 RMS QA Specification R57 – Load cases for design

Load Case	Description
A	Loads applicable during construction
B	Maximum values of all loads, excluding earthquake effects
C	Maximum overturning loads with minimum gravity loads, excluding earthquake effects
D	Dead loads with partial live loads, earthquake and differential settlement effects
E	Maximum overturning loads with minimum gravity loads, partial live loads, earthquake and differential settlement effects
F	Dead and live loads with differential settlements effects at the serviceability limit state

The loads considered in the loads combinations outlined in Table 17 for the stability analysis of the RSW are as follows:

- Dead Loads – Dead loads considered in the analysis include a combination of soil weight, reinforced block weight and groundwater weight.
- Live loads – A 20kPa surcharge live load above and behind the RSWs has been considered to represent the loadings induced by construction operations, traffic and pedestrian transit.
- Collision Loads – An ultimate horizontal barrier collision impact of 100 kN/m has been conservatively considered in accordance with AS5100.2. This load will be refined once the parkland development trackdesign is available.

- Earthquake Loads – The earthquake hazard factor (Z) adopted for the project area is 0.09 as shown in Figure 3.2(A) of AS1170.4:2007. Based on Table R57.2 of RMS QA Specification R57, this corresponds to a nominal horizontal pseudo-static acceleration coefficient, kh, of 0.07 and a design horizontal acceleration coefficient, a_{ih}, of 0.097. As the RSW's do not support a bridge sill beam, the design vertical acceleration coefficient, a_{iv} , is taken as zero.

5.3.6 Design methodology and results

Internal design

GHD has undertaken a preliminary design of the reinforced block to provide Council with a feasible retaining system solution that could be used for costing purposes. However, it is noted that, as stated in RMS QA Specification R57, the internal wall design of the RSW system is to be undertaken by the respective system owner engaged to build the RSW.

It is highlighted that, as recommended in RMS QA Specification R57, a material with effective friction angle no greater than 36° has been adopted for the RSW backfill material on the assumption that site specific test data will be available before commencement of construction.

Furthermore, the available Green Terramesh system specification sheet (refer MacCaferri, Greeen Terramesh System – Contractors sheet, dated June 2015) has been used as a guideline to define the RSW geometry and reinforcement requirements (refer to Appendix C).

A summary of the results for the preliminary internal design for different RSW heights is summarised in the Table below and included in Appendix D.

Table 18 Summary of preliminary RSW dimensions and internal reinforcement

RSW ID	Wall Height (m)	Face inclination (°)	Reinforcement type	Reinforcement length (m)	Reinforcement vertical spacing (m)
RW02/RW03	5.5	70	GX 100/30	6	0.6
RW02	8.5	70	GX 100/30	8	0.6
RW02	10.5	70	GX 100/30	10	0.6

External design

The failure mechanisms detailed in the following sections have been considered when conducting the external design of the retaining structure. It is highlighted that the results presented have been calculated on the assumption that the quarry void backfill immediately beneath the RSWs will be fully compacted (i.e. 98% compaction or better). The thickness of the fully compacted backfill layer has been assessed to satisfy the RSW global stability requirements (Refer to section *Global slope failure*).

Bearing failure

The general form of bearing capacity equation proposed by Meyerhof (1963) has been used to calculate the ultimate bearing capacity of the underlying material with shape, depth and inclination factors considered. The ultimate bearing capacity (q_{ult}) in its general form is expressed as:

$$q_{ult}= cN_c\, S_{c1}S_{c2}S_{c3}S_{c4} \;+\; \gamma DN_q\, S_{q1}S_{q2}S_{q3}S_{q4} \;+\; 0.5\gamma B'N_\gamma\, S_{g1}S_{g2}S_{g3}S_{g4}$$

The above equation incorporates the following factors to account for:

S_{c1}, S_{q1}, S_{g1} = Foundation Shape Factors

S_{c2}, S_{q2}, S_{g2} = Load Inclination Factors

S_{c3}, S_{q3}, S_{g3} = Base tilt factors

S_{c4}, S_{q4}, S_{g4} = Ground slope factors

For retaining walls subjected to eccentric loading, the resultant vertical load shall be inside the middle third of the base width (i.e. $e < B/6$). A reduced effective contact width, B', needs to be considered for calculating the ultimate bearing capacity, that is:

$$B' = B - 2e$$

Where:

B = actual base width;
B' = effective base width; and
e = eccentricity.

A summary of the factors of safety obtained for the critical load case (Load case B as defined in Table 17) and wall heights is presented in Table 19. Results for all the load cases specified in RMS QA Specification R57 are included in Appendix E.

Table 19 Summary of factors of safety against bearing failure

Wall height (m)	Load case	Eccentricity (m)	FoS [1]
5	B	0.18	5.50
8	B	0.70	3.33
10	B	1.36	2.20

Notes:

1. Minimum required FoS≥ 1.0 (Loads have been factored up in accordance with RMS QA Specification R57)

Sliding failure

Base shear resistance was assessed in accordance with section 4.7.2 of RMS QA Specification R57.

In a similar approach to the bearing capacity assessment outline in the previous section, sliding resistance will be considered over a reduced footing width, B'.

A summary of the factors of safety obtained for the critical load cases (Load case C and E as defined in Table 17) and wall heights is presented in Table 20. Results for all the load cases specified in RMS QA Specification R57 are included in Appendix E.

Table 20 Summary of factors of safety against sliding failure

Wall height (m)	Load case	Eccentricity (m)	FoS [1]
5	C / E	0.99 / 0.50	1.00 / 1.13
8	C / E	0.31 / 0.14	1.31 /1. 31
10	C / E	0.71 / 0.69	2.44 / 2.23

Notes:

1. Minimum required FoS≥ 1.0 (Loads have been factored up in accordance with RMS QA Specification R57)

Overturning failure

The moments acting about the toe of the RSW block are evaluated to check for overturning potential and the eccentricity, e, for the different load cases was calculated to ensure that the resultant load falls within the middle third of the wall base.

A summary of the factors of safety obtained for the critical load cases (Load case C and E as defined in Table 17) and wall heights is presented in Table 21. Results for all the load cases specified in RMS QA Specification R57 are included in Appendix E.

Table 21 Summary of factors of safety against overturning failure

Wall height (m)	Load case	Eccentricity (m)	FoS [1]
5	C / E	0.99 / 0.50	1.81 / 2.40
8	C / E	0.31 / 0.14	6.27 /6.56
10	C / E	0.71 / 0.69	5.21 / 5.11

Notes:

1. Minimum required FoS≥ 1.0 (Loads have been factored up in accordance with RMS QA Specification R57)

Global slip failure

The overall stability of the RSW's has been assessed using Geostudio's Slope/W 2012 package software commercially available from GEO-SLOPE International Pty. Ltd. The Morgensten-Price limit equilibrium method was adopted to undertake the global stability check of the selected critical RSW section (wall height of 10m) for both circular and non-circular failure surfaces in accordance with section 4.7.4 of RMS QA Specification R57. Similarly, a minimum design factor of safety (FoS) of 1.35 for RSW's not supporting bridge abutments has been adopted as required by RMS QA Specification R57.

An iterative process varying the thickness of the fully compacted backfill layer immediately below the RSW has been conducted to satisfy the global stability requirements. It should be noted that this depth from where a full scheme of compaction has to be carried out is indicative and will need to be reviewed once the geotechnical investigation and laboratory testing proposed to assess the strength properties of the backfill material are completed.

The results of the stability analyses undertaken for a RSW height of 10m are presented in Table 22 and the graphical outputs from Slope/W are included in Appendix F.

Table 22 Summary of assessed FoS for global stability failure

Adopted bottom RL of fully compacted material beneath RSW	Load Case	Target FoS	Assessed FoS (Circular failure)	Assessed FoS (Non-circular failure)
65mAHD	Short term	1.35	1.77	1.64
	Long term		1.60	1.50
	Earthquake		1.41	1.34[1]
	Rapid drawdown		1.52	1.43

Notes:

1. Result below required FoS of 1.35 to be reviewed once the proposed geotechnical investigation and laboratory testing is completed.

Settlement

Surface settlement of the tunnelling spoil backfill is expected to be dependent on the self weight and compactive state of the material, additional loading and the inundation of the back-fill material by surface water infiltration and groundwater rise. Although surface water derived from precipitation is not considered a significant contributor to the backfill settlement as limited infiltration of moisture to deeper levels is to occur due to natural segregation and weathering of the backfill material exposed at the surface, water infiltration through the quarry walls as a result of regional recharge of groundwater derived from rainfall events is envisaged as the main factor responsible for long term and deep seated settlement.

Opencast backfills are principally subjected to settlement by means of two mechanisms, namely creep settlement and collapse settlement:

Creep settlement

The mechanism for creep settlement is one gradual re-arrangement of the material fragments resulting in a reduction in the voids ratio due to the crushing of highly stressed contact points. Sowers et al, examining creep behaviour as seen in earth/rockfill embankments, demonstrated that creep settlement generaly follows a log-time relationship that can be described by the following general equation:

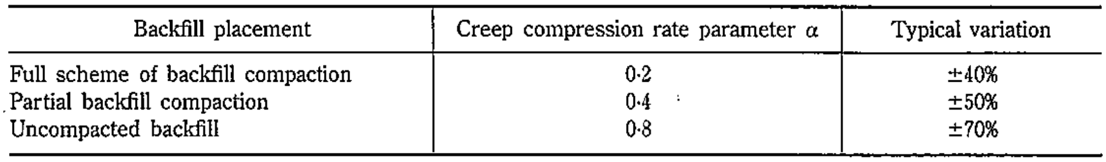
$$S = \alpha H \log (t/t_0)$$

Where:

- S = settlement;
- α = coefficient of creep (% per log cycle of time);
- H = fill thickness;
- t = time at which settlement is to be calculated; and
- t_0 = ‘zero time’ or starting time from which settlement is calculated.

The following observations are highlighted:

- The time at which settlement begins is in most cases indefinite as the lowest layers will have started to settle before the upper ones are placed.
- Based on published literature, measured α values show an approximate inverse relationship with measurements of the compactive state of the material (i.e. values ranging from 0.1 to 0.3 where a full scheme of backfill compaction was carried out to values in excess of 1.0 where no compaction was applied). The Figure below presents an indicative creep compression rate values for different compaction effort [Ref: The prediction of opencast backfill settlement, C.W.W. Hills and B. Denby, dated September 1996]:



Backfill placement	Creep compression rate parameter α	Typical variation
Full scheme of backfill compaction	0·2	±40%
Partial backfill compaction	0·4	±50%
Uncompacted backfill	0·8	±70%

Figure 43 Creep compression rate values for opencast backfill placed with varying degrees of compaction

- Creep settlement for compacted deep fills with light additional loading is mainly caused by the self-weight of the material. Figure 44 presents a summary of the creep compression rates versus vertical stress for rock fills derived from sedimentary rocks commonly available within the Sydney Region (refer Settlement Characteristics of Deep Engineered Fills, P.J. Wadell and P.K. Wong):

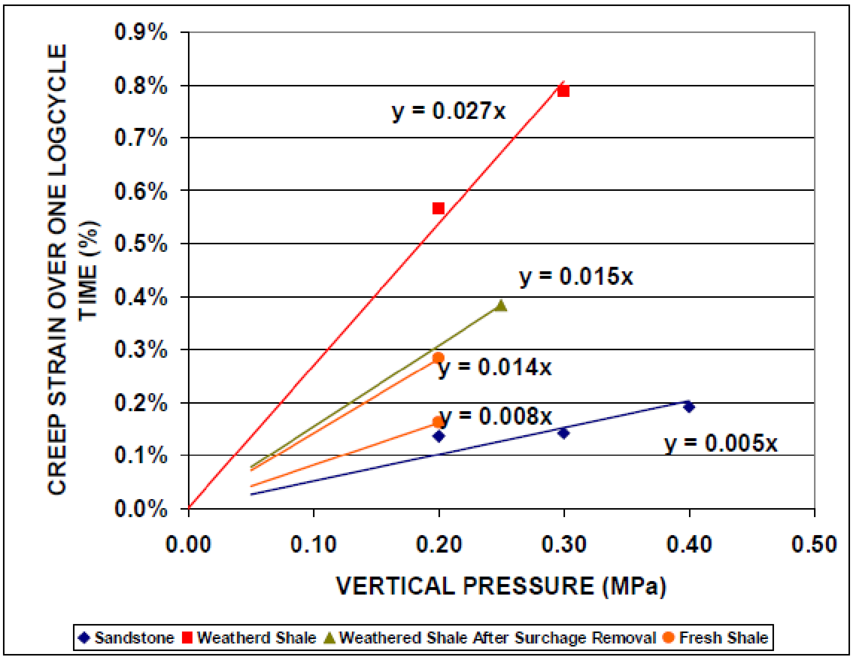


Figure 44 Correlation between creep strain rate and vertical stress for high compaction effort

Based on the review and interpretation of the published literature, the creep strain rates adopted for the material for different compaction degrees are as follows:

Table 23 Adopted creep strain rates for backfill material with varying compaction degrees

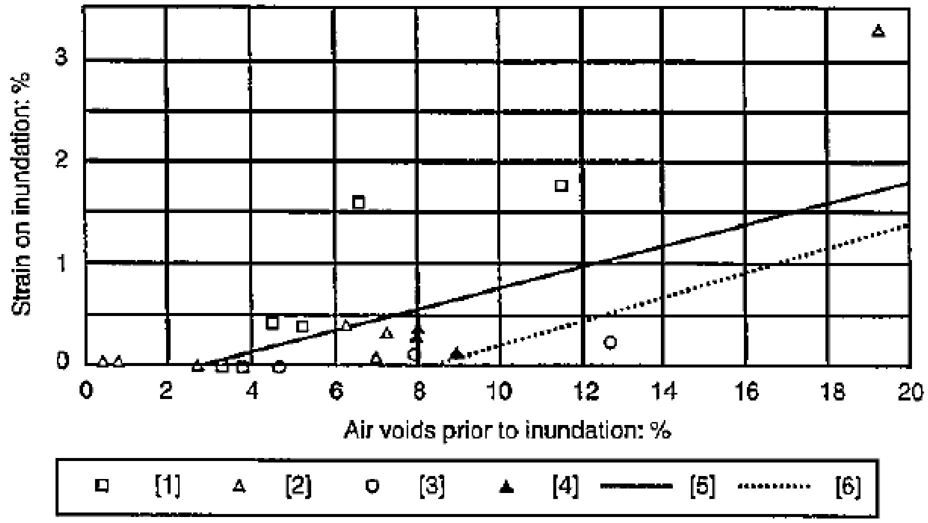
Compaction Effort	Description	α (%)
98% compaction	Full compaction scheme	0.0014 σ
95% compaction	Track compacted	0.006
90% compaction	Conveyor dumped and dozed/ spread	0.008

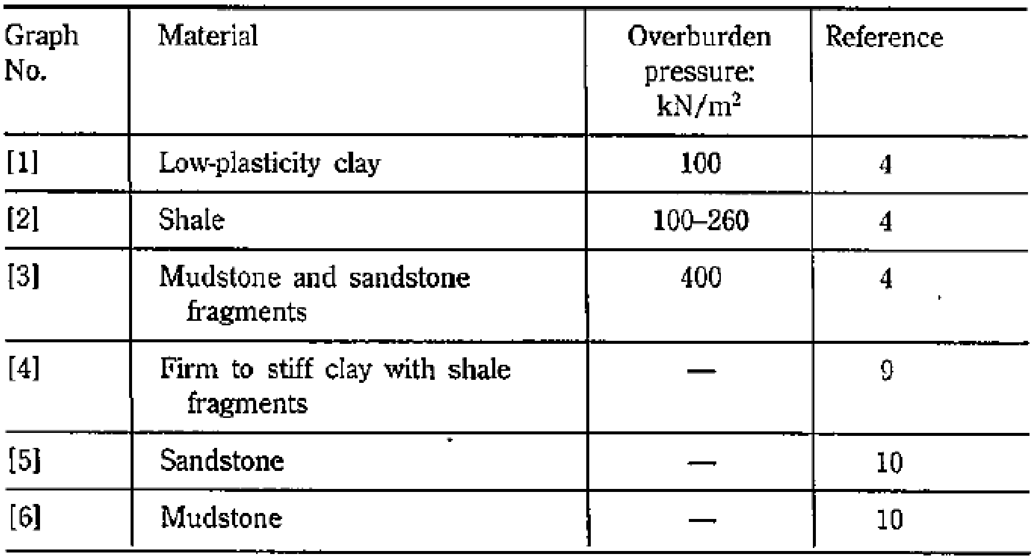
Collapse settlement

Collapse settlement consists of a volumetric change under constant total stress due to an increase in water content. In the case of Hornsby Quarry, the increase in water content is expected to occur at the deep fill layers due to the cessation of the pumping operations and gradually increase of the water level to the proposed lake feature level at RL 55mAHD.

Published research indicate that inundation is a major cause of fill settlement especially with uncompacted opencast backfills. The magnitude of collapse settlement will depend on the type of backfill, its density and moisture content, stress level and stress history. Values range from 01% to 0.4% strain at sites where backfill compaction has been carried out to 1.5% to 2.5% strain at areas where poor or no compaction was carried out.

The Figure below shows a relationship between air voids prior to inundation and collapse settlement for different backfill materials [Ref: The prediction of opencast backfill settlement, C.W.W. Hills and B. Denby, dated September 1996]:





Graph No.	Material	Overburden pressure: kN/m²	Reference
[1]	Low-plasticity clay	100	4
[2]	Shale	100–260	4
[3]	Mudstone and sandstone fragments	400	4
[4]	Firm to stiff clay with shale fragments	—	9
[5]	Sandstone	—	10
[6]	Mudstone	—	10

Figure 45 Relationship between collapse settlement and air voids prior to inundation

For this preliminary design, it has been assumed that the backfill material is at a compactive state of 90% up to the proposed lake level, at 95% compaction up to RL65 mAHD and at 98% up to the base of the retaining structures. Based on the calculated dry density at 90% compaction effort (refer to Table 14), a void content of roughly 40% of the total material volume has been estimated. From conversations with Council, it is understood that the material is being placed in the quarry void at about optimum moisture content and therefore the air void volume of the fill is expected to be much lower than the calculated total voids content. Thus, a collapse settlement strain of 1% of the inundated fill height corresponding to an approximate air void volume of 12% has been adopted for this analysis.

It is also noted that based on the hydrological study undertaken to calculate the groundwater flow into the quarry void estimates that the time to reach the proposed lake feature level is between the years 2021 and 2025. This timing will have an impact on the post construction collapse settlement as the longer it takes to achieve the lake target RL, the greater is the fill height that will be subjected to inundation after completion of the retaining structures. Thus, two time scenarios have been considered to estimate the collapse settlement based on the hydrological study outcomes.

Summary of results

Long term settlement has been estimated for a time period of 100 years (3 log cycles of time) along the proposed retaining structures alignment and at the four sections across the west wall (Section 2 to 5) shown in Figure 46

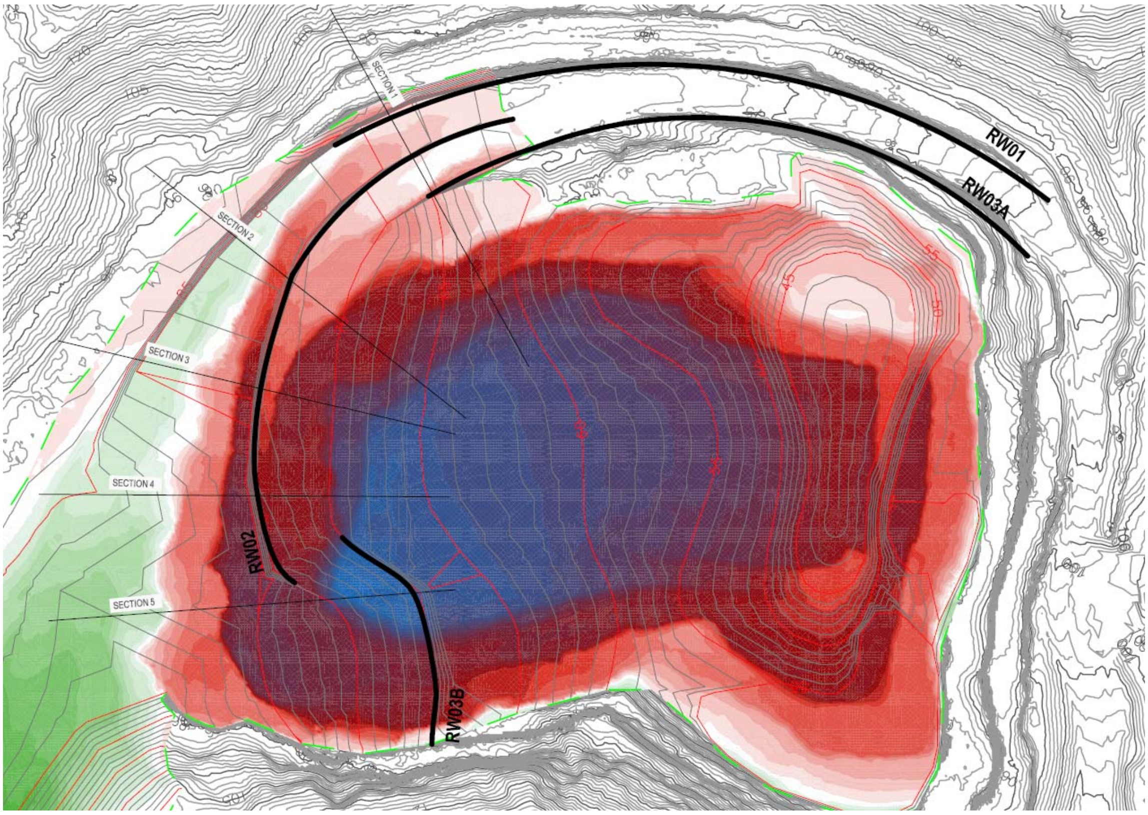


Figure 46 Study sections for analysis

Table 24 summarises the maximum settlement values along the settlement profiles obtained for the different study sections.

Table 24 Summary of maximum 100 year settlement values

Section ID	Max. Fill Thickness (m)	Max. Estimated 100 year settlement (mm)[1]	
		WT establish in 2021	WT establish in 2025
Section 2	45.6	1380	1530
Section 3	47.6	1423	1573
Section 4	50.2	1439	1589
Section 5	55.3	1468	1618
RSW02	26.2	586	586
RSW03A	6.0	114	114
RSW03B	48.9	1288	1388

Notes:

1. Maximum values at this stage are likely to be substantially over-estimates and values will be revised following more detailed investigation and settlement plate monitoring. If required relatively inexpensive ground improvement techniques could be used to reduce settlement values further.

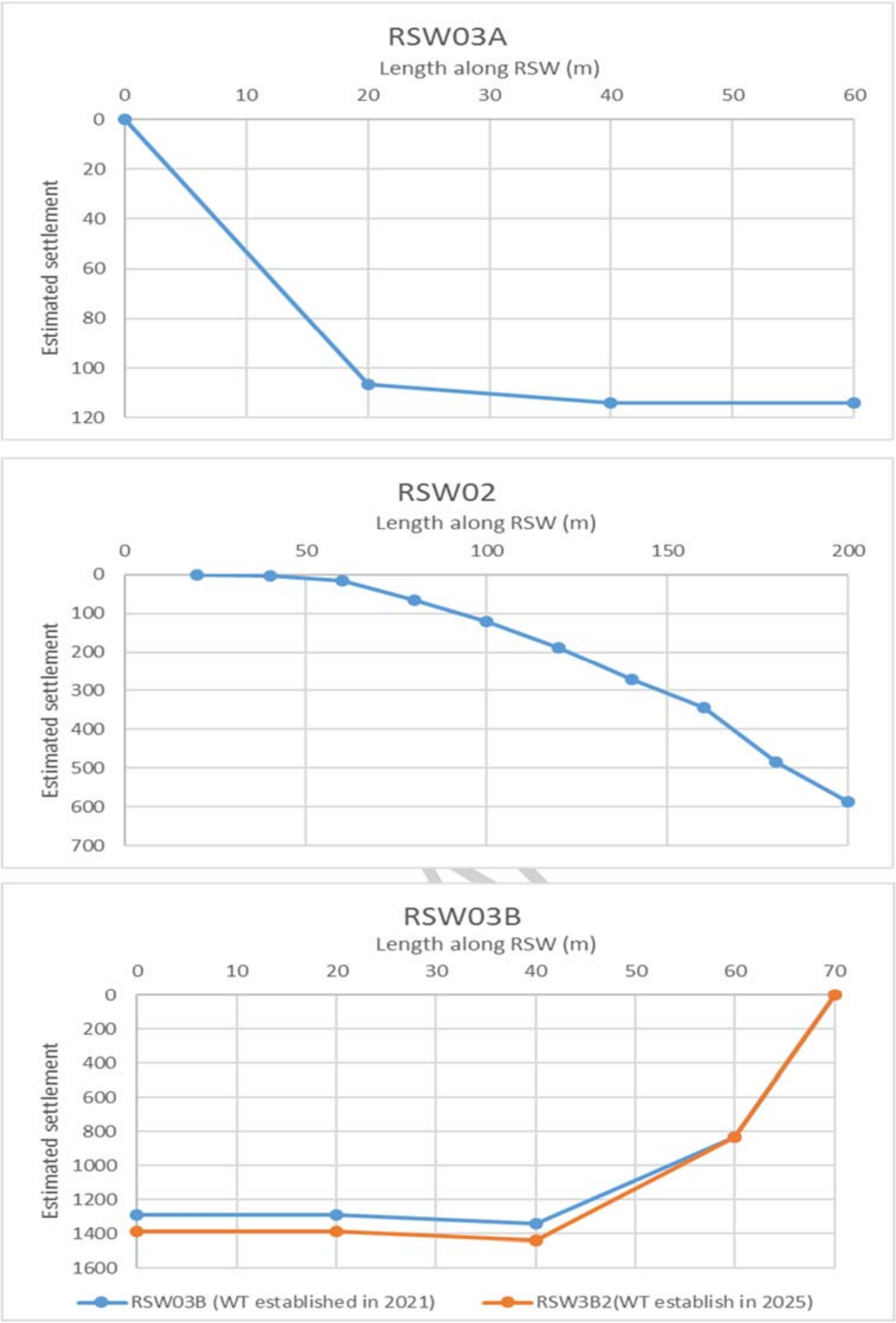


Figure 47 Settlement profiles along proposed RSWs, 100 years

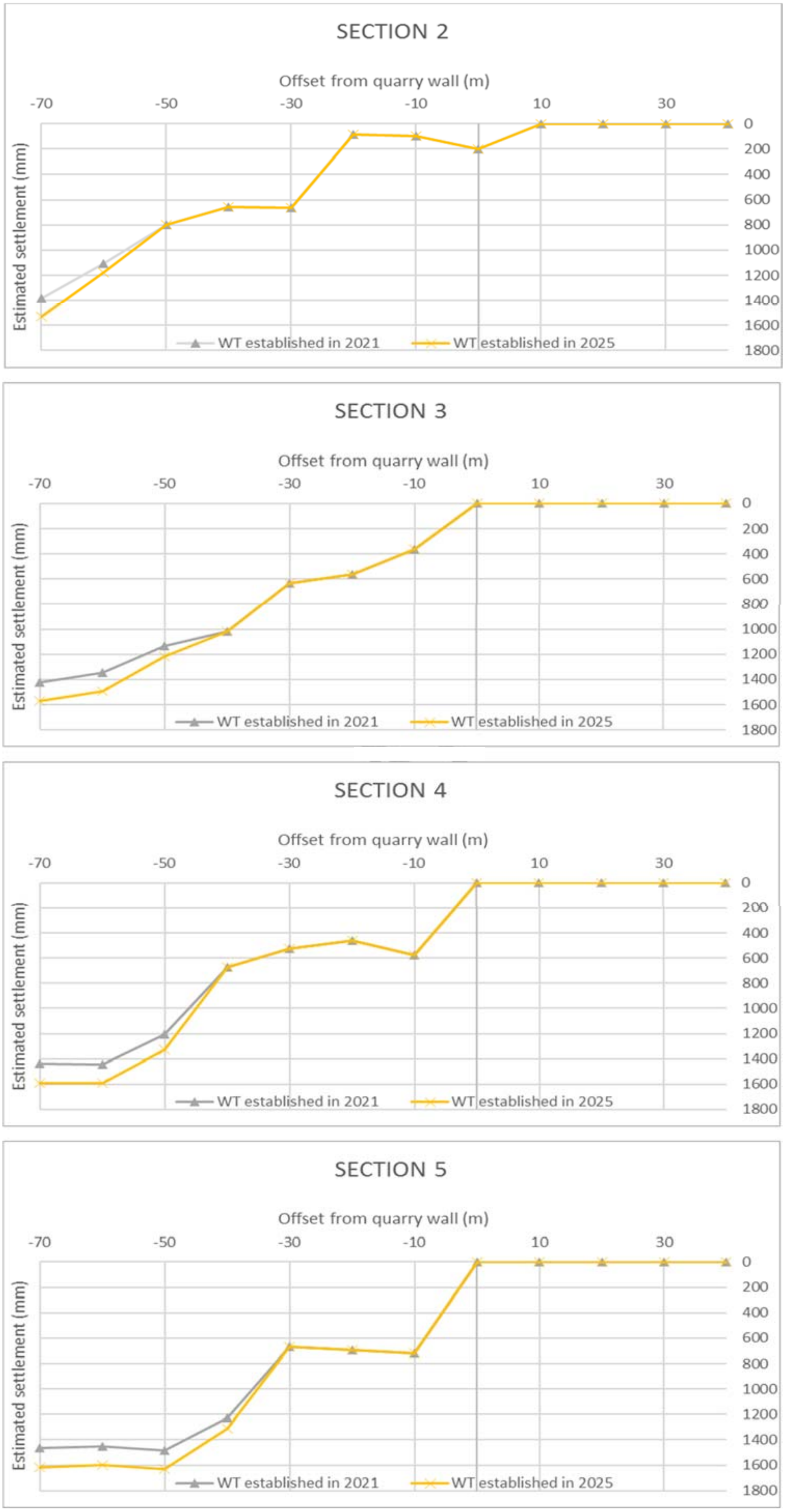


Figure 48 Settlement profiles along sections 2 to 5, 100 years

5.4 Pier & Deck Structure Option for Track Widening

In RW03A area it is understood existing rock benches are required to be widened to accommodate bi-directional traffic, parking and pedestrian tracks. Due to the relatively small extent of widening required (<4m typically) it is considered impractical to construct simple retaining structures (Reinforced earth or gravity type walls) which will require a footing width greater than the area available at the toe of the existing rock cutting to construct.

Therefore, it is proposed to develop a structural solution utilising commonly available steel members and pre-cast concrete deck units as illustrated in Figure 49 below.

Note it will be required to undertake geological mapping of the exposed quarry face prior to construction with any rock slope stabilisation measures installed prior to track widening. From preliminary observations extensive rock slope support measures are not anticipated.

Exposed steel columns can be covered by locally sourced stone work, if required to enhance the visual appearance of the structure.

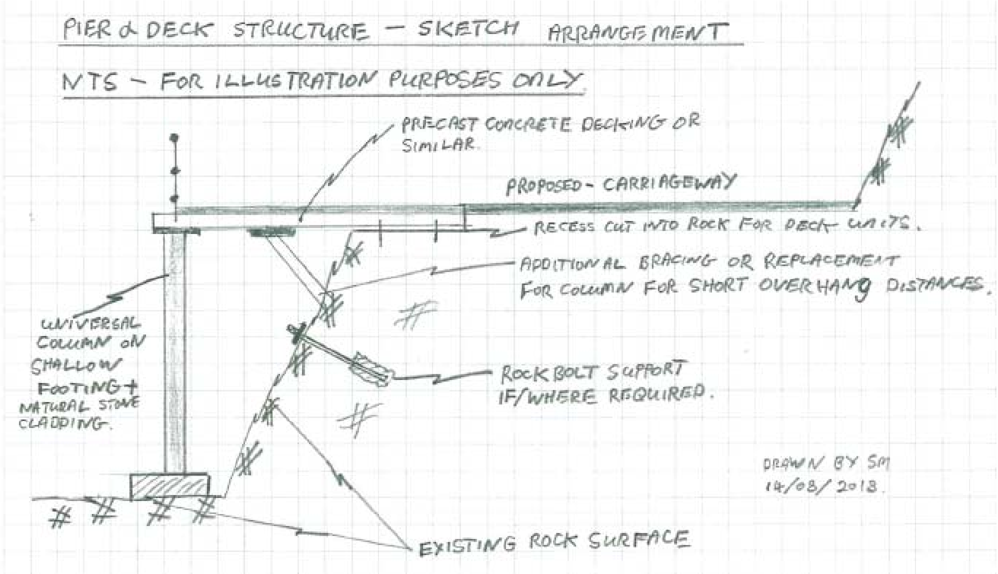


Figure 49 Concept sketch of existing access widening

6. Southern Access Track

6.1 Existing Stability and Potential Failure Mechanisms

A steeply actively eroding slope in residual soil/weathered rock underlays the existing track (see Figure 50 below) located close to the quarry edge.

In addition, large trees located along the crest line are unsupported on the down-slope side and are therefore at risk of falling into the quarry void (often this occurs during storm conditions) potentially further undermining the existing track. Trees generally have appositive effect on soil slope stability. However, for the particular case where trees are located on the crest of a rock slope they can pose a hazard.

Figure 50 Erosional degradation below southern access track

Due to the active erosional mechanisms and potential instability from large trees there remains a significant likelihood of instability undermining the existing track and also posing a potential hazard to park users below from falling trees in particular. These type of failure mechanisms can occur suddenly at any-time, but are more likely to occur during or shortly after high wind / rain storm events. Considering the above, if the existing Southern access track is to be incorporated into the quarry rehabilitation scheme the following engineering and control measures are suggested:

- Trees along the crest line and growing out of the rock slope should be assessed and, if deemed to be a potential risk to future park users removed.
- If the southern access track is required to remain open for walkers and light maintenance vehicles, in addition to the tree removal measures described above it is recommended that the existing access track is fully supported by a structural engineering solution which is not reliant on support from the eroding residual soils (refer to Figure 52).

Concept level details of a potential structural solution to stabilise the southern access track are provided below.

6.2 Engineering Solution

Design options for the Southern track to maintain its long term viability as access for pedestrians and light maintenance vehicles are constrained by the narrow track width and proximity to a steep high slope. Therefore any design solution must be able to provide progressive stabilisation of the slope as the construction advances and only use relatively small / light plant. From experience on other projects with similar constraints it is considered that a micro-pile and capping beam solution would be the preferred option for the reasons given below:

- The equipment can be attached to a standard excavator. The attachment can drill at a range of angles enabling the rear pile to act as an anchor into the rock thus providing considerable lateral stability.
- The micro-pile system is designed for limited access where access for large machinery / concrete trucks and reinforcing cages is expensive or impractical.
- Micropiles can be 'self-drilling'. The pile reinforcement (hollow bar) uses an oversize drill bit on the end. The pile reinforcement is also the drill string with drilling fluids circulated through the hollow reinforcing bar. The annulus between the reinforcement and the drill hole is grouted up by replacing the drilling support fluid with high strength grout at the end of the process to form a 150 diameter micro pile with single central reinforcing bar.
- Front and rear piles work together via the capping beam to provide a stable edge which can support railings or fencing to form a permanent access behind the capping beam.
- The technique is relatively cheap and quick compared to traditional piling and can be done in a single operation. The technique is particularly useful for relatively low loading applications.

Illustrative figures of the micropile installation process and example project drawings and photographs showing the installed piles before capping beam construction are shown below for illustration.

Figure 51 Illustration of micropile installation process and photograph of partially completed micropile wall

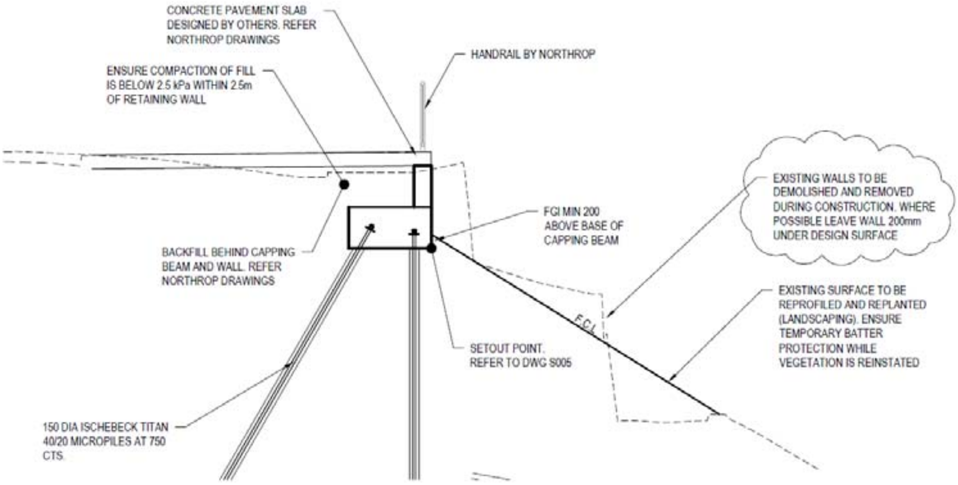


Figure 52 Example drawing showing typical layout details of a micropile wall

6.3 Further work

Based on site observations and information from boreholes in the general area it is anticipated that the bedrock profile is shallow on the inside of the access track deepening towards the quarry face. This anticipated geometry is favourable for the above solution. However, the underlying rock profile geometry and properties should be investigated to confirm the suitability of the above approach and inform the detailed design.

Therefore initially it is proposed to undertake a seismic refraction geophysical survey to obtain an indicative bedrock profile along the southern access track alignment (hand carry equipment). Following the geophysical survey and using the results from the survey, targeted intrusive investigations including boreholes should be undertaken to confirm the bedrock profile and geotechnical properties with sufficient confidence to inform a detailed design.

7. Unit Cost Estimates

7.1 Guidance notes

The following table draws on Rawlinson's published rates and informal discussions with contractors for typical rates on major earthworks projects, as well as a Quantity Survey report prepared for this project by Infrasol. It should be noted that Rawlinson's rates are more orientated towards smaller scale projects and the contractor's rates presented represent large scale earthworks rates, where significant economy of scale is a significant factor. A more realistic unit rate is likely to be price somewhere between the two quoted values (where two values are provided).

The rates should only be used for general guidance purposes only pending refinement / confirmation of the design, extents and associated quantities which impact the rates. The rates presented should not be relied upon to establish project budgets without further scheme design development and engagement of a quantities surveyor to provide specialist input to budget estimate development.

The rates presented do not include any preliminaries, design and management associated with a project of this nature. The rates are 'production' rates except for the southern access track estimate which is based on previous project experience with a separate lump sum cost estimate.

Table 25 Bulk Earthworks Unit Rates Estimation

Item	Item Coverage	Unit	Unit rate ($AUD)	Source	Comments
Excavation in soil	Bulk excavation of granular fill material, loading and haulage to nearby stockpile or embankment < 1Km away	m^3	$5.5, $9.9 to $10.8	Contractor (lower), InfraSol (mid) and Rawlinson (upper) rates.	Assumed only existing 'loose' granular fills will be excavated, residual soils or clays would be approx 25% more expensive due to bulking factors / less efficient excavation.
Excavation in rippable sandstone	Bulk excavation of rippable sandstone, loading and haulage to nearby stockpile or embankment <1Km away	m^3	$6 to $15.1	Contractor (lower), InfraSol (upper) rates. Indicative contractor rate only for large volumes. Likely to be on the low side.	Assumes dozer rippable. Will also require crushing and screening before use as fill. See separate rate below
Excavation in non-rippable sandstone	Hydraulic breakers – blasting not permitted or trackheader.	m^3	$115 (rock breakers / saw cuts) $100 (trackheader) $69	Rawlinson's rate Contractor rate InfraSol rate	Will require crushing and screening before use as fill. See separate rate below. May not require crushing and screening before use as fill.
Blasting in non-rippable sandstone	Drill and blast	m^3	$8	Indicative contractor rate available only for large volumes. Likely to be on the low side.	Will require crushing and screening before use as fill. See separate rate below.
Crushing and screening of excavated rock materials	Crusher plant / stockpile management and material handling	m^3	$15	InfraSol and Contractor value. Indicative contractor rate only for large volumes. Likely to be on the low side.	Add onto "excavation in sandstone" rates where appropriate.
Place spread and compact site won soil material.	Short haul from stockpile, place, compact and trim.	m^3	$3.50, $7.70 to $8.20	Contractor (lower), InfraSol (mid) and Rawlinson (upper) rates.	Assumes the material can be placed "as dug' or direct from local stockpile.

Item	Item Coverage	Unit	Unit rate ($AUD)	Source	Comments
Place spread and compact site won crushed material.	Haul, place, compact and trim up to 1KM. Note does not include all the prelim costs associated with mobilisation / compliance testing and the like.	m^3	$9	Indicative contractor rate available only for large volumes. Likely to be on the low side.	Higher than soil rates, likely a reflection of the nature of the material.

Table 26 Structures and Rock Slope Treatment Unit Rate Estimation

Item	Item Coverage	Unit	Unit rate ($AUD)	Source	Comments
Gabion skin wall over existing quarry rock face	1m x 1m x 1m baskets stacked vertically or staggered near vertical	m^2 of wall	$575	Contractor source only.	For double or triple skin walls if used to widen existing access tracks double or triple the rate accordingly.
Gabion retaining walls (retaining soil) up to 1.5m high.	Assumed 1.5m wide base and 1m wide crest tapering to a single basket for 1m high (2 baskets per m run of wall average assumed)	m^2 of wall	$862 $750	Contractor source. InfraSol value	n/a
Reinforced earth walls up to 3m high.	Either vertical faced concrete panel / gabion faced OR steep green faced "slopes' – Prices considered likely comparable. Includes all components footings and backfill (for the length of the straps only..assume strap length on average = 2/3 wall height on average.	m^2 of wall	$490 $450	Based on Rawlinsons vertical pre-cast concrete panel faced. InfraSol value	n/a
Reinforced earth walls 3 m to 6 m high.	As above	m^2 of wall	$530 $600	Based on Rawlinsons vertical pre-cast concrete panel faced. InfraSol value	n/a
Reinforced earth walls over 6 m high.	As above	m^2 of wall	$575	Based on Rawlinsons vertical pre-cast concrete panel faced.	n/a
Rock slope treatment	Scaling and rock bolting of locally unstable blocks too large to remove / rock mesh coverage and the like.	m^2 of rock face	See comments	See comments	The scope and form of rock face treatment can vary considerably and is subject to detailed rock face mapping. Therefore costings cannot reasonably be generalised at this stage. However it is considered unlikely such treatments will constitute a major cost item.
Structural Steel Deck	Universal columns and beams with a concrete deck. Extents vary.	m^2 of deck	See comments	See comments	The extent of the northern quarry bench that will need to be marginally widened (typically <4m) through the construction of deck structures is subject to the detailed design

Item	Item Coverage	Unit	Unit rate ($AUD)	Source	Comments
					alignment model. Therefore costings cannot reasonably be generalised at this stage. However it is estimated that the cost of these structures, especially for sections of considerable height, will be substantially more economic than using other retaining elements such as gabions.
Southern access track stabilisation	Spaced Micro piles / mini-pile “hard edge” – potentially use self-drilling micro pile system drilling one pile at an angle into the rock face and the front pile vertical to work together in pairs connected to a capping beam with handrail.	Allow	No unit rates available		Previous project (Newcastle 2015) approx. 45m long cost around $300K. Additional allowances may need to be made due to location, complexity of the project, access and other factors.

8. Further Work

8.1 General

The following provides general guidance on future geotechnical investigation and assessment requirements to confirm the concepts presented herein and inform detailed design where shortfalls in information are identified. Generally capturing additional geotechnical data will usually lead to opportunities to adopt less conservative assumptions in design leading to more economy in design and construction solutions.

8.2 Northern Spoil Mound

To inform detailed design of the Northern Spoil Mound a geophysical survey to assess the underlying fill and bed-rock profile would be useful in determining stability for construction and in the permanent condition. The survey would also assist in determining excavation conditions and identify potential areas of rock excavation which will influence costs and quantities.

In conjunction with the geophysical survey hand-dug inspection pits are proposed to examine the near-surface materials and take samples for geotechnical and landscaping purposes (topsoil thickness etc).

The scope of investigation as described above is anticipated to take one to two days to complete using hand carry equipment.

8.3 Rock-Fall Trials

Rock-fall trials would be invaluable to refine the rock-fall predictive models and identify the location of protective measures such as ‘catch’ ditches or bunds. Rock-fall trials involve releasing rocks of various shapes and sizes at representative locations around the quarry. Travel time, trajectory and travel distance away from the quarry face are recorded along with slope angle / geometry (e.g. benches) and height at a given trial location.

The results are used to calibrate theoretical software models which simulate thousands of different potential falling rock shapes and sizes to make predictions. Introducing rock-fall trial data to current models would significantly increase confidence and accuracy of the models and would likely lead to reduced exclusion area extents.

The scope of investigation as described above would involve the use of a small excavator to move and drop larger rocks (where access and safety permits) along with two observers to supervise and record results / release smaller rocks by hand (where access and safety permits). It is anticipated that a suitable source of rocks could be located from within the quarry area in advance of the trials.

The trials would be expected to be completed within two days (including finding and stockpiling suitable rocks from the quarry). The trials should be undertaken when the bulk quarry infilling activities are completed to more closely reflect the final condition.

8.4 Southern Access Track

Investigation is required to confirm the micro-pile concept and inform detailed design of the Southern Access Track. The investigation should involve a geophysical survey to estimate bedrock levels followed by a series of short boreholes to confirm the rock profile and provide soil engineering properties to inform detailed design.

The geophysical survey should be undertaken first (hand carry equipment only required) to identify the underlying rock profile and inform suitable locations for a subsequent more detailed investigation involving boreholes, insitu and laboratory testing. The initial geophysical investigation will dictate how many boreholes are needed therefore the borehole investigation cannot be defined at this stage, however it is anticipated the investigation is unlikely to last more than 1 week on site including the geophysical survey.

8.5 Retaining Walls

The proposed earth retaining structures are required to transverse areas of shallow rock and very deep fill in some areas which poses significant challenges in design from the resulting potential for large differential settlements. Therefore it is important to rigorously assess the potential for settlement in advance of design.

Investigation and testing of the placed NorthConnex fill is required to determine compaction, permeability properties and densification with depth. An investigation involving two boreholes with piezometer installations (to measure ground water recharge rates in the fill) including sampling and in situ strength testing is suggested along with a suite of laboratory (earthworks) testing. The borehole investigation should also be supplemented by cone penetrometer testing to assess the placed fill compaction under self-weight with depth to assist with long term settlement predictions to inform suitable engineering solutions for potentially vulnerable retaining structures to high differential settlements.

In addition to the intrusive investigations it is also recommended during early park construction to install settlement plates to monitor creep and inundation settlement within the fill over time to calibrate the settlement predictions against actual measurements. This is particularly important for retaining structures as it may be advantageous to utilise ground improvement or delay the construction of some walls to later in the construction programme. Delaying retaining structure construction in some areas will allow some of the time dependent settlement to occur. Temporary granular pavements and drainage can be used until settlement measurements indicate it is appropriate for permanent construction measures.

The above investigation phase (2 boreholes and a CPT rig) can be completed within a week on site with the settlement plates installed at the same time. The settlement plates and piezometers would need to be monitored throughout the detailed design and construction process to refine settlement predictions as the situation develops.

8.6 Rock Slopes

Existing and proposed new cut slopes in rock should be mapped during and post excavation to identify any rock reinforcement (rock bolts for large blocks and mesh for extensive weak or rubbly zones) assessed on a case-by-case basis. The rock face mapping of existing rock slopes to be retained should be undertaken prior to construction to inform the tender process. Proposed new rock cut slopes would need to be mapped and any additional support requirements defined during the construction process.

8.7 Design Development

This report represents the outcomes of concept level design development to inform the master planning process. Additional geotechnical investigations and design activities will be required to confirm some of the concepts described in this report and develop all the concepts to a level of confidence suitable to enter into a tender process for the park construction. The design development should only commence further beyond the high level assessments undertaken as part of this report once the investigations described above are completed and reported to avoid potentially abortive work on detailed design.

9. Conclusions

GHD identified some potential geotechnical challenges associated with redeveloping the site economically. These included global slope stability, erosion, rock-fall and long-term settlement.

Stability issues with the existing quarry can be summarised as follows:

- Southern quarry wall global and localised stability
- Northern quarry-wall spoil mound stability
- Localised rock-falls or soil erosion (encompassing discrete blocks detaching and falling from the quarry face or shallow depth soil slumping).

GHD undertook a series of Factor of Safety and risk-based assessments, which enabled the following recommendations to be made:

- Further detailed assessment of the southern quarry wall global stability shows that the stability is acceptable. Therefore, no access constraints or design response are proposed to address the global stability of the southern quarry wall. The existing quarry access track arrangements can be maintained and monitored to keep the factor of safety within acceptable limits. Details can be found in Section 2 of this report.
- The Southern Access Track at the crest of the southern quarry wall has localised instability issues associated with residual soils and fill material eroding and ‘slipping off’ the rock profile beneath. A robust structural solution (raked mini-pile wall including capping beam with edge protection) is suggested. It is envisaged that this will enable the existing southern access track to continue to be used for maintenance and pedestrian access in the long term. Details of the concept level proposed solution are contained in Section 6 of this report.
- Northern Spoil Mound stability issues are proposed to be addressed by a combination of proactive engineering measures to improve stability (regrading to a shallower angle, slope reinforcement and drainage measures) with a continuance of long term monitoring and maintenance preferred in some areas.
- Throughout the site a combined approach is proposed to address the localised effects of erosion and small scale slope failures in soil and rock slopes A ‘tool box’ of measures is proposed including:
  - Toe exclusion zones to prevent park users from exposure to rock-fall and small-scale soil slope failure hazards.
  - Preventative measures such as rock bolts, face mesh, catch fences, catch ditches, facing ‘skin’ walls (e.g. gabions secured to exposed rock faces) and maintained erosion protection on soil slopes (vegetation erosion protection envisaged in most areas).
  - Monitoring and maintenance as required, in all areas.

The future parkland layout proposes widening, re-alignment and extension of access tracks to enable the public to drive into the quarry space. This generates several new retaining / deck structures and new cuttings of differing heights and curved geometries.

Some of the proposed new retaining structures will be founded over deep (up to 55 m) NorthConnex fill material and in some areas founded within a few metres of dolerite bedrock at the edges of the park. This situation creates the potential for high differential settlement within the same structure and between adjacent structures.

The structures will need to be carefully designed to minimise the potential for high differential settlements. The following suite of design solutions is proposed as part of this report: See Section 5 of this report for details.

- Reinforced earth retaining walls or steep reinforced earth slopes (50 to 70 degrees) are suggested in fill areas. The walls can be faced with gabions or similar architectural finishes and steep slopes can be vegetated. Reinforced earth walls/slopes are relatively flexible structures and can make use of the existing fill on the site. They are also able to tolerate significant post construction settlement.
- Where existing access tracks need to be extended out beyond the current cliff-line, a short distance (approx. 4 m or less), a structural solution (suspended deck on column arrangement) is considered more favourable than using retaining solutions. Simple gravity or reinforced earth retaining structures are unlikely to be practical or economic in these areas due to the rock slope geometry.
- Existing and proposed new cut slopes in rock should be mapped during and post excavation to identify any rock reinforcement (rock bolts for large blocks and mesh for extensive weak or rubbly zones) and assessed on a case-by-case basis.
- Earthworks to form the foundation for the retaining walls in fill areas should be subject to suitable levels of compaction to achieve the required soil strength parameters and limit post construction settlement to manageable levels. Ground improvement may be required in some areas subject to detailed design level investigation and assessment.

The strategies and preferred options described above require further investigative work in some cases to confirm the concepts and inform the detailed design process. GHD’s suggested investigation requirements are summarised below. See Section 8 of this report for details.

- Physical investigation is required to confirm the concept and inform detailed design of the Southern Access Track (where a raked mini-piles and capping beam solution is proposed). The investigation should involve a geophysical survey to estimate bedrock levels followed by a series of short boreholes to confirm the rock profile and provide soil engineering properties.
- A geophysical survey of the Northern Spoil Mound is required to assess the underlying fill and bed-rock profile. This would be useful in determining stability for construction and long term operation. The survey would also assist in determining excavation conditions and identify potential areas of rock, which may influence costs and quantities estimates.
- Rock-fall trials are needed to refine the rock-fall predictive models and identify the location of protective measures such as ditches or bunds. Rock-fall trial data may justify the use of smaller protection zones / reduced preventative measures than predicted by the analytical methods used for this report.
- Investigation and testing of the NorthConnex fill would enable levels of compaction, permeability properties and densification with depth to be determined. The investigation could include two boreholes with piezometer installations (to measure ground water recharge rates in the fill) with sampling and in situ strength testing, along with a suite of laboratory (earthworks) testing and cone penetration testing. It is also advisable during early park construction to install settlement plates and piezometers to monitor creep and inundation settlement within the fill over time to make predictions regarding when retaining walls can be built, pavements sealed or if ground improvement measures may be required in some areas.

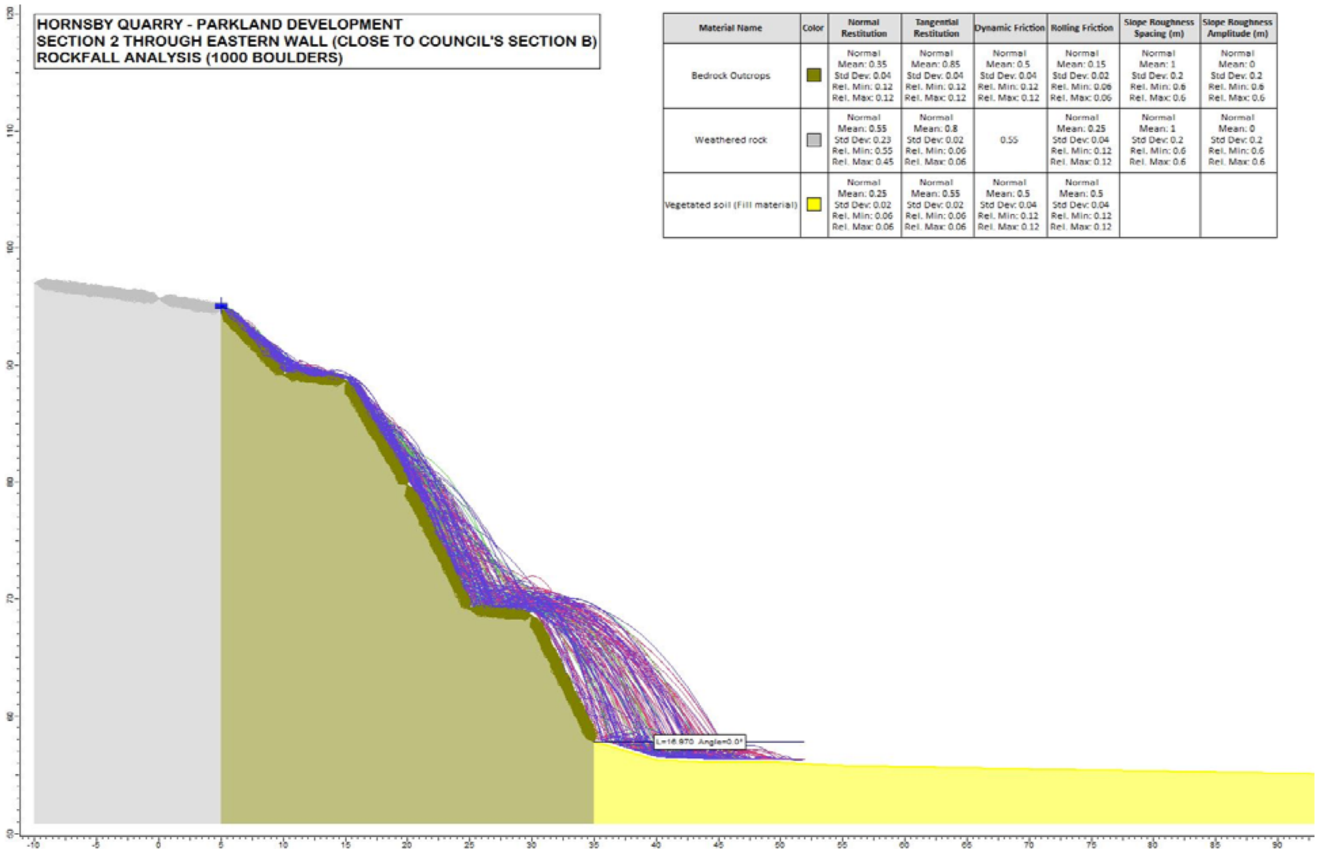
This report presents the outcomes of concept level geotechnical design that has been undertaken to inform the master planning and EIS process. Additional geotechnical investigations and design activities are required to confirm some of the concepts described in this report and to further develop all the concepts to a level where they are suitable for Council to enter into a tender process for the park construction.

In GHD’s opinion, if the detailed design work commences after the required additional investigations are completed, this will avoid the need to potentially rework the detailed design.

Appendices

Appendix A – Rock-fall Analysis Results

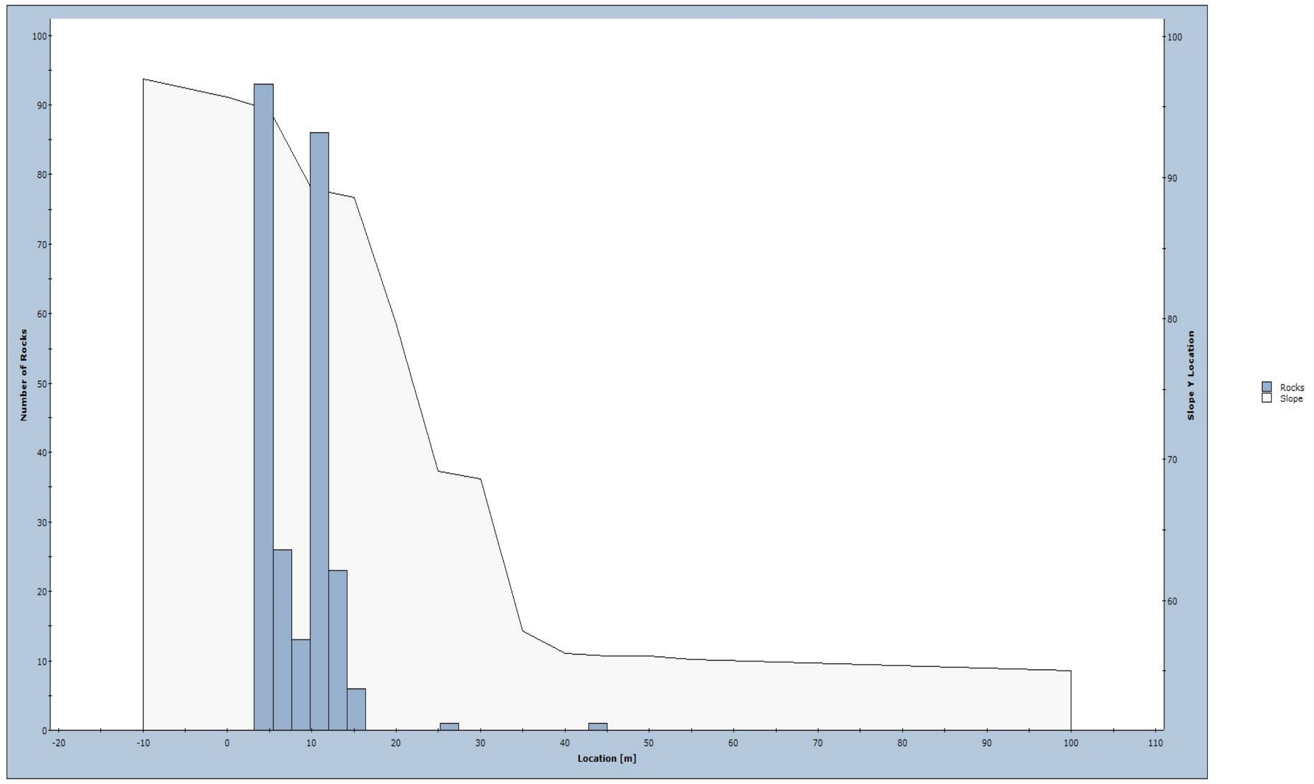
EAST WALL



HORNSBY QUARRY - PARKLAND DEVELOPMENT
SECTION 2 THROUGH EASTERN WALL (CLOSE TO COUNCIL'S SECTION B)
ROCKFALL ANALYSIS (1000 BOULDERS)

Material Name	Color	Normal Restitution	Tangential Restitution	Dynamic Friction	Rolling Friction	Slope Roughness Spacing (m)	Slope Roughness Amplitude (m)
Bedrock Outcrops	🟫	Normal Mean: 0.35 Std Dev: 0.04 Rel. Min: 0.12 Rel. Max: 0.12	Normal Mean: 0.85 Std Dev: 0.04 Rel. Min: 0.12 Rel. Max: 0.12	Normal Mean: 0.5 Std Dev: 0.04 Rel. Min: 0.12 Rel. Max: 0.12	Normal Mean: 0.15 Std Dev: 0.02 Rel. Min: 0.06 Rel. Max: 0.06	Normal Mean: 1 Std Dev: 0.2 Rel. Min: 0.6 Rel. Max: 0.6	Normal Mean: 0 Std Dev: 0.2 Rel. Min: 0.6 Rel. Max: 0.6
Weathered rock	⬜	Normal Mean: 0.55 Std Dev: 0.23 Rel. Min: 0.55 Rel. Max: 0.45	Normal Mean: 0.8 Std Dev: 0.02 Rel. Min: 0.06 Rel. Max: 0.06	0.55	Normal Mean: 0.25 Std Dev: 0.04 Rel. Min: 0.12 Rel. Max: 0.12	Normal Mean: 1 Std Dev: 0.2 Rel. Min: 0.6 Rel. Max: 0.6	Normal Mean: 0 Std Dev: 0.2 Rel. Min: 0.6 Rel. Max: 0.6
Vegetated soil (Fill material)	🟨	Normal Mean: 0.25 Std Dev: 0.02 Rel. Min: 0.06 Rel. Max: 0.06	Normal Mean: 0.55 Std Dev: 0.02 Rel. Min: 0.06 Rel. Max: 0.06	Normal Mean: 0.5 Std Dev: 0.04 Rel. Min: 0.12 Rel. Max: 0.12	Normal Mean: 0.5 Std Dev: 0.04 Rel. Min: 0.12 Rel. Max: 0.12		

Distribution of Rock Path End Locations



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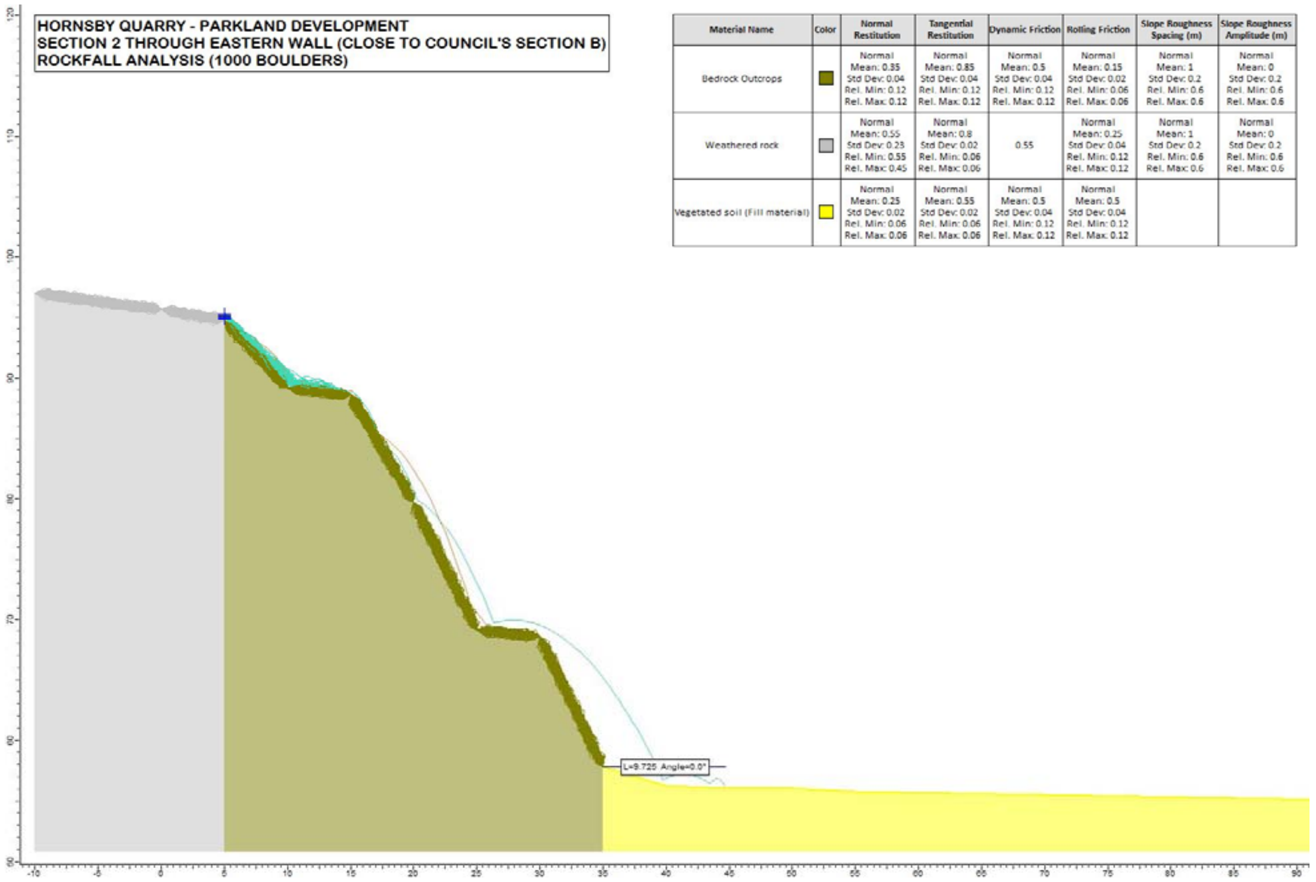
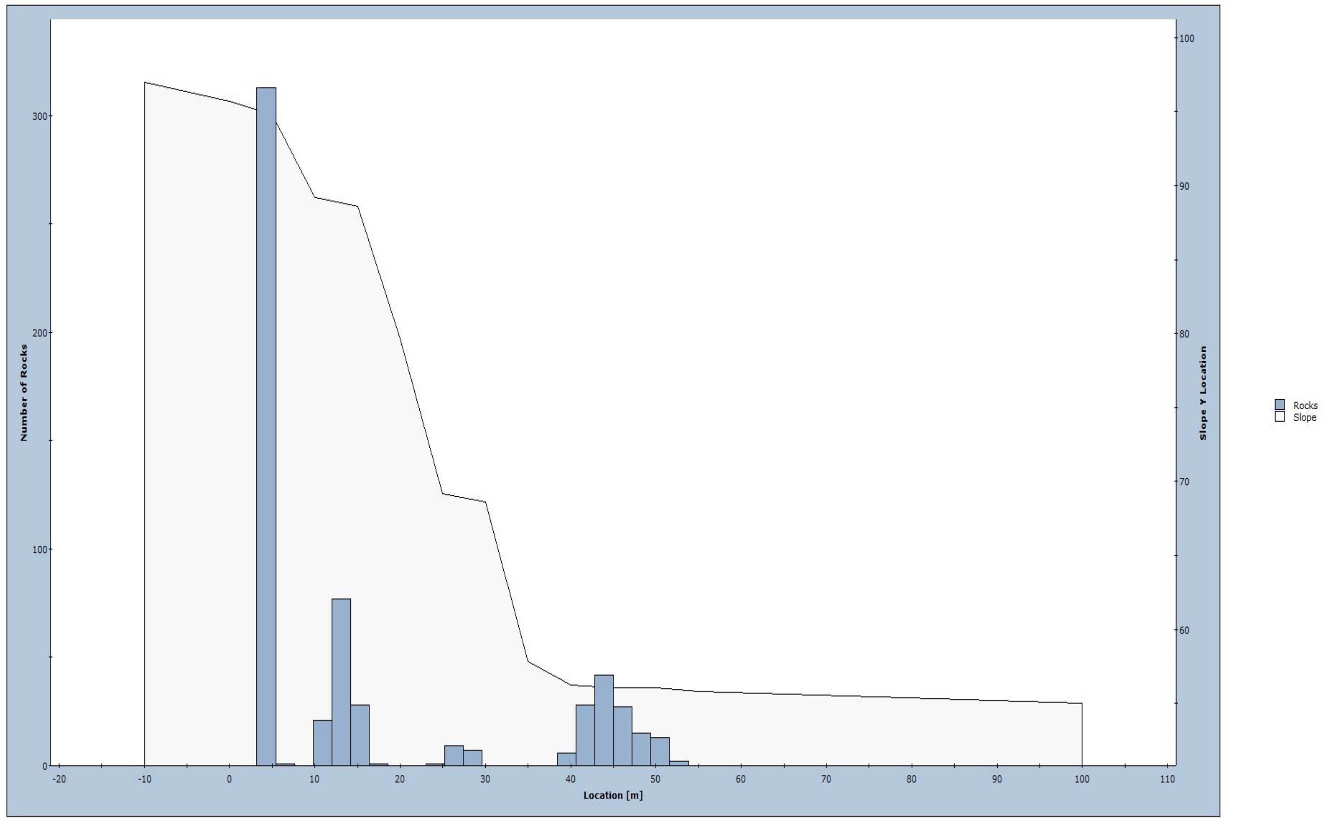


HORNSBY QUARRY - PARKLAND DEVELOPMENT
SECTION 2 THROUGH EASTERN WALL (CLOSE TO COUNCIL'S SECTION B)
ROCKFALL ANALYSIS (1000 BOULDERS)

Material Name	Color	Normal Restitution	Tangential Restitution	Dynamic Friction	Rolling Friction	Slope Roughness Spacing (m)	Slope Roughness Amplitude (m)
Bedrock Outcrops	🟫	Normal Mean: 0.35 Std Dev: 0.04 Rel. Min: 0.12 Rel. Max: 0.12	Normal Mean: 0.85 Std Dev: 0.04 Rel. Min: 0.12 Rel. Max: 0.12	Normal Mean: 0.5 Std Dev: 0.04 Rel. Min: 0.12 Rel. Max: 0.12	Normal Mean: 0.15 Std Dev: 0.02 Rel. Min: 0.06 Rel. Max: 0.06	Normal Mean: 1 Std Dev: 0.2 Rel. Min: 0.6 Rel. Max: 0.6	Normal Mean: 0 Std Dev: 0.2 Rel. Min: 0.6 Rel. Max: 0.6
Weathered rock	⬜	Normal Mean: 0.55 Std Dev: 0.23 Rel. Min: 0.55 Rel. Max: 0.45	Normal Mean: 0.8 Std Dev: 0.02 Rel. Min: 0.06 Rel. Max: 0.06	0.55	Normal Mean: 0.25 Std Dev: 0.04 Rel. Min: 0.12 Rel. Max: 0.12	Normal Mean: 1 Std Dev: 0.2 Rel. Min: 0.6 Rel. Max: 0.6	Normal Mean: 0 Std Dev: 0.2 Rel. Min: 0.6 Rel. Max: 0.6
Vegetated soil (Fill material)	🟨	Normal Mean: 0.25 Std Dev: 0.02 Rel. Min: 0.06 Rel. Max: 0.06	Normal Mean: 0.55 Std Dev: 0.02 Rel. Min: 0.06 Rel. Max: 0.06	Normal Mean: 0.5 Std Dev: 0.04 Rel. Min: 0.12 Rel. Max: 0.12	Normal Mean: 0.5 Std Dev: 0.04 Rel. Min: 0.12 Rel. Max: 0.12		

Distribution of Rock Path End Locations



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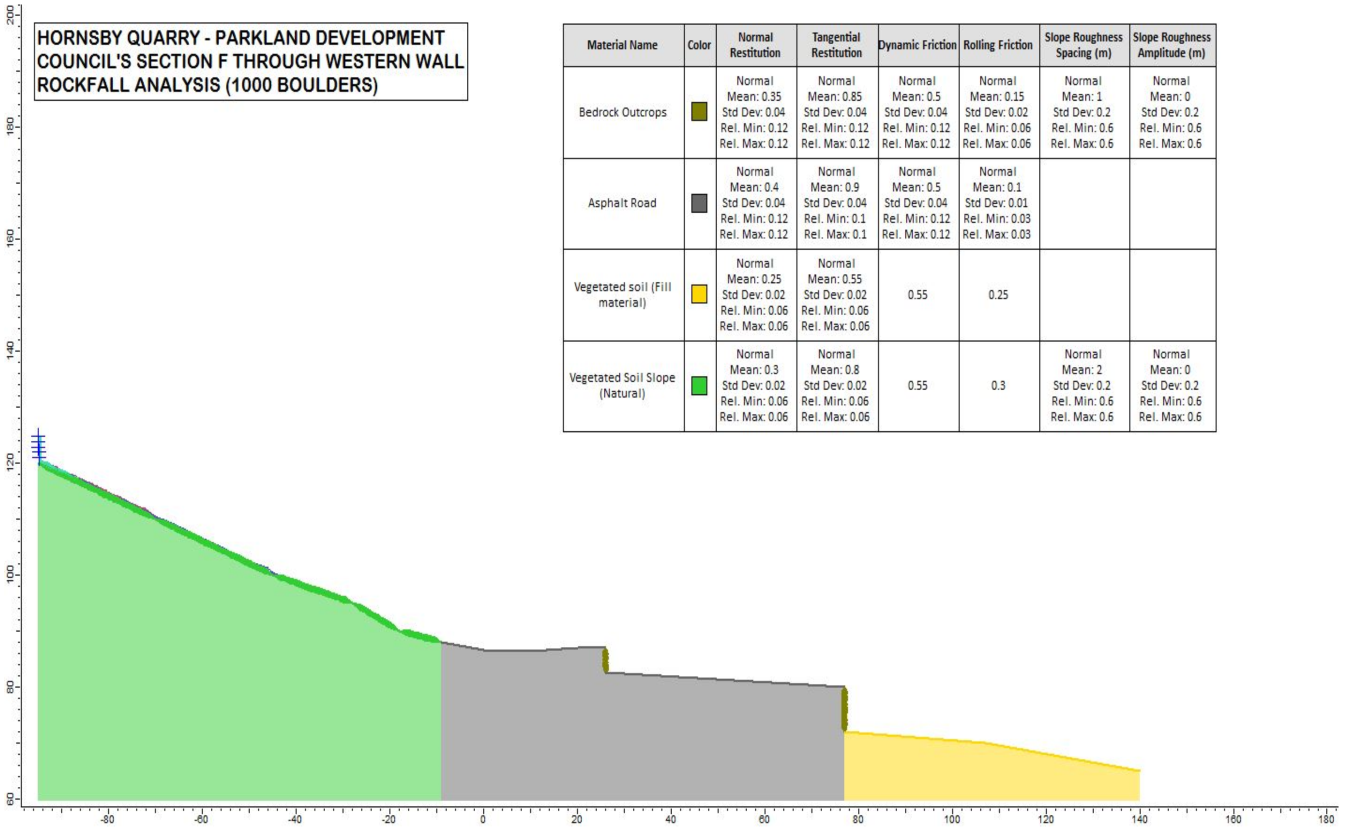
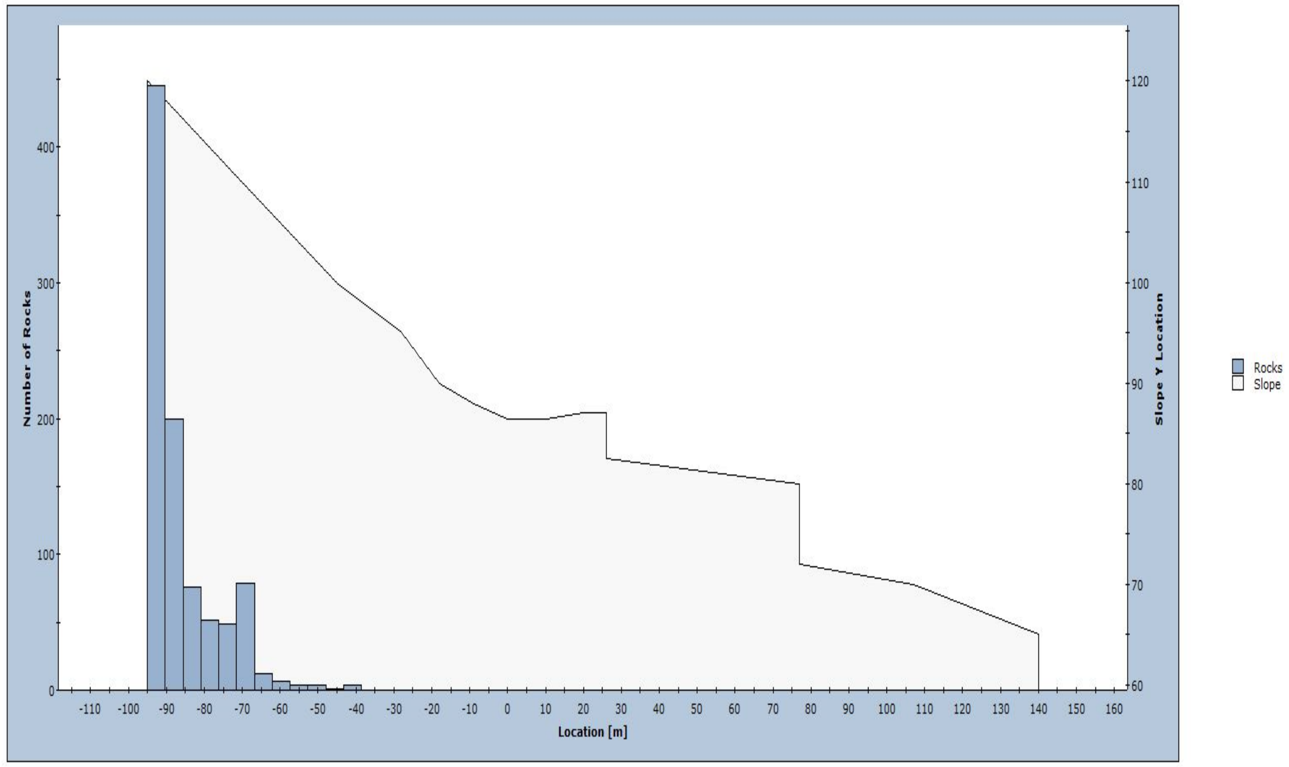
WEST WALL



HORNSBY QUARRY - PARKLAND DEVELOPMENT
COUNCIL'S SECTION F THROUGH WESTERN WALL
ROCKFALL ANALYSIS (1000 BOULDERS)

Material Name	Color	Normal Restitution	Tangential Restitution	Dynamic Friction	Rolling Friction	Slope Roughness Spacing (m)	Slope Roughness Amplitude (m)
Bedrock Outcrops	🟫	Normal Mean: 0.35 Std Dev: 0.04 Rel. Min: 0.12 Rel. Max: 0.12	Normal Mean: 0.85 Std Dev: 0.04 Rel. Min: 0.12 Rel. Max: 0.12	Normal Mean: 0.5 Std Dev: 0.04 Rel. Min: 0.12 Rel. Max: 0.12	Normal Mean: 0.15 Std Dev: 0.02 Rel. Min: 0.06 Rel. Max: 0.06	Normal Mean: 1 Std Dev: 0.2 Rel. Min: 0.6 Rel. Max: 0.6	Normal Mean: 0 Std Dev: 0.2 Rel. Min: 0.6 Rel. Max: 0.6
Asphalt Road	⬛	Normal Mean: 0.4 Std Dev: 0.04 Rel. Min: 0.12 Rel. Max: 0.12	Normal Mean: 0.9 Std Dev: 0.04 Rel. Min: 0.1 Rel. Max: 0.1	Normal Mean: 0.5 Std Dev: 0.04 Rel. Min: 0.12 Rel. Max: 0.12	Normal Mean: 0.1 Std Dev: 0.01 Rel. Min: 0.03 Rel. Max: 0.03		
Vegetated soil (Fill material)	🟨	Normal Mean: 0.25 Std Dev: 0.02 Rel. Min: 0.06 Rel. Max: 0.06	Normal Mean: 0.55 Std Dev: 0.02 Rel. Min: 0.06 Rel. Max: 0.06	0.55	0.25		
Vegetated Soil Slope (Natural)	🟩	Normal Mean: 0.3 Std Dev: 0.02 Rel. Min: 0.06 Rel. Max: 0.06	Normal Mean: 0.8 Std Dev: 0.02 Rel. Min: 0.06 Rel. Max: 0.06	0.55	0.3	Normal Mean: 2 Std Dev: 0.2 Rel. Min: 0.6 Rel. Max: 0.6	Normal Mean: 0 Std Dev: 0.2 Rel. Min: 0.6 Rel. Max: 0.6

Distribution of Rock Path End Locations



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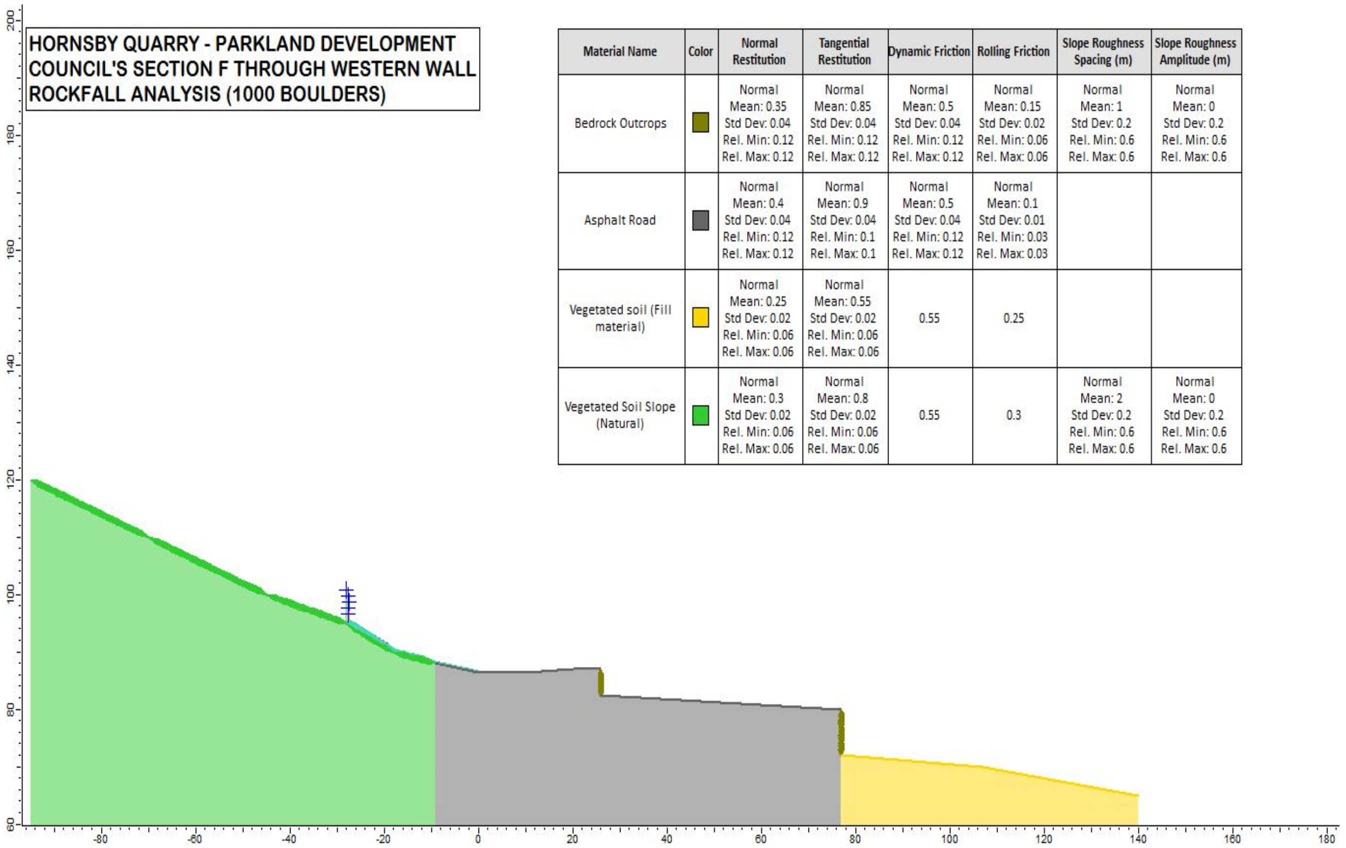

HORNSBY QUARRY - PARKLAND DEVELOPMENT
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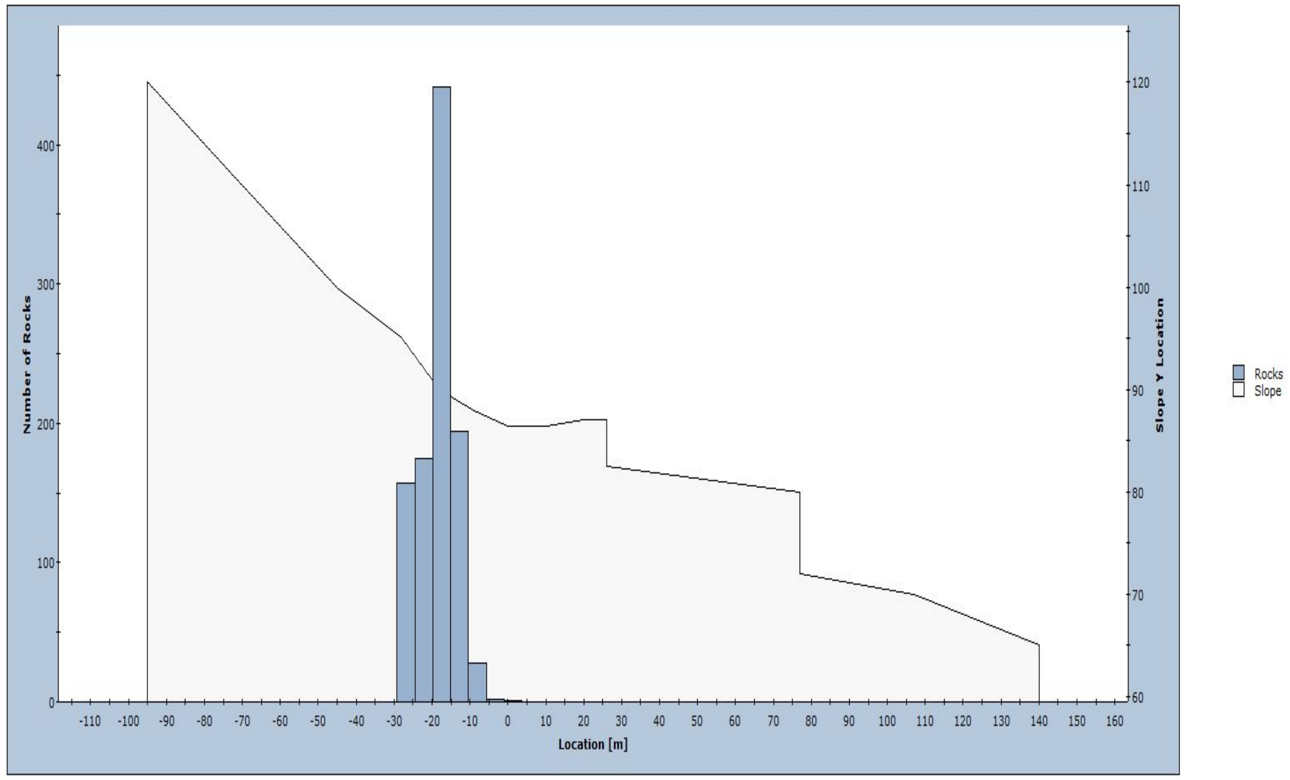
ROCKFALL ANALYSIS (1000 BOULDERS)

Material Name	Color	Normal Restitution	Tangential Restitution	Dynamic Friction	Rolling Friction	Slope Roughness Spacing (m)	Slope Roughness Amplitude (m)
Bedrock Outcrops	🟫	Normal Mean: 0.35 Std Dev: 0.04 Rel. Min: 0.12 Rel. Max: 0.12	Normal Mean: 0.85 Std Dev: 0.04 Rel. Min: 0.12 Rel. Max: 0.12	Normal Mean: 0.5 Std Dev: 0.04 Rel. Min: 0.12 Rel. Max: 0.12	Normal Mean: 0.15 Std Dev: 0.02 Rel. Min: 0.06 Rel. Max: 0.06	Normal Mean: 1 Std Dev: 0.2 Rel. Min: 0.6 Rel. Max: 0.6	Normal Mean: 0 Std Dev: 0.2 Rel. Min: 0.6 Rel. Max: 0.6
Asphalt Road	⬛	Normal Mean: 0.4 Std Dev: 0.04 Rel. Min: 0.12 Rel. Max: 0.12	Normal Mean: 0.9 Std Dev: 0.04 Rel. Min: 0.1 Rel. Max: 0.1	Normal Mean: 0.5 Std Dev: 0.04 Rel. Min: 0.12 Rel. Max: 0.12	Normal Mean: 0.1 Std Dev: 0.01 Rel. Min: 0.03 Rel. Max: 0.03		
Vegetated soil (Fill material)	🟨	Normal Mean: 0.25 Std Dev: 0.02 Rel. Min: 0.06 Rel. Max: 0.06	Normal Mean: 0.55 Std Dev: 0.02 Rel. Min: 0.06 Rel. Max: 0.06	0.55	0.25		
Vegetated Soil Slope (Natural)	🟩	Normal Mean: 0.3 Std Dev: 0.02 Rel. Min: 0.06 Rel. Max: 0.06	Normal Mean: 0.8 Std Dev: 0.02 Rel. Min: 0.06 Rel. Max: 0.06	0.55	0.3	Normal Mean: 2 Std Dev: 0.2 Rel. Min: 0.6 Rel. Max: 0.6	Normal Mean: 0 Std Dev: 0.2 Rel. Min: 0.6 Rel. Max: 0.6

Distribution of Rock Path End Locations



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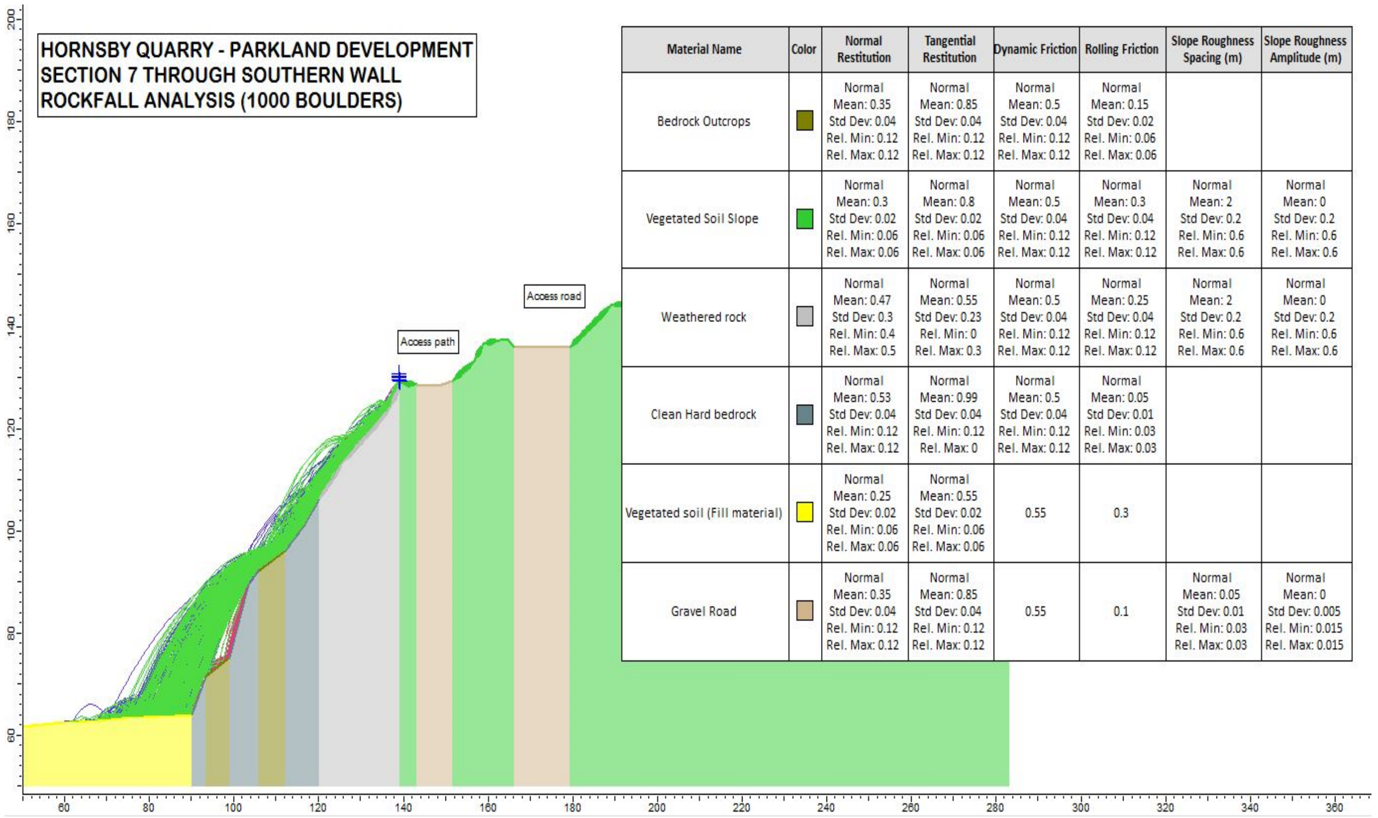
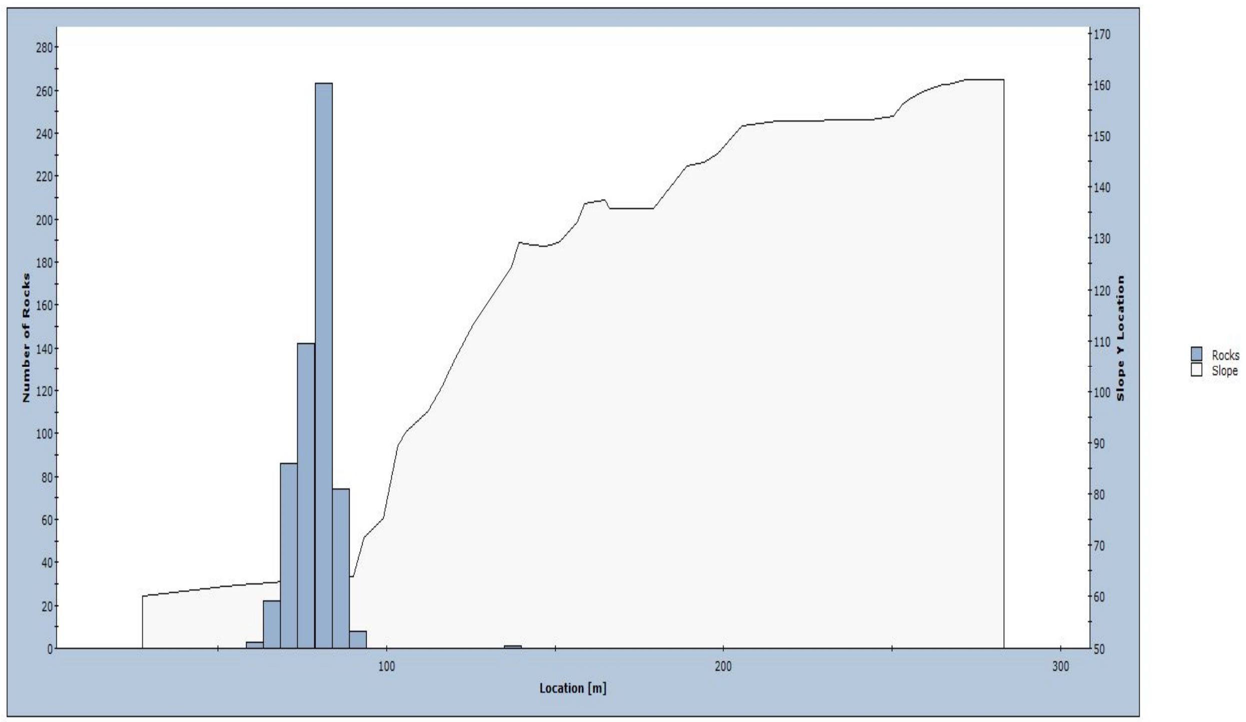
SOUTH WALL



Material Name	Color	Normal Restitution	Tangential Restitution	Dynamic Friction	Rolling Friction	Slope Roughness Spacing (m)	Slope Roughness Amplitude (m)
Bedrock Outcrops	🟫	Normal Mean: 0.35 Std Dev: 0.04 Rel. Min: 0.12 Rel. Max: 0.12	Normal Mean: 0.85 Std Dev: 0.04 Rel. Min: 0.12 Rel. Max: 0.12	Normal Mean: 0.5 Std Dev: 0.04 Rel. Min: 0.12 Rel. Max: 0.12	Normal Mean: 0.15 Std Dev: 0.02 Rel. Min: 0.06 Rel. Max: 0.06		
Vegetated Soil Slope	🟩	Normal Mean: 0.3 Std Dev: 0.02 Rel. Min: 0.06 Rel. Max: 0.06	Normal Mean: 0.8 Std Dev: 0.02 Rel. Min: 0.06 Rel. Max: 0.06	Normal Mean: 0.5 Std Dev: 0.04 Rel. Min: 0.12 Rel. Max: 0.12	Normal Mean: 0.3 Std Dev: 0.04 Rel. Min: 0.12 Rel. Max: 0.12	Normal Mean: 2 Std Dev: 0.2 Rel. Min: 0.6 Rel. Max: 0.6	Normal Mean: 0 Std Dev: 0.2 Rel. Min: 0.6 Rel. Max: 0.6
Weathered rock	⬜	Normal Mean: 0.47 Std Dev: 0.3 Rel. Min: 0.4 Rel. Max: 0.5	Normal Mean: 0.55 Std Dev: 0.23 Rel. Min: 0 Rel. Max: 0.3	Normal Mean: 0.5 Std Dev: 0.04 Rel. Min: 0.12 Rel. Max: 0.12	Normal Mean: 0.25 Std Dev: 0.04 Rel. Min: 0.12 Rel. Max: 0.12	Normal Mean: 2 Std Dev: 0.2 Rel. Min: 0.6 Rel. Max: 0.6	Normal Mean: 0 Std Dev: 0.2 Rel. Min: 0.6 Rel. Max: 0.6
Clean Hard bedrock	⬛	Normal Mean: 0.53 Std Dev: 0.04 Rel. Min: 0.12 Rel. Max: 0.12	Normal Mean: 0.99 Std Dev: 0.04 Rel. Min: 0.12 Rel. Max: 0	Normal Mean: 0.5 Std Dev: 0.04 Rel. Min: 0.12 Rel. Max: 0.12	Normal Mean: 0.05 Std Dev: 0.01 Rel. Min: 0.03 Rel. Max: 0.03		
Vegetated soil (Fill material)	🟨	Normal Mean: 0.25 Std Dev: 0.02 Rel. Min: 0.06 Rel. Max: 0.06	Normal Mean: 0.55 Std Dev: 0.02 Rel. Min: 0.06 Rel. Max: 0.06	0.55	0.3		
Gravel Road	🟫	Normal Mean: 0.35 Std Dev: 0.04 Rel. Min: 0.12 Rel. Max: 0.12	Normal Mean: 0.85 Std Dev: 0.04 Rel. Min: 0.12 Rel. Max: 0.12	0.55	0.1	Normal Mean: 0.05 Std Dev: 0.01 Rel. Min: 0.03 Rel. Max: 0.03	Normal Mean: 0 Std Dev: 0.005 Rel. Min: 0.015 Rel. Max: 0.015

Distribution of Rock Path End Locations



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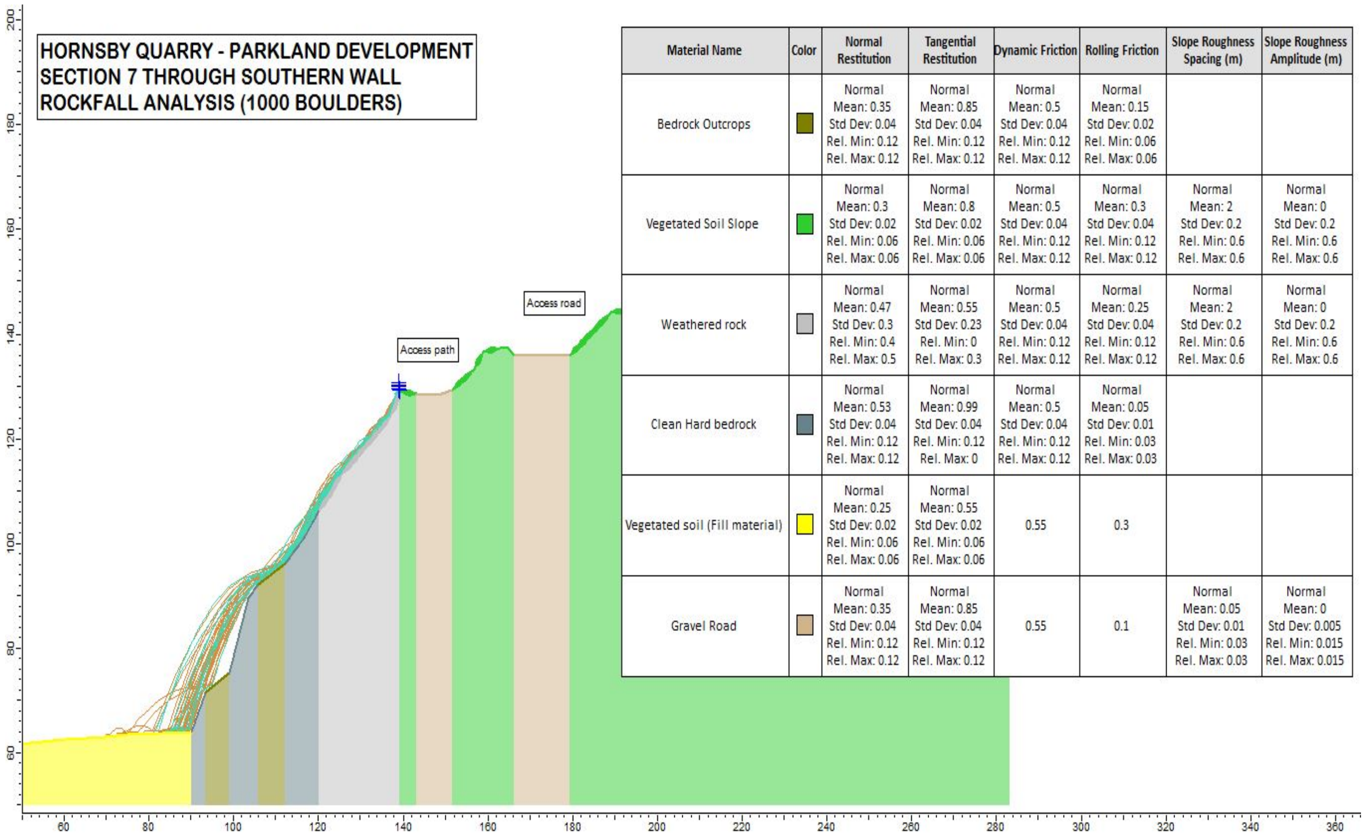
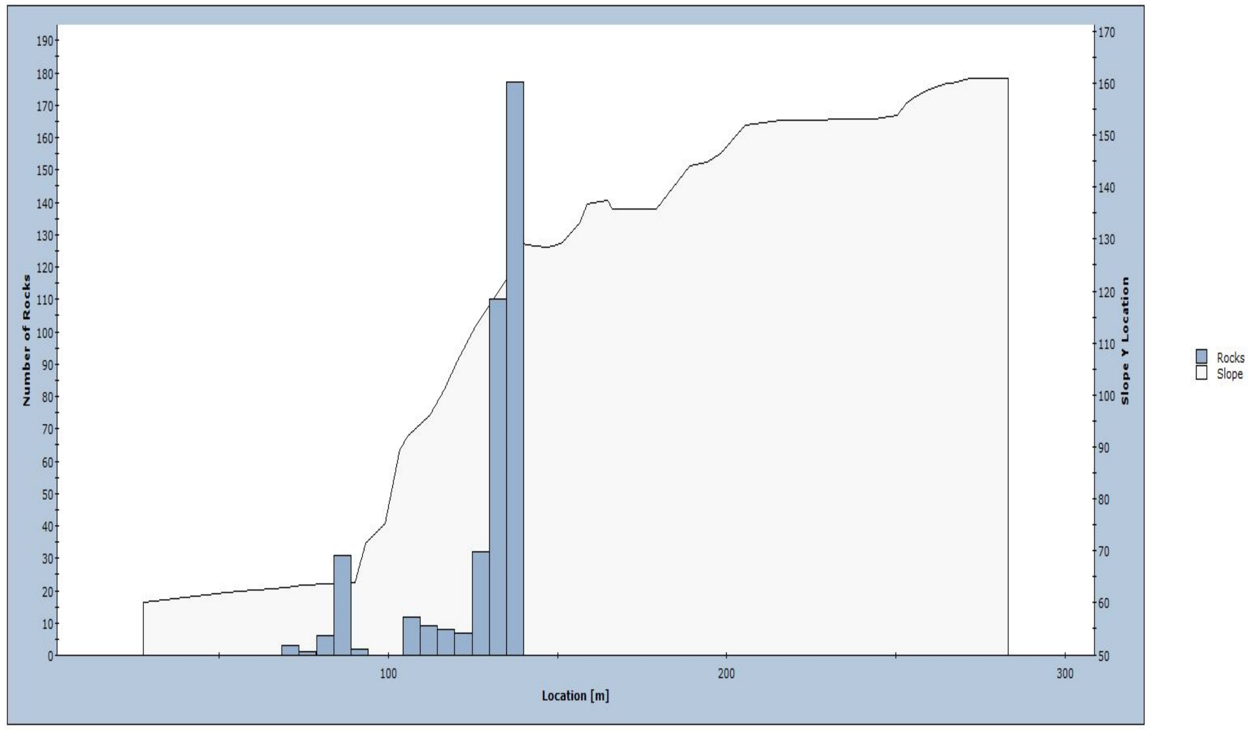


Material Name	Color	Normal Restitution	Tangential Restitution	Dynamic Friction	Rolling Friction	Slope Roughness Spacing (m)	Slope Roughness Amplitude (m)
Bedrock Outcrops	🟫	Normal Mean: 0.35 Std Dev: 0.04 Rel. Min: 0.12 Rel. Max: 0.12	Normal Mean: 0.85 Std Dev: 0.04 Rel. Min: 0.12 Rel. Max: 0.12	Normal Mean: 0.5 Std Dev: 0.04 Rel. Min: 0.12 Rel. Max: 0.12	Normal Mean: 0.15 Std Dev: 0.02 Rel. Min: 0.06 Rel. Max: 0.06		
Vegetated Soil Slope	🟩	Normal Mean: 0.3 Std Dev: 0.02 Rel. Min: 0.06 Rel. Max: 0.06	Normal Mean: 0.8 Std Dev: 0.02 Rel. Min: 0.06 Rel. Max: 0.06	Normal Mean: 0.5 Std Dev: 0.04 Rel. Min: 0.12 Rel. Max: 0.12	Normal Mean: 0.3 Std Dev: 0.04 Rel. Min: 0.12 Rel. Max: 0.12	Normal Mean: 2 Std Dev: 0.2 Rel. Min: 0.6 Rel. Max: 0.6	Normal Mean: 0 Std Dev: 0.2 Rel. Min: 0.6 Rel. Max: 0.6
Weathered rock	⬜	Normal Mean: 0.47 Std Dev: 0.3 Rel. Min: 0.4 Rel. Max: 0.5	Normal Mean: 0.55 Std Dev: 0.23 Rel. Min: 0 Rel. Max: 0.3	Normal Mean: 0.5 Std Dev: 0.04 Rel. Min: 0.12 Rel. Max: 0.12	Normal Mean: 0.25 Std Dev: 0.04 Rel. Min: 0.12 Rel. Max: 0.12	Normal Mean: 2 Std Dev: 0.2 Rel. Min: 0.6 Rel. Max: 0.6	Normal Mean: 0 Std Dev: 0.2 Rel. Min: 0.6 Rel. Max: 0.6
Clean Hard bedrock	⬛	Normal Mean: 0.53 Std Dev: 0.04 Rel. Min: 0.12 Rel. Max: 0.12	Normal Mean: 0.99 Std Dev: 0.04 Rel. Min: 0.12 Rel. Max: 0	Normal Mean: 0.5 Std Dev: 0.04 Rel. Min: 0.12 Rel. Max: 0.12	Normal Mean: 0.05 Std Dev: 0.01 Rel. Min: 0.03 Rel. Max: 0.03		
Vegetated soil (Fill material)	🟨	Normal Mean: 0.25 Std Dev: 0.02 Rel. Min: 0.06 Rel. Max: 0.06	Normal Mean: 0.55 Std Dev: 0.02 Rel. Min: 0.06 Rel. Max: 0.06	0.55	0.3		
Gravel Road	🟫	Normal Mean: 0.35 Std Dev: 0.04 Rel. Min: 0.12 Rel. Max: 0.12	Normal Mean: 0.85 Std Dev: 0.04 Rel. Min: 0.12 Rel. Max: 0.12	0.55	0.1	Normal Mean: 0.05 Std Dev: 0.01 Rel. Min: 0.03 Rel. Max: 0.03	Normal Mean: 0 Std Dev: 0.005 Rel. Min: 0.015 Rel. Max: 0.015

Distribution of Rock Path End Locations



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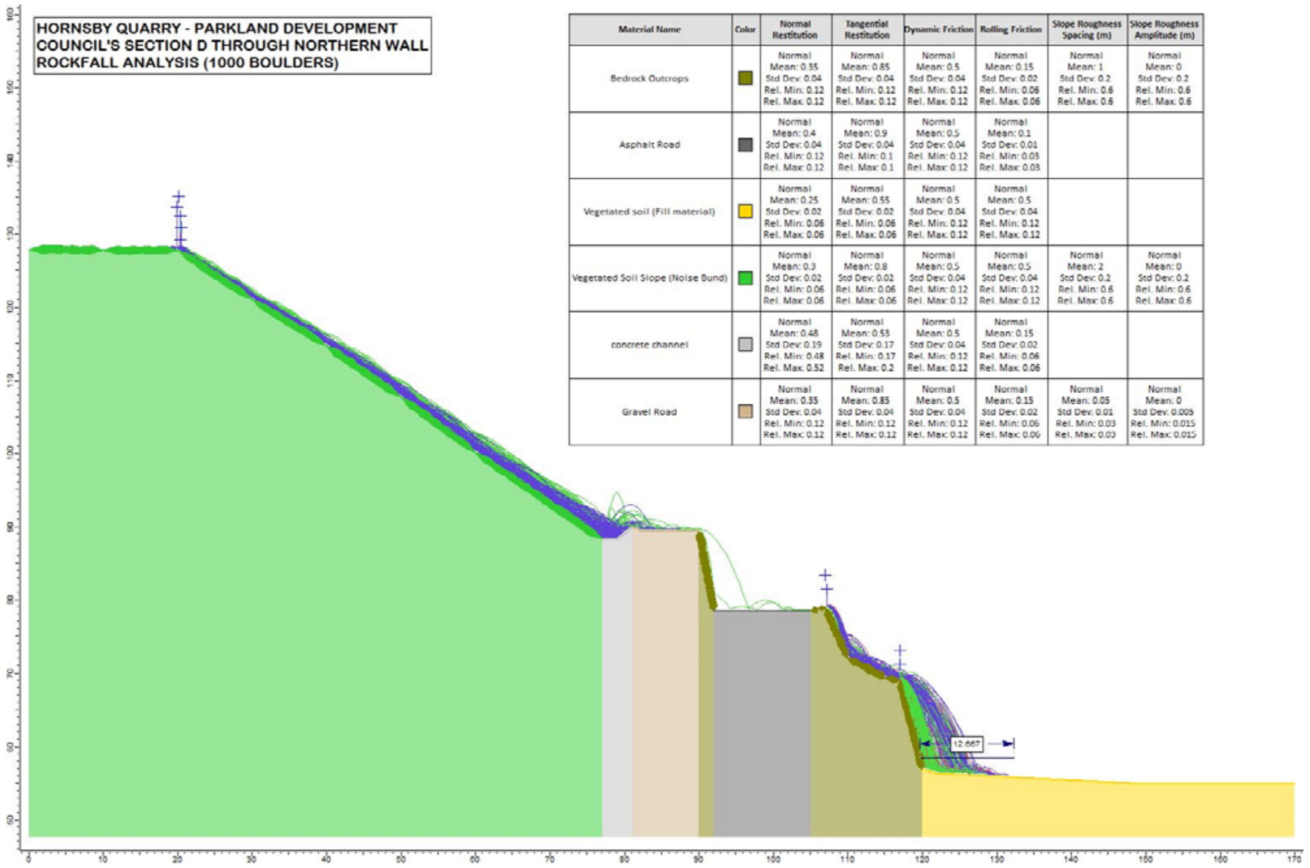
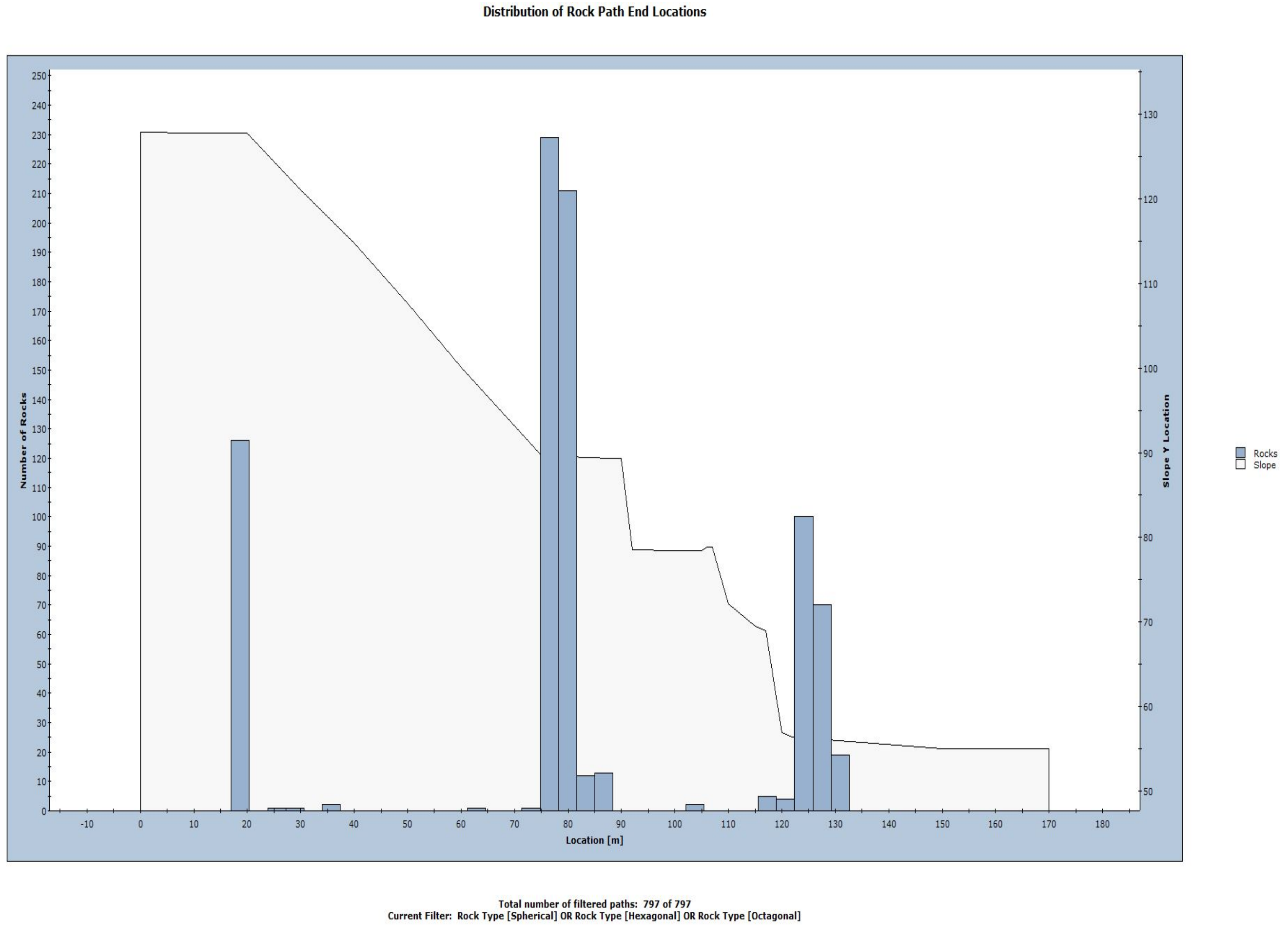
NORTH WALL (EASTERN END)



HORNSBY QUARRY - PARKLAND DEVELOPMENT
COUNCIL'S SECTION D THROUGH NORTHERN WALL
ROCKFALL ANALYSIS (1000 BOULDERS)

Material Name	Color	Normal Restitution	Tangential Restitution	Dynamic Friction	Rolling Friction	Slope Roughness Spacing (m)	Slope Roughness Amplitude (m)
Bedrock Outcrops	🟫	Normal Mean: 0.35 Std Dev: 0.04 Rel. Min: 0.12 Rel. Max: 0.12	Normal Mean: 0.85 Std Dev: 0.04 Rel. Min: 0.12 Rel. Max: 0.12	Normal Mean: 0.5 Std Dev: 0.04 Rel. Min: 0.12 Rel. Max: 0.12	Normal Mean: 0.15 Std Dev: 0.02 Rel. Min: 0.06 Rel. Max: 0.06	Normal Mean: 1 Std Dev: 0.2 Rel. Min: 0.6 Rel. Max: 0.6	Normal Mean: 0 Std Dev: 0.2 Rel. Min: 0.6 Rel. Max: 0.6
Asphalt Road	⬛	Normal Mean: 0.4 Std Dev: 0.04 Rel. Min: 0.12 Rel. Max: 0.12	Normal Mean: 0.9 Std Dev: 0.04 Rel. Min: 0.1 Rel. Max: 0.1	Normal Mean: 0.5 Std Dev: 0.04 Rel. Min: 0.12 Rel. Max: 0.12	Normal Mean: 0.1 Std Dev: 0.01 Rel. Min: 0.03 Rel. Max: 0.03		
Vegetated soil (Fill material)	🟨	Normal Mean: 0.25 Std Dev: 0.02 Rel. Min: 0.06 Rel. Max: 0.06	Normal Mean: 0.55 Std Dev: 0.02 Rel. Min: 0.06 Rel. Max: 0.06	Normal Mean: 0.5 Std Dev: 0.04 Rel. Min: 0.12 Rel. Max: 0.12	Normal Mean: 0.5 Std Dev: 0.04 Rel. Min: 0.12 Rel. Max: 0.12		
Vegetated Soil Slope (Noise Bund)	🟩	Normal Mean: 0.3 Std Dev: 0.02 Rel. Min: 0.06 Rel. Max: 0.06	Normal Mean: 0.8 Std Dev: 0.02 Rel. Min: 0.06 Rel. Max: 0.06	Normal Mean: 0.5 Std Dev: 0.04 Rel. Min: 0.12 Rel. Max: 0.12	Normal Mean: 0.5 Std Dev: 0.04 Rel. Min: 0.12 Rel. Max: 0.12	Normal Mean: 2 Std Dev: 0.2 Rel. Min: 0.6 Rel. Max: 0.6	Normal Mean: 0 Std Dev: 0.2 Rel. Min: 0.6 Rel. Max: 0.6
concrete channel	⬜	Normal Mean: 0.48 Std Dev: 0.19 Rel. Min: 0.48 Rel. Max: 0.52	Normal Mean: 0.53 Std Dev: 0.17 Rel. Min: 0.17 Rel. Max: 0.2	Normal Mean: 0.5 Std Dev: 0.04 Rel. Min: 0.12 Rel. Max: 0.12	Normal Mean: 0.15 Std Dev: 0.02 Rel. Min: 0.06 Rel. Max: 0.06		
Gravel Road	🟫	Normal Mean: 0.35 Std Dev: 0.04 Rel. Min: 0.12 Rel. Max: 0.12	Normal Mean: 0.85 Std Dev: 0.04 Rel. Min: 0.12 Rel. Max: 0.12	Normal Mean: 0.5 Std Dev: 0.04 Rel. Min: 0.12 Rel. Max: 0.12	Normal Mean: 0.15 Std Dev: 0.02 Rel. Min: 0.06 Rel. Max: 0.06	Normal Mean: 0.05 Std Dev: 0.01 Rel. Min: 0.03 Rel. Max: 0.03	Normal Mean: 0 Std Dev: 0.005 Rel. Min: 0.015 Rel. Max: 0.015



Distribution of Rock Path End Locations

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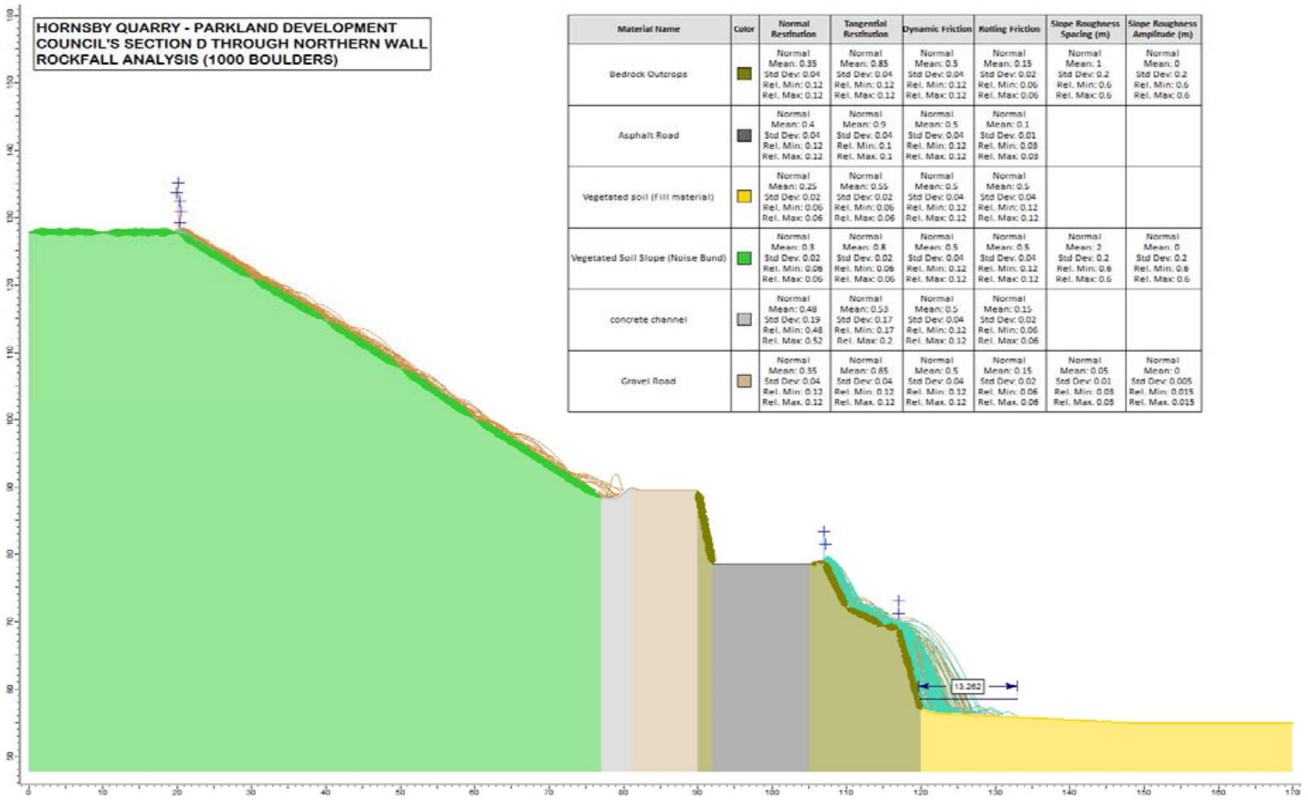
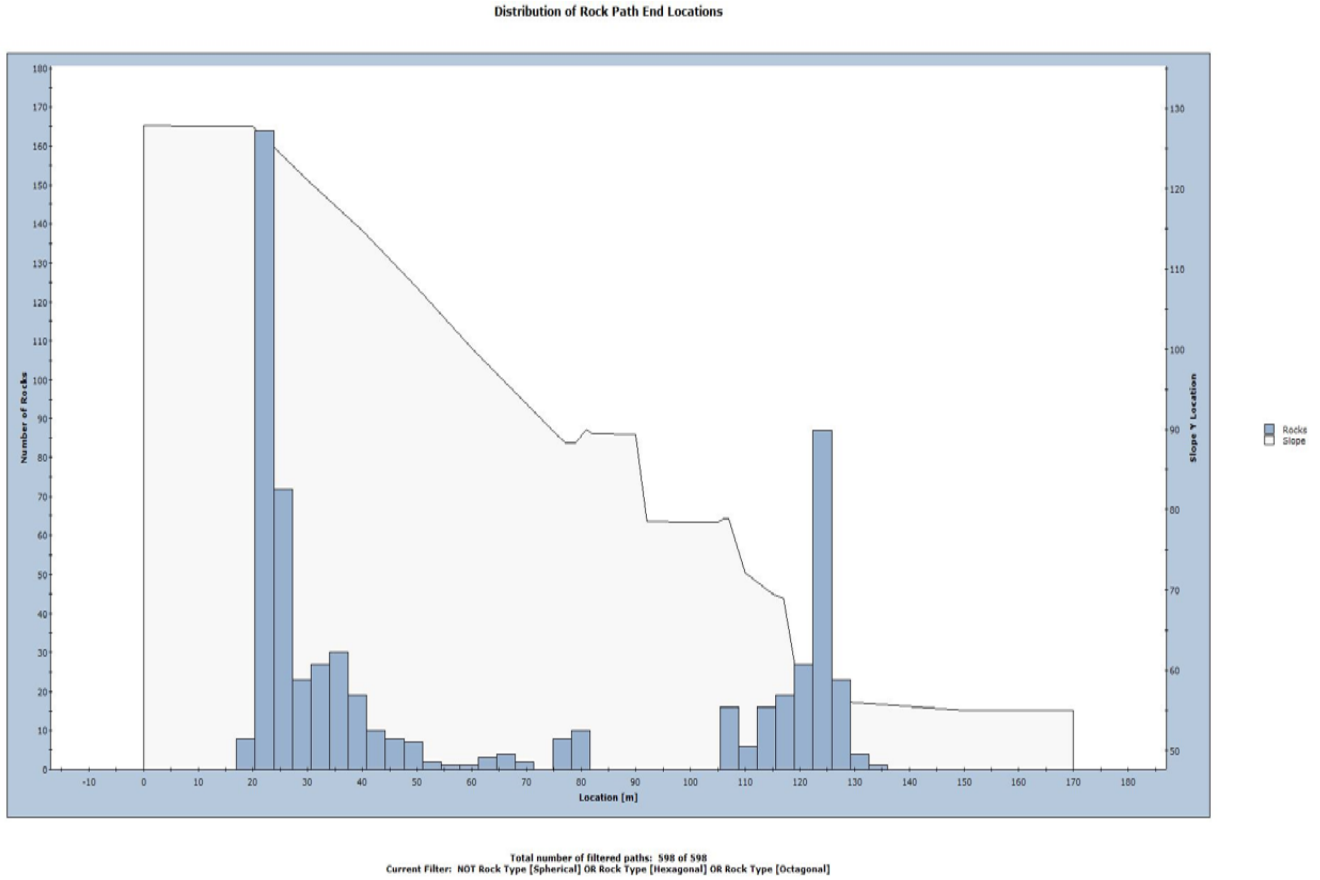


HORNSBY QUARRY - PARKLAND DEVELOPMENT
COUNCIL'S SECTION D THROUGH NORTHERN WALL
ROCKFALL ANALYSIS (1000 BOULDERS)

Material Name	Color	Normal Restitution	Tangential Restitution	Dynamic Friction	Rolling Friction	Slope Roughness Spacing (m)	Slope Roughness Amplitude (m)
Bedrock Outcrops	🟫	Normal Mean: 0.35 Std Dev: 0.04 Rel. Min: 0.12 Rel. Max: 0.12	Normal Mean: 0.85 Std Dev: 0.04 Rel. Min: 0.12 Rel. Max: 0.12	Normal Mean: 0.5 Std Dev: 0.04 Rel. Min: 0.12 Rel. Max: 0.12	Normal Mean: 0.15 Std Dev: 0.02 Rel. Min: 0.06 Rel. Max: 0.06	Normal Mean: 1 Std Dev: 0.2 Rel. Min: 0.6 Rel. Max: 0.6	Normal Mean: 0 Std Dev: 0.2 Rel. Min: 0.6 Rel. Max: 0.6
Asphalt Road	⬛	Normal Mean: 0.4 Std Dev: 0.04 Rel. Min: 0.12 Rel. Max: 0.12	Normal Mean: 0.9 Std Dev: 0.04 Rel. Min: 0.1 Rel. Max: 0.1	Normal Mean: 0.5 Std Dev: 0.04 Rel. Min: 0.12 Rel. Max: 0.12	Normal Mean: 0.1 Std Dev: 0.01 Rel. Min: 0.03 Rel. Max: 0.03		
Vegetated soil (Fill material)	🟨	Normal Mean: 0.25 Std Dev: 0.02 Rel. Min: 0.06 Rel. Max: 0.06	Normal Mean: 0.55 Std Dev: 0.02 Rel. Min: 0.06 Rel. Max: 0.06	Normal Mean: 0.5 Std Dev: 0.04 Rel. Min: 0.12 Rel. Max: 0.12	Normal Mean: 0.5 Std Dev: 0.04 Rel. Min: 0.12 Rel. Max: 0.12		
Vegetated Soil Slope (Noise Bund)	🟩	Normal Mean: 0.3 Std Dev: 0.02 Rel. Min: 0.06 Rel. Max: 0.06	Normal Mean: 0.8 Std Dev: 0.02 Rel. Min: 0.06 Rel. Max: 0.06	Normal Mean: 0.5 Std Dev: 0.04 Rel. Min: 0.12 Rel. Max: 0.12	Normal Mean: 0.5 Std Dev: 0.04 Rel. Min: 0.12 Rel. Max: 0.12	Normal Mean: 2 Std Dev: 0.2 Rel. Min: 0.6 Rel. Max: 0.6	Normal Mean: 0 Std Dev: 0.2 Rel. Min: 0.6 Rel. Max: 0.6
concrete channel	⬜	Normal Mean: 0.48 Std Dev: 0.19 Rel. Min: 0.48 Rel. Max: 0.52	Normal Mean: 0.53 Std Dev: 0.17 Rel. Min: 0.17 Rel. Max: 0.2	Normal Mean: 0.5 Std Dev: 0.04 Rel. Min: 0.12 Rel. Max: 0.12	Normal Mean: 0.15 Std Dev: 0.02 Rel. Min: 0.06 Rel. Max: 0.06		
Gravel Road	🟫	Normal Mean: 0.35 Std Dev: 0.04 Rel. Min: 0.12 Rel. Max. 0.12	Normal Mean: 0.85 Std Dev: 0.04 Rel. Min: 0.12 Rel. Max. 0.12	Normal Mean: 0.5 Std Dev: 0.04 Rel. Min: 0.12 Rel. Max. 0.12	Normal Mean: 0.15 Std Dev: 0.02 Rel. Min: 0.06 Rel. Max. 0.06	Normal Mean: 0.05 Std Dev: 0.01 Rel. Min: 0.03 Rel. Max. 0.03	Normal Mean: 0 Std Dev: 0.005 Rel. Min: 0.015 Rel. Max. 0.015



Distribution of Rock Path End Locations

Total number of filtered paths: 598 of 598
Current Filter: NOT Rock Type [Spherical] OR Rock Type [Hexagonal] OR Rock Type [Octagonal]

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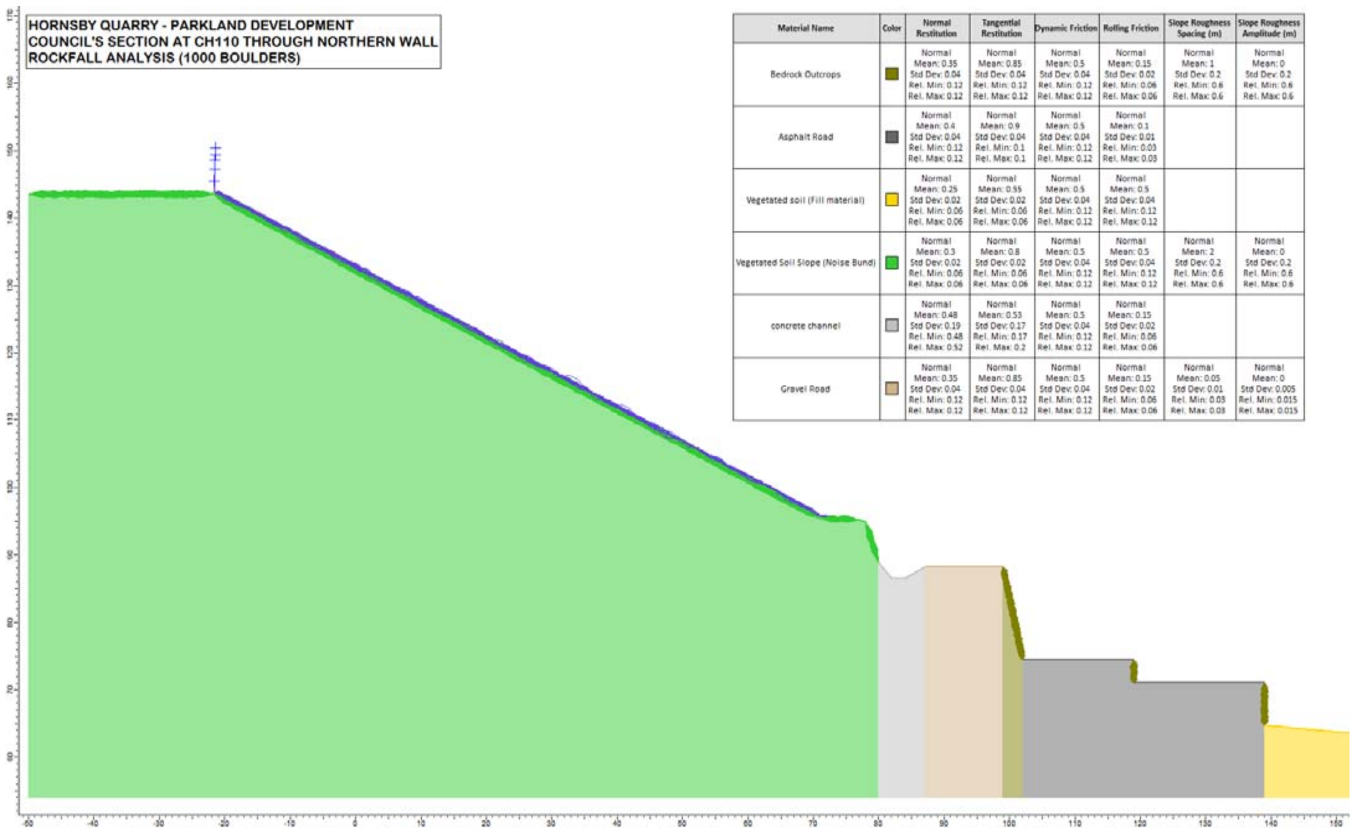
NORTH WALL (WESTERN END)



Material Name	Color	Normal Restitution	Tangential Restitution	Dynamic Friction	Rolling Friction	Slope Roughness Spacing (m)	Slope Roughness Amplitude (m)
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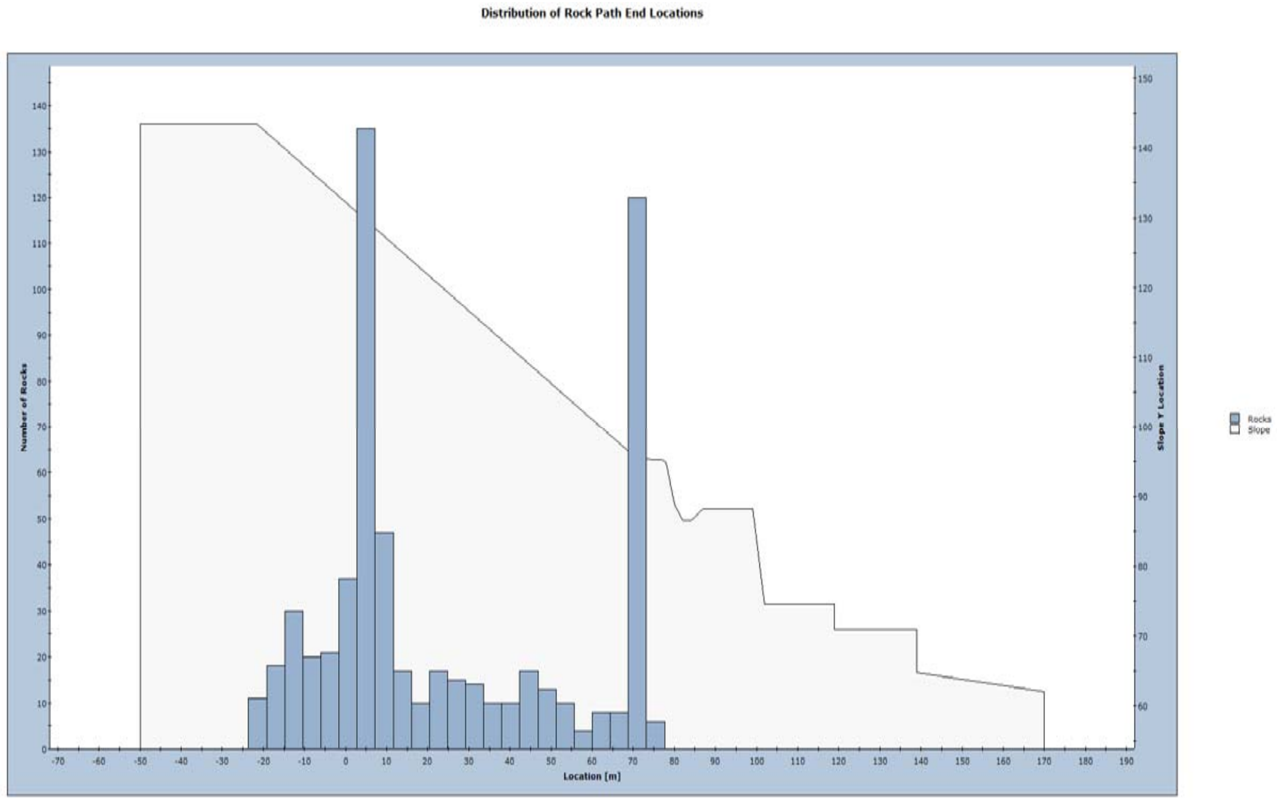
Asphalt Road	⬛	Normal Mean: 0.4 Std Dev: 0.04 Rel. Min: 0.12 Rel. Max: 0.12	Normal Mean: 0.9 Std Dev: 0.04 Rel. Min: 0.1 Rel. Max: 0.1	Normal Mean: 0.5 Std Dev: 0.04 Rel. Min: 0.12 Rel. Max: 0.12	Normal Mean: 0.1 Std Dev: 0.01 Rel. Min: 0.03 Rel. Max: 0.03		
Vegetated soil (Fill material)	🟨	Normal Mean: 0.25 Std Dev: 0.02 Rel. Min: 0.06 Rel. Max: 0.06	Normal Mean: 0.55 Std Dev: 0.02 Rel. Min: 0.06 Rel. Max: 0.06	Normal Mean: 0.5 Std Dev: 0.04 Rel. Min: 0.12 Rel. Max: 0.12	Normal Mean: 0.5 Std Dev: 0.04 Rel. Min: 0.12 Rel. Max: 0.12		
Vegetated Soil Slope (Noise Bund)	🟩	Normal Mean: 0.3 Std Dev: 0.02 Rel. Min: 0.06 Rel. Max: 0.06	Normal Mean: 0.8 Std Dev: 0.02 Rel. Min: 0.06 Rel. Max: 0.06	Normal Mean: 0.5 Std Dev: 0.04 Rel. Min: 0.12 Rel. Max: 0.12	Normal Mean: 0.5 Std Dev: 0.04 Rel. Min: 0.12 Rel. Max: 0.12	Normal Mean: 2 Std Dev: 0.2 Rel. Min: 0.6 Rel. Max: 0.6	Normal Mean: 0 Std Dev: 0.2 Rel. Min: 0.6 Rel. Max: 0.6
concrete channel	⬜	Normal Mean: 0.48 Std Dev: 0.19 Rel. Min: 0.48 Rel. Max: 0.52	Normal Mean: 0.53 Std Dev: 0.17 Rel. Min: 0.17 Rel. Max: 0.2	Normal Mean: 0.5 Std Dev: 0.04 Rel. Min: 0.12 Rel. Max: 0.12	Normal Mean: 0.15 Std Dev: 0.02 Rel. Min: 0.06 Rel. Max: 0.06		
Gravel Road	🟫	Normal Mean: 0.35 Std Dev: 0.04 Rel. Min: 0.12 Rel. Max: 0.12	Normal Mean: 0.85 Std Dev: 0.04 Rel. Min: 0.12 Rel. Max: 0.12	Normal Mean: 0.5 Std Dev: 0.04 Rel. Min: 0.12 Rel. Max: 0.12	Normal Mean: 0.15 Std Dev: 0.02 Rel. Min: 0.06 Rel. Max: 0.06	Normal Mean: 0.05 Std Dev: 0.01 Rel. Min: 0.03 Rel. Max: 0.03	Normal Mean: 0 Std Dev: 0.005 Rel. Min: 0.015 Rel. Max: 0.015



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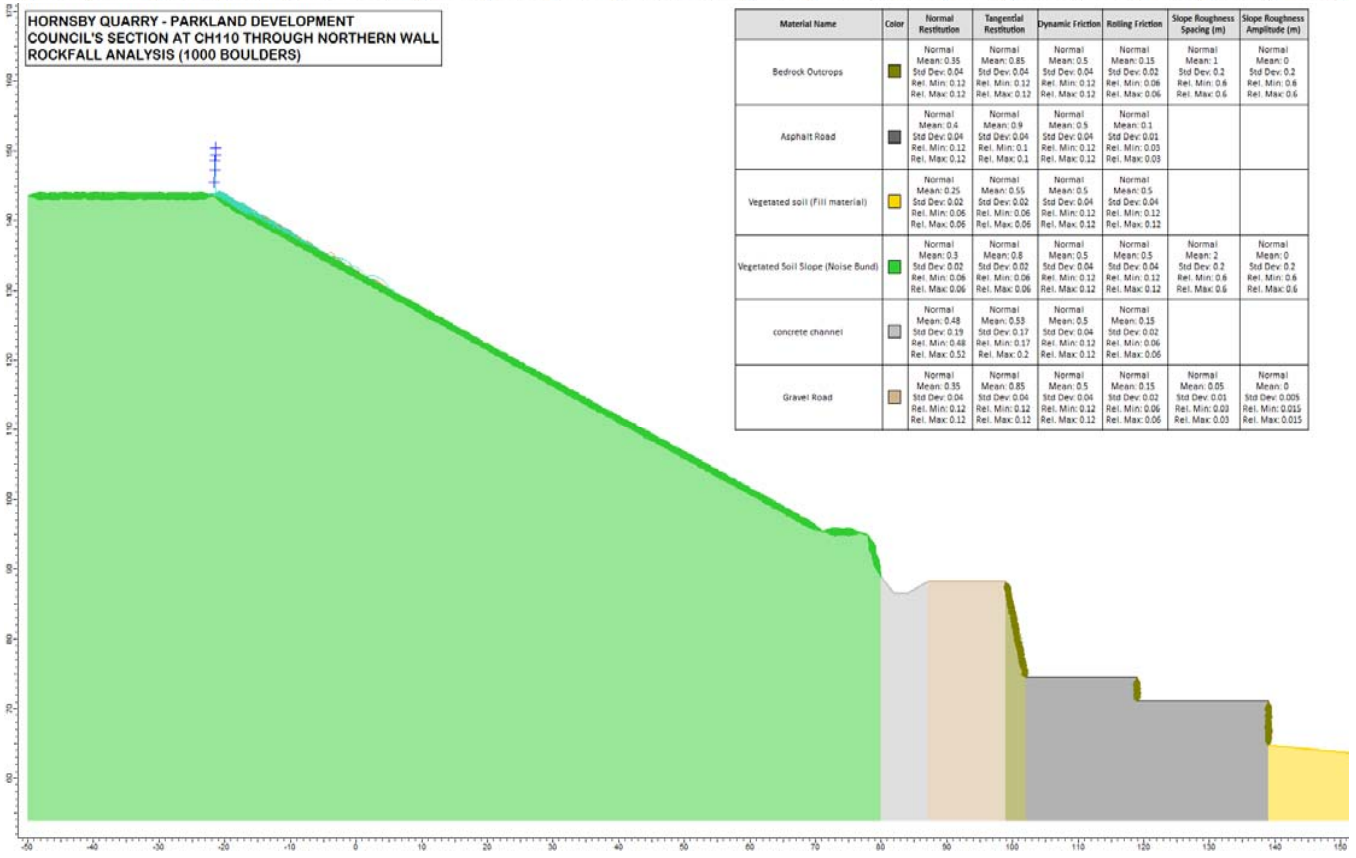

Material Name	Color	Normal Restitution	Tangential Restitution	Dynamic Friction	Rolling Friction	Slope Roughness Spacing (m)	Slope Roughness Amplitude (m)
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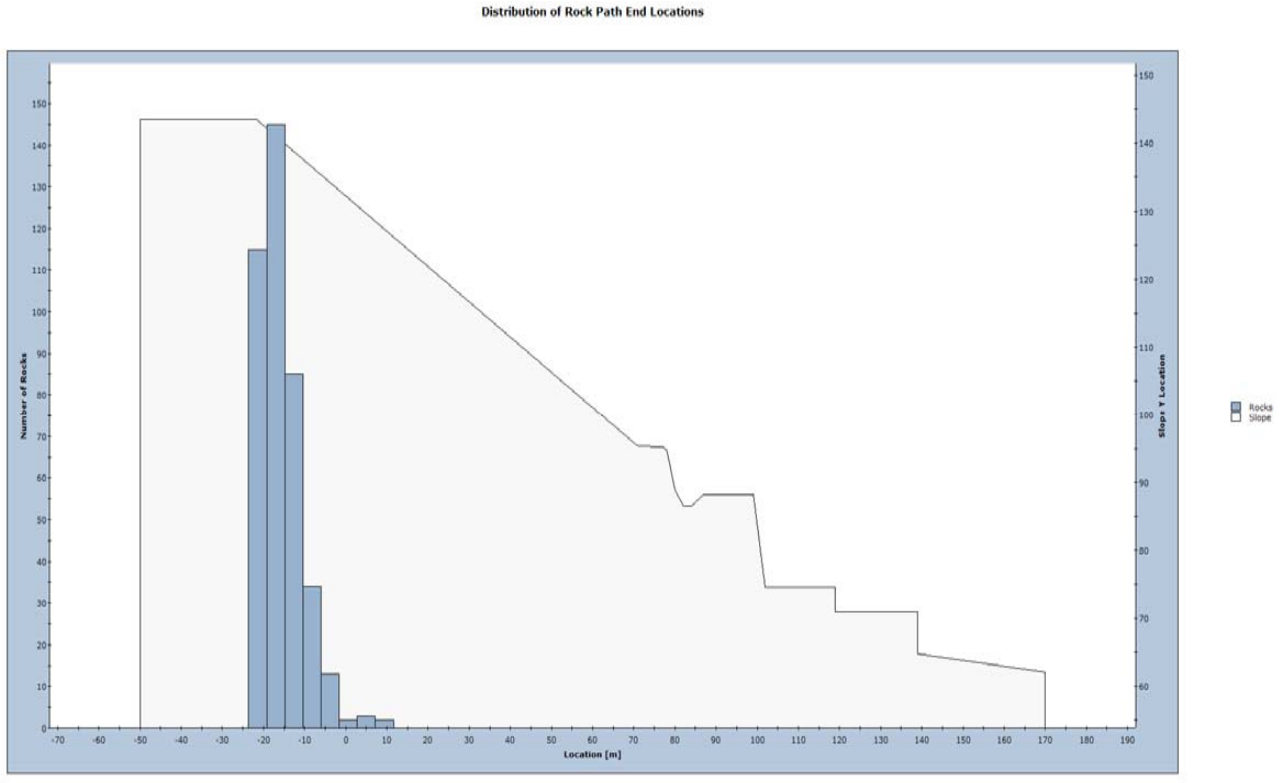
concrete channel	⬜	Normal Mean: 0.48 Std Dev: 0.19 Rel. Min: 0.48 Rel. Max: 0.52	Normal Mean: 0.53 Std Dev: 0.17 Rel. Min: 0.17 Rel. Max: 0.2	Normal Mean: 0.5 Std Dev: 0.04 Rel. Min: 0.12 Rel. Max: 0.12	Normal Mean: 0.15 Std Dev: 0.02 Rel. Min: 0.06 Rel. Max: 0.06		
Gravel Road	🟫	Normal Mean: 0.35 Std Dev: 0.04 Rel. Min: 0.12 Rel. Max: 0.12	Normal Mean: 0.85 Std Dev: 0.04 Rel. Min: 0.12 Rel. Max: 0.12	Normal Mean: 0.5 Std Dev: 0.04 Rel. Min: 0.12 Rel. Max: 0.12	Normal Mean: 0.15 Std Dev: 0.02 Rel. Min: 0.06 Rel. Max: 0.06	Normal Mean: 0.05 Std Dev: 0.01 Rel. Min: 0.03 Rel. Max: 0.03	Normal Mean: 0 Std Dev: 0.005 Rel. Min: 0.015 Rel. Max: 0.015



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Appendix B – Green Terramesh - Specification Sheet

MACCAFERRI

INSTALLATION GUIDE

Rev: 02, Issue Date June 2015

GREEN TERRAMESH SYSTEM

CONTRACTORS SHEET

Reference

Please refer to full specification NZ-PSS-GTMESH 10/04 and installation drawing TM_GreenNZ.dwg.
Working at height - Refer to the Health and Safety provisions in Employment Act 1992 regarding the need to take all practicable steps to ensure safety of workers. Further information of on how to prevent falls from height can be obtained from the Department of Labour at www.dol.govt.nz and Site Safe New Zealand at www.sitesafe.org.nz

Supply

Green Terramesh units are pre-assembled during manufacturing (excluding Biomac Grasstrike R300 erosion blankets) and are supplied folded flat in bundles of 30 units. The biodegradable Biomac Grasstrike R300 matting is supplied in rolls 1.8m x 30m and is used where a vegetated face option has been chosen.

Assembly

Prior to installing the assembled units, the foundation shall be prepared to the correct lines and grades . Surface irregularities, loose material, and vegetation shall be removed during the preparation of the foundation.
Units are carried to and placed in their final position. Raise the unit's facing, turn the triangular stiffening brackets perpendicular to the face and connect to the base panel with lacing wire or steel fasteners.

Biomac Grasstrike Placement

The Biomac Grasstrike R300 is rolled out, placed through the triangular brackets located behind the front face of the Green Terramesh unit and fixed top and bottom to the mesh face.
Slitting of the Biomac Grasstrike R300 in line with the triangular brackets is required to ensure that it extends horizontally back against the horizontal mesh by at least 400mm top and bottom.

Backfill and Compaction

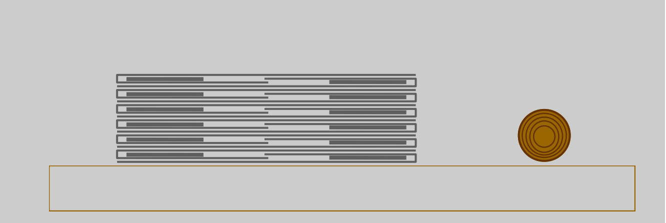
Approved backfill shall be placed up to 500mm of the face in maximum 300mm vertical lifts and compacted to a minimum of 95% of Standard Proctor Density.
Compaction is to proceed parallel to the slope face, ensuring that the compacting machine does not come within 1m of the face element. Lighter compaction equipment should be used towards the front face zone.

Topsoil Placement

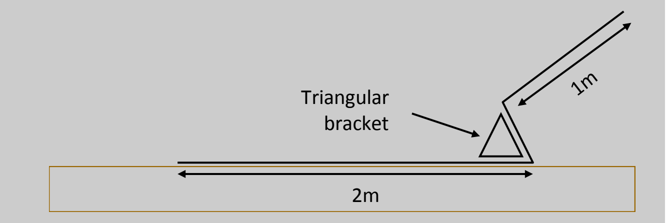
Vegetative soil shall be placed in the 0.3m to 0.5m zone of the structure, behind the Green Terramesh and Biomac Grasstrike R300 face to enable long-term sustainable vegetation growth.
The soil should be firmly compacted by plate or small machine compactor. Overfill topsoil zone by 5% to allow for some local settlement of the vegetative soil.

Completion

The Biomac Grasstrike R300 and 1m long Green Terramesh tieback is folded back into the slope ready for the next unit.
The next row of Green Terramesh units shall be laid out as previously described directly on the lower Green Terramesh units.
The upper and lower units shall be all connected along the front reinforced bar.

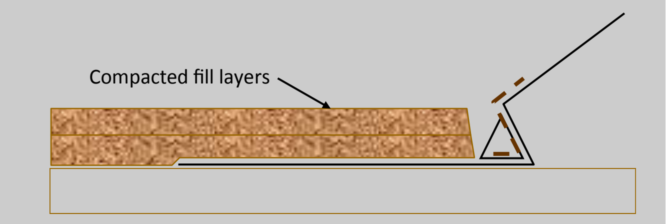


Step 1

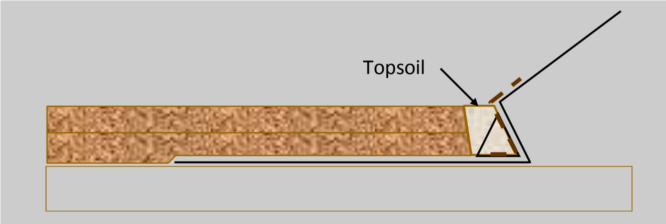


Step 2

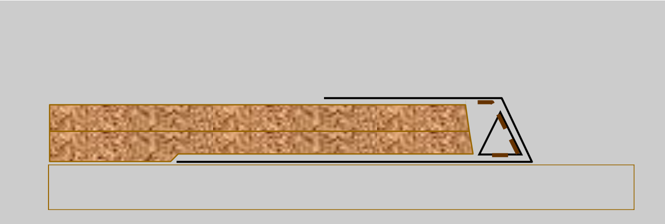
Step 3



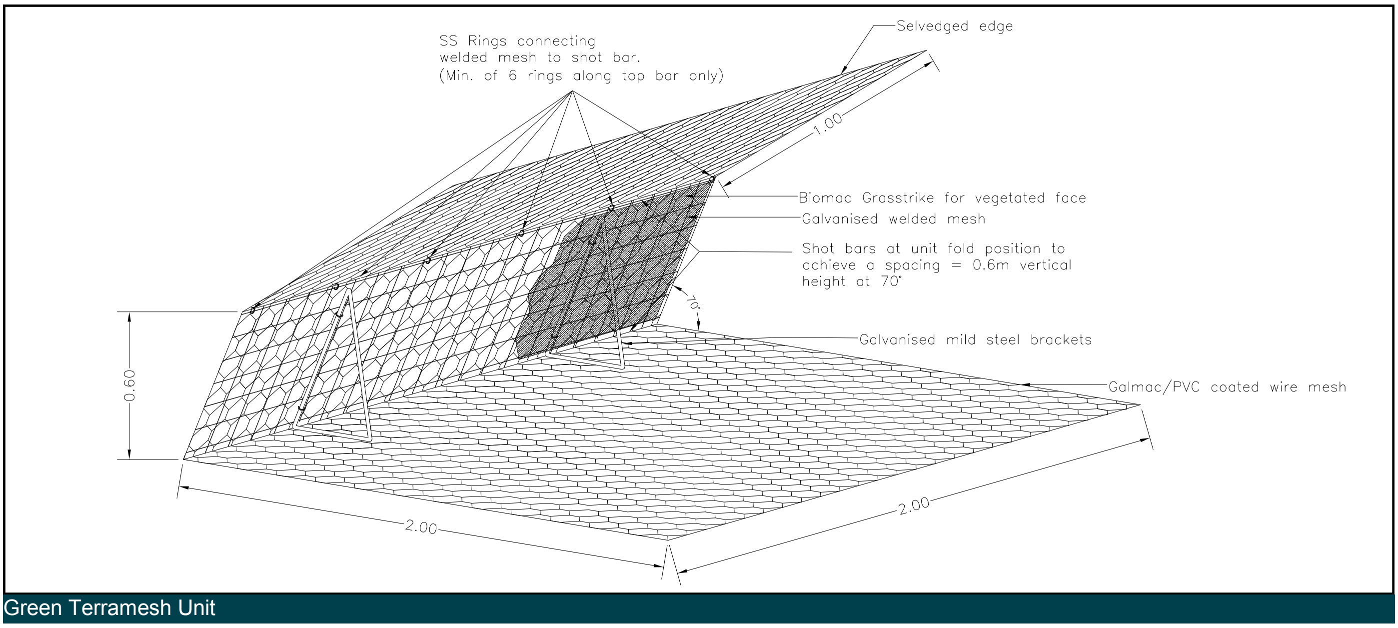
Step 4



Step 5



Step 6



Green Terramesh Unit

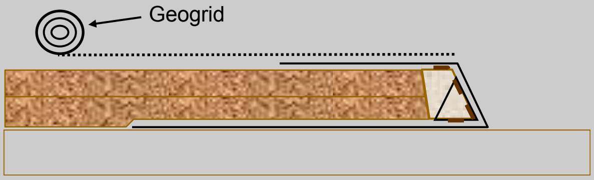
Green Terramesh Combined with Geogrid

Installation

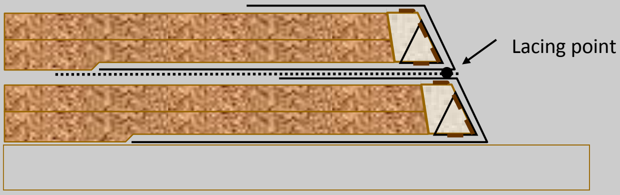
Prior to placing of any geogrid reinforcement, the soil profile shall be graded to the lines and grades shown on the construction drawings. Surface irregularities, loose material, and vegetation shall be removed during the preparation of the foundation.

The geogrid reinforcement shall be laid out in a manner so that the strength direction (roll direction) is perpendicular to the slope face. Proper geogrid orientation is of extreme importance due to the difference in geogrid strengths in either direction. The contractor will be responsible for proper geogrid orientation. The geogrids shall be cut to correct lengths and placed at correct elevation as shown on the construction drawings.

Installation of the Green Terramesh® units and Biomac Grasstrike R300 follows the steps described on page 1. Once the first row of units are placed in position, the units shall be connected through the geogrid layer along the front reinforced bar using lacing wire or stainless steel fasteners.



Roll out geogrid and cut to length



Place next layer of Green Terramesh, Biomac and fill

Green Terramesh - Italy

Green Terramesh Wall - New Zealand

Geofabrics New Zealand Ltd
14 Goodman Place, PO Box 12536, Penrose, Auckland, New Zealand
T: (+64) 9 6436495 F: (+64) 9 634 6492, FREEPHONE 0800 60 60 20
E: sales@geofabrics.co.nz
www.geofabrics.co.nz

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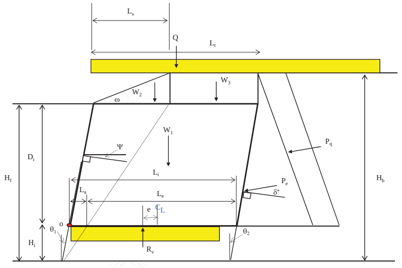
Appendix C – RSW Internal Design Results

GEOFABRIC WALL DESIGN (INTERNAL STABILITY ONLY)

Project: **HORNSBY QUARRY**
Job No: **21/26457**
Wall location: **5m high wall**
Load combination: **B**
Case No: **1 - 9m Depth GWT**



DATA

Wall geometry

Height at Face, H_f = 5.50 m
Length at Top, L_t = 6.00 m
Face angle (vert.), θ_1 = 20.00 deg.
Back angle (vert.), θ_2 = 20.00 deg.
Slope Angle(horiz.), ω = 0.0 deg.
Slope Distance, L_s = 0.00 m
WT depth, d_w = 1.00 m
(from wall top)

Applied load

Uniform Surcharge, q = 20 kPa
Sill beam, S^*_{vb} = 0 kN/m
Eccentricity, E = 0 m
Sill beam, S^*_{hb} = 100 kN/m
Sill beam width, b = 0 m
Sill beam dist. from wall, a = 0 m

Soil properties

Select Fill, γ_1 = 20.0 kN/m3
Select Fill, ϕ_1 = 36.0 deg.
Select Fill, c'_1 = 0.0 kPa
General Fill, γ_2 = 20.0 kN/m3
General Fill, ϕ_2 = 40.0 deg.
General Fill, c'_2 = 0.0 kPa

Reinforcement

Use variable soil/reinforcement coefficient (Y/N)? N

Constant coefficient = 0.67

Load factors

γ_{gs} = 1.25
γ_{gw} = 1.00
γ_{g1} = 1.25
γ_{g2} = 1.25
γ_{g3} = 1.25
γ_{q1} = 1.50
γ_{q2} = 1.50

CALCULATIONS

Select Slope Dist, L^*_s = 0.00 m
Height at Back, H_b = 5.50 m
Average Height, H_{ave} = 5.50 m

rad conv. (180/π) = 57.30

cot(ξ) = 0.788
tan(ξ) = 1.269
G = 0.182 (1/m)
1/G = 5.500 m

Back friction angle, δ* = 0.0 deg.
Design Angle, ϕ^*_1 = 36.0 deg.
Design Angle, ϕ^*_2 = 40.0 deg.
Select Fill, K_{o1} = 0.218
Select Fill, K_{a1} = 0.143
General Fill, K_{a2} = 0.106

Notes

† Includes sill beam effect where appropriate
* Min. F.O.S. Rupture using design strap strength =1.0
(equivalent to 4.0 using short term ultimate strength)
‡ Min. F.O.S. Pull-out =1.5

														VERTICAL LOADING						OTHER LOADING			RUPTURE		PULL-OUT	
Layer No.	**Vertical spacing Top (s_{vi}) (m)**	**Height (H_i) (m)**	**Depth from top (D_i) (m)**		**Strap length (L_i) (m)**	**L_a (active) (m)**	**L_e (effective) (m)**	**$K^*_{1(zi)}$**	**μ_p**	**Design strap strength (P_{strap}) (kN)**	**Product**	**Avg. vert. spacing (s_{ave}) (m)**	**Strap angle (Ψ) (deg)**	**W_{water} (kN)**	**W_1 (kN)**	**W_2 (kN)**	**W_3 (kN)**	**Q (kN)**	**R_v (kN)**	**P_e (kN)**	**P_q (kN)**	**P_w (kN)**	**Tensile† strength (kN/m)**	**F.O.S. Rupture***	**Pullout resistance (kN/m)**	**F.O.S. Pull-out‡**
1	0.600	5.400	0.100	74.900	7.00	1.73	5.27	0.143	0.67	58.0	GX 100/30	0.600	0.00	0.00	15.0	0.0	0.0	180.0	195.0	0.01	0.32	0.00	52.2	**2.15**	76.16	**3.14**
2	0.600	4.800	0.700	74.300	7.00	1.54	5.46	0.143	0.67	58.0	GX 100/30	0.600	0.00	0.00	105.0	0.0	0.0	180.0	285.0	0.65	2.23	0.00	52.2	**2.23**	122.00	**5.22**
3	0.600	4.200	1.300	73.700	7.00	1.35	5.65	0.143	0.67	58.0	GX 100/30	0.600	0.00	17.66	195.0	0.0	0.0	180.0	357.3	2.20	4.14	0.44	52.2	**2.30**	159.94	**7.05**
4	0.600	3.600	1.900	73.100	7.00	1.15	5.85	0.143	0.67	58.0	GX 100/30	0.600	0.00	52.97	285.0	0.0	0.0	180.0	412.0	4.37	6.06	3.97	52.2	**2.32**	188.87	**8.40**
5	0.600	3.000	2.500	72.500	7.00	0.96	6.04	0.143	0.67	58.0	GX 100/30	0.600	0.00	88.29	375.0	0.0	0.0	180.0	466.7	7.13	7.97	11.04	52.2	**2.29**	219.35	**9.62**
6	0.600	2.400	3.100	71.900	7.00	0.77	6.23	0.143	0.67	58.0	GX 100/30	0.600	0.00	123.61	465.0	0.0	0.0	180.0	521.4	10.46	9.88	21.63	52.2	**2.19**	251.38	**10.55**
7	0.600	1.800	3.700	71.300	7.00	0.58	6.42	0.143	0.67	58.0	GX 100/30	0.600	0.00	158.92	555.0	0.0	0.0	180.0	576.1	14.38	11.79	35.76	52.2	**2.03**	284.95	**11.07**
8	0.600	1.200	4.300	70.700	7.00	0.38	6.62	0.143	0.67	58.0	GX 100/30	0.600	0.00	194.24	645.0	0.0	0.0	180.0	630.8	18.88	13.70	53.42	52.2	**1.73**	320.07	**10.62**
9	0.600	0.600	4.900	70.100	7.00	0.19	6.81	0.143	0.67	58.0	GX 100/30	0.600	0.00	229.55	735.0	0.0	0.0	180.0	685.4	23.96	15.62	74.61	52.2	**1.38**	356.73	**9.43**

GEOFABRIC WALL DESIGN (INTERNAL STABILITY ONLY)

Project: **HORNSBY QUARRY**
Job No: **21/26457**
Wall location: **8m high wall**
Load combination: **B**
Case No: **1 - 9m Depth GWT**

DATA

Wall geometry

Height at Face, H_f = 8.50 m
Length at Top, L_t = 8.00 m
Face angle (vert.), θ_1 = 20.00 deg.
Back angle (vert.), θ_2 = 20.00 deg.
Slope Angle(horiz.), ω = 0.0 deg.
Slope Distance, L_s = 0.00 m
WT depth, d_w = 5.00 m
(from wall top)

Applied load

Uniform Surcharge, q = 20 kPa
Sill beam, S^*_{vb} = 0 kN/m
Eccentricity, E = 0 m
Sill beam, S^*_{hb} = 100 kN/m
Sill beam width, b = 0 m
Sill beam dist. from wall, a = 0 m

Soil properties

Select Fill, γ_1 = 20.0 kN/m3
Select Fill, ϕ_1 = 36.0 deg.
Select Fill, c'_1 = 0.0 kPa
General Fill, γ_2 = 20.0 kN/m3
General Fill, ϕ_2 = 40.0 deg.
General Fill, c'_2 = 0.0 kPa

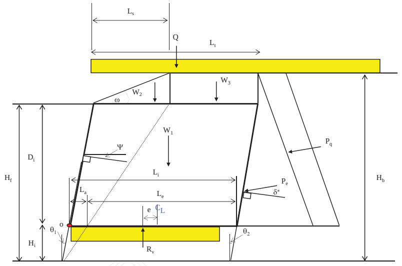
Reinforcement

Use variable soil/reinforcement coefficient (Y/N)? N

Constant coefficient = 0.67

Load factors

γ_{gs} = 1.25
γ_{gw} = 1.00
γ_{g1} = 1.25
γ_{g2} = 1.25
γ_{g3} = 1.25
γ_{q1} = 1.50
γ_{q2} = 1.50



CALCULATIONS

Select Slope Dist, L^*_s = 0.00 m
Height at Back, H_b = 8.50 m
Average Height, H_{ave} = 8.50 m

rad conv. (180/π) = 57.30

cot(ξ) = 0.788
tan(ξ) = 1.269
G = 0.118 (1/m)
1/G = 8.500 m

Back friction angle, δ* = 0.0 deg.
Design Angle, ϕ^*_1 = 36.0 deg.
Design Angle, ϕ^*_2 = 40.0 deg.
Select Fill, K_{o1} = 0.218
Select Fill, K_{a1} = 0.143
General Fill, K_{a2} = 0.106

Notes

† Includes sill beam effect where appropriate

* Min. F.O.S. Rupture using design strap strength =1.0
(equivalent to 4.0 using short term ultimate strength)

‡ Min. F.O.S. Pull-out =1.5

														VERTICAL LOADING						OTHER LOADING			RUPTURE		PULL-OUT	
Layer No.	**Vertical spacing Top (s_{vi}) (m)**	**Height (H_i) (m)**	**Depth from top (D_i) (m)**		**Strap length (L_i) (m)**	**L_a (active) (m)**	**L_e (effective) (m)**	**$K^*_{1(zi)}$**	**μ_p**	**Design strap strength (P_{strap}) (kN)**	**Product**	**Avg. vert. spacing (s_{ave}) (m)**	**Strap angle (Ψ) (deg)**	**W_{water} (kN)**	**W_1 (kN)**	**W_2 (kN)**	**W_3 (kN)**	**Q (kN)**	**R_v (kN)**	**P_e (kN)**	**P_q (kN)**	**P_w (kN)**	**Tensile† strength (kN/m)**	**F.O.S. Rupture***	**Pullout resistance (kN/m)**	**F.O.S. Pull-out‡**
1	0.600	8.400	0.100	78.500	8.00	2.69	5.31	0.143	0.67	58.0	GX 100/30	0.600	0.00	0.00	20.0	0.0	0.0	240.0	260.0	0.01	0.32	0.00	52.2	**3.12**	76.70	**4.58**
2	0.600	7.800	0.700	77.900	8.00	2.50	5.50	0.143	0.67	58.0	GX 100/30	0.600	0.00	0.00	140.0	0.0	0.0	240.0	380.0	0.65	2.23	0.00	52.2	**3.03**	122.84	**7.13**
3	0.600	7.200	1.300	77.300	8.00	2.31	5.69	0.143	0.67	58.0	GX 100/30	0.600	0.00	0.00	260.0	0.0	0.0	240.0	500.0	2.24	4.14	0.00	52.2	**2.94**	172.01	**9.69**
4	0.600	6.600	1.900	76.700	8.00	2.12	5.88	0.143	0.67	58.0	GX 100/30	0.600	0.00	0.00	380.0	0.0	0.0	240.0	620.0	4.79	6.06	0.00	52.2	**2.84**	224.22	**12.21**
5	0.600	6.000	2.500	76.100	8.00	1.92	6.08	0.143	0.67	58.0	GX 100/30	0.600	0.00	0.00	500.0	0.0	0.0	240.0	740.0	8.30	7.97	0.00	52.2	**2.74**	279.46	**14.66**
6	0.600	5.400	3.100	75.500	8.00	1.73	6.27	0.143	0.67	58.0	GX 100/30	0.600	0.00	0.00	620.0	0.0	0.0	240.0	860.0	12.76	9.88	0.00	52.2	**2.63**	337.74	**17.03**
7	0.600	4.800	3.700	74.900	8.00	1.54	6.46	0.143	0.67	58.0	GX 100/30	0.600	0.00	0.00	740.0	0.0	0.0	240.0	980.0	18.18	11.79	0.00	52.2	**2.52**	399.06	**19.27**
8	0.600	4.200	4.300	74.300	8.00	1.35	6.65	0.143	0.67	58.0	GX 100/30	0.600	0.00	0.00	860.0	0.0	0.0	240.0	1100.0	24.55	13.70	0.00	52.2	**2.41**	463.41	**21.39**
9	0.600	3.600	4.900	73.700	8.00	1.15	6.85	0.143	0.67	58.0	GX 100/30	0.600	0.00	0.00	980.0	0.0	0.0	240.0	1220.0	31.88	15.62	0.00	52.2	**2.30**	530.80	**23.36**
10	0.600	3.000	5.500	73.100	8.00	0.96	7.04	0.143	0.67	58.0	GX 100/30	0.600	0.00	39.24	1100.0	0.0	0.0	240.0	1300.8	40.04	17.53	1.23	52.2	**2.15**	578.54	**23.83**
11	0.600	2.400	6.100	72.500	8.00	0.77	7.23	0.143	0.67	58.0	GX 100/30	0.600	0.00	86.33	1220.0	0.0	0.0	240.0	1373.7	48.78	19.44	5.94	52.2	**1.92**	623.41	**22.92**
12	0.600	1.800	6.700	71.900	8.00	0.58	7.42	0.143	0.67	58.0	GX 100/30	0.600	0.00	133.42	1340.0	0.0	0.0	240.0	1446.6	58.11	21.35	14.18	52.2	**1.68**	669.83	**21.50**
13	0.600	1.200	7.300	71.300	8.00	0.38	7.62	0.143	0.67	58.0	GX 100/30	0.600	0.00	180.50	1460.0	0.0	0.0	240.0	1519.5	68.01	23.27	25.95	52.2	**1.46**	717.80	**20.13**
14	0.600	0.600	7.900	70.700	8.00	0.19	7.81	0.143	0.67	58.0	GX 100/30	0.600	0.00	227.59	1580.0	0.0	0.0	240.0	1592.4	78.50	25.18	41.25	52.2	**1.28**	767.31	**18.80**

GEOFABRIC WALL DESIGN (INTERNAL STABILITY ONLY)

Project: **HORNSBY QUARRY**
Job No: **21/26457**
Wall location: **10m high wall (CH 380)**
Load combination: **B**
Case No: **1 - 9m Depth GWT**

DATA

Wall geometry

Height at Face, H_f = 10.50 m
Length at Top, L_t = 10.00 m
Face angle (vert.), θ_1 = 20.00 deg.
Back angle (vert.), θ_2 = 20.00 deg.
Slope Angle(horiz.), ω = 0.0 deg.
Slope Distance, L_s = 0.00 m
WT depth, d_w = 5.00 m
(from wall top)

Applied load

Uniform Surcharge, q = 20 kPa
Sill beam, S^*_{vb} = 0 kN/m
Eccentricity, E = 0 m
Sill beam, S^*_{hb} = 100 kN/m
Sill beam width, b = 0 m
Sill beam dist. from wall, a = 0 m

Soil properties

Select Fill, γ_1 = 20.0 kN/m3
Select Fill, ϕ_1 = 36.0 deg.
Select Fill, c'_1 = 0.0 kPa
General Fill, γ_2 = 20.0 kN/m3
General Fill, ϕ_2 = 40.0 deg.
General Fill, c'_2 = 0.0 kPa

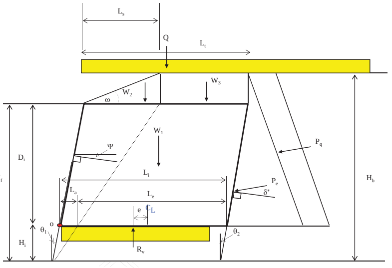
Reinforcement

Use variable soil/reinforcement coefficient (Y/N)? N

Constant coefficient = 0.67

Load factors

γ_{gs} = 1.25
γ_{gw} = 1.00
γ_{g1} = 1.25
γ_{g2} = 1.25
γ_{g3} = 1.25
γ_{q1} = 1.50
γ_{q2} = 1.50



CALCULATIONS

Select Slope Dist, L^*_s = 0.00 m
Height at Back, H_b = 10.50 m
Average Height, H_{ave} = 10.50 m

rad conv. (180/π) = 57.30

cot(ξ) = 0.788
tan(ξ) = 1.269
G = 0.095 (1/m)
1/G = 10.500 m

Back friction angle, δ* = 0.0 deg.
Design Angle, ϕ^*_1 = 36.0 deg.
Design Angle, ϕ^*_2 = 40.0 deg.
Select Fill, K_{o1} = 0.218
Select Fill, K_{a1} = 0.143
General Fill, K_{a2} = 0.106

Notes

† Includes sill beam effect where appropriate

* Min. F.O.S. Rupture using design strap strength =1.0

(equivalent to 4.0 using short term ultimate strength)

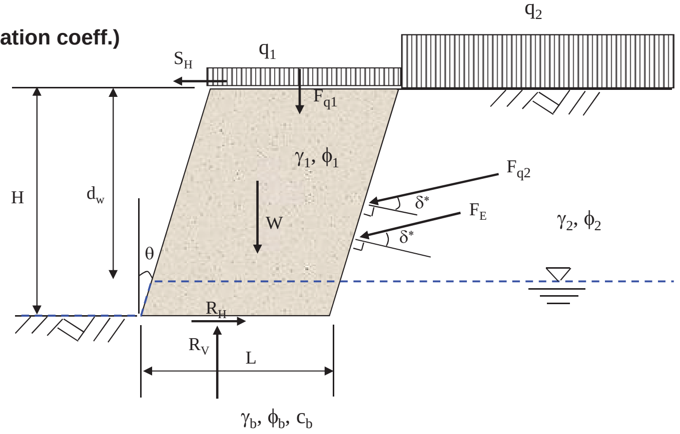
‡ Min. F.O.S. Pull-out =1.5

													VERTICAL LOADING						OTHER LOADING			RUPTURE		PULL-OUT	
Layer No.	**Vertical spacing Top (s_{vi}) (m)**	**Height (H_i) (m)**	**Depth from top (D_i) (m)**		**Strap length (L_i) (m)**	**L_a (active) (m)**	**L_e (effective) (m)**	**$K^*_{1(zi)}$**	**μ_p**	**Design strap strength (P_{strap}) (kN)**	**Product**	**Avg. vert. spacing (s_{ave}) (m)**	**Strap angle (Ψ) (deg)**	**W_{water} (kN)**	**W_1 (kN)**	**W_2 (kN)**	**W_3 (kN)**	**Q (kN)**	**R_v (kN)**	**P_e (kN)**	**P_q (kN)**	**P_w (kN)**	**Tensile† strength (kN/m)**	**F.O.S. Rupture***	**Pullout resistance (kN/m)**	**F.O.S. Pull-out‡**
1	0.600	10.200	0.300	83.200	10.00	3.27	6.73	0.143	0.67	58.0	GX 100/30	0.600	0.00	0.00	75.0	0.0	0.0	300.0	375.0	0.12	0.96	0.00	52.2	**3.63**	114.95	**8.00**
2	0.600	9.600	0.900	82.600	10.00	3.08	6.92	0.143	0.67	58.0	GX 100/30	0.600	0.00	0.00	225.0	0.0	0.0	300.0	525.0	1.08	2.87	0.00	52.2	**3.44**	172.81	**11.40**
3	0.600	9.000	1.500	82.000	10.00	2.89	7.11	0.143	0.67	58.0	GX 100/30	0.750	0.00	0.00	375.0	0.0	0.0	300.0	675.0	2.99	4.78	0.00	52.2	**2.61**	233.71	**11.68**
4	0.600	8.400	2.100	81.400	10.00	2.69	7.31	0.143	0.67	58.0	GX 100/30	0.600	0.00	0.00	525.0	0.0	0.0	300.0	825.0	5.86	6.69	0.00	52.2	**3.09**	297.64	**17.60**
5	0.600	7.800	2.700	80.800	10.00	2.50	7.50	0.143	0.67	58.0	GX 100/30	0.600	0.00	0.00	675.0	0.0	0.0	300.0	975.0	9.68	8.61	0.00	52.2	**2.92**	364.61	**20.39**
6	0.600	7.200	3.300	80.200	10.00	2.31	7.69	0.143	0.67	58.0	GX 100/30	0.600	0.00	0.00	825.0	0.0	0.0	300.0	1125.0	14.46	10.52	0.00	52.2	**2.76**	434.61	**22.98**
7	0.600	6.600	3.900	79.600	10.00	2.12	7.88	0.143	0.67	58.0	GX 100/30	0.600	0.00	0.00	975.0	0.0	0.0	300.0	1275.0	20.20	12.43	0.00	52.2	**2.61**	507.65	**25.37**
8	0.600	6.000	4.500	79.000	10.00	1.92	8.08	0.143	0.67	58.0	GX 100/30	0.600	0.00	0.00	1125.0	0.0	0.0	300.0	1425.0	26.89	14.34	0.00	52.2	**2.46**	583.73	**27.56**
9	0.600	5.400	5.100	78.400	10.00	1.73	8.27	0.143	0.67	58.0	GX 100/30	0.600	0.00	9.81	1275.0	0.0	0.0	300.0	1565.2	34.54	16.25	0.05	52.2	**2.32**	657.51	**29.26**
10	0.600	4.800	5.700	77.800	10.00	1.54	8.46	0.143	0.67	58.0	GX 100/30	0.600	0.00	68.67	1425.0	0.0	0.0	300.0	1656.3	42.89	18.17	2.40	52.2	**2.16**	706.81	**29.22**
11	0.600	4.200	6.300	77.200	10.00	1.35	8.65	0.143	0.67	58.0	GX 100/30	0.600	0.00	127.53	1575.0	0.0	0.0	300.0	1747.5	51.83	20.08	8.29	52.2	**1.99**	757.66	**28.91**
12	0.600	3.600	6.900	76.600	10.00	1.15	8.85	0.143	0.67	58.0	GX 100/30	0.600	0.00	186.39	1725.0	0.0	0.0	300.0	1838.6	61.34	21.99	17.71	52.2	**1.83**	810.05	**28.36**
13	0.600	3.000	7.500	76.000	10.00	0.96	9.04	0.143	0.67	58.0	GX 100/30	0.600	0.00	245.25	1875.0	0.0	0.0	300.0	1929.8	71.44	23.90	30.66	52.2	**1.64**	863.99	**27.09**
14	0.600	2.400	8.100	75.400	10.00	0.77	9.23	0.143	0.67	58.0	GX 100/30	0.600	0.00	304.11	2025.0	0.0	0.0	300.0	2020.9	82.12	25.82	47.14	52.2	**1.45**	919.48	**25.51**
15	0.600	1.800	8.700	74.800	10.00	0.58	9.42	0.143	0.67	58.0	GX 100/30	0.600	0.00	362.97	2175.0	0.0	0.0	300.0	2112.0	93.38	27.73	67.15	52.2	**1.28**	976.51	**23.98**
16	0.600	1.200	9.300	74.200	10.00	0.38	9.62	0.143	0.67	58.0	GX 100/30	0.600	0.00	421.83	2325.0	0.0	0.0	300.0	2203.2	105.22	29.64	90.69	52.2	**1.14**	1035.09	**22.52**
17	0.600	0.600	9.900	73.600	10.00	0.19	9.81	0.143	0.67	58.0	GX 100/30	0.600	0.00	480.69	2475.0	0.0	0.0	300.0	2294.3	117.64	31.55	117.77	52.2	**1.01**	1095.22	**21.10**

Appendix D – RSW External Design Results

PROJECT: HORNSBY QUARRY
JOB No.: 21/26457
EXTERNAL STABILITY CALCULATIONS
Design friction angle δ* for R57/1 Extensible Systems

5m High Wall + Earthquake loading (0.1 acceleration coeff.)



Select fill properties

γ_1 = 20 (kN/m^3)
ϕ_1 = 36 (degrees)

Back fill properties

γ_2 = 20 (kN/m^3)
ϕ_2 = 40 (degrees)

Foundation soil properties

q_{ult} = 800 (kPa) (Adopted)
γ_b = 20 (kN/m^3)
ϕ_b = 40 (degrees)
c_b = 0 (kPa)

Retaining wall dimensions and applied loads

H = 5.5 (m) (wall height)
L = 6 (m) (base width)
d_w = 1 (m) (Depth of water)
θ = 20 (deg) (wall inclination angle) θ = 0.3491 (rad)
q_1 = 20 (kPa) (traffic load above RSS)
q_2 = 20 (kPa) (traffic load behind RSS)
S_H = 100 (kN/m) (Crash barrier load)
a_{IH} = 0.1 (Earthquake acceleration coefficient)

Load combination factor coefficients (R57)

Load Combinations	Load Factors									Material Factors				Economic Ramification Factor, Φn
	γ_{gs}	γ_{gw}	γ_{g1}	γ_{g2}	γ_{g3}	γ_{q1}	γ_{q2}	$\gamma_{e'quake}$	γ_{SH}	$\Phi_{\phi1}/\Phi_{\phi2}/\Phi_{\phi3}$	$\Phi_{\phi b}$	Φ_{cb}	$\Phi_{\gamma b}$	
A	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00	1.00	0.80	0.50	1.00	0.90
B	1.25	1.00	1.25	1.25	1.25	1.50	1.50	0.00	1.00	1.00	0.80	0.50	1.00	0.90
C	1.00	1.00	1.00	1.25	1.00	0.00	1.50	0.00	1.00	1.00	0.80	0.50	1.00	0.90
D	1.25	1.00	1.25	1.25	1.25	0.50	0.50	1.00	0.50	1.00	0.80	0.50	1.00	0.90
E	1.00	1.00	1.00	1.25	1.00	0.00	0.50	1.00	0.50	1.00	0.80	0.50	1.00	0.90
F	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00

Factor of Safety

Load Combinations	ϕ^*_1 (rad)	ϕ^*_2 (rad)	ϕ^*_b (rad)	δ^* (rad)	c^*_b (kPa)	K_a	F_E (kN/m)	F_{q2} (kN/m)	$F_{e'quake}$ (kN/m)	W (kN/m)	R_V (kN/m)	R_H (kN/m)	$M_{Resisting}$ (kNm/m)	$M_{Driving}$ (kNm/m)	Eccentricity e (m)	q_r (kPa)	Factor of Safety		
																	Sliding	Overturning	Bearing
A	0.628	0.698	0.591	0.314	0.0	0.091	117.9	0.0	0.0	395.1	394.5	117.9	1576.6	183.0	0.533	79.9	2.02	7.76	9.01
B	0.628	0.698	0.591	0.314	0.0	0.091	122.5	15.1	0.0	560.1	738.8	237.5	3132.3	782.8	0.180	131.0	1.88	3.60	5.50
C	0.628	0.698	0.591	0.314	0.0	0.091	122.5	15.1	0.0	395.1	393.8	237.5	1571.8	782.8	0.996	98.3	1.00	1.81	7.33
D	0.628	0.698	0.591	0.314	0.0	0.091	122.5	5.0	33.0	560.1	619.1	210.5	2534.5	589.1	0.142	108.3	1.78	3.87	6.65
E	0.628	0.698	0.591	0.314	0.0	0.091	122.5	5.0	33.0	395.1	394.1	210.5	1574.3	589.1	0.501	78.8	1.13	2.40	9.13
F	0.628	0.698	0.698	0.314	0.0	0.091	117.9	10.0	0.0	395.1	514.1	227.9	2174.3	760.6	0.250	93.5	1.64	2.86	8.56

GHD GEOTECHNICS
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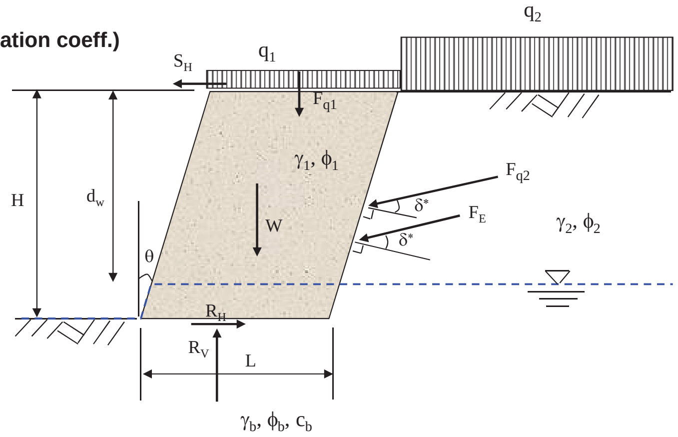
PROJECT: HORNSBY QUARRY
JOB No.: 21/26457
EXTERNAL STABILITY CALCULATIONS
Design friction angle δ* for R57/1 Extensible Systems

8m High Wall + Earthquake loading (0.1 acceleration coeff.)



Select fill properties

γ_1 = 20 (kN/m^3)

ϕ_1 = 36 (degrees)

Back fill properties

γ_2 = 20 (kN/m^3)

ϕ_2 = 40 (degrees)

Foundation soil properties

q_{ult} = 800 (kPa) (Adopted)

γ_b = 20 (kN/m^3)

ϕ_b = 40 (degrees)

c_b = 0 (kPa)

Retaining wall dimensions and applied loads

H = 8.5 (m) (wall height)

L = 8 (m) (base width)

d_w = 2 (m) (Depth of water)

θ = 20 (deg) (wall inclination angle) θ = 0.3491 (rad)

q_1 = 20 (kPa) (traffic load above RSS)

q_2 = 20 (kPa) (traffic load behind RSS)

S_H = 100 (kN/m) (Crash barrier load)

a_{IH} = 0.1 (Earthquake acceleration coefficient)

Load combination factor coefficients (R57)

Load Combinations	Load Factors									Material Factors				Economic Ramification Factor, Φn
	γ_{gs}	γ_{gw}	γ_{g1}	γ_{g2}	γ_{g3}	γ_{q1}	γ_{q2}	$\gamma_{e'quake}$	γ_{SH}	$\Phi_{\phi1}/\Phi_{\phi2}/\Phi_{\phi3}$	$\Phi_{\phi b}$	Φ_{cb}	$\Phi_{\gamma b}$	
A	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00	1.00	0.80	0.50	1.00	0.90
B	1.25	1.00	1.25	1.25	1.25	1.50	1.50	0.00	1.00	1.00	0.80	0.50	1.00	0.90
C	1.00	1.00	1.00	1.25	1.00	0.00	1.50	0.00	1.00	1.00	0.80	0.50	1.00	0.90
D	1.25	1.00	1.25	1.25	1.25	0.50	0.50	1.00	0.50	1.00	0.80	0.50	1.00	0.90
E	1.00	1.00	1.00	1.25	1.00	0.00	0.50	1.00	0.50	1.00	0.80	0.50	1.00	0.90
F	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00

Factor of Safety

Load Combinations	ϕ^*_1 (rad)	ϕ^*_2 (rad)	ϕ^*_b (rad)	δ* (rad)	c^*_b (kPa)	K_a	F_E (kN/m)	F_{q2} (kN/m)	$F_{e'quake}$ (kN/m)	W (kN/m)	R_V (kN/m)	R_H (kN/m)	$M_{Resisting}$ (kNm/m)	$M_{Driving}$ (kNm/m)	Eccentricity e (m)	q_r (kPa)	Factor of Safety		
																	Sliding	Overturning	Bearing
A	0.628	0.698	0.591	0.314	0.0	0.091	254.3	0.0	0.0	849.9	848.2	254.2	4699.4	582.2	0.854	134.8	2.02	7.27	5.34
B	0.628	0.698	0.591	0.314	0.0	0.091	266.0	23.3	0.0	1189.9	1427.0	389.2	8276.3	1564.3	0.704	216.4	2.21	4.76	3.33
C	0.628	0.698	0.591	0.314	0.0	0.091	266.0	23.3	0.0	849.9	847.0	389.2	4687.9	1564.3	0.312	114.8	1.31	2.70	6.27
D	0.628	0.698	0.591	0.314	0.0	0.091	266.0	7.8	68.0	1189.9	1267.6	391.7	7146.5	1420.2	0.518	182.0	1.95	4.53	3.96
E	0.628	0.698	0.591	0.314	0.0	0.091	266.0	7.8	68.0	849.9	847.6	391.7	4693.1	1420.2	0.138	109.7	1.31	2.97	6.56
F	0.628	0.698	0.698	0.314	0.0	0.091	254.3	15.5	0.0	849.9	1007.7	369.7	5829.2	1498.1	0.298	136.1	1.98	3.89	5.88

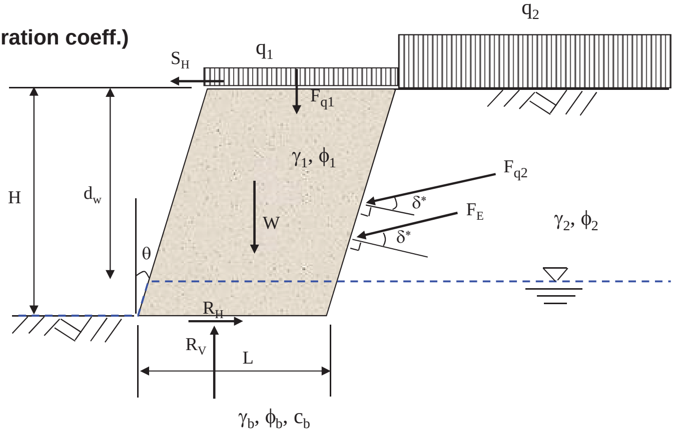
GHD GEOTECHNICS

HornsbyQuarry_External stability of reinforced soil wall_5m_70 - Copy\G:\21\26457\Tech\Geotech\2126457-REP-GEO-004-Civil Geotechnical Options Review, preferred Options and Risk Assessment\Reinforced Soil Wall\External stability

14/08/2018

PROJECT: HORNSBY QUARRY
JOB No.: 21/26457
EXTERNAL STABILITY CALCULATIONS
Design friction angle δ* for R57/1 Extensible Systems

10m High Wall + Earthquake loading (0.1 acceleration coeff.)



Select fill properties

γ_1 = 20 (kN/m^3)
ϕ_1 = 36 (degrees)

Back fill properties

γ_2 = 20 (kN/m^3)
ϕ_2 = 40 (degrees)

Foundation soil properties

q_{ult} = 800 (kPa) (Adopted)
γ_b = 20 (kN/m^3)
ϕ_b = 40 (degrees)
c_b = 0 (kPa)

Retaining wall dimensions and applied loads

H = 10.5 (m) (wall height)
L = 10 (m) (base width)
d_w = 5 (m) (Depth of water)
θ = 20 (deg) (wall inclination angle) θ = 0.3491 (rad)
q_1 = 20 (kPa) (traffic load above RSS)
q_2 = 20 (kPa) (traffic load behind RSS)
S_H = 100 (kN/m) (Crash barrier load)
a_{IH} = 0.1 (Earthquake acceleration coefficient)

Load combination factor coefficients (R57)

Load Combinations	Load Factors									Material Factors				Economic Ramification Factor, Φn
	γ_{gs}	γ_{gw}	γ_{g1}	γ_{g2}	γ_{g3}	γ_{q1}	γ_{q2}	$\gamma_{e'quake}$	γ_{SH}	$\Phi_{\phi1}/\Phi_{\phi2}/\Phi_{\phi3}$	$\Phi_{\phi b}$	Φ_{cb}	$\Phi_{\gamma b}$	
A	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00	1.00	0.80	0.50	1.00	0.90
B	1.25	1.00	1.25	1.25	1.25	1.50	1.50	0.00	1.00	1.00	0.80	0.50	1.00	0.90
C	1.00	1.00	1.00	1.25	1.00	0.00	1.50	0.00	1.00	1.00	0.80	0.50	1.00	0.90
D	1.25	1.00	1.25	1.25	1.25	0.50	0.50	1.00	0.50	1.00	0.80	0.50	1.00	0.90
E	1.00	1.00	1.00	1.25	1.00	0.00	0.50	1.00	0.50	1.00	0.80	0.50	1.00	0.90
F	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00

Factor of Safety

Load Combinations	ϕ^*_1 (rad)	ϕ^*_2 (rad)	ϕ^*_b (rad)	δ* (rad)	c^*_b (kPa)	K_a	F_E (kN/m)	F_{q2} (kN/m)	$F_{e'quake}$ (kN/m)	W (kN/m)	R_V (kN/m)	R_H (kN/m)	$M_{Resisting}$ (kNm/m)	$M_{Driving}$ (kNm/m)	Eccentricity e (m)	q_r (kPa)	Factor of Safety		
																	Sliding	Overturning	Bearing
A	0.628	0.698	0.591	0.314	0.0	0.091	235.5	0.0	0.0	1560.5	1557.4	235.4	10749.8	576.6	1.532	224.5	4.00	16.78	3.21
B	0.628	0.698	0.591	0.314	0.0	0.091	257.2	28.7	0.0	2085.5	2380.6	385.9	17004.0	1853.6	1.364	327.4	3.73	8.26	2.20
C	0.628	0.698	0.591	0.314	0.0	0.091	257.2	28.7	0.0	1560.5	1555.6	385.9	10729.3	1853.6	0.705	181.1	2.44	5.21	3.98
D	0.628	0.698	0.591	0.314	0.0	0.091	257.2	9.6	105.0	2085.5	2181.3	421.7	15247.6	1889.5	1.124	281.4	3.12	7.26	2.56
E	0.628	0.698	0.591	0.314	0.0	0.091	257.2	9.6	105.0	1560.5	1556.3	421.7	10737.2	1889.5	0.685	180.3	2.23	5.11	3.99
F	0.628	0.698	0.698	0.314	0.0	0.091	235.5	19.2	0.0	1560.5	1756.7	354.6	12506.1	1727.1	1.136	227.3	3.60	7.24	3.52

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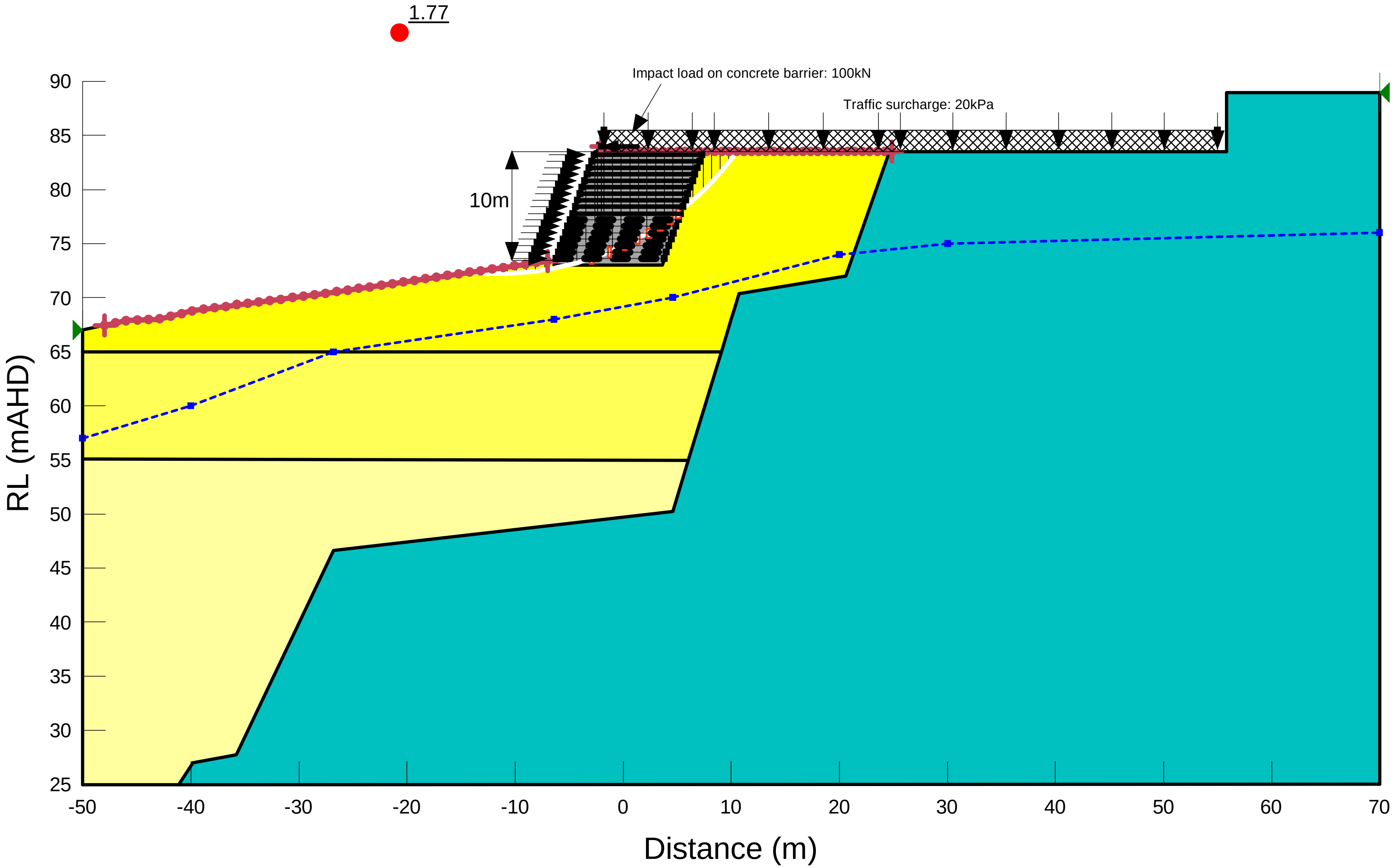
Appendix E – RSW Global Stability Results

HORNSBY QUARRY - PARKLAND DEVELOPMENT
Reinforced Soil Wall RSW02.Section at CH 380 on CL01. Wall height: 10m
Short Term case Stability

RSW backfill	Mohr-Coulomb	20 kN/m³	0 kPa	36 °
Quarry void backfill material (98% compaction)	Mohr-Coulomb	20 kN/m³	0 kPa	40 °
Hornsby dolerite	Shear/Normal Fn.	21 kN/m³	HB - weathered dolerite (intact)	
Concrete barrier	Undrained (Phi=0)	24 kN/m³	1,000 kPa	
Quarry void backfill material (95% compaction)	Mohr-Coulomb	20 kN/m³	0 kPa	37.5 °
Quarry void backfill material (90% compaction)	Mohr-Coulomb	20 kN/m³	0 kPa	34 °

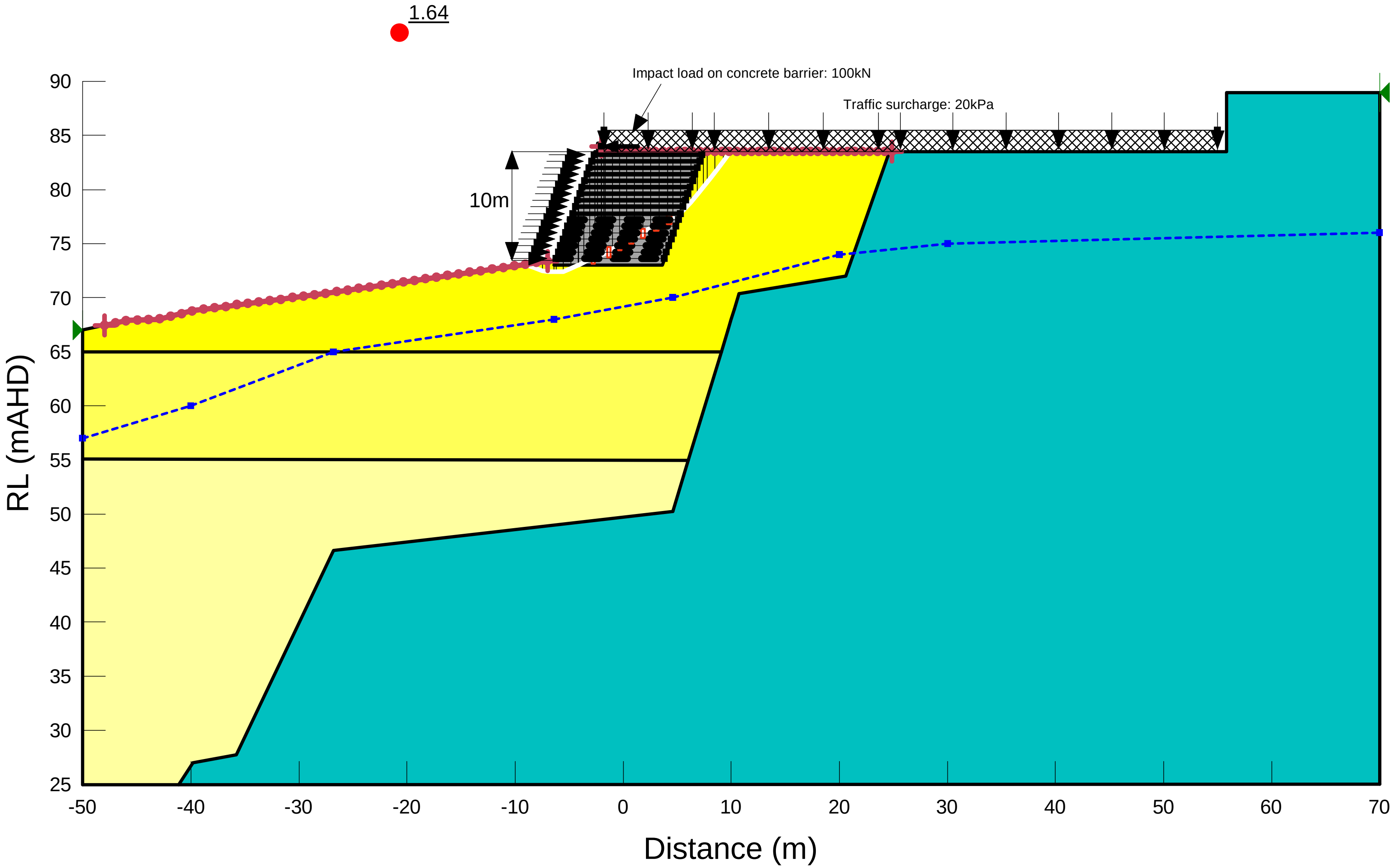


HORNSBY QUARRY - PARKLAND DEVELOPMENT

Reinforced Soil Wall RSW02.Section at CH 380 on CL01. Wall height: 10m

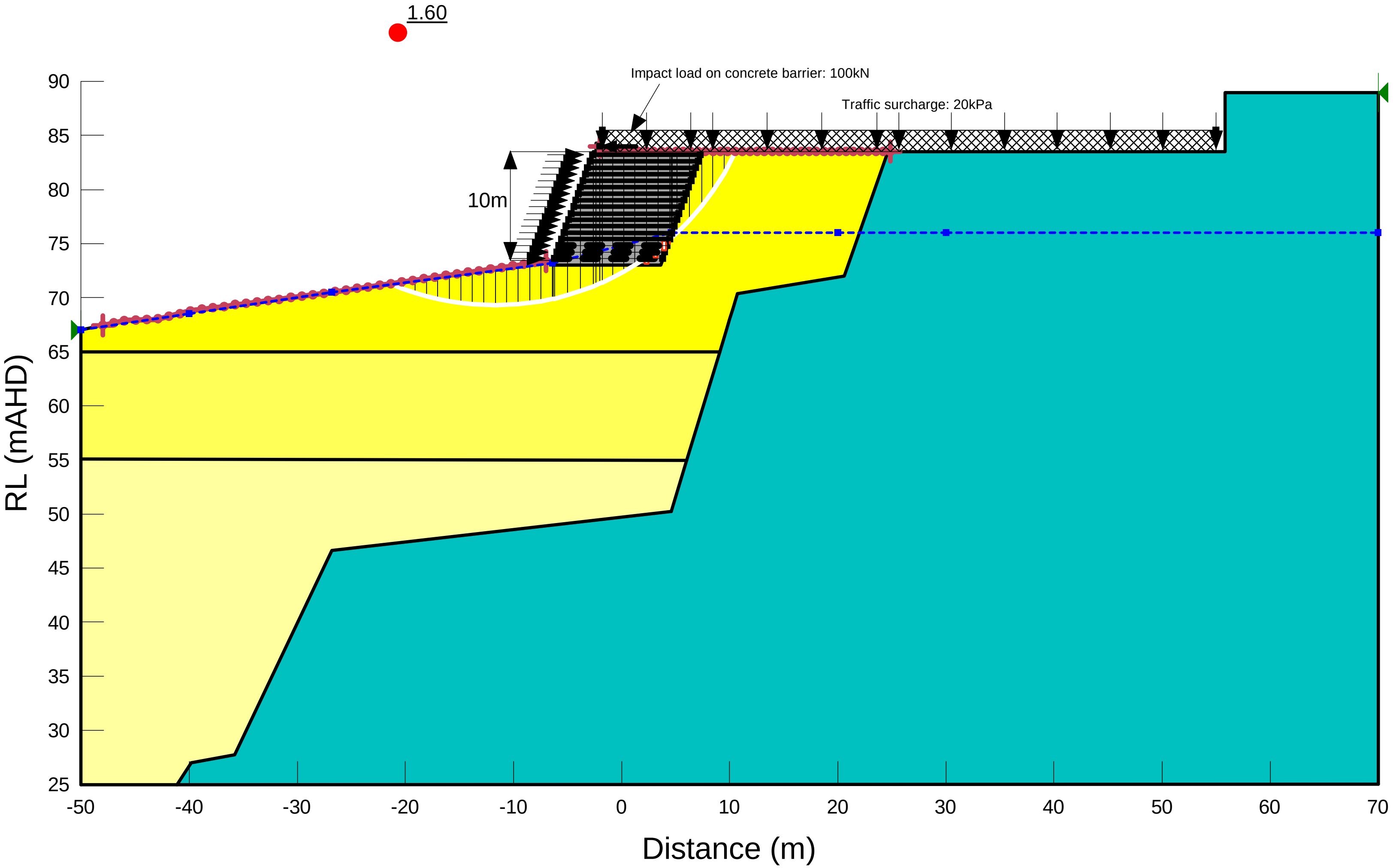
Short Term case Stability

RSW backfill	Mohr-Coulomb	20 kN/m³	0 kPa	36 °	
Quarry void backfill material (98% compaction)	Mohr-Coulomb	20 kN/m³	0 kPa	40 °	
Hornsby dolerite	Shear/Normal Fn.	21 kN/m³	HB - weathered dolerite (intact)		
Concrete barrier	Undrained (Phi=0)	24 kN/m³	1,000 kPa		
Quarry void backfill material (95% compaction)	Mohr-Coulomb	20 kN/m³	0 kPa	37.5 °	
Quarry void backfill material (90% compaction)	Mohr-Coulomb	20 kN/m³	0 kPa	34 °	



HORNSBY QUARRY - PARKLAND DEVELOPMENT
Reinforced Soil Wall RSW02.Section at CH 380 on CL01. Wall height: 10m
Long Term case Stability

RSW backfill Mohr-Coulomb 20 kN/m³ 0 kPa 36 °
Quarry void backfill material (98% compaction) Mohr-Coulomb 20 kN/m³ 0 kPa 40 °
Hornsby dolerite Shear/Normal Fn. 21 kN/m³ HB - weathered dolerite (intact)
Concrete barrier Undrained (Phi=0) 24 kN/m³ 1,000 kPa
Quarry void backfill material (95% compaction) Mohr-Coulomb 20 kN/m³ 0 kPa 37.5 °
Quarry void backfill material (90% compaction) Mohr-Coulomb 20 kN/m³ 0 kPa 34 °

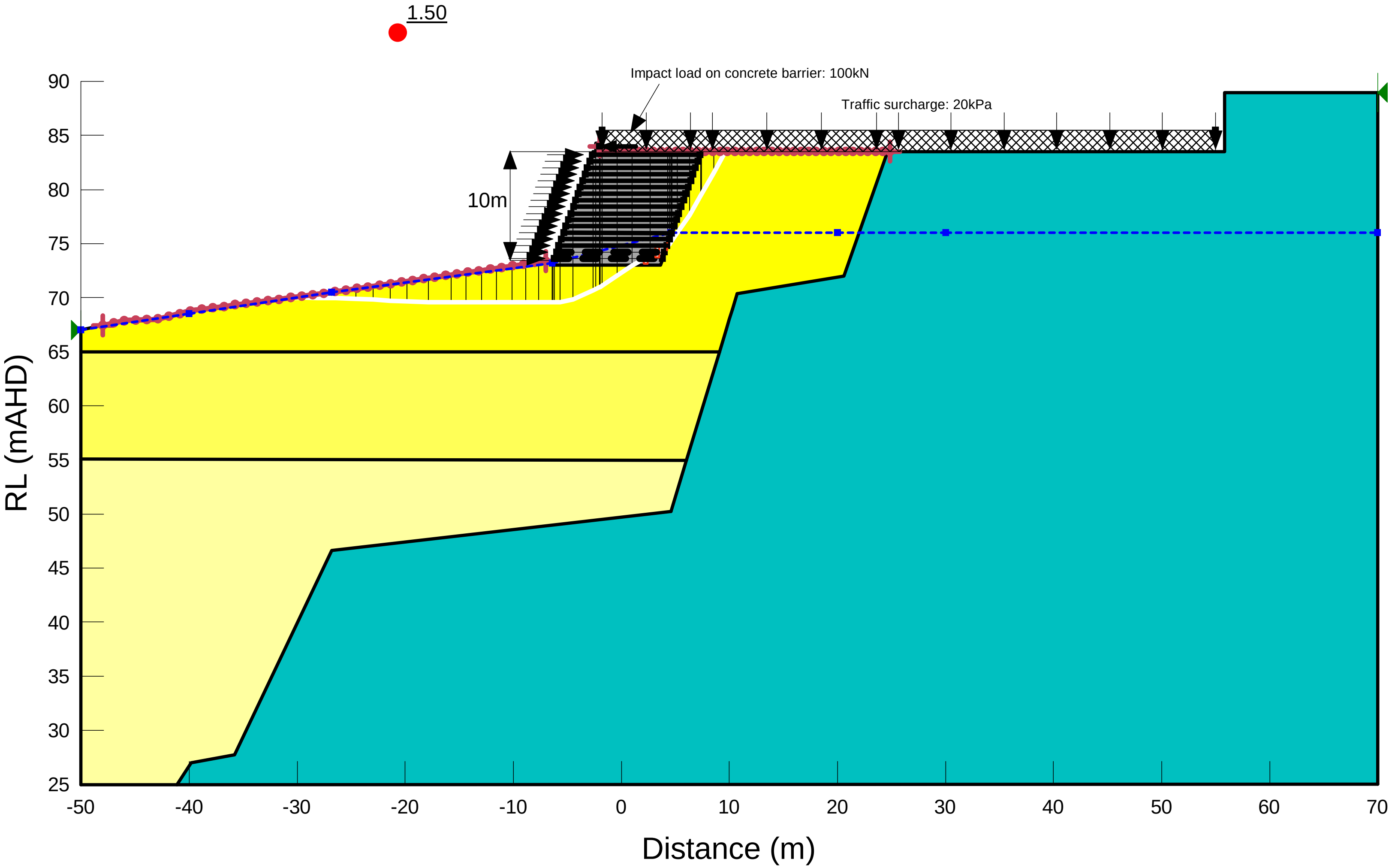


HORNSBY QUARRY - PARKLAND DEVELOPMENT

Reinforced Soil Wall RSW02.Section at CH 380 on CL01. Wall height: 10m

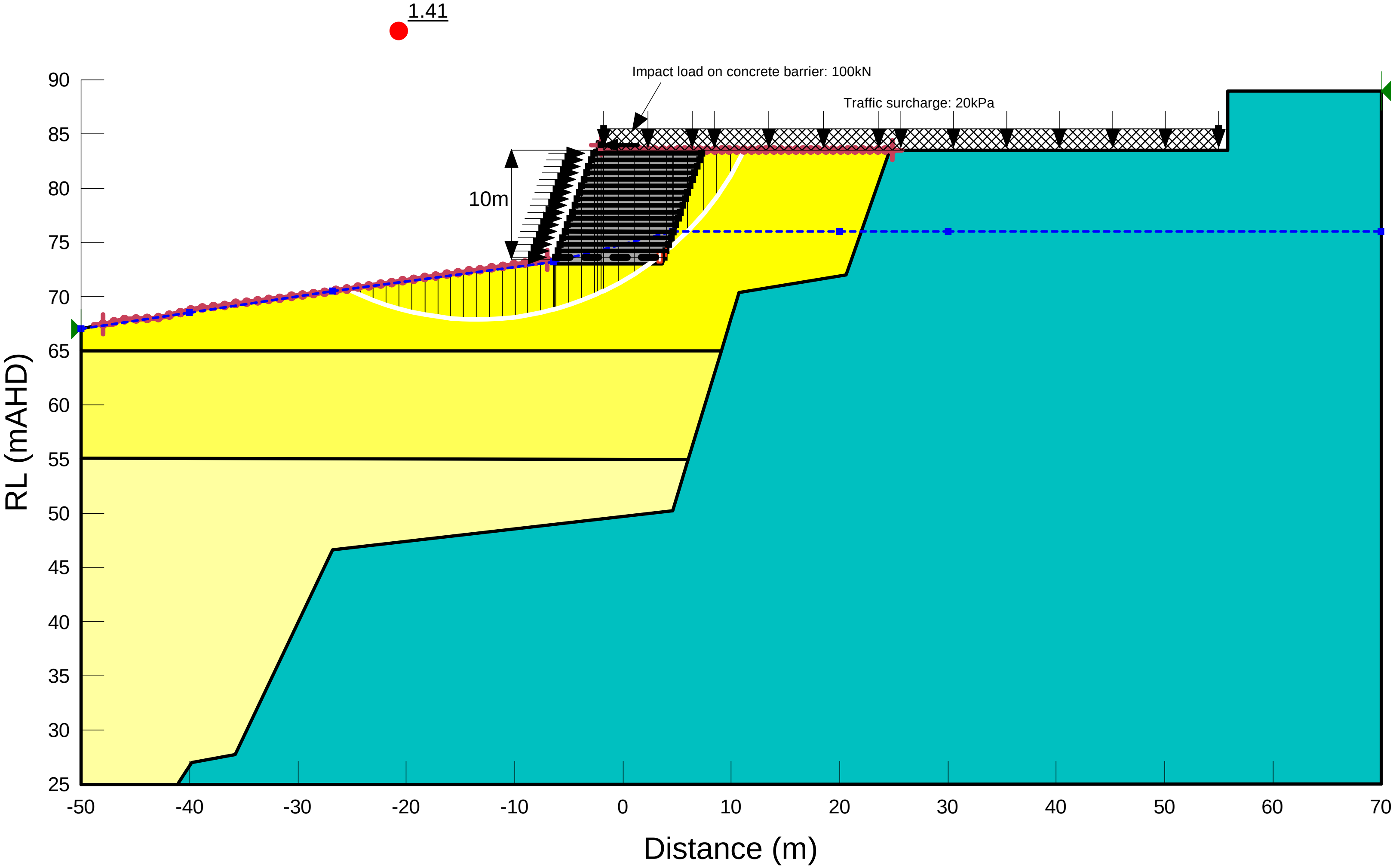
Long Term case Stability

RSW backfill	Mohr-Coulomb	20 kN/m³	0 kPa	36 °
Quarry void backfill material (98% compaction)	Mohr-Coulomb	20 kN/m³	0 kPa	40 °
Hornsby dolerite	Shear/Normal Fn.	21 kN/m³	HB - weathered dolerite (intact)	
Concrete barrier	Undrained (Phi=0)	24 kN/m³	1,000 kPa	
Quarry void backfill material (95% compaction)	Mohr-Coulomb	20 kN/m³	0 kPa	37.5 °
Quarry void backfill material (90% compaction)	Mohr-Coulomb	20 kN/m³	0 kPa	34 °



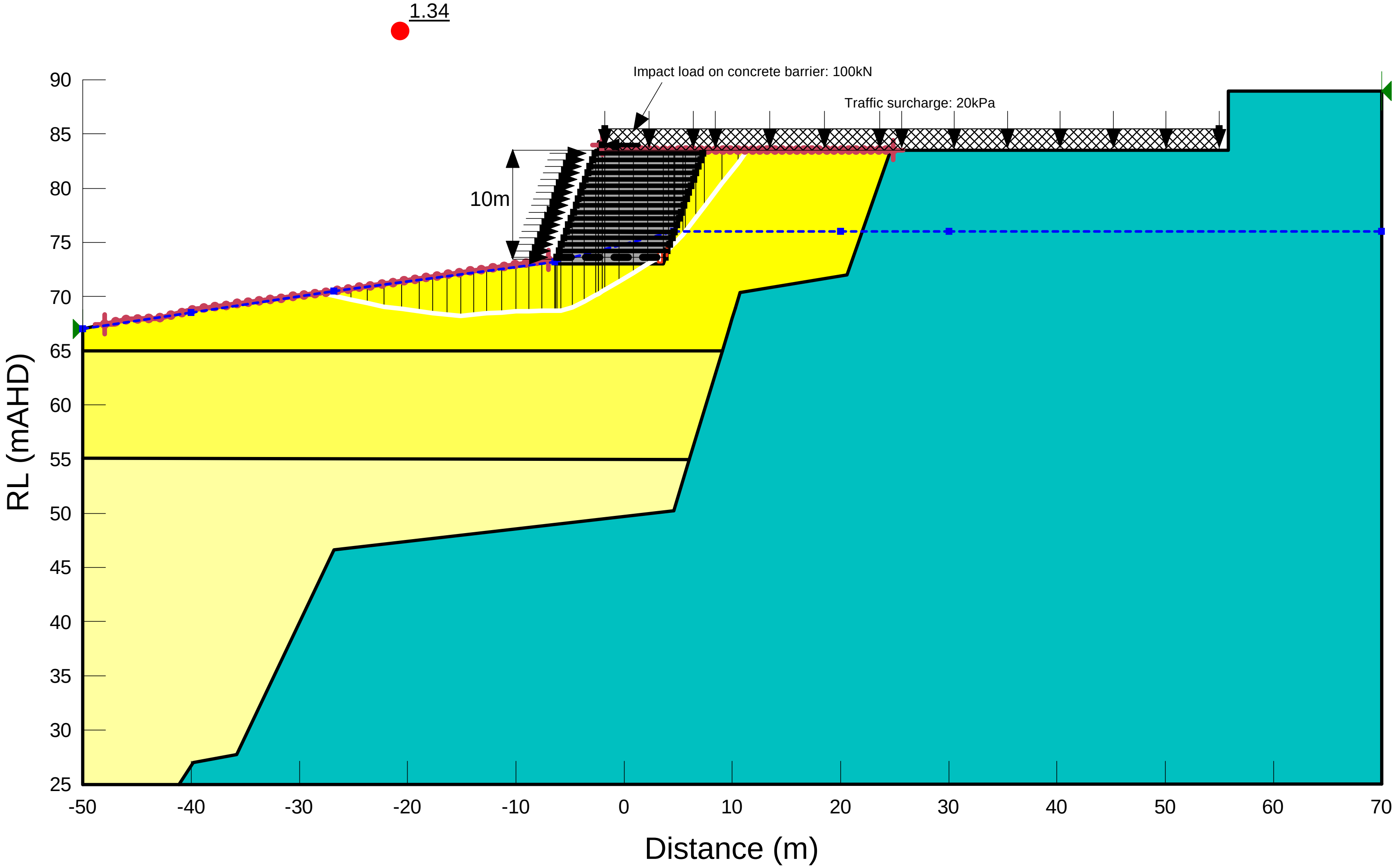
HORNSBY QUARRY - PARKLAND DEVELOPMENT
Reinforced Soil Wall RSW02.Section at CH 380 on CL01. Wall height: 10m
Seismic case Stability

RSW backfill	Mohr-Coulomb	20 kN/m³	0 kPa	36 °
Quarry void backfill material (98% compaction)	Mohr-Coulomb	20 kN/m³	0 kPa	40 °
Hornsby dolerite	Shear/Normal Fn.	21 kN/m³	HB - weathered dolerite (intact)	
Concrete barrier	Undrained (Phi=0)	24 kN/m³	1,000 kPa	
Quarry void backfill material (95% compaction)	Mohr-Coulomb	20 kN/m³	0 kPa	37.5 °
Quarry void backfill material (90% compaction)	Mohr-Coulomb	20 kN/m³	0 kPa	34 °



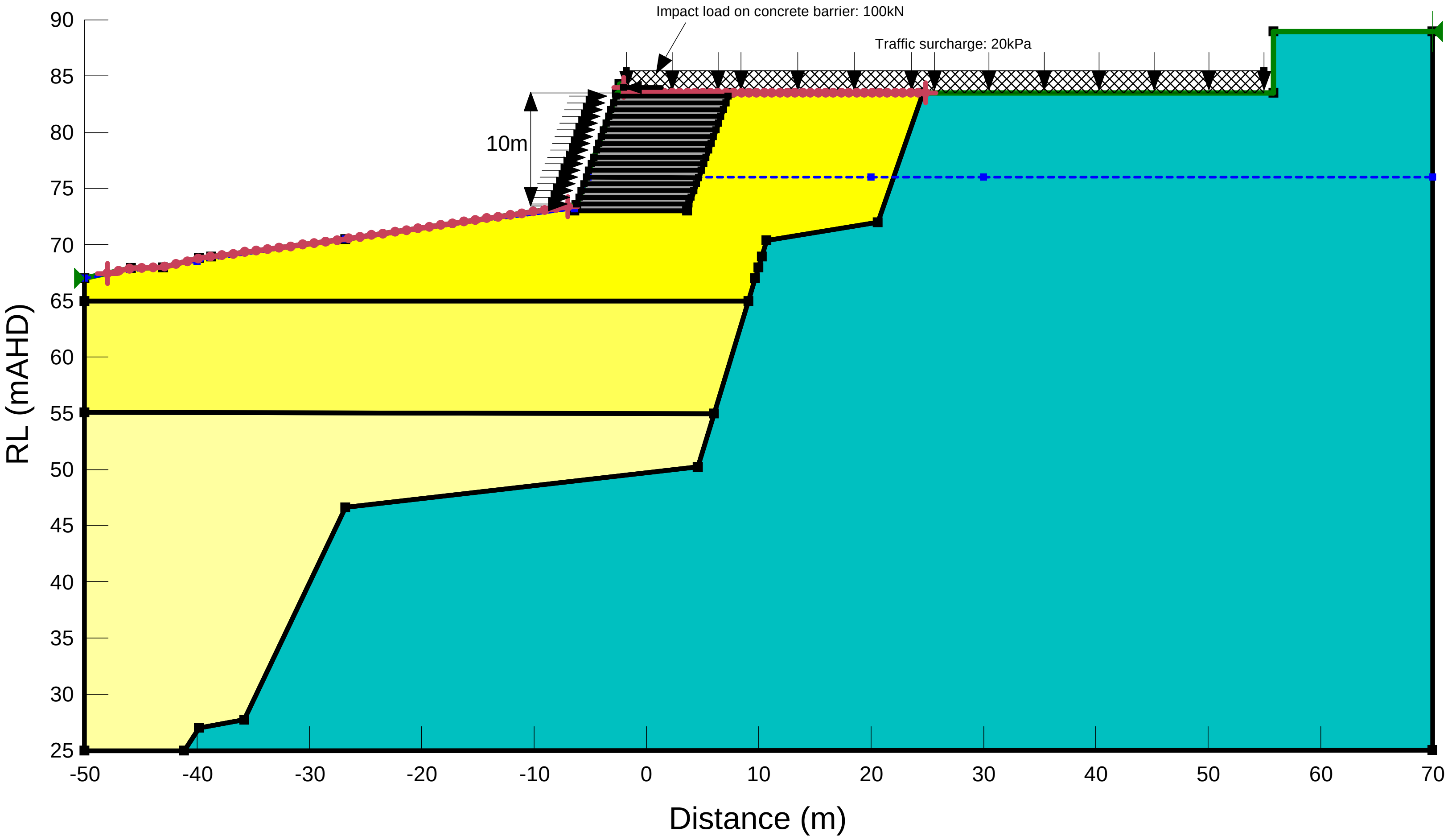
HORNSBY QUARRY - PARKLAND DEVELOPMENT
Reinforced Soil Wall RSW02.Section at CH 380 on CL01. Wall height: 10m
Seismic case Stability

RSW backfill	Mohr-Coulomb	20 kN/m³	0 kPa	36 °
Quarry void backfill material (98% compaction)	Mohr-Coulomb	20 kN/m³	0 kPa	40 °
Hornsby dolerite	Shear/Normal Fn.	21 kN/m³	HB - weathered dolerite (intact)	
Concrete barrier	Undrained (Phi=0)	24 kN/m³	1,000 kPa	
Quarry void backfill material (95% compaction)	Mohr-Coulomb	20 kN/m³	0 kPa	37.5 °
Quarry void backfill material (90% compaction)	Mohr-Coulomb	20 kN/m³	0 kPa	34 °



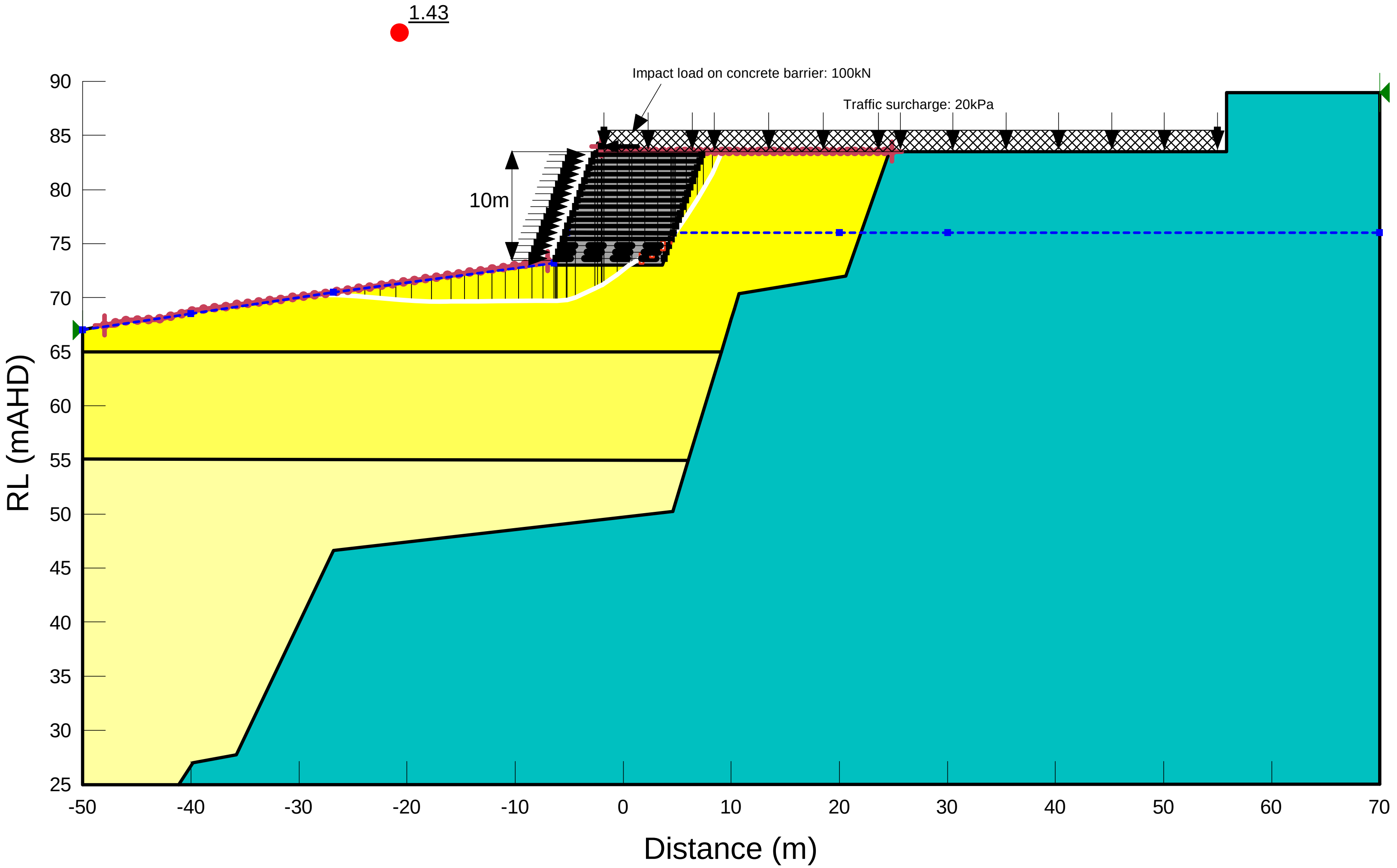
HORNSBY QUARRY - PARKLAND DEVELOPMENT
Reinforced Soil Wall RSW02.Section at CH 380 on CL01. Wall height: 10m
Rapid Drawdown case Stability

RSW backfill	Mohr-Coulomb	20 kN/m³	0 kPa	36 °
Quarry void backfill material (98% compaction)	Mohr-Coulomb	20 kN/m³	0 kPa	40 °
Hornsby dolerite	Shear/Normal Fn.	21 kN/m³	HB - weathered dolerite (intact)	
Concrete barrier	Undrained (Phi=0)	24 kN/m³	1,000 kPa	
Quarry void backfill material (95% compaction)	Mohr-Coulomb	20 kN/m³	0 kPa	37.5 °
Quarry void backfill material (90% compaction)	Mohr-Coulomb	20 kN/m³	0 kPa	34 °



HORNSBY QUARRY - PARKLAND DEVELOPMENT
Reinforced Soil Wall RSW02.Section at CH 380 on CL01. Wall height: 10m
Rapid Drawdown case Stability

RSW backfill	Mohr-Coulomb	20 kN/m³	0 kPa	36 °
Quarry void backfill material (98% compaction)	Mohr-Coulomb	20 kN/m³	0 kPa	40 °
Hornsby dolerite	Shear/Normal Fn.	21 kN/m³	HB - weathered dolerite (intact)	
Concrete barrier	Undrained (Phi=0)	24 kN/m³	1,000 kPa	
Quarry void backfill material (95% compaction)	Mohr-Coulomb	20 kN/m³	0 kPa	37.5 °
Quarry void backfill material (90% compaction)	Mohr-Coulomb	20 kN/m³	0 kPa	34 °



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2126457-28690/https://projects.ghd.com/oc/Sydney/hornsbyquarryrehabil/Delivery/Documents/2126457-REP-GEO-004 Civil Geotechnical Options Review, preferred Options and Risk Assessment Final.docx

Document Status

Revision	Author	Reviewer		Approved for Issue		
		Name	Signature	Name	Signature	Date
Draft A	M.Lecina A.Narsey	S.Mortimer				17/08/18
Draft B	M. Lecina A. Narsey	S.Mortimer				14/11/18
Rev 0	M. Lecina A. Narsey	S.Mortimer		D Gamble		22/11/18

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Appendix K – Soil profile investigation

Hornsby Park / Quarry

Soil Profile Investigation

Hornsby, NSW 2077

Prepared for:

Hornsby Council

February 2018

(Ref: C791 B45863 Report FA)

Document Record

Revision No.	Reviewed By	Action	Issued To	Date	Release Authorisation Signature
0.1	Simon Leake	Initial draft	Internal	09/02/2018	
0.2					
0.3					
0.4					

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Technical Reviewer:	Simon Leake
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Final Reviewer	Simon Leake
Qualifications:	BScAg (Hons) CPSS RH
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Document Title:	Hornsby Quarry / Hornsby Park
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TABLE OF CONTENTS

DOCUMENT TABLES IN TEXT

1 EXECUTIVE SUMMARY

This report details the site investigation works by SESL Australia at the Hornsby Quarry, Hornsby NSW. These investigatory works were commissioned by Hornsby Council in November 2017 to better understand the soils for redevelopment of the Site for recreational purposes and rehabilitation and regrowth of the endangered Blue Gum forest community.

The objective of this investigation to better understand the chemical and physical characteristics of specifically the breccia soils to benchmark profile properties for redevelopment of recreational areas and re-establishment of Blue Gum forest as well as other landscape aims.

The Hornsby Quarry soil landscape is complex and contain few intact soils in the mined area apart from sandstone soils around mainly the northern edges. In the rest of the area soils are composed mainly of disturbed overburden breccia and sandstone in various stages of development from completely new deposits to soils showing some decades of profile development. The soils mainly of interest are those that contain breccia which are characterised by higher cation exchange capacity and general fertility than sandstone soils. These soils are desirable for rehabilitation of vegetation types with higher fertility requirements such as the endangered Blue Gum forest and gully rainforest elements. Sandstone soils consist of a sandy quartz and poor quality clay minerals and are known for supporting native woodland with lower fertility requirements such as dry eucalypt woodland.

Previous investigations of Hornsby Quarry have been undertaken by PSM (2006), Parsons Brinckerhoff (2004) and Coffeys & Partners (1990) and detailed bore logs from their investigations have been used in this report.

Through SESLs investigation an undisturbed intact breccia soil profile was not found however a 30-year profile was found in the north eastern section of the site which can be used as a benchmark for developing soil profile and fertility concepts. The nutritional analysis showed bioaccumulation of phosphorus, potassium, calcium and, magnesium that had occurred over the 30 years which is useful information for redevelopment of new profiles.

2 INTRODUCTION

SESL Australia (SESL) has been engaged by Hornsby Shire Council to undertake an on-site soil investigation of *Hornsby Quarry / Park, NSW* to assess the natural and fill areas that comprise this landscape. SESL understands that Hornsby Park includes Hornsby Quarry and a crusher plant, and the natural landscape has been dramatically transformed since the early 1900's when the Quarry was first established.

Hornsby Quarry holds great ecological importance due to being the largest volcanic diatreme in the Sydney region. The exposed eastern face of the diatreme is particularly impressive with geological layering displayed. Hornsby Park contains endangered remnant blue gum high forest which is also ecologically important.

There are plans for this area to be redeveloped into an open space for recreation and entertainment whilst still preserving the significant historical and ecological heritage. Landscaping plans are still at the conceptual stage therefore the project design is not yet formalised. SESL's objective for this investigatory assessment is to characterise the physical and chemical properties of the natural Hornsby soil landscape to be able to determine a natural breccia and sandstone benchmark in order to transform the available overburden deposits to meet the benchmark. The aim of improving and redeveloping the profiles is to establish the endangered Blue Gum and grow other plant species endemic to this area.

Previous assessments have been carried out by Coffeys and Partners Investigations (1990), Parsons Brickenhoff Investigations (2004) and PSM Investigations (2006). In this investigatory report, SESL has applied information sourced from these consultancy reports in combination with SESL's own exploratory works to gain a deeper understanding of the soils across the Site.

2.1 GEOLOGY AND SOILS

The natural soil landscapes of this area include the Hornsby diatreme which is an outcrop of volcanic sedimentary breccia. There is also basaltic breccia and metamorphosed Hawkesbury sandstone. We even found examples of granite boulders likely blown up from depth during formation of the diatreme. The pre-existing landscape consisted of gently undulating rises to steep low hills on deeply weathered basaltic breccia. Diatremes and shallow intrusions are often located on sandstone valley floors. The soils in this area vary depending on the location.

The formation of the Hornsby Diatreme is thought to have derived either from gaseous explosions that deposited volcanic breccia horizontally and then slumped to form a bowl shape. A second point of view is that the breccia was deposited on the steep slopes with no consequential deformation (PSM Appendix A). The latter is the most supported view as there has been minimal evidence of depositional deformation. Surrounding the breccia is metamorphosed Hawkesbury sandstone. Ashfield Shales are seen as outcrops to the east and northeast of the quarry.

There are two types of breccia found at Hornsby Quarry, volcanic breccia and muddy breccia. Volcanic breccia consists grey to green-grey volcanic rock combined with mantle material, sandstone and shale. This material is higher-strength and doesn't weather as easily as muddy breccia. The muddy breccia consists of the finer volcanic breccia materials and has a low to medium strength and can weather quickly. There is now a colluvial breccia which consists of basaltic or muddy breccia fines eroded and deposited at the bottom of slopes of overburden during the life of the mine as seen in Bore Hole 9 to 12.

Chapman and Murphy describes six (6) dominant soil types on site which are summarised in Table 1 and illustrated in Figure 1.

Table 1. Soil types and descriptions by Chapman and Murphy (1989).

Soil Type	Soil Description
ho1	Black (10YR 1.7/1 to 10YR 2/2), organic, sandy loam. Generally, occurs as a topsoil (A1). High amounts of organic material. pH is strongly to moderately acidic. Quartz sand grains are Hawkesbury Sandstone derived.
ho2	Hard-setting, dark brown (10YR 1.7/1 to 10YR 2/2), sandy clay loam. Generally, occurs as the A2 horizon. Coarse quartz sand grains are Hawkesbury Sandstone derived.
ho3	Strongly pedal, brown light clay. Occurs as subsoil over breccia (B-Horizon). Common colours include reddish brown and bright brown. The material is slightly to moderately acidic.
ho4	Earthy, brown sandy loam. Generally, occurs as a subsoil over sandstone colluvium (B-Horizon). Colour varies from bright yellowish-brown to dull yellowish brown. Sandstone derived.
ho5	Earthy reddish-brown, sandy clay. Occurs as a subsoil on sandstone colluvium (C-Horizon). Bright reddish brown and moderately to strongly acidic. Sandstone derived.
ho6	Weathered volcanic breccia clay. Colour ranges from bright reddish brown to light brownish grey. Moderately to strongly acidic. Breccia derived.

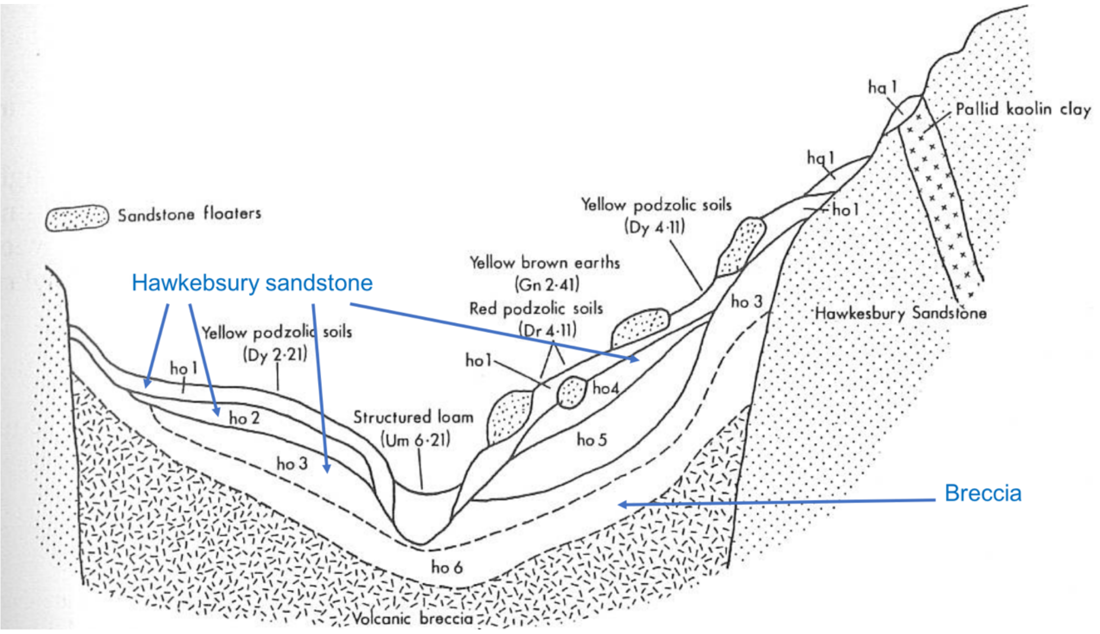

Figure 1. Schematic cross section of Hornsby (ho) soil landscape illustrating the dominant materials (Chapman and Murphy 1989).

Figure 2. Hornsby Quarry, diatreme. (Source: Lost Collective).

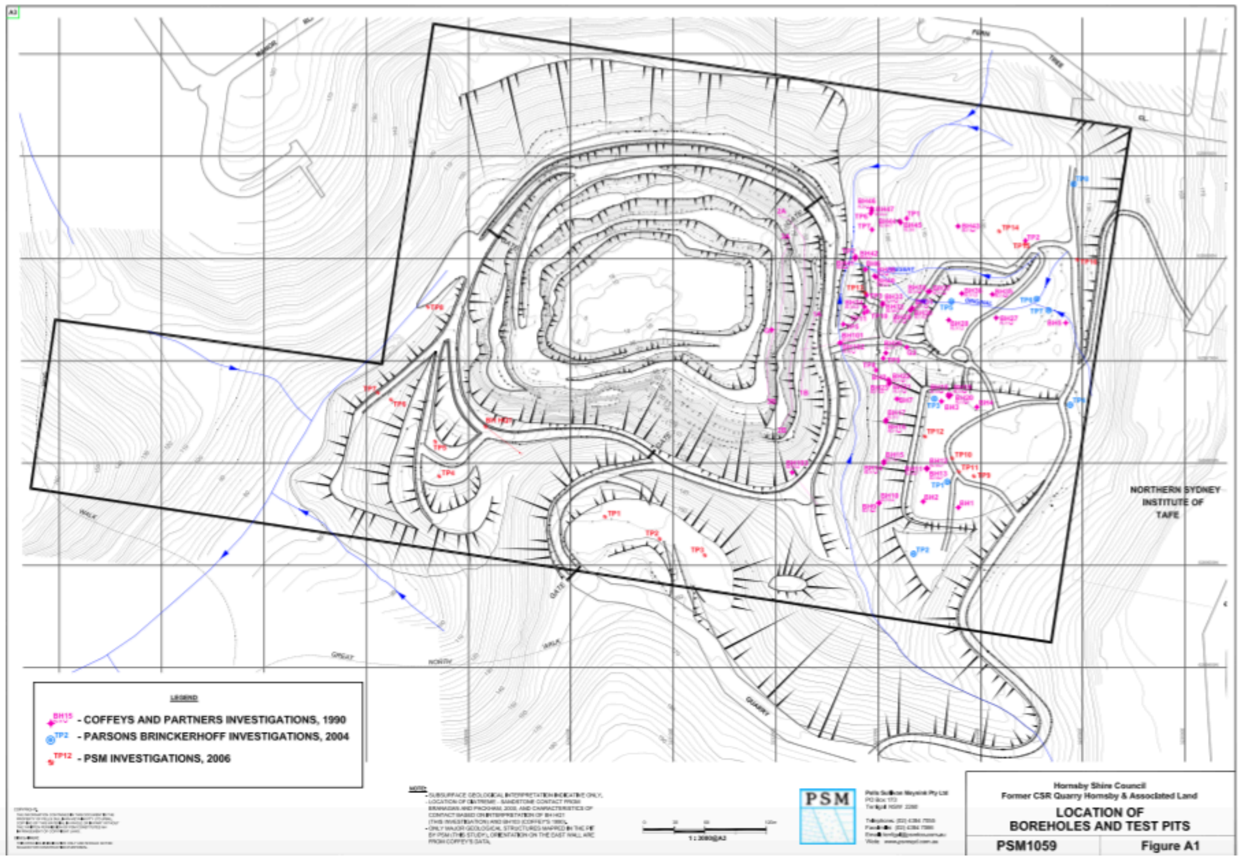

Figure 3. Composite bore hole locations for previous consultancy investigations.

2.2 SOIL OBSERVATIONS

Three surveys were undertaken by SESL Australia to collect the soil data from a total of 21 locations to gain an understanding of the soils across the Sites. The aim was to find a basaltic breccia soil which could be used as a benchmark to understand the complexity of the chemical and physical soil parameters for developing soils from disturbed locations.

1. An initial investigation was undertaken by Chantal Milner and Jesse Fenn of SESL on Wednesday 22nd November 2017 in the northern, western and southern areas of the site. Samples 1 – 8 were collected and analysed from this inspection.
2. A second assessment with Simon Leake and Chantal Milner was conducted on the 10th January 2018. Samples 11 – 16 were collected during this inspection from the north-eastern and south-western areas.

3. A third assessment with Simon Leake and Chantal Milner was conducted on 17th January 2018 in the south-western area of fill material that is a potential material for site re-use.

During the inspections, it was evident that there were five types of soils found on the site, that of the Hawkesbury sandstone and the basaltic breccia, muddy breccia, colluvial breccia and a sandy clay fill.

2.2.1 *22nd November 2017: 1st Site Investigation*

The first sample, Bore Hole 1 (BH1) was obtained from an intact sandstone landscape with minimal anthropological impact. The topsoil was a black loamy sand that became greyer with depth. BH4 had similar physical properties and was obtained from another natural benchmark location.

Figure 4. Natural benchmark profile of sandstone at bore hole 1.

Figure 5. Natural benchmark profile of sandstone at bore hole 4.

The remaining soils resembled soils of a basaltic breccia nature however the profile was not intact and jumbled. BH5 was sampled to a depth of only 150mm due to the gravelly nature of the soil and BH7 contained blue metal therefore these profiles won't be discussed in this report.

BH3, 5 and 8 fit the description of the breccia soils. They are sandy clay loams with the typical kraznozem colouring of bright reddish brown to a light brownish grey.

Figure 6. Bore Hole 2 - very dark greyish brown light sandy clay loam with a fine weak crumb structure.

Figure 7. Bore Hole 3 - dark brown sandy clay loam (0-300m). Dark yellowish brown sandy clay loam (300-560mm).

Figure 8. Bore Hole 6 - Dark yellowish brown sandy clay loam (0-210mm). Dark yellowish brown sandy clay loam (210-540mm).

Figure 9. Bore Hole 8 - brown sandy clay loam with a fine weak crumb structure.

2.2.2 *Site Map from 1st Investigation*

Figure 10. Site Map from 1st Investigation conducted on 22nd November 2017

2.2.3 *Wednesday 10th January 2018: 2nd Site Investigation*

During the second investigation Bore Holes 9 to 16 were examined and were described as either colluvial breccia (Bore Holes 9 to 12) or muddy breccia (Bore Holes 14 and 16).

Figure 11. Bore Hole 11. Very dark grey colluvial breccia clay loam.

Figure 12. Bore Hole 6. Intact muddy breccia profile. Dusky red becoming a reddish brown with depth.

2.2.4 *Site Map from 2nd Investigation*

Figure 13. Site map of bore hole locations in 2nd site visit.

2.2.5 *Wednesday 17th January 2018: 3rd Site Investigation*

The southern-western corner of the site was inspected for to understand the soils from a potential re-use standpoint. The soils observed consisted of dull-yellow brown weathered breccia, a dark brown topsoil. Foreign objects such as piping and bottles were found as well as high percentage of rocks ranging from 15% to 60% depending on the location of the excavation. The vegetative covering was very sparse with minimal grass coverage.

Figure 14. (a) Poor grass and vegetative growth in the south-western corner. (b) Rock inclusion is high ranging from an estimated 15% to 60% (c) Excavation hole 3 had a mixture of a dull-yellowish breccia and dark brown loam.

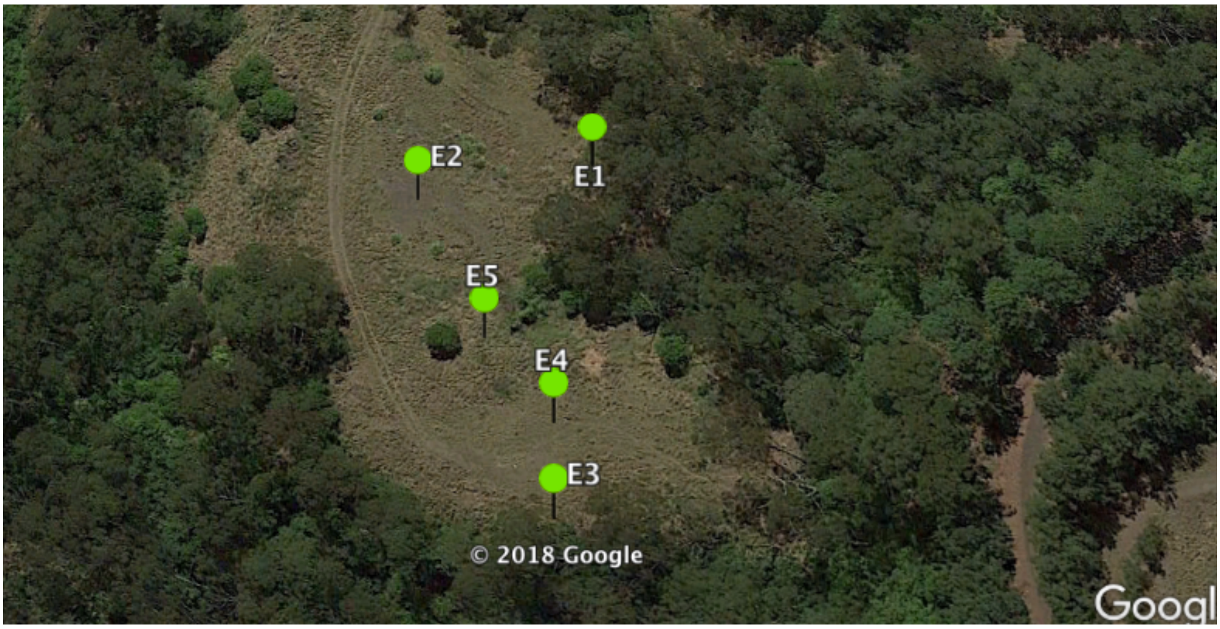

Figure 15. Site map of site inspection 3 with marked exaction holes.

3 LABORATORY ANALYSIS METHODOLOGY

Samples were collected by SESL using a hand auger in site inspections 1 and 2 and excavator in inspection 3. Approximately 1L - 15L of soil was collected per sample and returned to SESL's NATA Accredited Laboratory (Accreditation N°: 15633) for chemical and physical analysis.

The pH, EC, exchangeable cations and plant available nutrients were all analysed utilising the Mehlich 3 extract. Mehlich 3 (M3) estimates plant availability of most macro- and micronutrients on soils acid to neutral pH using a dilute acid-fluoride-EDTA solution of pH 2.5. The method has shown to be well correlated to crop response to fertilizer phosphorus and applicable for the determination of extractable potassium, calcium, magnesium, sodium and micronutrients, such as manganese, iron, copper and zinc (Mehlich, 1984).

Total Phosphorus and total calcium were assessed by Acid Digest using an ICP using the principal standard USEPA 3050B + 6010C (nearest equivalent method is Rayment & Lyons 17B1).

Organic Matter was assessed by Walkley Black using the prnicpal standard Rayment & Lyons 6A1,6B1-2011 (nearest equivalent method is AS 1289.4.1.1-1997 (OM from AS 4419-2003/4454-2012)).

Texture was undertaken using SESLs method, SESL PM0003 (nearest equivalent method is Northcote -1992). Structure uses SESLs method, SESL PM0003 (nearest equivalent method is P.E.V. Charman & B.W. Murphy-1991 Chapter 10: Craze & Hamilton). Colour is uses SESLs method, SESL PM0003 (nearest method Munsell-2000).

4 LABORATORY ANALYSIS

For ease of viewing, the laboratory analysis has been grouped into soil types initially and then later the benchmarking data has been collated from the multiple visits. The analysis grouping is as follows:

4.1. Basaltic breccia soils – Site visit 1
4.2. Breccia soils – Site visit 2
4.3. Breccia, 30-year soil profile – Samples 14 and 16
4.4. Sandstone soils
4.5. Fill soils – Site visit 3

4.1 Basaltic Breccia Soils – Site Visit 1

The basaltic breccia soils can be grouped according to their chemical and physical properties. Breccia soils have a higher cation exchange (eCEC) which allows for better nutrient retention. This is a consequence of its parent material and the presence of higher charge clays than are present in sandstone.. The breccia soils can be generally described as dark brown, dark yellowish brown and dark red clay loams. Another defining characteristic is that the cation exchange capacity (CEC) is highly magnesic.

The key properties of the basaltic breccia soils are as follows:

- Very slightly to moderately acidic in $CaCl_2$. BH6 and BH8 are slightly alkaline in H_2O. A large difference between pH results in H_2O and $CaCl_2$ indicates that the soil is not strongly buffered;
- The cation exchange is highly Magnesic;
- The effective cation exchange capacity (eCEC) is high indicating good nutrient uptake.
- Magnesium and manganese are high, however all other nutrients are low.
- BH6 and BH8 have high calcium levels
- There is colour variation in the soils from very dark grayish brown (10 YR 3/2) to dark brown (7.5YR 3/3) to Dark yellowish brown (10YR 4/4);
- The soils are all sandy clay loams with a fine weak crumb structure and moderate permeability.

A high percentage of the samples are breccias or have breccia like characteristics.

Table 2 outlines the chemical and physical properties of the breccia soils from Site Visit 1.

Table 2. Site Visit 1: Chemical and physical analysis of breccia soils.

	TOPSOILS						**SUBSOILS**			
Sample Name	BH2 0-170	BH3 0-300	BH5 0-150	BH6 0-210	BH7 Surface	BH8 0-220	BH2 170-400	BH2 400-580	BH3 300-560	BH6 210-540
pH in H_2O	6.1	6.9	7.8	7.9	8.3	8	6.5	6.8	7.8	7.8
pH in $CaCl_2$	5.7	6.3	6.5	6.6	6.9	7.0	6.1	6.2	6.5	6.7
Na mg/kg	41.2	104	80.7	41.6	36.6	33.1	93.8	100	515	108
Cl mg/kg	40.9	100	47	74.4	64.7	144	55.9	61.1	163	77.1
Ca % CEC	47.9	45.3	64.4	45.7	71.8	51.9	38.9	39.3	17.2	25.1
Mg % CEC	49.6	51.2	33.2	52.8	24.4	45.7	59	58.7	74.2	73.1

H % CEC	0	0	0	0	0	0	0	0	0	0
Al % CEC	0	0	0	0	0	0	0	0	0	0
eCEC meq/100g	27.9	27.9	35.5	42.6	35.9	31.9	38.6	36.2	28.6	40.1
PO_4 mg/kg	< 5	< 5	6.15	19.7	< 5	< 5	< 5	< 5	17.3	18
SO_4 mg/kg	11	16	29	14	28	13	14	14	3.2	8.2
Ca mg/kg	2680	2530	4580	3900	5170	3320	3010	2850	986	2010
Mg mg/kg	1681	1735	1433	2731	1065	1772	2767	2584	2578	3561
Texture	Light Sandy Clay Loam	Sandy Clay Loam	Sandy Clay Loam	Sandy Clay Loam	Sandy Loam	Sandy Clay Loam	Sandy Loam	Sandy Loam	Sandy Clay Loam	Sandy Clay Loam
 **Soil Colour**	10YR 3/2 Very Dark Grayish Bro	10YR 4/3 Brown	10YR 3/3 Dark Brown	7.5YR 3/3 Dark Brown	10YR 4/6 Dark Yellowish Brown	2.5Y 4/2 Dark Grayish Brown	10YR 4/4 Dark Yellowish Brown	10YR 4/4 Dark Yellowish Brown	2.5YR 3/4 Dark reddish brown	7.5YR 4/3 Brown

4.2 BRECCIA SOILS – SITE VISIT 2

The majority of the soils sampled during the 2nd site inspection had breccia characteristics. A description of the breccia soils are outlined in Site Visit 1 (Basaltic breccia soils – Site visit 1). The important properties of note are samples BH14 and BH16 which provide a good representation of a 30-year profile. Section Breccia, 30-year soil profile – Samples 14 and 16 outline this in more detail.

Table 3 outlines the chemical and physical properties of the breccia soils from Site Visit 2.

Table 3. Site Visit 1: Chemical and physical analysis of breccia soils.

			TOPSOILS				SUBSOILS
Sample Name	BH9 0-300mm	BH16	BH10 0-200mm	BH11 0-400mm	BH14 0-75mm	BH14 75-250mm	BH14 250+mm
pH in H_2O	6.9	6.4	7.7	7.6	5.9	6.3	6.4
pH in $CaCl_2$	6.3	6.2	6.6	6.8	5.6	5.3	5.5
EC dSm	0.1	0.2	0.1	0.2	0.1	0.04	0.03
Na mg/kg	47.1	14.4	22.4	90.6	71.2	45.4	42.6
Cl mg/kg	66.6	52	63.4	37.8	116	147	0
Na % CEC	0.7	0.2	0.4	1.4	1.2	1	1.3
K % CEC	1.1	3.5	1.7	1.1	4.1	3.1	2.6
Ca % CEC	58.3	54.1	74.9	65.5	44.1	28.9	34.3

Mg % CEC	39.9	42.2	22.9	31.8	50.7	44.3	59.4
H % CEC	0	0	0	0	0	22.6	2.1
Al % CEC	0	0	0	0	0	0	0
eCEC meq/100g	29.5	37.5	26.1	28.7	25.5	20.2	14.5
NO_3 mg/kg	23	76	11	3.1	2.1	4	0
PO_4 mg/kg	5	27.8	5	5	9.23	5	0
K mg/kg	121	508	171	131	410	245	150
SO_4 mg/kg	18	20	18	19	22	13	0
Ca mg/kg	3440	4070	3920	3770	2250	1170	999
Mg mg/kg	1430	1925	725	1110	1572	1087	1046
Texture	Clay Loam	Loam Fine Sandy	Clay Loam	Clay Loam	Clay Loam	Light Clay	-
Soil Colour	7.5YR 3/1 Very Dark Gray	7.5YR 3/1 Very Dark Gray	10YR 4/1 Dark Gray	2.5YR 3/2 Dusky Red	2.5YR 4/2 Weak Red	5YR 4/3 Reddish Brown	10YR 3/2 Very Dark Grayish Bro

4.3 BRECCIA 30-YEAR SOIL PROFILE – SAMPLES 14 AND 16

Samples 14 and 16 are an example of a developed profile over an undisturbed 30-year period. The chemical properties are correlated with soil that has received naturally deposited organic matter from decomposing micro and macro flora and fauna. The consequential nutrient cycling is clearly higher in the soil surface where bioaccumulation is taking place and decreases with depth. The properties of note are the bioaccumulation of potassium, calcium and magnesium. Figure 16 and Figure 17 show a distinct difference in the organic matter and nutrition from the surface to a depth of 250mm. This bioaccumulation down the profile has occurred over a 30-year period which is very rapid.

Breccia has a high eCEC which has contributed to the retention of the nutrients. This profile example is what SESL will use as a benchmark for other breccia profiles that are to be remediated.

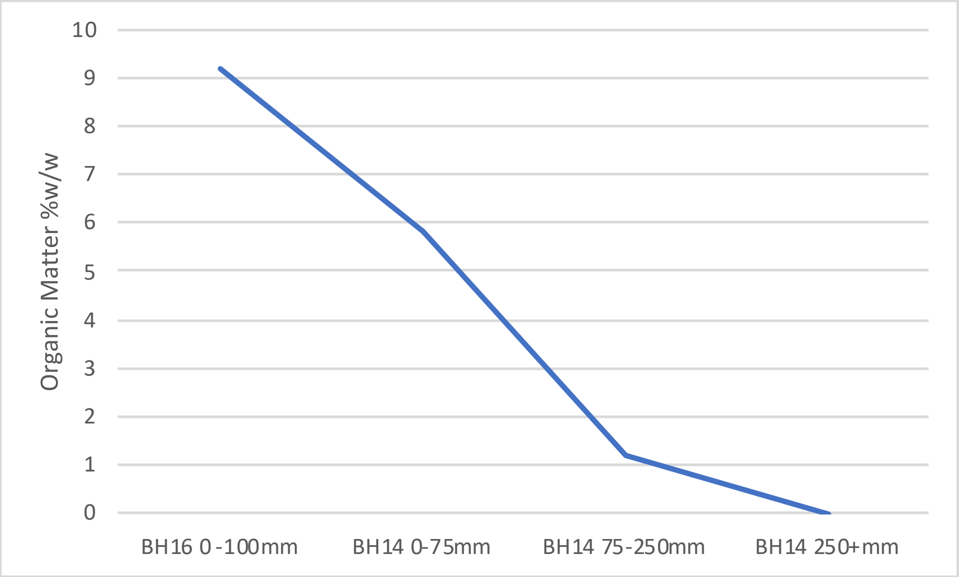

Figure 16. Organic matter declination with depth. Fertility is high in the surface at >9% w/w however drops to 0%w/w at 250mm.

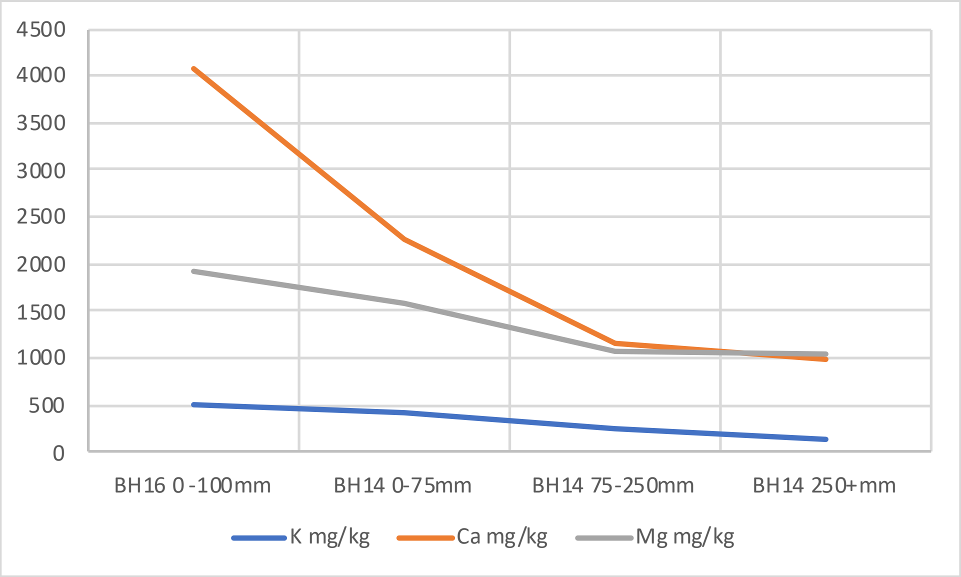

Figure 17. Nutrient levels (Potassium, K, Calcium, Ca and Magnesium, Mg) declination with depth.

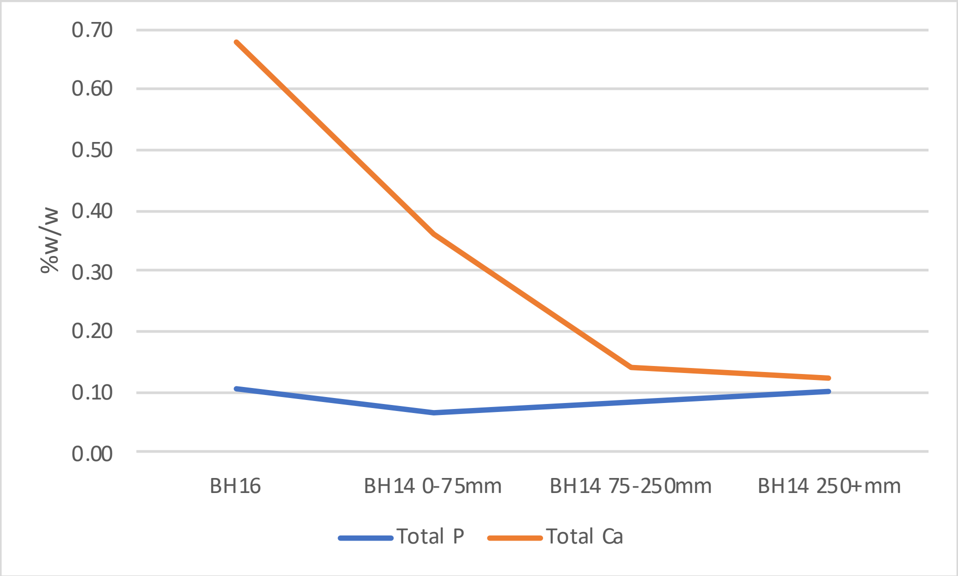

Figure 18. Total phosphorus and total calcium levels. Total calcium declines with soil depth indicating bioaccumulation in the surface soil.

4.4 SANDSTONE SOILS

Sandstone soils were also observed at some locations on the Site. An intact sandstone location was found in Bore Hole 1. Bore hole 4 and 12 were also sandstone soils however were not intact. BH12 also has breccia properties.

The key properties of the sandstone soils are as follows:

- Very strongly to extremely acidic in $CaCl_2$;
- The cation exchange is dominated by hydrogen which explains the acidity;
- As a result of the acidity, aluminium has become available;
- Due to the low effective cation exchange and the acidity, nutrients are deficient;
- Topsoils are a black (10 YR 2/1) loamy sand to sandy loam with a weak crumb structure and very rapid permeability;
- Subsoils are a very dark grayish brown (10 YR 3/2) to dark grayish brown (10 YR 4/2) sandy loam with a weak crumb structure and rapid permeability.
-

Table 4. Chemical and physical properties of the sandstone soils.

Sample Name	BH1 0-300	BH1 300-610	BH1 610-900	BH4 0-550	BH12 0-100mm
pH in H_2O	6	5.2	5.2	5.1	5.2
pH in $CaCl_2$	4.9	4.5	4.5	4.4	4.2
EC dSm	0.04	0.02	0.03	0.05	26.4
Na % CEC	1.2	1.6	2.1	2	0
K % CEC	1.9	2.4	2.9	2.8	4.2
Ca % CEC	39.5	12.6	5.6	10.5	30.1
Mg % CEC	25.1	14.4	15.1	25.2	45.6
H % CEC	32.5	67.8	72.5	55.9	16.2
Al % CEC	0.1	0.8	3.1	2.8	11.4
eCEC meq/100g	13.8	5	5.2	8.3	0
Texture	Loamy Sand	Sandy Loam	Sandy Loam	Sandy Loam	Light medium clay
Structure	Crumb	Crumb	Crumb	Crumb	Crumb
Est. Infiltration rate	Very Rapid	Rapid	Rapid	Rapid	Moderate
Aggregate Strength	Pedal - Weak	Pedal - Weak	Pedal - Weak	Pedal - Weak	Moderate
Soil Colour	10YR 2/1 Black	10YR 3/2 Very Dark Grayish Brown	10YR 4/2 Dark Grayish Brown	10YR 2/1 Black	7.5YR 5/8 Strong Brown

4.5 FILL SOILS – SITE VISIT 3

The soils from the fill area showed similar chemical and physical properties. The soils are slightly alkaline in $CaCl_2$ with low salinity and chloride levels but high sodium. The cation exchange is highly magnesic and has a very high eCEC. Calcium, magnesium and manganese levels are very high. Organic matter is low at 0.7 – 1.1% Excavation 2 (0-200m) and excavation 5 had a balanced cation exchange and the salinity and nutrient levels at excavation hole 2 were a lot higher. Chemically these soils have a gypsiferous characteristic therefore have high calcium and sulphur levels.The soils are a fine to light sandy clay loam with a moderate polyhedral structure and moderate to rapid permeability.

Table 5. Site visit 3 fill soils.

Sample Name	Excavation 1	Excavation 2 0-200	Excavation 2 comp	Excavation 3	Excavation 4	Excavation 5
pH in H2O	8.1	8.6	8	7.8	7.7	7.2
pH in $CaCl_2$	7.5	7.6	7.5	7.4	7.3	7.2
EC dSm	0.18	0.1	0.03	0.03	0.04	1.9
Na mg/kg	207	50.9	50.8	52.6	69.8	36.7
Cl mg/kg	31.9	42.6	58.9	69.7	58.3	26.5
Na % CEC	2.2	0.6	0.6	0.6	0.8	0.3
K % CEC	0.7	0.9	1.1	1.1	1.2	0.8
Ca % CEC	50.8	76.7	45.7	44.8	48.9	83
Mg % CEC	46.4	21.7	52.7	53.5	49.3	16
H % CEC	0	0	0	0	0	0
Al % CEC	0	0	0	0	0	0
eCEC meq/100g	40.6	35	36.6	37.1	38.6	48.4
NO_3 mg/kg	1.1	2	3.5	4.2	4.7	1.5
PO_4 mg/kg	13.8	7.5	11	11	10.6	14.7
K mg/kg	116	124	165	162	176	151
SO_4 mg/kg	71	39	14	13	14	2090
Ca mg/kg	4130	5380	3350	3330	3780	8050
Mg mg/kg	2288	922	2343	2412	2311	938
Texture	Fine Sandy Clay Loam	Fine Sandy Clay Loam	Light Sandy Clay Loam	Light Sandy Clay Loam	Sandy Clay Loam	Sandy Clay Loam
Structure	Polyhedral	Polyhedral	Polyhedral	Polyhedral	Crumb	Crumb
Infiltration rate	Moderate	Moderate	Rapid	Rapid	Moderate	Moderate

4.6 COFFEYS & PARTNERS (1990) AND PSM (2006) INVESTIGATIONS

Previous investigations were undertaken by Coffeys and Partners in 1990 and PSM in 2006. To understand the soils further SESL has examined the bore logs undertaken in the areas of interest such as in the north eastern corner where PSM have stated the presence of residual breccia. Upon inspection of the bore logs to a depth of 5m it can be seen that the breccia does not start until 1500m depth. Above this is either silty clays or sandy clays. However, in some locations there is residual breccia in the surface i.e. BH44. Figure 19 illustrates the bore logs and the different depths at which the soil type changes.

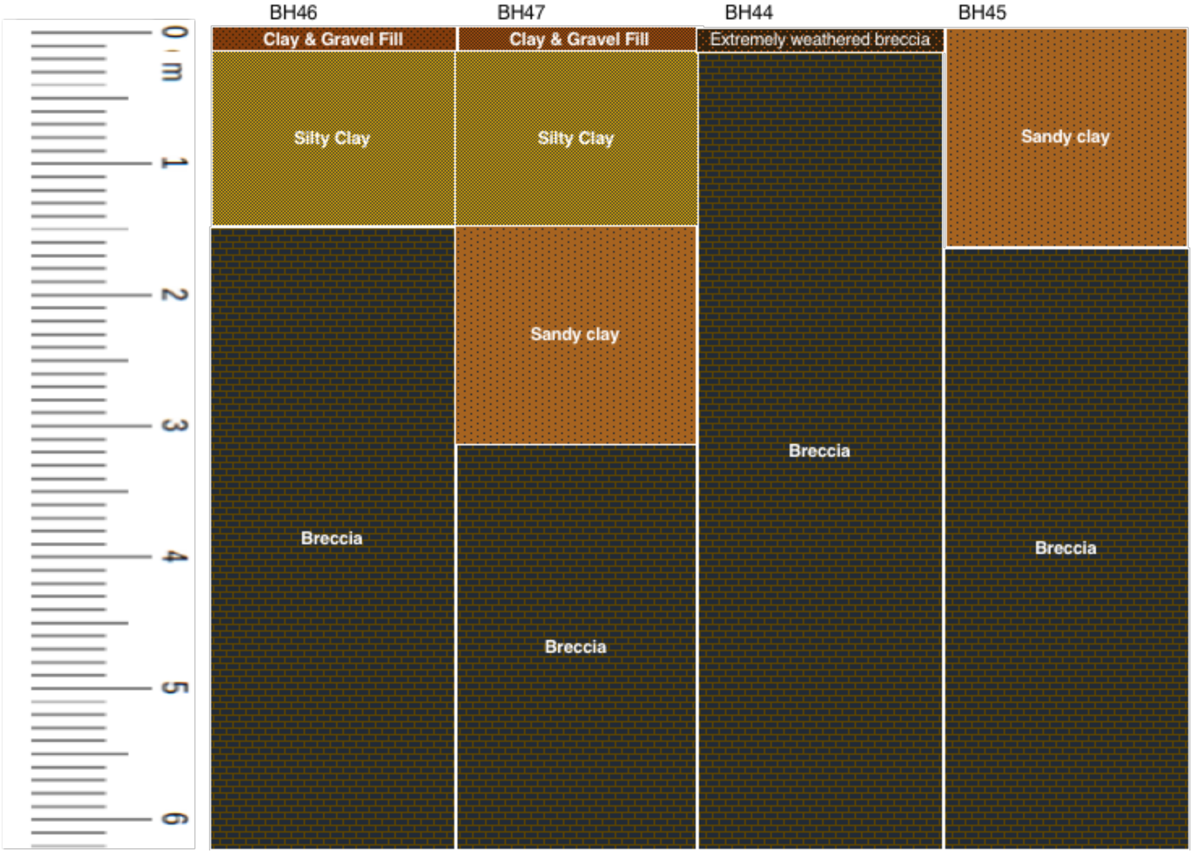

Figure 19. Coffeys and Partners bore logs obtained from the bores in the north-eastern corner. Breccia doesn't begin until a depth of 1500mm.

5 DISCUSSION

The soil materials now present at Hornsby Quarry soils are a complex in nature, particularly to the north west and a variety of highly disturbed overburden materials of diatreme origin. The intact soils are largely sandstone based but at the lower slope position some can be found with breccia-derived clays in their subsoil (eg BH 14). The undulating landscape, steep hills, mining and excavation works has also added another dimension of complexity.

Locating an intact breccia profile did not prove possible however pockets of breccia and soils that have breccia properties were located. The soils found at BH14 and BH16 were found to be a good example of a breccia profile that had been disturbed but had redeveloped over a 30-year period. Its high cation exchange properties give it excellent nutrient holding properties making it an ideal fertile soil for Blue Gum growth. The area is now well vegetated with Blue Gum. These properties from BH14 and BH16 can be used as a benchmark or “concept” profile for redeveloping on-site soils using breccia overburden in other sections of the site. Our analysis has shown that phosphorus is moderate however potassium, calcium and magnesium levels are all high in the 30 year old topsoil through bioaccumulation. These levels decrease in the subsoil back to those levels found in a range of hard and soft breccia overburden placements around the site.

It was found that silty clays and sandy clays tend to dominate the top 1000mm of soils and below an intact breccia becomes the dominant soil type. The dominate upper profiles in the north east corner are a disturbed and weathered breccia with some intermixed sandstone and fine matter. However the upper profile can be treated as most similar to a breccia based soil. When breccia is in the upper profile it is extremely weathered in its nature. This is consistent with Chapman and Murphys illustration (see Figure 1). Sandstone is noted to be surrounding the outside of diatreme and SESL identified an undisturbed area of sandstone soils located in the upmost northern section of the Site and the soil was intact and consistent with chemical and physical properties.

It was found that the darker grey breccia and lighter red/brown muddy breccia does not differ much in their chemical properties. There are large amounts of both of these materials available in terraced placement in the SW corner of the site. With their high ECEC qualities and clay nature of breccia overburdens making them suitable for redevelopment into breccia like soils there appears to be an abundant resource to recreate Blue Gum high forest and recreational areas.

Once the final landscape treatments are known this report gives confidence that soils can be made cost effectively from resources available on site.

6 APPENDICES

Appendix A: Laboratory Results: Site Visit 1 - 22nd November 2017

Appendix B: Laboratory Results: Site Visit 2 - 10th January 2018

Appendix C: Laboratory Results: Site Visit 3 - 17th January 2018

7 REFERENCES

Benson, D. H. (Douglas Howard) & Howell, Jocelyn, 1944- & Royal Botanic Gardens (Sydney, N.S.W.) (1990). Taken for granted : the bushland of Sydney and its suburbs. Kangaroo Press/Royal Botanic Gardens, Sydney.

Chapman, G. A & Murphy, C. L & Soil Conservation Service of New South Wales (1989). Soil landscapes of the Sydney 1:100 000 sheet. Soil Conservation Service of N.S.W, Sydney.

8 LIMITATIONS

Limitations of This Report:

SESL has performed an investigation and consulting services for this project as outlined in our discussions and in accordance with current professional and industry standards for this horticultural site assessment. The findings of this report are the result of discrete/specific methodologies used in accordance with normal practices and standards. To the best of our knowledge, they represent a reasonable interpretation of the general condition of this site and do not represent the actual state of the site at all points. Should materials or conditions be encountered other than those which have been described these will require additional assessment.

SESL assessment is based on the result of limited site investigation. SESL cannot provide unqualified warranties nor assume any liability for site conditions not observed, accessible during the time of the investigations.

Despite all reasonable care and diligence, the ground conditions encountered, and the nutrient analysis measured may not be representative of conditions between the locations samples and investigated. In addition, site characteristics may change as a result of soil heterogeneity, chemical reactions and other events. These changes may occur subsequent to SESL investigation and assessment.

This report and associated documentation and the information herein have been prepared solely for the use of the client and any relevant authority. Any reliance assumed by third parties on this report shall be at such parties own risk. Any ensuring liability resulting from use of the report by third parties cannot be transferred to SESL.

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Appendix A

Laboratory Analysis: Site Visit 1

Soil Chemistry Profile

Mehlich 3 - Multi-nutrient Extractant

Sample Drop Off: 16 Chilvers Road
Thornleigh NSW 2120
Mailing Address: PO Box 357
Pennant Hills NSW 1715
Tel: 1300 30 40 80
Fax: 1300 64 46 89
Em: info@sesl.com.au
Web: www.sesl.com.au

Batch N°: 45863 **Sample N°: 1** **Date Received: 22/11/17** **Report Status: ● Draft ○ Final**

Client Name: **Hornsby Shire Council**
Client Contact: **Kurt Henkel**
Client Job N°:
Client Order N°:
Address: **PO Box 37**
HORNSBY NSW 2077

Project Name: **Hornsby Park Initial soil benchmarking**
SESL Quote N°:
Sample Name: **BH1 0-300**
Description: **Soil**
Test Type: **FSC, CSP**

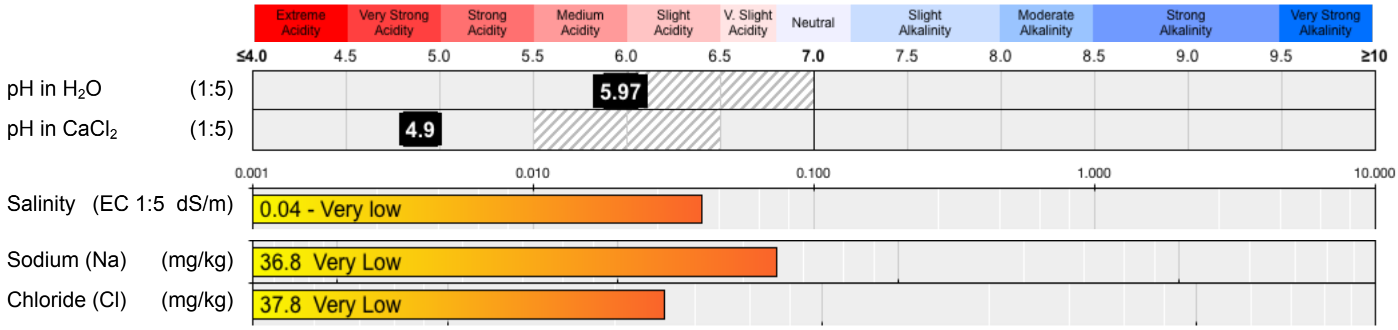
RECOMMENDATIONS

BH1 soil is very strongly acidic with desirably low salinity and sodium chloride levels. The cation exchange is dominated by hydrogen. The eCEC is moderate indicating good nutrient uptake. Nutrients are deficient to low aside from magnesium.
Soil is a black loamy sand with a fine weak crumb structure and very rapid permeability.

SOIL SAMPLE DEPTH (mm): ● 100 ○ 150 ○ 200

FERTILITY RATING: ○ Low ● Moderate ○ High

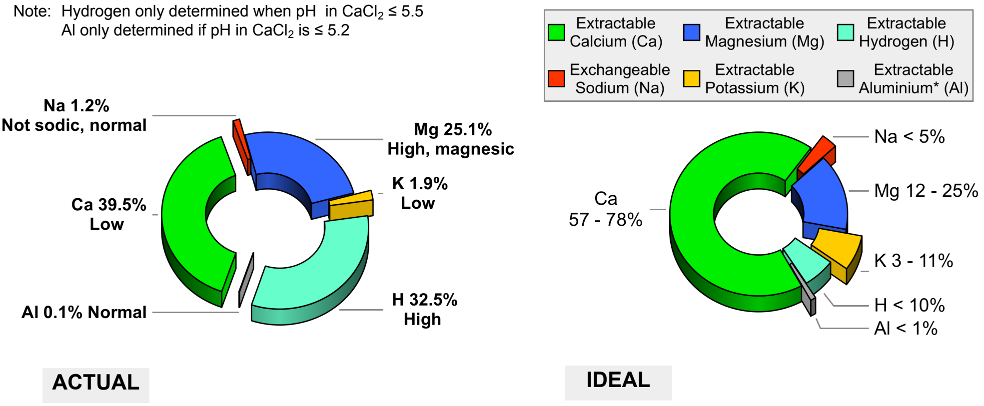
pH and ELECTRICAL CONDUCTIVITY



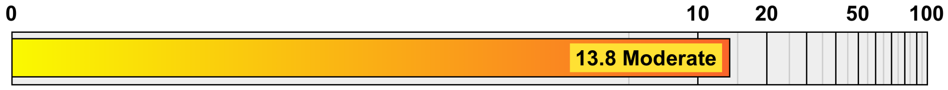
CATION BALANCE

EXCHANGEABLE CATION PERCENTAGE

Note: Hydrogen only determined when pH in $CaCl_2 \leq 5.5$
Al only determined if pH in $CaCl_2$ is ≤ 5.2



EFFECTIVE CATION EXCHANGE CAPACITY (eCEC)



CATION RATIOS

Ratio	Result	Target Range
Ca:Mg	1.6	4.1 – 6.0
Comment: Calcium low		
Mg:K	13.3	2.6 – 5.0
Comment: Potential Potassium deficiency		
K/(Ca+Mg)	0.03	< 0.07
Comment: Acceptable		
K:Na	1.6	N/A

Sodium Absorption Ratio: D.N.T.

EXCHANGEABLE CATIONS cmol(+)/kg

Na:	K:	Ca:	Mg:	H:	Al:
0.16	0.26	5.45	3.46	4.48	0.01

SOLUBLE CATIONS cmol(+)/kg

Na:	K:	Ca:	Mg:

A member of the Australasian Soil and Plant Analysis Council
† This laboratory has been awarded a Certificate of Proficiency for specific soil and plant tissue analyses by the Australasian Soil and Plant Analysis Council (ASPAC). Tests for which proficiency has been demonstrated are highlighted in this report.

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Soil Chemistry Profile

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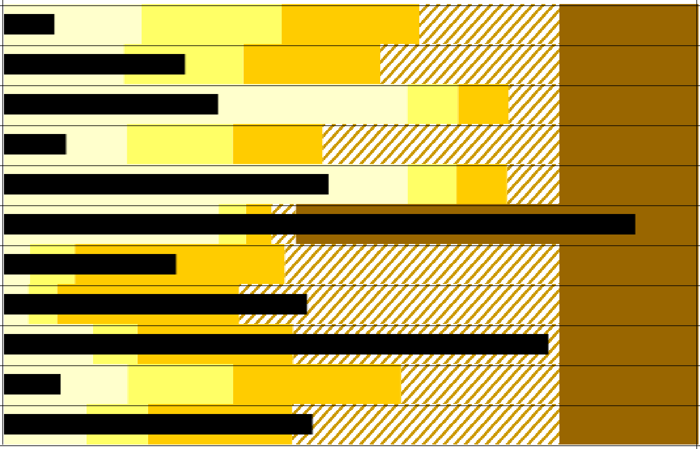
Batch N°: 45863 **Sample N°: 1** **Date Received: 22/11/17** **Report Status: ● Draft ○ Final**

PLANT AVAILABLE NUTRIENTS



Major Nutrients	**Result** (mg/kg)	☐ Very Low ☐ Low ☐ Marginal ▨ Adequate ■ High	**Result** (g/sqm)	**Desirable** (g/sqm)	**Adjustment** (g/sqm)
Nitrate-N (NO_3)	1.9		0.3	4	3.7
Phosphate-P (PO_4)	21.2		2.8	8.4	5.6
Potassium (K) †	101		13.4	34.8	21.4
Sulphate-S (SO_4)	7.6		1	9	8
Calcium (Ca) †	1090		145	248	103
Magnesium (Mg) †	420		55.9	25.8	Drawdown
Iron (Fe)	171		22.7	73.4	50.7
Manganese (Mn) †	24		3.2	5.9	2.7
Zinc (Zn) †	4.9		0.7	0.7	0
Copper (Cu)	<0.64		0.1	0.8	0.7
Boron (B) †	1.5		0.2	0.4	0.2

Explanation of graph ranges:

☐ **Very Low**
Growth is likely to be severely depressed and deficiency symptoms present. Large applications for soil building purposes are usually recommended. Potential response to nutrient addition is >90%.

☐ **Low**
Potential "hidden hunger", or sub-clinical deficiency. Potential response to nutrient addition is 60 to 90%.

☐ **Marginal**
Supply of this nutrient is barely adequate for the plant, and build-up is still recommended. Potential response to nutrient addition is 30 to 60%.

▨ **Adequate**
Supply of this nutrient is adequate for the plant, and and only maintenance application rates are recommended. Potential response to nutrient addition is 5 to 30%.

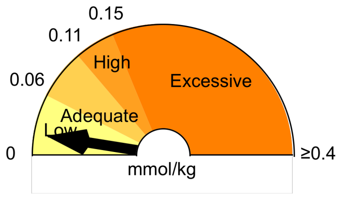
■ **High**
The level is excessive and may be detrimental to plant growth (i.e. phytotoxic) and may contribute to pollution of ground and surface waters. Drawdown is recommended. Potential response to nutrient addition is <2%.

NOTES: Adjustment recommendation calculates the elemental application to shift the soil test level to within the **Adequate** band, which maximises growth/yield, and economic efficiency, and minimises impact on the environment.

Drawdown: The objective nutrient management is to utilise residual soil nutrients. There is no agronomic reason to apply fertiliser when soil test levels exceed **Adequate**.

- g/sqm measurements are based on soil bulk density of 1.33 tonne/m^3 and selected soil depth.

Phosphorus Saturation Index



0.02

Low. Plant response to applied P is likely.

Exchangeable Acidity

Adams-Evans Buffer pH (BpH):	**7.3**
Sum of Base Cations (meq/100g^{-1}):	**9.3**
Eff. Cation Exch. Capacity (eCEC):	**13.8**
Base Saturation (%):	**67.39**
Exchangeable Acidity (meq/100g^{-1}):	**4.48**
Exchangeable Acidity (%):	**32.46**

Lime Application Rate

– to achieve pH 6.0 (g/sqm):	**174**
– to neutralise Al (g/sqm):	**1**

Gypsum Application Rate

– to achieve 67.5% exch. Ca (g/sqm):	**144**

The CGAR is corrected for a soil depth of 100mm and any Lime addition to achieve pH 6.0.

Physical Description

Texture:	**Loamy Sand**
Colour:	**10YR 2/1 Black**
Estimated clay content:	**5 - 10%**
Size:	**Fine (1 - 10mm)**
Gravel content:	**Gravelly**
Aggregate strength:	**Pedal - Weak**
Structural unit:	**Crumb**
Potential infiltration rate:	**Very Rapid**
Permeability (mm/hr):	**>120**
Calculated EC_{SE} (dS/m):	**0.9**

– Non-saline. Salinity effects on plants are mostly negligible.

Organic Carbon (OC%)†: **Did not test**
Organic Matter (OM%): **-**
Additional comments:

Consultant: Chantal Milner

Authorised Signatory:

Date Report Generated 22/12/2017

METHOD REFERENCES:
pH (1:5 H_2O) - Rayment & Higginson (1992) 4A1,
pH (1:5 $CaCl_2$) - Rayment & Higginson (1992) 4B1,
EC (1:5) - Rayment & Higginson (1992) 3A1,
Chloride - Rayment & Higginson (1992) 5A2,
Nitrate - Rayment & Higginson (1992) 7B1
Aluminium - SESL in-house,
PO_4, K, SO_4, Ca, Mg, Na, Fe, Mn, Zn, Cu, B - Mehlich 3 (1984),
Buffer pH and Hydrogen - Adams-Evans (1972)
Texture/Structure/Colour - PM0003 (Texture- "Northcote" (1992), Structure- "Murphy" (1991), Colour- "Munsell" (2000))

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Soil Chemistry Profile

Mehlich 3 - Multi-nutrient Extractant

Sample Drop Off: 16 Chilvers Road
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Mailing Address: PO Box 357
Pennant Hills NSW 1715
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Em: info@sesl.com.au
Web: www.sesl.com.au

Batch N°: 45863 **Sample N°: 2** **Date Received: 22/11/17** **Report Status: ● Draft ○ Final**

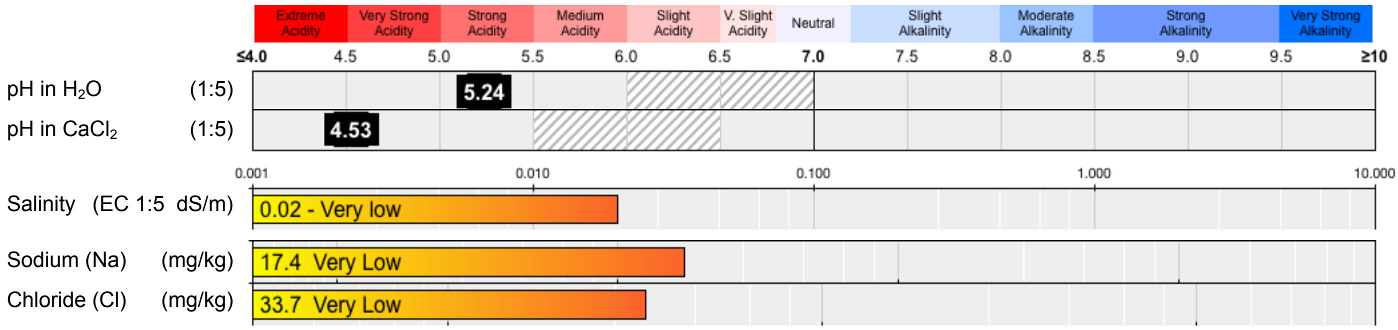
Client Name:	**Hornsby Shire Council**	Project Name:	**Hornsby Park Initial soil benchmarking**
Client Contact:	**Kurt Henkel**		
Client Job N°:		SESL Quote N°:	
Client Order N°:		Sample Name:	**BH1 300-610**
Address:	**PO Box 37 HORNSBY NSW 2077**	Description:	**Soil**
		Test Type:	**FSC, CSP**

RECOMMENDATIONS

BH1 soil (300-610) is very strongly acidic with desirably low salinity and sodium chloride levels. The cation exchange is dominated by hydrogen. The eCEC is very low indicating poor nutrient uptake. Nutrients are deficient.
Soil is a very dark greyish brown sandy loam with a fine weak crumb structure and rapid permeability.

SOIL SAMPLE DEPTH (mm): ● 100 ○ 150 ○ 200 **FERTILITY RATING:** ○ Low ● Moderate ○ High

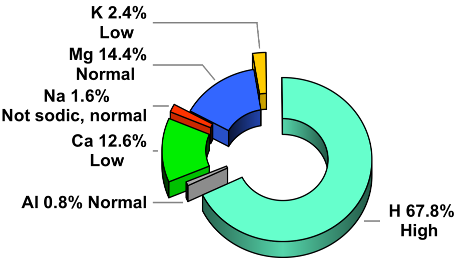
pH and ELECTRICAL CONDUCTIVITY



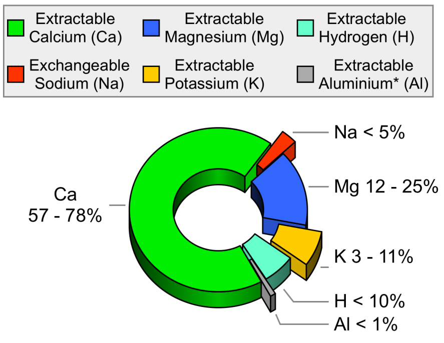
CATION BALANCE

EXCHANGEABLE CATION PERCENTAGE

Note: Hydrogen only determined when pH in $CaCl_2 \leq 5.5$
Al only determined if pH in $CaCl_2$ is ≤ 5.2

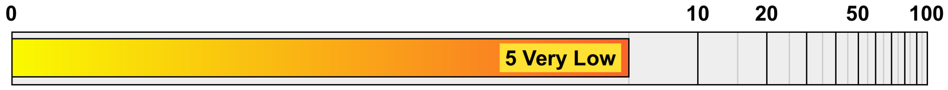


ACTUAL



IDEAL

EFFECTIVE CATION EXCHANGE CAPACITY (eCEC)



CATION RATIOS

Ratio	Result	Target Range
Ca:Mg	**0.9**	4.1 – 6.0
Comment: Potential Calcium deficiency		
Mg:K	**6**	2.6 – 5.0
Comment: Potassium low		
K/(Ca+Mg)	**0.09**	< 0.07
Comment: High		
K:Na	**1.5**	N/A

Sodium Absorption Ratio: D.N.T.

EXCHANGEABLE CATIONS cmol(+)/kg

Na:	K:	Ca:	Mg:	H:	Al:
0.08	0.12	0.63	0.72	3.39	0.04

SOLUBLE CATIONS cmol(+)/kg

Na:	K:	Ca:	Mg:

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Soil Chemistry Profile

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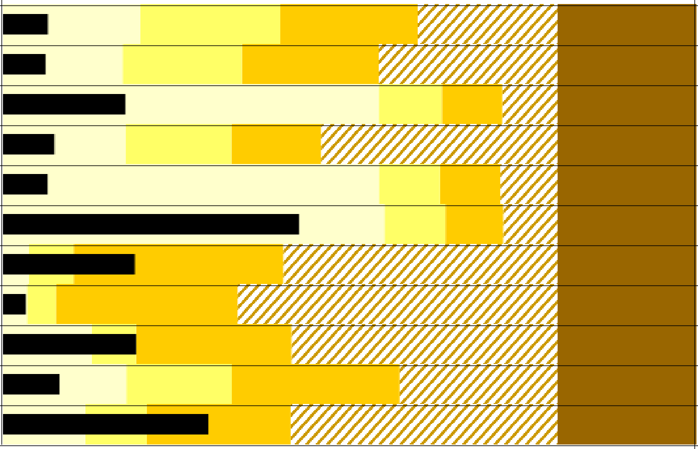
Batch N°: 45863 **Sample N°: 2** **Date Received: 22/11/17** **Report Status:** ● **Draft** ○ **Final**

PLANT AVAILABLE NUTRIENTS



Major Nutrients	**Result** (mg/kg)	🟨 Very Low 🟨 Low 🟧 Marginal ▨ Adequate 🟫 High	**Result** (g/sqm)	**Desirable** (g/sqm)	**Adjustment** (g/sqm)
Nitrate-N (NO_3)	1.7		0.2	4	3.8
Phosphate-P (PO_4)	<5		0.7	8.4	7.7
Potassium (K) †	48.5		6.5	29.3	22.8
Sulphate-S (SO_4)	6.3		0.8	9	8.2
Calcium (Ca) †	126		16.8	208.3	191.5
Magnesium (Mg) †	87		11.6	21.7	10.1
Iron (Fe)	131		17.4	73.4	56
Manganese (Mn) †	1.8		0.2	5.9	5.7
Zinc (Zn) †	1.2		0.2	0.7	0.5
Copper (Cu)	<0.64		0.1	0.8	0.7
Boron (B) †	1		0.1	0.4	0.3

Explanation of graph ranges:

🟨 **Very Low**
Growth is likely to be severely depressed and deficiency symptoms present. Large applications for soil building purposes are usually recommended. Potential response to nutrient addition is >90%.

🟨 **Low**
Potential "hidden hunger", or sub-clinical deficiency. Potential response to nutrient addition is 60 to 90%.

🟧 **Marginal**
Supply of this nutrient is barely adequate for the plant, and build-up is still recommended. Potential response to nutrient addition is 30 to 60%.

▨ **Adequate**
Supply of this nutrient is adequate for the plant, and and only maintenance application rates are recommended. Potential response to nutrient addition is 5 to 30%.

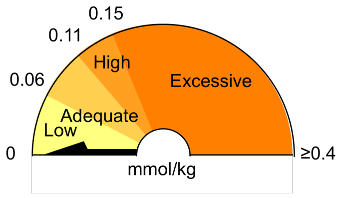
🟫 **High**
The level is excessive and may be detrimental to plant growth (i.e. phytotoxic) and may contribute to pollution of ground and surface waters. Drawdown is recommended. Potential response to nutrient addition is <2%.

NOTES: Adjustment recommendation calculates the elemental application to shift the soil test level to within the **Adequate** band, which maximises growth/yield, and economic efficiency, and minimises impact on the environment.

Drawdown: The objective nutrient management is to utilise residual soil nutrients. There is no agronomic reason to apply fertiliser when soil test levels exceed **Adequate**.

- g/sqm measurements are based on soil bulk density of 1.33 tonne/m^3 and selected soil depth.

Phosphorus Saturation Index



0

Low. Plant response to applied P is likely.

Exchangeable Acidity

Adams-Evans Buffer pH (BpH): **7.5**
Sum of Base Cations (meq/100g^{-1}): **1.6**
Eff. Cation Exch. Capacity (eCEC): **5**
Base Saturation (%): **32**
Exchangeable Acidity (meq/100g^{-1}): **3.39**
Exchangeable Acidity (%): **67.8**

Lime Application Rate

– to achieve pH 6.0 (g/sqm): **223**
– to neutralise Al (g/sqm): **4**

Gypsum Application Rate

– to achieve 67.5% exch. Ca (g/sqm): **0**
The CGAR is corrected for a soil depth of 100mm and any Lime addition to achieve pH 6.0.

Physical Description

Texture: **Sandy Loam**
Colour: **10YR 3/2 Very Dark Grayish Bro**
Estimated clay content: **10 - 20%**
Size: **Fine (1 - 10mm)**
Gravel content: **Gravelly**
Aggregate strength: **Pedal - Weak**
Structural unit: **Crumb**
Potential infiltration rate: **Rapid**
Permeability (mm/hr): **>120**
Calculated EC_{SE} (dS/m): **0.3**
– Non-saline. Salinity effects on plants are mostly negligible.
Organic Carbon (OC%)†: **Did not test**
Organic Matter (OM%): **-**
Additional comments:

Consultant: Chantal Milner **Authorised Signatory:**

Date Report Generated 22/12/2017

METHOD REFERENCES:
pH (1:5 H_2O) - Rayment & Higginson (1992) 4A1,
pH (1:5 $CaCl_2$) - Rayment & Higginson (1992) 4B1,
EC (1:5) - Rayment & Higginson (1992) 3A1,
Chloride - Rayment & Higginson (1992) 5A2,
Nitrate - Rayment & Higginson (1992) 7B1
Aluminium - SESL in-house,
PO_4, K, SO_4, Ca, Mg, Na, Fe, Mn, Zn, Cu, B - Mehlich 3 (1984),
Buffer pH and Hydrogen - Adams-Evans (1972)
Texture/Structure/Colour - PM0003 (Texture- "Northcote" (1992), Structure- "Murphy" (1991), Colour- "Munsell" (2000))

ASPAC

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Batch N°: 45863 **Sample N°: 3** **Date Received: 22/11/17** **Report Status: ● Draft ○ Final**

Client Name: **Hornsby Shire Council**
Client Contact: **Kurt Henkel**
Client Job N°:
Client Order N°:
Address: **PO Box 37**
HORNSBY NSW 2077

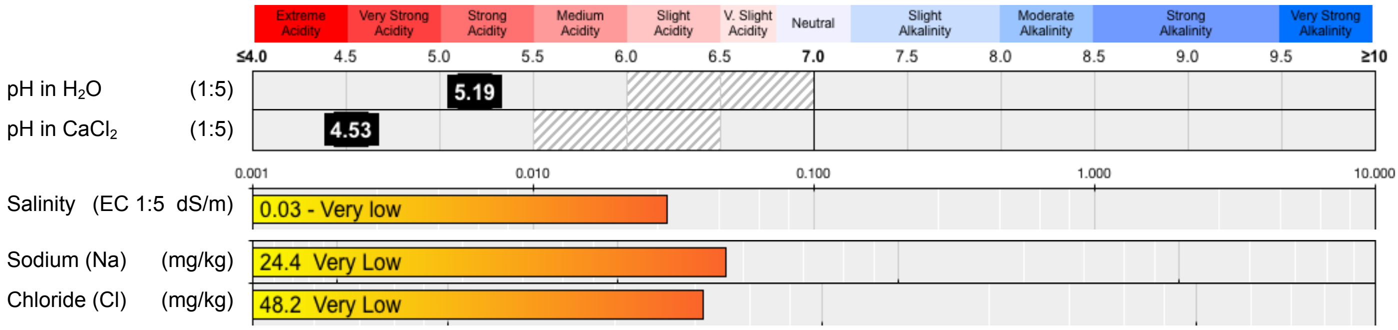
Project Name: **Hornsby Park Initial soil benchmarking**
SESL Quote N°:
Sample Name: **BH1 610-900**
Description: **Soil**
Test Type: **FSC, CSP**

RECOMMENDATIONS

BH1 soil (610-900) is very strongly acidic with desirably low salinity and sodium chloride levels. The cation exchange is dominated by hydrogen. The eCEC is low indicating poor nutrient uptake. Nutrients are deficient.
Soil is a dark greyish brown sandy loam with a fine weak crumb structure and rapid permeability.

SOIL SAMPLE DEPTH (mm): ● 100 ○ 150 ○ 200 **FERTILITY RATING:** ○ Low ● Moderate ○ High

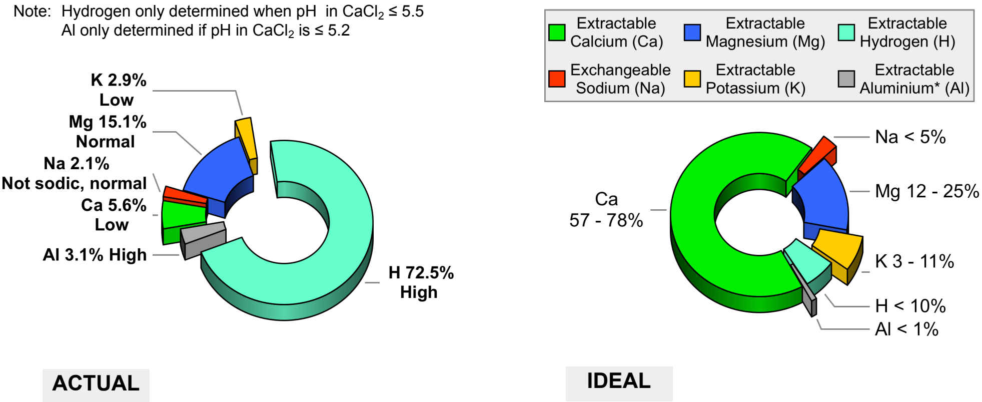
pH and ELECTRICAL CONDUCTIVITY



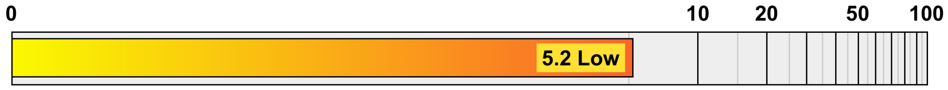
CATION BALANCE

EXCHANGEABLE CATION PERCENTAGE

Note: Hydrogen only determined when pH in $CaCl_2 \leq 5.5$
Al only determined if pH in $CaCl_2$ is ≤ 5.2



EFFECTIVE CATION EXCHANGE CAPACITY (eCEC)



CATION RATIOS

Ratio	Result	Target Range
Ca:Mg	0.4	4.1 – 6.0
Comment: Potential Calcium deficiency		
Mg:K	5.2	2.6 – 5.0
Comment: Potassium low		
K/(Ca+Mg)	0.14	< 0.07
Comment: High		
K:Na	1.4	N/A

Sodium Absorption Ratio: D.N.T.

EXCHANGEABLE CATIONS cmol(+)/kg

Na:	K:	Ca:	Mg:	H:	Al:
0.11	0.15	0.29	0.78	3.77	0.16

SOLUBLE CATIONS cmol(+)/kg

Na:	K:	Ca:	Mg:

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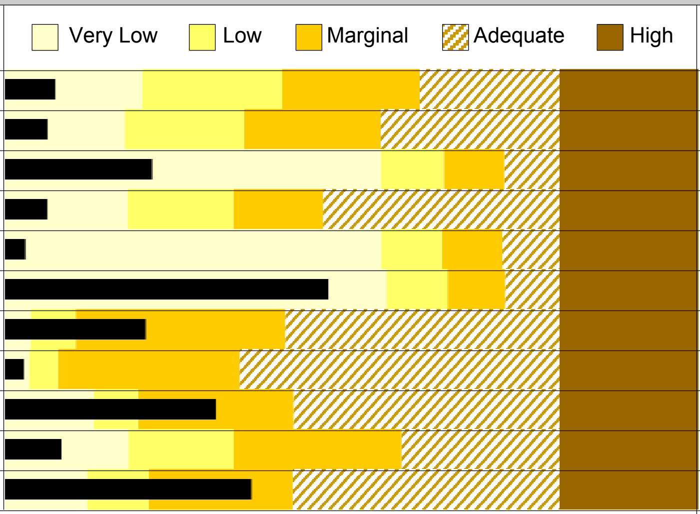
Batch N°: 45863 **Sample N°: 3** **Date Received: 22/11/17** **Report Status: ● Draft ○ Final**

PLANT AVAILABLE NUTRIENTS

Major Nutrients	Result (mg/kg)	Result (g/sqm)	Desirable (g/sqm)	Adjustment (g/sqm)
Nitrate-N (NO_3)	1.9	0.3	4	3.7
Phosphate-P (PO_4)	<5	0.7	8.4	7.7
Potassium (K) †	58.4	7.8	29.3	21.5
Sulphate-S (SO_4)	5.2	0.7	9	8.3
Calcium (Ca) †	57.8	7.7	208.3	200.6
Magnesium (Mg) †	95	12.6	21.7	9.1
Iron (Fe)	140	18.6	73.4	54.8
Manganese (Mn) †	1.5	0.2	5.9	5.7
Zinc (Zn) †	1.9	0.3	0.7	0.4
Copper (Cu)	<0.64	0.1	0.8	0.7
Boron (B) †	1.2	0.2	0.4	0.2



Explanation of graph ranges:

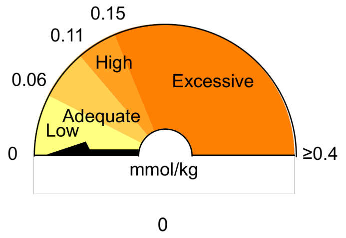
- **Very Low** Growth is likely to be severely depressed and deficiency symptoms present. Large applications for soil building purposes are usually recommended. Potential response to nutrient addition is >90%.
- **Low** Potential "hidden hunger", or sub-clinical deficiency. Potential response to nutrient addition is 60 to 90%.
- **Marginal** Supply of this nutrient is barely adequate for the plant, and build-up is still recommended. Potential response to nutrient addition is 30 to 60%.
- **Adequate** Supply of this nutrient is adequate for the plant, and and only maintenance application rates are recommended. Potential response to nutrient addition is 5 to 30%.
- **High** The level is excessive and may be detrimental to plant growth (i.e. phytotoxic) and may contribute to pollution of ground and surface waters. Drawdown is recommended. Potential response to nutrient addition is <2%.

NOTES: Adjustment recommendation calculates the elemental application to shift the soil test level to within the **Adequate** band, which maximises growth/yield, and economic efficiency, and minimises impact on the environment.

Drawdown: The objective nutrient management is to utilise residual soil nutrients. There is no agronomic reason to apply fertiliser when soil test levels exceed **Adequate**.

- g/sqm measurements are based on soil bulk density of 1.33 tonne/m^3 and selected soil depth.

Phosphorus Saturation Index



Low. Plant response to applied P is likely.

Exchangeable Acidity

Adams-Evans Buffer pH (BpH):	**7.4**
Sum of Base Cations (meq/100g^{-1}):	**1.3**
Eff. Cation Exch. Capacity (eCEC):	**5.2**
Base Saturation (%):	**25**
Exchangeable Acidity (meq/100g^{-1}):	**3.77**
Exchangeable Acidity (%):	**72.5**

Lime Application Rate

– to achieve pH 6.0 (g/sqm):	**276**
– to neutralise Al (g/sqm):	**16**

Gypsum Application Rate

– to achieve 67.5% exch. Ca (g/sqm): **0**
The CGAR is corrected for a soil depth of 100mm and any Lime addition to achieve pH 6.0.

Physical Description

Texture:	**Sandy Loam**
Colour:	**10YR 4/2 Dark Grayish Brown**
Estimated clay content:	**10 - 20%**
Size:	**Fine (1 - 10mm)**
Gravel content:	**Gravelly**
Aggregate strength:	**Pedal - Weak**
Structural unit:	**Crumb**
Potential infiltration rate:	**Rapid**
Permeability (mm/hr):	**>120**
Calculated EC_{SE} (dS/m):	**0.4**

– Non-saline. Salinity effects on plants are mostly negligible.

Organic Carbon (OC%)†: **Did not test**
Organic Matter (OM%): **-**
Additional comments:

Consultant: Chantal Milner **Authorised Signatory:**

Date Report Generated 22/12/2017

METHOD REFERENCES:
pH (1:5 H_2O) - Rayment & Higginson (1992) 4A1,
pH (1:5 $CaCl_2$) - Rayment & Higginson (1992) 4B1,
EC (1:5) - Rayment & Higginson (1992) 3A1,
Chloride - Rayment & Higginson (1992) 5A2,
Nitrate - Rayment & Higginson (1992) 7B1
Aluminium - SESL in-house,
PO_4, K, SO_4, Ca, Mg, Na, Fe, Mn, Zn, Cu, B - Mehlich 3 (1984),
Buffer pH and Hydrogen - Adams-Evans (1972)
Texture/Structure/Colour - PM0003 (Texture-"Northcote" (1992), Structure- "Murphy" (1991), Colour- "Munsell" (2000))

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Environment & Soil Sciences

Soil Chemistry Profile

Mehlich 3 - Multi-nutrient Extractant

Sample Drop Off: 16 Chilvers Road
Thornleigh NSW 2120
Mailing Address: PO Box 357
Pennant Hills NSW 1715
Tel: 1300 30 40 80
Fax: 1300 64 46 89
Em: info@sesl.com.au
Web: www.sesl.com.au

Batch N°: 45863 **Sample N°: 4** **Date Received: 22/11/17** **Report Status: ● Draft ○ Final**

Client Name: **Hornsby Shire Council**
Client Contact: **Kurt Henkel**
Client Job N°:
Client Order N°:
Address: **PO Box 37**
HORNSBY NSW 2077

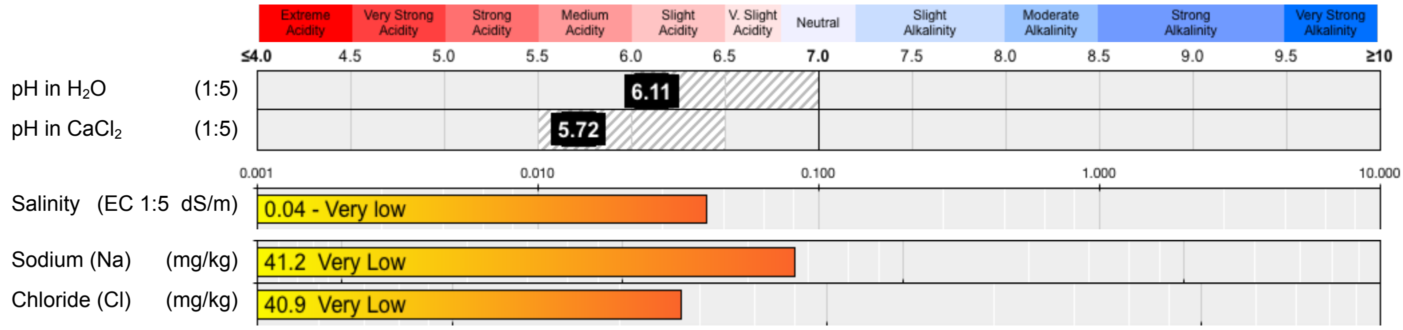
Project Name: **Hornsby Park Initial soil benchmarking**
SESL Quote N°:
Sample Name: **BH2 0-170**
Description: **Soil**
Test Type: **FSC, CSP**

RECOMMENDATIONS

BH2 soil (1-170) is moderately acidic with desirably low salinity and sodium chloride levels. The cation exchange is highly magnesic indicating the soil will be hardsetting. The eCEC is high indicating good nutrient uptake. Nutrients are deficient to low aside from magnesium.
Soil is a very dark greyish brown light sandy clay loam with a fine weak crumb structure and rapid permeability.

SOIL SAMPLE DEPTH (mm): ● 100 ○ 150 ○ 200 **FERTILITY RATING:** ○ Low ● Moderate ○ High

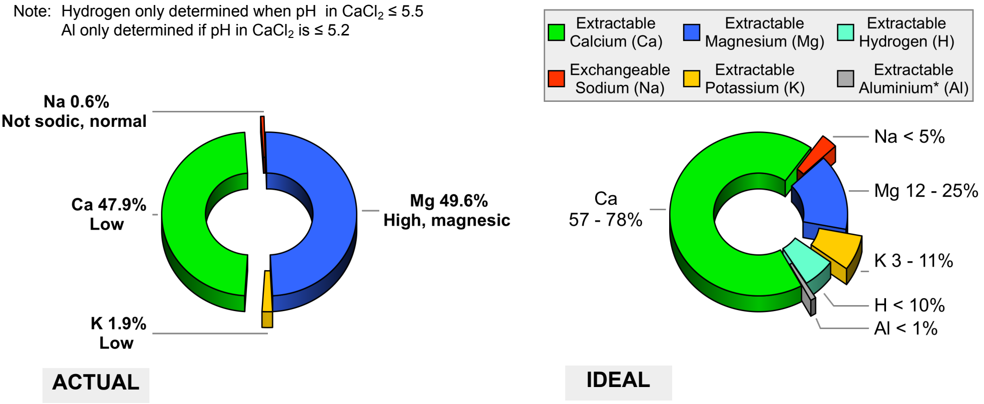
pH and ELECTRICAL CONDUCTIVITY



CATION BALANCE

EXCHANGEABLE CATION PERCENTAGE

Note: Hydrogen only determined when pH in $CaCl_2 \leq 5.5$
Al only determined if pH in $CaCl_2$ is ≤ 5.2



CATION RATIOS

Ratio	Result	Target Range
Ca:Mg	1	4.1 – 6.0
Comment: Calcium low		
Mg:K	26.1	2.6 – 5.0
Comment: Potential Potassium deficiency		
K/(Ca+Mg)	0.02	< 0.07
Comment: Acceptable		
K:Na	2.9	N/A

Sodium Absorption Ratio: D.N.T.

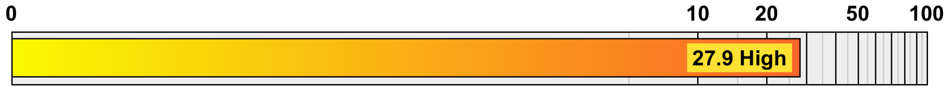
EXCHANGEABLE CATIONS cmol(+)/kg

Na:	K:	Ca:	Mg:	H:	Al:
0.18	0.53	13.37	13.84		

SOLUBLE CATIONS cmol(+)/kg

Na: K: Ca: Mg:

EFFECTIVE CATION EXCHANGE CAPACITY (eCEC)



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Soil Chemistry Profile

Mehlich 3 - Multi-nutrient Extractant

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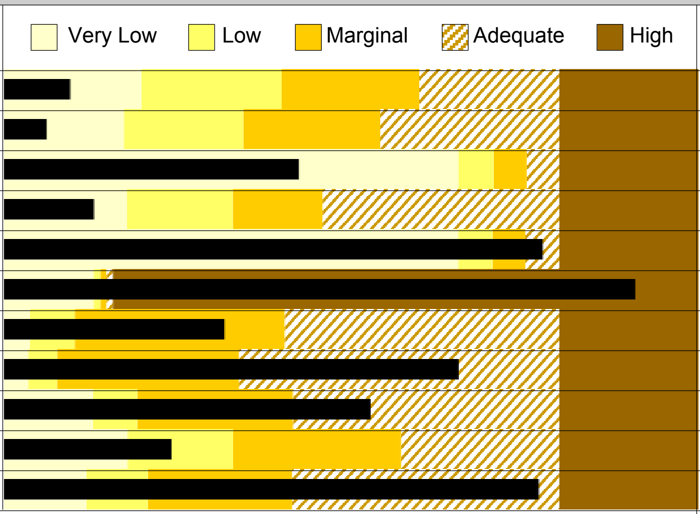
Web: www.sesl.com.au

Batch N°: 45863 **Sample N°: 4** **Date Received: 22/11/17** **Report Status: ● Draft ○ Final**

PLANT AVAILABLE NUTRIENTS

Major Nutrients	Result (mg/kg)	Result (g/sqm)	Desirable (g/sqm)	Adjustment (g/sqm)
Nitrate-N (NO_3)	2.5	0.3	4	3.7
Phosphate-P (PO_4)	<5	0.7	8.4	7.7
Potassium (K) †	206	27.4	51.6	24.2
Sulphate-S (SO_4)	11	1.5	9	7.5
Calcium (Ca) †	2680	356.4	367.5	11.1
Magnesium (Mg) †	1681	223.6	38.4	Drawdown
Iron (Fe)	219	29.1	73.4	44.3
Manganese (Mn) †	36	4.8	5.9	1.1
Zinc (Zn) †	3.3	0.4	0.7	0.3
Copper (Cu)	1.9	0.3	0.8	0.5
Boron (B) †	2.6	0.3	0.4	0.1



Explanation of graph ranges:

Very Low Growth is likely to be severely depressed and deficiency symptoms present. Large applications for soil building purposes are usually recommended. Potential response to nutrient addition is >90%.

Low Potential “hidden hunger”, or sub-clinical deficiency. Potential response to nutrient addition is 60 to 90%.

Marginal Supply of this nutrient is barely adequate for the plant, and build-up is still recommended. Potential response to nutrient addition is 30 to 60%.

Adequate Supply of this nutrient is adequate for the plant, and and only maintenance application rates are recommended. Potential response to nutrient addition is 5 to 30%.

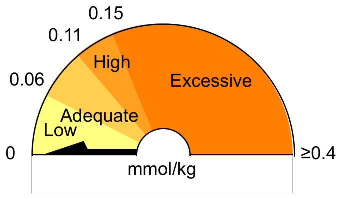
High The level is excessive and may be detrimental to plant growth (i.e. phytotoxic) and may contribute to pollution of ground and surface waters. Drawdown is recommended. Potential response to nutrient addition is <2%.

NOTES: Adjustment recommendation calculates the elemental application to shift the soil test level to within the **Adequate** band, which maximises growth/yield, and economic efficiency, and minimises impact on the environment.

Drawdown: The objective nutrient management is to utilise residual soil nutrients. There is no agronomic reason to apply fertiliser when soil test levels exceed **Adequate**.

- g/sqm measurements are based on soil bulk density of 1.33 tonne/m^3 and selected soil depth.

Phosphorus Saturation Index



0

Low. Plant response to applied P is likely.

Exchangeable Acidity

Adams-Evans Buffer pH (BpH): -
Sum of Base Cations (meq/100g^{-1}): **27.9**
Eff. Cation Exch. Capacity (eCEC): **27.9**
Base Saturation (%): **100**
Exchangeable Acidity (meq/100g^{-1}): -
Exchangeable Acidity (%): -

Lime Application Rate

– to achieve pH 6.0 (g/sqm): **0**
– to neutralise Al (g/sqm): -

Gypsum Application Rate

– to achieve 67.5% exch. Ca (g/sqm): **625**
The CGAR is corrected for a soil depth of 100mm and any Lime addition to achieve pH 6.0.

Physical Description

Texture: **Light Sandy Clay Loam**
Colour: **10YR 3/2 Very Dark Grayish Bro**
Estimated clay content: **25%**
Size: **Fine (1 - 10mm)**
Gravel content: **Gravelly**
Aggregate strength: **Pedal - Weak**
Structural unit: **Crumb**
Potential infiltration rate: **Rapid**
Permeability (mm/hr): **>120**
Calculated EC_{SE} (dS/m): **0.4**
– Non-saline. Salinity effects on plants are mostly negligible.
Organic Carbon (OC%)†: **Did not test**
Organic Matter (OM%): **-**
Additional comments:

Consultant: Chantal Milner

Authorised Signatory:

Date Report Generated 22/12/2017

METHOD REFERENCES:
pH (1:5 H_2O) - Rayment & Higginson (1992) 4A1,
pH (1:5 $CaCl_2$) - Rayment & Higginson (1992) 4B1,
EC (1:5) - Rayment & Higginson (1992) 3A1,
Chloride - Rayment & Higginson (1992) 5A2,
Nitrate - Rayment & Higginson (1992) 7B1
Aluminium - SESL in-house,
PO_4, K, SO_4, Ca, Mg, Na, Fe, Mn, Zn, Cu, B - Mehlich 3 (1984),
Buffer pH and Hydrogen - Adams-Evans (1972)
Texture/Structure/Colour - PM0003 (Texture- "Northcote" (1992), Structure- "Murphy" (1991), Colour- "Munsell" (2000))

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Soil Chemistry Profile

Mehlich 3 - Multi-nutrient Extractant

Sample Drop Off: 16 Chilvers Road
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Web: www.sesl.com.au

Batch N°: 45863 **Sample N°: 5** **Date Received: 22/11/17** **Report Status: ● Draft ○ Final**

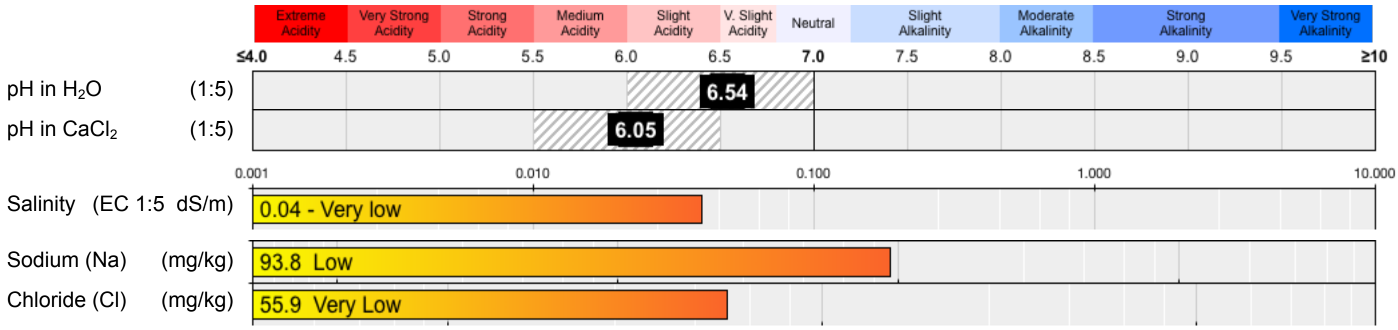
Client Name:	**Hornsby Shire Council**	Project Name:	**Hornsby Park Initial soil benchmarking**
Client Contact:	**Kurt Henkel**		
Client Job N°:		SESL Quote N°:	
Client Order N°:		Sample Name:	**BH2 170-400**
Address:	**PO Box 37** **HORNSBY NSW 2077**	Description:	**Soil**
		Test Type:	**FSC, CSP**

RECOMMENDATIONS

BH2 soil (170-400) is slightly acidic with desirably low salinity and sodium chloride levels. The cation exchange is highly magnesic indicating the soil will be hardsetting. The eCEC is high indicating good nutrient uptake. Nutrients are deficient to low aside from calcium, magnesium and manganese.
Soil is a brown sandy loam with a fine weak crumb structure and rapid permeability.

SOIL SAMPLE DEPTH (mm): ● 100 ○ 150 ○ 200 **FERTILITY RATING:** ○ Low ● Moderate ○ High

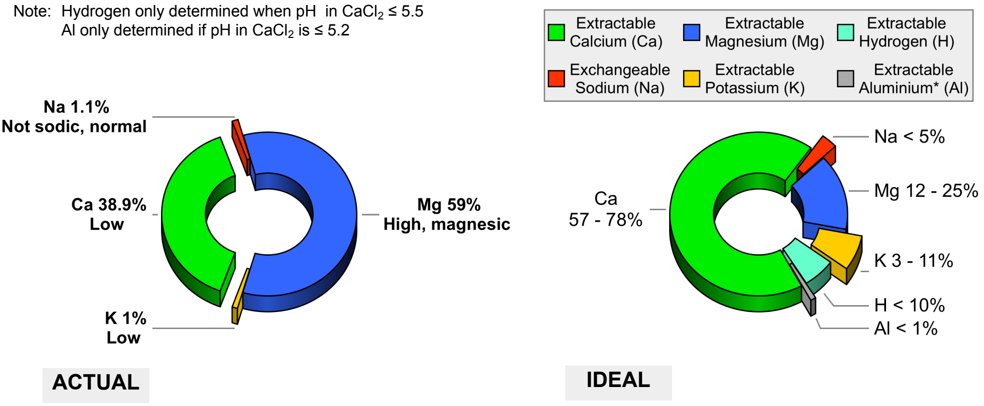
pH and ELECTRICAL CONDUCTIVITY



CATION BALANCE

EXCHANGEABLE CATION PERCENTAGE

Note: Hydrogen only determined when pH in $CaCl_2 \leq 5.5$
Al only determined if pH in $CaCl_2$ is ≤ 5.2



CATION RATIOS

Ratio	Result	Target Range
Ca:Mg	**0.7**	4.1 – 6.0
Comment: Potential Calcium deficiency		
Mg:K	**59.9**	2.6 – 5.0
Comment: Potential Potassium deficiency		
K/(Ca+Mg)	**0.01**	< 0.07
Comment: Acceptable		
K:Na	**0.9**	N/A

Sodium Absorption Ratio: D.N.T.

EFFECTIVE CATION EXCHANGE CAPACITY (eCEC)

EXCHANGEABLE CATIONS cmol(+)/kg

Na:	K:	Ca:	Mg:	H:	Al:
0.41	0.38	15.01	22.78		

SOLUBLE CATIONS cmol(+)/kg

Na:	K:	Ca:	Mg:

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Soil Chemistry Profile

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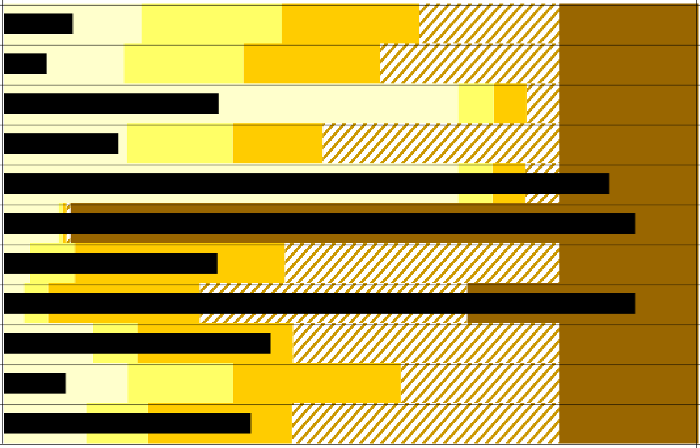
Batch N°: 45863 **Sample N°: 5** **Date Received: 22/11/17** **Report Status: ● Draft ○ Final**

PLANT AVAILABLE NUTRIENTS

Major Nutrients	**Result** (mg/kg)	□ Very Low 🟨 Low 🟧 Marginal ▨ Adequate 🟫 High	**Result** (g/sqm)	**Desirable** (g/sqm)	**Adjustment** (g/sqm)
Nitrate-N (NO_3)	2.6		0.3	4	3.7
Phosphate-P (PO_4)	<5		0.7	8.4	7.7
Potassium (K) †	150		20	51.6	31.6
Sulphate-S (SO_4)	14		1.9	9	7.1
Calcium (Ca) †	3010		400.3	367.5	Drawdown
Magnesium (Mg) †	2767		368	38.4	Drawdown
Iron (Fe)	212		28.2	73.4	45.2
Manganese (Mn) †	60		8	5.9	Drawdown
Zinc (Zn) †	2.4		0.3	0.7	0.4
Copper (Cu)	0.7		0.1	0.8	0.7
Boron (B) †	1.2		0.2	0.4	0.2

Explanation of graph ranges:

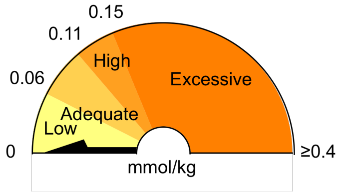
□ **Very Low**	Growth is likely to be severely depressed and deficiency symptoms present. Large applications for soil building purposes are usually recommended. Potential response to nutrient addition is >90%.
🟨 **Low**	Potential "hidden hunger", or sub-clinical deficiency. Potential response to nutrient addition is 60 to 90%.
🟧 **Marginal**	Supply of this nutrient is barely adequate for the plant, and build-up is still recommended. Potential response to nutrient addition is 30 to 60%.
▨ **Adequate**	Supply of this nutrient is adequate for the plant, and and only maintenance application rates are recommended. Potential response to nutrient addition is 5 to 30%.
🟫 **High**	The level is excessive and may be detrimental to plant growth (i.e. phytotoxic) and may contribute to pollution of ground and surface waters. Drawdown is recommended. Potential response to nutrient addition is <2%.

NOTES: Adjustment recommendation calculates the elemental application to shift the soil test level to within the **Adequate** band, which maximises growth/yield, and economic efficiency, and minimises impact on the environment.

Drawdown: The objective nutrient management is to utilise residual soil nutrients. There is no agronomic reason to apply fertiliser when soil test levels exceed **Adequate**.

- g/sqm measurements are based on soil bulk density of 1.33 tonne/m^3 and selected soil depth.

Phosphorus Saturation Index



0

Low. Plant response to applied P is likely.

Exchangeable Acidity

Adams-Evans Buffer pH (BpH): -
Sum of Base Cations (meq/100g^{-1}): **38.6**
Eff. Cation Exch. Capacity (eCEC): **38.6**
Base Saturation (%): **100**
Exchangeable Acidity (meq/100g^{-1}): -
Exchangeable Acidity (%): -

Lime Application Rate

– to achieve pH 6.0 (g/sqm): **0**
– to neutralise Al (g/sqm): -

Gypsum Application Rate

– to achieve 67.5% exch. Ca (g/sqm): **1264**
The CGAR is corrected for a soil depth of 100mm and any Lime addition to achieve pH 6.0.

Physical Description

Texture: **Sandy Loam**
Colour: **10YR 4/3 Brown**
Estimated clay content: **10 - 20%**
Size: **Fine (1 - 10mm)**
Gravel content: **Gravelly**
Aggregate strength: **Pedal - Weak**
Structural unit: **Crumb**
Potential infiltration rate: **Rapid**
Permeability (mm/hr): **>120**
Calculated EC_{SE} (dS/m): **0.6**
– Non-saline. Salinity effects on plants are mostly negligible.
Organic Carbon (OC%)†: **Did not test**
Organic Matter (OM%): **-**
Additional comments:

Consultant: Chantal Milner

Authorised Signatory:

Date Report Generated 22/12/2017

METHOD REFERENCES:
pH (1:5 H_2O) - Rayment & Higginson (1992) 4A1,
pH (1:5 $CaCl_2$) - Rayment & Higginson (1992) 4B1,
EC (1:5) - Rayment & Higginson (1992) 3A1,
Chloride - Rayment & Higginson (1992) 5A2,
Nitrate - Rayment & Higginson (1992) 7B1
Aluminium - SESL in-house,
PO_4, K, SO_4, Ca, Mg, Na, Fe, Mn, Zn, Cu, B - Mehlich 3 (1984),
Buffer pH and Hydrogen - Adams-Evans (1972)
Texture/Structure/Colour - PM0003 (Texture-"Northcote" (1992), Structure- "Murphy" (1991), Colour- "Munsell" (2000))

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Soil Chemistry Profile

Mehlich 3 - Multi-nutrient Extractant

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Batch N°: 45863 **Sample N°: 6** **Date Received: 22/11/17** **Report Status: ● Draft ○ Final**

Client Name: **Hornsby Shire Council**
Client Contact: **Kurt Henkel**
Client Job N°:
Client Order N°:
Address: **PO Box 37**
HORNSBY NSW 2077

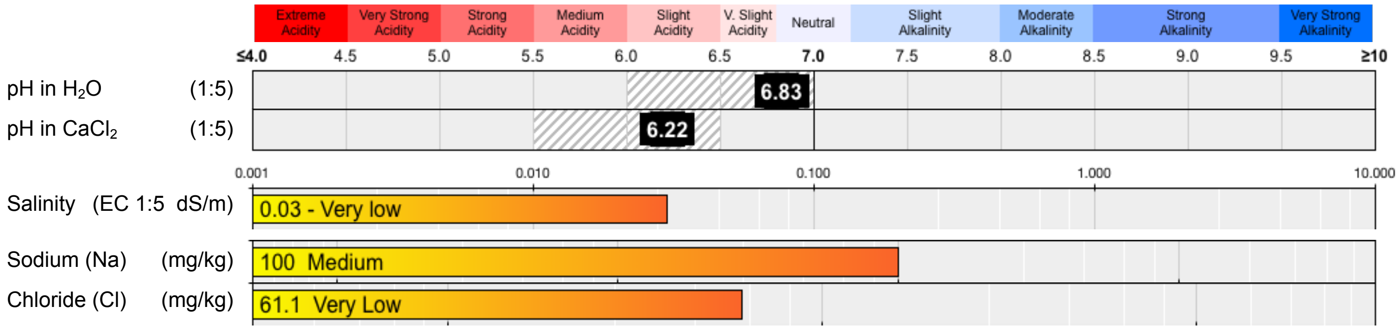
Project Name: **Hornsby Park Initial soil benchmarking**
SESL Quote N°:
Sample Name: **BH2 400-580**
Description: **Soil**
Test Type: **FSC, CSP**

RECOMMENDATIONS

BH2 soil (400-580) is slightly acidic with desirably low salinity and chloride levels. Sodium is moderate. The cation exchange is highly magnesic indicating the soil will be hardsetting. The eCEC is high indicating good nutrient uptake. Nutrients are deficient to low aside from calcium, magnesium and manganese.
Soil is a dark brown sandy loam with a fine weak crumb structure and rapid permeability.

SOIL SAMPLE DEPTH (mm): ● 100 ○ 150 ○ 200 **FERTILITY RATING:** ○ Low ● Moderate ○ High

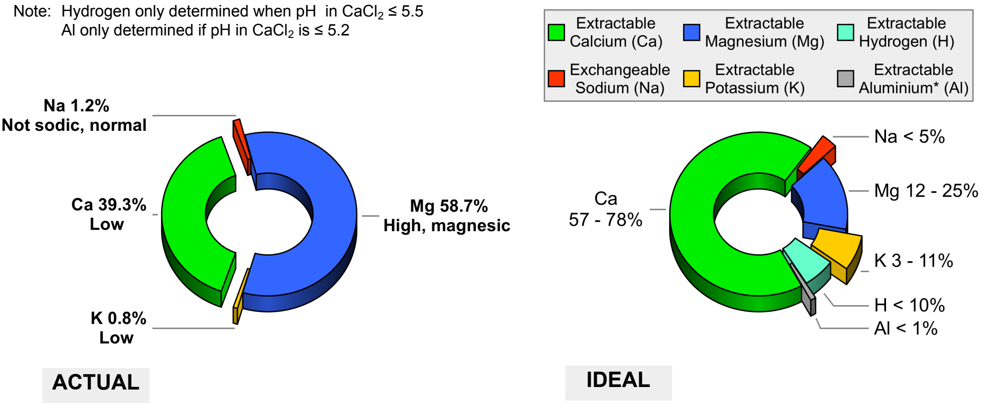
pH and ELECTRICAL CONDUCTIVITY



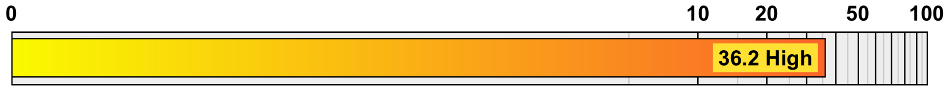
CATION BALANCE

EXCHANGEABLE CATION PERCENTAGE

Note: Hydrogen only determined when pH in $CaCl_2 \leq 5.5$
Al only determined if pH in $CaCl_2$ is ≤ 5.2



EFFECTIVE CATION EXCHANGE CAPACITY (eCEC)



CATION RATIOS

Ratio	Result	Target Range
Ca:Mg	**0.7**	4.1 – 6.0
Comment: Potential Calcium deficiency		
Mg:K	**70.9**	2.6 – 5.0
Comment: Potential Potassium deficiency		
K/(Ca+Mg)	**0.01**	< 0.07
Comment: Acceptable		
K:Na	**0.7**	N/A

Sodium Absorption Ratio: D.N.T.

EXCHANGEABLE CATIONS cmol(+)/kg

Na:	K:	Ca:	Mg:	H:	Al:
0.44	0.30	14.21	21.27		

SOLUBLE CATIONS cmol(+)/kg

Na:	K:	Ca:	Mg:

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Soil Chemistry Profile

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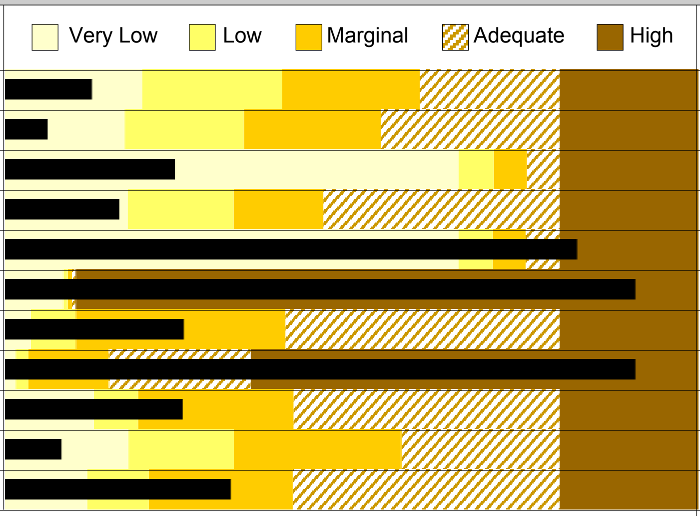
Batch N°: 45863 **Sample N°: 6** **Date Received: 22/11/17** **Report Status: ● Draft ○ Final**

PLANT AVAILABLE NUTRIENTS



Major Nutrients	Result (mg/kg)	Result (g/sqm)	Desirable (g/sqm)	Adjustment (g/sqm)
Nitrate-N (NO_3)	3.3	0.4	4	3.6
Phosphate-P (PO_4)	<5	0.7	8.4	7.7
Potassium (K) †	119	15.8	51.6	35.8
Sulphate-S (SO_4)	14	1.9	9	7.1
Calcium (Ca) †	2850	379.1	367.5	Drawdown
Magnesium (Mg) †	2584	343.7	38.4	Drawdown
Iron (Fe)	178	23.7	73.4	49.7
Manganese (Mn) †	113	15	5.9	Drawdown
Zinc (Zn) †	1.6	0.2	0.7	0.5
Copper (Cu)	<0.64	0.1	0.8	0.7
Boron (B) †	1.1	0.1	0.4	0.3

Explanation of graph ranges:

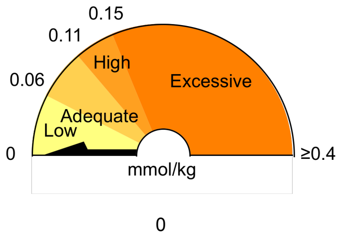
☐ Very Low	☐ Low	☐ Marginal	▨ Adequate	■ High
Growth is likely to be severely depressed and deficiency symptoms present. Large applications for soil building purposes are usually recommended. Potential response to nutrient addition is >90%.	Potential "hidden hunger", or sub-clinical deficiency. Potential response to nutrient addition is 60 to 90%.	Supply of this nutrient is barely adequate for the plant, and build-up is still recommended. Potential response to nutrient addition is 30 to 60%.	Supply of this nutrient is adequate for the plant, and and only maintenance application rates are recommended. Potential response to nutrient addition is 5 to 30%.	The level is excessive and may be detrimental to plant growth (i.e. phytotoxic) and may contribute to pollution of ground and surface waters. Drawdown is recommended. Potential response to nutrient addition is <2%.

NOTES: Adjustment recommendation calculates the elemental application to shift the soil test level to within the **Adequate** band, which maximises growth/yield, and economic efficiency, and minimises impact on the environment.

Drawdown: The objective nutrient management is to utilise residual soil nutrients. There is no agronomic reason to apply fertiliser when soil test levels exceed **Adequate**.

- g/sqm measurements are based on soil bulk density of 1.33 tonne/m^3 and selected soil depth.

Phosphorus Saturation Index



Low. Plant response to applied P is likely.

Exchangeable Acidity

Adams-Evans Buffer pH (BpH): -
Sum of Base Cations (meq/100g^{-1}): **36.2**
Eff. Cation Exch. Capacity (eCEC): **36.2**
Base Saturation (%): **100**
Exchangeable Acidity (meq/100g^{-1}): -
Exchangeable Acidity (%): -

Lime Application Rate

– to achieve pH 6.0 (g/sqm): **0**
– to neutralise Al (g/sqm): -

Gypsum Application Rate

– to achieve 67.5% exch. Ca (g/sqm): **1170**
The CGAR is corrected for a soil depth of 100mm and any Lime addition to achieve pH 6.0.

Physical Description

Texture:	**Sandy Loam**
Colour:	**10YR 3/3 Dark Brown**
Estimated clay content:	**10 - 20%**
Size:	**Fine (1 - 10mm)**
Gravel content:	**Gravelly**
Aggregate strength:	**Pedal - Weak**
Structural unit:	**Crumb**
Potential infiltration rate:	**Rapid**
Permeability (mm/hr):	**>120**
Calculated EC_{SE} (dS/m):	**0.4**

– Non-saline. Salinity effects on plants are mostly negligible.

Organic Carbon (OC%)†: **Did not test**
Organic Matter (OM%): **-**
Additional comments:

Consultant: Chantal Milner **Authorised Signatory:**

Date Report Generated 22/12/2017

METHOD REFERENCES:
pH (1:5 H_2O) - Rayment & Higginson (1992) 4A1,
pH (1:5 $CaCl_2$) - Rayment & Higginson (1992) 4B1,
EC (1:5) - Rayment & Higginson (1992) 3A1,
Chloride - Rayment & Higginson (1992) 5A2,
Nitrate - Rayment & Higginson (1992) 7B1
Aluminium - SESL in-house,
PO_4, K, SO_4, Ca, Mg, Na, Fe, Mn, Zn, Cu, B - Mehlich 3 (1984),
Buffer pH and Hydrogen - Adams-Evans (1972)
Texture/Structure/Colour - PM0003 (Texture- "Northcote" (1992), Structure- "Murphy" (1991), Colour- "Munsell" (2000))

A member of the Australasian Soil and Plant Analysis Council
† This laboratory has been awarded a Certificate of Proficiency for specific soil and plant tissue analyses by the Australasian Soil and Plant Analysis Council (ASPAC). Tests for which proficiency has been demonstrated are highlighted in this report.

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Soil Chemistry Profile

Mehlich 3 - Multi-nutrient Extractant

Sample Drop Off: 16 Chilvers Road
Thornleigh NSW 2120
Mailing Address: PO Box 357
Pennant Hills NSW 1715
Tel: 1300 30 40 80
Fax: 1300 64 46 89
Em: info@sesl.com.au
Web: www.sesl.com.au

Batch N°: 45863 **Sample N°: 7** **Date Received: 22/11/17** **Report Status:** ● **Draft** ○ **Final**

Client Name: **Hornsby Shire Council**
Client Contact: **Kurt Henkel**
Client Job N°:
Client Order N°:
Address: **PO Box 37**
HORNSBY NSW 2077

Project Name: **Hornsby Park Initial soil benchmarking**
SESL Quote N°:
Sample Name: **BH3 0-300**
Description: **Soil**
Test Type: **FSC, CSP**

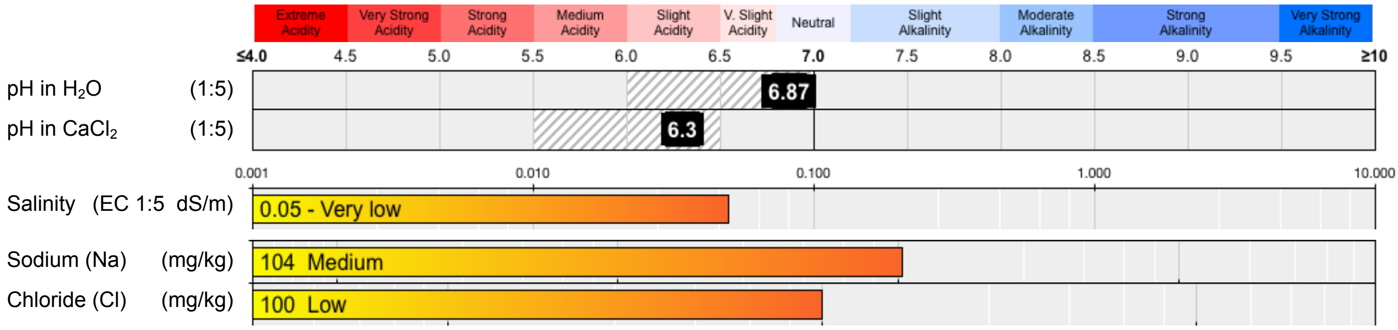
RECOMMENDATIONS

BH3 soil (0-300) is slightly acidic with desirably low salinity and chloride levels. Sodium is moderate. The cation exchange is highly magnesic indicating the soil will be hardsetting. The eCEC is high indicating good nutrient uptake. Nutrients are deficient to low aside from magnesium and manganese. High manganese levels are an indication that this soil waterlogs.
Soil is a dark brown sandy clay loam with a fine weak crumb structure and moderate permeability.

SOIL SAMPLE DEPTH (mm): ● 100 ○ 150 ○ 200

FERTILITY RATING: ○ Low ● Moderate ○ High

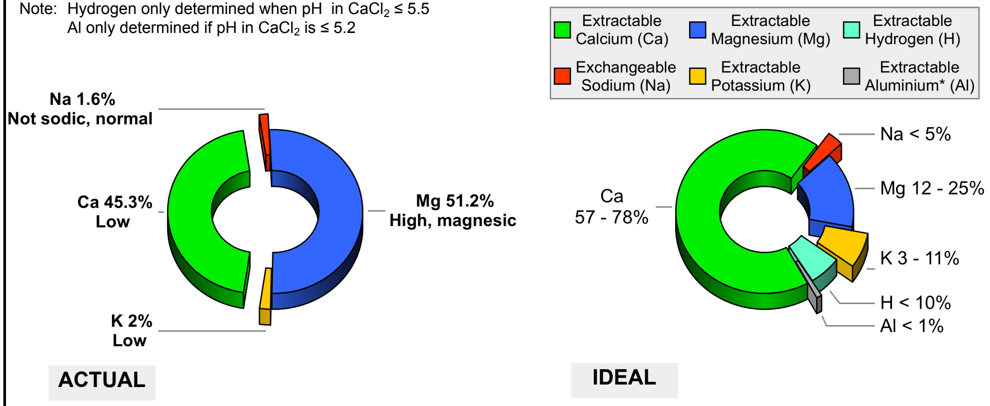
pH and ELECTRICAL CONDUCTIVITY



CATION BALANCE

EXCHANGEABLE CATION PERCENTAGE

Note: Hydrogen only determined when pH in $CaCl_2$ ≤ 5.5
Al only determined if pH in $CaCl_2$ is ≤ 5.2



CATION RATIOS

Ratio	Result	Target Range
Ca:Mg	0.9	4.1 – 6.0
Comment: Potential Calcium deficiency		
Mg:K	26	2.6 – 5.0
Comment: Potential Potassium deficiency		
K/(Ca+Mg)	0.02	< 0.07
Comment: Acceptable		
K:Na	1.2	N/A

Sodium Absorption Ratio: D.N.T.

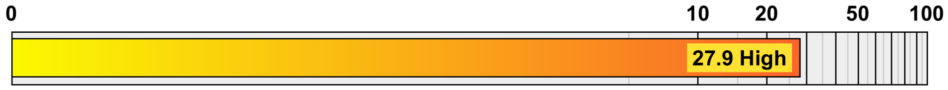
EXCHANGEABLE CATIONS cmol(+)/kg

Na:	K:	Ca:	Mg:	H:	Al:
0.45	0.55	12.65	14.28		

SOLUBLE CATIONS cmol(+)/kg

Na:	K:	Ca:	Mg:

EFFECTIVE CATION EXCHANGE CAPACITY (eCEC)



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Soil Chemistry Profile

Mehlich 3 - Multi-nutrient Extractant

Sample Drop Off: 16 Chilvers Road
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Mailing Address: PO Box 357
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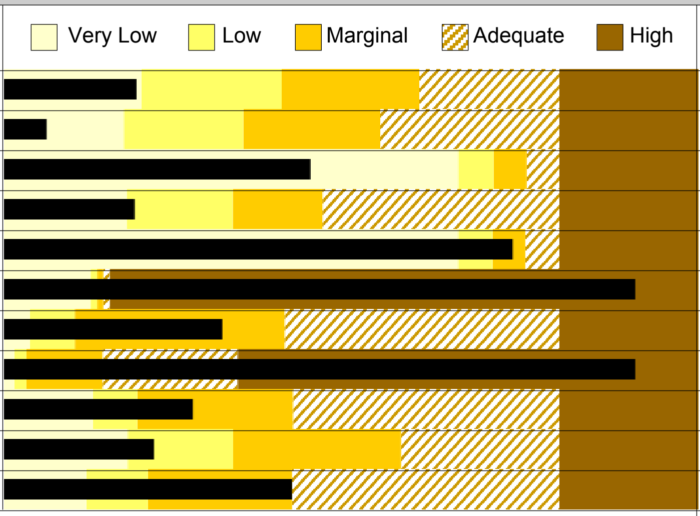
Web: www.sesl.com.au

Batch N°: 45863 **Sample N°: 7** **Date Received: 22/11/17** **Report Status:** ● **Draft** ○ **Final**

PLANT AVAILABLE NUTRIENTS

Major Nutrients	**Result** (mg/kg)	**Result** (g/sqm)	**Desirable** (g/sqm)	**Adjustment** (g/sqm)
Nitrate-N (NO_3)	5	0.7	4	3.3
Phosphate-P (PO_4)	<5	0.7	8.4	7.7
Potassium (K) †	214	28.5	51.6	23.1
Sulphate-S (SO_4)	16	2.1	9	6.9
Calcium (Ca) †	2530	336.5	367.5	31
Magnesium (Mg) †	1735	230.8	38.4	Drawdown
Iron (Fe)	217	28.9	73.4	44.5
Manganese (Mn) †	119	15.8	5.9	Drawdown
Zinc (Zn) †	1.7	0.2	0.7	0.5
Copper (Cu)	1.7	0.2	0.8	0.6
Boron (B) †	1.4	0.2	0.4	0.2



Explanation of graph ranges:

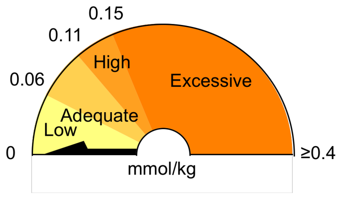
☐ **Very Low**	🟨 **Low**	🟧 **Marginal**	▨ **Adequate**	🟫 **High**
Growth is likely to be severely depressed and deficiency symptoms present. Large applications for soil building purposes are usually recommended. Potential response to nutrient addition is >90%.	Potential "hidden hunger", or sub-clinical deficiency. Potential response to nutrient addition is 60 to 90%.	Supply of this nutrient is barely adequate for the plant, and build-up is still recommended. Potential response to nutrient addition is 30 to 60%.	Supply of this nutrient is adequate for the plant, and and only maintenance application rates are recommended. Potential response to nutrient addition is 5 to 30%.	The level is excessive and may be detrimental to plant growth (i.e. phytotoxic) and may contribute to pollution of ground and surface waters. Drawdown is recommended. Potential response to nutrient addition is <2%.

NOTES: Adjustment recommendation calculates the elemental application to shift the soil test level to within the **Adequate** band, which maximises growth/yield, and economic efficiency, and minimises impact on the environment.

Drawdown: The objective nutrient management is to utilise residual soil nutrients. There is no agronomic reason to apply fertiliser when soil test levels exceed **Adequate**.

- g/sqm measurements are based on soil bulk density of 1.33 tonne/m^3 and selected soil depth.

Phosphorus Saturation Index



0

Low. Plant response to applied P is likely.

Exchangeable Acidity

Adams-Evans Buffer pH (BpH):	-
Sum of Base Cations (meq/100g^{-1}):	**27.9**
Eff. Cation Exch. Capacity (eCEC):	**27.9**
Base Saturation (%):	**100**
Exchangeable Acidity (meq/100g^{-1}):	-
Exchangeable Acidity (%):	-

Lime Application Rate

– to achieve pH 6.0 (g/sqm):	**0**
– to neutralise Al (g/sqm):	-

Gypsum Application Rate

– to achieve 67.5% exch. Ca (g/sqm): **708**
The CGAR is corrected for a soil depth of 100mm and any Lime addition to achieve pH 6.0.

Physical Description

Texture:	**Sandy Clay Loam**
Colour:	**7.5YR 3/3 Dark Brown**
Estimated clay content:	**20 - 30%**
Size:	**Fine (1 - 10mm)**
Gravel content:	**Gravelly**
Aggregate strength:	**Pedal - Weak**
Structural unit:	**Crumb**
Potential infiltration rate:	**Moderate**
Permeability (mm/hr):	**5 - 20**
Calculated EC_{SE} (dS/m):	**0.5**

– Non-saline. Salinity effects on plants are mostly negligible.

Organic Carbon (OC%)†: **Did not test**
Organic Matter (OM%): **-**
Additional comments:

Consultant: Chantal Milner **Authorised Signatory:**

Date Report Generated 22/12/2017

METHOD REFERENCES:
pH (1:5 H_2O) - Rayment & Higginson (1992) 4A1,
pH (1:5 $CaCl_2$) - Rayment & Higginson (1992) 4B1,
EC (1:5) - Rayment & Higginson (1992) 3A1,
Chloride - Rayment & Higginson (1992) 5A2,
Nitrate - Rayment & Higginson (1992) 7B1
Aluminium - SESL in-house,
PO_4, K, SO_4, Ca, Mg, Na, Fe, Mn, Zn, Cu, B - Mehlich 3 (1984),
Buffer pH and Hydrogen - Adams-Evans (1972)
Texture/Structure/Colour - PM0003 (Texture- "Northcote" (1992), Structure- "Murphy" (1991), Colour- "Munsell" (2000))

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Soil Chemistry Profile

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Web: www.sesl.com.au

Batch N°: 45863 **Sample N°: 8** **Date Received: 22/11/17** **Report Status: ● Draft ○ Final**

Client Name: **Hornsby Shire Council**
Client Contact: **Kurt Henkel**
Client Job N°:
Client Order N°:
Address: **PO Box 37**
HORNSBY NSW 2077

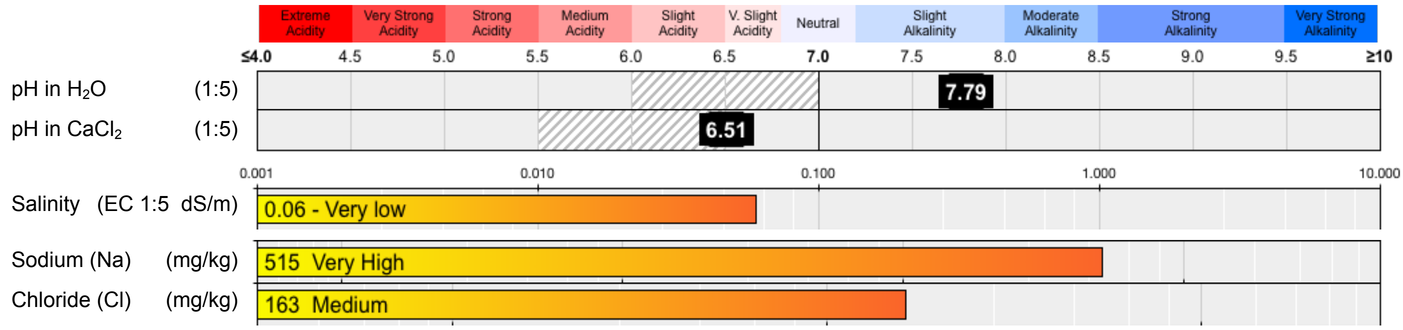
Project Name: **Hornsby Park Initial soil benchmarking**
SESL Quote N°:
Sample Name: **BH3 300-560**
Description: **Soil**
Test Type: **FSC, CSP**

RECOMMENDATIONS

BH3 soil (300-560) is very slightly acidic with desirably low salinity and chloride levels. Sodium is very high. The cation exchange is slightly sodic and highly magnesic indicating the soil will be hardsetting. The eCEC is high indicating good nutrient uptake. Nutrients are deficient to low aside from magnesium and manganese. High manganese levels are an indication that this soil waterlogs.
Soil is a dark yellowish brown sandy clay loam with a fine weak crumb structure and moderate permeability.

SOIL SAMPLE DEPTH (mm): ● 100 ○ 150 ○ 200 **FERTILITY RATING:** ○ Low ● Moderate ○ High

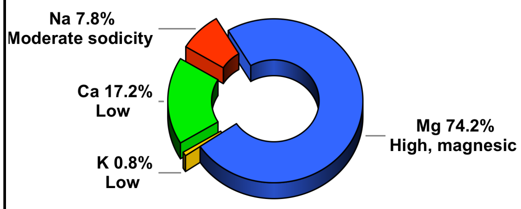
pH and ELECTRICAL CONDUCTIVITY



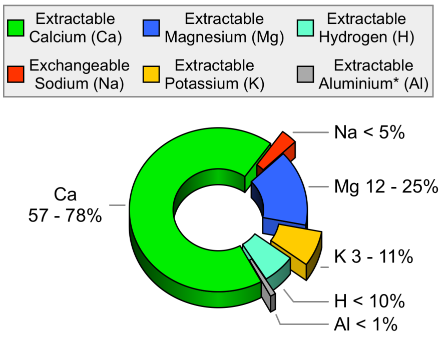
CATION BALANCE

EXCHANGEABLE CATION PERCENTAGE

Note: Hydrogen only determined when pH in $CaCl_2 \leq 5.5$
Al only determined if pH in $CaCl_2$ is ≤ 5.2

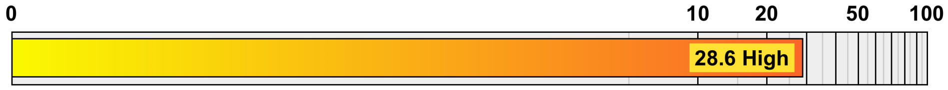


ACTUAL



IDEAL

EFFECTIVE CATION EXCHANGE CAPACITY (eCEC)



CATION RATIOS

Ratio	Result	Target Range
Ca:Mg	0.2	4.1 – 6.0
Comment: Potential Calcium deficiency		
Mg:K	88.4	2.6 – 5.0
Comment: Potential Potassium deficiency		
K/(Ca+Mg)	0.01	< 0.07
Comment: Acceptable		
K:Na	0.1	N/A

Sodium Absorption Ratio: D.N.T.

EXCHANGEABLE CATIONS cmol(+)/kg

Na:	K:	Ca:	Mg:	H:	Al:
2.24	0.24	4.92	21.22		

SOLUBLE CATIONS cmol(+)/kg

Na:	K:	Ca:	Mg:

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Soil Chemistry Profile

Mehlich 3 - Multi-nutrient Extractant

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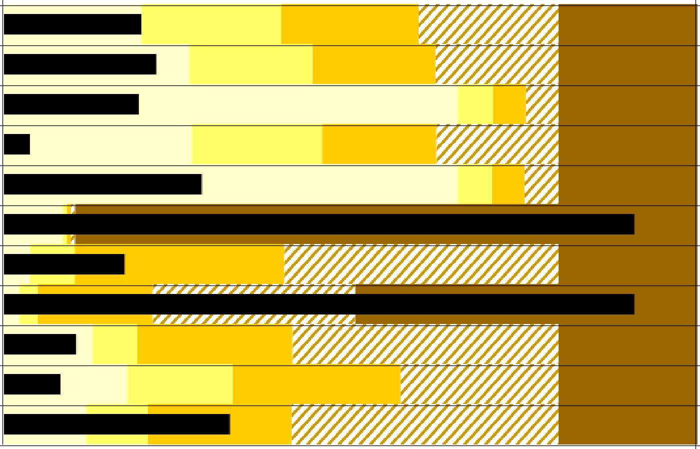
Batch N°: 45863 **Sample N°: 8** **Date Received: 22/11/17** **Report Status: ● Draft ○ Final**

PLANT AVAILABLE NUTRIENTS

Major Nutrients	Result (mg/kg)	☐ Very Low ☐ Low ☐ Marginal ▨ Adequate ■ High	Result (g/sqm)	Desirable (g/sqm)	Adjustment (g/sqm)
Nitrate-N (NO_3)	5.2		0.7	4	3.3
Phosphate-P (PO_4)	17.3		2.3	8.4	6.1
Potassium (K) †	94.2		12.5	51.6	39.1
Sulphate-S (SO_4)	<3.20		0.4	9	8.6
Calcium (Ca) †	986		131.1	367.5	236.4
Magnesium (Mg) †	2578		342.9	38.4	Drawdown
Iron (Fe)	120		16	73.4	57.4
Manganese (Mn) †	79		10.5	5.9	Drawdown
Zinc (Zn) †	<0.65		0.1	0.7	0.6
Copper (Cu)	<0.64		0.1	0.8	0.7
Boron (B) †	1.1		0.1	0.4	0.3



Explanation of graph ranges:

☐ **Very Low**
Growth is likely to be severely depressed and deficiency symptoms present. Large applications for soil building purposes are usually recommended. Potential response to nutrient addition is >90%.

☐ **Low**
Potential "hidden hunger", or sub-clinical deficiency. Potential response to nutrient addition is 60 to 90%.

☐ **Marginal**
Supply of this nutrient is barely adequate for the plant, and build-up is still recommended. Potential response to nutrient addition is 30 to 60%.

▨ **Adequate**
Supply of this nutrient is adequate for the plant, and and only maintenance application rates are recommended. Potential response to nutrient addition is 5 to 30%.

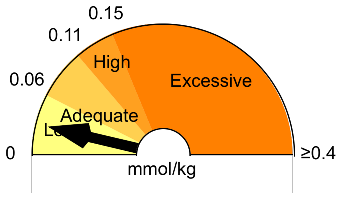
■ **High**
The level is excessive and may be detrimental to plant growth (i.e. phytotoxic) and may contribute to pollution of ground and surface waters. Drawdown is recommended. Potential response to nutrient addition is <2%.

NOTES: Adjustment recommendation calculates the elemental application to shift the soil test level to within the **Adequate** band, which maximises growth/yield, and economic efficiency, and minimises impact on the environment.

Drawdown: The objective nutrient management is to utilise residual soil nutrients. There is no agronomic reason to apply fertiliser when soil test levels exceed **Adequate**.

- g/sqm measurements are based on soil bulk density of 1.33 tonne/m^3 and selected soil depth.

Phosphorus Saturation Index



0.03

Low. Plant response to applied P is likely.

Exchangeable Acidity

Adams-Evans Buffer pH (BpH):	-
Sum of Base Cations (meq/100g^{-1}):	**28.6**
Eff. Cation Exch. Capacity (eCEC):	**28.6**
Base Saturation (%):	**100**
Exchangeable Acidity (meq/100g^{-1}):	-
Exchangeable Acidity (%):	-

Lime Application Rate

– to achieve pH 6.0 (g/sqm):	**0**
– to neutralise Al (g/sqm):	-

Gypsum Application Rate

– to achieve 67.5% exch. Ca (g/sqm): **1647**
The CGAR is corrected for a soil depth of 100mm and any Lime addition to achieve pH 6.0.

Physical Description

Texture:	**Sandy Clay Loam**
Colour:	**10YR 4/6 Dark Yellowish Brown**
Estimated clay content:	**20 - 30%**
Size:	**Fine (1 - 10mm)**
Gravel content:	**Gravelly**
Aggregate strength:	**Pedal - Weak**
Structural unit:	**Crumb**
Potential infiltration rate:	**Moderate**
Permeability (mm/hr):	**5 - 20**
Calculated EC_{SE} (dS/m):	**0.6**

– Non-saline. Salinity effects on plants are mostly negligible.

Organic Carbon (OC%)†: **Did not test**
Organic Matter (OM%): **-**
Additional comments:

Consultant: Chantal Milner **Authorised Signatory:**

Date Report Generated 22/12/2017

METHOD REFERENCES:
pH (1:5 H_2O) - Rayment & Higginson (1992) 4A1,
pH (1:5 $CaCl_2$) - Rayment & Higginson (1992) 4B1,
EC (1:5) - Rayment & Higginson (1992) 3A1,
Chloride - Rayment & Higginson (1992) 5A2,
Nitrate - Rayment & Higginson (1992) 7B1
Aluminium - SESL in-house,
PO_4, K, SO_4, Ca, Mg, Na, Fe, Mn, Zn, Cu, B - Mehlich 3 (1984),
Buffer pH and Hydrogen - Adams-Evans (1972)
Texture/Structure/Colour - PM0003 (Texture- "Northcote" (1992), Structure- "Murphy" (1991), Colour- "Munsell" (2000))

SESL AUSTRALIA
Environment & Soil Sciences

Soil Chemistry Profile

Mehlich 3 - Multi-nutrient Extractant

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Web: www.sesl.com.au

Batch N°: 45863 **Sample N°: 9** **Date Received: 22/11/17** **Report Status: ● Draft ○ Final**

Client Name: **Hornsby Shire Council**
Client Contact: **Kurt Henkel**
Client Job N°:
Client Order N°:
Address: **PO Box 37**
HORNSBY NSW 2077

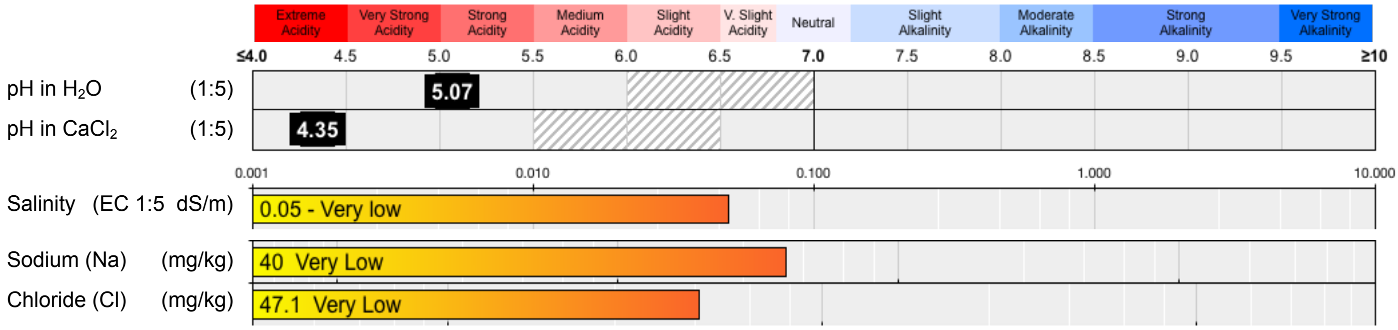
Project Name: **Hornsby Park Initial soil benchmarking**
SESL Quote N°:
Sample Name: **BH4 0-550**
Description: **Soil**
Test Type: **FSC, CSP**

RECOMMENDATIONS

BH4 soil (0-550) is extremely acidic with desirably low salinity, sodium and chloride levels. The cation exchange is dominated by hydrogen. Aluminium has become available as a result of the hydrogen. The eCEC is low indicating poor nutrient uptake. Nutrients are deficient to low aside from magnesium.
Soil is a black sandy loam with a fine weak crumb structure and rapid permeability.

SOIL SAMPLE DEPTH (mm): ● 100 ○ 150 ○ 200 **FERTILITY RATING:** ○ Low ● Moderate ○ High

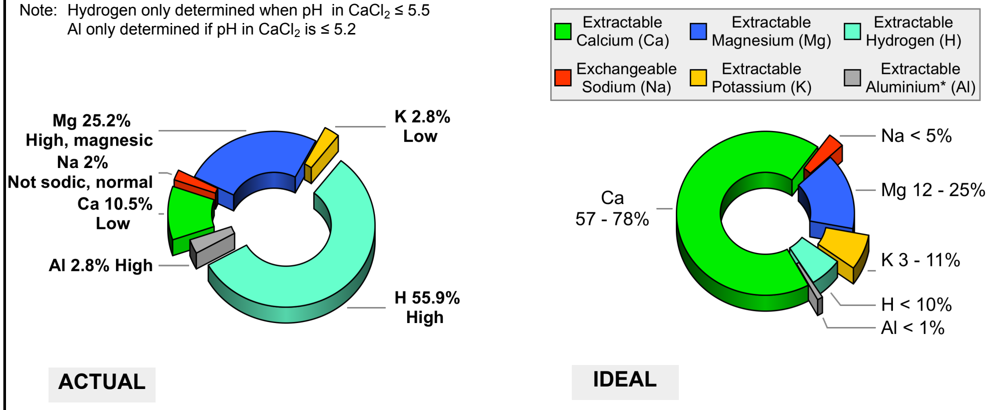
pH and ELECTRICAL CONDUCTIVITY



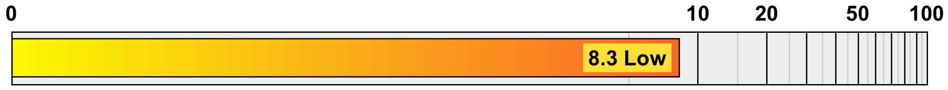
CATION BALANCE

EXCHANGEABLE CATION PERCENTAGE

Note: Hydrogen only determined when pH in $CaCl_2$ ≤ 5.5
Al only determined if pH in $CaCl_2$ is ≤ 5.2



EFFECTIVE CATION EXCHANGE CAPACITY (eCEC)



CATION RATIOS

Ratio	Result	Target Range
Ca:Mg	0.4	4.1 – 6.0
Comment: Potential Calcium deficiency		
Mg:K	9.1	2.6 – 5.0
Comment: Potassium low		
K/(Ca+Mg)	0.08	< 0.07
Comment: High		
K:Na	1.4	N/A

Sodium Absorption Ratio: D.N.T.

EXCHANGEABLE CATIONS cmol(+)/kg

Na:	K:	Ca:	Mg:	H:	Al:
0.17	0.23	0.87	2.09	4.64	0.23

SOLUBLE CATIONS cmol(+)/kg

Na:	K:	Ca:	Mg:

A member of the Australasian Soil and Plant Analysis Council
† This laboratory has been awarded a Certificate of Proficiency for specific soil and plant tissue analyses by the Australasian Soil and Plant Analysis Council (ASPAC). Tests for which proficiency has been demonstrated are highlighted in this report.

SESL AUSTRALIA
Environment & Soil Sciences

Soil Chemistry Profile

Mehlich 3 - Multi-nutrient Extractant

Sample Drop Off: 16 Chilvers Road
Thornleigh NSW 2120
Mailing Address: PO Box 357
Pennant Hills NSW 1715
Tel: 1300 30 40 80
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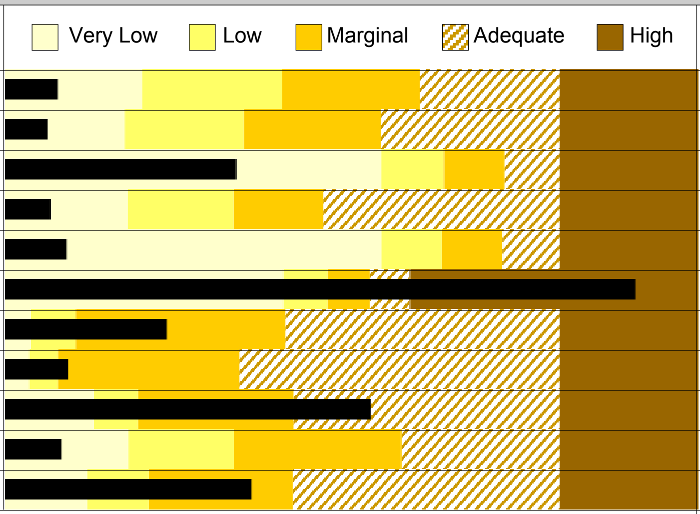
Batch N°: 45863 **Sample N°: 9** **Date Received: 22/11/17** **Report Status:** ● **Draft** ○ **Final**

PLANT AVAILABLE NUTRIENTS

Major Nutrients	Result (mg/kg)	Result (g/sqm)	Desirable (g/sqm)	Adjustment (g/sqm)
Nitrate-N (NO_3)	2	0.3	4	3.7
Phosphate-P (PO_4)	<5	0.7	8.4	7.7
Potassium (K) †	91.7	12.2	29.3	17.1
Sulphate-S (SO_4)	5.6	0.7	9	8.3
Calcium (Ca) †	174	23.1	208.3	185.2
Magnesium (Mg) †	254	33.8	21.7	Drawdown
Iron (Fe)	161	21.4	73.4	52
Manganese (Mn) †	5	0.7	5.9	5.2
Zinc (Zn) †	3.3	0.4	0.7	0.3
Copper (Cu)	<0.64	0.1	0.8	0.7
Boron (B) †	1.2	0.2	0.4	0.2



Explanation of graph ranges:

Very Low Growth is likely to be severely depressed and deficiency symptoms present. Large applications for soil building purposes are usually recommended. Potential response to nutrient addition is >90%.

Low Potential “hidden hunger”, or sub-clinical deficiency. Potential response to nutrient addition is 60 to 90%.

Marginal Supply of this nutrient is barely adequate for the plant, and build-up is still recommended. Potential response to nutrient addition is 30 to 60%.

Adequate Supply of this nutrient is adequate for the plant, and and only maintenance application rates are recommended. Potential response to nutrient addition is 5 to 30%.

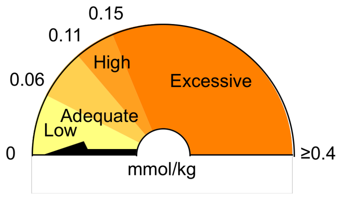
High The level is excessive and may be detrimental to plant growth (i.e. phytotoxic) and may contribute to pollution of ground and surface waters. Drawdown is recommended. Potential response to nutrient addition is <2%.

NOTES: Adjustment recommendation calculates the elemental application to shift the soil test level to within the **Adequate** band, which maximises growth/yield, and economic efficiency, and minimises impact on the environment.

Drawdown: The objective nutrient management is to utilise residual soil nutrients. There is no agronomic reason to apply fertiliser when soil test levels exceed **Adequate**.

- g/sqm measurements are based on soil bulk density of 1.33 tonne/m^3 and selected soil depth.

Phosphorus Saturation Index



0

Low. Plant response to applied P is likely.

Exchangeable Acidity

Adams-Evans Buffer pH (BpH):	**7.2**
Sum of Base Cations (meq/100g^{-1}):	**3.4**
Eff. Cation Exch. Capacity (eCEC):	**8.3**
Base Saturation (%):	**40.96**
Exchangeable Acidity (meq/100g^{-1}):	**4.64**
Exchangeable Acidity (%):	**55.9**

Lime Application Rate

– to achieve pH 6.0 (g/sqm):	**350**
– to neutralise Al (g/sqm):	**22**

Gypsum Application Rate

– to achieve 67.5% exch. Ca (g/sqm): **0**

The CGAR is corrected for a soil depth of 100mm and any Lime addition to achieve pH 6.0.

Physical Description

Texture:	**Sandy Loam**
Colour:	**10YR 2/1 Black**
Estimated clay content:	**10 - 20%**
Size:	**Fine (1 - 10mm)**
Gravel content:	**Gravelly**
Aggregate strength:	**Pedal - Weak**
Structural unit:	**Crumb**
Potential infiltration rate:	**Rapid**
Permeability (mm/hr):	**>120**
Calculated EC_{SE} (dS/m):	**0.7**

– Non-saline. Salinity effects on plants are mostly negligible.

Organic Carbon (OC%)†: **Did not test**
Organic Matter (OM%): **-**
Additional comments:

Consultant: Chantal Milner **Authorised Signatory:**

Date Report Generated 22/12/2017

METHOD REFERENCES:
pH (1:5 H_2O) - Rayment & Higginson (1992) 4A1,
pH (1:5 $CaCl_2$) - Rayment & Higginson (1992) 4B1,
EC (1:5) - Rayment & Higginson (1992) 3A1,
Chloride - Rayment & Higginson (1992) 5A2,
Nitrate - Rayment & Higginson (1992) 7B1
Aluminium - SESL in-house,
PO_4, K, SO_4, Ca, Mg, Na, Fe, Mn, Zn, Cu, B - Mehlich 3 (1984),
Buffer pH and Hydrogen - Adams-Evans (1972)
Texture/Structure/Colour - PM0003 (Texture-"Northcote" (1992), Structure- "Murphy" (1991), Colour- "Munsell" (2000))

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Environment & Soil Sciences

Soil Chemistry Profile

Mehlich 3 - Multi-nutrient Extractant

Sample Drop Off: 16 Chilvers Road
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Batch N°: 45863 **Sample N°: 10** **Date Received: 22/11/17** **Report Status:** ● **Draft** ○ **Final**

Client Name: **Hornsby Shire Council**
Client Contact: **Kurt Henkel**
Client Job N°:
Client Order N°:
Address: **PO Box 37**
HORNSBY NSW 2077

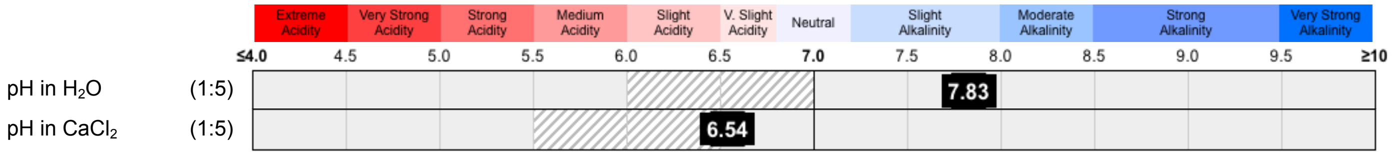
Project Name: **Hornsby Park Initial soil benchmarking**
SESL Quote N°:
Sample Name: **BH5 0-150**
Description: **Soil**
Test Type: **FSC, CSP**

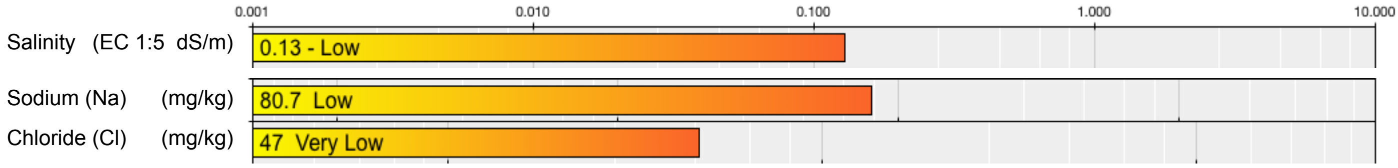
RECOMMENDATIONS

BH5 soil (0-150) is very slightly acidic with desirably low salinity, sodium and chloride levels. The cation exchange is moderately magnesic. The eCEC is high indicating good nutrient uptake. Nutrients are low aside from calcium, magnesium and manganese.
Soil is a dark greyish brown sandy clay loam with a fine weak crumb structure and moderate permeability.

SOIL SAMPLE DEPTH (mm): ● 100 ○ 150 ○ 200 **FERTILITY RATING:** ○ Low ● Moderate ○ High

pH and ELECTRICAL CONDUCTIVITY

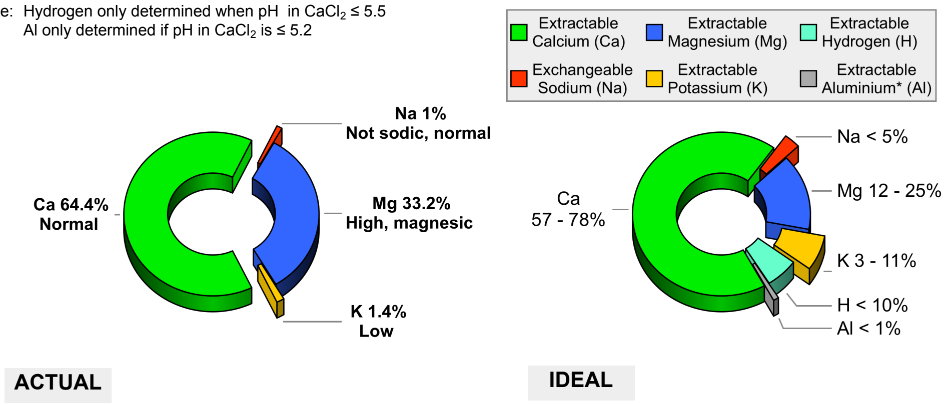




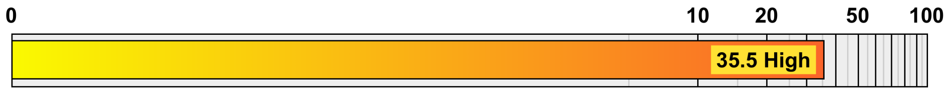
CATION BALANCE

EXCHANGEABLE CATION PERCENTAGE

Note: Hydrogen only determined when pH in $CaCl_2 \leq 5.5$
Al only determined if pH in $CaCl_2$ is ≤ 5.2



EFFECTIVE CATION EXCHANGE CAPACITY (eCEC)



CATION RATIOS

Ratio	Result	Target Range
Ca:Mg	**1.9**	4.1 – 6.0
Comment: Calcium low		
Mg:K	**24.6**	2.6 – 5.0
Comment: Potential Potassium deficiency		
K/(Ca+Mg)	**0.01**	< 0.07
Comment: Acceptable		
K:Na	**1.4**	N/A

Sodium Absorption Ratio: D.N.T.

EXCHANGEABLE CATIONS cmol(+)/kg

Na:	K:	Ca:	Mg:	H:	Al:
0.35	0.48	22.87	11.79		

SOLUBLE CATIONS cmol(+)/kg

Na:	K:	Ca:	Mg:

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Soil Chemistry Profile

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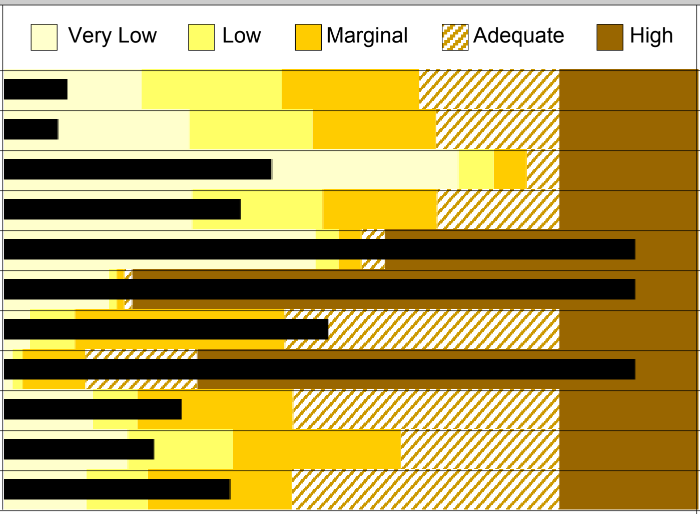
Batch N°: 45863 **Sample N°: 10** **Date Received: 22/11/17** **Report Status: ● Draft ○ Final**

PLANT AVAILABLE NUTRIENTS



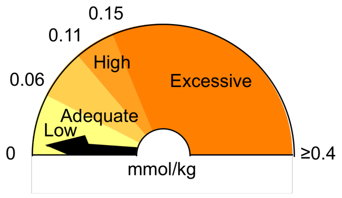
Major Nutrients	Result (mg/kg)	Result (g/sqm)	Desirable (g/sqm)	Adjustment (g/sqm)
Nitrate-N (NO_3)	2.4	0.3	4	3.7
Phosphate-P (PO_4)	6.15	0.8	8.4	7.6
Potassium (K) †	187	24.9	51.6	26.7
Sulphate-S (SO_4)	29	3.9	9	5.1
Calcium (Ca) †	4580	609.1	367.5	Drawdown
Magnesium (Mg) †	1433	190.6	38.4	Drawdown
Iron (Fe)	322	42.8	73.4	30.6
Manganese (Mn) †	144	19.2	5.9	Drawdown
Zinc (Zn) †	1.6	0.2	0.7	0.5
Copper (Cu)	1.7	0.2	0.8	0.6
Boron (B) †	1.1	0.1	0.4	0.3

Explanation of graph ranges:

☐ **Very Low**	🟨 **Low**	🟧 **Marginal**	▨ **Adequate**	🟫 **High**
Growth is likely to be severely depressed and deficiency symptoms present. Large applications for soil building purposes are usually recommended. Potential response to nutrient addition is >90%.	Potential "hidden hunger", or sub-clinical deficiency. Potential response to nutrient addition is 60 to 90%.	Supply of this nutrient is barely adequate for the plant, and build-up is still recommended. Potential response to nutrient addition is 30 to 60%.	Supply of this nutrient is adequate for the plant, and and only maintenance application rates are recommended. Potential response to nutrient addition is 5 to 30%.	The level is excessive and may be detrimental to plant growth (i.e. phytotoxic) and may contribute to pollution of ground and surface waters. Drawdown is recommended. Potential response to nutrient addition is <2%.

NOTES: Adjustment recommendation calculates the elemental application to shift the soil test level to within the **Adequate** band, which maximises growth/yield, and economic efficiency, and minimises impact on the environment.
Drawdown: The objective nutrient management is to utilise residual soil nutrients. There is no agronomic reason to apply fertiliser when soil test levels exceed **Adequate**.
• g/sqm measurements are based on soil bulk density of 1.33 tonne/m³ and selected soil depth.

Phosphorus Saturation Index



0.01

Low. Plant response to applied P is likely.

Exchangeable Acidity

Adams-Evans Buffer pH (BpH): -
Sum of Base Cations (meq/100g^{-1}): **35.5**
Eff. Cation Exch. Capacity (eCEC): **35.5**
Base Saturation (%): **100**
Exchangeable Acidity (meq/100g^{-1}): -
Exchangeable Acidity (%): -

Lime Application Rate

– to achieve pH 6.0 (g/sqm): **0**
– to neutralise Al (g/sqm): -

Gypsum Application Rate

– to achieve 67.5% exch. Ca (g/sqm): **125**
The CGAR is corrected for a soil depth of 100mm and any Lime addition to achieve pH 6.0.

Physical Description

Texture:	**Sandy Clay Loam**
Colour:	**2.5Y 4/2 Dark Grayish Brown**
Estimated clay content:	**20 - 30%**
Size:	**Fine (1 - 10mm)**
Gravel content:	**Gravelly**
Aggregate strength:	**Pedal - Weak**
Structural unit:	**Crumb**
Potential infiltration rate:	**Moderate**
Permeability (mm/hr):	**5 - 20**
Calculated EC_{SE} (dS/m):	**1.2**

– Non-saline. Salinity effects on plants are mostly negligible.

Organic Carbon (OC%)†: **Did not test**
Organic Matter (OM%): **-**
Additional comments:

Consultant: Chantal Milner **Authorised Signatory:**

Date Report Generated 22/12/2017

METHOD REFERENCES:
pH (1:5 H_2O) - Rayment & Higginson (1992) 4A1,
pH (1:5 $CaCl_2$) - Rayment & Higginson (1992) 4B1,
EC (1:5) - Rayment & Higginson (1992) 3A1,
Chloride - Rayment & Higginson (1992) 5A2,
Nitrate - Rayment & Higginson (1992) 7B1
Aluminium - SESL in-house,
PO_4, K, SO_4, Ca, Mg, Na, Fe, Mn, Zn, Cu, B - Mehlich 3 (1984),
Buffer pH and Hydrogen - Adams-Evans (1972)
Texture/Structure/Colour - PM0003 (Texture- "Northcote" (1992), Structure- "Murphy" (1991), Colour- "Munsell" (2000))

SESL AUSTRALIA
Environment & Soil Sciences

Soil Chemistry Profile

Mehlich 3 - Multi-nutrient Extractant

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Batch N°: 45863 **Sample N°: 11** **Date Received: 22/11/17** **Report Status:** ● **Draft** ○ **Final**

Client Name: **Hornsby Shire Council**
Client Contact: **Kurt Henkel**
Client Job N°:
Client Order N°:
Address: **PO Box 37**
HORNSBY NSW 2077

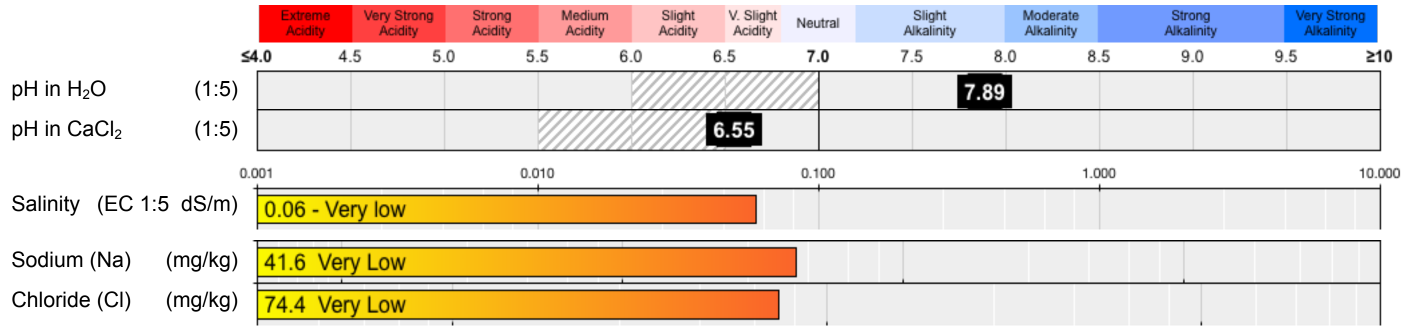
Project Name: **Hornsby Park Initial soil benchmarking**
SESL Quote N°:
Sample Name: **BH6 0-210**
Description: **Soil**
Test Type: **FSC, CSP**

RECOMMENDATIONS

BH6 soil (0-210) is very slightly acidic in CaCl2 whilst in H2O is slightly alkaline. This large difference in pH is the result of this soil not being strongly buffered. This soil has desirably low salinity, sodium and chloride levels. The cation exchange is highly magnesic which is indicative of hardsetting characeristics. The eCEC is very high indicating good nutrient uptake. Nutrients are low aside from calcium, magnesium.
Soil is a dark yellowish brown sandy clay loam with a fine weak crumb structure and moderate permeability.

SOIL SAMPLE DEPTH (mm): ● 100 ○ 150 ○ 200 **FERTILITY RATING:** ○ Low ● Moderate ○ High

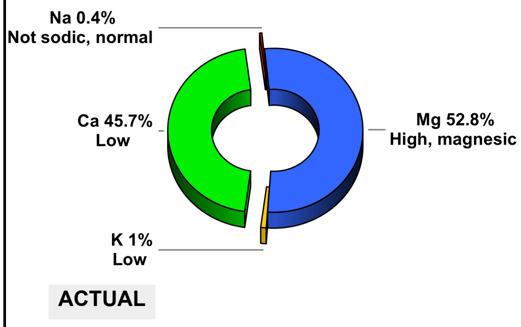
pH and ELECTRICAL CONDUCTIVITY

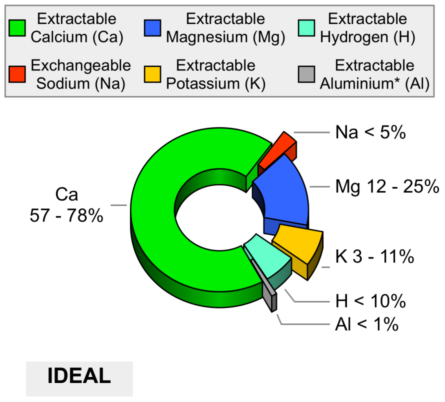


CATION BALANCE

EXCHANGEABLE CATION PERCENTAGE

Note: Hydrogen only determined when pH in $CaCl_2$ ≤ 5.5
Al only determined if pH in $CaCl_2$ is ≤ 5.2





CATION RATIOS

Ratio	Result	Target Range
Ca:Mg	**0.9**	4.1 – 6.0
Comment: Potential Calcium deficiency		
Mg:K	**51.1**	2.6 – 5.0
Comment: Potential Potassium deficiency		
K/(Ca+Mg)	**0.01**	< 0.07
Comment: Acceptable		
K:Na	**2.4**	N/A

Sodium Absorption Ratio: D.N.T.

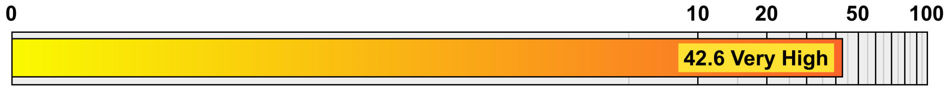
EXCHANGEABLE CATIONS cmol(+)/kg

Na:	K:	Ca:	Mg:	H:	Al:
0.18	0.44	19.48	22.47		

SOLUBLE CATIONS cmol(+)/kg

Na: K: Ca: Mg:

EFFECTIVE CATION EXCHANGE CAPACITY (eCEC)



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SESL AUSTRALIA
Environment & Soil Sciences

Soil Chemistry Profile

Mehlich 3 - Multi-nutrient Extractant

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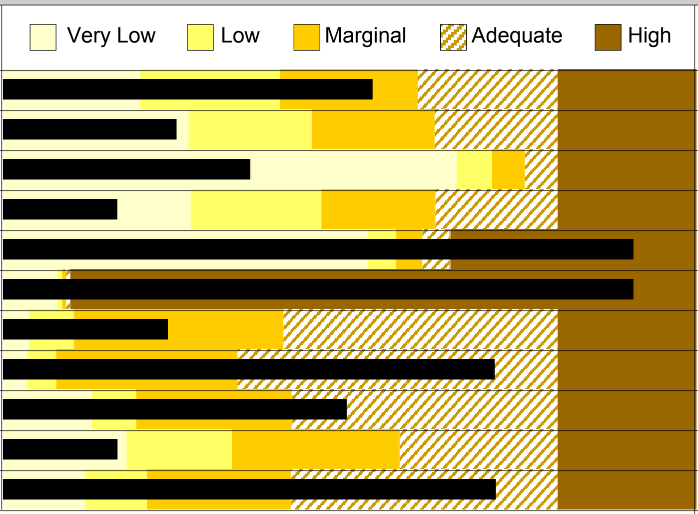
Batch N°: 45863 **Sample N°: 11** **Date Received: 22/11/17** **Report Status: ● Draft ○ Final**

PLANT AVAILABLE NUTRIENTS



Major Nutrients	Result (mg/kg)	Result (g/sqm)	Desirable (g/sqm)	Adjustment (g/sqm)
Nitrate-N (NO_3)	14	1.9	4	2.1
Phosphate-P (PO_4)	19.7	2.6	8.4	5.8
Potassium (K) †	173	23	51.6	28.6
Sulphate-S (SO_4)	14	1.9	9	7.1
Calcium (Ca) †	3900	518.7	367.5	Drawdown
Magnesium (Mg) †	2731	363.2	38.4	Drawdown
Iron (Fe)	164	21.8	73.4	51.6
Manganese (Mn) †	39	5.2	5.9	0.7
Zinc (Zn) †	3.1	0.4	0.7	0.3
Copper (Cu)	1.3	0.2	0.8	0.6
Boron (B) †	2.4	0.3	0.4	0.1

Explanation of graph ranges:

☐ **Very Low**
Growth is likely to be severely depressed and deficiency symptoms present. Large applications for soil building purposes are usually recommended. Potential response to nutrient addition is >90%.

☐ **Low**
Potential "hidden hunger", or sub-clinical deficiency. Potential response to nutrient addition is 60 to 90%.

☐ **Marginal**
Supply of this nutrient is barely adequate for the plant, and build-up is still recommended. Potential response to nutrient addition is 30 to 60%.

▨ **Adequate**
Supply of this nutrient is adequate for the plant, and and only maintenance application rates are recommended. Potential response to nutrient addition is 5 to 30%.

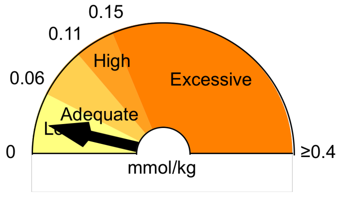
■ **High**
The level is excessive and may be detrimental to plant growth (i.e. phytotoxic) and may contribute to pollution of ground and surface waters. Drawdown is recommended. Potential response to nutrient addition is <2%.

NOTES: Adjustment recommendation calculates the elemental application to shift the soil test level to within the **Adequate** band, which maximises growth/yield, and economic efficiency, and minimises impact on the environment.

Drawdown: The objective nutrient management is to utilise residual soil nutrients. There is no agronomic reason to apply fertiliser when soil test levels exceed **Adequate**.

- g/sqm measurements are based on soil bulk density of 1.33 tonne/m^3 and selected soil depth.

Phosphorus Saturation Index



0.03

Low. Plant response to applied P is likely.

Exchangeable Acidity

Adams-Evans Buffer pH (BpH):	-
Sum of Base Cations (meq/100g^{-1}):	**42.6**
Eff. Cation Exch. Capacity (eCEC):	**42.6**
Base Saturation (%):	**100**
Exchangeable Acidity (meq/100g^{-1}):	-
Exchangeable Acidity (%):	-

Lime Application Rate

– to achieve pH 6.0 (g/sqm):	**0**
– to neutralise Al (g/sqm):	-

Gypsum Application Rate

– to achieve 67.5% exch. Ca (g/sqm): **1062**
The CGAR is corrected for a soil depth of 100mm and any Lime addition to achieve pH 6.0.

Physical Description

Texture:	**Sandy Clay Loam**
Colour:	**10YR 4/4 Dark Yellowish Brown**
Estimated clay content:	**20 - 30%**
Size:	**Fine (1 - 10mm)**
Gravel content:	**Gravelly**
Aggregate strength:	**Pedal - Weak**
Structural unit:	**Crumb**
Potential infiltration rate:	**Moderate**
Permeability (mm/hr):	**5 - 20**
Calculated EC_{SE} (dS/m):	**0.6**

– Non-saline. Salinity effects on plants are mostly negligible.

Organic Carbon (OC%)†: **Did not test**
Organic Matter (OM%): **-**
Additional comments:

Consultant: Chantal Milner **Authorised Signatory:**

Date Report Generated 22/12/2017

METHOD REFERENCES:
pH (1:5 H_2O) - Rayment & Higginson (1992) 4A1,
pH (1:5 $CaCl_2$) - Rayment & Higginson (1992) 4B1,
EC (1:5) - Rayment & Higginson (1992) 3A1,
Chloride - Rayment & Higginson (1992) 5A2,
Nitrate - Rayment & Higginson (1992) 7B1
Aluminium - SESL in-house,
PO_4, K, SO_4, Ca, Mg, Na, Fe, Mn, Zn, Cu, B - Mehlich 3 (1984),
Buffer pH and Hydrogen - Adams-Evans (1972)
Texture/Structure/Colour - PM0003 (Texture- "Northcote" (1992), Structure- "Murphy" (1991), Colour- "Munsell" (2000))

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Environment & Soil Sciences

Soil Chemistry Profile

Mehlich 3 - Multi-nutrient Extractant

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Batch N°: 45863 **Sample N°: 12** **Date Received: 22/11/17** **Report Status: ● Draft ○ Final**

Client Name: **Hornsby Shire Council**
Client Contact: **Kurt Henkel**
Client Job N°:
Client Order N°:
Address: **PO Box 37**
HORNSBY NSW 2077

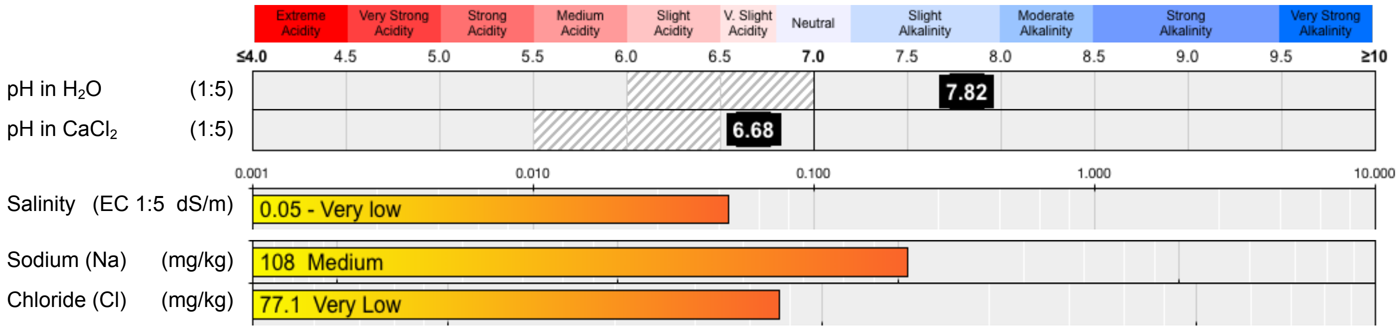
Project Name: **Hornsby Park Initial soil benchmarking**
SESL Quote N°:
Sample Name: **BH6 210-540**
Description: **Soil**
Test Type: **FSC, CSP**

RECOMMENDATIONS

BH6 soil (210-540) is very slightly acidic in CaCl2 whilst in H2O is slightly alkaline. This large difference in pH is the result of this soil not being strongly buffered. This soil has desirably low salinity and chloride levels. Sodium is moderate. The cation exchange is highly magnesic which is indicative of hardsetting characteristics. The eCEC is very high indicating good nutrient uptake. Nutrients are low aside from magnesium and manganese.
Soil is a dark yellowish brown sandy clay loam with a fine weak crumb structure and moderate permeability.

SOIL SAMPLE DEPTH (mm): ● 100 ○ 150 ○ 200 **FERTILITY RATING:** ○ Low ● Moderate ○ High

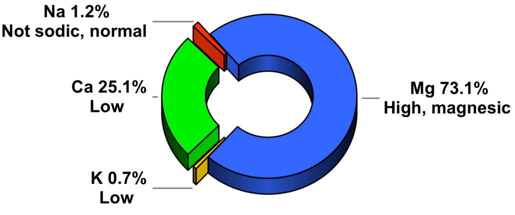
pH and ELECTRICAL CONDUCTIVITY



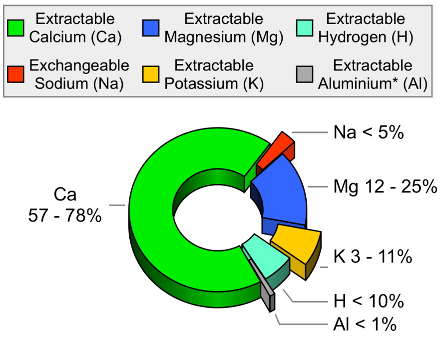
CATION BALANCE

EXCHANGEABLE CATION PERCENTAGE

Note: Hydrogen only determined when pH in $CaCl_2 \leq 5.5$
Al only determined if pH in $CaCl_2$ is ≤ 5.2

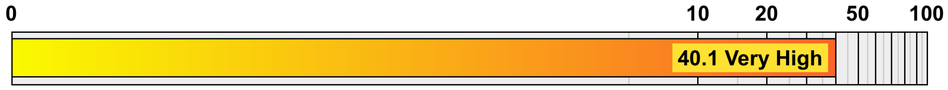


ACTUAL



IDEAL

EFFECTIVE CATION EXCHANGE CAPACITY (eCEC)



CATION RATIOS

Ratio	Result	Target Range
Ca:Mg	0.3	4.1 – 6.0
Comment: Potential Calcium deficiency		
Mg:K	108.6	2.6 – 5.0
Comment: Potential Potassium deficiency		
K/(Ca+Mg)	0.01	< 0.07
Comment: Acceptable		
K:Na	0.6	N/A

Sodium Absorption Ratio: D.N.T.

EXCHANGEABLE CATIONS cmol(+)/kg

Na:	K:	Ca:	Mg:	H:	Al:
0.47	0.27	10.05	29.31		

SOLUBLE CATIONS cmol(+)/kg

Na:	K:	Ca:	Mg:

ASPAC

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† This laboratory has been awarded a Certificate of Proficiency for specific soil and plant tissue analyses by the Australasian Soil and Plant Analysis Council (ASPAC). Tests for which proficiency has been demonstrated are highlighted in this report.

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Soil Chemistry Profile

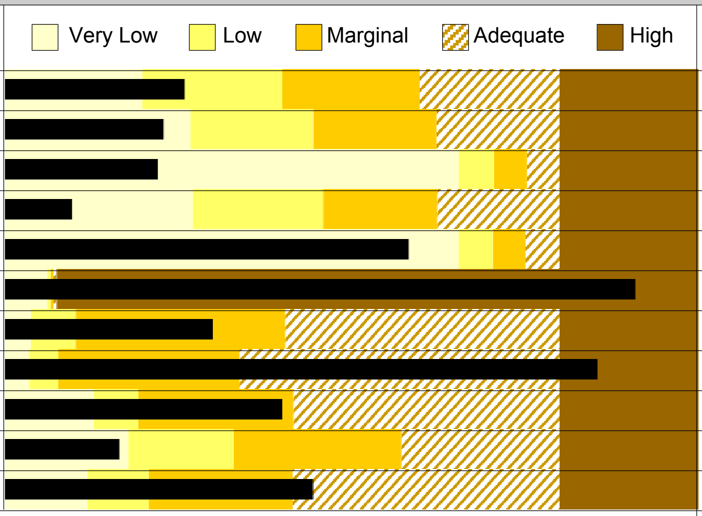
Mehlich 3 - Multi-nutrient Extractant

Sample Drop Off: 16 Chilvers Road
Thornleigh NSW 2120
Mailing Address: PO Box 357
Pennant Hills NSW 1715
Tel: 1300 30 40 80
Fax: 1300 64 46 89
Em: info@sesl.com.au
Web: www.sesl.com.au

Batch N°: 45863 **Sample N°: 12** **Date Received: 22/11/17** **Report Status: ● Draft ○ Final**

PLANT AVAILABLE NUTRIENTS

Major Nutrients	Result (mg/kg)	Result (g/sqm)	Desirable (g/sqm)	Adjustment (g/sqm)
Nitrate-N (NO_3)	6.8	0.9	4	3.1
Phosphate-P (PO_4)	18	2.4	8.4	6
Potassium (K) †	107	14.2	51.6	37.4
Sulphate-S (SO_4)	8.2	1.1	9	7.9
Calcium (Ca) †	2010	267.3	367.5	100.2
Magnesium (Mg) †	3561	473.6	38.4	Drawdown
Iron (Fe)	207	27.5	73.4	45.9
Manganese (Mn) †	47	6.3	5.9	Drawdown
Zinc (Zn) †	2.5	0.3	0.7	0.4
Copper (Cu)	1.3	0.2	0.8	0.6
Boron (B) †	1.5	0.2	0.4	0.2



Explanation of graph ranges:

Very Low Growth is likely to be severely depressed and deficiency symptoms present. Large applications for soil building purposes are usually recommended. Potential response to nutrient addition is >90%.

Low Potential “hidden hunger”, or sub-clinical deficiency. Potential response to nutrient addition is 60 to 90%.

Marginal Supply of this nutrient is barely adequate for the plant, and build-up is still recommended. Potential response to nutrient addition is 30 to 60%.

Adequate Supply of this nutrient is adequate for the plant, and and only maintenance application rates are recommended. Potential response to nutrient addition is 5 to 30%.

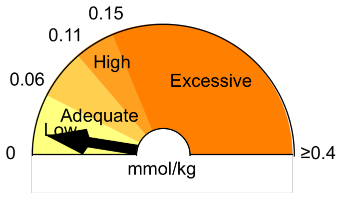
High The level is excessive and may be detrimental to plant growth (i.e. phytotoxic) and may contribute to pollution of ground and surface waters. Drawdown is recommended. Potential response to nutrient addition is <2%.

NOTES: Adjustment recommendation calculates the elemental application to shift the soil test level to within the **Adequate** band, which maximises growth/yield, and economic efficiency, and minimises impact on the environment.

Drawdown: The objective nutrient management is to utilise residual soil nutrients. There is no agronomic reason to apply fertiliser when soil test levels exceed **Adequate**.

- g/sqm measurements are based on soil bulk density of 1.33 tonne/m³ and selected soil depth.

Phosphorus Saturation Index



0.02

Low. Plant response to applied P is likely.

Exchangeable Acidity

Adams-Evans Buffer pH (BpH): -
Sum of Base Cations (meq/100g^{-1}): **40.1**
Eff. Cation Exch. Capacity (eCEC): **40.1**
Base Saturation (%): **100**
Exchangeable Acidity (meq/100g^{-1}): -
Exchangeable Acidity (%): -

Lime Application Rate

– to achieve pH 6.0 (g/sqm): **0**
– to neutralise Al (g/sqm): -

Gypsum Application Rate

– to achieve 67.5% exch. Ca (g/sqm): **1948**
The CGAR is corrected for a soil depth of 100mm and any Lime addition to achieve pH 6.0.

Physical Description

Texture:	**Sandy Clay Loam**
Colour:	**10YR 4/4 Dark Yellowish Brown**
Estimated clay content:	**20 - 30%**
Size:	**Fine (1 - 10mm)**
Gravel content:	**Gravelly**
Aggregate strength:	**Pedal - Weak**
Structural unit:	**Crumb**
Potential infiltration rate:	**Moderate**
Permeability (mm/hr):	**5 - 20**
Calculated EC_{SE} (dS/m):	**0.5**

– Non-saline. Salinity effects on plants are mostly negligible.

Organic Carbon (OC%)†: **Did not test**
Organic Matter (OM%): **-**
Additional comments:

Consultant: Chantal Milner **Authorised Signatory:**

Date Report Generated 22/12/2017

METHOD REFERENCES:
pH (1:5 H_2O) - Rayment & Higginson (1992) 4A1,
pH (1:5 $CaCl_2$) - Rayment & Higginson (1992) 4B1,
EC (1:5) - Rayment & Higginson (1992) 3A1,
Chloride - Rayment & Higginson (1992) 5A2,
Nitrate - Rayment & Higginson (1992) 7B1
Aluminium - SESL in-house,
PO_4, K, SO_4, Ca, Mg, Na, Fe, Mn, Zn, Cu, B - Mehlich 3 (1984),
Buffer pH and Hydrogen - Adams-Evans (1972)
Texture/Structure/Colour - PM0003 (Texture- "Northcote" (1992), Structure- "Murphy" (1991), Colour- "Munsell" (2000))

A member of the Australasian Soil and Plant Analysis Council
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Soil Chemistry Profile

Mehlich 3 - Multi-nutrient Extractant

Sample Drop Off: 16 Chilvers Road
Thornleigh NSW 2120
Mailing Address: PO Box 357
Pennant Hills NSW 1715
Tel: 1300 30 40 80
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Em: info@sesl.com.au
Web: www.sesl.com.au

Batch N°: 45863 **Sample N°: 13** **Date Received: 22/11/17** **Report Status:** ● **Draft** ○ **Final**

Client Name: **Hornsby Shire Council**
Client Contact: **Kurt Henkel**
Client Job N°:
Client Order N°:
Address: **PO Box 37**
HORNSBY NSW 2077

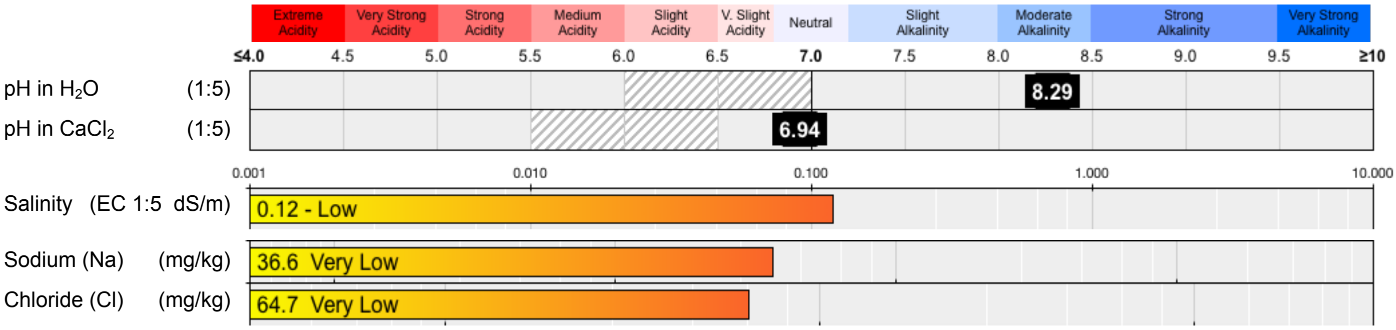
Project Name: **Hornsby Park Initial soil benchmarking**
SESL Quote N°:
Sample Name: **BH7 Surface**
Description: **Soil**
Test Type: **FSC, CSP**

RECOMMENDATIONS

BH7 soil (surface) has a neutral pH in CaCl2 whilst in H2O is moderately alkaline. This large difference in pH is the result of this soil not being strongly buffered. This soil has desirably low salinity, sodium and chloride levels. The cation exchange is close to being balanced. The eCEC is high indicating good nutrient uptake. Nutrients are high aside from nitrate, phosphate and sulphate,
Soil is a very dark grey with a fine weak crumb structure and rapid permeability.

SOIL SAMPLE DEPTH (mm): ● **100** ○ **150** ○ **200** **FERTILITY RATING:** ○ Low ● Moderate ○ High

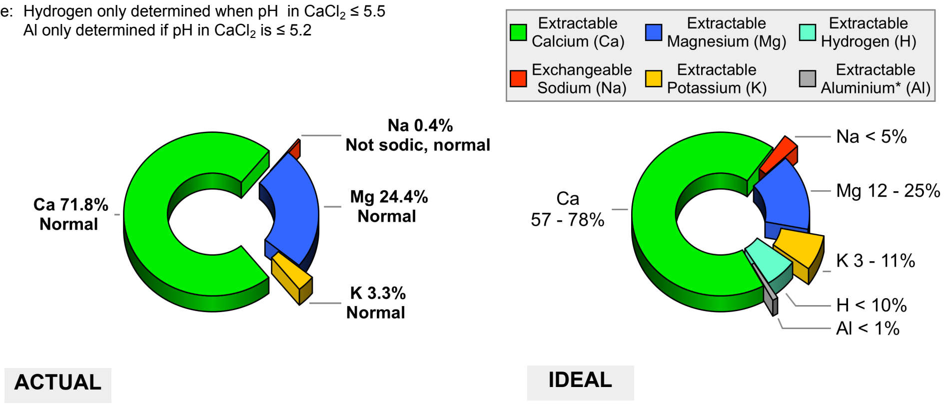
pH and ELECTRICAL CONDUCTIVITY



CATION BALANCE

EXCHANGEABLE CATION PERCENTAGE

Note: Hydrogen only determined when pH in $CaCl_2$ ≤ 5.5
Al only determined if pH in $CaCl_2$ is ≤ 5.2



CATION RATIOS

Ratio	Result	Target Range
Ca:Mg	**2.9**	4.1 – 6.0
Comment: Calcium low		
Mg:K	**7.5**	2.6 – 5.0
Comment: Potassium low		
K/(Ca+Mg)	**0.03**	< 0.07
Comment: Acceptable		
K:Na	**7.3**	N/A

Sodium Absorption Ratio: D.N.T.

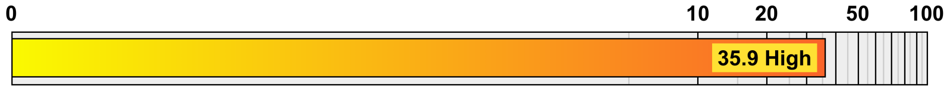
EXCHANGEABLE CATIONS cmol(+)/kg

Na:	K:	Ca:	Mg:	H:	Al:
0.16	1.17	25.78	8.76		

SOLUBLE CATIONS cmol(+)/kg

Na:	K:	Ca:	Mg:

EFFECTIVE CATION EXCHANGE CAPACITY (eCEC)



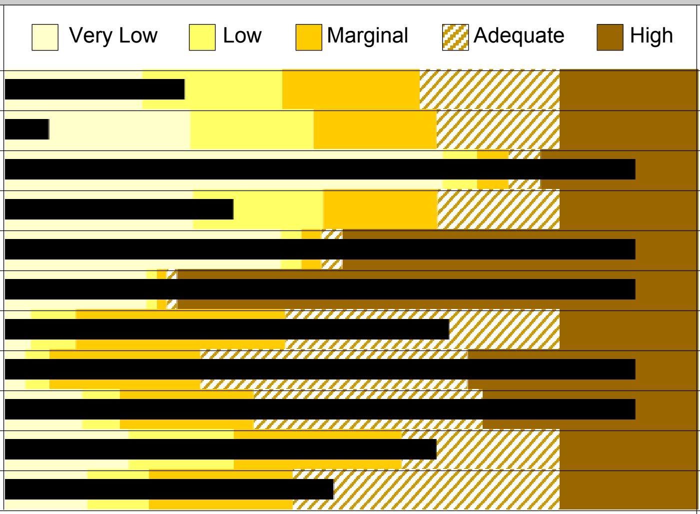
Soil Chemistry Profile

Mehlich 3 - Multi-nutrient Extractant

Sample Drop Off: 16 Chilvers Road
Thornleigh NSW 2120
Mailing Address: PO Box 357
Pennant Hills NSW 1715
Tel: 1300 30 40 80
Fax: 1300 64 46 89
Em: info@sesl.com.au
Web: www.sesl.com.au

Batch N°: 45863 **Sample N°: 13** **Date Received: 22/11/17** **Report Status: ● Draft ○ Final**

PLANT AVAILABLE NUTRIENTS



Major Nutrients	Result (mg/kg)	Result (g/sqm)	Desirable (g/sqm)	Adjustment (g/sqm)
Nitrate-N (NO_3)	6.8	0.9	4	3.1
Phosphate-P (PO_4)	<5	0.7	8.4	7.7
Potassium (K) †	457	60.8	51.6	Drawdown
Sulphate-S (SO_4)	28	3.7	9	5.3
Calcium (Ca) †	5170	687.6	367.5	Drawdown
Magnesium (Mg) †	1065	141.6	38.4	Drawdown
Iron (Fe)	442	58.8	73.4	14.6
Manganese (Mn) †	60	8	5.9	Drawdown
Zinc (Zn) †	6.6	0.9	0.7	Drawdown
Copper (Cu)	4.9	0.7	0.8	0.1
Boron (B) †	1.6	0.2	0.4	0.2

Explanation of graph ranges:

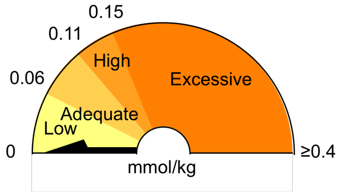
☐ **Very Low**	🟨 **Low**	🟧 **Marginal**	▨ **Adequate**	🟫 **High**
Growth is likely to be severely depressed and deficiency symptoms present. Large applications for soil building purposes are usually recommended. Potential response to nutrient addition is >90%.	Potential "hidden hunger", or sub-clinical deficiency. Potential response to nutrient addition is 60 to 90%.	Supply of this nutrient is barely adequate for the plant, and build-up is still recommended. Potential response to nutrient addition is 30 to 60%.	Supply of this nutrient is adequate for the plant, and and only maintenance application rates are recommended. Potential response to nutrient addition is 5 to 30%.	The level is excessive and may be detrimental to plant growth (i.e. phytotoxic) and may contribute to pollution of ground and surface waters. Drawdown is recommended. Potential response to nutrient addition is <2%.

NOTES: Adjustment recommendation calculates the elemental application to shift the soil test level to within the **Adequate** band, which maximises growth/yield, and economic efficiency, and minimises impact on the environment.

Drawdown: The objective nutrient management is to utilise residual soil nutrients. There is no agronomic reason to apply fertiliser when soil test levels exceed **Adequate**.

- g/sqm measurements are based on soil bulk density of 1.33 tonne/m^3 and selected soil depth.

Phosphorus Saturation Index



0

Low. Plant response to applied P is likely.

Exchangeable Acidity

Adams-Evans Buffer pH (BpH): -
Sum of Base Cations (meq/100g^{-1}): **35.9**
Eff. Cation Exch. Capacity (eCEC): **35.9**
Base Saturation (%): **100**
Exchangeable Acidity (meq/100g^{-1}): -
Exchangeable Acidity (%): -

Lime Application Rate

– to achieve pH 6.0 (g/sqm): **0**
– to neutralise Al (g/sqm): -

Gypsum Application Rate

– to achieve 67.5% exch. Ca (g/sqm): **0**
The CGAR is corrected for a soil depth of 100mm and any Lime addition to achieve pH 6.0.

Physical Description

Texture: **Sandy Loam**
Colour: **2.5Y 3/4 Very Dark Gray**
Estimated clay content: **10 - 20%**
Size: **Fine (1 - 10mm)**
Gravel content: **Gravelly**
Aggregate strength: **Pedal - Weak**
Structural unit: **Crumb**
Potential infiltration rate: **Rapid**
Permeability (mm/hr): **>120**
Calculated EC_{SE} (dS/m): **1.7**
– Non-saline. Salinity effects on plants are mostly negligible.
Organic Carbon (OC%)†: **Did not test**
Organic Matter (OM%): -
Additional comments:

Consultant: Chantal Milner **Authorised Signatory:**

Date Report Generated 22/12/2017

METHOD REFERENCES:
pH (1:5 H_2O) - Rayment & Higginson (1992) 4A1,
pH (1:5 $CaCl_2$) - Rayment & Higginson (1992) 4B1,
EC (1:5) - Rayment & Higginson (1992) 3A1,
Chloride - Rayment & Higginson (1992) 5A2,
Nitrate - Rayment & Higginson (1992) 7B1
Aluminium - SESL in-house,
PO_4, K, SO_4, Ca, Mg, Na, Fe, Mn, Zn, Cu, B - Mehlich 3 (1984),
Buffer pH and Hydrogen - Adams-Evans (1972)
Texture/Structure/Colour - PM0003 (Texture- "Northcote" (1992), Structure- "Murphy" (1991), Colour- "Munsell" (2000))

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Soil Chemistry Profile

Mehlich 3 - Multi-nutrient Extractant

Sample Drop Off: 16 Chilvers Road
Thornleigh NSW 2120
Mailing Address: PO Box 357
Pennant Hills NSW 1715
Tel: 1300 30 40 80
Fax: 1300 64 46 89
Em: info@sesl.com.au
Web: www.sesl.com.au

Batch N°: 45863 **Sample N°: 14** **Date Received: 22/11/17** **Report Status:** ● **Draft** ○ **Final**

Client Name: **Hornsby Shire Council**
Client Contact: **Kurt Henkel**
Client Job N°:
Client Order N°:
Address: **PO Box 37**
HORNSBY NSW 2077

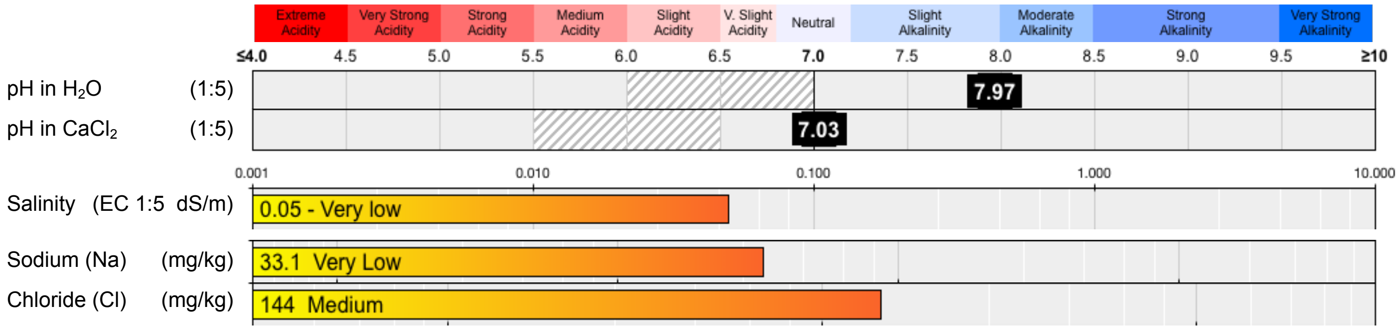
Project Name: **Hornsby Park Initial soil benchmarking**
SESL Quote N°:
Sample Name: **BH8 0-220**
Description: **Soil**
Test Type: **FSC, CSP**

RECOMMENDATIONS

BH7 soil (surface) has a neutral pH in CaCl2 whilst in H2O is slightly alkaline. This soil has desirably low salinity, and sodium levels. Chloride is moderate. The cation exchange is highly magnesic indicating hardsetting characteristics. The eCEC is high indicating good nutrient uptake. Calcium, magnesium and manganese are high however all other nutrients are low.
Soil is a brown sandy clay loam with a fine weak crumb structure and moderate permeability.

SOIL SAMPLE DEPTH (mm): ● 100 ○ 150 ○ 200 **FERTILITY RATING:** ○ Low ● Moderate ○ High

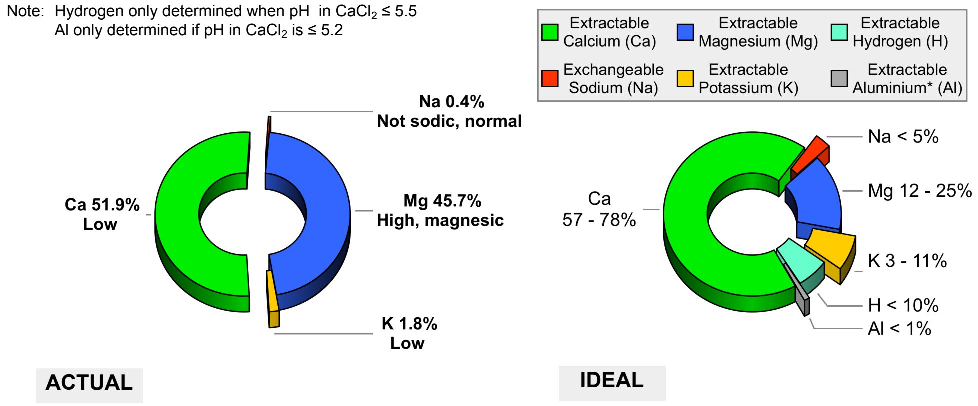
pH and ELECTRICAL CONDUCTIVITY



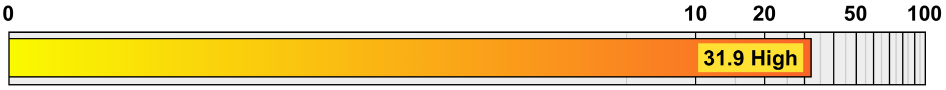
CATION BALANCE

EXCHANGEABLE CATION PERCENTAGE

Note: Hydrogen only determined when pH in CaCl₂ ≤ 5.5
Al only determined if pH in CaCl₂ is ≤ 5.2



EFFECTIVE CATION EXCHANGE CAPACITY (eCEC)



CATION RATIOS

Ratio	Result	Target Range
Ca:Mg	**1.1**	4.1 – 6.0
Comment: Calcium low		
Mg:K	**25.6**	2.6 – 5.0
Comment: Potential Potassium deficiency		
K/(Ca+Mg)	**0.02**	< 0.07
Comment: Acceptable		
K:Na	**4.1**	N/A

Sodium Absorption Ratio: D.N.T.

EXCHANGEABLE CATIONS cmol(+)/kg

Na:	K:	Ca:	Mg:	H:	Al:
0.14	0.57	16.55	14.59		

SOLUBLE CATIONS cmol(+)/kg

Na:	K:	Ca:	Mg:

ASPAC

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Soil Chemistry Profile

Mehlich 3 - Multi-nutrient Extractant

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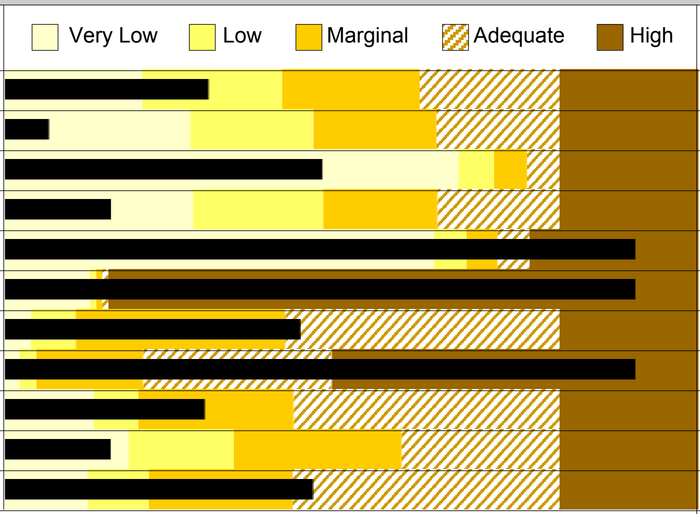
Web: www.sesl.com.au

Batch N°: 45863 **Sample N°: 14** **Date Received: 22/11/17** **Report Status: ● Draft ○ Final**

PLANT AVAILABLE NUTRIENTS



Major Nutrients	Result (mg/kg)	Result (g/sqm)	Desirable (g/sqm)	Adjustment (g/sqm)
Nitrate-N (NO_3)	7.7	1	4	3
Phosphate-P (PO_4)	<5	0.7	8.4	7.7
Potassium (K) †	222	29.5	51.6	22.1
Sulphate-S (SO_4)	13	1.7	9	7.3
Calcium (Ca) †	3320	441.6	367.5	Drawdown
Magnesium (Mg) †	1772	235.7	38.4	Drawdown
Iron (Fe)	294	39.1	73.4	34.3
Manganese (Mn) †	85	11.3	5.9	Drawdown
Zinc (Zn) †	1.8	0.2	0.7	0.5
Copper (Cu)	1.2	0.2	0.8	0.6
Boron (B) †	1.5	0.2	0.4	0.2

Explanation of graph ranges:

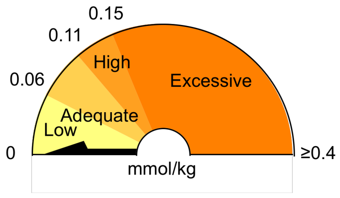
▫ **Very Low**	🟨 **Low**	🟧 **Marginal**	▨ **Adequate**	🟫 **High**
Growth is likely to be severely depressed and deficiency symptoms present. Large applications for soil building purposes are usually recommended. Potential response to nutrient addition is >90%.	Potential “hidden hunger”, or sub-clinical deficiency. Potential response to nutrient addition is 60 to 90%.	Supply of this nutrient is barely adequate for the plant, and build-up is still recommended. Potential response to nutrient addition is 30 to 60%.	Supply of this nutrient is adequate for the plant, and and only maintenance application rates are recommended. Potential response to nutrient addition is 5 to 30%.	The level is excessive and may be detrimental to plant growth (i.e. phytotoxic) and may contribute to pollution of ground and surface waters. Drawdown is recommended. Potential response to nutrient addition is <2%.

NOTES: Adjustment recommendation calculates the elemental application to shift the soil test level to within the **Adequate** band, which maximises growth/yield, and economic efficiency, and minimises impact on the environment.

Drawdown: The objective nutrient management is to utilise residual soil nutrients. There is no agronomic reason to apply fertiliser when soil test levels exceed **Adequate**.

- g/sqm measurements are based on soil bulk density of 1.33 tonne/m^3 and selected soil depth.

Phosphorus Saturation Index



0

Low. Plant response to applied P is likely.

Exchangeable Acidity

Adams-Evans Buffer pH (BpH): -
Sum of Base Cations (meq/100g^{-1}): **31.9**
Eff. Cation Exch. Capacity (eCEC): **31.9**
Base Saturation (%): **100**
Exchangeable Acidity (meq/100g^{-1}): -
Exchangeable Acidity (%): -

Lime Application Rate

– to achieve pH 6.0 (g/sqm): **0**
– to neutralise Al (g/sqm): -

Gypsum Application Rate

– to achieve 67.5% exch. Ca (g/sqm): **570**
The CGAR is corrected for a soil depth of 100mm and any Lime addition to achieve pH 6.0.

Physical Description

Texture:	**Sandy Clay Loam**
Colour:	**7.5YR 4/3 Brown**
Estimated clay content:	**20 - 30%**
Size:	**Fine (1 - 10mm)**
Gravel content:	**Gravelly**
Aggregate strength:	**Pedal - Weak**
Structural unit:	**Crumb**
Potential infiltration rate:	**Moderate**
Permeability (mm/hr):	**5 - 20**
Calculated EC_{SE} (dS/m):	**0.5**

– Non-saline. Salinity effects on plants are mostly negligible.

Organic Carbon (OC%)†: **Did not test**
Organic Matter (OM%): -
Additional comments:

Consultant: Chantal Milner **Authorised Signatory:**

Date Report Generated 22/12/2017

METHOD REFERENCES:
pH (1:5 H_2O) - Rayment & Higginson (1992) 4A1,
pH (1:5 $CaCl_2$) - Rayment & Higginson (1992) 4B1,
EC (1:5) - Rayment & Higginson (1992) 3A1,
Chloride - Rayment & Higginson (1992) 5A2,
Nitrate - Rayment & Higginson (1992) 7B1
Aluminium - SESL in-house,
PO_4, K, SO_4, Ca, Mg, Na, Fe, Mn, Zn, Cu, B - Mehlich 3 (1984),
Buffer pH and Hydrogen - Adams-Evans (1972)
Texture/Structure/Colour - PM0003 (Texture-"Northcote" (1992), Structure- "Murphy" (1991), Colour- "Munsell" (2000))

ASPAC

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Appendix B

Laboratory Analysis: Site Visit 2

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Soil Chemistry Profile

Mehlich 3 - Multi-nutrient Extractant

Sample Drop Off: 16 Chilvers Road
Thornleigh NSW 2120
Mailing Address: PO Box 357
Pennant Hills NSW 1715
Tel: 1300 30 40 80
Fax: 1300 64 46 89
Em: info@sesl.com.au
Web: www.sesl.com.au

Batch N°: 46326 **Sample N°: 1** **Date Received: 10/1/18** **Report Status: ● Draft ○ Final**

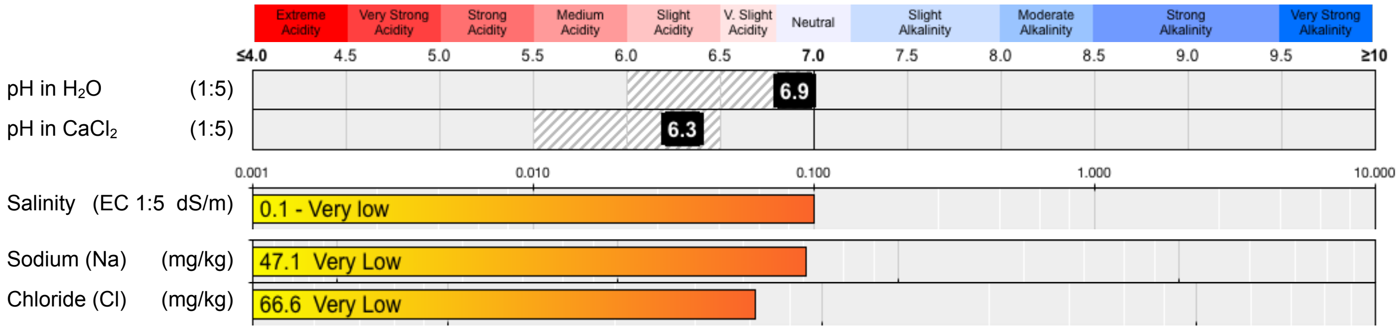
Client Name: **Hornsby Shire Council**
Client Contact: **James Frawley**
Client Order N°:
Address: **PO Box 37**
HORNSBY NSW 2077

Project Name: **Hornsby Parks**
SESL Quote N°:
Sample Name: **BH9 0-300mm**
Description: **Soil**
Test Type: **FSC, OM_WB, P_AD, Ca_AD**

RECOMMENDATIONS

Soil sample BH1 0-300mm is slightly acidic in CaCl2 with desirably low salinity levels. The cation exchange is magnesic therefore is potentially hardsetting. The ECEC is very high indicating good nutrient retention. Nitrate, calcium and magnesium are high and most traces are moderate. P, K and S are low.
Organic matter = 8.7% (very high).
Total P = 0.07%
Total Ca = 0.80%

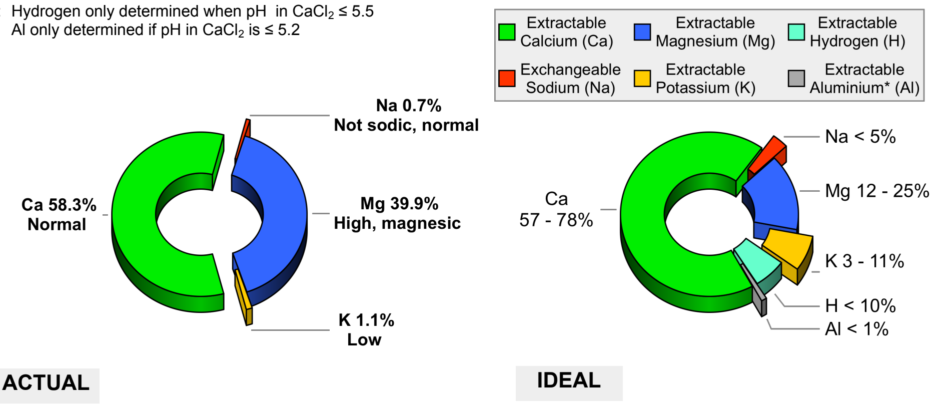
pH and ELECTRICAL CONDUCTIVITY



CATION BALANCE

EXCHANGEABLE CATION PERCENTAGE

Note: Hydrogen only determined when pH in CaCl₂ ≤ 5.5
Al only determined if pH in CaCl₂ is ≤ 5.2



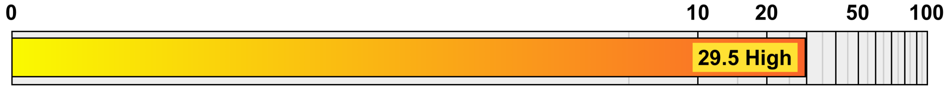
CATION RATIOS

Ratio	Result	Target Range
Ca:Mg	1.5	4.1 – 6.0
Comment: Calcium low		
Mg:K	38	2.6 – 5.0
Comment: Potential Potassium deficiency		
K/(Ca+Mg)	0.01	< 0.07
Comment: Acceptable		
K:Na	1.6	N/A

EXCHANGEABLE CATIONS (cmol(+)/kg)

Na:	K:	Ca:	Mg:	H:	Al:
0.20	0.31	17.19	11.77		

EFFECTIVE CATION EXCHANGE CAPACITY (eCEC) (cmol(+)/kg)



eCEC does not include correction for soluble salts as standard. Where exchangeable calcium exceeds 80 % of eCEC and/or salinity exceeds 0.75 dS/m, alternative methods are recommended to determine true eCEC.

The units of eCEC *cmol(+)/kg* are the SI unit and are equivalent to *meq/100g*.

Disclaimer
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Soil Chemistry Profile

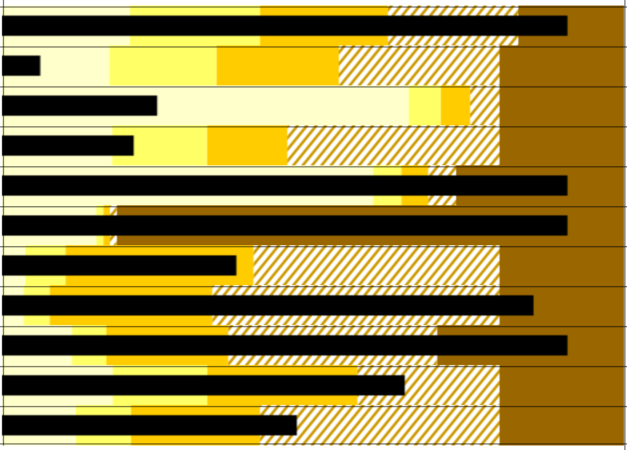
Mehlich 3 - Multi-nutrient Extractant

Sample Drop Off: 16 Chilvers Road
Thornleigh NSW 2120
Mailing Address: PO Box 357
Pennant Hills NSW 1715
Tel: 1300 30 40 80
Fax: 1300 64 46 89
Em: info@sesl.com.au
Web: www.sesl.com.au

Batch N°: 46326 **Sample N°: 1** **Date Received: 10/1/18** **Report Status: ● Draft ○ Final**

PLANT AVAILABLE NUTRIENTS

EFFECTIVE AMELIORATION DEPTH (mm): ● 100 ○ 150 ○ 200 **DESIRED FERTILITY CLASS:** ○ Low ● Moderate ○ High

Major Nutrients	Unit	Result	☐ Very Low ☐ Low ☐ Marginal ▨ Adequate ■ High	Result (g/sqm)	Desirable (g/sqm)	Adjustment (g/sqm)
Nitrate-N (NO_3)	mg N/kg	23		3.1	4	0.9
Phosphorus (P)	mg P/kg	<5		0.7	8.4	7.7
Potassium (K)	mg/kg	121		16.1	51.6	35.5
Sulphur (S)	mg S/kg	18		2.4	9	6.6
Calcium (Ca)	mg/kg	3440		457.5	367.5	Drawdown
Magnesium (Mg)	mg/kg	1430		190.2	38.4	Drawdown
Iron (Fe)	mg/kg	260		34.6	73.4	38.8
Manganese (Mn)	mg/kg	47		6.3	5.9	Drawdown
Zinc (Zn)	mg/kg	6.5		0.9	0.7	Drawdown
Copper (Cu)	mg/kg	5.1		0.7	0.8	0.1
Boron (B)	mg/kg	1.6		0.2	0.4	0.2

Explanation of graph ranges:

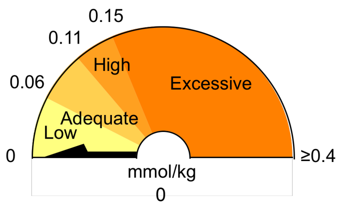
☐ **Very Low**	☐ **Low**	☐ **Marginal**	▨ **Adequate**	■ **High**
Growth is likely to be severely depressed and deficiency symptoms present. Large applications for soil building purposes are usually recommended. Potential response to nutrient addition is >90%.	Potential “hidden hunger”, or sub-clinical deficiency. Potential response to nutrient addition is 60 to 90%.	Supply of this nutrient is barely adequate for the plant, and build-up is still recommended. Potential response to nutrient addition is 30 to 60%.	Supply of this nutrient is adequate for the plant, and and only maintenance application rates are recommended. Potential response to nutrient addition is 5 to 30%.	The level is excessive and may be detrimental to plant growth (i.e. phytotoxic) and may contribute to pollution of ground and surface waters. Drawdown is recommended. Potential response to nutrient addition is <2%.

NOTES: Adjustment recommendation calculates the elemental application to shift the soil test level to within the **Adequate** band, which maximises growth/yield, and economic efficiency, and minimises impact on the environment.

Drawdown: The objective nutrient management is to utilise residual soil nutrients. There is no agronomic reason to apply fertiliser when soil test levels exceed **Adequate**.

- g/sqm measurements are based on soil bulk density of 1.33 tonne/m^3 and selected soil depth.

Phosphorus Saturation Index



Low. Plant response to applied P is likely.

Exchangeable Acidity

Adams-Evans Buffer pH (BpH):	-
Sum of Base Cations (cmol(+)/kg):	**29.5**
Eff. Cation Exch. Capacity (eCEC):	**29.5**
Base Saturation (%):	**100**
Exchangeable Acidity (cmol(+)/kg):	-
Exchangeable Acidity (%):	-

Lime Application Rate (g/sqm)

– to achieve pH 6.0:	**0**
– to neutralise Al:	**-**

Calculated Gypsum Application Rate (CGAR)

(g/sqm) to achieve 67.5 % exch. Ca: **312**

The CGAR is corrected for the selected effective amelioration depth (100 mm) and any Lime addition to achieve pH 6.0.

PHYSICAL DESCRIPTION

Texture:	**Clay Loam**
Estimated clay content:	**25 - 35%**
Tactually gravelly:	**Not gravelly**
Tactually organic:	**Not Organic**
Calculated EC_{SE} (dS/m):	**0.9**

– Non-saline. Salinity effects on plants are mostly negligible.

Munsell Colour:	**7.5YR 3/1 Very Dark**
Structure Size:	**Fine (1 - 10mm)**
Structural Organisation:	**Pedal - Weak**
Structural Unit:	**Crumb**
Potential infiltration rate:	**Moderate**
Est. Permeability Class (mm/hr):	**5 - 20**

Additional comments:

Organic Carbon (OC %):	**4 – Very high**
Organic Matter (OM %):	**8.7**
Est. Field Capacity (% water):	**34**
Est. Permanent Wilting Point (% water):	**18**
Est. Plant Available Water (% water):	**16**
Est. Plant Available Water (mm/m):	**160**

Date Report Generated 12/02/2018

Consultant: Chantal Milner

Authorised Signatory: Simon Leake

METHOD REFERENCES:
pH (1:5 H_2O) - Rayment & Higginson (1992) 4A1,
pH (1:5 $CaCl_2$) - Rayment & Higginson (1992) 4B1,
EC (1:5) - Rayment & Higginson (1992) 3A1,
Chloride - Rayment & Higginson (1992) 5A2,
Nitrate - Rayment & Higginson (1992) 7B1
Aluminium - SESL in-house,
PO_4, K, SO_4, Ca, Mg, Na, Fe, Mn, Zn, Cu, B - Mehlich 3 (1984),
Buffer pH and Hydrogen - Adams-Evans (1972)
Texture/Structure/Colour - PM0003 (Texture-"Northcote" (1992), Structure* - "Murphy" (1991), Colour- "Munsell" (2000))

*Structure analysed in the laboratory is conducted on a disturbed sample, therefore is only a representation of the macro-structures that may be present in the field, which provide an indication of the soil physical characteristics and behaviours that may exist.

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Soil Chemistry Profile

Mehlich 3 - Multi-nutrient Extractant

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Mailing Address: PO Box 357
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Em: info@sesl.com.au
Web: www.sesl.com.au

Batch N°: 46326 **Sample N°: 2** **Date Received: 10/1/18** **Report Status: ● Draft ○ Final**

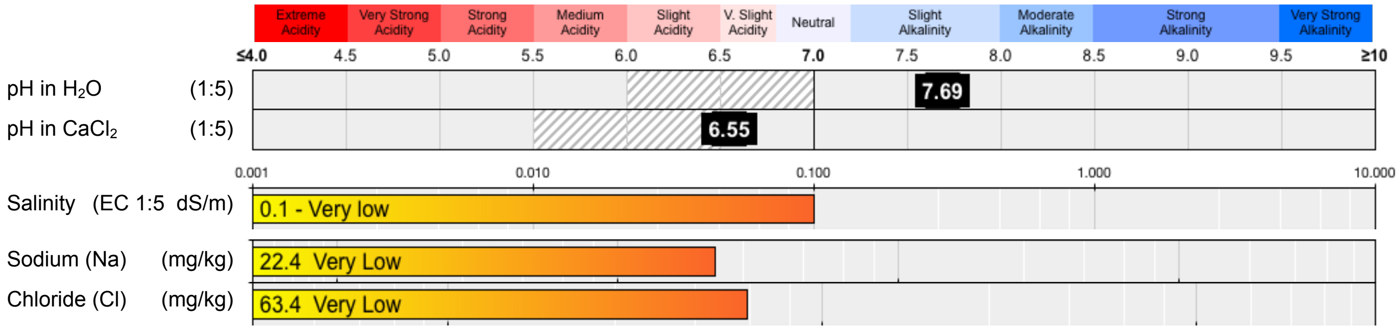
Client Name: **Hornsby Shire Council**
Client Contact: **James Frawley**
Client Order N°:
Address: **PO Box 37**
HORNSBY NSW 2077

Project Name: **Hornsby Parks**
SESL Quote N°:
Sample Name: **BH10 0-200mm**
Description: **Soil**
Test Type: **FSC, OM_WB, P_AD, Ca_AD**

RECOMMENDATIONS

Soil sample is very slightly acidic in CaCl2 with desirably low salinity levels. The cation exchange is close to being balanced. The ECEC is high indicating good nutrient retention. N, P, K and S are low however all other nutrients are high.
Organic matter = 3.7% (moderate).
Total P = 0.11%
Total Ca = 2.5%

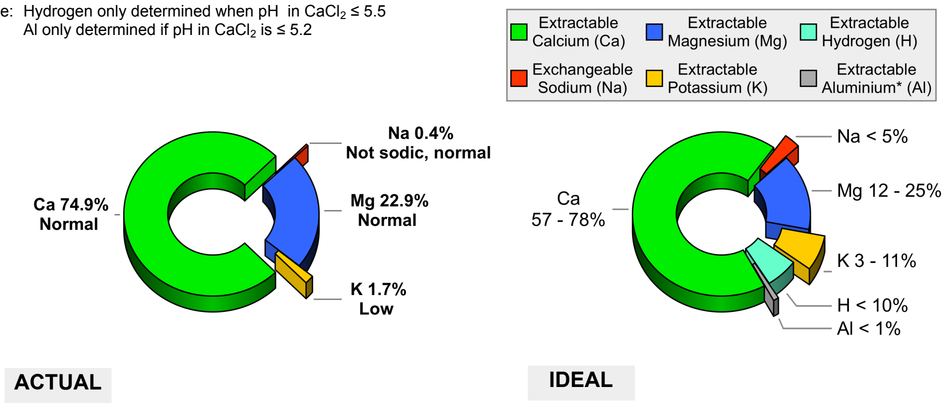
pH and ELECTRICAL CONDUCTIVITY



CATION BALANCE

EXCHANGEABLE CATION PERCENTAGE

Note: Hydrogen only determined when pH in $CaCl_2 \le 5.5$
Al only determined if pH in $CaCl_2$ is ≤ 5.2



CATION RATIOS

Ratio	Result	Target Range
Ca:Mg	**3.3**	4.1 – 6.0
Comment: Calcium low		
Mg:K	**13.6**	2.6 – 5.0
Comment: Potential Potassium deficiency		
K/(Ca+Mg)	**0.02**	< 0.07
Comment: Acceptable		
K:Na	**4.4**	N/A

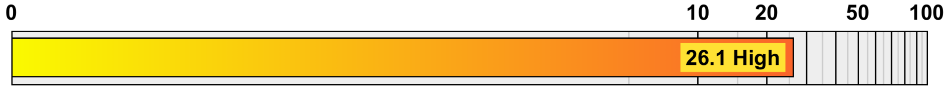
EXCHANGEABLE CATIONS (cmol(+)/kg)

Na:	K:	Ca:	Mg:	H:	Al:
0.10	0.44	19.55	5.96		

eCEC does not include correction for soluble salts as standard. Where exchangeable calcium exceeds 80 % of eCEC and/or salinity exceeds 0.75 dS/m, alternative methods are recommended to determine true eCEC.

The units of eCEC *cmol(+)/kg* are the SI unit and are equivalent to *meq/100g.*

EFFECTIVE CATION EXCHANGE CAPACITY (eCEC) (cmol(+)/kg)



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Soil Chemistry Profile

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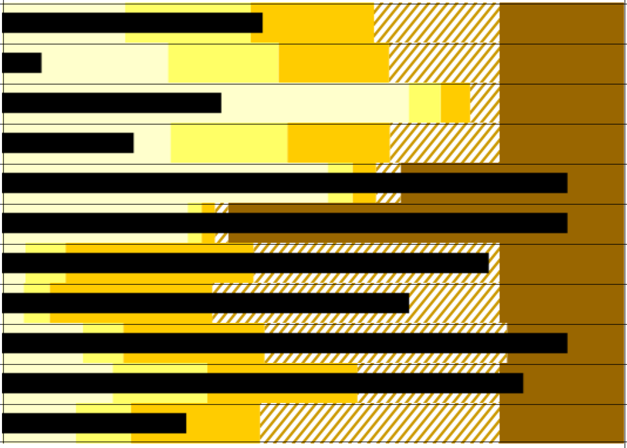
Web: www.sesl.com.au

Batch N°: 46326 **Sample N°: 2** **Date Received: 10/1/18** **Report Status:** ◉ **Draft** ○ **Final**

PLANT AVAILABLE NUTRIENTS

EFFECTIVE AMELIORATION DEPTH (mm): ◉ 100 ○ 150 ○ 200 **DESIRED FERTILITY CLASS:** ○ Low ◉ Moderate ○ High

Major Nutrients	Unit	Result	☐ Very Low ☐ Low ☐ Marginal ▨ Adequate ■ High	Result (g/sqm)	Desirable (g/sqm)	Adjustment (g/sqm)
Nitrate-N (NO_3)	mg N/kg	11		1.5	4	2.5
Phosphorus (P)	mg P/kg	<5		0.7	8.4	7.7
Potassium (K)	mg/kg	171		22.7	51.6	28.9
Sulphur (S)	mg S/kg	18		2.4	9	6.6
Calcium (Ca)	mg/kg	3920		521.4	367.5	Drawdown
Magnesium (Mg)	mg/kg	725		96.4	38.4	Drawdown
Iron (Fe)	mg/kg	540		71.8	73.4	1.6
Manganese (Mn)	mg/kg	36		4.8	5.9	1.1
Zinc (Zn)	mg/kg	5.6		0.7	0.7	0
Copper (Cu)	mg/kg	6.6		0.9	0.8	Drawdown
Boron (B)	mg/kg	1		0.1	0.4	0.3



Explanation of graph ranges:

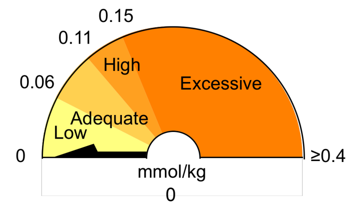
☐ **Very Low**	☐ **Low**	☐ **Marginal**	▨ **Adequate**	■ **High**
Growth is likely to be severely depressed and deficiency symptoms present. Large applications for soil building purposes are usually recommended. Potential response to nutrient addition is >90%.	Potential "hidden hunger", or sub-clinical deficiency. Potential response to nutrient addition is 60 to 90%.	Supply of this nutrient is barely adequate for the plant, and build-up is still recommended. Potential response to nutrient addition is 30 to 60%.	Supply of this nutrient is adequate for the plant, and and only maintenance application rates are recommended. Potential response to nutrient addition is 5 to 30%.	The level is excessive and may be detrimental to plant growth (i.e. phytotoxic) and may contribute to pollution of ground and surface waters. Drawdown is recommended. Potential response to nutrient addition is <2%.

NOTES: Adjustment recommendation calculates the elemental application to shift the soil test level to within the **Adequate** band, which maximises growth/yield, and economic efficiency, and minimises impact on the environment.

Drawdown: The objective nutrient management is to utilise residual soil nutrients. There is no agronomic reason to apply fertiliser when soil test levels exceed **Adequate**.

- g/sqm measurements are based on soil bulk density of 1.33 tonne/m^3 and selected soil depth.

Phosphorus Saturation Index



Low. Plant response to applied P is likely.

Exchangeable Acidity

Adams-Evans Buffer pH (BpH): -
Sum of Base Cations (cmol(+)/kg): **26.1**
Eff. Cation Exch. Capacity (eCEC): **26.1**
Base Saturation (%): **100**
Exchangeable Acidity (cmol(+)/kg): -
Exchangeable Acidity (%): -

Lime Application Rate (g/sqm)
– to achieve pH 6.0: **0**
– to neutralise Al: **-**

Calculated Gypsum Application Rate (CGAR)
(g/sqm) to achieve 67.5 % exch. Ca: **0**

The CGAR is corrected for the selected effective amelioration depth (100 mm) and any Lime addition to achieve pH 6.0.

PHYSICAL DESCRIPTION

Texture: **Clay Loam**
Estimated clay content: **25 - 35%**
Tactually gravelly: **Gravelly**
Tactually organic: **Not Organic**
Calculated EC_{SE} (dS/m): **0.9**
– Non-saline. Salinity effects on plants are mostly negligible.

Munsell Colour: **10YR 3/1 Very Dark**
Structure Size: **Fine (1 - 10mm)**
Structural Organisation: **Pedal - Weak**
Structural Unit: **Crumb**
Potential infiltration rate: **Moderate**
Est. Permeability Class (mm/hr): **5 - 20**
Additional comments:

Organic Carbon (OC %): **1.7 – Moderate**
Organic Matter (OM %): **3.7**
Est. Field Capacity (% water): **34**
Est. Permanent Wilting Point (% water): **18**
Est. Plant Available Water (% water): **16**
Est. Plant Available Water (mm/m): **160**

Date Report Generated 12/02/2018

Consultant: Chantal Milner

Authorised Signatory: Simon Leake

METHOD REFERENCES:
pH (1:5 H_2O) - Rayment & Higginson (1992) 4A1,
pH (1:5 $CaCl_2$) - Rayment & Higginson (1992) 4B1,
EC (1:5) - Rayment & Higginson (1992) 3A1,
Chloride - Rayment & Higginson (1992) 5A2,
Nitrate - Rayment & Higginson (1992) 7B1
Aluminium - SESL in-house,
PO_4, K, SO_4, Ca, Mg, Na, Fe, Mn, Zn, Cu, B - Mehlich 3 (1984),
Buffer pH and Hydrogen - Adams-Evans (1972)
Texture/Structure/Colour - PM0003 (Texture- "Northcote" (1992), Structure* - "Murphy" (1991), Colour- "Munsell" (2000))

*Structure analysed in the laboratory is conducted on a disturbed sample, therefore is only a representation of the macro-structures that may be present in the field, which provide an indication of the soil physical characteristics and behaviours that may exist.

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Soil Chemistry Profile

Mehlich 3 - Multi-nutrient Extractant

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Thornleigh NSW 2120
Mailing Address: PO Box 357
Pennant Hills NSW 1715
Tel: 1300 30 40 80
Fax: 1300 64 46 89
Em: info@sesl.com.au
Web: www.sesl.com.au

Batch N°: 46326 **Sample N°: 3** **Date Received: 10/1/18** **Report Status: ● Draft ○ Final**

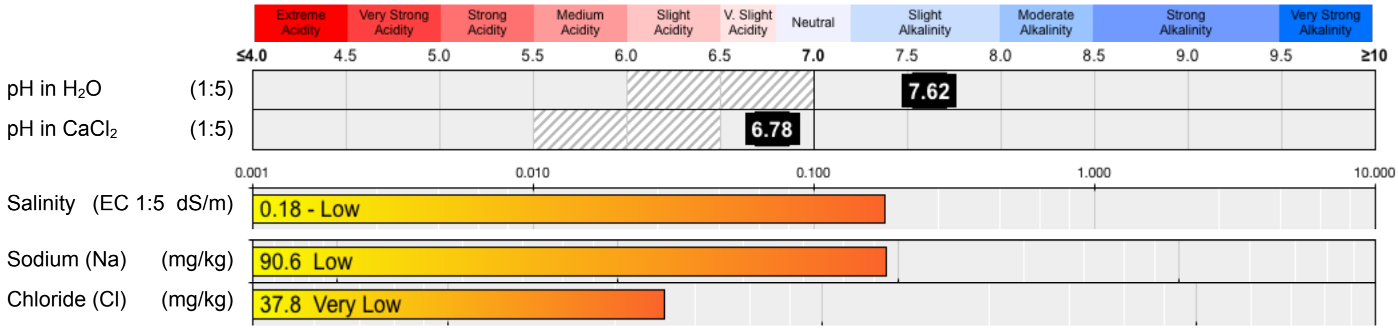
Client Name: **Hornsby Shire Council**
Client Contact: **James Frawley**
Client Order N°:
Address: **PO Box 37**
HORNSBY NSW 2077

Project Name: **Hornsby Parks**
SESL Quote N°:
Sample Name: **BH11 0-400mm**
Description: **Soil**
Test Type: **FSC, OM_WB, P_AD, Ca_AD**

RECOMMENDATIONS

Soil sample BH3 0-400mm is very slightly acidic in CaCl2 with desirably low salinity levels. The cation exchange is magnesic therefore is potentially hardsetting. The ECEC is high indicating good nutrient retention. N, P, K and S are low and need boosting.
Organic matter = 4.4% (moderate).
Total P = 0.09%
Total Ca = 0.81%

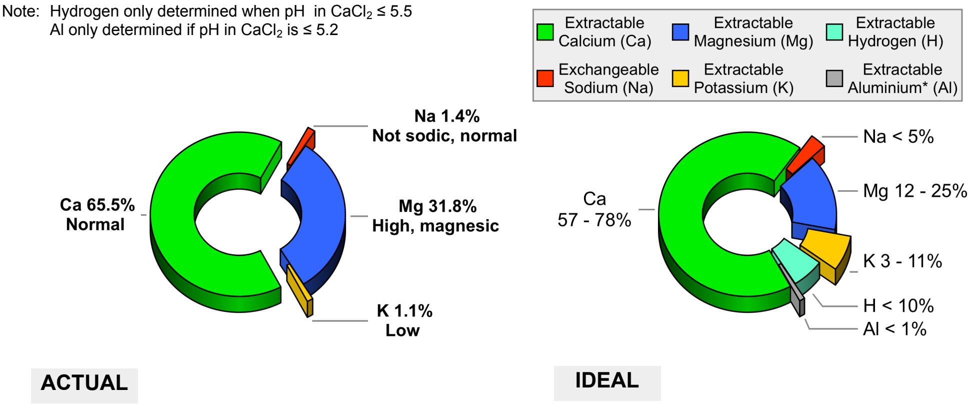
pH and ELECTRICAL CONDUCTIVITY



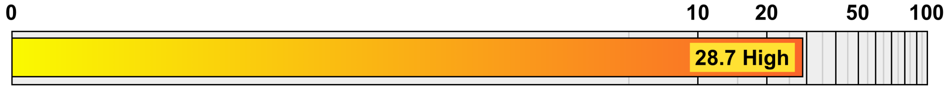
CATION BALANCE

EXCHANGEABLE CATION PERCENTAGE

Note: Hydrogen only determined when pH in $CaCl_2 \leq 5.5$
Al only determined if pH in $CaCl_2$ is ≤ 5.2



EFFECTIVE CATION EXCHANGE CAPACITY (eCEC) (cmol(+)/kg)



CATION RATIOS

Ratio	Result	Target Range
Ca:Mg	**2.1**	4.1 – 6.0
Comment: Calcium low		
Mg:K	**27.7**	2.6 – 5.0
Comment: Potential Potassium deficiency		
K/(Ca+Mg)	**0.01**	< 0.07
Comment: Acceptable		
K:Na	**0.8**	N/A

EXCHANGEABLE CATIONS (cmol(+)/kg)

Na:	K:	Ca:	Mg:	H:	Al:
0.39	0.33	18.80	9.14		

eCEC does not include correction for soluble salts as standard. Where exchangeable calcium exceeds 80 % of eCEC and/or salinity exceeds 0.75 dS/m, alternative methods are recommended to determine true eCEC.

The units of eCEC *cmol(+)/kg* are the SI unit and are equivalent to *meq/100g.*

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Soil Chemistry Profile

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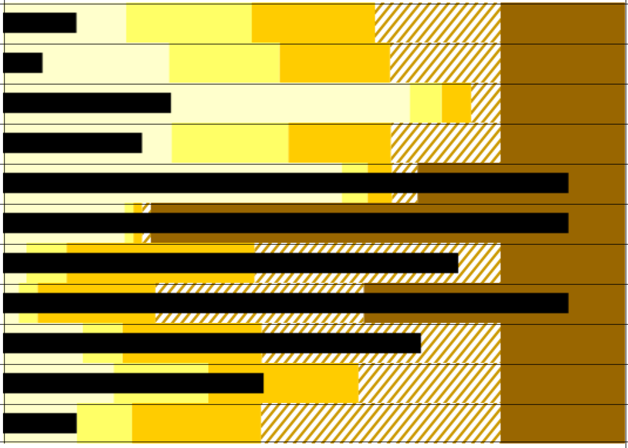
Web: www.sesl.com.au

Batch N°: 46326 **Sample N°: 3** **Date Received: 10/1/18** **Report Status:** ● **Draft** ○ **Final**

PLANT AVAILABLE NUTRIENTS

EFFECTIVE AMELIORATION DEPTH (mm): ● 100 ○ 150 ○ 200 **DESIRED FERTILITY CLASS:** ○ Low ● Moderate ○ High



Major Nutrients	**Unit**	**Result**	☐ Very Low ☐ Low ☐ Marginal ▨ Adequate ■ High	**Result (g/sqm)**	**Desirable (g/sqm)**	**Adjustment (g/sqm)**
Nitrate-N (NO_3)	mg N/kg	3.1		0.4	4	3.6
Phosphorus (P)	mg P/kg	<5		0.7	8.4	7.7
Potassium (K)	mg/kg	131		17.4	51.6	34.2
Sulphur (S)	mg S/kg	19		2.5	9	6.5
Calcium (Ca)	mg/kg	3770		501.4	367.5	Drawdown
Magnesium (Mg)	mg/kg	1110		147.6	38.4	Drawdown
Iron (Fe)	mg/kg	505		67.2	73.4	6.2
Manganese (Mn)	mg/kg	69		9.2	5.9	Drawdown
Zinc (Zn)	mg/kg	4.2		0.6	0.7	0.1
Copper (Cu)	mg/kg	3.3		0.4	0.8	0.4
Boron (B)	mg/kg	0.4		0.1	0.4	0.3

Explanation of graph ranges:

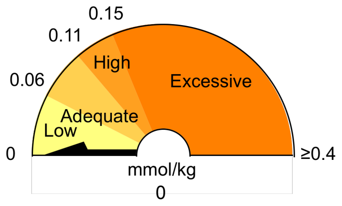
- ☐ **Very Low** Growth is likely to be severely depressed and deficiency symptoms present. Large applications for soil building purposes are usually recommended. Potential response to nutrient addition is >90%.
- ☐ **Low** Potential "hidden hunger", or sub-clinical deficiency. Potential response to nutrient addition is 60 to 90%.
- ☐ **Marginal** Supply of this nutrient is barely adequate for the plant, and build-up is still recommended. Potential response to nutrient addition is 30 to 60%.
- ▨ **Adequate** Supply of this nutrient is adequate for the plant, and and only maintenance application rates are recommended. Potential response to nutrient addition is 5 to 30%.
- ■ **High** The level is excessive and may be detrimental to plant growth (i.e. phytotoxic) and may contribute to pollution of ground and surface waters. Drawdown is recommended. Potential response to nutrient addition is <2%.

NOTES: Adjustment recommendation calculates the elemental application to shift the soil test level to within the **Adequate** band, which maximises growth/yield, and economic efficiency, and minimises impact on the environment.

Drawdown: The objective nutrient management is to utilise residual soil nutrients. There is no agronomic reason to apply fertiliser when soil test levels exceed **Adequate**.

- g/sqm measurements are based on soil bulk density of 1.33 tonne/m^3 and selected soil depth.

Phosphorus Saturation Index



Low. Plant response to applied P is likely.

Exchangeable Acidity

Adams-Evans Buffer pH (BpH): **-**
Sum of Base Cations (cmol(+)/kg): **28.7**
Eff. Cation Exch. Capacity (eCEC): **28.7**
Base Saturation (%): **100**
Exchangeable Acidity (cmol(+)/kg): **-**
Exchangeable Acidity (%): **-**

Lime Application Rate (g/sqm)

– to achieve pH 6.0: **0**
– to neutralise Al: **-**

Calculated Gypsum Application Rate (CGAR)

(g/sqm) to achieve 67.5 % exch. Ca: **66**

The CGAR is corrected for the selected effective amelioration depth (100 mm) and any Lime addition to achieve pH 6.0.

PHYSICAL DESCRIPTION

Texture: **Clay Loam**
Estimated clay content: **25 - 35%**
Tactually gravelly: **Not gravelly**
Tactually organic: **Not Organic**
Calculated EC_{SE} (dS/m): **1.5**
– Non-saline. Salinity effects on plants are mostly negligible.

Munsell Colour: **10YR 4/1 Dark Gray**
Structure Size: **Fine (1 - 10mm)**
Structural Organisation: **Pedal - Weak**
Structural Unit: **Crumb**
Potential infiltration rate: **Moderate**
Est. Permeability Class (mm/hr): **5 - 20**
Additional comments:

Organic Carbon (OC %): **2 – Moderate**
Organic Matter (OM %): **4.4**
Est. Field Capacity (% water): **34**
Est. Permanent Wilting Point (% water): **18**
Est. Plant Available Water (% water): **16**
Est. Plant Available Water (mm/m): **160**

Date Report Generated 12/02/2018

Consultant: Chantal Milner

Authorised Signatory: Simon Leake

METHOD REFERENCES:
pH (1:5 H_2O) - Rayment & Higginson (1992) 4A1,
pH (1:5 $CaCl_2$) - Rayment & Higginson (1992) 4B1,
EC (1:5) - Rayment & Higginson (1992) 3A1,
Chloride - Rayment & Higginson (1992) 5A2,
Nitrate - Rayment & Higginson (1992) 7B1
Aluminium - SESL in-house,
PO_4, K, SO_4, Ca, Mg, Na, Fe, Mn, Zn, Cu, B - Mehlich 3 (1984),
Buffer pH and Hydrogen - Adams-Evans (1972)
Texture/Structure/Colour - PM0003 (Texture-"Northcote" (1992), Structure* - "Murphy" (1991), Colour- "Munsell" (2000))

*Structure analysed in the laboratory is conducted on a disturbed sample, therefore is only a representation of the macro-structures that may be present in the field, which provide an indication of the soil physical characteristics and behaviours that may exist.

SESL AUSTRALIA
Environment & Soil Sciences

Soil Chemistry Profile

Mehlich 3 - Multi-nutrient Extractant

Sample Drop Off: 16 Chilvers Road
Thornleigh NSW 2120
Mailing Address: PO Box 357
Pennant Hills NSW 1715
Tel: 1300 30 40 80
Fax: 1300 64 46 89
Em: info@sesl.com.au
Web: www.sesl.com.au

Batch N°: 46326 **Sample N°: 4** **Date Received: 10/1/18** **Report Status: ● Draft ○ Final**

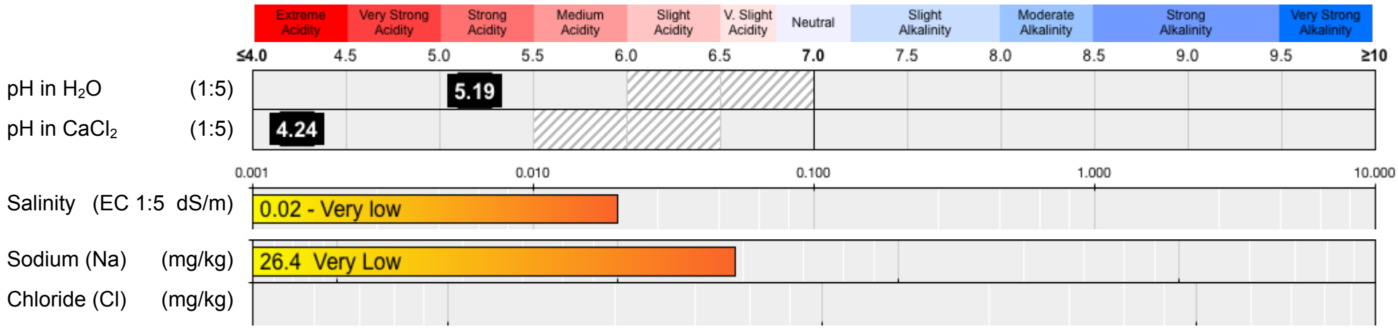
Client Name: **Hornsby Shire Council**
Client Contact: **James Frawley**
Client Order N°:
Address: **PO Box 37**
HORNSBY NSW 2077

Project Name: **Hornsby Parks**
SESL Quote N°:
Sample Name: **BH12 0-100mm**
Description: **Soil**
Test Type: **ECEC_M3, P_AD, Ca_AD**

RECOMMENDATIONS

Soil sample BH4 0-4100mm is extremely acidic in CaCl2 with desirably low salinity levels. The cation exchange is dominated by hydrogen and due to the acidity, aluminium has become available. The ECEC is low indicating poor nutrient retention. Tested nutrients are low and need boosting.
Total P = 0.01%
Total Ca = 0.02%

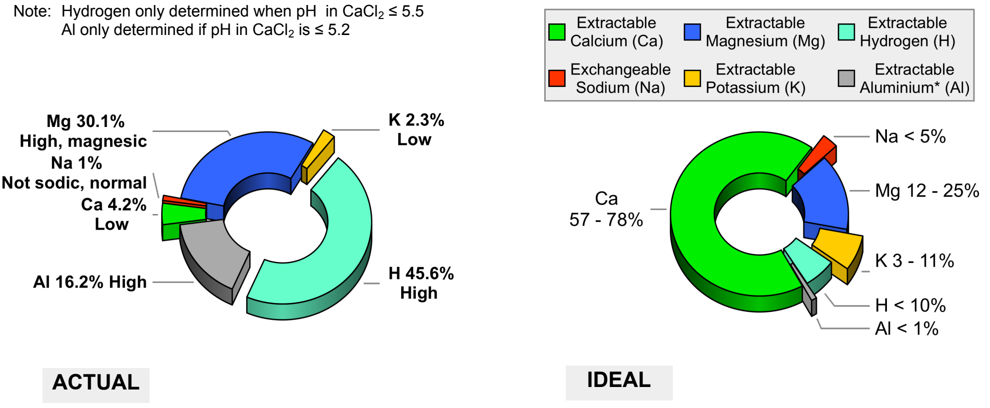
pH and ELECTRICAL CONDUCTIVITY



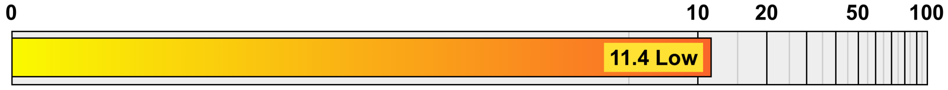
CATION BALANCE

EXCHANGEABLE CATION PERCENTAGE

Note: Hydrogen only determined when pH in $CaCl_2 \leq 5.5$
Al only determined if pH in $CaCl_2$ is ≤ 5.2



EFFECTIVE CATION EXCHANGE CAPACITY (eCEC) (cmol(+)/kg)



CATION RATIOS

Ratio	Result	Target Range
Ca:Mg	**0.1**	4.1 – 6.0
Comment: Potential Calcium deficiency		
Mg:K	**13.2**	2.6 – 5.0
Comment: Potential Potassium deficiency		
K/(Ca+Mg)	**0.07**	< 0.07
Comment: High		
K:Na	**2.4**	N/A

EXCHANGEABLE CATIONS (cmol(+)/kg)

Na:	K:	Ca:	Mg:	H:	Al:
0.11	0.26	0.48	3.43	5.20	1.85

eCEC does not include correction for soluble salts as standard. Where exchangeable calcium exceeds 80 % of eCEC and/or salinity exceeds 0.75 dS/m, alternative methods are recommended to determine true eCEC.

The units of eCEC *cmol(+)/kg* are the SI unit and are equivalent to *meq/100g.*

SESL AUSTRALIA
Environment & Soil Sciences

Soil Chemistry Profile

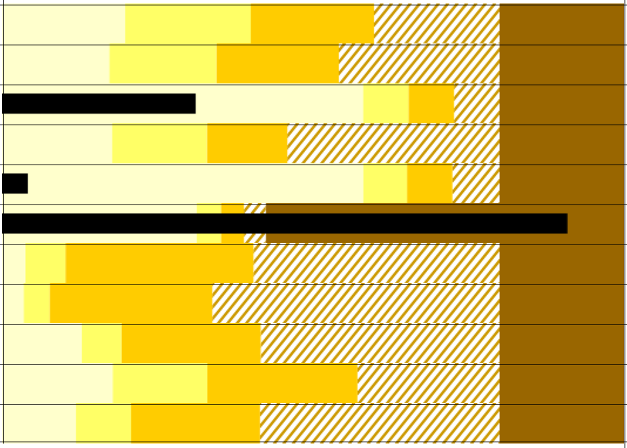
Mehlich 3 - Multi-nutrient Extractant

Sample Drop Off: 16 Chilvers Road
Thornleigh NSW 2120
Mailing Address: PO Box 357
Pennant Hills NSW 1715
Tel: 1300 30 40 80
Fax: 1300 64 46 89
Em: info@sesl.com.au
Web: www.sesl.com.au

Batch N°: 46326 **Sample N°: 4** **Date Received: 10/1/18** **Report Status:** ● **Draft** ○ **Final**

PLANT AVAILABLE NUTRIENTS

EFFECTIVE AMELIORATION DEPTH (mm): ● 100 ○ 150 ○ 200 **DESIRED FERTILITY CLASS:** ○ Low ● Moderate ○ High

Major Nutrients	Unit	Result	☐ Very Low ☐ Low 🟨 Marginal ▨ Adequate 🟫 High	Result (g/sqm)	Desirable (g/sqm)	Adjustment (g/sqm)
Nitrate-N (NO$_3$)	mg N/kg	-		-	4	Did not test
Phosphorus (P)	mg P/kg	-		-	8.4	Did not test
Potassium (K)	mg/kg	102		13.6	34.8	21.2
Sulphur (S)	mg S/kg	-		-	9	9
Calcium (Ca)	mg/kg	96.8		12.9	248	235.1
Magnesium (Mg)	mg/kg	416		55.3	25.8	Drawdown
Iron (Fe)	mg/kg	-		-	73.4	Did not test
Manganese (Mn)	mg/kg	-		-	5.9	Did not test
Zinc (Zn)	mg/kg	-		-	0.7	Did not test
Copper (Cu)	mg/kg	-		-	0.8	Did not test
Boron (B)	mg/kg	-		-	0.4	Did not test

Explanation of graph ranges:

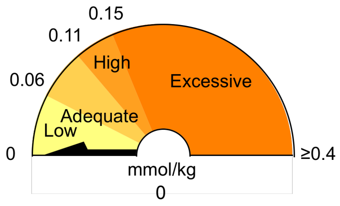
☐ Very Low	☐ Low	🟨 Marginal	▨ Adequate	🟫 High
Growth is likely to be severely depressed and deficiency symptoms present. Large applications for soil building purposes are usually recommended. Potential response to nutrient addition is >90%.	Potential “hidden hunger”, or sub-clinical deficiency. Potential response to nutrient addition is 60 to 90%.	Supply of this nutrient is barely adequate for the plant, and build-up is still recommended. Potential response to nutrient addition is 30 to 60%.	Supply of this nutrient is adequate for the plant, and and only maintenance application rates are recommended. Potential response to nutrient addition is 5 to 30%.	The level is excessive and may be detrimental to plant growth (i.e. phytotoxic) and may contribute to pollution of ground and surface waters. Drawdown is recommended. Potential response to nutrient addition is <2%.

NOTES: Adjustment recommendation calculates the elemental application to shift the soil test level to within the **Adequate** band, which maximises growth/yield, and economic efficiency, and minimises impact on the environment.

Drawdown: The objective nutrient management is to utilise residual soil nutrients. There is no agronomic reason to apply fertiliser when soil test levels exceed **Adequate**.

- g/sqm measurements are based on soil bulk density of 1.33 tonne/m^3 and selected soil depth.

Phosphorus Saturation Index



Low. Plant response to applied P is likely.

Exchangeable Acidity

Adams-Evans Buffer pH (BpH): **6.9**
Sum of Base Cations (cmol(+)/kg): **4.3**
Eff. Cation Exch. Capacity (eCEC): **11.4**
Base Saturation (%): **37.72**
Exchangeable Acidity (cmol(+)/kg): **5.2**
Exchangeable Acidity (%): **45.61**

Lime Application Rate (g/sqm)

– to achieve pH 6.0: **469**
– to neutralise Al: **180**

Calculated Gypsum Application Rate (CGAR)

(g/sqm) to achieve 67.5 % exch. Ca: **20**

The CGAR is corrected for the selected effective amelioration depth (100 mm) and any Lime addition to achieve pH 6.0.

PHYSICAL DESCRIPTION

Texture: **Light Medium Clay**
Estimated clay content: **40 - 45%**
Tactually gravelly: **Not gravelly**
Tactually organic: **Not Organic**
Calculated EC$_{SE}$ (dS/m): **0.2**
– Non-saline. Salinity effects on plants are mostly negligible.

Munsell Colour: **7.5YR 5/8 Strong**
Structure Size: **Fine (1 - 10mm)**
Structural Organisation: **Pedal - Moderate**
Structural Unit: **Crumb**
Potential infiltration rate: **Slow**
Est. Permeability Class (mm/hr): **2.5 - 5**
Additional comments:

Organic Carbon (OC %): **Did not test**
Organic Matter (OM %): **-**
Est. Field Capacity (% water): **40**
Est. Permanent Wilting Point (% water): **23**
Est. Plant Available Water (% water): **17**
Est. Plant Available Water (mm/m): **170**

Date Report Generated 12/02/2018

Consultant: Chantal Milner

Authorised Signatory: Simon Leake

METHOD REFERENCES:
pH (1:5 H_2O) - Rayment & Higginson (1992) 4A1,
pH (1:5 $CaCl_2$) - Rayment & Higginson (1992) 4B1,
EC (1:5) - Rayment & Higginson (1992) 3A1,
Chloride - Rayment & Higginson (1992) 5A2,
Nitrate - Rayment & Higginson (1992) 7B1
Aluminium - SESL in-house,
PO_4, K, SO_4, Ca, Mg, Na, Fe, Mn, Zn, Cu, B - Mehlich 3 (1984),
Buffer pH and Hydrogen - Adams-Evans (1972)
Texture/Structure/Colour - PM0003 (Texture- "Northcote" (1992), Structure* - "Murphy" (1991), Colour- "Munsell" (2000))

*Structure analysed in the laboratory is conducted on a disturbed sample, therefore is only a representation of the macro-structures that may be present in the field, which provide an indication of the soil physical characteristics and behaviours that may exist.

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AUSTRALIA
Environment & Soil Sciences

Soil Chemistry Profile

Mehlich 3 - Multi-nutrient Extractant

Sample Drop Off: 16 Chilvers Road
Thornleigh NSW 2120
Mailing Address: PO Box 357
Pennant Hills NSW 1715
Tel: 1300 30 40 80
Fax: 1300 64 46 89
Em: info@sesl.com.au
Web: www.sesl.com.au

Batch N°: 46326 **Sample N°: 5** **Date Received: 10/1/18** **Report Status: ● Draft ○ Final**

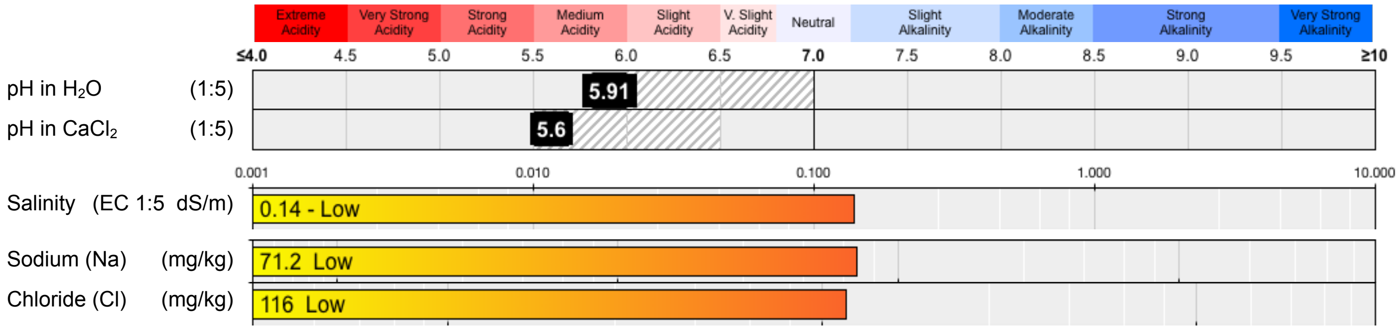
Client Name: **Hornsby Shire Council**
Client Contact: **James Frawley**
Client Order N°:
Address: **PO Box 37**
HORNSBY NSW 2077

Project Name: **Hornsby Parks**
SESL Quote N°:
Sample Name: **BH14 0-75mm**
Description: **Soil**
Test Type: **FSC, OM_WB, P_AD, Ca_AD**

RECOMMENDATIONS

Soil sample BH6 0-75mm is moderately acidic in CaCl2 with desirably low salinity levels. The cation exchange is magnesic therefore is potentially hardsetting. The ECEC is high indicating good nutrient retention. N, P and S are low and need boosting.
Organic matter = 17.6% (very high).
Total P = 0.07%
Total Ca = 0.36%

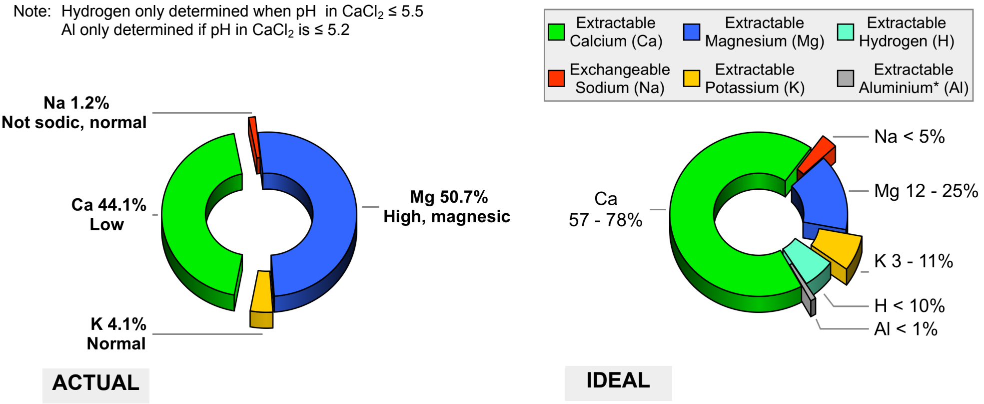
pH and ELECTRICAL CONDUCTIVITY



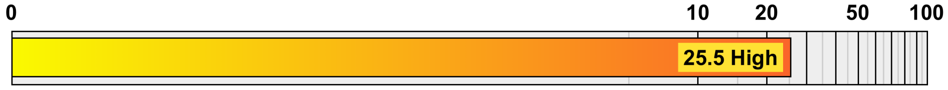
CATION BALANCE

EXCHANGEABLE CATION PERCENTAGE

Note: Hydrogen only determined when pH in $CaCl_2 \le 5.5$
Al only determined if pH in $CaCl_2$ is ≤ 5.2



EFFECTIVE CATION EXCHANGE CAPACITY (eCEC) (cmol(+)/kg)



CATION RATIOS

Ratio	Result	Target Range
Ca:Mg	0.9	4.1 – 6.0
Comment: Potential Calcium deficiency		
Mg:K	12.3	2.6 – 5.0
Comment: Potential Potassium deficiency		
K/(Ca+Mg)	0.04	< 0.07
Comment: Acceptable		
K:Na	3.4	N/A

EXCHANGEABLE CATIONS (cmol(+)/kg)

Na:	K:	Ca:	Mg:	H:	Al:
0.31	1.05	11.24	12.94		

eCEC does not include correction for soluble salts as standard. Where exchangeable calcium exceeds 80 % of eCEC and/or salinity exceeds 0.75 dS/m, alternative methods are recommended to determine true eCEC.

The units of eCEC *cmol(+)/kg* are the SI unit and are equivalent to *meq/100g*.

Soil Chemistry Profile

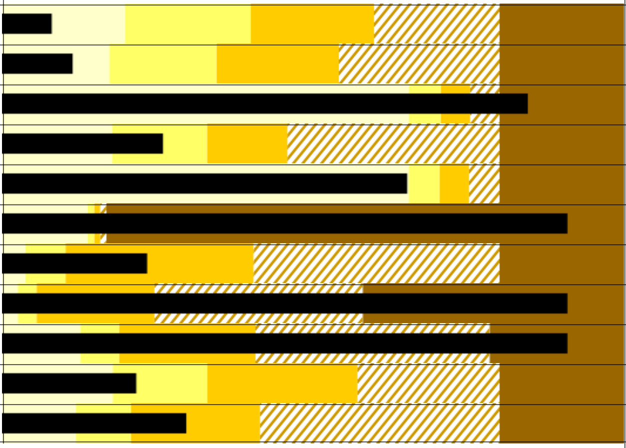
Mehlich 3 - Multi-nutrient Extractant

Sample Drop Off: 16 Chilvers Road
Thornleigh NSW 2120
Mailing Address: PO Box 357
Pennant Hills NSW 1715
Tel: 1300 30 40 80
Fax: 1300 64 46 89
Em: info@sesl.com.au
Web: www.sesl.com.au

Batch N°: 46326 **Sample N°: 5** **Date Received: 10/1/18** **Report Status: ● Draft ○ Final**

PLANT AVAILABLE NUTRIENTS

EFFECTIVE AMELIORATION DEPTH (mm): ● 100 ○ 150 ○ 200 **DESIRED FERTILITY CLASS: ○ Low ● Moderate ○ High**

Major Nutrients	Unit	Result	☐ Very Low ☐ Low ☐ Marginal ▨ Adequate ■ High	Result (g/sqm)	Desirable (g/sqm)	Adjustment (g/sqm)
Nitrate-N (NO_3)	mg N/kg	2.1		0.3	4	3.7
Phosphorus (P)	mg P/kg	9.23		1.2	8.4	7.2
Potassium (K)	mg/kg	410		54.5	51.6	Drawdown
Sulphur (S)	mg S/kg	22		2.9	9	6.1
Calcium (Ca)	mg/kg	2250		299.3	367.5	68.2
Magnesium (Mg)	mg/kg	1572		209.1	38.4	Drawdown
Iron (Fe)	mg/kg	161		21.4	73.4	52
Manganese (Mn)	mg/kg	69		9.2	5.9	Drawdown
Zinc (Zn)	mg/kg	5.8		0.8	0.7	Drawdown
Copper (Cu)	mg/kg	1.7		0.2	0.8	0.6
Boron (B)	mg/kg	1		0.1	0.4	0.3

Explanation of graph ranges:

☐ **Very Low**
Growth is likely to be severely depressed and deficiency symptoms present. Large applications for soil building purposes are usually recommended. Potential response to nutrient addition is >90%.

☐ **Low**
Potential "hidden hunger", or sub-clinical deficiency. Potential response to nutrient addition is 60 to 90%.

☐ **Marginal**
Supply of this nutrient is barely adequate for the plant, and build-up is still recommended. Potential response to nutrient addition is 30 to 60%.

▨ **Adequate**
Supply of this nutrient is adequate for the plant, and and only maintenance application rates are recommended. Potential response to nutrient addition is 5 to 30%.

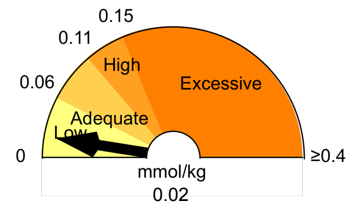
■ **High**
The level is excessive and may be detrimental to plant growth (i.e. phytotoxic) and may contribute to pollution of ground and surface waters. Drawdown is recommended. Potential response to nutrient addition is <2%.

NOTES: Adjustment recommendation calculates the elemental application to shift the soil test level to within the **Adequate** band, which maximises growth/yield, and economic efficiency, and minimises impact on the environment.

Drawdown: The objective nutrient management is to utilise residual soil nutrients. There is no agronomic reason to apply fertiliser when soil test levels exceed **Adequate**.

- g/sqm measurements are based on soil bulk density of 1.33 tonne/m^3 and selected soil depth.

Phosphorus Saturation Index



Low. Plant response to applied P is likely.

Exchangeable Acidity

Adams-Evans Buffer pH (BpH):	-
Sum of Base Cations (cmol(+)/kg):	**25.5**
Eff. Cation Exch. Capacity (eCEC):	**25.5**
Base Saturation (%):	**100**
Exchangeable Acidity (cmol(+)/kg):	-
Exchangeable Acidity (%):	-

Lime Application Rate (g/sqm)

– to achieve pH 6.0:	-
– to neutralise Al:	-

Calculated Gypsum Application Rate (CGAR)

(g/sqm) to achieve 67.5 % exch. Ca: **684**

The CGAR is corrected for the selected effective amelioration depth (100 mm) and any Lime addition to achieve pH 6.0.

PHYSICAL DESCRIPTION

Texture:	**Clay Loam**
Estimated clay content:	**25 - 35%**
Tactually gravelly:	**Not gravelly**
Tactually organic:	**Not Organic**
Calculated EC_{SE} (dS/m):	**1.2**

– Non-saline. Salinity effects on plants are mostly negligible.

Munsell Colour:	**2.5YR 3/2 Dusky Red**
Structure Size:	**Fine (1 - 10mm)**
Structural Organisation:	**Pedal - Moderate**
Structural Unit:	**Crumb**
Potential infiltration rate:	**Moderate**
Est. Permeability Class (mm/hr):	**20 - 60**

Additional comments:

Organic Carbon (OC %):	**8 – Very high**
Organic Matter (OM %):	**17.6**
Est. Field Capacity (% water):	**34**
Est. Permanent Wilting Point (% water):	**18**
Est. Plant Available Water (% water):	**16**
Est. Plant Available Water (mm/m):	**160**

Date Report Generated 12/02/2018

Consultant: Chantal Milner

Authorised Signatory: Simon Leake

METHOD REFERENCES:
pH (1:5 H_2O) - Rayment & Higginson (1992) 4A1,
pH (1:5 $CaCl_2$) - Rayment & Higginson (1992) 4B1,
EC (1:5) - Rayment & Higginson (1992) 3A1,
Chloride - Rayment & Higginson (1992) 5A2,
Nitrate - Rayment & Higginson (1992) 7B1
Aluminium - SESL in-house,
PO_4, K, SO_4, Ca, Mg, Na, Fe, Mn, Zn, Cu, B - Mehlich 3 (1984),
Buffer pH and Hydrogen - Adams-Evans (1972)
Texture/Structure/Colour - PM0003 (Texture-"Northcote" (1992), Structure* - "Murphy" (1991), Colour- "Munsell" (2000))

*Structure analysed in the laboratory is conducted on a disturbed sample, therefore is only a representation of the macro-structures that may be present in the field, which provide an indication of the soil physical characteristics and behaviours that may exist.

Disclaimer
Tests are performed under a quality system complying with ISO 9001: 2008. Results are based on the analysis of the samples collected or received by SESL. Due to the spatial and temporal variability of soils within a given site, and the variability of sampling techniques, environmental conditions and managerial factors, SESL does not accept any liability for a lack of general compliance or performance based on the interpretation and recommendations given (where applicable). This document must not be reproduced except in full.

SESL AUSTRALIA
Environment & Soil Sciences

Soil Chemistry Profile

Mehlich 3 - Multi-nutrient Extractant

Sample Drop Off: 16 Chilvers Road
Thornleigh NSW 2120
Mailing Address: PO Box 357
Pennant Hills NSW 1715
Tel: 1300 30 40 80
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Em: info@sesl.com.au
Web: www.sesl.com.au

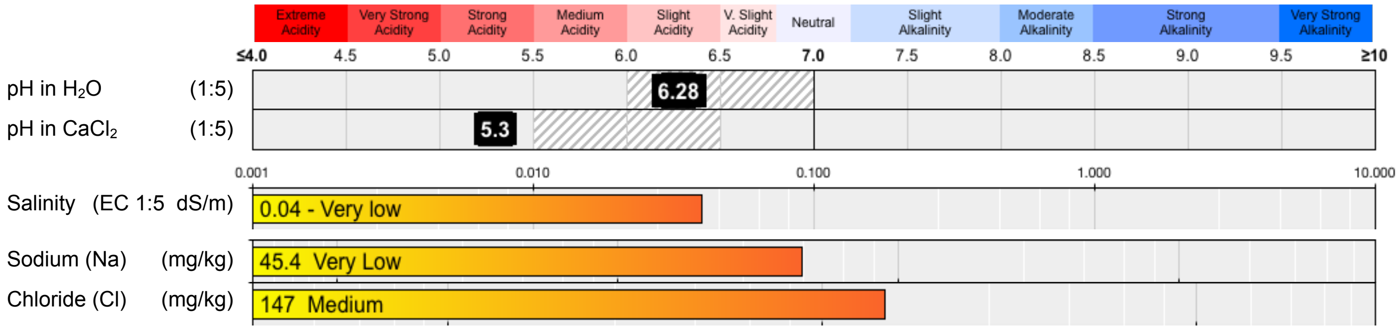
Batch N°: 46326 **Sample N°: 6** **Date Received: 10/1/18** **Report Status:** ● **Draft** ○ **Final**

Client Name:	**Hornsby Shire Council**	Project Name:	**Hornsby Parks**
		SESL Quote N°:	
Client Contact:	**James Frawley**	Sample Name:	**BH14 75-250mm**
Client Order N°:		Description:	**Soil**
Address:	**PO Box 37** **HORNSBY NSW 2077**	Test Type:	**FSC**

RECOMMENDATIONS

Soil sample BH6 75-250mm is strongly acidic in CaCl2 with desirably low salinity levels. The cation exchange is magnesic therefore is potentially hardsetting and is also acidic. The ECEC is moderate indicating good nutrient retention. N, P, K, S and Ca are low and need boosting.

pH and ELECTRICAL CONDUCTIVITY

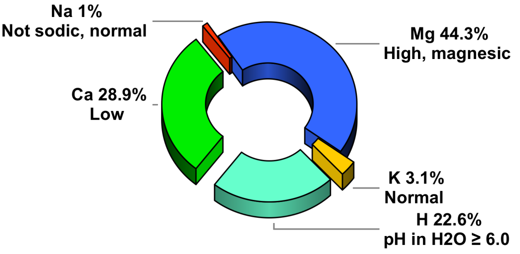


CATION BALANCE

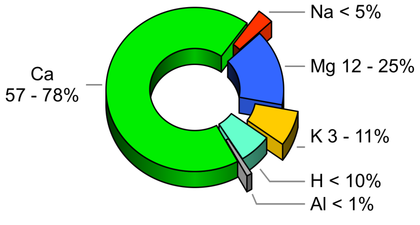
EXCHANGEABLE CATION PERCENTAGE

Note: Hydrogen only determined when pH in $CaCl_2 \leq 5.5$
Al only determined if pH in $CaCl_2$ is ≤ 5.2

🟩 Extractable Calcium (Ca)	🟦 Extractable Magnesium (Mg)	🟩 Extractable Hydrogen (H)
🟥 Exchangeable Sodium (Na)	🟨 Extractable Potassium (K)	⬜ Extractable Aluminium* (Al)

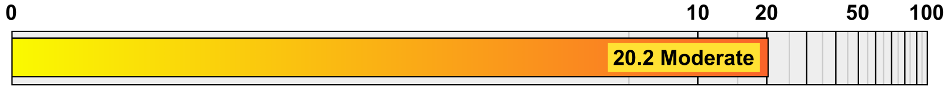


ACTUAL



IDEAL

EFFECTIVE CATION EXCHANGE CAPACITY (eCEC) (cmol(+)/kg)



CATION RATIOS

Ratio	Result	Target Range
Ca:Mg	**0.7**	4.1 – 6.0
Comment: Potential Calcium deficiency		
Mg:K	**14.2**	2.6 – 5.0
Comment: Potential Potassium deficiency		
K/(Ca+Mg)	**0.04**	< 0.07
Comment: Acceptable		
K:Na	**3.2**	N/A

EXCHANGEABLE CATIONS (cmol(+)/kg)

Na:	K:	Ca:	Mg:	H:	Al:
0.20	0.63	5.83	8.95	4.56	

eCEC does not include correction for soluble salts as standard. Where exchangeable calcium exceeds 80 % of eCEC and/or salinity exceeds 0.75 dS/m, alternative methods are recommended to determine true eCEC.

The units of eCEC *cmol(+)/kg* are the SI unit and are equivalent to *meq/100g.*

A member of the Australian Soil and Plant Analysis Council (ASPAC)
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Disclaimer
Tests are performed under a quality system complying with ISO 9001: 2008. Results are based on the analysis of the samples collected or received by SESL. Due to the spatial and temporal variability of soils within a given site, and the variability of sampling techniques, environmental conditions and managerial factors, SESL does not accept any liability for a lack of general compliance or performance based on the interpretation and recommendations given (where applicable). This document must not be reproduced except in full.

SESL AUSTRALIA
Environment & Soil Sciences

Soil Chemistry Profile

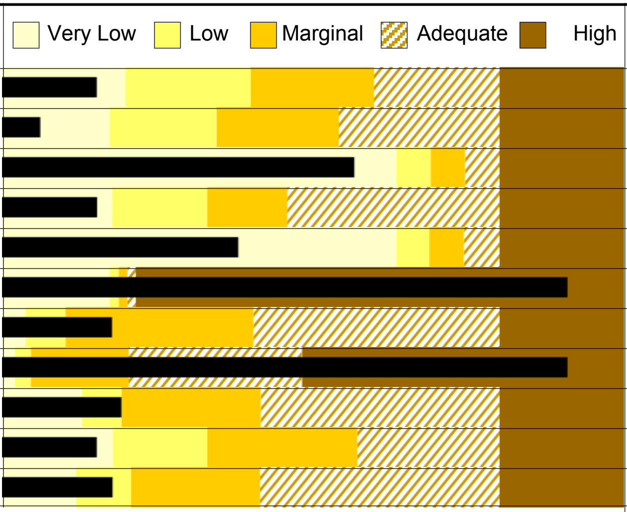
Mehlich 3 - Multi-nutrient Extractant

Sample Drop Off: 16 Chilvers Road
Thornleigh NSW 2120
Mailing Address: PO Box 357
Pennant Hills NSW 1715
Tel: 1300 30 40 80
Fax: 1300 64 46 89
Em: info@sesl.com.au
Web: www.sesl.com.au

Batch N°: 46326 **Sample N°: 6** **Date Received: 10/1/18** **Report Status:** ● Draft ○ Final

PLANT AVAILABLE NUTRIENTS

EFFECTIVE AMELIORATION DEPTH (mm): ● 100 ○ 150 ○ 200 **DESIRED FERTILITY CLASS:** ○ Low ● Moderate ○ High



Major Nutrients	Unit	Result	Result (g/sqm)	Desirable (g/sqm)	Adjustment (g/sqm)
Nitrate-N (NO_3)	mg N/kg	4	0.5	4	3.5
Phosphorus (P)	mg P/kg	<5	0.7	8.4	7.7
Potassium (K)	mg/kg	245	32.6	46	13.4
Sulphur (S)	mg S/kg	13	1.7	9	7.3
Calcium (Ca)	mg/kg	1170	155.6	327.7	172.1
Magnesium (Mg)	mg/kg	1087	144.6	34.2	Drawdown
Iron (Fe)	mg/kg	122	16.2	73.4	57.2
Manganese (Mn)	mg/kg	83	11	5.9	Drawdown
Zinc (Zn)	mg/kg	1.2	0.2	0.7	0.5
Copper (Cu)	mg/kg	1.2	0.2	0.8	0.6
Boron (B)	mg/kg	0.6	0.1	0.4	0.3

Explanation of graph ranges:

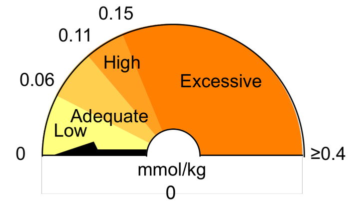
□ **Very Low**	Growth is likely to be severely depressed and deficiency symptoms present. Large applications for soil building purposes are usually recommended. Potential response to nutrient addition is >90%.
□ **Low**	Potential "hidden hunger", or sub-clinical deficiency. Potential response to nutrient addition is 60 to 90%.
■ **Marginal**	Supply of this nutrient is barely adequate for the plant, and build-up is still recommended. Potential response to nutrient addition is 30 to 60%.
▨ **Adequate**	Supply of this nutrient is adequate for the plant, and and only maintenance application rates are recommended. Potential response to nutrient addition is 5 to 30%.
■ **High**	The level is excessive and may be detrimental to plant growth (i.e. phytotoxic) and may contribute to pollution of ground and surface waters. Drawdown is recommended. Potential response to nutrient addition is <2%.

NOTES: Adjustment recommendation calculates the elemental application to shift the soil test level to within the **Adequate** band, which maximises growth/yield, and economic efficiency, and minimises impact on the environment.

Drawdown: The objective nutrient management is to utilise residual soil nutrients. There is no agronomic reason to apply fertiliser when soil test levels exceed **Adequate**.

- g/sqm measurements are based on soil bulk density of 1.33 tonne/m^3 and selected soil depth.

Phosphorus Saturation Index



Low. Plant response to applied P is likely.

Exchangeable Acidity

Adams-Evans Buffer pH (BpH):	**7.3**
Sum of Base Cations (cmol(+)/kg):	**15.6**
Eff. Cation Exch. Capacity (eCEC):	**20.2**
Base Saturation (%):	**77.23**
Exchangeable Acidity (cmol(+)/kg):	-
Exchangeable Acidity (%):	-

Lime Application Rate (g/sqm)

– to achieve pH 6.0: **0**
– to neutralise Al: **-**

Calculated Gypsum Application Rate (CGAR)

(g/sqm) to achieve 67.5 % exch. Ca: **893**

The CGAR is corrected for the selected effective amelioration depth (100 mm) and any Lime addition to achieve pH 6.0.

PHYSICAL DESCRIPTION

Texture:	**Light Clay**
Estimated clay content:	**35 - 40%**
Tactually gravelly:	**Not gravelly**
Tactually organic:	**Not Organic**
Calculated EC_{SE} (dS/m):	**0.3**

– Non-saline. Salinity effects on plants are mostly negligible.

Munsell Colour:	**2.5YR 4/2 Weak Red**
Structure Size:	**Fine (1 - 10mm)**
Structural Organisation:	**Pedal - Moderate**
Structural Unit:	**Crumb**
Potential infiltration rate:	**Slow**
Est. Permeability Class (mm/hr):	**2.5 - 5**
Additional comments:	

Organic Carbon (OC %):	**Did not test**
Organic Matter (OM %):	**-**
Est. Field Capacity (% water):	**38**
Est. Permanent Wilting Point (% water):	**23**
Est. Plant Available Water (% water):	**15**
Est. Plant Available Water (mm/m):	**150**

Date Report Generated 12/02/2018

Consultant: Chantal Milner

Authorised Signatory: Simon Leake

METHOD REFERENCES:
pH (1:5 H_2O) - Rayment & Higginson (1992) 4A1,
pH (1:5 $CaCl_2$) - Rayment & Higginson (1992) 4B1,
EC (1:5) - Rayment & Higginson (1992) 3A1,
Chloride - Rayment & Higginson (1992) 5A2,
Nitrate - Rayment & Higginson (1992) 7B1
Aluminium - SESL in-house,
PO_4, K, SO_4, Ca, Mg, Na, Fe, Mn, Zn, Cu, B - Mehlich 3 (1984),
Buffer pH and Hydrogen - Adams-Evans (1972)
Texture/Structure/Colour - PM0003 (Texture-"Northcote" (1992), Structure* - "Murphy" (1991), Colour- "Munsell" (2000))

*Structure analysed in the laboratory is conducted on a disturbed sample, therefore is only a representation of the macro-structures that may be present in the field, which provide an indication of the soil physical characteristics and behaviours that may exist.

SESL AUSTRALIA
Environment & Soil Sciences

Soil Chemistry Profile

Mehlich 3 - Multi-nutrient Extractant

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Em: info@sesl.com.au
Web: www.sesl.com.au

Batch N°: 46326 **Sample N°: 7** **Date Received: 10/1/18** **Report Status: ● Draft ○ Final**

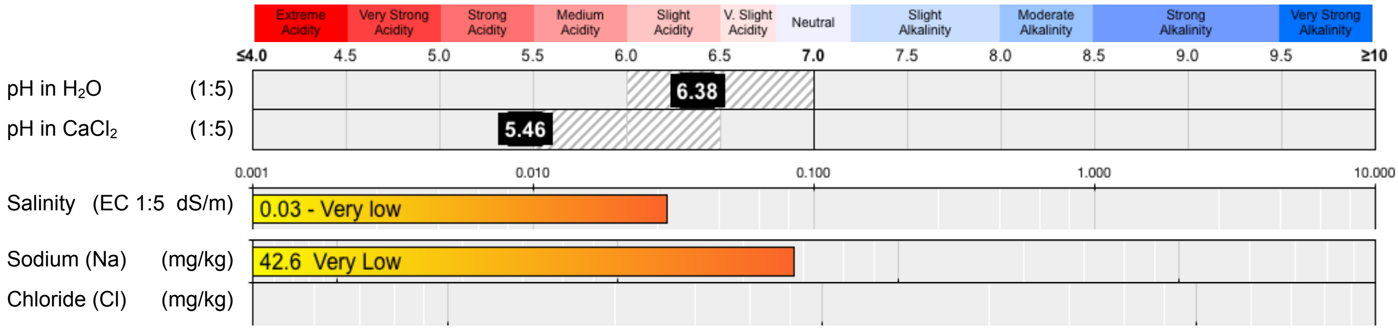
Client Name: **Hornsby Shire Council**
Client Contact: **James Frawley**
Client Order N°:
Address: **PO Box 37**
HORNSBY NSW 2077

Project Name: **Hornsby Parks**
SESL Quote N°:
Sample Name: **BH14 250+mm**
Description: **Soil**
Test Type: **SSCP**

RECOMMENDATIONS

Soil sample BH6 250mm+ is strongly acidic in CaCl2 with desirably low salinity levels. The cation exchange is magnesic therefore is potentially hardsetting. The ECEC is moderate indicating good nutrient retention. Tested nutrients are low.

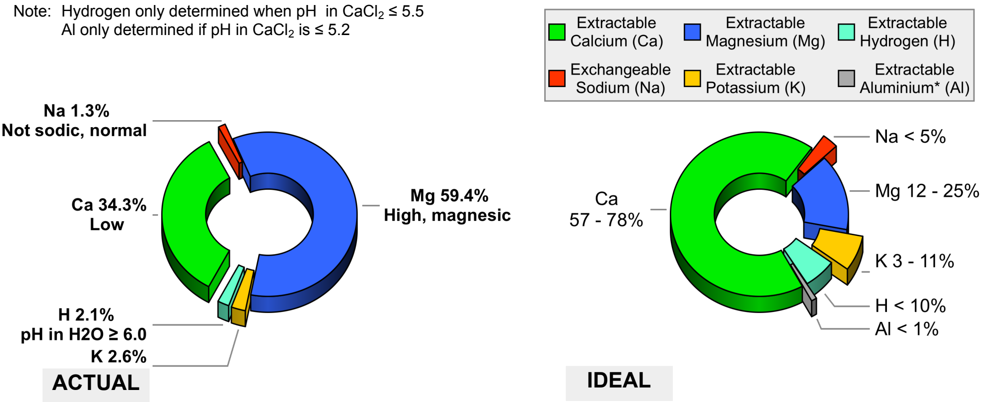
pH and ELECTRICAL CONDUCTIVITY



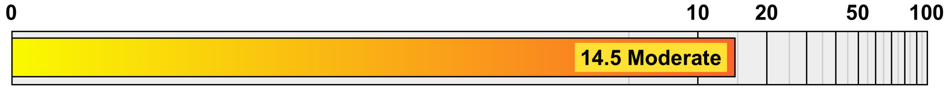
CATION BALANCE

EXCHANGEABLE CATION PERCENTAGE

Note: Hydrogen only determined when pH in $CaCl_2 \leq 5.5$
Al only determined if pH in $CaCl_2$ is ≤ 5.2



EFFECTIVE CATION EXCHANGE CAPACITY (eCEC) (cmol(+)/kg)



CATION RATIOS

Ratio	Result	Target Range
Ca:Mg	0.6	4.1 – 6.0
Comment: Potential Calcium deficiency		
Mg:K	22.7	2.6 – 5.0
Comment: Potential Potassium deficiency		
K/(Ca+Mg)	0.03	< 0.07
Comment: Acceptable		
K:Na	2	N/A

EXCHANGEABLE CATIONS (cmol(+)/kg)

Na:	K:	Ca:	Mg:	H:	Al:
0.19	0.38	4.98	8.61	0.31	

eCEC does not include correction for soluble salts as standard. Where exchangeable calcium exceeds 80 % of eCEC and/or salinity exceeds 0.75 dS/m, alternative methods are recommended to determine true eCEC.

The units of eCEC *cmol(+)/kg* are the SI unit and are equivalent to *meq/100g*.

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Soil Chemistry Profile

Mehlich 3 - Multi-nutrient Extractant

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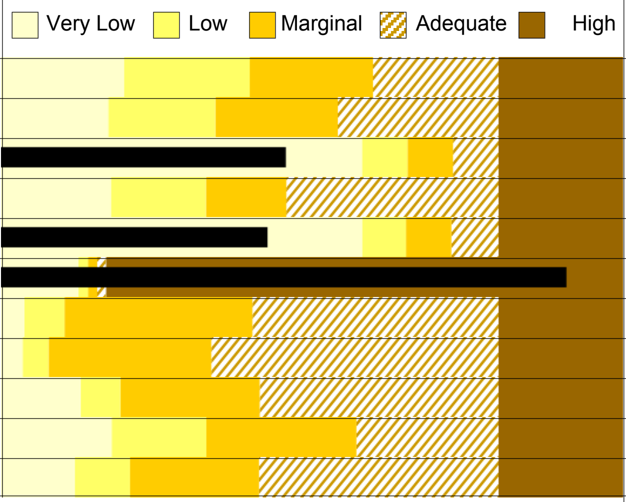
Em: info@sesl.com.au
Web: www.sesl.com.au

Batch N°: 46326 **Sample N°: 7** **Date Received: 10/1/18** **Report Status: ● Draft ○ Final**

PLANT AVAILABLE NUTRIENTS

EFFECTIVE AMELIORATION DEPTH (mm): ● 100 ○ 150 ○ 200 **DESIRED FERTILITY CLASS: ○ Low ● Moderate ○ High**



Major Nutrients	Unit	Result	☐ Very Low ☐ Low ☐ Marginal ▨ Adequate ■ High	Result (g/sqm)	Desirable (g/sqm)	Adjustment (g/sqm)
Nitrate-N (NO_3)	mg N/kg	-		-	4	Did not test
Phosphorus (P)	mg P/kg	-		-	8.4	Did not test
Potassium (K)	mg/kg	150		20	34.8	14.8
Sulphur (S)	mg S/kg	-		-	9	9
Calcium (Ca)	mg/kg	999		132.9	248	115.1
Magnesium (Mg)	mg/kg	1046		139.1	25.8	Drawdown
Iron (Fe)	mg/kg	-		-	73.4	Did not test
Manganese (Mn)	mg/kg	-		-	5.9	Did not test
Zinc (Zn)	mg/kg	-		-	0.7	Did not test
Copper (Cu)	mg/kg	-		-	0.8	Did not test
Boron (B)	mg/kg	-		-	0.4	Did not test

Explanation of graph ranges:

☐ **Very Low**
Growth is likely to be severely depressed and deficiency symptoms present. Large applications for soil building purposes are usually recommended. Potential response to nutrient addition is >90%.

☐ **Low**
Potential "hidden hunger", or sub-clinical deficiency. Potential response to nutrient addition is 60 to 90%.

☐ **Marginal**
Supply of this nutrient is barely adequate for the plant, and build-up is still recommended. Potential response to nutrient addition is 30 to 60%.

▨ **Adequate**
Supply of this nutrient is adequate for the plant, and and only maintenance application rates are recommended. Potential response to nutrient addition is 5 to 30%.

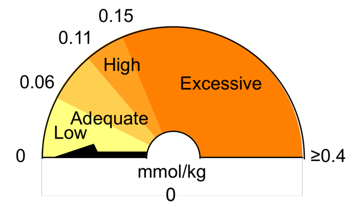
■ **High**
The level is excessive and may be detrimental to plant growth (i.e. phytotoxic) and may contribute to pollution of ground and surface waters. Drawdown is recommended. Potential response to nutrient addition is <2%.

NOTES: Adjustment recommendation calculates the elemental application to shift the soil test level to within the **Adequate** band, which maximises growth/yield, and economic efficiency, and minimises impact on the environment.

Drawdown: The objective nutrient management is to utilise residual soil nutrients. There is no agronomic reason to apply fertiliser when soil test levels exceed **Adequate**.

- g/sqm measurements are based on soil bulk density of 1.33 tonne/m^3 and selected soil depth.

Phosphorus Saturation Index



Low. Plant response to applied P is likely.

Exchangeable Acidity

Adams-Evans Buffer pH (BpH):	**8**
Sum of Base Cations (cmol(+)/kg):	**14.2**
Eff. Cation Exch. Capacity (eCEC):	**14.5**
Base Saturation (%):	**97.93**
Exchangeable Acidity (cmol(+)/kg):	**-**
Exchangeable Acidity (%):	**-**

Lime Application Rate (g/sqm)

– to achieve pH 6.0:	**0**
– to neutralise Al:	**-**

Calculated Gypsum Application Rate (CGAR)

(g/sqm) to achieve 67.5 % exch. Ca: **550**

The CGAR is corrected for the selected effective amelioration depth (100 mm) and any Lime addition to achieve pH 6.0.

PHYSICAL DESCRIPTION

Texture:	**Light Clay**
Estimated clay content:	**35 - 40%**
Tactually gravelly:	**Not gravelly**
Tactually organic:	**Not Organic**
Calculated EC_{SE} (dS/m):	**0.3**

– Non-saline. Salinity effects on plants are mostly negligible.

Munsell Colour:	**5YR 4/3 Reddish**
Structure Size:	**Medium (11 - 25mm)**
Structural Organisation:	**Pedal - Strong**
Structural Unit:	**Crumb**
Potential infiltration rate:	**Slow**
Est. Permeability Class (mm/hr):	**5 - 20**
Additional comments:	

Organic Carbon (OC %):	**Did not test**
Organic Matter (OM %):	**-**
Est. Field Capacity (% water):	**38**
Est. Permanent Wilting Point (% water):	**23**
Est. Plant Available Water (% water):	**15**
Est. Plant Available Water (mm/m):	**150**

Date Report Generated 12/02/2018

Consultant: Chantal Milner

Authorised Signatory: Simon Leake

METHOD REFERENCES:
pH (1:5 H_2O) - Rayment & Higginson (1992) 4A1,
pH (1:5 $CaCl_2$) - Rayment & Higginson (1992) 4B1,
EC (1:5) - Rayment & Higginson (1992) 3A1,
Chloride - Rayment & Higginson (1992) 5A2,
Nitrate - Rayment & Higginson (1992) 7B1
Aluminium - SESL in-house,
PO_4, K, SO_4, Ca, Mg, Na, Fe, Mn, Zn, Cu, B - Mehlich 3 (1984),
Buffer pH and Hydrogen - Adams-Evans (1972)
Texture/Structure/Colour - PM0003 (Texture-"Northcote" (1992), Structure* - "Murphy" (1991), Colour- "Munsell" (2000))

*Structure analysed in the laboratory is conducted on a disturbed sample, therefore is only a representation of the macro-structures that may be present in the field, which provide an indication of the soil physical characteristics and behaviours that may exist.

SESL AUSTRALIA
Environment & Soil Sciences

Soil Chemistry Profile

Mehlich 3 - Multi-nutrient Extractant

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Em: info@sesl.com.au
Web: www.sesl.com.au

Batch N°: 46326 **Sample N°: 8** **Date Received: 10/1/18** **Report Status: ● Draft ○ Final**

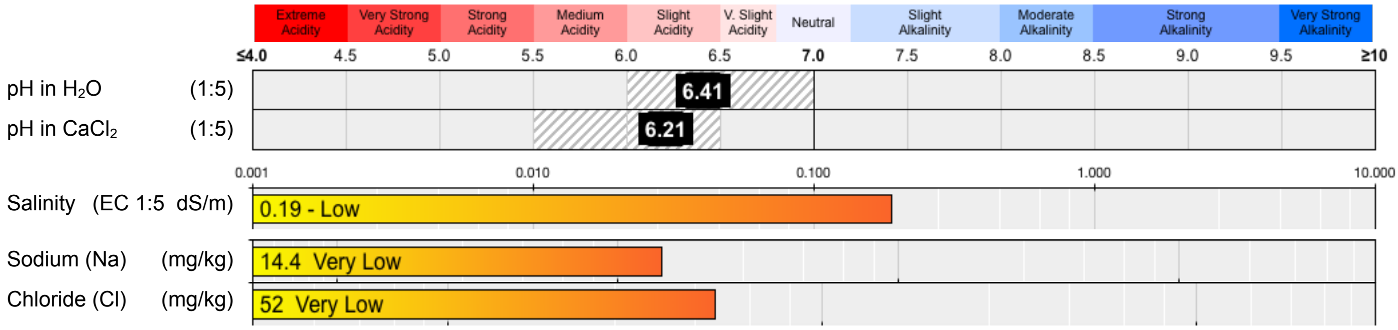
Client Name: **Hornsby Shire Council**
Client Contact: **James Frawley**
Client Order N°:
Address: **PO Box 37**
HORNSBY NSW 2077

Project Name: **Hornsby Parks**
SESL Quote N°:
Sample Name: **BH16**
Description: **Soil**
Test Type: **FSC, OM_WB, P_AD, Ca_AD**

RECOMMENDATIONS

Soil sample BH8 is slightly acidic in CaCl2 with desirably low salinity levels. The cation exchange is magnesic therefore is potentially hardsetting. The ECEC is high indicating good nutrient retention. P and S are low and need boosting.
Organic matter = 13.5% (very high).
Total P = 0.11%
Total Ca = 0.68%

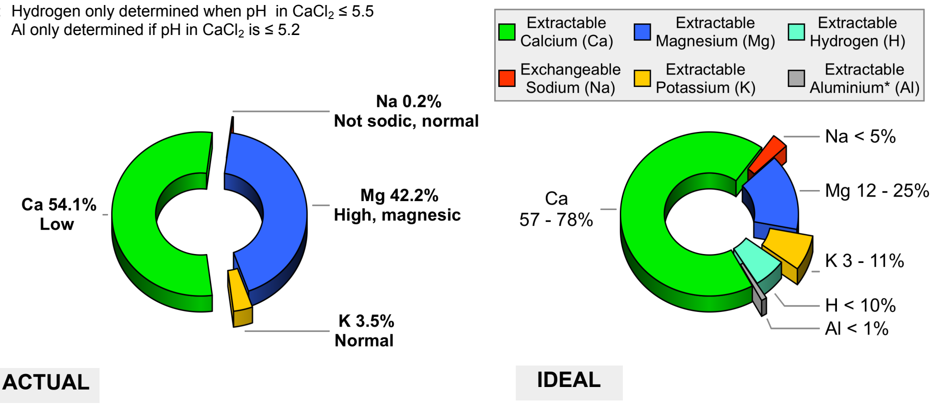
pH and ELECTRICAL CONDUCTIVITY



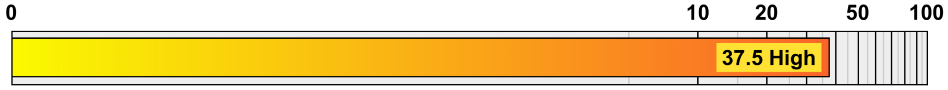
CATION BALANCE

EXCHANGEABLE CATION PERCENTAGE

Note: Hydrogen only determined when pH in $CaCl_2$ ≤ 5.5
Al only determined if pH in $CaCl_2$ is ≤ 5.2



EFFECTIVE CATION EXCHANGE CAPACITY (eCEC) (cmol(+)/kg)



CATION RATIOS

Ratio	Result	Target Range
Ca:Mg	**1.3**	4.1 – 6.0
Comment: Calcium low		
Mg:K	**12.2**	2.6 – 5.0
Comment: Potential Potassium deficiency		
K/(Ca+Mg)	**0.04**	< 0.07
Comment: Acceptable		
K:Na	**21.7**	N/A

EXCHANGEABLE CATIONS (cmol(+)/kg)

Na:	K:	Ca:	Mg:	H:	Al:
0.06	1.30	20.29	15.84		

eCEC does not include correction for soluble salts as standard. Where exchangeable calcium exceeds 80 % of eCEC and/or salinity exceeds 0.75 dS/m, alternative methods are recommended to determine true eCEC.

The units of eCEC *cmol(+)/kg* are the SI unit and are equivalent to *meq/100g*.

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SESL AUSTRALIA
Environment & Soil Sciences

Soil Chemistry Profile

Mehlich 3 - Multi-nutrient Extractant

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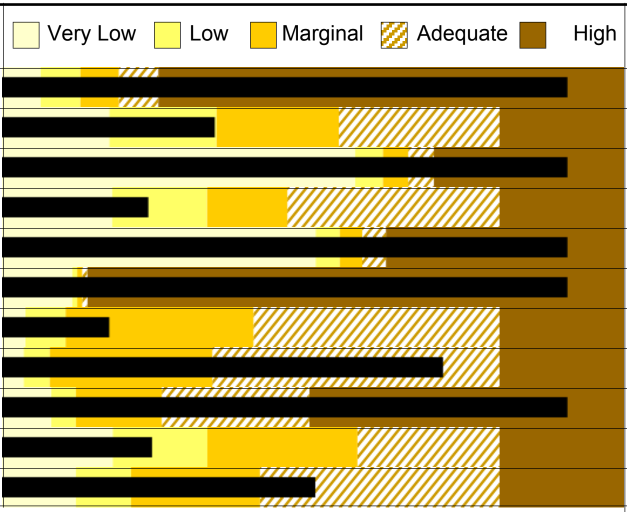
Batch N°: 46326 **Sample N°: 8** **Date Received: 10/1/18** **Report Status: ● Draft ○ Final**

PLANT AVAILABLE NUTRIENTS

EFFECTIVE AMELIORATION DEPTH (mm): ● 100 ○ 150 ○ 200 **DESIRED FERTILITY CLASS: ○ Low ● Moderate ○ High**



Major Nutrients	Unit	Result	Result (g/sqm)	Desirable (g/sqm)	Adjustment (g/sqm)
Nitrate-N (NO_3)	mg N/kg	76	10.1	4	Maintenance
Phosphorus (P)	mg P/kg	27.8	3.7	8.4	4.7
Potassium (K)	mg/kg	508	67.6	51.6	Drawdown
Sulphur (S)	mg S/kg	20	2.7	9	6.3
Calcium (Ca)	mg/kg	4070	541.3	367.5	Drawdown
Magnesium (Mg)	mg/kg	1925	256	38.4	Drawdown
Iron (Fe)	mg/kg	119	15.8	73.4	57.6
Manganese (Mn)	mg/kg	39	5.2	5.9	0.7
Zinc (Zn)	mg/kg	9.2	1.2	0.7	Drawdown
Copper (Cu)	mg/kg	1.9	0.3	0.8	0.5
Boron (B)	mg/kg	1.7	0.2	0.4	0.2

Explanation of graph ranges:

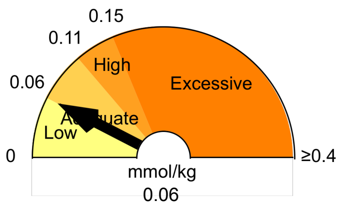
- ☐ **Very Low** Growth is likely to be severely depressed and deficiency symptoms present. Large applications for soil building purposes are usually recommended. Potential response to nutrient addition is >90%.
- ☐ **Low** Potential "hidden hunger", or sub-clinical deficiency. Potential response to nutrient addition is 60 to 90%.
- ☐ **Marginal** Supply of this nutrient is barely adequate for the plant, and build-up is still recommended. Potential response to nutrient addition is 30 to 60%.
- ▨ **Adequate** Supply of this nutrient is adequate for the plant, and and only maintenance application rates are recommended. Potential response to nutrient addition is 5 to 30%.
- ■ **High** The level is excessive and may be detrimental to plant growth (i.e. phytotoxic) and may contribute to pollution of ground and surface waters. Drawdown is recommended. Potential response to nutrient addition is <2%.

NOTES: Adjustment recommendation calculates the elemental application to shift the soil test level to within the **Adequate** band, which maximises growth/yield, and economic efficiency, and minimises impact on the environment.

Drawdown: The objective nutrient management is to utilise residual soil nutrients. There is no agronomic reason to apply fertiliser when soil test levels exceed **Adequate**.

• g/sqm measurements are based on soil bulk density of 1.33 tonne/m^3 and selected soil depth.

Phosphorus Saturation Index



Adequate. Economic response to P unlikely. P application recommended maintaining current P level

Exchangeable Acidity

Adams-Evans Buffer pH (BpH): **-**
Sum of Base Cations (cmol(+)/kg): **37.5**
Eff. Cation Exch. Capacity (eCEC): **37.5**
Base Saturation (%): **100**
Exchangeable Acidity (cmol(+)/kg): **-**
Exchangeable Acidity (%): **-**

Lime Application Rate (g/sqm)

– to achieve pH 6.0: **0**
– to neutralise Al: **-**

Calculated Gypsum Application Rate (CGAR)
(g/sqm) to achieve 67.5 % exch. Ca: **575**

The CGAR is corrected for the selected effective amelioration depth (100 mm) and any Lime addition to achieve pH 6.0.

PHYSICAL DESCRIPTION

Texture: **Loam Fine Sandy**
Estimated clay content: **25%**
Tactually gravelly: **Not gravelly**
Tactually organic: **Not Organic**
Calculated EC_{SE} (dS/m): **1.8**
– Non-saline. Salinity effects on plants are mostly negligible.

Munsell Colour: **7.5YR 3/2 Dark Brown**
Structure Size: **Fine (1 - 10mm)**
Structural Organisation: **Pedal - Weak**
Structural Unit: **Crumb**
Potential infiltration rate: **Rapid**
Est. Permeability Class (mm/hr): **20 - 60**
Additional comments:

Organic Carbon (OC %): **6.1 – Very high**
Organic Matter (OM %): **13.5**
Est. Field Capacity (% water): **28**
Est. Permanent Wilting Point (% water): **12**
Est. Plant Available Water (% water): **16**
Est. Plant Available Water (mm/m): **160**

Date Report Generated 12/02/2018

Consultant: Chantal Milner

Authorised Signatory: Simon Leake

METHOD REFERENCES:
pH (1:5 H_2O) - Rayment & Higginson (1992) 4A1,
pH (1:5 $CaCl_2$) - Rayment & Higginson (1992) 4B1,
EC (1:5) - Rayment & Higginson (1992) 3A1,
Chloride - Rayment & Higginson (1992) 5A2,
Nitrate - Rayment & Higginson (1992) 7B1
Aluminium - SESL in-house,
PO_4, K, SO_4, Ca, Mg, Na, Fe, Mn, Zn, Cu, B - Mehlich 3 (1984),
Buffer pH and Hydrogen - Adams-Evans (1972)
Texture/Structure/Colour - PM0003 (Texture- "Northcote" (1992), Structure* - "Murphy" (1991), Colour- "Munsell" (2000))

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This laboratory participates in, and is awarded certification based on results of the scores returned in, ASPAC inter-laboratory proficiency rounds. For detailed current certification status and for more information on the ASPAC inter-laboratory proficiency testing programs, see the ASPAC website: http://www.aspac-australasia.com

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Tests are performed under a quality system complying with ISO 9001: 2008. Results are based on the analysis of the samples collected or received by SESL. Due to the spatial and temporal variability of soils within a given site, and the variability of sampling techniques, environmental conditions and managerial factors, SESL does not accept any liability for a lack of general compliance or performance based on the interpretation and recommendations given (where applicable). This document must not be reproduced except in full.

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Environment & Soil Sciences

Physical Soil Profile

Sample Drop Off: 16 Chilvers Road
Thornleigh NSW 2120
Tel: 1300 30 40 80
Fax: 1300 64 46 89
Mailing Address: PO Box 357
Pennant Hills NSW 1715
Em: info@sesl.com.au
Web: www.sesl.com.au

Batch N°: 46326A **Date Received: 18/1/18** **Report Status: ● Draft ○ Final**

Client Name: **Hornsby Shire Council**
Project Name: **Hornsby Parks**
SESL Quote N°:
Client Contact: **James Frawley**
Sample Name: **BH9 0-300mm**
Client Order N°:
Description: **Soil**
Address: **PO Box 37**
HORNSBY NSW 2077
Test Type: **CSP**

1

BH9 0-300mm

Texture : Clay Loam
Structural Unit : Crumb
Aggregate Strength : Pedal - Weak
Colour : 7.5YR 3/1 Very Dark Gray
Ksat (mm/hr) : 5 - 20
Potential Infiltration Rate : Moderate

2

BH10 0-200mm

Texture : Clay Loam
Structural Unit : Crumb
Aggregate Strength : Pedal - Weak
Colour : 10YR 3/1 Very Dark Gray
Ksat (mm/hr) : 5 - 20
Potential Infiltration Rate : Moderate

3

BH11 0-400mm

Texture : Clay Loam
Structural Unit : Crumb
Aggregate Strength : Pedal - Weak
Colour : 10YR 4/1 Dark Gray
Ksat (mm/hr) : 5 - 20
Potential Infiltration Rate : Moderate

4

BH12 0-100mm

Texture : Light Medium Clay
Structural Unit : Crumb
Aggregate Strength : Pedal - Moderate
Colour : 7.5YR 5/8 Strong Brown
Ksat (mm/hr) : 2.5 - 5
Potential Infiltration Rate : Slow

Date Report Generated
12/02/2018

Consultant
Chantal Milner

Authorised Signatory
Simon Leake

Physical Soil Profile

Batch N°: 46326A **Date Received: 18/1/18** **Report Status: ● Draft ○ Final**

Client Name: **Hornsby Shire Council**
Project Name: **Hornsby Parks**
SESL Quote N°:
Client Contact: **James Frawley**
Sample Name: **BH14 0-75mm**
Client Order N°:
Description: **Soil**
Address: **PO Box 37**
HORNSBY NSW 2077
Test Type: **CSP**

5

BH14 0-75mm

Texture : Clay Loam
Structural Unit : Crumb
Aggregate Strength : Pedal - Moderate
Colour : 2.5YR 3/2 Dusky Red
Ksat (mm/hr) : 20 - 60
Potential Infiltration Rate : Moderate

6

BH14 75-250mm

Texture : Light Clay
Structural Unit : Crumb
Aggregate Strength : Pedal - Moderate
Colour : 2.5YR 4/2 Weak Red
Ksat (mm/hr) : 2.5 - 5
Potential Infiltration Rate : Slow

7

BH14 250+mm

Texture : -
Structural Unit :
Aggregate Strength : -
Colour : 5YR 4/3 Reddish Brown
Ksat (mm/hr) : Did not test
Potential Infiltration Rate : Did not test

8

BH16

Texture : Loam Fine Sandy
Structural Unit : Crumb
Aggregate Strength : Pedal - Weak
Colour : 7.5YR 3/2 Dark Brown
Ksat (mm/hr) : 20 - 60
Potential Infiltration Rate : Rapid

Date Report Generated
12/02/2018

Consultant
Chantal Milner

Authorised Signatory
Simon Leake

Total Elemental Analysis

Sample Drop Off: 16 Chilvers Road
Thornleigh NSW 2120
Tel: 1300 30 40 80
Fax: 1300 64 46 89
Mailing Address: PO Box 357
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Batch N°: 46326 **Sample N°: 1** **Date Received: 10/1/18** **Report Status: ◉ Draft ○ Final**

Client Name: **Hornsby Shire Council**
Client Contact: **James Frawley**
Client Order N°:
Address: **PO Box 37**
HORNSBY NSW 2077

Project Name: **Hornsby Parks**
SESL Quote N°:
Sample Name: **BH9 0-300mm**
Description: **Soil**
Test Type: **FSC, OM_WB, P_AD, Ca_AD**

Category	Element		Results:	Comments
Major Elements %	Nitrogen	(N)	-	
	Phosphorus	(P)	0.073	
	Potassium	(K)	-	
Minor Elements %	Calcium	(Ca)	0.802	
	Magnesium	(Mg)	-	
	Sulphur	(S)	-	
	Sodium	(Na)	-	
	Chloride	(Cl)	0.01	
Trace Elements mg/kg	Iron	(Fe)	-	
	Manganese	(Mn)	-	
	Zinc	(Zn)	-	
	Copper	(Cu)	-	
	Boron	(B)	-	
Heavy Metals mg/kg	Molybdenum	(Mo)	-	
	Arsenic	(As)	-	
	Cadmium	(Cd)	-	
	Cobalt	(Co)	-	
	Chromium	(Cr)	-	
	Lead	(Pb)	-	
	Mercury	(Hg)	-	
	Selenium	(Se)	-	
	Nickel	(Ni)	-	
	Silver	(Ag)	-	

Summary and Recommendations

Consultant:

Chantal Milner

Checked by:

Simon Leake

Date Report Generated 12/02/2018

Results given on a dry weight basis unless otherwise stated.

Explanation of the Methods:
N:- Leco Furnace or Kjeldahl.
Heavy Metals:- Multiacid digest - AAS, ICP or CVAP finish.
Major, Minor & Trace Elements by HCl or Aqua Regia digest - AAS finish.

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Total Elemental Analysis

Sample Drop Off: 16 Chilvers Road
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Batch N°: 46326 **Sample N°: 2** **Date Received: 10/1/18** **Report Status: ● Draft ○ Final**

Client Name: **Hornsby Shire Council**
Client Contact: **James Frawley**
Client Order N°:
Address: **PO Box 37**
HORNSBY NSW 2077

Project Name: **Hornsby Parks**
SESL Quote N°:
Sample Name: **BH10 0-200mm**
Description: **Soil**
Test Type: **FSC, OM_WB, P_AD, Ca_AD**

Category	Element		Results:	Comments
Major Elements %	Nitrogen	(N)	-	
	Phosphorus	(P)	0.113	
	Potassium	(K)	-	
Minor Elements %	Calcium	(Ca)	2.47	
	Magnesium	(Mg)	-	
	Sulphur	(S)	-	
	Sodium	(Na)	-	
	Chloride	(Cl)	0.01	
Trace Elements mg/kg	Iron	(Fe)	-	
	Manganese	(Mn)	-	
	Zinc	(Zn)	-	
	Copper	(Cu)	-	
	Boron	(B)	-	
Heavy Metals mg/kg	Molybdenum	(Mo)	-	
	Arsenic	(As)	-	
	Cadmium	(Cd)	-	
	Cobalt	(Co)	-	
	Chromium	(Cr)	-	
	Lead	(Pb)	-	
	Mercury	(Hg)	-	
	Selenium	(Se)	-	
	Nickel	(Ni)	-	
	Silver	(Ag)	-	

Summary and Recommendations

Consultant:

Chantal Milner

Checked by:

Simon Leake

Date Report Generated 12/02/2018

Results given on a dry weight basis unless otherwise stated.

Explanation of the Methods:
N:- Leco Furnace or Kjeldahl.
Heavy Metals:- Multiacid digest - AAS, ICP or CVAP finish.
Major, Minor & Trace Elements by HCl or Aqua Regia digest - AAS finish.

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Total Elemental Analysis

Sample Drop Off: 16 Chilvers Road
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Em: info@sesl.com.au
Web: www.sesl.com.au

Batch N°: 46326 **Sample N°: 3** **Date Received: 10/1/18** **Report Status:** ● **Draft** ○ **Final**

Client Name: **Hornsby Shire Council**
Client Contact: **James Frawley**
Client Order N°:
Address: **PO Box 37**
HORNSBY NSW 2077

Project Name: **Hornsby Parks**
SESL Quote N°:
Sample Name: **BH11 0-400mm**
Description: **Soil**
Test Type: **FSC, OM_WB, P_AD, Ca_AD**

Category	Element		Results:	Comments
Major Elements %	Nitrogen	(N)	-	
	Phosphorus	(P)	0.092	
	Potassium	(K)	-	
Minor Elements %	Calcium	(Ca)	0.808	
	Magnesium	(Mg)	-	
	Sulphur	(S)	-	
	Sodium	(Na)	-	
	Chloride	(Cl)	0	
Trace Elements mg/kg	Iron	(Fe)	-	
	Manganese	(Mn)	-	
	Zinc	(Zn)	-	
	Copper	(Cu)	-	
	Boron	(B)	-	
Heavy Metals mg/kg	Molybdenum	(Mo)	-	
	Arsenic	(As)	-	
	Cadmium	(Cd)	-	
	Cobalt	(Co)	-	
	Chromium	(Cr)	-	
	Lead	(Pb)	-	
	Mercury	(Hg)	-	
	Selenium	(Se)	-	
	Nickel	(Ni)	-	
	Silver	(Ag)	-	

Summary and Recommendations

Consultant:

Chantal Milner

Checked by:

Simon Leake

Date Report Generated 12/02/2018

Results given on a dry weight basis unless otherwise stated.

Explanation of the Methods:
N:- Leco Furnace or Kjeldahl.
Heavy Metals:- Multiacid digest - AAS, ICP or CVAP finish.
Major, Minor & Trace Elements by HCl or Aqua Regia digest - AAS finish.

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Total Elemental Analysis

Sample Drop Off: 16 Chilvers Road
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Web: www.sesl.com.au

Batch N°: 46326 **Sample N°: 4** **Date Received: 10/1/18** **Report Status: ● Draft ○ Final**

Client Name: **Hornsby Shire Council**
Client Contact: **James Frawley**
Client Order N°:
Address: **PO Box 37**
HORNSBY NSW 2077

Project Name: **Hornsby Parks**
SESL Quote N°:
Sample Name: **BH12 0-100mm**
Description: **Soil**
Test Type: **ECEC_M3, P_AD, Ca_AD**

Category	Element		Results:	Comments
Major Elements %	Nitrogen	(N)	-	
	Phosphorus	(P)	0.01	
	Potassium	(K)	-	
Minor Elements %	Calcium	(Ca)	0.022	
	Magnesium	(Mg)	-	
	Sulphur	(S)	-	
	Sodium	(Na)	-	
	Chloride	(Cl)	-	
Trace Elements mg/kg	Iron	(Fe)	-	
	Manganese	(Mn)	-	
	Zinc	(Zn)	-	
	Copper	(Cu)	-	
	Boron	(B)	-	
Heavy Metals mg/kg	Molybdenum	(Mo)	-	
	Arsenic	(As)	-	
	Cadmium	(Cd)	-	
	Cobalt	(Co)	-	
	Chromium	(Cr)	-	
	Lead	(Pb)	-	
	Mercury	(Hg)	-	
	Selenium	(Se)	-	
	Nickel	(Ni)	-	
	Silver	(Ag)	-	

Summary and Recommendations

Consultant:

Chantal Milner

Checked by:

Simon Leake

Date Report Generated 12/02/2018

Results given on a dry weight basis unless otherwise stated.

Explanation of the Methods:
N:- Leco Furnace or Kjeldahl.
Heavy Metals:- Multiacid digest - AAS, ICP or CVAP finish.
Major, Minor & Trace Elements by HCl or Aqua Regia digest - AAS finish.

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Environment & Soil Sciences

Total Elemental Analysis

Sample Drop Off: 16 Chilvers Road
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Batch N°: 46326 **Sample N°: 5** **Date Received: 10/1/18** **Report Status:** ● **Draft** ○ **Final**

Client Name: **Hornsby Shire Council**
Client Contact: **James Frawley**
Client Order N°:
Address: **PO Box 37**
HORNSBY NSW 2077

Project Name: **Hornsby Parks**
SESL Quote N°:
Sample Name: **BH14 0-75mm**
Description: **Soil**
Test Type: **FSC, OM_WB, P_AD, Ca_AD**

Category	Element		Results:	Comments
Major Elements %	Nitrogen	(N)	-	
	Phosphorus	(P)	0.067	
	Potassium	(K)	-	
Minor Elements %	Calcium	(Ca)	0.359	
	Magnesium	(Mg)	-	
	Sulphur	(S)	-	
	Sodium	(Na)	-	
	Chloride	(Cl)	0.01	
Trace Elements mg/kg	Iron	(Fe)	-	
	Manganese	(Mn)	-	
	Zinc	(Zn)	-	
	Copper	(Cu)	-	
	Boron	(B)	-	
Heavy Metals mg/kg	Molybdenum	(Mo)	-	
	Arsenic	(As)	-	
	Cadmium	(Cd)	-	
	Cobalt	(Co)	-	
	Chromium	(Cr)	-	
	Lead	(Pb)	-	
	Mercury	(Hg)	-	
	Selenium	(Se)	-	
	Nickel	(Ni)	-	
	Silver	(Ag)	-	

Summary and Recommendations

Consultant:

Chantal Milner

Checked by:

Simon Leake

Date Report Generated 12/02/2018

Results given on a dry weight basis unless otherwise stated.

Explanation of the Methods:
N:- Leco Furnace or Kjeldahl.
Heavy Metals:- Multiacid digest - AAS, ICP or CVAP finish.
Major, Minor & Trace Elements by HCl or Aqua Regia digest - AAS finish.

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Total Elemental Analysis

Sample Drop Off: 16 Chilvers Road
Thornleigh NSW 2120
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Pennant Hills NSW 1715
Em: info@sesl.com.au
Web: www.sesl.com.au

Batch N°: 46326 **Sample N°: 8** **Date Received: 10/1/18** **Report Status:** ● **Draft** ○ **Final**

Client Name: **Hornsby Shire Council**
Client Contact: **James Frawley**
Client Order N°:
Address: **PO Box 37**
HORNSBY NSW 2077

Project Name: **Hornsby Parks**
SESL Quote N°:
Sample Name: **BH16**
Description: **Soil**
Test Type: **FSC, OM_WB, P_AD, Ca_AD**

Category	Element		Results:	Comments
Major Elements %	Nitrogen	(N)	-	
	Phosphorus	(P)	0.106	
	Potassium	(K)	-	
Minor Elements %	Calcium	(Ca)	0.676	
	Magnesium	(Mg)	-	
	Sulphur	(S)	-	
	Sodium	(Na)	-	
	Chloride	(Cl)	0.01	
Trace Elements mg/kg	Iron	(Fe)	-	
	Manganese	(Mn)	-	
	Zinc	(Zn)	-	
	Copper	(Cu)	-	
	Boron	(B)	-	
Heavy Metals mg/kg	Molybdenum	(Mo)	-	
	Arsenic	(As)	-	
	Cadmium	(Cd)	-	
	Cobalt	(Co)	-	
	Chromium	(Cr)	-	
	Lead	(Pb)	-	
	Mercury	(Hg)	-	
	Selenium	(Se)	-	
	Nickel	(Ni)	-	
	Silver	(Ag)	-	

Summary and Recommendations

Consultant:

Chantal Milner

Checked by:

Simon Leake

Date Report Generated 12/02/2018

Results given on a dry weight basis unless otherwise stated.

Explanation of the Methods:
N:- Leco Furnace or Kjeldahl.
Heavy Metals:- Multiacid digest - AAS, ICP or CVAP finish.
Major, Minor & Trace Elements by HCl or Aqua Regia digest - AAS finish.

Appendix C

Laboratory Analysis: Site Visit 3

SESL AUSTRALIA
Environment & Soil Sciences

Soil Chemistry Profile

Mehlich 3 - Multi-nutrient Extractant

Sample Drop Off: 16 Chilvers Road
Thornleigh NSW 2120
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Pennant Hills NSW 1715
Tel: 1300 30 40 80
Fax: 1300 64 46 89
Em: info@sesl.com.au
Web: www.sesl.com.au

Batch N°: 46403 **Sample N°: 1** **Date Received: 17/1/18** **Report Status: ● Draft ○ Final**

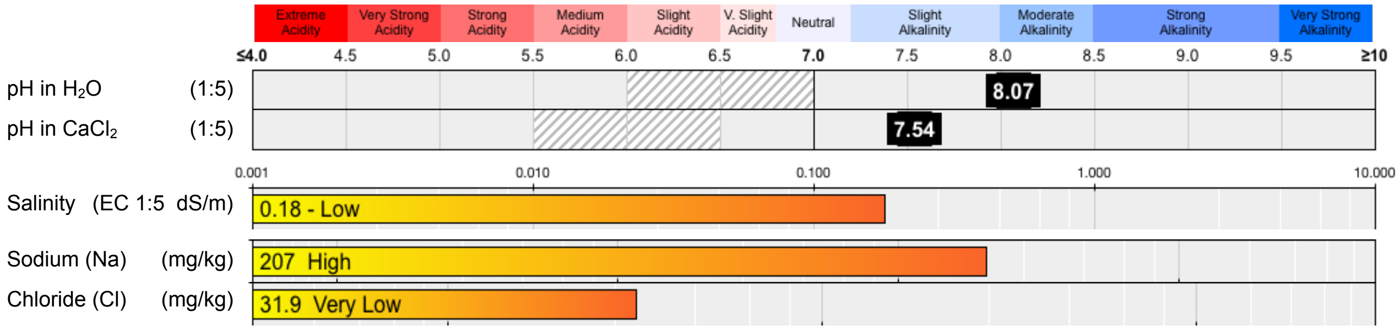
Client Name:	**Hornsby Shire Council**	Project Name:	**Site assessment 3 - Hornsby Park**
		SESL Quote N°:	
Client Contact:	**James Frawley**	Sample Name:	**Excavation 1**
Client Order N°:		Description:	**Soil**
Address:	**PO Box 37** **HORNSBY NSW 2077**	Test Type:	**FSC, OM_WB, BSP**

RECOMMENDATIONS

Soil is slightly alkaline in CaCl2 with low salinity and chloride levels but high sodium, The cation exchange is highly magnesic and has a very high eCEC. Calcium, magnesium and manganese levels are very high. Organic matter is low at 0.7%

This soil is a fine sandy clay loam with a moderate polyhedral structure and moderate permeability.

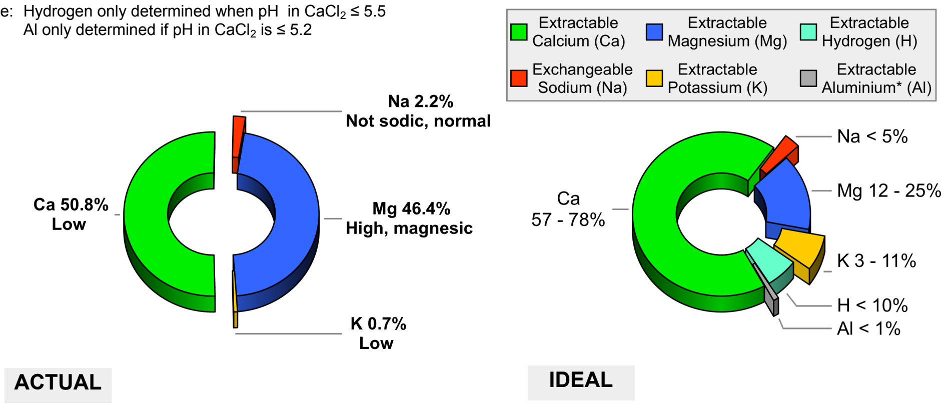
pH and ELECTRICAL CONDUCTIVITY



CATION BALANCE

EXCHANGEABLE CATION PERCENTAGE

Note: Hydrogen only determined when pH in $CaCl_2 \leq 5.5$
Al only determined if pH in $CaCl_2$ is ≤ 5.2



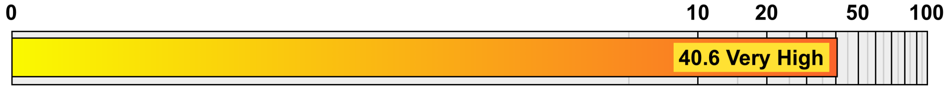
CATION RATIOS

Ratio	Result	Target Range
Ca:Mg	**1.1**	4.1 – 6.0
Comment: Calcium low		
Mg:K	**62.8**	2.6 – 5.0
Comment: Potential Potassium deficiency		
K/(Ca+Mg)	**0.01**	< 0.07
Comment: Acceptable		
K:Na	**0.3**	N/A

EXCHANGEABLE CATIONS (cmol(+)/kg)

Na:	K:	Ca:	Mg:	H:	Al:
0.90	0.30	20.61	18.83		

EFFECTIVE CATION EXCHANGE CAPACITY (eCEC) (cmol(+)/kg)



eCEC does not include correction for soluble salts as standard. Where exchangeable calcium exceeds 80 % of eCEC and/or salinity exceeds 0.75 dS/m, alternative methods are recommended to determine true eCEC.

The units of eCEC *cmol(+)/kg* are the SI unit and are equivalent to *meq/100g.*

SESL AUSTRALIA
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Soil Chemistry Profile

Mehlich 3 - Multi-nutrient Extractant

Sample Drop Off: 16 Chilvers Road
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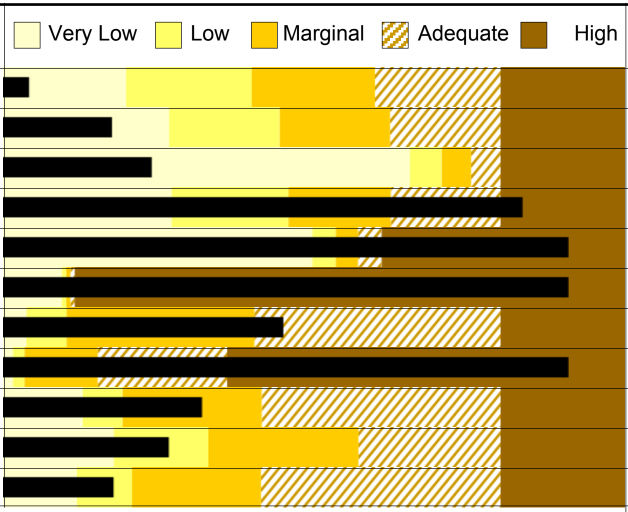
Batch N°: 46403 **Sample N°: 1** **Date Received: 17/1/18** **Report Status: ● Draft ○ Final**

PLANT AVAILABLE NUTRIENTS

EFFECTIVE AMELIORATION DEPTH (mm): ● 100 ○ 150 ○ 200 **DESIRED FERTILITY CLASS: ○ Low ● Moderate ○ High**



Major Nutrients	Unit	Result	Result (g/sqm)	Desirable (g/sqm)	Adjustment (g/sqm)
Nitrate-N (NO_3)	mg N/kg	1.1	0.1	4	3.9
Phosphorus (P)	mg P/kg	13.8	1.8	8.4	6.6
Potassium (K)	mg/kg	116	15.4	51.6	36.2
Sulphur (S)	mg S/kg	71	9.4	9	Drawdown
Calcium (Ca)	mg/kg	4130	549.3	367.5	Drawdown
Magnesium (Mg)	mg/kg	2288	304.3	38.4	Drawdown
Iron (Fe)	mg/kg	311	41.4	73.4	32
Manganese (Mn)	mg/kg	111	14.8	5.9	Drawdown
Zinc (Zn)	mg/kg	2	0.3	0.7	0.4
Copper (Cu)	mg/kg	2.1	0.3	0.8	0.5
Boron (B)	mg/kg	0.6	0.1	0.4	0.3

Explanation of graph ranges:

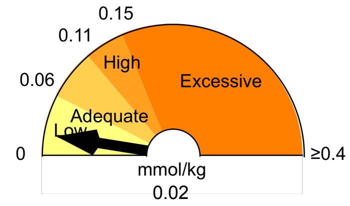
☐ Very Low	🟨 Low	🟧 Marginal	▨ Adequate	🟫 High
Growth is likely to be severely depressed and deficiency symptoms present. Large applications for soil building purposes are usually recommended. Potential response to nutrient addition is >90%.	Potential "hidden hunger", or sub-clinical deficiency. Potential response to nutrient addition is 60 to 90%.	Supply of this nutrient is barely adequate for the plant, and build-up is still recommended. Potential response to nutrient addition is 30 to 60%.	Supply of this nutrient is adequate for the plant, and and only maintenance application rates are recommended. Potential response to nutrient addition is 5 to 30%.	The level is excessive and may be detrimental to plant growth (i.e. phytotoxic) and may contribute to pollution of ground and surface waters. Drawdown is recommended. Potential response to nutrient addition is <2%.

NOTES: Adjustment recommendation calculates the elemental application to shift the soil test level to within the **Adequate** band, which maximises growth/yield, and economic efficiency, and minimises impact on the environment.

Drawdown: The objective nutrient management is to utilise residual soil nutrients. There is no agronomic reason to apply fertiliser when soil test levels exceed **Adequate**.

- g/sqm measurements are based on soil bulk density of 1.33 tonne/m^3 and selected soil depth.

Phosphorus Saturation Index



Low. Plant response to applied P is likely.

Exchangeable Acidity

Adams-Evans Buffer pH (BpH):	-
Sum of Base Cations (cmol(+)/kg):	**40.6**
Eff. Cation Exch. Capacity (eCEC):	**40.6**
Base Saturation (%):	**100**
Exchangeable Acidity (cmol(+)/kg):	-
Exchangeable Acidity (%):	-

Lime Application Rate (g/sqm)

– to achieve pH 6.0:	**0**
– to neutralise Al:	-

Calculated Gypsum Application Rate (CGAR)

(g/sqm) to achieve 67.5 % exch. Ca: **778**

The CGAR is corrected for the selected effective amelioration depth (100 mm) and any Lime addition to achieve pH 6.0.

PHYSICAL DESCRIPTION

Texture:	**Fine Sandy Clay Loam**
Estimated clay content:	**20 - 30%**
Tactually gravelly:	**Gravelly**
Tactually organic:	**Not Organic**
Calculated EC_{SE} (dS/m):	**1.5**

– Non-saline. Salinity effects on plants are mostly negligible.

Munsell Colour:	-
Structure Size:	**Medium (11 - 25mm)**
Structural Organisation:	**Pedal - Moderate**
Structural Unit:	**Polyhedral**
Potential infiltration rate:	**Moderate**
Est. Permeability Class (mm/hr):	**20 - 60**
Additional comments:	

Organic Carbon (OC %):	**0.7 – Low**
Organic Matter (OM %):	**1.5**
Est. Field Capacity (% water):	**28**
Est. Permanent Wilting Point (% water):	**15**
Est. Plant Available Water (% water):	**13**
Est. Plant Available Water (mm/m):	**130**

Date Report Generated 12/02/2018

Consultant: Chantal Milner

Authorised Signatory: Simon Leake

METHOD REFERENCES:
pH (1:5 H_2O) - Rayment & Higginson (1992) 4A1,
pH (1:5 $CaCl_2$) - Rayment & Higginson (1992) 4B1,
EC (1:5) - Rayment & Higginson (1992) 3A1,
Chloride - Rayment & Higginson (1992) 5A2,
Nitrate - Rayment & Higginson (1992) 7B1
Aluminium - SESL in-house,
PO_4, K, SO_4, Ca, Mg, Na, Fe, Mn, Zn, Cu, B - Mehlich 3 (1984),
Buffer pH and Hydrogen - Adams-Evans (1972)
Texture/Structure/Colour - PM0003 (Texture-
"Northcote" (1992), Structure* - "Murphy" (1991), Colour- "Munsell" (2000))

*Structure analysed in the laboratory is conducted on a disturbed sample, therefore is only a representation of the macro-structures that may be present in the field, which provide an indication of the soil physical characteristics and behaviours that may exist.

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Soil Chemistry Profile

Mehlich 3 - Multi-nutrient Extractant

Sample Drop Off: 16 Chilvers Road
Thornleigh NSW 2120
Mailing Address: PO Box 357
Pennant Hills NSW 1715
Tel: 1300 30 40 80
Fax: 1300 64 46 89
Em: info@sesl.com.au
Web: www.sesl.com.au

Batch N°: 46403 **Sample N°: 2** **Date Received: 17/1/18** **Report Status: ● Draft ○ Final**

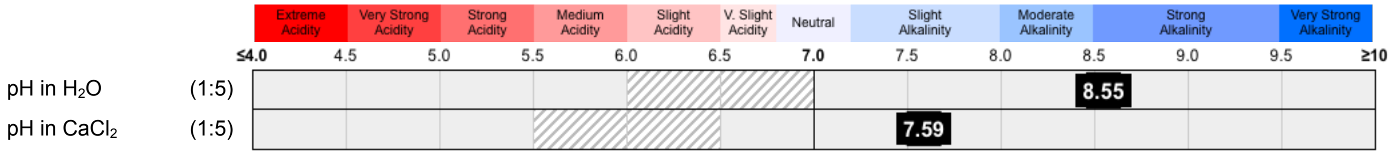
Client Name: **Hornsby Shire Council**
Client Contact: **James Frawley**
Client Order N°:
Address: **PO Box 37**
HORNSBY NSW 2077

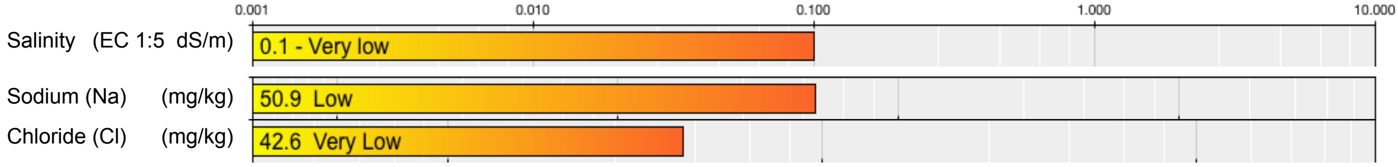
Project Name: **Site assessment 3 - Hornsby Park**
SESL Quote N°:
Sample Name: **Excavation 2 0-200**
Description: **Soil**
Test Type: **FSC, OM_WB, BSP**

RECOMMENDATIONS

Soil is slightly alkaline in CaCl2 with low salinity, sodium and chloride levels. The cation exchange is close to being balanced and has a high eCEC. Calcium, magnesium and manganese levels are very high. Organic matter is low at 1.4%
This soil is a fine sandy clay loam with a moderate polyhedral structure and moderate permeability.

pH and ELECTRICAL CONDUCTIVITY

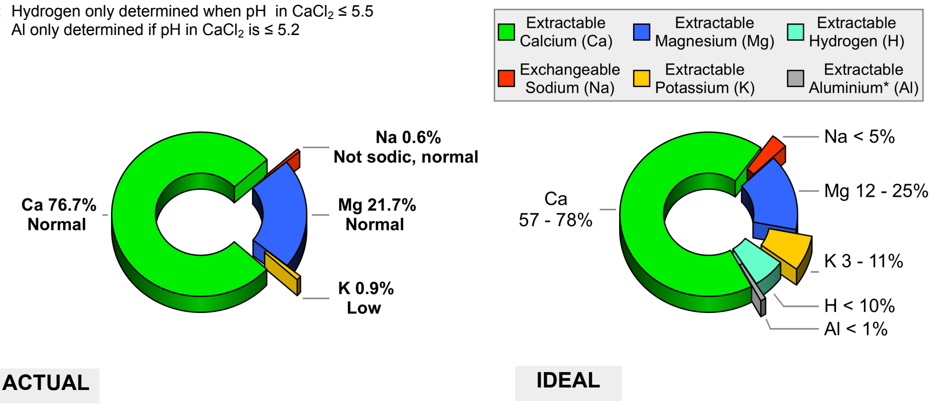




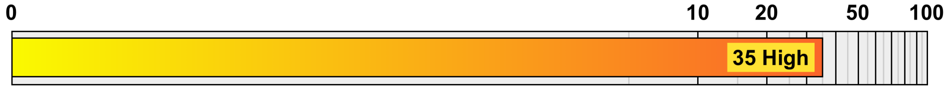
CATION BALANCE

EXCHANGEABLE CATION PERCENTAGE

Note: Hydrogen only determined when pH in $CaCl_2 \leq 5.5$
Al only determined if pH in $CaCl_2$ is ≤ 5.2



EFFECTIVE CATION EXCHANGE CAPACITY (eCEC) (cmol(+)/kg)



CATION RATIOS

Ratio	Result	Target Range
Ca:Mg	**3.5**	4.1 – 6.0
Comment: Calcium low		
Mg:K	**23.7**	2.6 – 5.0
Comment: Potential Potassium deficiency		
K/(Ca+Mg)	**0.01**	< 0.07
Comment: Acceptable		
K:Na	**1.5**	N/A

EXCHANGEABLE CATIONS (cmol(+)/kg)

Na:	K:	Ca:	Mg:	H:	Al:
0.22	0.32	26.83	7.59		

eCEC does not include correction for soluble salts as standard. Where exchangeable calcium exceeds 80 % of eCEC and/or salinity exceeds 0.75 dS/m, alternative methods are recommended to determine true eCEC.

The units of eCEC *cmol(+)/kg* are the SI unit and are equivalent to *meq/100g.*

ASPAC

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Soil Chemistry Profile

Mehlich 3 - Multi-nutrient Extractant

Sample Drop Off: 16 Chilvers Road
Thornleigh NSW 2120
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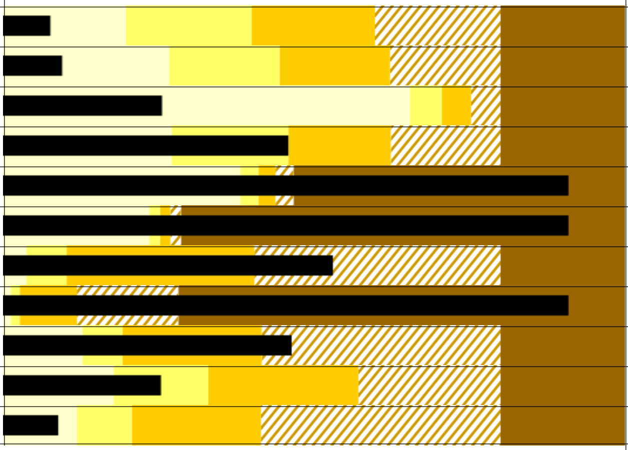
Em: info@sesl.com.au
Web: www.sesl.com.au

Batch N°: 46403 **Sample N°: 2** **Date Received: 17/1/18** **Report Status:** ● **Draft** ○ **Final**

PLANT AVAILABLE NUTRIENTS

EFFECTIVE AMELIORATION DEPTH (mm): ● 100 ○ 150 ○ 200 **DESIRED FERTILITY CLASS:** ○ Low ● Moderate ○ High

Major Nutrients	Unit	Result	☐ Very Low ☐ Low ☐ Marginal ▨ Adequate ■ High	Result (g/sqm)	Desirable (g/sqm)	Adjustment (g/sqm)
Nitrate-N (NO_3)	mg N/kg	2		0.3	4	3.7
Phosphorus (P)	mg P/kg	7.49		1	8.4	7.4
Potassium (K)	mg/kg	124		16.5	51.6	35.1
Sulphur (S)	mg S/kg	39		5.2	9	3.8
Calcium (Ca)	mg/kg	5380		715.5	367.5	Drawdown
Magnesium (Mg)	mg/kg	922		122.6	38.4	Drawdown
Iron (Fe)	mg/kg	366		48.7	73.4	24.7
Manganese (Mn)	mg/kg	142		18.9	5.9	Drawdown
Zinc (Zn)	mg/kg	2.9		0.4	0.7	0.3
Copper (Cu)	mg/kg	2		0.3	0.8	0.5
Boron (B)	mg/kg	0.3		0	0.4	0.4



Explanation of graph ranges:

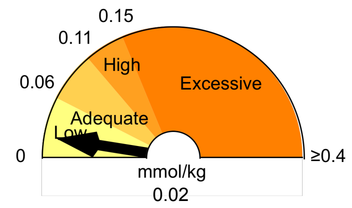
☐ **Very Low**	☐ **Low**	☐ **Marginal**	▨ **Adequate**	■ **High**
Growth is likely to be severely depressed and deficiency symptoms present. Large applications for soil building purposes are usually recommended. Potential response to nutrient addition is >90%.	Potential "hidden hunger", or sub-clinical deficiency. Potential response to nutrient addition is 60 to 90%.	Supply of this nutrient is barely adequate for the plant, and build-up is still recommended. Potential response to nutrient addition is 30 to 60%.	Supply of this nutrient is adequate for the plant, and and only maintenance application rates are recommended. Potential response to nutrient addition is 5 to 30%.	The level is excessive and may be detrimental to plant growth (i.e. phytotoxic) and may contribute to pollution of ground and surface waters. Drawdown is recommended. Potential response to nutrient addition is <2%.

NOTES: Adjustment recommendation calculates the elemental application to shift the soil test level to within the **Adequate** band, which maximises growth/yield, and economic efficiency, and minimises impact on the environment.

Drawdown: The objective nutrient management is to utilise residual soil nutrients. There is no agronomic reason to apply fertiliser when soil test levels exceed **Adequate**.

- g/sqm measurements are based on soil bulk density of 1.33 tonne/m^3 and selected soil depth.

Phosphorus Saturation Index



Low. Plant response to applied P is likely.

Exchangeable Acidity

Adams-Evans Buffer pH (BpH): **-**
Sum of Base Cations (cmol(+)/kg): **35**
Eff. Cation Exch. Capacity (eCEC): **35**
Base Saturation (%): **100**
Exchangeable Acidity (cmol(+)/kg): **-**
Exchangeable Acidity (%): **-**

Lime Application Rate (g/sqm)

– to achieve pH 6.0: **0**
– to neutralise Al: **-**

Calculated Gypsum Application Rate (CGAR)

(g/sqm) to achieve 67.5 % exch. Ca: **0**

The CGAR is corrected for the selected effective amelioration depth (100 mm) and any Lime addition to achieve pH 6.0.

PHYSICAL DESCRIPTION

Texture: **Fine Sandy Clay Loam**
Estimated clay content: **20 - 30%**
Tactually gravelly: **Gravelly**
Tactually organic: **Not Organic**
Calculated EC_{SE} (dS/m): **0.9**
– Non-saline. Salinity effects on plants are mostly negligible.

Munsell Colour: **-**
Structure Size: **Fine (1 - 10mm)**
Structural Organisation: **Pedal - Moderate**
Structural Unit: **Polyhedral**
Potential infiltration rate: **Moderate**
Est. Permeability Class (mm/hr): **20 - 60**
Additional comments:

Organic Carbon (OC %): **1.4 – Moderate**
Organic Matter (OM %): **3**
Est. Field Capacity (% water): **28**
Est. Permanent Wilting Point (% water): **15**
Est. Plant Available Water (% water): **13**
Est. Plant Available Water (mm/m): **130**

Date Report Generated 12/02/2018

Consultant: Chantal Milner

Authorised Signatory: Simon Leake

METHOD REFERENCES:
pH (1:5 H_2O) - Rayment & Higginson (1992) 4A1,
pH (1:5 $CaCl_2$) - Rayment & Higginson (1992) 4B1,
EC (1:5) - Rayment & Higginson (1992) 3A1,
Chloride - Rayment & Higginson (1992) 5A2,
Nitrate - Rayment & Higginson (1992) 7B1
Aluminium - SESL in-house,
PO_4, K, SO_4, Ca, Mg, Na, Fe, Mn, Zn, Cu, B - Mehlich 3 (1984),
Buffer pH and Hydrogen - Adams-Evans (1972)
Texture/Structure/Colour - PM0003 (Texture- "Northcote" (1992), Structure* - "Murphy" (1991), Colour- "Munsell" (2000))

*Structure analysed in the laboratory is conducted on a disturbed sample, therefore is only a representation of the macro-structures that may be present in the field, which provide an indication of the soil physical characteristics and behaviours that may exist.

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Soil Chemistry Profile

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Web: www.sesl.com.au

Batch N°: 46403 **Sample N°: 3** **Date Received: 17/1/18** **Report Status:** ● **Draft** ○ **Final**

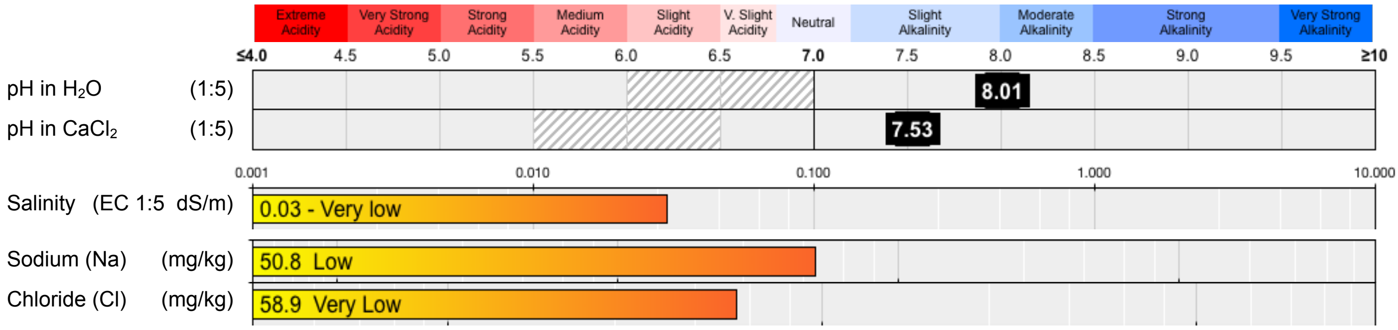
Client Name: **Hornsby Shire Council**
Client Contact: **James Frawley**
Client Order N°:
Address: **PO Box 37**
HORNSBY NSW 2077

Project Name: **Site assessment 3 - Hornsby Park**
SESL Quote N°:
Sample Name: **Excavation 2 comp**
Description: **Soil**
Test Type: **FSC, OM_WB, BSP**

RECOMMENDATIONS

Soil is slightly alkaline in CaCl2 with low salinity, sodium and chloride levels. The cation exchange is highly magnesic and has a high eCEC. Calcium, magnesium and manganese levels are very high. Organic matter is low at 1.1%
This soil is a light sandy clay loam with a moderate polyhedral structure and rapid permeability.

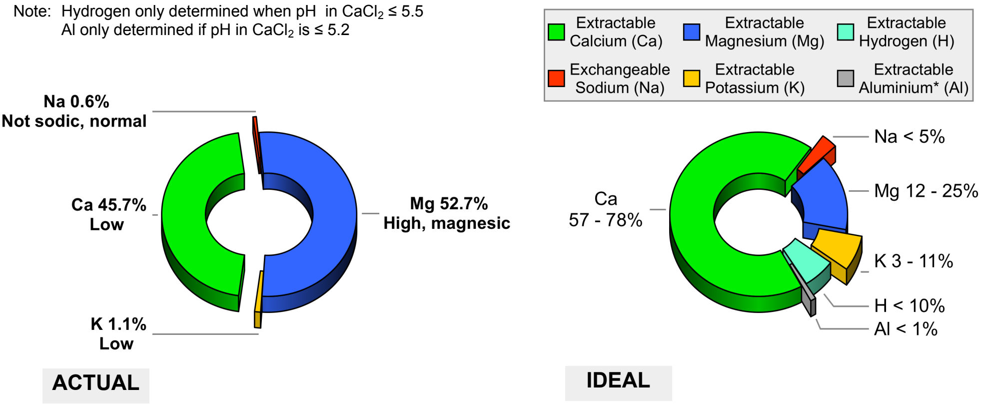
pH and ELECTRICAL CONDUCTIVITY



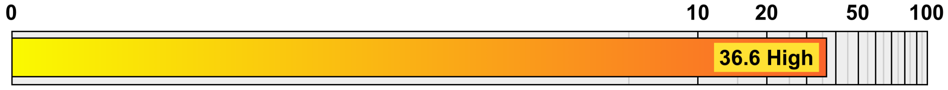
CATION BALANCE

EXCHANGEABLE CATION PERCENTAGE

Note: Hydrogen only determined when pH in $CaCl_2 \leq 5.5$
Al only determined if pH in $CaCl_2$ is ≤ 5.2



EFFECTIVE CATION EXCHANGE CAPACITY (eCEC) (cmol(+)/kg)



CATION RATIOS

Ratio	Result	Target Range
Ca:Mg	0.9	4.1 – 6.0
Comment: Potential Calcium deficiency		
Mg:K	45.9	2.6 – 5.0
Comment: Potential Potassium deficiency		
K/(Ca+Mg)	0.01	< 0.07
Comment: Acceptable		
K:Na	1.9	N/A

EXCHANGEABLE CATIONS (cmol(+)/kg)

Na:	K:	Ca:	Mg:	H:	Al:
0.22	0.42	16.71	19.28		

eCEC does not include correction for soluble salts as standard. Where exchangeable calcium exceeds 80 % of eCEC and/or salinity exceeds 0.75 dS/m, alternative methods are recommended to determine true eCEC.

The units of eCEC *cmol(+)/kg* are the SI unit and are equivalent to *meq/100g.*

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Mehlich 3 - Multi-nutrient Extractant

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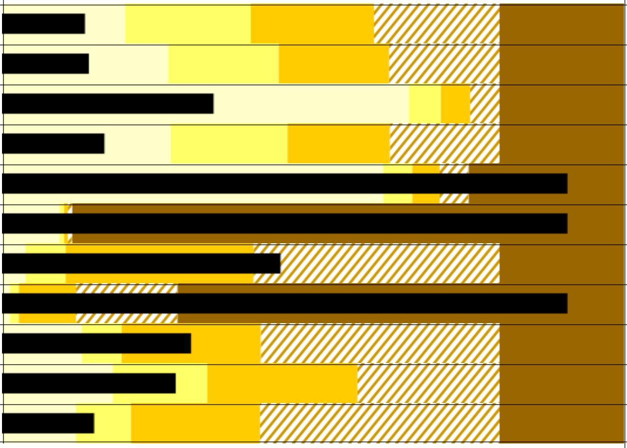
Batch N°: 46403 **Sample N°: 3** **Date Received: 17/1/18** **Report Status:** ● **Draft** ○ **Final**

PLANT AVAILABLE NUTRIENTS

EFFECTIVE AMELIORATION DEPTH (mm): ● 100 ○ 150 ○ 200 **DESIRED FERTILITY CLASS:** ○ Low ● Moderate ○ High



Major Nutrients	Unit	Result	▢ Very Low ▢ Low ▢ Marginal ▨ Adequate ■ High	Result (g/sqm)	Desirable (g/sqm)	Adjustment (g/sqm)
Nitrate-N (NO_3)	mg N/kg	3.5		0.5	4	3.5
Phosphorus (P)	mg P/kg	11		1.5	8.4	6.9
Potassium (K)	mg/kg	165		21.9	51.6	29.7
Sulphur (S)	mg S/kg	14		1.9	9	7.1
Calcium (Ca)	mg/kg	3350		445.6	367.5	Drawdown
Magnesium (Mg)	mg/kg	2343		311.6	38.4	Drawdown
Iron (Fe)	mg/kg	309		41.1	73.4	32.3
Manganese (Mn)	mg/kg	142		18.9	5.9	Drawdown
Zinc (Zn)	mg/kg	1.9		0.3	0.7	0.4
Copper (Cu)	mg/kg	2.2		0.3	0.8	0.5
Boron (B)	mg/kg	0.5		0.1	0.4	0.3

Explanation of graph ranges:

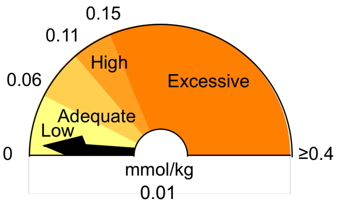
▢ **Very Low**	▢ **Low**	▢ **Marginal**	▨ **Adequate**	■ **High**
Growth is likely to be severely depressed and deficiency symptoms present. Large applications for soil building purposes are usually recommended. Potential response to nutrient addition is >90%.	Potential "hidden hunger", or sub-clinical deficiency. Potential response to nutrient addition is 60 to 90%.	Supply of this nutrient is barely adequate for the plant, and build-up is still recommended. Potential response to nutrient addition is 30 to 60%.	Supply of this nutrient is adequate for the plant, and and only maintenance application rates are recommended. Potential response to nutrient addition is 5 to 30%.	The level is excessive and may be detrimental to plant growth (i.e. phytotoxic) and may contribute to pollution of ground and surface waters. Drawdown is recommended. Potential response to nutrient addition is <2%.

NOTES: Adjustment recommendation calculates the elemental application to shift the soil test level to within the **Adequate** band, which maximises growth/yield, and economic efficiency, and minimises impact on the environment.

Drawdown: The objective nutrient management is to utilise residual soil nutrients. There is no agronomic reason to apply fertiliser when soil test levels exceed **Adequate**.

- g/sqm measurements are based on soil bulk density of 1.33 tonne/m^3 and selected soil depth.

Phosphorus Saturation Index



Low. Plant response to applied P is likely.

Exchangeable Acidity

Adams-Evans Buffer pH (BpH):	-
Sum of Base Cations (cmol(+)/kg):	**36.6**
Eff. Cation Exch. Capacity (eCEC):	**36.6**
Base Saturation (%):	**100**
Exchangeable Acidity (cmol(+)/kg):	-
Exchangeable Acidity (%):	-

Lime Application Rate (g/sqm)

– to achieve pH 6.0:	**0**
– to neutralise Al:	**-**

Calculated Gypsum Application Rate (CGAR)

(g/sqm) to achieve 67.5 % exch. Ca: **915**

The CGAR is corrected for the selected effective amelioration depth (100 mm) and any Lime addition to achieve pH 6.0.

PHYSICAL DESCRIPTION

Texture:	**Light Sandy Clay Loam**
Estimated clay content:	**25%**
Tactually gravelly:	**Gravelly**
Tactually organic:	**Not Organic**
Calculated EC_{SE} (dS/m):	**0.3**

– Non-saline. Salinity effects on plants are mostly negligible.

Munsell Colour:	-
Structure Size:	**Medium (11 - 25mm)**
Structural Organisation:	**Pedal - Moderate**
Structural Unit:	**Polyhedral**
Potential infiltration rate:	**Rapid**
Est. Permeability Class (mm/hr):	**Unusual Structure**
Additional comments:	

Organic Carbon (OC %):	**1.1 – Low**
Organic Matter (OM %):	**2.4**
Est. Field Capacity (% water):	**26**
Est. Permanent Wilting Point (% water):	**12**
Est. Plant Available Water (% water):	**14**
Est. Plant Available Water (mm/m):	**140**

Date Report Generated 12/02/2018

Consultant: Chantal Milner

Authorised Signatory: Simon Leake

METHOD REFERENCES:
pH (1:5 H_2O) - Rayment & Higginson (1992) 4A1,
pH (1:5 $CaCl_2$) - Rayment & Higginson (1992) 4B1,
EC (1:5) - Rayment & Higginson (1992) 3A1,
Chloride - Rayment & Higginson (1992) 5A2,
Nitrate - Rayment & Higginson (1992) 7B1
Aluminium - SESL in-house,
PO_4, K, SO_4, Ca, Mg, Na, Fe, Mn, Zn, Cu, B - Mehlich 3 (1984),
Buffer pH and Hydrogen - Adams-Evans (1972)
Texture/Structure/Colour - PM0003 (Texture- "Northcote" (1992), Structure* - "Murphy" (1991), Colour- "Munsell" (2000))

*Structure analysed in the laboratory is conducted on a disturbed sample, therefore is only a representation of the macro-structures that may be present in the field, which provide an indication of the soil physical characteristics and behaviours that may exist.

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Soil Chemistry Profile

Mehlich 3 - Multi-nutrient Extractant

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Web: www.sesl.com.au

Batch N°: 46403 **Sample N°: 4** **Date Received: 17/1/18** **Report Status: ● Draft ○ Final**

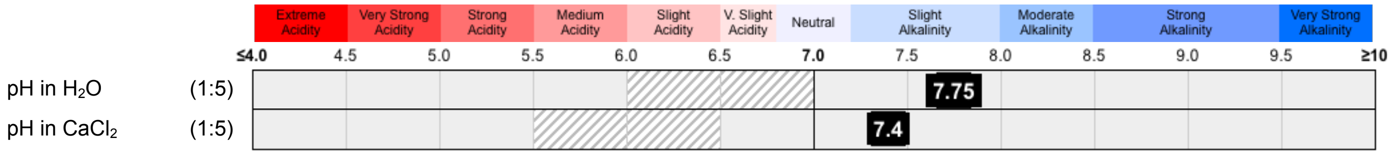
Client Name: **Hornsby Shire Council**
Client Contact: **James Frawley**
Client Order N°:
Address: **PO Box 37**
HORNSBY NSW 2077

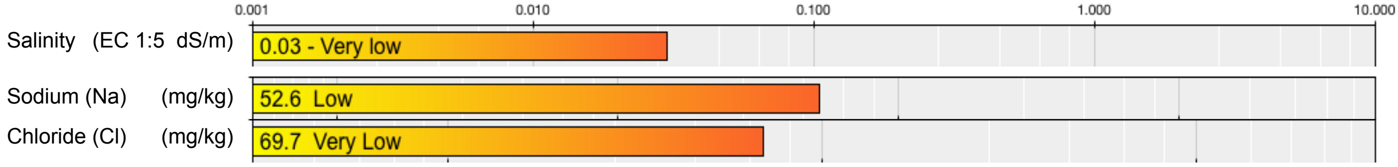
Project Name: **Site assessment 3 - Hornsby Park**
SESL Quote N°:
Sample Name: **Excavation 3**
Description: **Soil**
Test Type: **FSC, OM_WB, BSP**

RECOMMENDATIONS

Soil is slightly alkaline in CaCl2 with low salinity, sodium and chloride levels. The cation exchange is highly magnesic and has a high eCEC. Calcium, magnesium and manganese levels are very high. Organic matter is low at 0.9%
This soil is a light sandy clay loam with a moderate polyhedral structure and rapid permeability.

pH and ELECTRICAL CONDUCTIVITY

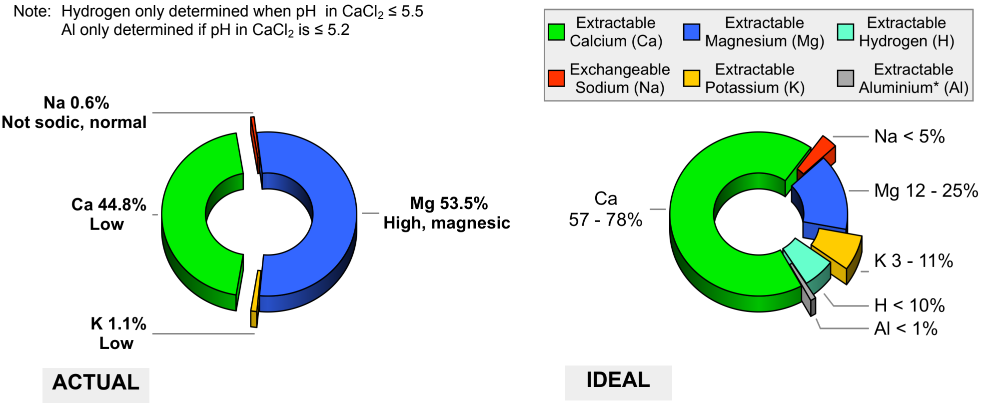




CATION BALANCE

EXCHANGEABLE CATION PERCENTAGE

Note: Hydrogen only determined when pH in $CaCl_2 \leq 5.5$
Al only determined if pH in $CaCl_2$ is ≤ 5.2



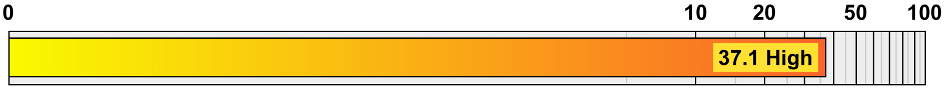
CATION RATIOS

Ratio	Result	Target Range
Ca:Mg	0.8	4.1 – 6.0
Comment: Potential Calcium deficiency		
Mg:K	48.4	2.6 – 5.0
Comment: Potential Potassium deficiency		
K/(Ca+Mg)	0.01	< 0.07
Comment: Acceptable		
K:Na	1.8	N/A

EXCHANGEABLE CATIONS (cmol(+)/kg)

Na:	K:	Ca:	Mg:	H:	Al:
0.23	0.41	16.62	19.85		

EFFECTIVE CATION EXCHANGE CAPACITY (eCEC) (cmol(+)/kg)



eCEC does not include correction for soluble salts as standard. Where exchangeable calcium exceeds 80 % of eCEC and/or salinity exceeds 0.75 dS/m, alternative methods are recommended to determine true eCEC.

The units of eCEC *cmol(+)/kg* are the SI unit and are equivalent to *meq/100g.*

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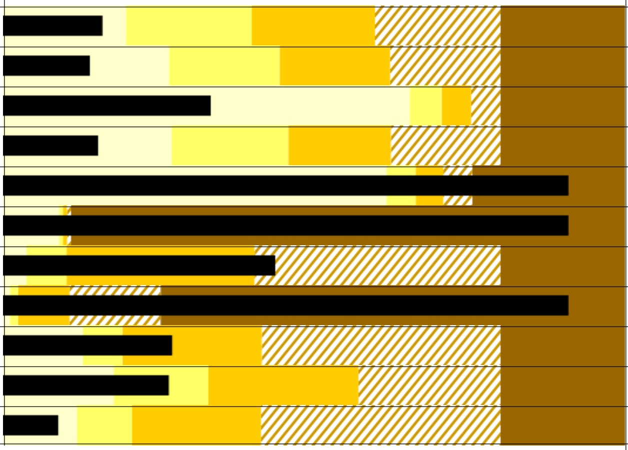
Batch N°: 46403 **Sample N°: 4** **Date Received: 17/1/18** **Report Status:** ● **Draft** ○ **Final**

PLANT AVAILABLE NUTRIENTS

EFFECTIVE AMELIORATION DEPTH (mm): ● **100** ○ **150** ○ **200** **DESIRED FERTILITY CLASS:** ○ Low ● Moderate ○ High



Major Nutrients	**Unit**	**Result**	☐ Very Low 🟨 Low 🟧 Marginal ▨ Adequate 🟫 High	**Result (g/sqm)**	**Desirable (g/sqm)**	**Adjustment (g/sqm)**
Nitrate-N (NO_3)	mg N/kg	4.2		0.6	4	3.4
Phosphorus (P)	mg P/kg	11		1.5	8.4	6.9
Potassium (K)	mg/kg	162		21.5	51.6	30.1
Sulphur (S)	mg S/kg	13		1.7	9	7.3
Calcium (Ca)	mg/kg	3330		442.9	367.5	Drawdown
Magnesium (Mg)	mg/kg	2412		320.8	38.4	Drawdown
Iron (Fe)	mg/kg	302		40.2	73.4	33.2
Manganese (Mn)	mg/kg	158		21	5.9	Drawdown
Zinc (Zn)	mg/kg	1.7		0.2	0.7	0.5
Copper (Cu)	mg/kg	2.1		0.3	0.8	0.5
Boron (B)	mg/kg	0.3		0	0.4	0.4

Explanation of graph ranges:

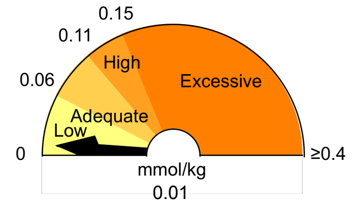
☐ **Very Low**	🟨 **Low**	🟧 **Marginal**	▨ **Adequate**	🟫 **High**
Growth is likely to be severely depressed and deficiency symptoms present. Large applications for soil building purposes are usually recommended. Potential response to nutrient addition is >90%.	Potential "hidden hunger", or sub-clinical deficiency. Potential response to nutrient addition is 60 to 90%.	Supply of this nutrient is barely adequate for the plant, and build-up is still recommended. Potential response to nutrient addition is 30 to 60%.	Supply of this nutrient is adequate for the plant, and and only maintenance application rates are recommended. Potential response to nutrient addition is 5 to 30%.	The level is excessive and may be detrimental to plant growth (i.e. phytotoxic) and may contribute to pollution of ground and surface waters. Drawdown is recommended. Potential response to nutrient addition is <2%.

NOTES: Adjustment recommendation calculates the elemental application to shift the soil test level to within the **Adequate** band, which maximises growth/yield, and economic efficiency, and minimises impact on the environment.

Drawdown: The objective nutrient management is to utilise residual soil nutrients. There is no agronomic reason to apply fertiliser when soil test levels exceed **Adequate**.

- g/sqm measurements are based on soil bulk density of 1.33 tonne/m^3 and selected soil depth.

Phosphorus Saturation Index



Low. Plant response to applied P is likely.

Exchangeable Acidity

Adams-Evans Buffer pH (BpH): **-**
Sum of Base Cations (cmol(+)/kg): **37.1**
Eff. Cation Exch. Capacity (eCEC): **37.1**
Base Saturation (%): **100**
Exchangeable Acidity (cmol(+)/kg): **-**
Exchangeable Acidity (%): **-**

Lime Application Rate (g/sqm)

– to achieve pH 6.0: **0**
– to neutralise Al: **-**

Calculated Gypsum Application Rate (CGAR)

(g/sqm) to achieve 67.5 % exch. Ca: **964**

The CGAR is corrected for the selected effective amelioration depth (100 mm) and any Lime addition to achieve pH 6.0.

PHYSICAL DESCRIPTION

Texture: **Light Sandy Clay Loam**
Estimated clay content: **25%**
Tactually gravelly: **Gravelly**
Tactually organic: **Not Organic**
Calculated EC_{SE} (dS/m): **0.3**
– Non-saline. Salinity effects on plants are mostly negligible.

Munsell Colour: **-**
Structure Size: **Medium (11 - 25mm)**
Structural Organisation: **Pedal - Moderate**
Structural Unit: **Polyhedral**
Potential infiltration rate: **Rapid**
Est. Permeability Class (mm/hr): **Unusual Structure**
Additional comments:

Organic Carbon (OC %): **0.9 – Low**
Organic Matter (OM %): **2**
Est. Field Capacity (% water): **26**
Est. Permanent Wilting Point (% water): **12**
Est. Plant Available Water (% water): **14**
Est. Plant Available Water (mm/m): **140**

Date Report Generated 12/02/2018

Consultant: Chantal Milner

Authorised Signatory: Simon Leake

METHOD REFERENCES:
pH (1:5 H_2O) - Rayment & Higginson (1992) 4A1,
pH (1:5 $CaCl_2$) - Rayment & Higginson (1992) 4B1,
EC (1:5) - Rayment & Higginson (1992) 3A1,
Chloride - Rayment & Higginson (1992) 5A2,
Nitrate - Rayment & Higginson (1992) 7B1
Aluminium - SESL in-house,
PO_4, K, SO_4, Ca, Mg, Na, Fe, Mn, Zn, Cu, B - Mehlich 3 (1984),
Buffer pH and Hydrogen - Adams-Evans (1972)
Texture/Structure/Colour - PM0003 (Texture-"Northcote" (1992), Structure* - "Murphy" (1991), Colour- "Munsell" (2000))

*Structure analysed in the laboratory is conducted on a disturbed sample, therefore is only a representation of the macro-structures that may be present in the field, which provide an indication of the soil physical characteristics and behaviours that may exist.

SESL
AUSTRALIA
Environment & Soil Sciences

Soil Chemistry Profile

Mehlich 3 - Multi-nutrient Extractant

Sample Drop Off: 16 Chilvers Road
Thornleigh NSW 2120
Mailing Address: PO Box 357
Pennant Hills NSW 1715
Tel: 1300 30 40 80
Fax: 1300 64 46 89
Em: info@sesl.com.au
Web: www.sesl.com.au

Batch N°: 46403 **Sample N°: 5** **Date Received: 17/1/18** **Report Status: ● Draft ○ Final**

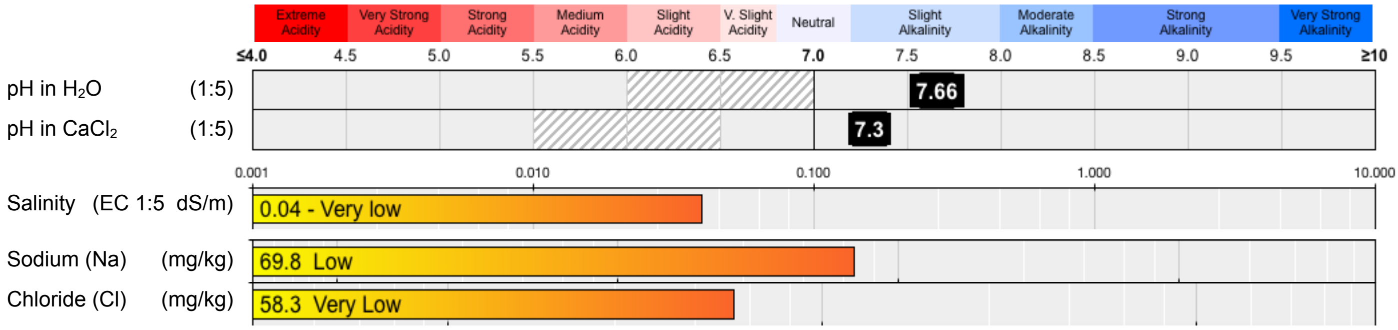
Client Name: **Hornsby Shire Council**
Client Contact: **James Frawley**
Client Order N°:
Address: **PO Box 37**
HORNSBY NSW 2077

Project Name: **Site assessment 3 - Hornsby Park**
SESL Quote N°:
Sample Name: **Excavation 4**
Description: **Soil**
Test Type: **FSC, OM_WB, BSP**

RECOMMENDATIONS

Soil is slightly alkaline in CaCl2 with low salinity, sodium and chloride levels. The cation exchange is highly magnesic and has a high eCEC. Calcium, magnesium and manganese levels are very high. Organic matter is low at 1.0%
This soil is a sandy clay loam with a moderate crumb structure and moderate permeability.

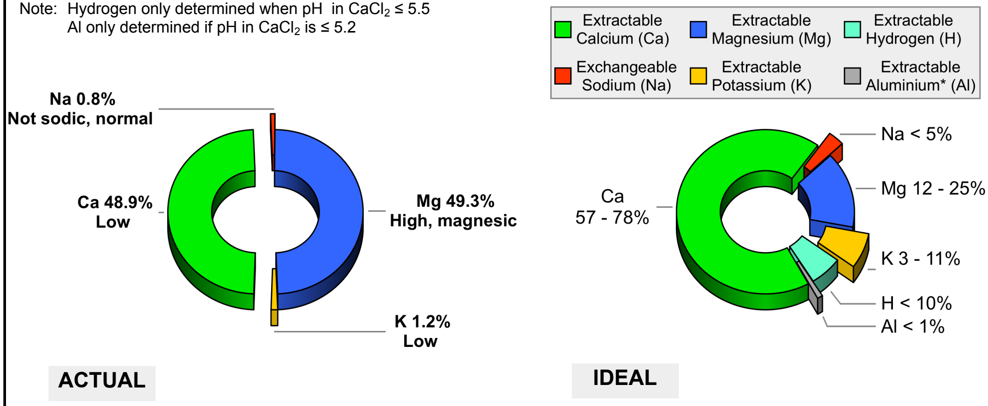
pH and ELECTRICAL CONDUCTIVITY



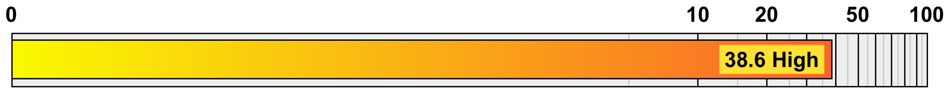
CATION BALANCE

EXCHANGEABLE CATION PERCENTAGE

Note: Hydrogen only determined when pH in $CaCl_2 \leq 5.5$
Al only determined if pH in $CaCl_2$ is ≤ 5.2



EFFECTIVE CATION EXCHANGE CAPACITY (eCEC) (cmol(+)/kg)



CATION RATIOS

Ratio	Result	Target Range
Ca:Mg	**1**	4.1 – 6.0
Comment: Calcium low		
Mg:K	**42.3**	2.6 – 5.0
Comment: Potential Potassium deficiency		
K/(Ca+Mg)	**0.01**	< 0.07
Comment: Acceptable		
K:Na	**1.5**	N/A

EXCHANGEABLE CATIONS (cmol(+)/kg)

Na:	K:	Ca:	Mg:	H:	Al:
0.30	0.45	18.86	19.02		

eCEC does not include correction for soluble salts as standard. Where exchangeable calcium exceeds 80 % of eCEC and/or salinity exceeds 0.75 dS/m, alternative methods are recommended to determine true eCEC.

The units of eCEC *cmol(+)/kg* are the SI unit and are equivalent to *meq/100g.*

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Soil Chemistry Profile

Mehlich 3 - Multi-nutrient Extractant

Sample Drop Off: 16 Chilvers Road
Thornleigh NSW 2120
Mailing Address: PO Box 357
Pennant Hills NSW 1715
Tel: 1300 30 40 80
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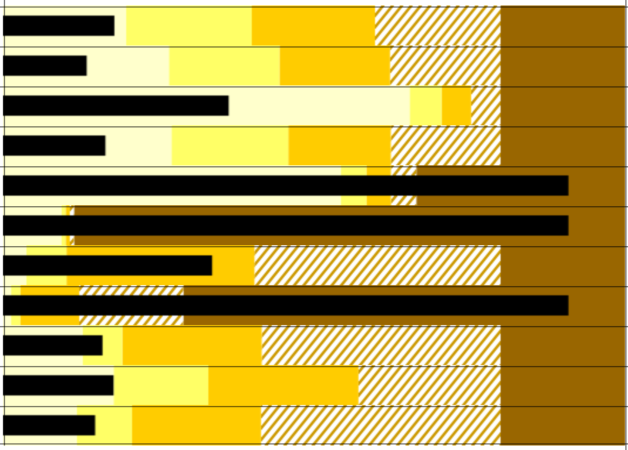
Em: info@sesl.com.au
Web: www.sesl.com.au

Batch N°: 46403 **Sample N°: 5** **Date Received: 17/1/18** **Report Status:** ● **Draft** ○ **Final**

PLANT AVAILABLE NUTRIENTS

EFFECTIVE AMELIORATION DEPTH (mm): ● **100** ○ **150** ○ **200** **DESIRED FERTILITY CLASS:** ○ Low ● Moderate ○ High

Major Nutrients	Unit	Result	⬜ Very Low 🟨 Low 🟧 Marginal ▨ Adequate 🟫 High	Result (g/sqm)	Desirable (g/sqm)	Adjustment (g/sqm)
Nitrate-N (NO_3)	mg N/kg	4.7		0.6	4	3.4
Phosphorus (P)	mg P/kg	10.6		1.4	8.4	7
Potassium (K)	mg/kg	176		23.4	51.6	28.2
Sulphur (S)	mg S/kg	14		1.9	9	7.1
Calcium (Ca)	mg/kg	3780		502.7	367.5	Drawdown
Magnesium (Mg)	mg/kg	2311		307.4	38.4	Drawdown
Iron (Fe)	mg/kg	232		30.9	73.4	42.5
Manganese (Mn)	mg/kg	138		18.4	5.9	Drawdown
Zinc (Zn)	mg/kg	1		0.1	0.7	0.6
Copper (Cu)	mg/kg	1.4		0.2	0.8	0.6
Boron (B)	mg/kg	0.5		0.1	0.4	0.3

Explanation of graph ranges:

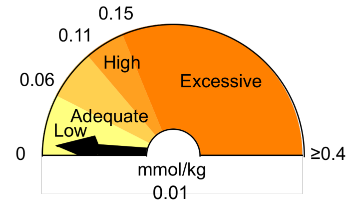
⬜ **Very Low**	🟨 **Low**	🟧 **Marginal**	▨ **Adequate**	🟫 **High**
Growth is likely to be severely depressed and deficiency symptoms present. Large applications for soil building purposes are usually recommended. Potential response to nutrient addition is >90%.	Potential "hidden hunger", or sub-clinical deficiency. Potential response to nutrient addition is 60 to 90%.	Supply of this nutrient is barely adequate for the plant, and build-up is still recommended. Potential response to nutrient addition is 30 to 60%.	Supply of this nutrient is adequate for the plant, and and only maintenance application rates are recommended. Potential response to nutrient addition is 5 to 30%.	The level is excessive and may be detrimental to plant growth (i.e. phytotoxic) and may contribute to pollution of ground and surface waters. Drawdown is recommended. Potential response to nutrient addition is <2%.

NOTES: Adjustment recommendation calculates the elemental application to shift the soil test level to within the **Adequate** band, which maximises growth/yield, and economic efficiency, and minimises impact on the environment.

Drawdown: The objective nutrient management is to utilise residual soil nutrients. There is no agronomic reason to apply fertiliser when soil test levels exceed **Adequate**.

- g/sqm measurements are based on soil bulk density of 1.33 tonne/m^3 and selected soil depth.

Phosphorus Saturation Index



Low. Plant response to applied P is likely.

Exchangeable Acidity

Adams-Evans Buffer pH (BpH):	-
Sum of Base Cations (cmol(+)/kg):	**38.6**
Eff. Cation Exch. Capacity (eCEC):	**38.6**
Base Saturation (%):	**100**
Exchangeable Acidity (cmol(+)/kg):	-
Exchangeable Acidity (%):	-

Lime Application Rate (g/sqm)

– to achieve pH 6.0:	**0**
– to neutralise Al:	**-**

Calculated Gypsum Application Rate (CGAR)

(g/sqm) to achieve 67.5 % exch. Ca: **824**

The CGAR is corrected for the selected effective amelioration depth (100 mm) and any Lime addition to achieve pH 6.0.

PHYSICAL DESCRIPTION

Texture:	**Sandy Clay Loam**
Estimated clay content:	**20 - 30%**
Tactually gravelly:	**Gravelly**
Tactually organic:	**Not Organic**
Calculated EC_{SE} (dS/m):	**0.4**

– Non-saline. Salinity effects on plants are mostly negligible.

Munsell Colour:	-
Structure Size:	**Fine (1 - 10mm)**
Structural Organisation:	**Pedal - Moderate**
Structural Unit:	**Crumb**
Potential infiltration rate:	**Moderate**
Est. Permeability Class (mm/hr):	**20 - 60**

Additional comments:

Organic Carbon (OC %):	**1 – Low**
Organic Matter (OM %):	**2.2**
Est. Field Capacity (% water):	**26**
Est. Permanent Wilting Point (% water):	**15**
Est. Plant Available Water (% water):	**11**
Est. Plant Available Water (mm/m):	**110**

Date Report Generated 12/02/2018

Consultant: Chantal Milner

Authorised Signatory: Simon Leake

METHOD REFERENCES:
pH (1:5 H_2O) - Rayment & Higginson (1992) 4A1,
pH (1:5 $CaCl_2$) - Rayment & Higginson (1992) 4B1,
EC (1:5) - Rayment & Higginson (1992) 3A1,
Chloride - Rayment & Higginson (1992) 5A2,
Nitrate - Rayment & Higginson (1992) 7B1
Aluminium - SESL in-house,
PO_4, K, SO_4, Ca, Mg, Na, Fe, Mn, Zn, Cu, B - Mehlich 3 (1984),
Buffer pH and Hydrogen - Adams-Evans (1972)
Texture/Structure/Colour - PM0003 (Texture-"Northcote" (1992), Structure* - "Murphy" (1991), Colour- "Munsell" (2000))

*Structure analysed in the laboratory is conducted on a disturbed sample, therefore is only a representation of the macro-structures that may be present in the field, which provide an indication of the soil physical characteristics and behaviours that may exist.

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Environment & Soil Sciences

Soil Chemistry Profile

Mehlich 3 - Multi-nutrient Extractant

Sample Drop Off: 16 Chilvers Road
Thornleigh NSW 2120
Mailing Address: PO Box 357
Pennant Hills NSW 1715
Tel: 1300 30 40 80
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Em: info@sesl.com.au
Web: www.sesl.com.au

Batch N°: 46403 **Sample N°: 6** **Date Received: 17/1/18** **Report Status:** ● **Draft** ○ **Final**

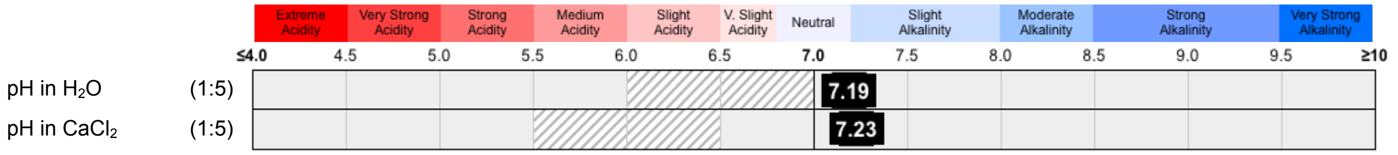
Client Name: **Hornsby Shire Council**
Client Contact: **James Frawley**
Client Order N°:
Address: **PO Box 37**
HORNSBY NSW 2077

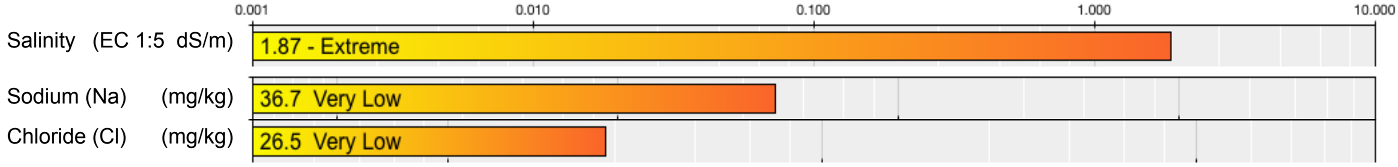
Project Name: **Site assessment 3 - Hornsby Park**
SESL Quote N°:
Sample Name: **Excavation 5**
Description: **Soil**
Test Type: **FSC, OM_WB, BSP**

RECOMMENDATIONS

Soil is slightly alkaline in CaCl2 with extreme salinity but very low sodium and chloride levels. The cation exchange is close to being balanced and has a high eCEC. Aside from NPK levels, nutrients are high. Organic matter is low at 1.3%
This soil is a sandy clay loam with a weak crumb structure and moderate permeability.

pH and ELECTRICAL CONDUCTIVITY

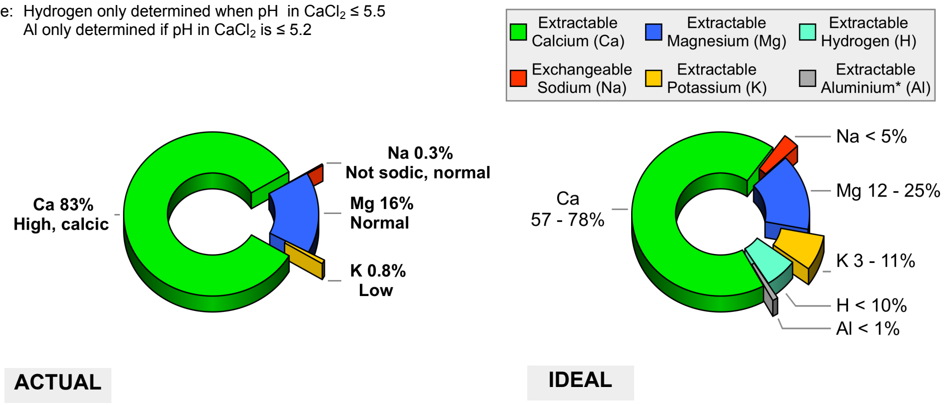




CATION BALANCE

EXCHANGEABLE CATION PERCENTAGE

Note: Hydrogen only determined when pH in $CaCl_2$ ≤ 5.5
Al only determined if pH in $CaCl_2$ is ≤ 5.2



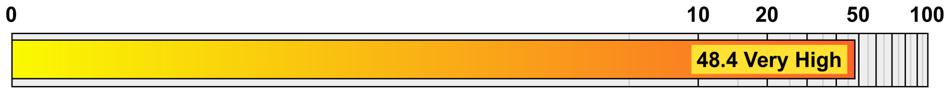
CATION RATIOS

Ratio	Result	Target Range
Ca:Mg	5.2	4.1 – 6.0
Comment: Balanced		
Mg:K	19.8	2.6 – 5.0
Comment: Potential Potassium deficiency		
K/(Ca+Mg)	0.01	< 0.07
Comment: Acceptable		
K:Na	2.4	N/A

EXCHANGEABLE CATIONS (cmol(+)/kg)

Na:	K:	Ca:	Mg:	H:	Al:
0.16	0.39	40.15	7.72		

EFFECTIVE CATION EXCHANGE CAPACITY (eCEC) (cmol(+)/kg)



eCEC does not include correction for soluble salts as standard. Where exchangeable calcium exceeds 80 % of eCEC and/or salinity exceeds 0.75 dS/m, alternative methods are recommended to determine true eCEC.

The units of eCEC *cmol(+)/kg* are the SI unit and are equivalent to *meq/100g.*

ASPAC

A member of the Australian Soil and Plant Analysis Council (ASPAC)
This laboratory participates in, and is awarded certification based on results of the scores returned in, ASPAC inter-laboratory proficiency rounds. For detailed current certification status and for more information on the ASPAC inter-laboratory proficiency testing programs, see the ASPAC website: http://www.aspac-australasia.com

Disclaimer
Tests are performed under a quality system complying with ISO 9001: 2008. Results are based on the analysis of the samples collected or received by SESL. Due to the spatial and temporal variability of soils within a given site, and the variability of sampling techniques, environmental conditions and managerial factors, SESL does not accept any liability for a lack of general compliance or performance based on the interpretation and recommendations given (where applicable). This document must not be reproduced except in full.

SESL AUSTRALIA
Environment & Soil Sciences

Soil Chemistry Profile

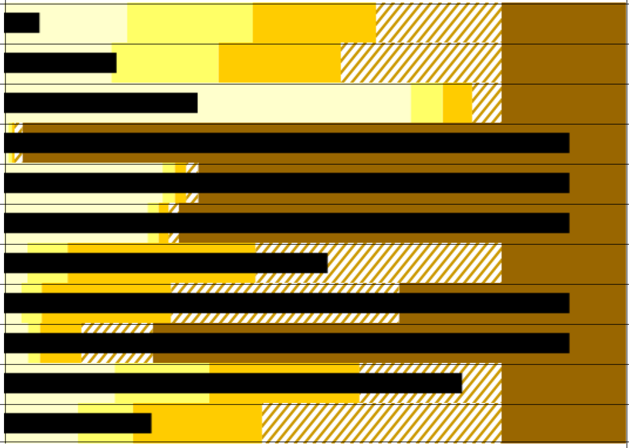
Mehlich 3 - Multi-nutrient Extractant

Sample Drop Off: 16 Chilvers Road
Thornleigh NSW 2120
Mailing Address: PO Box 357
Pennant Hills NSW 1715
Tel: 1300 30 40 80
Fax: 1300 64 46 89
Em: info@sesl.com.au
Web: www.sesl.com.au

Batch N°: 46403 **Sample N°: 6** **Date Received: 17/1/18** **Report Status: ● Draft ○ Final**

PLANT AVAILABLE NUTRIENTS

EFFECTIVE AMELIORATION DEPTH (mm): ● 100 ○ 150 ○ 200 **DESIRED FERTILITY CLASS: ○ Low ● Moderate ○ High**

Major Nutrients	Unit	Result	☐ Very Low ☐ Low ☐ Marginal ▨ Adequate ■ High	Result (g/sqm)	Desirable (g/sqm)	Adjustment (g/sqm)
Nitrate-N (NO_3)	mg N/kg	1.5		0.2	4	3.8
Phosphorus (P)	mg P/kg	14.7		2	8.4	6.4
Potassium (K)	mg/kg	151		20.1	51.6	31.5
Sulphur (S)	mg S/kg	2090		278	9	Drawdown
Calcium (Ca)	mg/kg	8050		1070.7	367.5	Drawdown
Magnesium (Mg)	mg/kg	938		124.8	38.4	Drawdown
Iron (Fe)	mg/kg	359		47.7	73.4	25.7
Manganese (Mn)	mg/kg	63		8.4	5.9	Drawdown
Zinc (Zn)	mg/kg	19		2.5	0.7	Drawdown
Copper (Cu)	mg/kg	5.8		0.8	0.8	0
Boron (B)	mg/kg	0.8		0.1	0.4	0.3

Explanation of graph ranges:

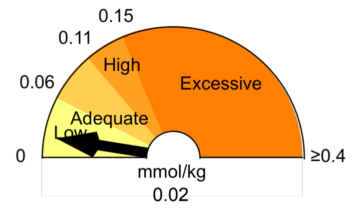
☐ **Very Low**	☐ **Low**	☐ **Marginal**	▨ **Adequate**	■ **High**
Growth is likely to be severely depressed and deficiency symptoms present. Large applications for soil building purposes are usually recommended. Potential response to nutrient addition is >90%.	Potential "hidden hunger", or sub-clinical deficiency. Potential response to nutrient addition is 60 to 90%.	Supply of this nutrient is barely adequate for the plant, and build-up is still recommended. Potential response to nutrient addition is 30 to 60%.	Supply of this nutrient is adequate for the plant, and and only maintenance application rates are recommended. Potential response to nutrient addition is 5 to 30%.	The level is excessive and may be detrimental to plant growth (i.e. phytotoxic) and may contribute to pollution of ground and surface waters. Drawdown is recommended. Potential response to nutrient addition is <2%.

NOTES: Adjustment recommendation calculates the elemental application to shift the soil test level to within the **Adequate** band, which maximises growth/yield, and economic efficiency, and minimises impact on the environment.

Drawdown: The objective nutrient management is to utilise residual soil nutrients. There is no agronomic reason to apply fertiliser when soil test levels exceed **Adequate**.

- g/sqm measurements are based on soil bulk density of 1.33 tonne/m^3 and selected soil depth.

Phosphorus Saturation Index



Low. Plant response to applied P is likely.

Exchangeable Acidity

Adams-Evans Buffer pH (BpH):	-
Sum of Base Cations (cmol(+)/kg):	**48.4**
Eff. Cation Exch. Capacity (eCEC):	**48.4**
Base Saturation (%):	**100**
Exchangeable Acidity (cmol(+)/kg):	-
Exchangeable Acidity (%):	-

Lime Application Rate (g/sqm)

– to achieve pH 6.0:	**0**
– to neutralise Al:	**-**

Calculated Gypsum Application Rate (CGAR)

(g/sqm) to achieve 67.5 % exch. Ca: **0**

The CGAR is corrected for the selected effective amelioration depth (100 mm) and any Lime addition to achieve pH 6.0.

PHYSICAL DESCRIPTION

Texture:	**Sandy Clay Loam**
Estimated clay content:	**20 - 30%**
Tactually gravelly:	**Gravelly**
Tactually organic:	**Not Organic**
Calculated EC_{SE} (dS/m):	**17.8**

– Extremely saline. Only very tolerant plant species (i.e. halophytes) grow satisfactorily.

Munsell Colour:	-
Structure Size:	**Fine (1 - 10mm)**
Structural Organisation:	**Pedal - Weak**
Structural Unit:	**Crumb**
Potential infiltration rate:	**Moderate**
Est. Permeability Class (mm/hr):	**5 - 20**
Additional comments:	

Organic Carbon (OC %):	**1.3 – Low**
Organic Matter (OM %):	**2.9**
Est. Field Capacity (% water):	**26**
Est. Permanent Wilting Point (% water):	**15**
Est. Plant Available Water (% water):	**11**
Est. Plant Available Water (mm/m):	**110**

Date Report Generated 12/02/2018

Consultant: Chantal Milner

Authorised Signatory: Simon Leake

METHOD REFERENCES:
pH (1:5 H_2O) - Rayment & Higginson (1992) 4A1,
pH (1:5 $CaCl_2$) - Rayment & Higginson (1992) 4B1,
EC (1:5) - Rayment & Higginson (1992) 3A1,
Chloride - Rayment & Higginson (1992) 5A2,
Nitrate - Rayment & Higginson (1992) 7B1
Aluminium - SESL in-house,
PO_4, K, SO_4, Ca, Mg, Na, Fe, Mn, Zn, Cu, B - Mehlich 3 (1984),
Buffer pH and Hydrogen - Adams-Evans (1972)
Texture/Structure/Colour - PM0003 (Texture- "Northcote" (1992), Structure* - "Murphy" (1991), Colour- "Munsell" (2000))

*Structure analysed in the laboratory is conducted on a disturbed sample, therefore is only a representation of the macro-structures that may be present in the field, which provide an indication of the soil physical characteristics and behaviours that may exist.

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Environment & Soil Sciences

Physical Soil Profile

Sample Drop Off: 16 Chilvers Road
Thornleigh NSW 2120
Tel: 1300 30 40 80
Fax: 1300 64 46 89
Mailing Address: PO Box 357
Pennant Hills NSW 1715
Em: info@sesl.com.au
Web: www.sesl.com.au

Batch N°: 46403A **Date Received: 18/1/18** **Report Status:** ● **Draft** ○ **Final**

Client Name: **Hornsby Shire Council**
Client Contact: **James Frawley**
Client Order N°:
Address: **PO Box 37**
HORNSBY NSW 2077

Project Name: **Site assessment 3 - Hornsby Park**
SESL Quote N°:
Sample Name: **Excavation 1**
Description: **Soil**
Test Type: **Colour_S**

1

Excavation 1

Texture : -
Structural Unit :
Aggregate Strength : -
Colour : 7.5YR 4/2 Brown
Ksat (mm/hr) : Did not test
Potential Infiltration Rate : Did not test

2

Excavation 2 0-200

Texture : -
Structural Unit :
Aggregate Strength : -
Colour : 2.5Y 4/1 Dark Gray
Ksat (mm/hr) : Did not test
Potential Infiltration Rate : Did not test

3

Excavation 2 comp

Texture : -
Structural Unit :
Aggregate Strength : -
Colour : 2.5Y 3/2 Very Dark Gray Brown
Ksat (mm/hr) : Did not test
Potential Infiltration Rate : Did not test

4

Excavation 3

Texture : -
Structural Unit :
Aggregate Strength : -
Colour : 2.5Y 3/1 Very Dark Gray
Ksat (mm/hr) : Did not test
Potential Infiltration Rate : Did not test

Date Report Generated
12/02/2018

Consultant
Chantal Milner

Authorised Signatory
Simon Leake

SESL AUSTRALIA
Environment & Soil Sciences

Physical Soil Profile

Sample Drop Off: 16 Chilvers Road
Thornleigh NSW 2120
Mailing Address: PO Box 357
Pennant Hills NSW 1715
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Batch N°: 46403A **Date Received: 18/1/18** **Report Status: ● Draft ○ Final**

Client Name: **Hornsby Shire Council**
Client Contact: **James Frawley**
Client Order N°:
Address: **PO Box 37**
HORNSBY NSW 2077

Project Name: **Site assessment 3 - Hornsby Park**
SESL Quote N°:
Sample Name: **Excavation 4**
Description: **Soil**
Test Type: **Colour_S**

5

Excavation 4

Texture : -
Structural Unit :
Aggregate Strength : -
Colour : 10YR 3/3 Dark Brown
Ksat (mm/hr) : Did not test
Potential Infiltration Rate : Did not test

6

Excavation 5

Texture : -
Structural Unit :
Aggregate Strength : -
Colour : 10YR 2/2 Very Dark Brown
Ksat (mm/hr) : Did not test
Potential Infiltration Rate : Did not test

7

Excavation 1 extra

Texture : -
Structural Unit :
Aggregate Strength : -
Colour : -
Ksat (mm/hr) : Did not test
Potential Infiltration Rate : Did not test

8

Excavation 4 extra

Texture : -
Structural Unit :
Aggregate Strength : -
Colour : -
Ksat (mm/hr) : Did not test
Potential Infiltration Rate : Did not test

Date Report Generated
12/02/2018

Consultant
Chantal Milner

Authorised Signatory
Simon Leake

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